ESE

Civil Engineering

Preliminary Examination

(Previous Years Solved Papers 1995-1999)

Volume-I

Contents

MADE EASY
PUBLICATIONS

UNIT

I

Building Materials

Syllabus

Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminum, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria;

Cement: Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.

Contents

1 Building Materials

1. Cement

1.1 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Fineness of cement
B. Setting time
C. Soundness
D. Workability

List-II

1. Le-Chatelier apparatus
2. Vicat's needle
3. Air permeability apparatus
4. Slump cone

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	1	4	2
(c)	3	2	1	4
(d)	1	4	3	2

[ESE : 1995]

1.2 If 'p' is the standard consistency of cement, the amount of water used in conducting the initial setting time test on cement is
(a) 0.65p (b) 0.85p
(c) 0.6p (d) 0.8p

[ESE : 1995]

1.3 **Assertion (A):** Pozzolana is added to cement to increase early strength.
Reason (R): It offers greater resistance to the attack of aggressive waters.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

1.4 For complete hydration of cement the water-cement ratio needed is
(a) less than 0.25
(b) more than 0.25 but less than 0.35
(c) more than 0.35 but less than 0.45
(d) more than 0.45 but less than 0.60

[ESE : 1996]

1.5 Match **List-I** (Type of cement) with **List-II** (Characteristics) and select the correct answer using the codes given below the lists:

List-I

A. Air entraining portland cement
B. Low-heat portland cement
C. Hydrophobic portland cement
D. Rapid hardening portland cement

List-II

1. Suitable for very large structures
2. Unsuitable for very large masses of concrete
3. Greater resistance to frost attack
4. Safe storage under unfavourable conditions of humidity

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	3	4	1	2
(c)	3	1	4	2
(d)	4	1	2	3

[ESE : 1996]

1.6 Gypsum is used as an admixture in cement grouts for
(a) accelerating the setting time
(b) retarding the setting time
(c) increasing the plasticity
(d) reducing the grout shrinkage

[ESE : 1996]

1.7 Blast furnace slag has approximately
(a) 45% calcium oxide and about 35% silica
(b) 50% alumina and 20% calcium oxide

(c) 25% magnesia and 15% silica
(d) 25% calcium sulphate and 15% alumina

[ESE : 1996]

1.8 Which of the following pairs in respect of Ordinary Portland Cement (OPC) are correctly matched?
1. Initial setting time ... 30 minutes
2. Final setting time ... 10 hours
3. Normal consistency ... 10%

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1 and 3

[ESE : 1997]

1.9 High alumina cement is produced by fusing together a mixture of
(a) limestone and bauxite
(b) limestone, bauxite and gypsum
(c) limestone, gypsum and clay
(d) limestone, gypsum, bauxite, clay and chalk

[ESE : 1997]

1.10 Consider the following statements:
High early strength of cement is obtained as a result of
1. fine grinding
2. decreasing the lime content
3. burning at higher temperatures
4. increasing the quantity of gypsum

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 3 and 4

[ESE : 1997]

1.11 Before testing setting time of cement one should test for
(a) soundness (b) strength
(c) fineness (d) consistency

[ESE : 1998]

1.12 The temperature range in a cement kiln is
(a) 500° to 1000°C (b) 1000° to 1200°C
(c) 1300° to 1500°C (d) 1600° to 2000°C

[ESE : 1998]

1.13 Consider the following statements:
1. Tests on cement paste to determine initial and final setting times are done at normal consistency condition.
2. Low heat cement has a high percentage of tricalcium aluminate.
3. High early strength portland cement contains a larger percentage of tricalcium silicate and a lower percentage of dicalcium silicate.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1999]

1.14 Match **List-I** (Property of cement) with **List-II** (Testing apparatus) and select the correct answer using the codes given below the lists:

List-I
A. Specific gravity
B. Setting time
C. Soundness
D. Fineness

List-II
1. Blain's apparatus
2. Le Chatelier's flask
3. Compressometer
4. Autoclave
5. Vicat's apparatus

Codes:

	A	B	C	D
(a)	3	5	1	2
(b)	2	5	1	4
(c)	2	5	4	1
(d)	5	3	4	1

[ESE : 1999]

1.15 The role of superplasticizer in a cement paste is to
(a) disperse the particles
(b) disperse the particles and to remove air bubbles
(c) disperse the particles, remove air bubbles and to retard setting
(d) retard setting

[ESE : 1999]

1.16 Consider the following oxides:
1. Al_2O_3 2. CaO 3. SiO_2

The correct sequence in increasing order of their percentage in an ordinary portland cement is
(a) 2, 1, 3 (b) 1, 3, 2
(c) 3, 1, 2 (d) 1, 2, 3

[ESE : 1999]

1.17 Increase in fineness of cement

(a) reduces the rate of strength development and leads to higher shrinkage
(b) increases the rate of strength development and reduces the rate of deterioration
(c) decreases the rate of strength development and increases the bleeding of cement
(d) increases the rate of strength development and leads to higher shrinkage

[ESE : 1999]

2. Mortar

2.1 The mortar used for masonry construction are classified based on strength in **IS:2250** and **IS:1905** according to their designations L_1, L_2, H_1, H_2, M_1, M_2. The correct sequence of increasing order of their strength is
(a) $L_1, L_2, H_1, H_2, M_1, M_2$
(b) $L_2, L_1, M_2, M_1, H_2, H_1$
(c) $M_1, M_2, H_1, H_2, L_1, L_2$
(d) $L_2, L_1, M_1, M_2, H_1, H_2$

[ESE : 1995]

2.2 The compressive strength of a standard good 1 : 3 portland cement-sand mortar after 3 days of curing should not be less than
(a) 70 kg/cm^2 (b) 115 kg/cm^2
(c) 175 kg/cm^2 (d) 210 kg/cm^2

[ESE : 1995]

2.3 Match **List-I** (Cement mortar for different work) with **List-II** (Proportion of cement : sand in mortar) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Normal brick work	**1.** 1 : 4
B. Plastering works	**2.** 1 : 3
C. Grouting the cavernous rocks	**3.** 1 : 6
D. Guniting	**4.** 1 : 1.5

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	1	2	4
(c)	3	1	4	2
(d)	4	3	2	1

[ESE : 1996]

2.4 The approximate proportion of dry cement mortar required for brickwork is
(a) 60% (b) 45%
(c) 30% (d) 10%

[ESE : 1997]

2.5 **Assertion (A):** In masonry, bricks are joined together by cement mortar.
Reason (R): Cement mortar adheres more effectively to brick surface than any other material.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.6 A gauged mortar is obtained by adding which of the following ingredient(s) to cement?
(a) Sand alone
(b) Sand and surkhi
(c) Sand and lime
(d) Surkhi alone

[ESE : 1998]

2.7 Surkhi is added to lime mortar to
(a) prevent shrinkage
(b) decrease setting time
(c) increase bulk
(d) impart hydraulicity

[ESE : 1999]

3. Lime

3.1 Lime mortar is generally made with
(a) quick lime (b) fat lime
(c) hydraulic lime (d) white lime

[ESE : 1995]

3.2 **Assertion (A):** Use of cement lime mortar is generally preferred to cement mortar.
Reason (R): Cement-lime mortar has higher workability and water retentivity characteristics than cement mortar.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

3.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Fat lime
B. Hydraulic lime
C. Quick lime
D. Non-hydraulic lime

List-II
1. Calcined dolomitie stone
2. Calcined lime stone
3. Kankar
4. Sea shells

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 1996]

3.4 The modulus of rupture of hydraulic lime mortar (28 days curing) should NOT be less than
(a) 1 N/mm^2 (b) 2 N/mm^2
(c) 2.5 N/mm^2 (d) 3.0 N/mm^2

[ESE : 1997]

3.5 **Assertion (A):** For identical strength, a composite cement-lime mortar is preferred over cement mortar.
Reason (R): Composite cement-lime mortar has higher drying shrinkage than cement mortar.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

3.6 Consider the following statements:
1. Masonry in rich cement mortar though having good strength with high shrinkage is much liable for surface cracks.
2. Lime mortar possesses poor workability and poor water retentivity and also suffers high shrinkage.
3. Masonry in lime mortar has better resistance against rain penetration and is less liable to crack when compared to masonry in cement mortar.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1999]

4. Concrete

4.1 The split tensile strength of M 15 grade concrete when expressed as percentage of its compressive strength is
(a) 10 to 15% (b) 15 to 20%
(c) 20 to 25% (d) 25 to 30%

[ESE : 1995]

4.2 The approximate ratio between the strengths of cement concrete at 7 days and at 28 days is
(a) 3/4 (b) 2/3
(c) 1/2 (d) 1/3

[ESE : 1995]

4.3 Modulus of elasticity of M 25 concrete as determined by formula of **IS:456** is
(a) 1,24,500 MPa (b) 90,125 MPa
(c) 28,500 MPa (d) 16,667 MPa

[ESE : 1995]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.4 **Assertion (A):** For identical mix, the cube compressive strength of concrete obtained from 15 cm cube is higher than 15 cm × 30 cm cylinder compressive strength.
Reason (R): Cube compressive strength is higher

than the cylinder compressive strength because of its higher contact area under the load.

[ESE : 1995]

4.5 **Assertion (A):** The specific surface of aggregate decreases with increase in size of the aggregate.
Reason (R): The workability of a mix is influenced more by the finer fractions than the coarse particles.

[ESE : 1996]

4.6 **Assertion (A):** Workability of concrete is improved by air entraining agent.
Reason (R): Air entraining agent increases concrete strength.

[ESE : 1996]

4.7 Tensile strength of concrete is measured by
(a) direct tension test in the universal testing machine
(b) applying compressive load along the diameter of the cylinder
(c) applying third point loading on a prism
(d) applying tensile load along the diameter of the cylinder

[ESE : 1996]

4.8 The approximate ratio of strength of 15 cm × 30 cm concrete cylinder to that of 15 cm cube of the same concrete is
(a) 1.25 (b) 1.00
(c) 0.85 (d) 0.50

[ESE : 1996]

4.9 If in a concrete mix the fineness modulus of coarse aggregate is 7.6, the fineness modulus of fine aggregate is 2.8 and the economical value of the fineness modulus of combined aggregate is 6.4, then the proportion of fine aggregate is
(a) 25% (b) $33\frac{1}{3}\%$
(c) 50% (d) $66\frac{2}{3}\%$

[ESE : 1996]

4.10 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Vicat's needle
B. Michaeli's compound lever apparatus
C. Le Chatelier's apparatus
D. Turbidimeter

List-II
1. Setting time
2. Specific surface
3. Tensile strength
4. Soundness

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	1	3	4	2
(c)	2	4	3	1
(d)	3	4	1	2

[ESE : 1996]

4.11 General shrinkage in cement concrete is caused by
(a) carbonation
(b) stressed due to external load
(c) drying with starting with a stiff consistency
(d) drying with starting with a wetter consistency

[ESE : 1996]

4.12 Weight-batching proceeds on
(a) the assumption of the declared weight in each bag of cement
(b) weighing the contents of each bag
(c) accurately estimating the weight of each material to be used in each batch
(d) the assumption of correct dry weight of each size range of each material and the weight of water

[ESE : 1996]

4.13 While concreting in cold weather where frosting is also likely, one uses
(a) high quality portland cement with minimum additives
(b) high alumina cement with calcium chloride additives
(c) portland cement together with calcium chloride additives
(d) a mixture of high alumina cement and portland cement

[ESE : 1996]

4.14 The modulus of elasticity (E) of concrete is given by
(a) $E = 1000\ f_{ck}$ (b) $E = 5700\sqrt{f_{ck}}$
(c) $E = 5500\sqrt{f_{ck}}$ (d) $E = 10{,}000\sqrt{f_{ck}}$

[ESE : 1997]

4.15 The optimum number of revolutions over which concrete is required to be mixed in a mixer machine is
(a) 10 (b) 20
(c) 50 (d) 100
[ESE : 1997]

4.16 Consider the following statements:
The addition of surfactants in the concrete mix results in
1. increase in the water-cement ratio
2. decrease in the water-cement ratio
3. increase in the strength of concrete
4. decrease in the curing duration
5. increase in the density of concrete
Which of these statements are correct?
(a) 1, 3 and 4 (b) 2, 3 and 5
(c) 3, 4 and 5 (d) 1, 4 and 5
[ESE : 1997]

4.17 Consider the following statements:
Higher water-cement ratio in concrete result in
1. stronger mix
2. better workable mix
3. a weak mix
4. less bleeding
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4
[ESE : 1997]

4.18 Match **List-I** (Admixtures) with **List-II** (Chemicals) and select the correct answer using the codes given below the lists:
List-I
A. Water-reducing admixture
B. Air-entraining agent
C. Superplasticiser
D. Accelerator
List-II
1. Sulphonated melanin formaldehyde
2. Calcium chloride
3. Lignosulphonate
4. Neutralised vinsol resin
Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	1	3	4	2
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 1998]

4.19 Batching refers to
(a) controlling the total quantity at each batch
(b) weighing accurately, the quantity of each material for a job before mixing
(c) controlling the quantity of each material into each batch
(d) adjusting the water to be added in each batch according to the moisture content of the materials being mixed in the batch
[ESE : 1998]

4.20 To make one cubic meter of 1 : 2 : 4 by volume concrete, the volume of coarse aggregates required is
(a) 0.95 m^3 (b) 0.85 m^3
(c) 0.75 m^3 (d) 0.65 m^3
[ESE : 1998]

4.21 The capacity of a "28 S type" concrete mixer is 0.8 m^3. For mixing one cubic meter of concrete, the quantity of cement required is 5.5 bags. In order to avoid fractional usage of cement bags, the volume of concrete (in m^3) to be mixed per batch will be
(a) 0.79 (b) 0.55
(c) 0.73 (d) 0.44
[ESE : 1998]

4.22 A splitting tensile test is performed on cylinder of diameter D and length L. If the ultimate load is P, then splitting tensile strength of concrete is given by
(a) $\frac{P}{\pi DL}$ (b) $\frac{2P}{\pi DL}$
(c) $\frac{4PL}{\pi D^3}$ (d) $\frac{4PD}{\pi L^3}$
[ESE : 1998]

4.23 Consider the following strengths of concrete:
1. Cube strength
2. Cylinder strength
3. Split-tensile strength
4. Modulus of rupture
The correct sequence in increasing order of these strengths is
(a) 3, 4, 2, 1 (b) 3, 4, 1, 2

(c) 4, 3, 2, 1 (d) 4, 3, 1, 2

[ESE : 1999]

4.24 Consider the following statements:
Shrinkage of concrete depends upon the
1. relative humidity of the atmosphere
2. passage of time
3. applied stress

Which of these statements is/are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 alone (d) 1, 2 and 3

[ESE : 1999]

4.25 Consider the following statements:
The effect of an air entrainment in concrete is to
1. increase resistance to freezing and thawing
2. improve workability
3. decrease strength

Which of these statements is/are correct?
(a) 2 and 3 (b) 1 and 3
(c) 1 alone (d) 1, 2 and 3

[ESE : 1999]

5. Stones, Bricks and Bricks Masonry

5.1 Match **List-I** (Name of stone) with **List-II** (Use of stone) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Granite	1. Ornamental work
B. Marble	2. Ballast
C. Chalk	3. Rough stone work
D. Laterite	4. Manufacture of cement

Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	2	3	1	4
(c)	2	1	4	3
(d)	1	4	2	3

[ESE : 1995]

5.2 A good brick should not absorb water by weight more than
(a) 10% (b) 20%
(c) 25% (d) 30%

[ESE : 1995]

5.3 For good bonding in bricks uniform in size
(a) all bricks need not be uniform in size
(b) bats must be used in alternate course only
(c) the vertical joints in alternate course should fall in plumb
(d) cement mortar used must have surkhi as additive

[ESE : 1995]

5.4 King closers are related to
(a) doors and windows
(b) king post truss
(c) queen post truss
(d) brick masonry

[ESE : 1996]

5.5 The texture of sandstone is
(a) porphyritic
(b) conglomerate
(c) vesicular
(d) granular crystalline

[ESE : 1996]

5.6 A good brick, when immersed in water bath for 24 hours, should not absorb more than
(a) 20% of its dry weight
(b) 30% of its saturated weight
(c) 10% of its dry weight
(d) 20% of its saturated weight

[ESE : 1996]

5.7 **Assertion (A):** The task work expected from a good mason with his team is about 7.00 sq.m (approximately 0.8 cu.m) in half -brick partition walls, whereas it is about 1.25 cu.m in one brick or thicker walls in superstructure.

Reason (R): Quantity of cement mortar in half-brick work is less than proportionate when compared to one-brick wall.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

5.8 At a Tee-junction between a 1½ brick wall and a 1 brick wall, one uses a
(a) half-queen closer in each course
(b) half-queen closer in every alternate course
(c) three-quarter bat in each course

(d) half-bat in every alternate course

[ESE : 1996]

5.9 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Pugmill	1.	Blasting
B.	Plug and feathers	2.	Lifting
C.	Lewis	3.	Splitting
D.	Gelignite	4.	Tempering

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	2	3	4	1
(c)	4	3	2	1
(d)	2	1	4	3

[ESE : 1997]

5.10 For one cubic metre of brick masonry, the number of modular bricks needed is

(a) 400 or less (b) 400 to 450
(c) 500 to 550 (d) 600 to 650

[ESE : 1997]

5.11 The function of coping is to serve as a

(a) covering to the wall to throw off water
(b) ornamental course between lintel level and roof level
(c) projection from a wall to support a structural member
(d) shade against solar radiation

[ESE : 1997]

5.12 **Assertion (A):** Facing bond is used when the bricks of different thicknesses are to be used in the facing and backing of the wall.

Reason (R): Facing bond is structurally good and results in uniform distribution of load.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

5.13 In brick masonry,

(a) mortar strength should match brick strength
(b) mortar strength should exceed brick strength
(c) brick strength should exceed mortar strength
(d) the strengths of masonry and brick are independent

[ESE : 1998]

5.14 The crushing strength of a good building stone should be at least

(a) 50 MPa (b) 100 MPa
(c) 150 MPa (d) 200 MPa

[ESE : 1998]

5.15 The slenderness ratio for masonry walls should NOT be more than

(a) 50 (b) 40
(c) 30 (d) 20

[ESE : 1998]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.16 **Assertion (A):** Brick work (especially new work) sometimes develops efflorescence on the surface after wetting and drying.

Reason (R): Fired clay bricks may contain soluble salts in which sulphates of sodium, potassium, magnesium and calcium usually predominate.

[ESE : 1999]

5.17 **Assertion (A):** In double Flemish bond, each course presents the same appearance both on front face and on back face.

Reason (R): Quoin closers are used next to quoin headers in every alternate course in double Flemish bond.

[ESE : 1999]

5.18 Consider the following statements:

1. About 25% of alumina in brick earth imparts the plasticity necessary for moulding bricks into required shape.
2. Iron pyrite present in brick earth preserves

the form of the bricks at high temperatures.
3. Presence of weeds in brick earth makes the bricks unsound.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1999]

5.19 The most important purpose of frog in a brick is to
(a) emboss manufacturer's name
(b) reduce the weight of brick
(c) form keyed joint between brick and mortar
(d) improve insulation by providing 'hollows'

[ESE : 1999]

5.20 Bricks are burnt at a temperature range of
(a) 500° to 700°C (b) 700° to 900°C
(c) 900° to 1200°C (d) 1200° to 1500°C

[ESE : 1999]

6. Timber

6.1 According to the relevant IS code, the weight of the timber is to be reckoned at a moisture content of
(a) zero (b) 4%
(c) 8% (d) 12%

[ESE : 1995]

6.2 The strength of timber is maximum when load applied is
(a) parallel to grain
(b) perpendicular to grain
(c) inclined at 45° to grain
(d) inclined at 60° to grain

[ESE : 1995]

6.3 **Assertion (A):** Dimensional changes in wood result due to variation in the moisture content of the wood with atmospheric condition.
Reason (R): The cell walls in wood are highly hygroscopic and when exposed to moisture, absorb large amounts of water and swell.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

6.4 The nail diameter should not be more than (t = least thickness of the wooden member to be connected)
(a) t/6 (b) t/8
(c) t/10 (d) t/12

[ESE : 1996]

6.5 The expansion and shrinkage of plywoods are comparatively very low as
(a) they are held in position by adhesives
(b) they are glued under pressure
(c) plies are placed at right angles to each other
(d) they are prepared from veneers

[ESE : 1996]

6.6 Seasoning of timber is required to
(a) soften the timber
(b) harden the timber
(c) straighten the timber
(d) remove sap from the timber

[ESE : 1996]

6.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

	List-I		List-II
A.	Deciduous	1.	Soft wood
B.	Conifer	2.	Hard wood
C.	Endogenous	3.	Eucalyptus
D.	Exogenous	4.	Bamboo

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	4	3

[ESE : 1997]

6.8 The modulus of elasticity of timber is about
(a) 0.5 to 1.0 × 10^4 N/mm^2
(b) 1.0 to 1.5 × 10^4 N/mm^2
(c) 1.5 to 2.0 × 10^4 N/mm^2
(d) 2.0 to 2.5 × 10^4 N/mm^2

[ESE : 1997]

6.9 During the conversion of timber by sawing, in order to obtain strong timber pieces, the cuts should be made by
(a) ordinary sawing (b) tangential sawing
(c) quarter sawing (d) radial sawing

[ESE : 1997]

6.10 A timber beam of effective span L and of cross-section $b \times d$ is said to be laterally supported if d/b and L/b are respectively
(a) less than 1 and less than 48
(b) less than 2 and less than 49
(c) less than 3 and less than 50
(d) less than 4 and less than 51
[ESE : 1997]

6.11 A timber column is made up of two individual members with longitudinal axes parallel, separated at the ends and middle points of their length by blocking, and joined at the ends by timber connectors. Such a column is called
(a) built-up column (b) composite column
(c) spaced column (d) flitched column
[ESE : 1997]

6.12 The moisture content in structural timber should be
(a) less than 5% (b) 5 to 10%
(c) 10 to 20% (d) 15 to 25%
[ESE : 1998]

6.13 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:
List-I
A. The innermost part or core of the stem of a tree
B. The vascular tissue which encloses the pith
C. A cellular tissue and woody fibre arranged in distinct concentric circles
D. The thin layer below the bark not converted into sapwood as yet
List-II
1. Transverse septa (medullary rays)
2. Annual rings
3. The cambium layer
4. The outermost cover or skin of the stem
5. Medulla (pith)
Codes:

	A	B	C	D
(a)	2	5	3	4
(b)	5	1	2	3
(c)	4	3	2	1
(d)	5	1	4	3

[ESE : 1998]

6.14 **Assertion (A):** Within a given species, green timber of large moisture content dries in the same length of time as that of lower moisture content.
Reason (R): The sapwood which contains most of the moisture, dries more rapidly than the heartwood.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

6.15 Consider the following methods of preservation of timber:
1. Dipping
2. Brushing or spraying
3. Pressure impregnation
The correct sequence in decreasing order of the effectiveness of these methods of preservation is
(a) 1, 2, 3 (b) 2, 1, 3
(c) 3, 1, 2 (d) 3, 2, 1
[ESE : 1999]

6.16 Radial splits in timber originating from 'bark' and narrowing towards the 'pith' are known as
(a) heart shakes (b) star shakes
(c) cup shakes (d) knots
[ESE : 1999]

7. Oil, Varnishes Paint, Distempers, Glass & Miscellaneous

7.1 Match **List-I** (Metals or alloys) with **List-II** (Their common use) and select the correct answer using the codes given below the lists:

List-I		List-II	
A.	Steel bars	**1.**	Water taps
B.	Zinc	**2.**	Door Frames
C.	Aluminium	**3.**	Reinforcement in concrete
D.	Brass castings	**4.**	Corrugated roof sheet

Codes:

	A	B	C	D
(a)	3	1	4	2

(b)	3	2	4	1
(c)	1	3	4	2
(d)	3	4	2	1

[ESE : 1995]

7.2 The modulus of elasticity of high tensile steel is
(a) smaller than that of mild steel
(b) equal to that of mild steel
(c) larger than that of mild steel
(d) equal to that of aluminium

[ESE : 1995]

7.3 Yield stress of ordinary mild steel bars after twisting to a pitch of about 9 to 12 diameters
(a) increases by about 50%
(b) decreases by about 30%
(c) increases by about 20%
(d) decreases by about 10%

[ESE : 1995]

7.4 The coefficient of linear expansion of granite is in the range of that of
(a) glass (b) mild steel
(c) high carbon steel (d) bamboo

[ESE : 1996]

7.5 The ratio of Young's modulus of high tensile steel to that of mild steel is about
(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0

[ESE : 1996]

7.6 Bureau of Indian Standards classifies bitumen into grades 65/25, 85/40 etc. The first and second numbers respectively refer to
(a) softening point and penetration
(b) penetration and softening point
(c) flash point and penetration
(d) flash point and softening point

[ESE : 1996]

7.7 Polyvinyl chloride (PVC) is a
(a) thermosetting material
(b) thermoplastic material
(c) elasto-plastic material
(d) rigid plastic material

[ESE : 1996]

7.8 **Assertion (A):** While painting on flush doors of plywood, putty-filling is done after prime coat.

Reason (R): This reduces the quantity of paint and effort involved in the regular coats of the paints.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

7.9 Which one of the following types of steel is used in the manufacture of rails?
(a) Mild steel
(b) Manganese steel
(c) Cast steel
(d) Bessemer steel

[ESE : 1997]

7.10 The ultimate strength of cold drawn steel wires
(a) increases with the increase in the diameter of the bar
(b) increases with reduction in the diameter of the bar
(c) does not depend upon the change in the diameter of the bar
(d) depends only on the diameter of the bar

[ESE : 1997]

7.11 Match **List-I** (Alloy metal) with **List-II** (Application/ Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. Aluminium alloy
B. Copper
C. Zinc
D. Lead

List-II
1. Building flashing and damp-proof course
2. Radiation shielding
3. Lightning conductors
4. Low density and high resistance to corrosion

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 1998]

7.12 The carbon content of structural steel is

(a) less than 0.1% (b) 0.10 to 0.25%
(c) 0.25 to 0.60% (d) 0.60 to 1.00%

[ESE : 1998]

7.13 In paints, linseed oil is used as

(a) a thinner
(b) a drier
(c) a vehicle
(d) a water-proofing base

[ESE : 1998]

7.14 Consider the following statements:
Casein glue is

1. obtained from milk
2. obtained from the blood of animals
3. used in painting of metals
4. used in the plywood industry
5. white in color
6. red in color

Which of these statements are correct?

(a) 1, 3, and 5 (b) 1, 4 and 5
(c) 2, 3 and 6 (d) 2, 4 and 6

[ESE : 1998]

7.15 Match **List-I** (Component of scaffolding) with **List-II** (Function) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Putlog	**1.** Diagonal member
B. Ledger	**2.** Vertical member
C. Brace	**3.** Horizontal member
D. Standard	**4.** Transverse member

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 1998]

■■■■

Answers Building Materials

1.1 (c)	1.2 (b)	1.3 (d)	1.4 (c)	1.5 (c)	1.6 (b)	1.7 (a)	1.8 (c)	1.9 (a)
1.10 (b)	1.11 (d)	1.12 (c)	1.13 (*)	1.14 (c)	1.15 (c)	1.16 (b)	1.17 (d)	2.1 (b)
2.2 (c)	2.3 (c)	2.4 (c)	2.5 (a)	2.6 (c)	2.7 (d)	3.1 (c)	3.2 (a)	3.3 (b)
3.4 (a)	3.5 (c)	3.6 (d)	4.1 (a)	4.2 (b)	4.3 (c)	4.4 (c)	4.5 (b)	4.6 (c)
4.7 (b)	4.8 (c)	4.9 (a)	4.10 (b)	4.11 (d)	4.12 (d)	4.13 (b)	4.14 (b)	4.15 (b)
4.16 (b)	4.17 (b)	4.18 (c)	4.19 (c)	4.20 (b)	4.21 (c)	4.22 (b)	4.23 (a)	4.24 (a)
4.25 (d)	5.1 (c)	5.2 (b)	5.3 (c)	5.4 (d)	5.5 (d)	5.6 (a)	5.7 (c)	5.8 (b)
5.9 (c)	5.10 (c)	5.11 (a)	5.12 (c)	5.13 (a)	5.14 (b)	5.15 (c)	5.16 (a)	5.17 (d)
5.18 (b)	5.19 (c)	5.20 (c)	6.1 (d)	6.2 (a)	6.3 (a)	6.4 (a)	6.5 (c)	6.6 (d)
6.7 (c)	6.8 (a)	6.9 (d)	6.10 (c)	6.11 (c)	6.12 (c)	6.13 (b)	6.14 (d)	6.15 (c)
6.16 (b)	7.1 (d)	7.2 (b)	7.3 (c)	7.4 (a)	7.5 (b)	7.6 (a)	7.7 (b)	7.8 (a)
7.9 (b)	7.10 (b)	7.11 (d)	7.12 (b)	7.13 (c)	7.14 (b)	7.15 (a)		

Explanations Building Materials

1. Cement

1.2 (b)
As per IS: 4031 Part 5-1988,while conducting initial setting time test on cement, a neat cement paste is prepared by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

1.3 (d)
Portland-pozzolana cement produces less heat of hydration and offers greater resistance to sulphate attack and chloride-ion penetration due to impurities in water than normal portland cement. All pozzolanas need not necessarily contribute to strength at early ages.

1.4 (c)
On an average 25% of water by weight of cement is required for chemical reaction with portland cement compounds. About 17% water by weight of cement is required to fill the gel-pores. Thus 42% water by weight is required for chemical reaction and gel pores. If more than 42% of water is used, the excess will cause undesirable cavities.

1.6 (b)
The retarder is an admixture that slow down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder. Gypsum is used in grouting to retard the setting time.

1.7 (a)
Blast furnace slag composition

CaO	:	42.4%
SiO_2	:	32.3%
Al_2O_3	:	13.3%
Fe_2O_3	:	0.3%
MgO	:	6.4%
SO_3	:	2.1%

1.8 (c)
According to IS code for Ordinary Portland Cement initial setting time should not be less than 30 minutes, final setting time should not be more than 600 minutes and normal consistency ranges from 20%-30% by weight of cement.

1.9 (a)
The raw materials used for manufacturing of high alumina cement are limestone and bauxite.

1.10 (b)
Gypsum is a retarder and prevents flash set. The rapid rate of development of strength is attributed to higher fineness and higher C_3S and lower C_2S content. Thus decreasing lime content will not result in rapid hardening or high early strength cement. The OPC has 63% CaO while rapid hardening cement has 64.5% CaO. A slight increase of CaO causes considerable increase in C_3S converting the OPC to a rapid hardening cement. A slight decrease in CaO and increase in SiO_2 decreases considerably the proportion of C_3S and increases proportion of C_2S thus forming low heat cement.

1.11 (d)
The test before which consistency test is required are:
(i) Initial and final setting time tests at water content 0.85P.
(ii) Compressive strength test at water content $\frac{P}{4} + 3\%$ of combined weight of 1 : 3 cement and Ennore (standard) sand mix.
(iii) Sound test by Le Chatelier apparatus at 0.78P for free lime soundness.

1.13 (*)
Low heat cement has a low percentage of C_3A and C_3S, instead C_2S content is increased at the cost of C_3A and C_3S.

Test on cement paste to determine initial and final setting times are not done at normal consistency but at 85% of normal consistency.
So only third statement is correct.

1.14 (c)
Autoclave test measures soundness due to both magnesia and free lime.
Fineness is measured by:
(i) Sieve test
(ii) Air permeability method using Blaine's apparatus

1.15 (c)
Superplasticizer enhance workability of concrete by dispersing the cement particles. They impart negative charges to individual particles. Thus they confer high mobility to particles.

The setting time may be retarded due to overdose of admixture or by lowering of ambient temperature.

The superplasticizers leave very few air void and thus decrease freezing and thawing resistance.

1.16 (b)

Oxides composition			Compounds composition		
CaO	—	63	C_3S	—	40
SiO_2	—	20.6	C_2S	—	30
Al_2O_3	—	6.3	C_3A	—	11
K_2O_3	—	3.6	C_4AF	—	11

1.17 (d)

Increase in fineness of cement increases rate of strength development by expediting the hydration reactions and increases shrinkage by leading to stronger reaction with alkali reactive aggregate making it more prone to cracking.

2. Mortar

2.1 (b)

The strength of various grades of mortars:

Grade	Strength (MPa)
L_2	0.5
L_1	0.7
M_2	2.0-3.0
M_1	3.0-5.0
H_2	6.0-7.5
H_1	10

2.2 (c)

The strength of standard mortar cube after 3 days, shall not be less than

(i) 16 MPa (160 kg/cm^2) for 33 grade OPC as per **IS : 269-1989**

(ii) 23 MPa (230 kg/cm^2) for 43 grade OPC as per **IS : 8112-1989**

(iii) 27 MPa (270 kg/cm^2) for 53 grade OPC as per **IS : 12269-1987**

2.3 (c)

The gunite is a mixture of 100 parts by weight of cement, 300 parts by weight of quartz sand, 35-50 parts by weight of water and 2 parts by weight approved quick compounds.

2.4 (c)

For 1 m^3 volume of brick work, the bricks required are 500. Therefore mortar needed

$= 1 - 500 \times 0.19 \times 0.09 \times 0.9 = 0.23$ m^3.

Add 15% extra for frog filling, brick bonding and wastage.

Volume of wet mortar $= 0.23 \times 1.15 = 0.265$ m^3

1 m^3 of wet mortar = 1.25 m^3 of dry mortar

$\therefore$ 0.265 m^3 wet mortar = 0.33 m^3 of dry mortar

Dry mortar as a percentage of brick work

$$= \frac{0.33}{1} \times 100 = 33\%$$

2.6 (c)

Gauged or lime-cement mortar is prepared by adding cement, sand and lime. Lower cement content in mortar leads to reduction in workability, less cohesion, and will produce porous joints with a tendency for low frost resistance. The inclusion of lime in cement mortar helps in rectifying these deficiencies by increasing the water retentivity, workability and bonding properties. In this way, early strength can also be achieved without the mature strength being too high.

2.7 (d)

Surkhi performs the same function as sand. But, in addition, it imparts strength and improve hydraulic property of mortar. As it disintegrates under the action of air and humidity, the mortar with surkhi should not be used for external plaster or pointing work.

Common functions of sand/surkhi in mortar:

(i) It acts as bulk.

(ii) It absorbs carbon dioxide from fat lime and setting of fat lime occurs effectively.

(iii) It increases resistance of mortar to crushing.

3. Lime

3.1 (c)

Lime used for mortar may be fat lime (quick or hydrated lime) or hydraulic lime. Slaked fat lime is used to prepare mortar for plastering, while hydraulic lime is used in preparing mortar for masonry construction.

3.2 (a)

Lime-cement mortar is also known as composite mortar or gauged mortar.

3.4 (a)

The modulus of rupture of hydraulic lime mortar (at 28 days curing) should be $\nless$ 1.05 N/mm^2.

3.5 (c)

Composite cement lime mortar has low drying shrinkage, high workability and high water retention as compared to cement mortar. So for identical strength composite cement lime mortar is preferred over cement mortar.

3.6 (d)

Lime mortar has high plasticity and it can be placed easily.

It possess good cohesiveness with other surfaces and shrinks very little and sufficiently durable.

4. Concrete

4.1 (a)

Split tensile strength is 5% to 12% higher than direct tensile strength. The ratio of split tensile strength to compressive strength for different grades of concrete are given below:

M10	10% – 15%
M15	15% – 20%
M20	20% – 25%
M30	25% – 30%

For approximation purpose one can take split tensile strength as $0.7\sqrt{f_{ck}}$ which is the flexural strength given by **IS : 456-2000.**

The ratio of split tensile strength to compressive strength is given by

$$\frac{0.7\sqrt{f_{ck}}}{f_{ck}} \times 100$$

For M15, f_{ck} = 15 N/mm^2

$$\Rightarrow \quad \frac{0.7\sqrt{15}}{15} \times 100 = 18\%$$

So 15% – 20% should be the choice.

4.2 (b)

The strength of concrete at any age, can be expressed by the relation

$$f_T = \frac{T}{a + bT} f_{28}$$

The 7-day and 28 day strength are related as

$$f_{28} = k_2 (f_7)^{k_1}$$

According to IS code, the ratio f_7/f_{28} is approximately 2/3.

Grade of concrete	7 day strength (N/mm^2)
M10	7
M15	10
M20	13.5
M25	17.0
M30	20.0
M35	23.5
M40	27.0

4.3 (c)

The modulus of elasticity as per **IS:456-1978**

$$E_c = 5700\sqrt{f_{ck}} \text{ N/mm}^2$$

The modulus of elasticity as per **IS:456-2000**

$$E_c = 5000\sqrt{f_{ck}} \text{ N/mm}^2$$

For M25

$$E_c = 5700\sqrt{f_{ck}} = 28{,}500 \text{ MPa}$$

$$E_c = 5000\sqrt{f_{ck}} = 25{,}000 \text{ MPa}$$

4.4 (c)

The restraining effect of the platens of the testing machine extends over the entire height of the cube but leaves unaffected a part of test cylinder because of its greater height. It is therefore, the strength of cube made from identical concrete will be higher from strength of cylinder.

4.5 (b)

Specific Surface of aggregate

$$\propto \frac{1}{\text{Size of aggregate}}$$

Workability of mix is influenced more by finer fractions . Greater contribution to total surface area is made by finer particles. Both statements are true but reason does not explain assertion.

4.6 (c)

Air entraining admixtures modify the properties of concrete viz. plasticity, workability, bleeding, seggregation, permeability and frost action.

Air entraining agent introduces air in the form of minute globals, which increases workability specially in harsh or lean mixes. Air entraining agents reduces concrete strength (1% air may cause a loss of 5% strength.

4.7 (b)
Tensile strength is generally determined indirectly. A compressive force is applied to a concrete specimen in such a way that specimen fails due to tensile stress induced in specimen. The compressive load is applied along opposite generators of concrete cylinder placed with its axis horizontal between the platens.

4.8 (c)
Ratio of cylinder strength to cube strength varies from 0.77-0.96. Thus 0.85 can be taken as approximate ratio.

4.9 (a)
The proportion of fine aggregate to combined aggregate,

$$R = \frac{p_2 - p}{p_2 - p_1} \times 100$$

$$\therefore \quad R = \frac{7.6 - 6.4}{7.6 - 2.8} \times 100 = 25\%$$

4.11 (d)
The drying in concrete starting from a wetter consistency causes shrinkage of concrete.

4.12 (d)
The correct dry weight of each size range of each material is calculated from their actual weight in weight batching and weight of water is measured by making adjustments for surface and absorbed water.

4.13 (b)
Calcium chloride is a rapid hardening agent. The acceleration of setting, hardening and evolution of this large quantity of heat in the early period of hydration makes the cement suitable for concreting in cold weather. The increased porosity of high alumina cement further develops more resistance to frosting. (Increased resistance to frosting due to high heat of hydration).

4.14 (b)
As per **IS : 456-1978**, $E_c = 5700\sqrt{f_{ck}}$

As per **IS : 456-2000**, $E_c = 5000\sqrt{f_{ck}}$

4.15 (b)
One complete cycle of material is discharged after about 20 revolutions and it takes $2\frac{1}{2}$ to 3 minutes. If the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption. While if the speed of mixer is increased to reduce mixing time, the quality of concrete will be poor.

4.16 (b)
The addition of surfactants in concrete mix decreases water-cement ratio thereby increasing the strength. Also curing duration is increased.

4.17 (b)
High water cement ratio improves the workability of the mixture but as the water content increases the strength of the mix decreases.

4.19 (c)
The measurement of material for making concrete is called batching. It is essential to ensure uniformity of proportions and aggregate grading in successive batches.

4.20 (b)
1 m^3 freshly mixed concrete corresponds to 1.54 m^3 dry volume of concrete.
Summation of proportions = 1 + 2 + 4 = 7

$$\text{Cement} = \frac{1.54}{7} = 0.22 \text{ m}^3 = 6.6 \text{ bags}$$

(1 m^3 cement equal 30 bags of cement or 1500 kg cement)
Sand = 0.22 × 2 = 0.44 m^3
Coarse aggregate = 0.22 × 4 = 0.88 m^3

4.21 (c)
As 5.5 bags of cement can produce 0.8 m^3 of concrete .The maximum number of full bags will be 5. So 5 bags can produce $\frac{5}{5.5} \times 0.8 = 0.73$ m^3 of concrete.

4.22 (b)
Split tensile strength in the case of cylinder is obtained by $\sigma_{sp} = \frac{2P}{\pi DL}$

The test can also be performed on cubes by either

(i) along its middle parallel to the edges by applying two opposite compressive force through 15 mm square bars of sufficient length

$\sigma_{sp} = 0.642\ P/S^2$ OR

(ii) along one of the diagonal planes by applying compressive forces along two opposite edges

$\sigma_{sp} = 0.518\ P/S^2$

where

$P \rightarrow$ Load at failure
$S \rightarrow$ Side of the cube
$L \rightarrow$ Length of cylinder
$D \rightarrow$ Diameter of cylinder

4.23 (a)

Split tensile strength (0.66 f_{cr}) - modulus of rupture (f_{cr})- cylinder strength (0.8 f_{ck})- cube strength (f_{ck}), is the increasing order of strength.

4.24 (a)

Shrinkage is used to describe the various aspects of volume change in concrete due to loss of moisture at different stages due to different reasons. One of the most important factors that affects shrinkage is the relative humidity of the atmosphere at which the concrete specimen is kept. Shrinkage also depends on time. Its magnitude increases with time and also with the reduction of relative humidity. Another important factor which affects shrinkage is water cement ratio and type of aggregates.

4.25 (d)

Air entrainment in concrete results in improved workability, increased plasticity, better resistance to freezing and thawing, reduction in bleeding and segregation, increased durability and easier placing and finishing. However it reduces the strength of concrete.

5. Stones, Bricks and Bricks Masonry

5.1 (c)

Chalk is used as a colouring material in the manufacture of portland cement.
Laterite is used as a road metal, in rough masonry work etc.

5.2 (b)

The brick should not absorb water more than 20% by weight for first class bricks and 22% by weight for second class bricks, when soaked in cold water for 24 hours.

5.3 (c)

For getting a good brick bond,

(i) the amount of lap should be one-fourth brick along the length of the wall and one-half brick across the thickness of wall.
(ii) the brick should be of uniform size to get uniform lap.
(iii) the stretchers should be used in the facing.
(iv) the use of brick bat should be discouraged except under special circumstances.
(v) the vertical joints in the alternate courses should be vertically above each other.

5.4 (d)

King closers are the portions of a brick obtained by cutting off the triangular piece between the centre of one end and the centre of one side.

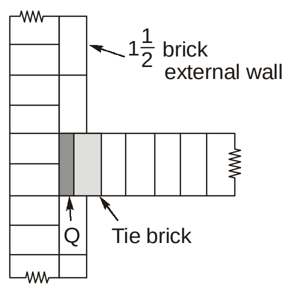
5.6 (a)

The bricks, when tested in accordance with the procedure in IS 3495 (Part 2) : 1992 after immersion in cold water for 24 hours, water absorption shall not be more than 20 percent by weight up to class 12.5 and 15 percent by weight for higher classes.

5.7 (c)

Half brick work is done in stretcher course only while other brickworks are done in both header and stretcher courses.

5.8 (b)



5.9 (c)

The process of grinding clay with water and making it plastic is known as pugging. So pugmill is used for tempering.

Gelignite is an explosive used in blasting. It is more convenient than dynamite and can be used under water.

5.10 (c)

Number of modular bricks size 20 cm × 10 cm × 10 cm with mortar

$$= \frac{1}{0.2 \times 0.1 \times 0.1} = \frac{1000}{2} = 500 \text{ bricks}$$

The nominal size of brick is taken as 20 cm × 10 cm × 10 cm while the actual size is 19 cm × 9 cm × 9 cm.

5.11 (a)

Coping is a covering placed on the exposed top of an external wall. It is essentially provided to prevent the seepage of water through the joints of the top most corner of the wall. It may be of concrete, stone, brick or terracotta.

5.12 (c)

Since the number of joints in the backing and facing differ greatly, the distribution of load is not uniform.

5.13 (a)

There is no point in using a mortar with higher strength than the masonry units since the units will crush earlier than the mortar. Also it will be wasteful of money to use a very weak mortar for high strength masonry units. Thus there is an optimum relationship between masonry unit strength and mortar strength.

5.14 (b)

Crushing strength for a good building stone should be more than 100 Mpa, Hardness coefficient should be more than 14, toughness index more than 13, high durability, specific gravity more than 2.7 and low water absorption.

5.15 (c)

Slenderness ratio of masonry walls is effective length/effective thickness or effective height/effective thickness which ever is less. As per code height of non load bearing walls shall not exceed 30 times the thickness. While for load bearing walls slenderness ratio is 27. (When Portland cement or Portland pozzolana cement is used in mortar.)

5.16 (a)

Soluble salts like potassium sulphate, sodium sulphate in fired clays develop efflorescence on brick surface after wetting and drying.

5.17 (d)

For wall of thickness equal to even number of half bricks no bats will be required and a stretcher or header will come out as a stretcher or header in the same course in front as well as back elevations. But the same is not true for wall of thickness equal to odd number of half bricks.

5.18 (b)

Silica imparts uniform shape to the bricks.

Iron pyrite causes disintegration of bricks due to oxidation of iron pyrite during burning. Vegetation makes the bricks porous as incomplete burning of these matter results in evolution of gases.

5.19 (c)

Frog is an indentation or depression on the top face of a brick made with the object of forming a key for the mortars. This also reduces the weight of the brick.

5.20 (c)

Bricks are burnt in temperature range of 900°C - 1200°C(1650°F-2190° F) in kilns or furnaces.

6. Timber

6.1 (d)

Weight and strength properties of timber are greatly influenced by moisture content. Therefore the strength values and weight obtained are usually standardized at 12% moisture content.

6.2 (a)

Timber is stronger in tension along the grain but it is quite difficult to determine this because of the difficulties in conducting the test.

6.3 (a)

Variation in moisture content of wood with atmospheric condition causes dimensional change in wood. If dry piece of timber is kept in saturated atmosphere, it absorbs water from air to about15% of weight and swells up. Drying of wood below saturation point results in shrinkage.

6.4 (a)

In nailed joints in timber, it is found that where prebore is necessary, the diameter of the hole should not be greater than 4/5 of the diameter of the nail and that the diameter of the nails must lie within $\frac{1}{4}$ and $\frac{1}{6}$ of the least thickness of timbers to be connected.

6.5 (c)

The expansion and shrinkage is comparatively low when plies are placed at right angles as in the cross grained construction the longitudinal grains of the core restrain any tangential movement and vice verse.

6.6 (d)

For using timber for engineering purpose, seasoning of timber is done to remove sap in order to prevent timber from the possible fermentation.

6.7 (c)

Deciduous trees are broad leaved hardwood trees. Coniferous are needle shaped softwood trees growing in high altitudes. Endogenous trees grow inward from a hard exterior shell e.g. Bamboo. In Exogenous plants, stems are formed by successive additional layer on outside that is they grow outwards e.g. Eucalyptus.

6.8 (a)

The species of timber recommended for construction purpose are classified into three groups on the basis of their modulus of elasticity.

Group A : with modulus of elasticity above 125 t/cm^2 (12500 N/mm^2)

Group B : with modulus of elasticity between 98 t/cm^2 (9800 N/mm^2) and 125 t/cm^2 (12500 N/mm^2)

Group C : with modulus of elasticity above 56 t/cm^2 (5600 N/mm^2) and below 98 t/cm^2 (9800 N/mm^2)

6.9 (d)

The order of strength of timber section is

Radial sawing > Quarter sawing > Ordinary sawing > Tangential sawing

6.10 (c)

To prevent lateral buckling, the minimum width of the beam is kept equal to or more than $L/50$ and $d/3$. In no case width should be less than 50 mm.

6.11 (c)

Built-up columns are made by spiking, nailing or bolting together planks or square sections.

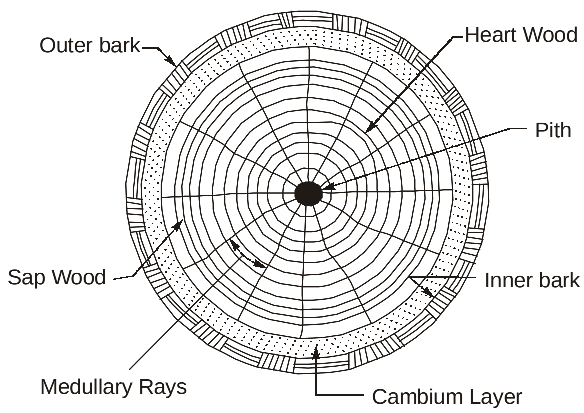
Spaced columns are employed usually in trusses with nailed connections. They are separated from each other by means of spacer blocks.

6.12 (c)

As per IS 287-1993

- Recommended moisture content for structural elements is 12-20 percent for doors.
- The maximum permissible moisture content of structural elements for use as beam and rafter varies from 12-20 percent (depending upon the zone in which structure lies).
- The moisture content of structural elements for use as building frames like windows may vary from 8 to 16 percent (depending upon the zone in which structure lies).

6.13 (b)



6.14 (d)

Green timber of large moisture content takes more time to dry than of lower moisture content. Reason statement is true.

6.15 (c)

The most effective method is pressure impregnation in which preservative is injected under pressure in timber. In dipping method timber is dipped in preservative for a short period, proves to be more effective than preservating through brushing or spraying.

6.16 (b)

Cup shakes are caused by rupture of tissue in a circular direction. It is a curved track and separates partly one annual ring from the other. Heart shakes occur in the centre of the cross-section and they extend from pith to sap wood in the direction of medullary rays. They occur due to shrinkage of interior part of tree which is approaching maturity. Radial shakes and star shakes extend from bark towards the sapwood. Star shakes are wider on the outside ends bark and narrower on the inside ends (sapwood). The radial shakes are fine, irregular and numerous.

7. Oil, Varnishes Paint, Distempers, Glass & Miscellaneous

7.2 (b)

$E = 2 \times 10^5$ N/mm^2 for both mild steel and high tensile bars.

7.3 (c)

The yield strength of mild steel plain rounded bar is 255 N/mm^2. So the increase is about 20% from a value of 250 N/mm^2.

7.4 (a)

The linear thermal coefficient range is 6×10^{-6} to 10×10^{-6} for both glass and granite.

7.5 (b)

Young's modulus of all steel types is same and hence the ratio is 1.0

7.6 (a)

Industrial bitumens are specified as per **IS:73-1961** as 65/25 meaning the penetration value is 20–30 and softening point is 55 –70°C. Thus first number is softening point and second is penetration value.

Paving grade bitumens are specified as 60/70 means that penetration value is 60 to 70.

7.7 (b)

Thermoplastic or heat non-convertible group means that the plastics become soft when heated and hard when cooled.

Thermosetting or heat convertible group means that plastics become rigid when moulded at suitable pressure and temperature.

Rigid plastics have a high modulus of elasticity and they retain their shape under external stresses application at normal or moderately increased temperatures.

7.8 (a)

The wood work painting has following steps:

(i) Preparation of surface
(ii) Knotting
(iii) Priming
(iv) Stopping or putty filling
(v) Second or surface coats or under coatings
(vi) Finishing coat

So putty filling is done after prime coat.

7.10 (b)

The ultimate tensile strength of a plain hard-drawn steel wire varies with its diameter. The tensile strength decreases with increase in the diameter of the wires. Tensile strengths and elongation characteristics of cold-drawn stress relieved wires as per IS: 1785 (Part1)-1983 is as given in the following table:

Nominal Diameter (mm)	Minimum tensile strength (N/mm^2)	Elongation (%)
2.5	2010	2.5
3.0	1865	2.5
4.0	1715	3.0
5.0	1570	4.0
6.0	1470	4.0
7.0	1375	4.0

7.12 (b)

The carbon content of mildsteel is about 0.10 to 0.25%. It is used as structural steel.

7.13 (c)

Vehicle is a non-volatile fluid in which the solid body material is suspended and comprises 85%-90% drying oil plus 10%-15% drier and thinner. Examples of vehicle are:

1. **Drying oil :** Linseed oil from flax seeds, fish oil, dehydrated castor oil, tung oil, perilla oil.
2. **Drier :** Organic salts of various metals such as PbO (litharge) for lead based paints and $ZnSO_4$ and MnO for zinc based paints.
3. **Thinner :** Volatile solvents like turpentine, petroleum fractions like naphtha, benzene.

7.14 (b)

Caesin glue is obtained from coagulating skimmed milk in vats and grinding the product to a fine powder. It is used in plywood industry for gluing together veneers. It is white in colour.

7.15 (a)

Standard are vertical members of scaffolding. Ledgers are the horizontal members at right angles to standard and parallel to the wall braces are fixed diagonally on the standards. Putlogs are placed on the horizontal member (i.e. ledgers) at right angle to the walls, one end of which is held in wall.

■■■■

UNIT

II

Solid Mechanics

Syllabus

Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.

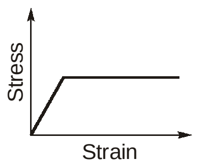
Contents

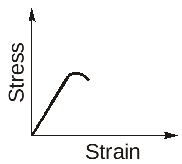
■■■■

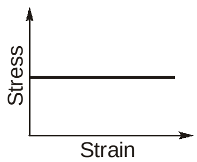
2 Solid Mechanics

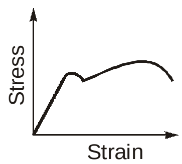
1. Properties of Materials

1.1 The stress-strain curve for an ideally plastic material is

(a) 

(b) 

(c) 

(d) 

[ESE : 1995]

1.2 The stress level, below which a material has a high probability of not failing under reversal of stress, is known as
(a) elastic limit (b) endurance limit
(c) proportional limit (d) tolerance limit
[ESE : 1995]

1.3 The stress at which a material fractures under large number of reversals of stress is called
(a) endurance limit (b) creep
(c) ultimate strength (d) residual stress
[ESE : 1996]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.4 **Assertion (A):** Strain is a fundamental behaviour of the material, while the stress is a derived concept.
Reason (R): Strain does not have a unit while the stress has a unit.
[ESE : 1996]

1.5 **Assertion (A):** The amount of elastic deformation at a certain point, which an elastic body undergoes, under given stress is the same irrespective of the stresses being tensile or compressive.
Reason (R): The modulus of elasticity and Poisson's ratio are assumed to be the same in tension as well as compression.
[ESE : 1996]

1.6 **Assertion (A):** A mild steel tension specimen has a cup and cone fracture at failure.
Reason (R): Mild steel is weak in shear and failure of the specimen in shear takes place at 45° to the direction of the applied tensile force.
[ESE : 1996]

1.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Ductility
B. Brittleness
C. Tenacity
D. Toughness

List-II
1. Failure without warning
2. Drawn permanently over great changes of shape without rupture
3. Absorption of energy at high stress without rupture
4. High tensile strength

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	2	3	4

(c)	2	3	4	1
(d)	2	1	4	3

[ESE : 1998]

1.8 Which one of the following pairs is NOT correctly matched?

(a) Visco-elastic : *Small plastic zone material*

(b) Strain hardening material : *Stiffening effect felt at some stage*

(c) Orthotropic material : *Different properties in three perpendicular directions*

(d) Isotropic material : *Same physical property in all directions at a point*

[ESE : 1998]

1.9 Match **List-I** (Material) with **List-II** (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Inelastic material

B. Rigid plastic material

C. Ductile material

D. Brittle material

List-II

1. No plastic zone
2. Large plastic zone
3. Strain is not recovered after unloading
4. Strain is zero upto a stress level and then stress remains constant.

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	3	4	1	2
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1999]

1.10 Match **List-I** (Property) with **List-II** (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Fatigue

B. Creep

C. Plasticity

D. Endurance limit

List-II

1. Material continues to deform with time under sustained loading
2. Decreased resistance of material to repeated reversals of stress
3. Material has a high probability of not failing under reversals of stress of magnitude below this level
4. Material continues to deform without any further increase in stress

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	2	1	3	4
(c)	1	2	4	3
(d)	1	2	3	4

[ESE : 1999]

1.11 **Assertion (A):** In a tensile test on a specimen, true stress in the specimen is more than the nominal stress.

Reason (R): Grip of universal testing machine introduces stress concentrations.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1999]

2. Simple Stress-Strain & Elastic Constants

2.1 Given that for an element in a body of homogeneous isotropic material subjected to plane stresses, ε_x, ε_y and ε_z are normal strains in x, y and z direction respectively and μ is the Poisson's ratio, the magnitude of unit volume change of the element is given by

(a) $\varepsilon_x + \varepsilon_y + \varepsilon_z$

(b) $\varepsilon_x + \mu(\varepsilon_y + \varepsilon_z)$

(c) $\mu(\varepsilon_x + \varepsilon_y + \varepsilon_z)$

(d) $\dfrac{1}{\varepsilon_x} + \dfrac{1}{\varepsilon_y} + \dfrac{1}{\varepsilon_z}$

[ESE : 1995]

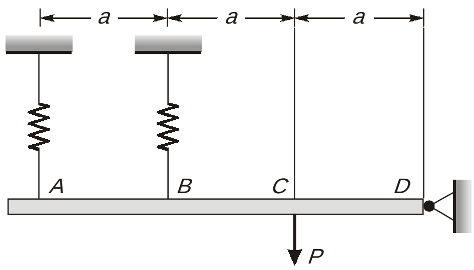
2.2 A solid metal bar of uniform diameter D and length L is hung vertically from a ceiling. If the density of the material of the bar is ρ and the modulus of elasticity is E, then the total elongation of the bar due to its own weight is

(a) $\frac{\rho L}{2E}$ (b) $\frac{\rho L^2}{2E}$

(c) $\frac{\rho E}{2L}$ (d) $\frac{\rho E}{2L^2}$

[ESE : 1995]

2.3 A rigid beam *ABCD* is hinged at *D* and supported by two springs at *A* and *B* as shown in the given figure. The beam carries a vertical load *P* at *C*. The stiffness of spring at *A* is 2*k* and that of *B* is *k*.



The ratio of forces of spring at A and that of spring at B is

(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 1995]

2.4 A steel cube of volume 8000 cc is subjected to all round stress of 1330 kg/cm^2. The bulk modulus of the material is 1.33×10^6 kg/cm^2. The volumetric change is

(a) 8 cc (b) 6 cc
(c) 0.8 cc (d) 10^{-3} cc

[ESE : 1995]

2.5 In terms of bulk modulus (*K*) and modulus of rigidity (*G*), Poisson's ratio can be expressed as

(a) $\frac{3K-4G}{6K+4G}$ (b) $\frac{3K+4G}{6K-4G}$

(c) $\frac{3K-2G}{6K+2G}$ (d) $\frac{3K+2G}{6K-2G}$

[ESE : 1995]

2.6 Two bars one of material *A* and the other of material *B* of same length are tightly secured between two unyielding walls. Coefficient of thermal expansion of bar *A* is more than that of *B*. When temperature rises the stresses induced are

(a) tension in both the materials
(b) tension in material A and compression in material *B*
(c) compression in material A and tension in material *B*
(d) compression in both the materials

[ESE : 1995]

2.7 A bar of diameter 30 mm is subjected to a tensile load such that the measured extension on a gauge length of 200 mm is 0.09 mm and the change in diameter is 0.0045 mm. The Poisson's ratio will be

(a) 1/4 (b) 1/3
(c) 1/5 (d) 1/6

[ESE : 1995]

2.8 A 2 m long bar of uniform section extends 2 mm under limiting axial stress of 200 N/mm^2. What is the modulus of resilience for the bar?

(a) 0.10 units (b) 0.20 units
(c) 10000 units (d) 200000 units

[ESE : 1995]

2.9 A rectangular block of size 200 mm × 100 mm × 50 mm is subjected to a shear stress of 500 kg/cm^2. If the modulus of rigidity of the material is 1×10^6 kg/cm^2, the strain energy stored will be

(a) 1000 kg-cm (b) 500 kg-cm
(c) 125 kg-cm (d) 100 kg-cm

[ESE : 1995]

2.10 If $E = 2.06 \times 10^5$ N/mm^2, an axial pull of 60 kN suddenly applied to a steel rod 50 mm in diameter and 4 m long. It causes an instantaneous elongation of the order of

(a) 1.19 mm (b) 2.19 mm
(c) 3.19 mm (d) 11.9 mm

[ESE : 1995]

2.11 A bar of circular cross-section varies uniformly from a cross-section 2*D* to *D*. If extension of the bar is calculated treating it as a bar of average diameter, then the percentage error will be

(a) 10 (b) 25
(c) 33.33 (d) 50

[ESE : 1996]

2.12 The length, coefficient of thermal expansion and Young's modulus of bar *A* are twice that of bar *B*. If the temperature of both bars is increased by the same amount while preventing any expansion, then the ratio of stress developed in bar *A* to that in bar *B* will be

(a) 2 (b) 4
(c) 8 (d) 16

[ESE : 1996]

2.13 The lists given below refer to a bar of length *L*, cross sectional area *A*, Young's modulus *E*, Poisson's ratio μ and subjected to axial stress '*p*'. Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Volumetric strain
B. Strain energy per unit volume
C. Ratio of Young's modulus to bulk modulus
D. Ratio of Young's modulus to modulus of rigidity

List-II
1. $2(1+\mu)$
2. $3(1-2\mu)$
3. $\frac{p}{E}(1-2\mu)$
4. $\frac{p^2}{2E}$
5. $2(1-\mu)$

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	5	4	1	2
(c)	5	4	2	1
(d)	2	3	1	5

[ESE : 1996]

2.14 If all the dimensions of a prismatic bar of square cross-section suspended freely from the ceiling of a roof are doubled then the total elongation produced by its own weight will increase
(a) eight times (b) four times
(c) three times (d) two times

[ESE : 1996]

2.15 A round steel bar of overall length 40 cm consists of two equal portions of 20 cm each having diameters of 10 cm and 8 cm respectively. Take *E* as 2×10^6 kg/cm^2. If the rod is subjected to a tensile load of 10 tonnes, the elongation in cm will be given by

(a) $\frac{1}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ (b) $\frac{2}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$

(c) $\frac{3}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$ (d) $\frac{4}{10\pi}\left(\frac{1}{25}+\frac{1}{16}\right)$

[ESE : 1997]

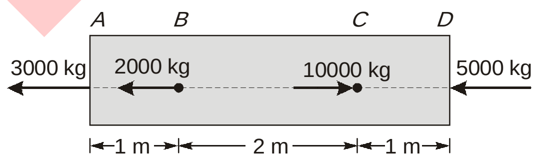
2.16 A copper bar of 25 cm length is fixed by means of supports at its ends. Supports can yield (total) by 0.01 cm. If the temperature of the bar is raised by 100°C, then the stress induced in the bar for $\alpha_c = 20 \times 10^{-6}$ °C and $E_c = 1 \times 10^6$ kg/cm^2 will be
(a) 2×10^2 kg/cm^2 (b) 4×10^2 kg/cm^2
(c) 8×10^2 kg/cm^2 (d) 16×10^2 kg/cm^2

[ESE : 1997]

2.17 A given material has Young's modulus *E*, modulus of rigidity *G* and Poisson's ratio 0.25. The ratio of Young's modulus to modulus of rigidity of this material is
(a) 3.75 (b) 3
(c) 2.5 (d) 1.5

[ESE : 1997]

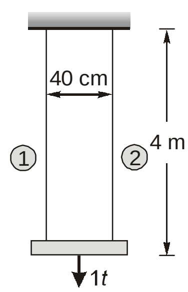
2.18 A prismatic bar of uniform cross-sectional area of 5 cm^2 is subjected to axial loads as shown in the given figure.



Portion *BC* is subjected to an axial stress of
(a) 400 kg/cm^2 tension
(b) 2000 kg/cm^2 compression
(c) 1000 kg/cm^2 tension
(d) 600 kg/cm^2 tension

[ESE : 1997]

2.19 Two wires of equal length are suspended vertically at a distance of 40 cm as shown in the figure below. Their upper ends are fixed to the ceiling while their lower ends support a rigid horizontal bar which carries a central load of 1t midway between the wires. Details of the two wires are given below:



Wire No.	Area (cm^2)	Material	Modulus of Elasticity (kg/cm^2)	Elongation
1	4	Copper	1×10^6	Δ_C
2	2	Steel	2×10^6	Δ_S

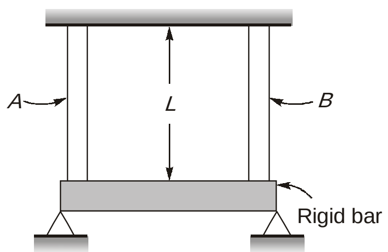
The ratio of the elongation of the two wires, Δ_c/Δ_s is

(a) 0.25 (b) 0.5

(c) 2 (d) 1

[ESE : 1997]

2.20 A composite section shown in the figure below was formed at 20°C and was made of two materials *A* and *B*. If the coefficient of thermal expansion of *A* is greater than that of *B* and the composite section is heated to 40°C, then *A* and *B* will



(a) be in tension and compression respectively

(b) both be in compression

(c) both be in tension

(d) be in compression and tension respectively

[ESE : 1998]

2.21 In an experiment it found that the bulk modulus of a material is equal to its shear modulus. The Poisson's ratio is

(a) 0.125 (b) 0.250

(c) 0.375 (d) 0.500

[ESE : 1998]

2.22 A mild steel bar is in two parts having equal lengths. The area of cross-section of Part-1 is double that of Part-2. If the bar carries an axial load *P*, then the ratio of elongation in Part-1 to that in Part-2 will be

(a) 2 (b) 4

(c) 1/2 (d) 1/4

[ESE : 1998]

2.23 Assertion (A): A bar tapers from a diameter of 'd_1' to a diameter of 'd_2' over its length *L* and is subjected to a tensile force *P*. If extension is calculated based on treating it as a bar of average diameter, the calculated extension will be more than the actual extension.

Reason (R): The actual extension in such bars is given by, $\Delta = \dfrac{4PL}{\pi d_1 d_2 E}$.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1998]

2.24 A round bar made of same material consists of 3 parts each of 100 mm length having diameters of 40 mm, 50 mm and 60 mm, respectively. If the bar is subjected to an axial load of 10 kN, the total elongation of the bar in mm would be (E is the modulus of elasticity in kN/mm^2)

(a) $\dfrac{0.4}{\pi E}\left(\dfrac{1}{16}+\dfrac{1}{25}+\dfrac{1}{36}\right)$

(b) $\dfrac{4}{\pi E}\left(\dfrac{1}{16}+\dfrac{1}{25}+\dfrac{1}{36}\right)$

(c) $\dfrac{4\sqrt{2}}{\pi E}\left(\dfrac{1}{16}+\dfrac{1}{25}+\dfrac{1}{36}\right)$

(d) $\dfrac{40}{\pi E}\left(\dfrac{1}{16}+\dfrac{1}{25}+\dfrac{1}{36}\right)$

[ESE : 1999]

2.25 If a member is subjected to tensile stress of 'p_x', compressive stress of 'p_y' and tensile stress of 'p_z', along the *X*, *Y* and *Z* directions respectively, then the resultant strain 'ϵ_x' along the *X* direction would be (*E* is Young's modulus of elasticity and 'μ' is Poisson's ratio)

(a) $\dfrac{1}{E}(p_x + \mu p_y - \mu p_z)$

(b) $\dfrac{1}{E}(p_x + \mu p_y + \mu p_z)$

(c) $\dfrac{1}{E}(p_x - \mu p_y + \mu p_z)$

(d) $\dfrac{1}{E}(p_x - \mu p_y - \mu p_z)$

[ESE : 1999]

2.26 A cylindrical bar of 20 mm diameter and 1 m length is subjected to a tensile test. Its longitudinal strain is 4 times that of its lateral strain. If the modulus of elasticity is 2×10^5 N/mm^2, then its modulus of rigidity will be

(a) 8×10^6 N/mm^2 (b) 8×10^5 N/mm^2
(c) 0.8×10^4 N/mm^2 (d) 0.8×10^5 N/mm^2

[ESE : 1999]

2.27 Assertion (A): A mild steel tension specimen subjected to an axial load fails along a surface at 45° to its axis.

Reason (R): Mild steel is weaker in shear than in tension and the place of maximum shear is at 45° to its axis.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

3. Shear Force & Bending Moment

3.1 Assertion (A): Bending moment in a beam is maximum at a section where shear force is zero.

Reason (R): Shear force at a section is given by the rate of change of bending moment.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

3.2 Match **List-I** (Type and position of load on cantilever) with **List-II** (Shape of moment diagram for cantilever) and select the correct answer using the codes given below the lists:

List-I

A. Carrying linearly varying load from zero at its free end and maximum at the fixed end
B. Subjected to uniformly distributed load
C. Carrying concentrated load at its free end
D. Whose free end is subjected to bending moment

List-II

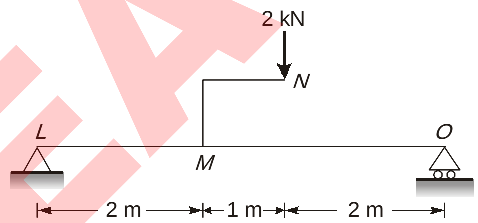
1. Parabola
2. Rectangle
3. Cubic parabola
4. Triangle

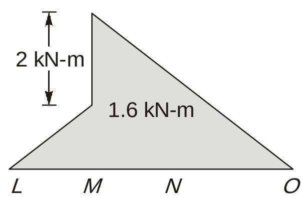
Codes:

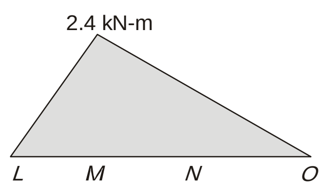
	A	B	C	D
(a)	3	2	1	4
(b)	4	3	2	1
(c)	3	1	4	2
(d)	2	4	1	3

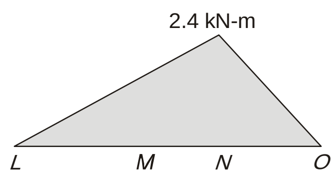
[ESE : 1995]

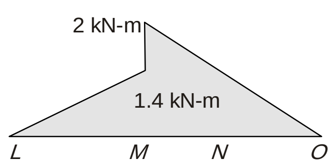
3.3 The bending moment diagram of the beam shown figure is



(a)


(b)


(c)


(d)


[ESE : 1995]

3.4 The SFD and BMD for a beam are shown in the given figures I and II. The corresponding loading diagram would be

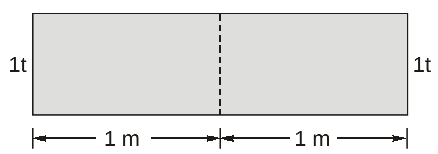


Figure-I

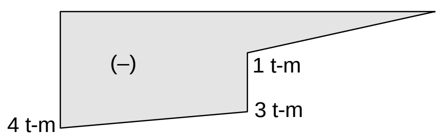
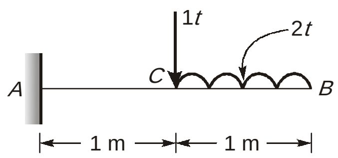
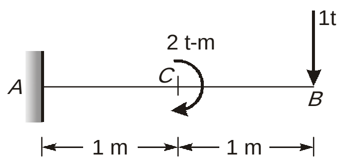
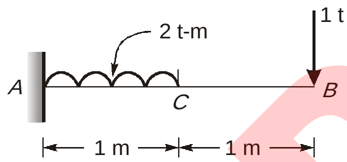
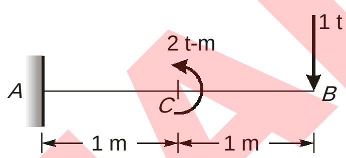


Figure-II

(a)


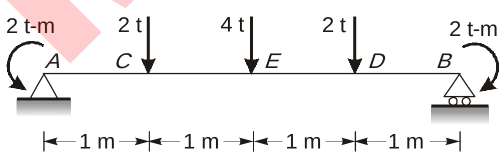
(b)


(c)


(d)


[ESE : 1995]

3.5 A simply supported beam is loaded as shown in the given figure. The bending moment at *E* would be



(a) 6 t-m (Sagging)
(b) 4 t-m (Hogging)
(c) 6 t-m (Hogging)
(d) 4 t-m (Sagging)

[ESE : 1995]

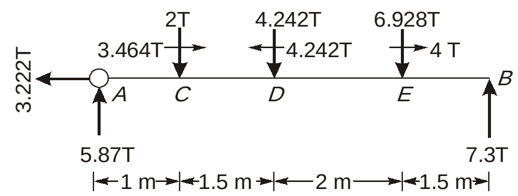
3.6 Which one of the following statements is correct?
(a) Shear force is the first derivative of bending moment.
(b) Shear force is the first derivative of intensity of load.
(c) Load intensity on a beam is the first derivative of bending moment.
(d) Bending moment is the first derivative of shear force.

[ESE : 1995]

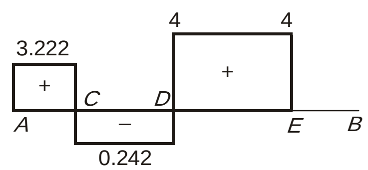
3.7 **Assertion (A):** The maximum bending moment occurs where the shear force is either zero or changes sign.
Reason (R): If the shear force diagram line between the two points is horizontal, the BM diagram line is inclined. But if the SF diagram is inclined, the BM diagram is a parabola of second degree.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

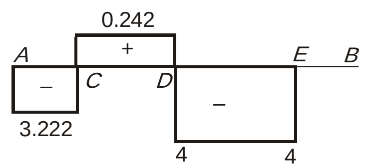
[ESE : 1996]

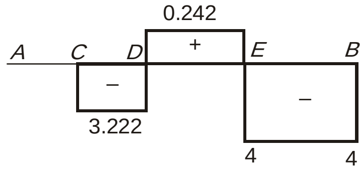
3.8 If the loads and reactions of the beam shown are as given in the following figure,

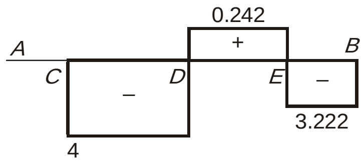


The thrust diagram on the section of the beam, taking tension positive, will be

(a)


(b)


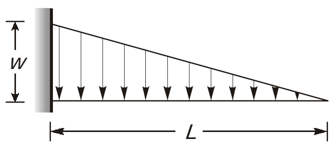
(c) 

(d) 

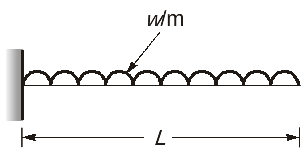
[ESE : 1996]

3.9 Match **List-I** (Type of beam with loading) with **List-II** (Maximum bending moment value) and select the correct answer given below the lists:

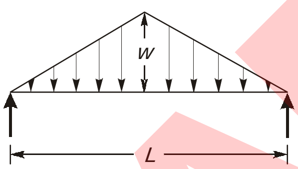
List-I | **List-II**

A. 

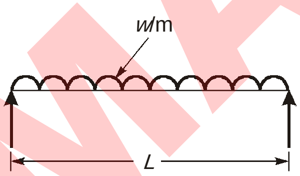
1. $\frac{wL^2}{12}$

B. 

2. $\frac{wL^2}{6}$

C. 

3. $\frac{wL^2}{2}$

D. 

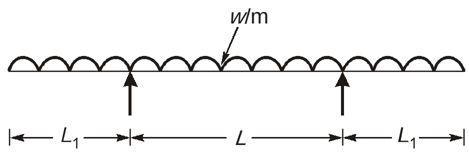
4. $\frac{wL^2}{8}$

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	2	4
(c)	2	3	1	4
(d)	2	4	1	3

[ESE : 1996]

3.10 For the beam shown in the given figure, the maximum positive bending moment is equal to negative bending moment. The value of L_1 is

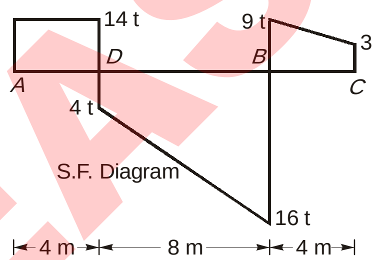


(a) $\frac{L}{\sqrt{2}}$ (b) $\frac{L}{\sqrt{3}}$

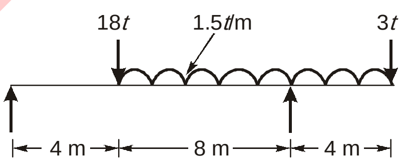
(c) $\frac{L}{2}$ (d) $\frac{L}{2\sqrt{2}}$

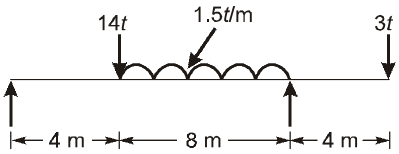
[ESE : 1996]

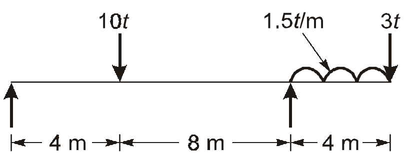
3.11 Consider the shear force diagram shown in given figure

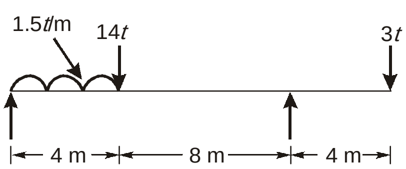


The loaded beam will be

(a) 

(b) 

(c) 

(d) 

[ESE : 1996]

3.12 Match **List-I** (Type and position of force on cantilever) with **List-II** (Shape of bending moment diagram for a cantilever) and select the correct answer using the codes given below the lists:

List-I

A. Carrying linearly varying load from zero at its free end and maximum at the fixed end
B. Subjected to uniformly distributed load
C. Carrying concentrated load at its free end
D. Whose free end is subjected to a couple

List-II

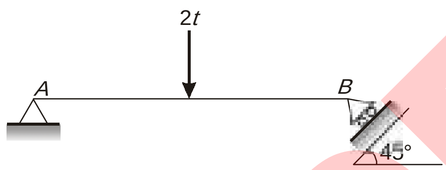
1. Parabola
2. Rectangle
3. Cubic Parabola
4. Triangle

Codes:

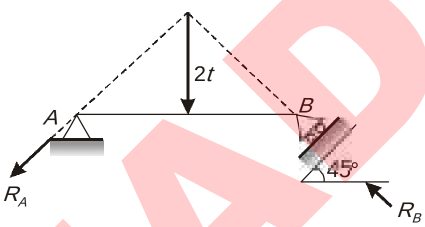
	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	3	1	4	2
(d)	1	3	4	2

[ESE : 1996]

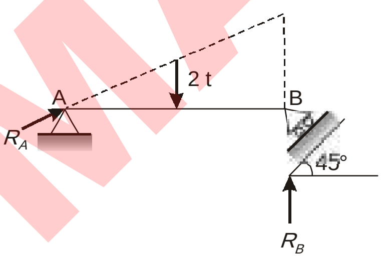
3.13 In a beam *AB*, support *A* is hinged and support *B* is on rollers as shown below. The directions of the reactions at *A* and *B* will be as in



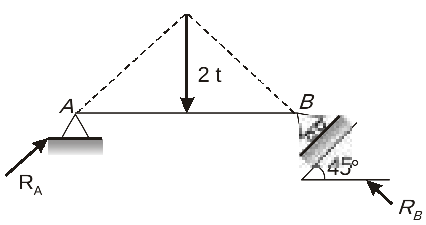
(a)



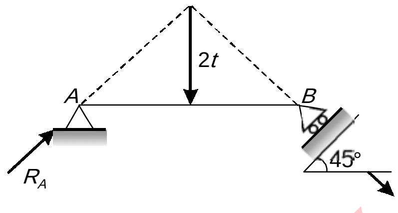
(b)



(c)



(d)

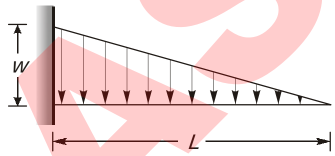


[ESE : 1997]

3.14 Match **List-I** (Type of beam with type of loading) with **List-II** (Max. BM Formula) and select the correct answer using the codes given below the lists:

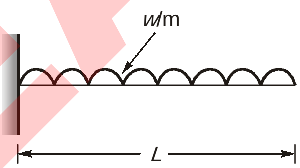
List-I | **List-II**

A.



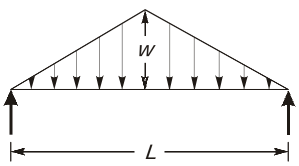
1. $\frac{wL^2}{12}$

B.



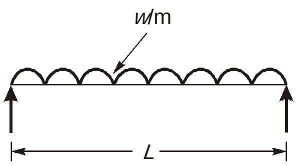
2. $\frac{wL^2}{6}$

C.



3. $\frac{wL^2}{2}$

D.



4. $\frac{wL^2}{8}$

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	1	2	3	4
(c)	4	3	1	2
(d)	2	1	4	3

[ESE : 1997]

3.15 If the area under the shear curve for a beam between the two points X_1 and X_2 is *k*, then the difference between the moments at the two points X_1 and X_2 will be equal to

(a) k (b) $2k$
(c) $k/2$ (d) k^2

[ESE : 1997]

3.16 Assertion (A): Bending moment may be defined as the algebraic sum of the moments of all forces on either side of the section.

Reason (R): The rate of change of bending moment is equal to shear force at the section.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

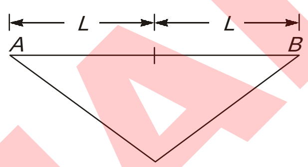
[ESE : 1998]

3.17 Which one of the following statements is **NOT** correct?

(a) A bending moment diagram can have a change of slope only under a transverse load.
(b) The bending moment is maximum where the shear force is zero.
(c) A non-linear bending moment diagram is possible only in the distributed load regions.
(d) At every support of a continuous beam, the maximum values of negative bending moment in the span are experienced.

[ESE : 1998]

3.18 For a cantilever *AB* with clamped end *A* and subjected to concentrated loads, the shape of the bending moment diagram is shown in the adjacent figure. This diagram is



(a) an absurdity
(b) possible only if the free end *B* has an additional couple
(c) possible only if the left half of the beam has twice the moment of inertia as compared to that of the right half
(d) none of the above

[ESE : 1998]

3.19 Consider the following statements:
A simply-supported beam is subjected to a couple somewhere in the span. It would produce

1. a rectangular *SF* diagram
2. parabolic *BM* diagrams
3. both +ve and –ve BMs which are maximum at the point of application of the couple.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

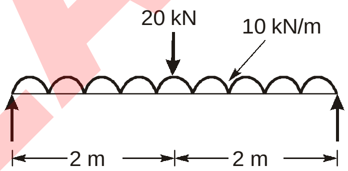
[ESE : 1998]

3.20 A beam of length 10 m carries a UDL of 20 kN/m over its entire length and rests on two simple supports. In order that the maximum *BM* produced in the beam is the least possible, the supports must be placed from the ends at a distance of

(a) 5.86 m (b) 4.14 m
(c) 2.93 m (d) 2.07 m

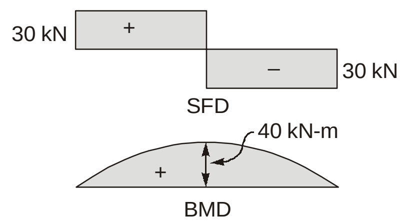
[ESE : 1998]

3.21 A simply supported beam is shown in the given figure

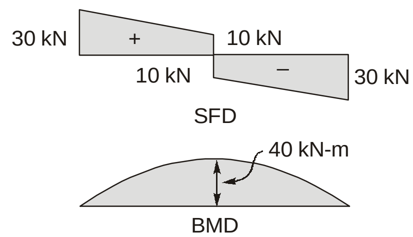


The corresponding SFD and BMD would be

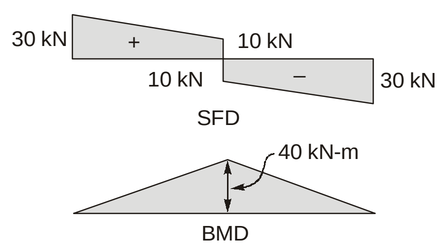
(a)



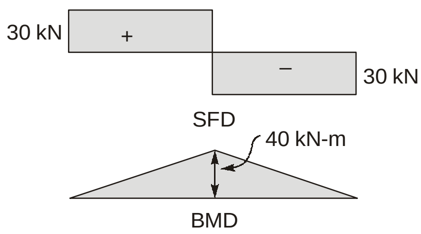
(b)



(c)

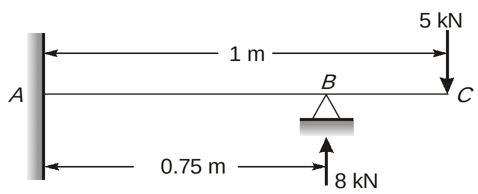


(d)



[ESE : 1999]

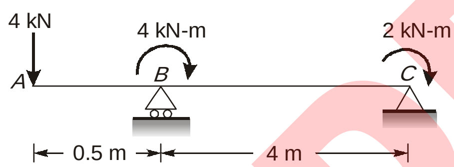
3.22 The beam *ABC* shown in the given figure is horizontal. The distance to the point of contraflexure from the fixed end *A* is



(a) 0.333 m (b) 0.666 m
(c) 0.25 m (d) 0.75 m

[ESE : 1999]

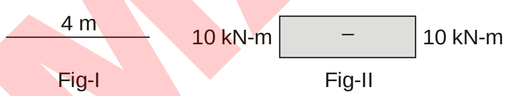
3.23 The beam shown in the given figure has a design bending moment value of



(a) 8 kN-m (b) 6 kN-m
(c) 4 kN-m (d) 2 kN-m

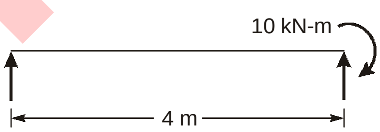
[ESE : 1999]

3.24 A beam's SFD and BMD are shown in Fig-I and Fig-II

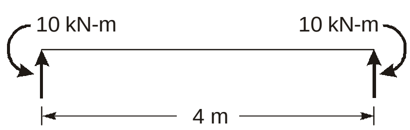


The corresponding load diagram will be

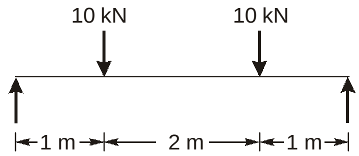
(a)



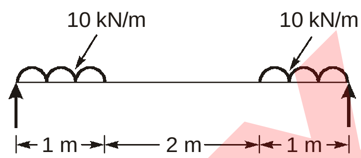
(b)



(c)

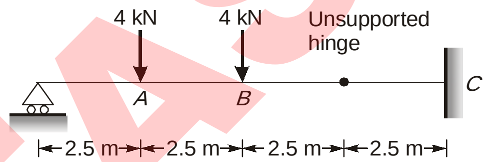


(d)



[ESE : 1999]

3.25 The bending moments at point A, B and C of the beam shown in the given figure will be



(a) 10 kN-m, 10 kN-m and 10 kN-m
(b) 10 kN-m, 10 kN-m and – 10 kN-m
(c) 20 kN-m, 10 kN-m and – 10 kN-m
(d) 10 kN-m, – 10 kN-m and 20 kN-m

[ESE : 1999]

3.26 The bending moment diagram of the beam shown in the figure-I is

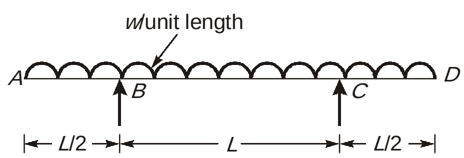
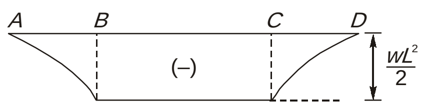
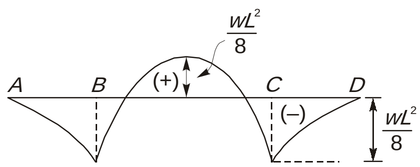


Figure-I

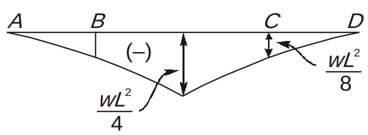
(a)



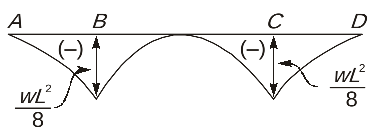
(b)



(c)



(d)



[ESE : 1999]

4. Principal Stress-Strain & Theories of Failure

4.1 The cross-section of a bar is subjected to a uniaxial tensile stress '*p*'. The tangential stress on a plane inclined at θ to the cross-section of the bar would be

(a) $\dfrac{p\sin 2\theta}{2}$ (b) $p\sin 2\theta$

(c) $\dfrac{p\cos 2\theta}{2}$ (d) $p\cos 2\theta$

[ESE : 1995]

4.2 Consider the following statements:

1. On planes having maximum and minimum principal stresses, there will be no tangential stress.
2. Shear stresses on mutually perpendicular planes are numerically equal.
3. Maximum shear stress is equal to half the sum of the maximum and minimum principal stresses.

Which of these statements is/are correct?

(a) Only 1 is (b) 1 and 2

(c) 2 and 3 (d) 1 and 3

[ESE : 1995]

4.3 In a stressed body, an elementary cube of material is taken at a point with its faces perpendicular to *X* and *Y* reference axes. Tensile stresses equal to 15 kN/cm^2 and 9 kN/cm^2 are observed on these respective faces. They are also accompanied by shear equal to 4 kN/cm^2. The magnitude of the principal stresses at the point are

(a) 12 kN/cm^2 tensile and 3 kN/cm^2 tensile

(b) 17 kN/cm^2 tensile and 7 kN/cm^2 tensile

(c) 9.5 kN/cm^2 compressive and 6.5 kN/cm^2 compressive

(d) 12 kN/cm^2 tensile and 13 kN/cm^2 tensile

[ESE : 1995]

4.4 In a rectangular element subjected to like principal tensile stresses 'p_1' and 'p_2' in two mutually perpendicular directions *X* and *Y*, the maximum shear would occur along the

(a) plane normal to *X*-axis

(b) plane normal to *Y*-axis

(c) plane at 45° to *Y*-direction

(d) planes at 45° and 135° to the *Y*-direction

[ESE : 1995]

4.5 At a point in a structure, there are two mutually perpendicular tensile stresses of 800 kg/cm^2 and 400 kg/cm^2. If the Poisson's ratio $\mu = 0.25$, what would be the equivalent stress in simple tension according to maximum principal strain theory?

(a) 1200 kg/cm^2 (b) 900 kg/cm^2

(c) 700 kg/cm^2 (d) 400 kg/cm^2

[ESE : 1995]

4.6 According to maximum shear stress failure criterion, yielding in material occurs when

(a) maximum shear stress = $\dfrac{1}{2}$ yield stress

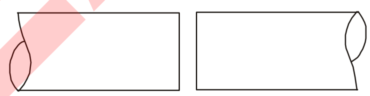
(b) maximum shear stress = $\sqrt{2}\times$ yield stress

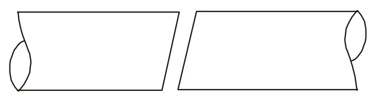
(c) maximum shear stress = $\sqrt{3}\times$ yield stress

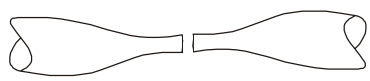
(d) maximum shear stress = 2 × yield stress

[ESE : 1995]

4.7 When a mild-steel specimen fails in a torsion test fracture looks like

(a) 

(b) 

(c) 

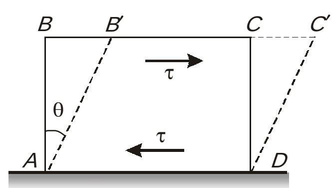
(d) 

[ESE : 1995]

4.8 The side *AD* of the square block *ABCD* as shown in the given figure is fixed at the base and it is under a stage of simple shear causing shear stress τ and shear strain ϕ,

where $\phi = \dfrac{\tau}{\text{Modulus of Rigidity (G)}}$

The distorted shape is *AB'C'D*. The diagonal strain (linear) will be



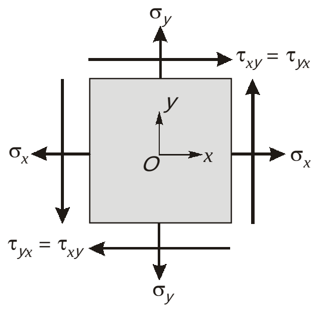
(a) $\phi/2$ (b) $\phi/\sqrt{2}$

(c) $\sqrt{2}\,\phi$ (d) ϕ

[ESE : 1996]

4.9 On an element shown in the given figure, the stresses are:

$\sigma_x = 110$ MPa
$\sigma_y = 30$ MPa
$\tau_{xy} = \tau_{yx} = 30$ MPa



The radius of Mohr's circle and the principal stresses σ_1, σ_2 are (in MPa)

	Radius = r	σ_1	σ_2
(a)	50	120	20
(b)	55	30	110
(c)	60	140	20
(d)	70	140	20

[ESE : 1996]

4.10 Consider the following statements:

1. In a member subjected to uniaxial tensile force the maximum normal stress is the external load divided by the maximum cross-sectional area.
2. When the structural member is subjected to uniaxial loading, the shear stress is zero on a plane where the normal stress is maximum.
3. In a member subjected to uniaxial loading, the normal stress on the planes of maximum shear stress is less than the maximum stress.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1996]

4.11 A certain steel has proportionality limit of 3000 kg/cm^2 in simple tension. It is subjected to principal stresses of 1200 kg/cm^2 (tensile), 600 kg/cm^2 (tensile) and 300 kg/cm^2 (compressive). The factor of safety according to maximum shear stress theory is

(a) 1.50 (b) 1.75
(c) 1.80 (d) 2.00 [ESE : 1996]

4.12 In a two dimensional stress system, it is assumed that the principal stress σ_1 and σ_2 are such that $\sigma_1 > \sigma_2$; then according to the maximum shear stress theory, the failure occurs when (where σ_y is the yield stress, μ is the Poisson's ratio and E is the modulus of elasticity)

(a) $\frac{1}{E}(\sigma_1 - \mu\sigma_2) \geq \frac{\sigma_y}{E}$
(b) $\sigma_1^2 + \sigma_2^2 + 2\mu\sigma_1\sigma_2 \geq \sigma_y^2$
(c) $\sigma_1 - \sigma_2 \geq \sigma_y$
(d) $\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 \geq \sigma_y$ [ESE : 1996]

4.13 Assertion (A): The inclination of the line joining any point P on the Mohr's circle and the origin O with X-axis equals twice the angle between the resultant stress and the normal of the plane for which P stands.

Reason (R): The inclination of the line joining any point P on the Mohr's circle and the centre of the circle C with X-axis equals twice the angle between the plane for which P stands and zero degree plane.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

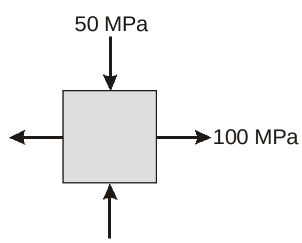
[ESE : 1996]

4.14 At a point in a strained material, if two mutually perpendicular tensile stresses of 2000 kg/cm^2 and 1000 kg/cm^2 are acting, then the intensity of tangential stress on a plane inclined at 15° to the axis of the minor stress will be

(a) 125 kg/cm^2 (b) 250 kg/cm^2
(c) 500 kg/cm^2 (d) 1000 kg/cm^2

[ESE : 1997]

4.15 For the state of stress shown in the below figure, normal stress acting on the plane of maximum shear stress is



(a) 25 MPa compression
(b) 75 MPa compression
(c) 25 MPa tension
(d) 75 MPa tension

[ESE : 1997]

4.16 According to the distortion energy theory, failure will NOT occur when (symbols have the usual meaning)

(a) $\left[\dfrac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{\frac{1}{2}} \le \sigma_0$

(b) $\left[(\sigma_1-\sigma_2)^2+4\tau^2\right]^{\frac{1}{2}} \le \sigma_0$

(c) $\left[(\sigma_1^2+\sigma_2^2+\sigma_3^2)-\dfrac{1}{m}(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)\right]^{\frac{1}{2}} \le \sigma_0$

(d) $\left[\dfrac{(\sigma_1-\sigma_2)+(\sigma_1-\sigma_2)^2+4\tau^2}{2}\right]^{\frac{1}{2}} \le \sigma_0$

[ESE : 1997]

4.17 In a strained body, the three principal stresses at a point are denoted by σ_1, σ_2 and σ_3 such that $\sigma_1 > \sigma_2 > \sigma_3$. If σ_0 denoted yield stress, then according to the maximum shear stress theory

(a) $\sigma_1 - \sigma_2 = \sigma_0$
(b) $\sigma_1 - \sigma_3 = \sigma_0$
(c) $\sigma_2 - \sigma_3 = \sigma_0$
(d) $\dfrac{\sigma_1+\sigma_3}{2} = \sigma_0$

[ESE : 1997]

4.18 All the failure theories gives nearly the same result

(a) when one of the principal stresses at a point is large in comparison to the other
(b) when shear stresses act
(c) when both the principal stresses are numerically equal
(d) for all situations of stress

[ESE : 1997]

4.19 A cube is subjected to equal tensile stress on all the three faces. If the yield stress of the material is 'σ_y' then based on the strain energy theory, the maximum tensile stress will be

(a) $\dfrac{\sigma_y}{\sqrt{3(1-2\mu)}}$
(b) $\dfrac{\sigma_y}{\sqrt{3(2-\mu)}}$
(c) $\dfrac{\sigma_y}{\sqrt{3(1-\mu)}}$
(d) $\dfrac{\sigma_y}{\sqrt{3(1+\mu)}}$

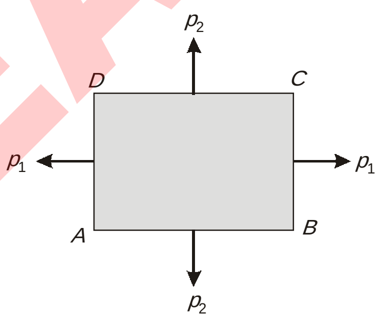
[ESE : 1997]

4.20 In a plane stress problem there are normal tensile stresses σ_x and σ_y accompanied by shear stress τ_{xy} at a point along orthogonal Cartesian co-ordinates x and y respectively. If it is observed that the minimum principal stress on a certain plane is zero then

(a) $\tau_{xy} = \sqrt{\sigma_x + \sigma_y}$
(b) $\tau_{xy} = \sqrt{\sigma_x - \sigma_y}$
(c) $\tau_{xy} = \sqrt{\sigma_x \sigma_y}$
(d) $\tau_{xy} = \sqrt{\dfrac{\sigma_x}{\sigma_y}}$

[ESE : 1998]

4.21 A plane rectangular element is subjected to two normal stresses 'p_1' and 'p_2' on two mutually perpendicular planes ($p_1 > p_2$) as shown in the figure.



Which one of the following statements is NOT true in this regard?

(a) The planes *BC* and *CD* are principal planes.
(b) Shear stress will act on planes inclined to planes *AB* and *CB*.
(c) There will not be any normal stress on planes having maximum shear stress.
(d) There will not be any shear stress on planes *AB* and *BC*.

[ESE : 1998]

4.22 At a point in a steel member, the major principal stress is 200 MPa (tensile) and the minor principal stress is compressive. If the uniaxial tensile yield stress is 250 MPa, then according to the maximum shear stress theory, the magnitude of the minor principal stress (compressive) at which yielding will commence is

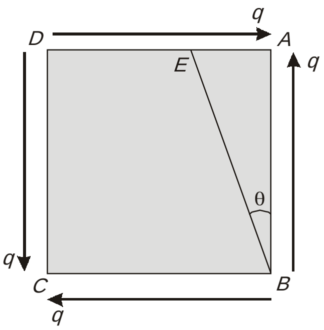
(a) 200 MPa
(b) 100 MPa
(c) 50 MPa
(d) 25 MPa

[ESE : 1998]

4.23 The limit of proportionality of a certain steel sample is 300 MPa in simple tension. It is subjected to principal stresses of 150 MPa (tensile), 60 MPa (tensile) and 30 MPa (tensile). According to the maximum principal stress theory, the factor of safety in this case would be

(a) 10 (b) 5
(c) 4 (d) 2 [ESE : 1998]

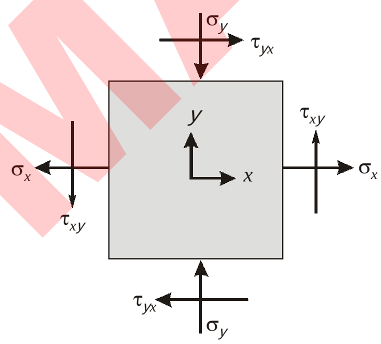
4.24 The rectangular block shown in the given figure is subjected to pure shear of intensity 'q'. If BE represents the principal plane and the principal stresses are σ_1, σ_2; then the values of θ, σ_1 and σ_2 will be respectively



(a) 0°, 90°; + q and – q
(b) 30°, 120°; + q and – q
(c) 45°, 135°; + $\frac{q}{2}$ and $-\frac{q}{2}$
(d) 45°, 135°; + q and – q

[ESE : 1999]

4.25 The state of stresses on an element is shown in the given figure. The values of stresses are σ_x (= 32 MPa); σ_y (= – 10 MPa) and major principal stress σ_1 (= 40 MPa). The minor principal stress σ_2 is



(a) – 22 MPa
(b) – 18 MPa
(c) 22 MPa
(d) indeterminable due to insufficient data

[ESE : 1999]

4.26 The radius of Mohr's circle of stress of a strained element is 20 N/mm² and minor principal tensile stress is 10 N/mm². The major principal stress is

(a) 30 N/mm² (b) 50 N/mm²
(c) 60 N/mm² (d) 100 N/mm²

[ESE : 1999]

4.27 A material of Young's modulus E and Poisson's ratio μ is subjected to two principal stresses σ_1 and σ_2 at a point in a two-dimensional stress system. The strain energy per unit volume of the material is

(a) $\frac{1}{2E}\left(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2\right)$

(b) $\frac{1}{2E}\left(\sigma_1^2 + \sigma_2^2 + 2\mu\sigma_1\sigma_2\right)$

(c) $\frac{1}{2E}\left(\sigma_1^2 - \sigma_2^2 + 2\mu\sigma_1\sigma_2\right)$

(d) $\frac{1}{2E}\left(\sigma_1^2 - \sigma_2^2 - 2\mu\sigma_1\sigma_2\right)$ [ESE : 1999]

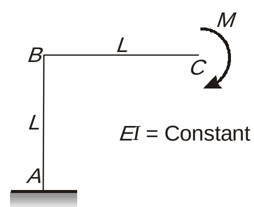
5. Deflection of Beams

5.1 A beam simply supported at both the ends, of length L carries two equal unlike couples M at the two ends. If the flexural rigidity EI = constant, then central deflection of the beam is given by

(a) $\frac{ML^2}{4EI}$ (b) $\frac{ML^2}{16EI}$
(c) $\frac{ML^2}{64EI}$ (d) $\frac{ML^2}{8EI}$

[ESE : 1995]

5.2 What is the horizontal deflection at free end C of the frame shown in the given figure?



(a) $\frac{ML^2}{2EI}$ (b) $\frac{ML^2}{EI}$
(c) $\frac{3ML^2}{2EI}$ (d) $\frac{2ML^2}{EI}$

[ESE : 1995]

5.3 A simply supported beam of span L and flexural rigidity EI, carries a unit point load at its centre. The strain energy in the beam due to bending is

(a) $\frac{L^3}{48\,EI}$ (b) $\frac{L^3}{192\,EI}$

(c) $\frac{L^3}{96\,EI}$ (d) $\frac{L^3}{16\,EI}$

[ESE : 1996]

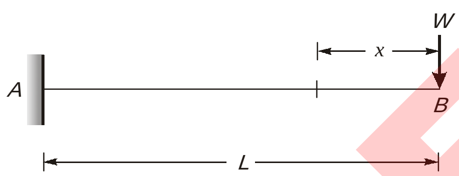
5.4 The maximum deflection of a fixed beam carrying a central load W is equal to

(a) $\frac{WL^3}{484EI}$ (b) $\frac{WL^3}{96EI}$

(c) $\frac{WL^3}{192EI}$ (d) $\frac{5}{384}\frac{WL^3}{EI}$

[ESE : 1996]

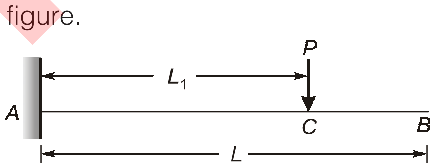
5.5 For the cantilever beam shown in the given figure, which one of the following pairs is not correctly matched?



Theorem	(EI)times deflection at B
(a) Mohr's Theorem	: Area of BMD × Distance of centroid of BMD from B
(b) Castigliano's Theorem	: $\int_0^L Wx^2\,dx$
(c) Conjugate beam	: Shear force at the fixed end of conjugate beam
(d) Successive integration	: $\iint -Wx\,dx$

[ESE : 1996]

5.6 A cantilever carries a load P at C as shown in the given figure.



EI = Constant

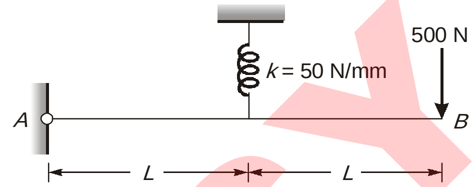
The deflection at B is

(a) $\frac{PL_1^2}{2EI}(L-L_1)$ (b) $\frac{PL_1^2}{3EI}(L-L_1)$

(c) $\frac{PL_1^2}{2EI}\left(L-\frac{L_1}{3}\right)$ (d) $\frac{PL_1^2}{3EI}\left(L-\frac{L_1}{3}\right)$

[ESE : 1996]

5.7 A rigid bar is supported by a spring as shown in the given figure.



The deflection of the point B will be

(a) 10 mm upward
(b) 20 mm downward
(c) 5 mm upward
(d) 40 mm downward [ESE : 1996]

5.8 If the strain energy absorbed in a cantilever beam in bending under its own weight is K times greater than the strain energy absorbed in an identical simply supported beam in bending under its own weight, then the magnitude of K is

(a) 2 (b) 4
(c) 6 (d) 8 [ESE : 1997]

5.9 Consider the following statements regarding a beam of uniform cross-section simply supported at its ends and carrying a concentrated load at one of its middle third points:

1. Its deflection under the load will be maximum.
2. The bending moment under the load will be maximum.
3. The deflection at the midpoint of the span will be maximum.
4. The slope at the nearest support will be maximum.

Which of these statements are correct?

(a) 1 and 3 (b) 2 and 4
(c) 1 and 2 (d) 3 and 4

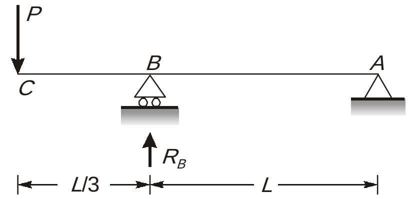
[ESE : 1997]

5.10 A simply supported rectangular beam of span L and depth 'd' carries a central load W. The ratio of maximum deflection to maximum bending stress is

(a) $\frac{L^2}{6Ed}$ (b) $\frac{L^2}{8Ed}$

(c) $\frac{L^2}{48Ed}$ (d) $\frac{L^2}{12Ed}$ [ESE : 1997]

5.11 An overhang beam of uniform EI is loaded as shown in the figure below. The deflection at the free end will be



(a) $\dfrac{PL^3}{81EI}$ (b) $\dfrac{PL^3}{27EI}$

(c) $\dfrac{4PL^3}{81EI}$ (d) $\dfrac{2PL^3}{27EI}$

[ESE : 1998]

5.12 Assertion (A): Macaulay's method to determine the slope and deflection at a point in a beam is suitable for beams subjected to concentrated loads and can be extended to uniformly distributed loads.

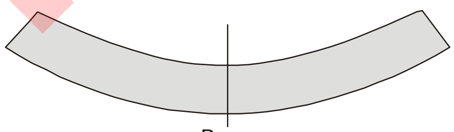
Reason (R): Macaulay's method is based upon the modification of moment area method. This is applicable to a simple beam carrying a single concentrated load but by superposition, this method can be extended to cover any kind of loading.

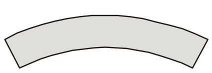
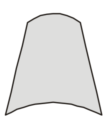
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

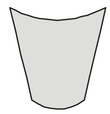
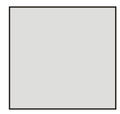
[ESE : 1999]

6. Bending & Shear Stresses in Beams

6.1 For a square-sectioned beam bent as shown in the given figure, the exaggerated view of the deformed cross-section is



(a)  (b) 

(c)  (d) 

[ESE : 1995]

6.2 Given that $m = \dfrac{E_s}{E_t}$, I_t = Moment of inertia of timber portion and I_s = Moment of inertia of steel portion, the equivalent moment of inertia of a flitched beam made of steel and timber is given by

(a) $I_t + \dfrac{I_s}{m}$ (b) $I_s + \dfrac{I_t}{m}$

(c) $I_s + mI_t$ (d) $I_t + mI_s$

[ESE : 1995]

6.3 A ratio of moment carrying capacity of a circular beam of diameter D and square beam of size D is

(a) $\pi/4$ (b) $3\pi/8$
(c) $\pi/3$ (d) $3\pi/16$

[ESE : 1995]

6.4 A beam has triangular cross-section, having base 'b' and altitude 'h'. If a section of the beam is subjected to a shear force F, the shear stress at the level of neutral axis in the cross-section is given by

(a) $\dfrac{4F}{3bh}$ (b) $\dfrac{3F}{4bh}$

(c) $\dfrac{8F}{3bh}$ (d) $\dfrac{3F}{8bh}$

[ESE : 1995]

6.5 A steel wire of 20 mm diameter is bent into a circular shape of 10 m radius. If the modulus of elasticity is 2×10^6 kg/cm^2, then the maximum stress induced in the wire is

(a) 10^3 kg/cm^2 (b) 2×10^3 kg/cm^2
(c) 4×10^3 kg/cm^2 (d) 6×10^3 kg/cm^2

[ESE : 1995]

Directions: The following items consists of two statements, one labelled as the **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both Assertion (A) and Reason (R) are individually true and Reason (R) is the correct explanation of Assertion (A).
(b) Both Assertion (A) and Reason (R) are individually true but Reason (R) is NOT the correct explanation of Assertion (A).
(c) Assertion (A) is true but Reason (R) is false.
(d) Assertion (A) is false but Reason (R) is true.

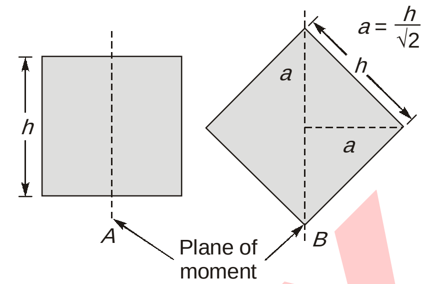
6.6 **Assertion (A):** I-Section is preferred to rectangular section for resisting bending moment.
Reason (R): In I-Section more than 80% of bending moment is resisted by flanges only.
[ESE : 1996]

6.7 **Assertion (A):** A beam of circular cross-section in comparison to rectangular section of the same material but of equal cross-section area can resist a larger shear force.
Reason (R): The maximum intensities of shear stress in the sections of a beam of circular cross-section and of a rectangular cross-section are $1\frac{1}{3}$ times and $1\frac{1}{2}$ times the average shear stress respectively.
[ESE : 1996]

6.8 A simply supported beam of span L carries a concentrated load W at mid-span. If the width 'b' of the beam is constant and its depth is varying throughout the span, then what should be its mid-span depth, when design stress is 'f'?

(a) $\sqrt{\frac{6WL}{bf}}$ (b) $\frac{6WL}{bf}$
(c) $\sqrt{\frac{3WL}{2bf}}$ (d) $\frac{3WL}{2bf}$
[ESE : 1996]

6.9 The span and the material of the two beams A and B are the same. The area of cross section of the two beams are equal. The cross-section is square. In the case of beam A, the plane of moment is parallel to the sides of the square and in the case of beam B, the plane of moment coincides with the diagonal as shown in the given figure.



Consider the following inferences from the above data:
1. For the same loading, the deflection of the beam B is smaller than that of beam A.
2. If the load on the two beams is the same, then the maximum stress in beam B is greater than that in beam A.
3. Beam A can resist smaller load than beam B.
4. Flexural rigidity of both the beams is equal.

Which of these inferences are incorrect?
(a) 2 and 4 (b) 1 and 3
(c) 1 and 4 (d) 2, 3 and 4
[ESE : 1996]

6.10 In a simply supported wooden beam under uniformly distributed load, a hole has to be made in the direction of width at midspan to provide a pipeline. From structural strength point of view, it would be advisable to have the hole made at
(a) the bottom
(b) the top
(c) mid-depth
(d) 1/4 depth either from the top or the bottom
[ESE : 1996]

6.11 A cantilever of constant depth carries a uniformly distributed load on the whole span. To make the maximum stress at all sections the same, the breadth of the section at a distance x from the free end should proportional to
(a) x (b) $\sqrt{x}$
(c) x^2 (d) x^3 [ESE : 1996]

6.12 Consider the following statements:
A beam of channel cross-section with vertical web loaded with a concentrated load at mid-span in a plane perpendicular to the plane of symmetry passing through the centroid subjected to
1. bending moment 2. twisting moment

3. shear force 4. axial thrust

Which of these statements are correct?

(a) 2, 3 and 4 (b) 1, 2 and 3
(c) 1 and 2 (d) 1 and 3

[ESE : 1996]

6.13 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Moment of inertia
B. Elongation
C. Neutral axis
D. Top fibre

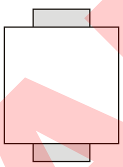
List-II
1. Tensile stress
2. Modulus of rupture
3. Zero shear stress
4. Zero longitudinal stress

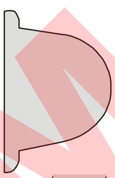
Codes:

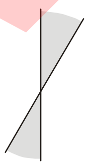
	A	B	C	D
(a)	2	1	3	4
(b)	1	2	4	3
(c)	3	4	1	2
(d)	2	1	4	3

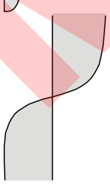
[ESE : 1997]

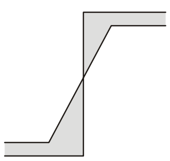
6.14 A flitched beam shown in the figure below is subjected to a bending moment. The strain variation across the cross-section will be as in



(a) 

(b) 

(c) 

(d) 

[ESE : 1997]

6.15 The ratio of the flexural strength of two beams of square cross-section, the first beam being placed with its top and bottom sides horizontally and the second beam being placed with one diagonal horizontally, is

(a) $\sqrt{3}$ (b) $1/\sqrt{3}$
(c) $1/\sqrt{2}$ (d) $\sqrt{2}$

[ESE : 1997]

6.16 A simply supported beam of span L carries a point load W at midspan. The breadth 'b' of the beam along the entire span is constant. Given, f = permissible stress is bending, for a beam of uniform strength, the depth of the beam at any cross-section at a distance 'x' from the support would be

(a) $\frac{6Wx}{fb}$ (b) $\sqrt{\frac{6Wx}{fb}}$
(c) $\frac{3Wx}{fb}$ (d) $\sqrt{\frac{3Wx}{fb}}$

[ESE : 1997]

6.17 A beam of square cross-section ($B \times B$) is used as a beam with one diagonal horizontal. The location of the maximum shear stress from the neutral axis will be at distance of

(a) zero (b) $\frac{B}{4}$
(c) $\frac{B}{4\sqrt{2}}$ (d) $\frac{B}{8}$ [ESE : 1998]

6.18 Assertion (A): Two beams, one placed directly over the other have total moment of resistance equal to the sum of the moments of resistance of individual sections.

Reason (R): In bending, the transverse sections which were plane before bending remain plane after bending as well.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1998]

6.19 A rectangular timber beam is cut out of a cylindrical log of diameter D. The depth of the strongest timber beam will be

(a) $\sqrt{\frac{1}{2}}D$ (b) $\sqrt{\frac{2}{3}}D$
(c) $\sqrt{\frac{5}{8}}D$ (d) $\sqrt{\frac{3}{4}}D$

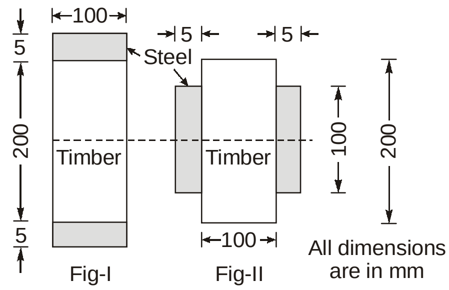
[ESE : 1998]

6.20 A high strength steel band-saw of 90 mm width and 0.5 mm thickness runs over a pulley of 500 mm diameter. Assuming $E = 200$ GPa, the maximum flexural stress developed would be

(a) 100 MPa (b) 200 MPa
(c) 400 MPa (d) 500 MPa

[ESE : 1998]

6.21 For the flitched beam shown in the below **figure-I** and **figure-II**, for the same value of maximum bending stress in timber,



(a) $MR_1 > MR_2$
(b) $MR_2 > MR_1$
(c) $MR_1 = MR_2$
(d) MR_1 and MR_2 cannot be compared

[ESE : 1998]

6.22 A simply supported beam of constant width and varying depth and uniform strength is subjected to a central concentrated load. The depth of the beam 'd_x' at a distance 'x' from one of the supports is proportional to

(a) $x^{1/2}$ (b) $x^{1/3}$
(c) x (d) x^2

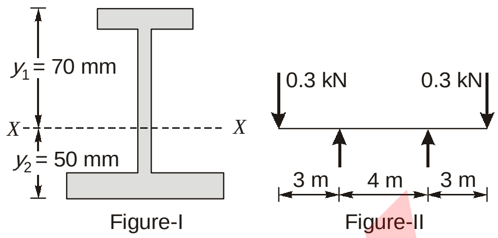
[ESE : 1999]

6.23 A mild flat of width 120 mm and thickness 10 mm is bent into an arc of a circle of radius 10 m by applying a pure moment M. If E is 2×10^5 N/mm^2, then the magnitude of the pure moment M will be

(a) 2×10^6 Nmm (b) 2×10^5 Nmm
(c) 0.2×10^5 Nmm (d) 0.2×10^4 Nmm

[ESE : 1999]

6.24 The cross-section of a beam is shown in **figure-I**. Its I_{xx} is equal to 3×10^6 mm^4. It is subjected to a load as shown in **figure-II**. The maximum tensile stress in the beam would be:

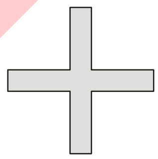
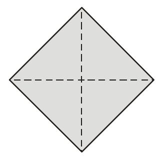


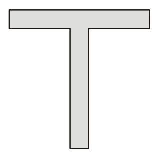
(a) indeterminable as data is insufficient
(b) 21 MN/m^2
(c) 21 kN/m^2 (d) 21 N/m^2

[ESE : 1999]

6.25 The shear stress distribution shown in **figure-I** represents a beam with cross-section

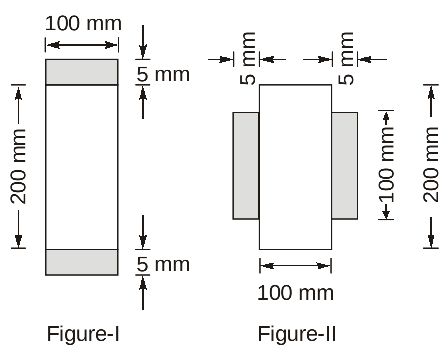
Figure-I

(a)  (b) 

(c)  (d) 

[ESE : 1999]

6.26 A timber beam of 100 mm width and 200 mm depth is reinforced with two steel plates of 100 mm width and 5 mm thickness as shown in **figure-I** and **figure-II**.

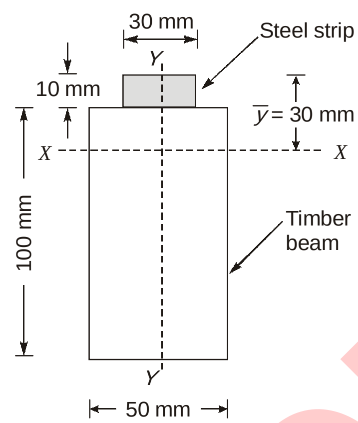


Which one of the following statements is correct for the same value of bending stress in the timber?

(a) Moment of resistance in **figure-I** will be more than that in **figure-II**.
(b) Moment of resistance in **figure-II** will be more than that in **figure-I**.
(c) Moment of resistance in **figure-I** will be equal to that in **figure-II**.
(d) No logical comparison can be made.

[ESE : 1999]

6.27 The cross-section of a timber beam with a steel strip is shown in the given figure. It is subjected to a sagging bending moment of 1000 Nm, I_{xx} = 1250 × 10^4 mm^4 and modular ratio m = 20. The stresses at the lower surfaces of timber (σ_t) and steel (σ_s) will be respectively.

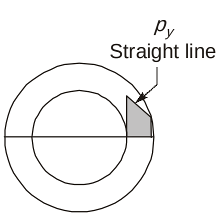


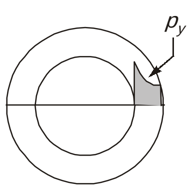
(a) + 6.4 MN/m^2 and – 6.4 MN/m^2
(b) – 6.4 MN/m^2 and – 32 MN/m^2
(c) + 6.4 MN/m^2 and – 32 MN/m^2
(d) + 32 MN/m^2 and – 6.4 MN/m^2

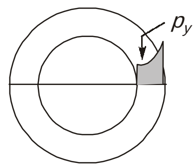
[ESE : 1999]

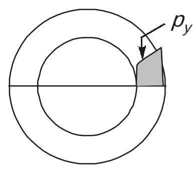
7. Thick & Thin Cylinders and Spheres

7.1 A thick cylindrical pressure vessel of inner diameter D_i and outer diameter D_o is subjected to an internal fluid pressure of intensity 'p'. The variation of the circumferential tensile stress 'p_y' in the thickness of the shell will be

(a)


(b)


(c)


(d)


[ESE : 1995]

7.2 A thin cylindrical steel pressure vessel of diameter 6 cm and wall thickness 3 mm is subjected to an internal fluid pressure of intensity 'p'. If the ultimate strength of steel 3600 kg/cm^2, the bursting pressure will be
(a) 18 kg/cm^2 (b) 36 kg/cm^2
(c) 180 kg/cm^2 (d) 360 kg/cm^2

[ESE : 1995]

7.3 Two closed thin vessels, one cylindrical and the other spherical with equal internal diameter and wall thickness are subjected to equal internal fluid pressure. The ratio of hoop stresses in the cylindrical to that of spherical vessel is
(a) 4.0 (b) 2.0
(c) 1.0 (d) 0.5

[ESE : 1996]

7.4 A thin cylindrical shell of internal diameter D and thickness 't' is subjected to internal pressure 'p'. The change in diameter is given by

(a) $\dfrac{pD^2}{4tE}(2-\mu)$ (b) $\dfrac{pD^2}{4tE}(1-2\mu)$

(c) $\dfrac{pD^2}{2tE}(1-2\mu)$ (d) $\dfrac{pD^2}{2tE}(2-\mu)$

[ESE : 1997]

7.5 A cast iron pipe of 1 m diameter is required to withstand a 200 m head of water. If the limiting tensile stress of the pipe material is 20 MPa, then the thickness of the pipe will be
(a) 25 mm (b) 50 mm
(c) 75 mm (d) 100 mm

[ESE : 1998]

7.6 Consider the following statements in respect of a thick cylinder subjected to internal pressure :
1. The stress on an element on the outer wall is unidirectional.
2. The stresses on an element on the inner wall are principal stresses.

3. The constants of the Lame's equation are positive.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1999]

8. Torsion in Shafts & Springs

8.1 A shaft is subjected to a bending moment M and a torque T. The equivalent bending moment M_{eq} on the shaft is given by

(a) $\dfrac{M+\sqrt{M^2+T^2}}{4}$ (b) $\dfrac{M-\sqrt{M^2+T^2}}{4}$

(c) $\dfrac{M-\sqrt{M^2+T^2}}{2}$ (d) $\dfrac{M+\sqrt{M^2+T^2}}{2}$

[ESE : 1995]

8.2 A solid shaft of circular cross-section is subjected to a torque T which produces a maximum shear stress f_s in the shaft. The diameter of the shaft should be

(a) $\sqrt{\dfrac{\pi f_s}{16T}}$ (b) $\sqrt[3]{\dfrac{\pi f_s}{16T}}$

(c) $\sqrt{\dfrac{16T}{\pi f_s}}$ (d) $\sqrt[3]{\dfrac{16T}{\pi f_s}}$

[ESE : 1995]

8.3 If two springs of stiffness k_1 and k_2 are connected in series, the stiffness of the combined spring is

(a) $\dfrac{k_1k_2}{k_1+k_2}$ (b) $\dfrac{k_1+k_2}{k_1k_2}$

(c) $k_1 + k_2$ (d) k_1k_2

[ESE : 1995]

8.4 A circular shaft is subjected to a twisting moment T and bending moment M. The ratio of maximum bending stress to maximum shear stress is given by

(a) $\dfrac{2M}{T}$ (b) $\dfrac{M}{T}$

(c) $\dfrac{2T}{M}$ (d) $\dfrac{M}{2T}$

[ESE : 1996]

8.5 Two closed coil springs of stiffness k and $2k$ are arranged in series in one case and in parallel in the other case. The ratio of stiffness of springs connected in series to parallel is

(a) $\dfrac{1}{3}$ (b) $\dfrac{1}{9}$

(c) $\dfrac{2}{3}$ (d) $\dfrac{2}{9}$

[ESE : 1996]

8.6 A section of a solid circular shaft with diameter D is subjected to bending moment M and torque T. The expression for maximum principal stress at the section is

(a) $\dfrac{2M+T}{\pi D^3}$

(b) $\dfrac{16\pi}{D^3}\left(M+\sqrt{M^2+T^2}\right)$

(c) $\dfrac{16\pi}{D^3}\left(\sqrt{M^2+T^2}\right)$

(d) $\dfrac{16}{\pi D^3}\left(M+\sqrt{M^2+T^2}\right)$

[ESE : 1996]

8.7 As per the maximum principal stress theory, when a shaft is subjected to a bending moment M and torque T. And σ is the allowable stress in axial tension, then the diameter d of the shaft is given by

(a) $d^3 = \dfrac{16}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(b) $d^3 = \dfrac{4}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(c) $d^3 = \dfrac{32}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(d) $d^3 = \dfrac{8}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

[ESE : 1997]

8.8 If the diameter of a shaft subjected to torque alone is doubled, then the horse power P can be increased to

(a) $16P$ (b) $8P$
(c) $4P$ (d) $2P$

[ESE : 1997]

8.9 If a circular shaft is subjected to a torque T and a bending moment M, the ratio of the maximum shear stress to the maximum bending stress is given by

(a) $\frac{2M}{T}$ (b) $\frac{T}{2M}$

(c) $\frac{2T}{M}$ (d) $\frac{M}{2T}$

[ESE : 1997]

8.10 Two shafts of solid circular cross-section are identical except for their diameter 'd_1' and 'd_2'. They are subjected to the same torque T. The ratio of the strain energies stored U_1/U_2 will be

(a) $\left(\frac{d_1}{d_2}\right)^4$ (b) $\left(\frac{d_1}{d_2}\right)^2$

(c) $\left(\frac{d_2}{d_1}\right)^2$ (d) $\left(\frac{d_2}{d_1}\right)^4$

[ESE : 1998]

8.11 Consider the following statements:

If a solid circular shaft and a hollow circular shaft have the same torsional strength, then

1. the weight of the hollow shaft will be greater than of the solid shaft
2. the external diameter of the hollow shaft will be greater than of the solid shaft
3. the stiffness of the hollow shaft will be equal to that of the solid shaft

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 2 and 3

(c) 1 alone (d) 1 and 2

[ESE : 1998]

8.12 A close-coiled helical spring shown below in Fig-I is to be cut into two equal pieces and combined as a parallel spring as shown in Fig-II. The ratio of the maximum angular twist of the situation shown in Fig-II to that of Fig-I, due to the same load W will be

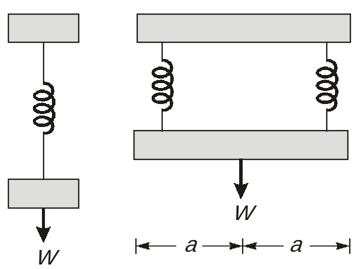


Fig-I Fig-II

(a) 1 (b) 1/2

(c) 1/4 (d) 1/8

[ESE : 1998]

8.13 A shaft turns at 150 rpm under a torque of 1500 Nm. Power transmitted is

(a) 15π kW (b) 10π kW

(c) 7.5π kW (d) 5π kW

[ESE : 1999]

8.14 A hollow steel shaft of external diameter 100 mm and internal diameter 50 mm is to be replaced by a solid alloy shaft. Assuming the same value of polar modulus for both, the diameter of the solid alloy shaft will be

(a) $10 \times \sqrt[3]{9375}$ mm (b) $10 \times \sqrt[2]{9375}$ mm

(c) $10 \times \sqrt[3]{\left(\frac{9375}{10}\right)}$ mm (d) $\sqrt[3]{9375}$ mm

[ESE : 1999]

8.15 The close-coiled spring shown in Fig-I is cut into two equal pieces which are combined to form a parallel spring as shown in Fig-II. The ratio of the angular twist for the spring in Fig-II to that of spring in Fig-I due to an axial load P is

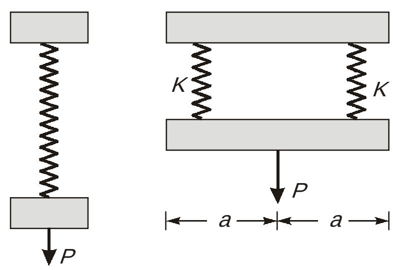


Fig-I Fig-II

(a) 1/2 (b) 1/4

(c) 1/8 (d) 1 **[ESE : 1999]**

8.16 A shaft of diameter 'd' is subjected to bending moment M and twisting moment T. The developed principal stress will be

(a) $\pm\frac{16}{\pi d^3}\sqrt{M^2 + T^2}$

(b) $\frac{16}{\pi d^3}\left(M \pm \sqrt{M^2 + T^2}\right)$

(c) $\frac{16}{\pi d^3}\left(T \pm \sqrt{M^2 + T^2}\right)$

(d) $\frac{16}{\pi d^3}\sqrt{M^2 + T^2} \pm M$ **[ESE : 1999]**

9. Theoray of Columns and Retaining Walls

9.1 If the crushing stress in the material of a mild steel column is 3300 kg/cm^2. Euler's Formula for crippling load is applicable for slenderness ratio equal to/greater than

(a) 40 (b) 50
(c) 60 (d) 80 **[ESE : 1995]**

9.2 The resultant cuts the base of a circular column of diameter 'd' with an eccentricity equal to one-fourth of 'd'. The ratio between the maximum compressive stress and the maximum tensile stress is

(a) 3 (b) 4
(c) 5 (d) infinity

[ESE : 1995]

9.3 **Assertion (A):** In the vertical face of triangular retaining wall of any $\frac{h}{b}$ ratio, the eccentricity is $\frac{b}{6}$ for dead storage condition.

Reason (R): For triangular retaining wall under full storage level (retained by vertical face) the eccentricity will be $\frac{b}{6}$ only if $\frac{h}{b}$ ratio is $\sqrt{S}$ (where S is specific gravity of the material of the wall).

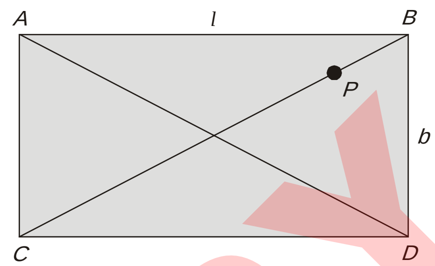
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

9.4 Which one of the following pairs is not correctly matched?

Boundary condition conditions of column	Euler's buckling load
(a) Pin-Pin	$\frac{\pi^2 EI}{L^2}$
(b) Fixed-Fixed	$\frac{4\pi^2 EI}{L^2}$
(c) Fixed-Free	$\frac{0.25\pi^2 EI}{L^2}$
(d) Fixed-Pin	$\frac{\sqrt{2}\pi^2 EI}{L^2}$

9.5 Consider the following statements for a rectangular footing of length l and breadth 'b' applied with load P as shown in the given figure:



1. The stresses developed at points A and D are equal.
2. The stress developed at point B is maximum.
3. The stresses developed at point B and C are compressive.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1995]

9.6 A column of height H and area at top A has the same strength throughout its length, under its own weight and applied stress p_0 at the top. Density of column material is ρ. To satisfy the above condition, the area of the column at the bottom should be

(a) $\frac{Ae^{Hp_0}}{\rho}$ (b) $\frac{Ae^{-\rho H}}{p_0}$

(c) $Ae^{(-\rho H/p_0)}$ (d) $\frac{A\rho^H}{e^{p_0}}$

[ESE : 1995]

9.7 For a circular column having its ends hinged, the slenderness ratio is 160. The l/d ratio of the column is

(a) 80 (b) 57
(c) 40 (d) 20

[ESE : 1996]

9.8 A hollow circular column of internal diameter 'd' and external diameter '1.5d' is subjected to compressive load. The maximum distance of the point of application of load from the centre for no tension is

(a) d/8 (b) 13d/48
(c) d/4 (d) 13d/96

[ESE : 1996]

9.9 Match **List-I** (Given sections) with **List-II** (Shape of the core) to ensure no tension condition and select the correct answer using the codes given below the lists:

List-I		List-II	
A.	Rectangular	1.	Circle
B.	I-section	2.	Annulus
C.	Hollow circular	3.	Rhombus
D.	Square	4.	I-section
		5.	Square
		6.	Rectangular

Codes:

	A	B	C	D
(a)	4	6	1	2
(b)	3	3	1	5
(c)	6	4	2	5
(d)	3	4	5	1

[ESE : 1996]

9.10 Which one of the following pairs is not correctly matched?

(a) Lame's constants : Thick cylinder
(b) Macaulay's method : Deflection of beam
(c) Euler's method : Theory of column
(d) Eddy's theorem : Torsion of shafts

[ESE : 1996]

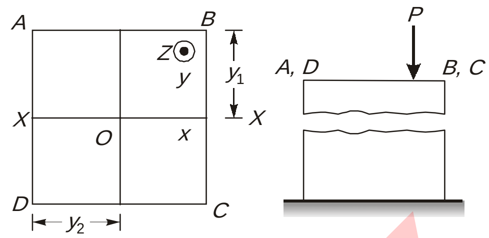
9.11 Assertion (A): The buckling load for a column of specified material, cross-section and end conditions calculated as per Euler's formula varies inversely with the column length.

Reason (R): Euler's formula takes into account the end conditions in determining the effective length of column.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

9.12 A column *ABCD* $(2y_1 \times 2y_2)$ of rectangular section carries a load *P* at *Z* having the coordinates (x, y) as shown in the given figure.



Plan Elevation

If the compressive stresses are taken as positive and area $A = 2y_1 \times 2y_2 = 4y_1\, y_2$ and the moment of inertia about *X* and *Y* axis being I_{xx} and I_{yy} respectively, then the stress at the corner *D* is

(a) $\frac{P}{A}+\frac{Py}{I_{xx}}y_1+\frac{Px}{I_{yy}}y_2$ (b) $\frac{P}{A}-\frac{Py}{I_{xx}}y_1-\frac{Px}{I_{yy}}y_2$

(c) $\frac{P}{A}+\frac{Py}{I_{yy}}y_1+\frac{Px}{I_{xx}}y_2$ (d) $\frac{P}{A}-\frac{Py}{I_{yy}}y_1-\frac{Px}{I_{xx}}y_2$

[ESE : 1996]

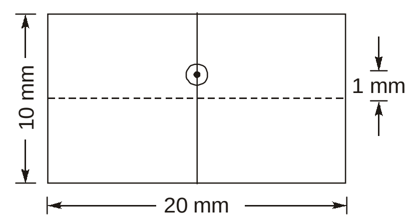
9.13 A short column of external diameter D_1 and internal diameter D_2 carries an external load *W*. For no-tension condition, the eccentricity will be

(a) $\frac{D_1^2 - D_2^2}{8D_2}$ (b) $\frac{D_2^2 - D_1^2}{8D_2}$

(c) $\frac{D_1^2 + D_2^2}{8D_1}$ (d) $\frac{D_1 + D_2}{8D_1}$

[ESE : 1997]

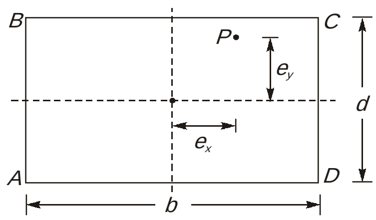
9.14 A tie bar (20 mm × 10 mm) carries a tensile load of 1 kN as shown in the figure below. Under this load, the maximum intensity of stress over the mean value will increase by



(a) 20% (b) 40%
(c) 60% (d) 80%

[ESE : 1997]

9.15 The rectangular column shown in the figure below carries a load *P* having eccentricities 'e_x' and 'e_y' along the *X*-axis and *Y*-axis respectively. The stress at any point (x, y) is given by



(a) $\frac{P}{bd}\left[1+\frac{12e_y \times y}{d^2}+\frac{12e_x \times x}{b^2}\right]$

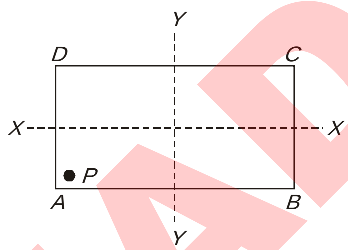
(b) $\frac{P}{bd}\left[1+\frac{12e_y \times y}{b^2}+\frac{12e_x \times x}{d^2}\right]$

(c) $\frac{P}{bd}\left[1+\frac{6e_y \times y}{d^2}+\frac{6e_x \times x}{b^2}\right]$

(d) $\frac{P}{bd}\left[1+\frac{6e_y \times y}{b^2}+\frac{6e_x \times x}{d^2}\right]$

[ESE : 1998]

9.16 A reinforced concrete footing loaded with a concentrated load P as shown in the given figure produces maximum bending stresses of 10 kN/m^2 and 15 kN/m^2 due to eccentricities about XX and YY axes respectively. If the direct stress due to load acting at P is 18 kN/m^2 (compressive), then the intensity of resultant stress at corner B will be



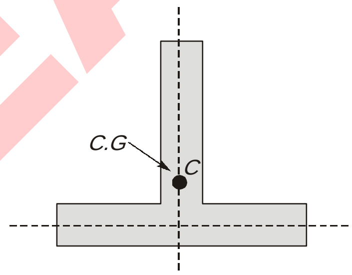
(a) 13 kN/m^2 tensile
(b) 13 kN/m^2 compressive
(c) 31 kN/m^2 compressive
(d) 31 kN/m^2 tensile [ESE : 1999]

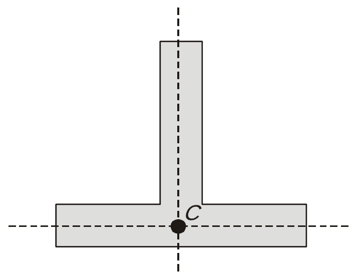
9.17 A column base is subjected to moment. If the intensity of bearing pressure due to axial load is equal to stress due to the moment, then the bearing pressure between the base and the concrete is
(a) uniform compression throughout
(b) zero at one end and compression at the other end
(c) tension at one end and compression at the other end
(d) uniform tension throughout [ESE : 1999]

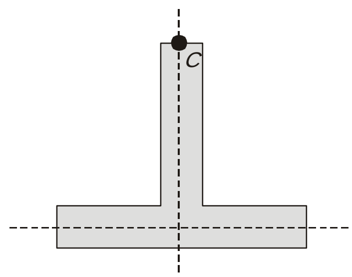
9.18 Assertion (A): Rankine's theory is generally used for finding out the buckling load of intermediate columns.
Reason (R): Euler's theory gives higher values for buckling loads in intermediate columns.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

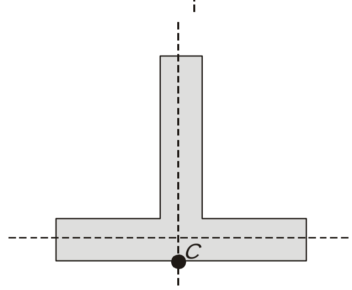
10. Shear Centre, Moment of Inertia & Principal Axes

10.1 In a thin-wall T-section, the shear centre C is located at the point shown in

(a)


(b)


(c)


(d)


[ESE : 1995]

10.2 Consider the following statements:
1. If a beam has two axes of symmetry even then shear centre does not coincide with the centroid.
2. For a section having one axis of symmetry, the shear centre does not coincide with the centroid but lies on the axis of symmetry.
3. If a load passes through the shear centre, then there will be only bending in the cross-section and no twisting.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE : 1995]

10.3 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Shear centre	**1.** Tension
B. Principal plane	**2.** Slope
C. Fixed end	**3.** Shear stress
D. Middle third rule	**4.** Twisting

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	3	1	4	2
(c)	4	1	2	3
(d)	4	2	3	1

[ESE : 1996]

10.4 The shear centre of a section is defined as that point
(a) through which the load must be applied to produce zero twisting moment on the section
(b) at which the shear force is zero
(c) at which the shear force is maximum
(d) at which the shear force is minimum
[ESE : 1997]

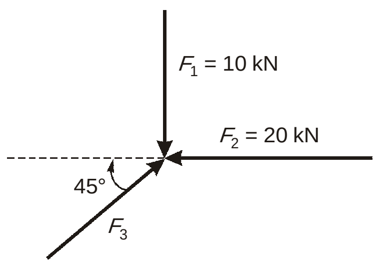
10.5 Shear centre of a semi-circular arc strip of radius 'r' will be at a distance of 'x' from the centre of the arc, where 'x' is equal to
(a) $\frac{\pi r}{2}$ (b) $\frac{2r}{\pi}$
(c) $\frac{4r}{\pi}$ (d) $\frac{\pi r}{4}$ [ESE : 1998]

10.6 Given that for a channel section, the width of flange = b, the depth of the web between centres of flanges = h, the thickness of flange = t, the moment of inertia of the channel about the axis of bending = I, the distance of the shear centre outside the channel section from the mid-thickness of the web is
(a) $\frac{th^2 b^2}{I}$ (b) $\frac{t^2 h^2 b}{4I}$
(c) $\frac{th^2 b^2}{4I}$ (d) $\frac{t^2 hb^2}{4I}$
[ESE : 1999]

10.7 **Assertion (A):** There is no twisting in an open section if the point of application of the load passes through its shear centre.
Reason (R): Shear centre coincides with the centre of gravity of the open section.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

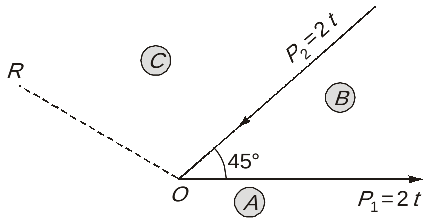
11. Miscellaneous

11.1 For the coplanar concurrent system of forces as shown in the given figure, the system will be

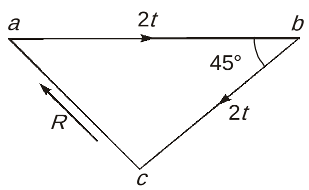


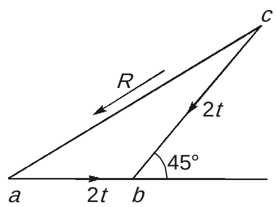
(a) in equilibrium if $|F_3|$ = 10 kN
(b) in equilibrium if $|F_3|$ = $10\sqrt{2}$ kN
(c) in equilibrium if $|F_3|$ = 20 kN
(d) will not be in equilibrium whatever be the magnitude of F_3
[ESE : 1995]

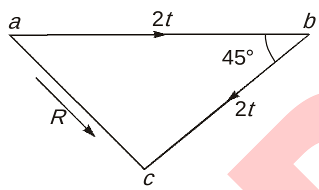
11.2 Two coplanar concurrent forces $P_1 = 2t$ and $P_2 = 2t$ meeting at O act on a lamina at 45° as shown in figure.

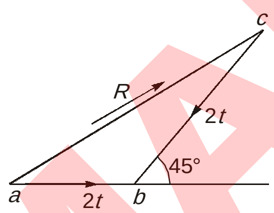


From the force diagram the force R to be applied at O in order to keep the body in equilibrium is given by

(a)


(b)


(c)


(d)


[ESE : 1995]

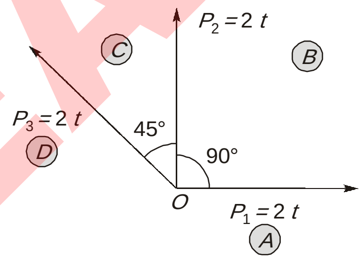
11.3 Parallelogram law of forces states that if two forces acting simultaneously at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant may be represented in magnitude and direction by
(a) longer side of the other two sides
(b) shorter side of the other two sides
(c) diagonal of the parallelogram which does not pass through their point of intersection
(d) diagonal for the parallelogram which passes through their point of intersection

[ESE : 1995]

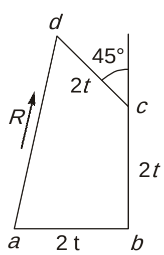
11.4 In order to find the resultant of a system of coplanar parallel system of forces, the correct sequence of the graphical procedure to be followed is
(a) force diagram, space diagram, funicular polygon and polar diagram
(b) funicular polygon, force diagram, space diagram and polar diagram
(c) space diagram, force diagram, polar diagram and funicular polygon
(d) space diagram, funicular polygon, force diagram and polar diagram

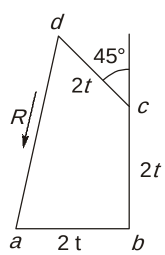
[ESE : 1996]

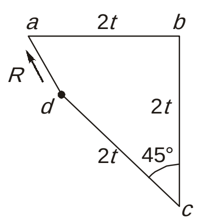
11.5 Three coplanar forces $P_1 = P_2 = P_3 = 2\ t$ act at a joint O, as shown in figure

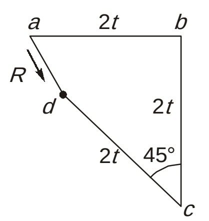


From the force diagram, the force R to be applied at O in the same plane to keep the joint O in equilibrium is given by

(a)


(b)


(c)


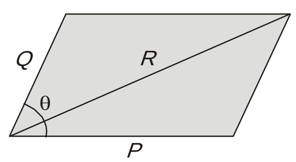
(d)


[ESE : 1996]

11.6 If A be the area of cross-section of a bar, the gauge length for the measurement of ductility will be
(a) $5.65 \times A^{1/2}$ (b) $5.65 \times A$
(c) $6.56 \times A^{1/2}$ (d) $6.56 \times A$

[ESE : 1998]

11.7 In the diagram below, if Q is made equal to P and the resultant force (R) is also made equal to P, then the value of angle θ will be



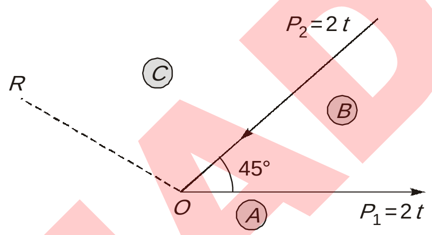
(a) 120° (b) 60°
(c) 45° (d) 30°

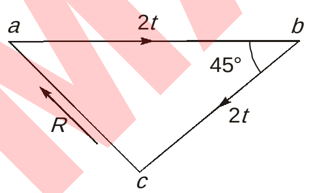
[ESE : 1998]

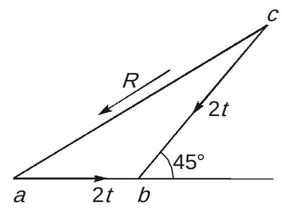
11.8 If the given forces P_1, P_2, P_3 and P_4 which are coplanar and concurrent are such that the force polygon does not close, then the system will
(a) be in equilibrium
(b) always reduce to a resultant force
(c) always reduce to a couple
(d) always be in equilibrium and will always reduce to a couple

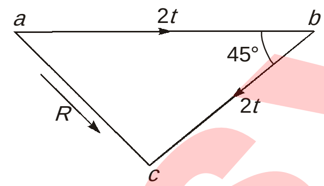
[ESE : 1998]

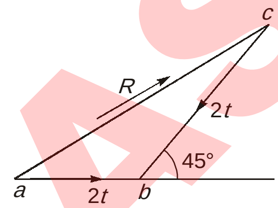
11.9 Two coplanar forces $P_1 = 2\,t$ and $P_2 = 2\,t$ meeting at O act on lamina at α = 45° as shown in the figure.
From the force diagram, force R, the resultant of P_1 and P_2, to be applied at O is given by



(a)


(b)


(c)


(d)


[ESE : 1998]

11.10 If forces P_1, P_2, P_3, and P_4 of a system are such that the force polygon does not close, then the system will
(a) be in equilibrium
(b) reduce to a resultant force
(c) reduce to a couple
(d) not be in equilibrium

[ESE : 1999]

■■■■

Answers Solid Mechanics

1.1 (c)	1.2 (b)	1.3 (a)	1.4 (b)	1.5 (a)	1.6 (a)	1.7 (d)	1.8 (a)	1.9 (a)
1.10 (a)	1.11 (b)	2.1 (a)	2.2 (b)	2.3 (c)	2.4 (a)	2.5 (c)	2.6 (d)	2.7 (b)
2.8 (a)	2.9 (c)	2.10 (a)	2.11 (a)	2.12 (b)	2.13 (a)	2.14 (b)	2.15 (a)	2.16 (d)
2.17 (c)	2.18 (c)	2.19 (d)	2.20 (b)	2.21 (a)	2.22 (c)	2.23 (d)	2.24 (d)	2.25 (a)
2.26 (d)	2.27 (a)	3.1 (a)	3.2 (c)	3.3 (a)	3.4 (b)	3.5 (d)	3.6 (a)	3.7 (b)
3.8 (a)	3.9 (c)	3.10 (d)	3.11 (a)	3.12 (c)	3.13 (c)	3.14 (a)	3.15 (a)	3.16 (b)
3.17 (d)	3.18 (d)	3.19 (d)	3.20 (d)	3.21 (b)	3.22 (a)	3.23 (d)	3.24 (b)	3.25 (b)
3.26 (d)	4.1 (a)	4.2 (b)	4.3 (b)	4.4 (d)	4.5 (c)	4.6 (a)	4.7 (a)	4.8 (a)
4.9 (a)	4.10 (c)	4.11 (d)	4.12 (c)	4.13 (d)	4.14 (b)	4.15 (c)	4.16 (a)	4.17 (b)
4.18 (a)	4.19 (a)	4.20 (c)	4.21 (c)	4.22 (c)	4.23 (d)	4.24 (d)	4.25 (b)	4.26 (b)
4.27 (a)	5.1 (d)	5.2 (a)	5.3 (c)	5.4 (c)	5.5 (c)	5.6 (c)	5.7 (d)	5.8 (c)
5.9 (b)	5.10 (a)	5.11 (c)	5.12 (c)	6.1 (c)	6.2 (b, d)	6.3 (d)	6.4 (c)	6.5 (b)
6.6 (a)	6.7 (b)	6.8 (c)	6.9 (b)	6.10 (c)	6.11 (c)	6.12 (b)	6.13 (d)	6.14 (b)
6.15 (d)	6.16 (d)	6.17 (c)	6.18 (b)	6.19 (b)	6.20 (b)	6.21 (a)	6.22 (a)	6.23 (b)
6.24 (b)	6.25 (a)	6.26 (a)	6.27 (c)	7.1 (b)	7.2 (d)	7.3 (b)	7.4 (a)	7.5 (b)
7.6 (d)	8.1 (d)	8.2 (d)	8.3 (a)	8.4 (a)	8.5 (d)	8.6 (d)	8.7 (a)	8.8 (b)
8.9 (b)	8.10 (d)	8.11 (b)	8.12 (c)	8.13 (c)	8.14 (c)	8.15 (b)	8.16 (b)	9.1 (d)
9.2 (a)	9.3 (b)	9.4 (d)	9.5 (c)	9.6 (c)	9.7 (c)	9.8 (b)	9.9 (b)	9.10 (d)
9.11 (d)	9.12 (b)	9.13 (c)	9.14 (c)	9.15 (a)	9.16 (b)	9.17 (b)	9.18 (b)	10.1 (b)
10.2 (c)	10.3 (a)	10.4 (a)	10.5 (c)	10.6 (c)	10.7 (c)	11.1 (d)	11.2 (a)	11.3 (d)
11.4 (c)	11.5 (b)	11.6 (a)	11.7 (a)	11.8 (b)	11.9 (a)	11.10 (d)		

Explanations Solid Mechanics

1. Properties of Materials

1.1 (c)

In plastic design the stress-strain curve is bi-linear as shown in figure (a). However, the stress-strain curve for ideal plastic materials is as shown in figure (c). Figure (b) shows stress-strain curve for brittle materials. Figure (d) shows stress-strain curve for ductile materials.

1.2 (b)

The stress which can be withstood for some specified number of cycles is the fatigue strength of material. The stress level which can be withstood for an infinite number of cycles, without failure is called endurance limit.

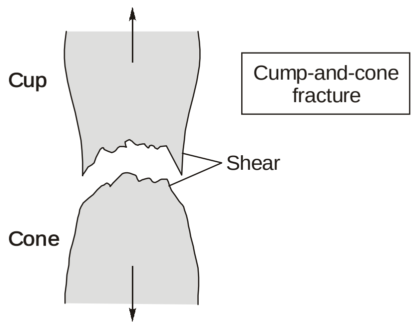
1.4 (b)

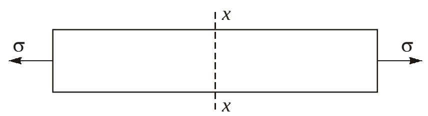
During experiment in laboratory, strain is measured that is why it is called fundamental quantity. While stress is derived from strain.

1.5 (a)

For an isotrpic homogensous material amount of elastic deformation is same irrespective of nature of stress.

1.6 (a)





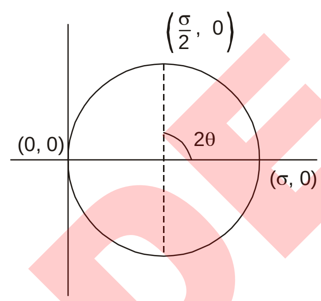
Mohr circle for this stress condition as shown:

$2\theta = 90°$

$\theta = 45°$

$2\theta = 90°$

$\theta = 45°$



Maximum shear stress is at 45° to direction of applied tensile force. Mild steel is weaker in shear.

1.7 (d)

- **Ductility:** Ability of a material (such as a metal or asphalt cement) to undergo permanent deformation through elongation.
- **Brittleness:** Tendency of a material to fracture or fail without significant deformation upon the application of a relatively small amount of force, impact, or shock.
- **Tenacity:** Ability to metal to resist fracture under heavy tensile load.
- **Toughness:** Ability of absorb energy at high stress without rupture.

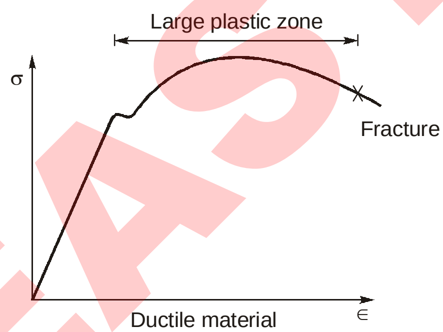
1.8 (a)

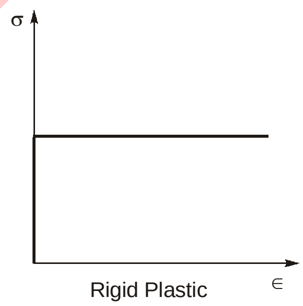
Visco-elastic material exhibit a mixture of creep and elastic after effects at room temperature. Thus their behaviour is time dependent. They do not have small plastic zone.

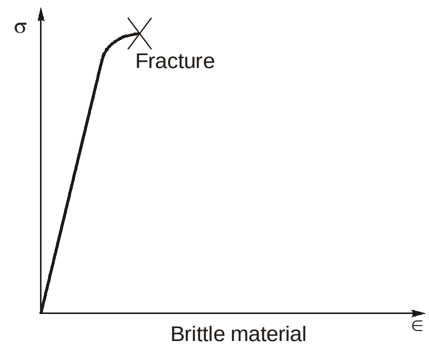
Materials with different properties in different directions are called anisotropic. Orthotropic material is a special case of an anisotropic material in three mutually perpendicular directions. However, these are symmetric about any axis.

1.9 (a)

In **inelastic material,** strain is not recovered after unloading.







1.11 (b)

For true stress, the actual area at any time is used. The actual area is less than original area, due to elongation in specimen therefore true stress is more than nominal stress.

2. Simple Stress-Strain & Elastic Constants

2.1 (a)

$$\frac{\Delta V}{V} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}}$$

$$= \varepsilon_x + \varepsilon_y + \varepsilon_z$$

2.2 (b)

The elongation of bar due to its own weight (W) is

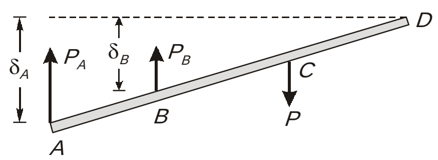
$$\Delta = \frac{WL}{2AE}$$

Now $W = \rho A L$

$$\therefore \quad \Delta = \frac{\rho L^2}{2E}$$

2.3 (c)

The rigid beam will rotate about point D, due to the load at C.



From similar triangle,

$$\frac{\delta_B}{2a} = \frac{\delta_A}{3a} \quad \text{or} \quad \frac{\delta_A}{\delta_B} = \frac{3}{2}$$

$$\frac{\text{Force in spring } A}{\text{Force in spring } B} = \frac{P_A}{P_B}$$

$$= \frac{k_A \delta_A}{k_B \delta_B} = \frac{2k}{k} \times \frac{3}{2} = 3$$

2.4 (a)

Bulk modulus, $K = \dfrac{p}{\Delta V/V}$

$$\therefore \quad \Delta V = \frac{1330 \times 8000}{1.33 \times 10^6}$$

$$= 8 \text{ cc}$$

2.5 (c)

There are four elastic constants viz.

E = Young's modulus of elasticity

G = Modulus of rigidity

K = Bulk modulus

μ = Poisson's ratio

The relations between these constants are:

(i) $G = \dfrac{E}{2(1+\mu)}$ (ii) $K = \dfrac{E}{3(1-2\mu)}$

(iii) $E = \dfrac{9KG}{G+3K}$ (iv) $\mu = \dfrac{3K-2G}{6K+2G}$

2.6 (d)

Since both the supports are fixed and both bars will try to expand, so rise in temperature will cause compressive stresses in the bars.

2.7 (b)

Longitudinal strain, $\epsilon_L = \dfrac{\Delta L}{L} = \dfrac{0.09}{200}$

Lateral strain, $\epsilon_D = \dfrac{\Delta D}{D} = -\dfrac{0.0045}{30}$

Poisson's ratio $= -\dfrac{\epsilon_D}{\epsilon_L} = \dfrac{0.0045}{30} \times \dfrac{200}{0.09} = \dfrac{1}{3}$

2.8 (a)

Modulus of resilience, $u = \dfrac{f^2}{2E}$

where $E = \dfrac{fL}{\Delta L}$

$$\therefore \quad u = \frac{f\Delta L}{2L} = \frac{200 \times 2}{2 \times 2000} = 0.10 \textit{ units}$$

2.9 (c)

Strain energy stored $= \dfrac{\tau^2 V}{2G}$

$$= \frac{(500)^2}{2 \times 10^6} \times 20 \times 10 \times 5$$

$$= 125 \text{ kg-cm}$$

2.10 (a)

Instantaneous elongation, $\Delta = \dfrac{2PL}{EA}$

$$= \frac{2 \times 60 \times 10^3 \times 4000}{2.06 \times 10^5 \times \left(\dfrac{\pi \times 50^2}{4}\right)}$$

$$= 1.19 \text{ mm}$$

2.11 (a)

$$\Delta_0 = \frac{4PL}{\pi E D_1 D_2}$$

Actual extension,

$$\Delta_0 = \frac{4PL}{\pi (2D^2) E} = \frac{2PL}{\pi D^2 E}$$

The average diameter of bar

$$= \frac{2D + D}{2} = 1.5\,D$$

Approximate extension,

$$\Delta = \frac{4PL}{\pi \times (1.5D)^2 E} = \frac{4PL}{2.25\pi D^2 E}$$

$$\therefore \text{ Error in calculation} = \left(1 - \frac{\Delta}{\Delta_0}\right) \times 100$$

$$= \left(1 - \frac{2}{2.25}\right) \times 100 = 11.11\% \approx 10\%$$

2.12 (b)

Temperature Stress = $E\,\alpha\,\Delta T$

$$\frac{\text{Stress in bar } A}{\text{Stress in bar } B} = \left(\frac{E_A}{E_B}\right)\left(\frac{\alpha_A}{\alpha_B}\right) = 2 \times 2 = 4$$

2.14 (b)

The area of bar will become 4 times, and the volume as well as weight will increase 8 times. So increase in elongation

$$\left(\Delta = \frac{WL}{2EA}\right) \text{ will be } \frac{8 \times 2}{4} = 4 \text{ times}$$

2.15 (a)

$$\text{Elongation} = \frac{PL}{EA_1} + \frac{PL}{EA_2}$$

$$= \frac{PL}{E} \times \frac{4}{\pi}\left(\frac{1}{d_1^2} + \frac{1}{d_2^2}\right)$$

$$= \frac{10 \times 1000 \times 20}{2 \times 10^6} \times \frac{4}{\pi}\left(\frac{1}{100} + \frac{1}{64}\right)$$

$$= \frac{1}{10\pi}\left(\frac{1}{25} + \frac{1}{16}\right) \text{cm}$$

2.16 (d)

The elongation in the bar due to increase in temperature = $L\alpha\Delta T$

Yield of support reduces strain in the bar by δ.

$$\therefore \quad \sigma = \left(\frac{L\alpha\Delta T - \delta}{L}\right) E = E\left(\alpha\,\Delta T - \frac{\delta}{L}\right)$$

$$= 1 \times 10^6 \times \left(20 \times 10^{-6} \times 100 - \frac{0.01}{25}\right)$$

$$= 1600 \text{ kg/cm}^2$$

2.17 (c)

$$\text{Modulus of rigidity, } G = \frac{E}{2(1+\mu)}$$

$$\therefore \quad \frac{E}{G} = 2 \times (1 + 0.25) = 2.5$$

2.18 (c)

Axial load on portion BC = 3000 + 2000

= 5000 kg (tensile)

$$\text{Tensile stress} = \frac{5000}{5} = 1000 \text{ kg/cm}^2$$

2.19 (d)

Since load of 1t is applied mid-way so force in both wires will be same and equals to 0.5 t.

$$\Delta_c = \frac{500 \times 4}{1 \times 10^6 \times 4} = 5 \times 10^{-4} \text{ m} = 0.5 \text{ mm}$$

$$\Delta_s = \frac{500 \times 4}{2 \times 10^6 \times 2} = 5 \times 10^{-4} \text{ m} = 0.5 \text{ mm}$$

$$\therefore \frac{\Delta_c}{\Delta_s} = 1.0$$

2.20 (b)

Since both the ends of the bar are unyielding. With increase in temperature, both bars will be in compression and the load will be transferred to the supports.

2.21 (a)

$$\text{We know that, } \mu = \frac{3K - 2G}{6K + 2G}$$

But here, $K = G$

$$\therefore \quad \mu = \frac{3 - 2}{6 + 2} = 0.125$$

2.22 (c)

$$\frac{\Delta_1}{\Delta_2} = \frac{L_1}{L_2} \times \frac{A_2}{A_1}$$

Since $L_1 = L_2$ and $A_1 = 2A_2$

$$\therefore \quad \frac{\Delta_1}{\Delta_2} = 1 \times \frac{1}{2} = \frac{1}{2}$$

2.23 (d)

Actual extension

$$\Delta_1 = \frac{4PL}{\pi d_1 d_2 E}$$

Extension base don average diameter

$$\Delta_2 = \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

Assuming $\Delta_1 > \Delta_2$

So, $$\frac{4PL}{\pi d_1 d_2 E} > \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

$$\Rightarrow \left(\frac{d_1+d_2}{2}\right)^2 > d_1 d_2$$

$$\Rightarrow \frac{d_1^2+d_2^2+2d_1d_2}{4} - d_1d_2 = 0$$

$\Rightarrow (d_1-d_2)^2 > 0$

Which is true.

2.24 (d)

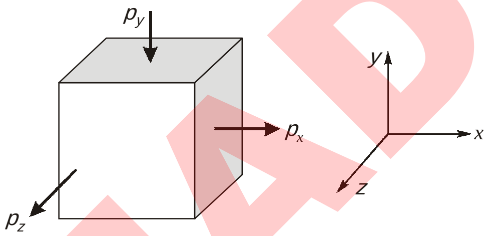
Total elongation

$$= \frac{4PL}{\pi E}\left(\frac{1}{d_1^2}+\frac{1}{d_2^2}+\frac{1}{d_3^2}\right)$$

$$= \frac{4\times 10\times 100}{\pi E\times 100}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right] \text{mm}$$

$$= \frac{40}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right) \text{mm}$$

2.25 (a)



$$\epsilon_x = \frac{p_x}{E} - \mu\left(-\frac{p_y}{E}\right) - \mu\left(\frac{p_z}{E}\right)$$

$$= \frac{1}{E}\left(p_x + \mu p_y - \mu p_z\right)$$

2.26 (d)

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = 0.25$$

$$G = \frac{E}{2(1+\mu)} = \frac{2\times 10^5}{2.5}$$

$= 0.8 \times 10^5$ N/mm^2

2.27 (a)

Mild steel is equally strong in tension and compression but it is weak in shear. Therefore cup and cone type failure of mild steel specimen occurs during tension test.

3. Shear Force & Bending Moment

3.1 (a)

We know that, $\frac{dM}{dx} = V$

So BM is maximum where shear force is zero or changes sign.

3.2 (c)

Bending moment

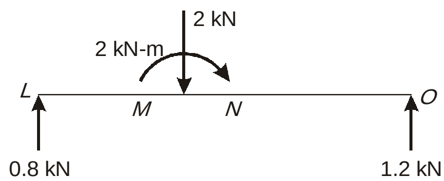
$$M = \int V dx$$

$$V = \int w dx$$

If loading is of nth degree, then bending moment is of (n+2) degree

Shear force diagram is of (n+1) degree

3.3 (a)



The reaction at end L,

$$R_L = \frac{1}{5}(2\times 3 - 2) = 0.8 \text{ kN}$$

The reaction at end O,

$$R_O = \frac{1}{5}(2\times 2 + 2) = 1.2 \text{ kN}$$

The beam will have FBD as

So the BMD will be as shown in figure (a)

3.4 (b)

The SFD does not change, while the sudden change in BMD denotes a concentrated moment at the point C. The triangular shape of BMD shows concentrated load is applied at free end.

3.5 (d)

Reaction at A,

$$R_A = \frac{2\times 1+4\times 2+2\times 3}{4} = 4\text{t}$$

$R_B = 4$ t

$\therefore$ Bending moment at E,

$$M_E = -2 + 4 \times 2 - 2 \times 1$$
$$= 4 \text{ t-m (sagging)}$$

3.6 (a)

$$\frac{dV}{dx} = -w \text{ and } \frac{dM}{dx} = V$$

3.8 (a)

Section	Thrust (T)
AC	3.222
CD	3.222 – 3.464 = – 0.242
DE	– 0.242 + 4.242 = 4.0
EB	4 – 4 = 0

So correct thrust diagram is given in figure (a).

3.9 (c)

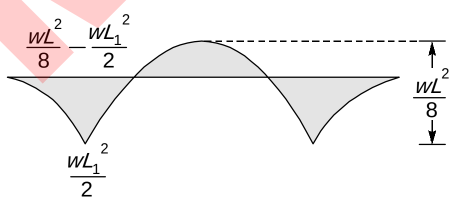
For cantilever beam maximum bending moment will occur at support while for simply supported beam maximum bending moment will occur at mid point.

Fig.	Maximum BM
A	$\left(\frac{wL}{2}\right) \times \frac{L}{3} = \frac{wL^2}{6}$
B	$(wL) \times \frac{L}{2} = \frac{wL^2}{2}$
C	$\frac{wL^2}{12}$
D	$\frac{wL^2}{8}$

3.10 (d)

The BM can be found from the area of SFD

The shear force diagram is



BMD of the above beam is

Maximum negative, bending moment,

$$M_1 = \frac{wL_1^2}{2}$$

Maximum positive, bending moment,

$$M_2 = \frac{wL^2}{8} - \frac{wL_1^2}{2}$$

For $\quad M_1 = M_2$

$$L_1 = \frac{L}{2\sqrt{2}}$$

3.11 (a)

The slope of shear force diagram can be used to find load intensity.

$$\frac{dV}{dx} = -w$$

For point loads and reaction, there is sudden change in shear force at point of application.

Support reaction at A = 14 t

There is no load between A and D as SFD does not change. At D there is sudden change in value of SF from 14 t to – 4 t. So there is point load of 18 t at point D. Between D and B the shape of SFD is linearly decreasing so there is uniformly distributed load between B and D. The intensity of UDL is

$$w = \frac{16-4}{8} = \frac{12}{8} = 1.5 \text{ t/m}$$

At B there is sudden change in the SF so there is reaction at B, $R_B = 16 + 9 = 25\ t$

Again between B and C the SFD decreases linearly from 9 t to 3 t. So load intensity

$$w = \frac{9-3}{4} = 1.5 \text{ t/m}$$

Finally the SFD decreases to zero suddenly at C. So a point load of 3 t is applied at C.

3.13 (c)

The vertical component of reaction at A and B will be in the upward direction and horizontal component should be equal to each other.

3.15 (a)

$$\frac{dM}{dx} = V$$

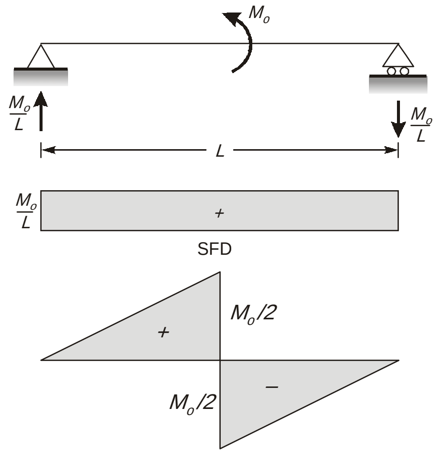
$$\therefore M_2 - M_1 = \int V dx = \text{Area under shear curve}$$

3.16 (b)

$$M = \Sigma M_i$$

$$\frac{dM}{dx} = V$$

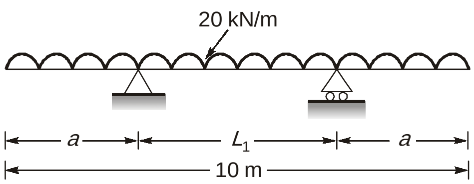
3.19 (d)



BMD

Thus 1 and 3 are correct.

3.20 (d)



Given $L_1 + 2a = 10$ m

The bending moment will be least when maximum negative moment is equal to maximum positive moment.

$$a = 0.207L = 2.07 \text{ m}$$

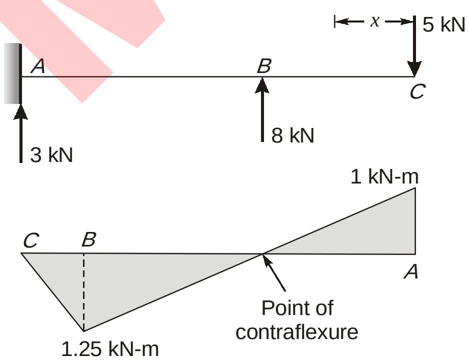
3.21 (b)

Support reaction = 10 + 10 × 2 = 30 kN

The shape of SFD will be linear with sudden drop at point of concentrated load. The shape of BMD will be parabolic.

3.22 (a)

The point where *BM* is zero and changes sign, is called point of contraflexure.



BMD

Distance of point of contraflexure from *A* is *x*,

$5(1 - x) - 8(0.75 - x) = 0$

$x = 0.333$ m

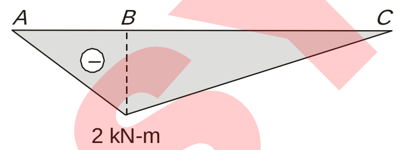
3.23 (d)

4 kN-m moment is sagging

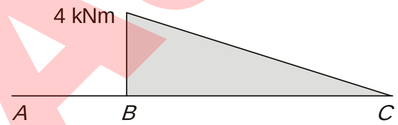
2 kN-m moment is hogging

BMDs

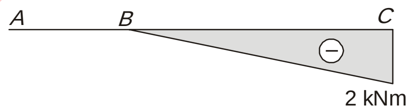
(i) Due to 4 kN load



(ii) Due to 4 kN-m moment



(iii) Due to 2 kN-m moment



BM at $A = 0$

BM at $B = 4 - 2 = 2$ kN-m sagging

BM at $C = -2$ kN-m hogging

So design *BM* is 2 kN-m

3.24 (b)

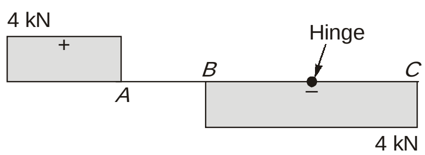
SFD is zero along the span so only opposite couple equal in magnitude are acting on member. The bending moment is hogging in nature.

3.25 (b)

Let *R* is vertical reaction and taking moment about hinge = 0

$\Rightarrow \quad R \times 7.5 - 4 \times 5 - 4 \times 2.5 = 0$

$\therefore \quad R = 4$



$\therefore$ *BM* at $A = 4 \times 2.5 = 10$ kN-m

BM at $B = 10 + 0 = 10$ kN-m

BM at $C = 10 - 4 \times 5 = -10$ kN-m

3.26 (d)

$$BM \text{ at } B = -\frac{1}{2}\frac{wL}{2}\times\frac{L}{2} = -\frac{wL^2}{8}$$

$$BM \text{ at } E = -\frac{wL^2}{8}+\frac{wL^2}{8} = 0$$

$$BM \text{ at } C = -\frac{wL^2}{8}$$

BM at $D = 0$

So the correct BMD is (d)

4. Principal Stress-Strain & Theories of Failure

4.1 (a)

Normal stress = $p\cos^2\theta$

Tangential stress = $p\sin\theta\cos\theta = p\dfrac{\sin 2\theta}{2}$

4.2 (b)

Maximum shear stress is half of the difference of the maximum and minimum principal stresses.

4.3 (b)

Principal stresses,

$$\sigma_{1,2} = \frac{\sigma_x+\sigma_y}{2}\pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}$$

Given $\sigma_x = 15 \text{ kN/cm}^2$

$\sigma_y = 9 \text{ kN/cm}^2$

$\tau_{xy} = 4 \text{ kN/cm}^2$

$\therefore \quad \sigma_{1,2} = 12\pm\sqrt{(3)^2+(4)^2}$

$= 12 \pm 5 \text{ kN/cm}^2$

$\sigma_1 = 17 \text{ kN/cm}^2$

$\sigma_2 = 7 \text{ kN/cm}^2$

Both of these are tensile in nature.

4.4 (d)

The shear stress $\tau = -\left(\dfrac{\sigma_1-\sigma_2}{2}\right)\sin 2\theta$

where, θ is the angle of inclination of the plane of major principal stress.

For shear stresses to be maximum,

$\sin 2\theta = 1$

$\therefore \quad \theta = 45°$ and $135°$

with y-direction (plane of p_1)

4.5 (c)

According to maximum principal strain theory

$$\frac{f}{E} = \frac{(\sigma_1-\mu\sigma_2)}{E}$$

The equivalent tensile stress

$f = 800 - 0.25 \times 400$

$= 700 \text{ kg/cm}^2$

4.6 (a)

The Maximum Shear Stress theory states that failure occurs when the maximum shear stress from a combination of principal stresses equals or exceeds the value obtained for the shear stress at yielding in the uniaxial tensile test.

For yielding in material,

Maximum shear stress = yield stress/ 2

4.7 (a)

For brittle material of low tensile strength and much larger strength in compression and shear the twisting will cause fracture along spiral line at 45° to the axis of cylinder.

For ductile material like mild steel, the plane of failure will be normal to the axis.

4.8 (a)

At 45° ,

$\sigma_1, \sigma_2 = \pm\tau$

$$\text{Strain} = \frac{\sigma_1}{E}-\frac{\mu\sigma_2}{E} \qquad [E = 2G(1+\mu)]$$

$$= \frac{\tau}{E}(1+\mu) = \frac{\phi}{2}$$

4.9 (a)

Centre of Mohr's circle,

$$C = \frac{\sigma_x+\sigma_y}{2} = 70 \text{ MPa}$$

Radius of Mohr's circle,

$$r = \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2} = 50 \text{ MPa}$$

Major principal stress

$\sigma_1 = C + r = 70 + 50 = 120 \text{ MPa}$

Minor principal stress

$\sigma_2 = C - r = 70 - 50 = 20 \text{ MPa}$

4.10 (c)

When a member is subjected to uniaxial tensile force, the maximum normal stress is the external load divided by the minimum cross sectional area. Also, on the plane of maximum normal stress shear stress is zero.

4.11 (d)

Proportionality limit shear stress

$$= \frac{3000}{2} = 1500 \text{ kg/cm}^2$$

Maximum shear stress

$$= \frac{1200-(-300)}{2} = 750 \text{ kg/cm}^2$$

$$\text{Factor of safety} = \frac{1500}{750} = 2.0$$

4.12 (c)

$(\sigma_1 - \sigma_2) \geq \sigma_y$: Maximum shear stress theory

$\frac{1}{E}(\sigma_1 - \mu\sigma_2) \geq \frac{\sigma_y}{E}$: Maximum principal strain theory

$(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2) \geq f_y^2$:Maximum strain energy theory

$(\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2) \geq f_y^2$: Distortion energy theory

4.13 (d)

The inclination of the line joining any point P on the Mohr's circle and the origin O with x-axis equals the angle between the resultant stress and the normal of the plane for which P stands.

4.14 (b)

$$\text{Tangential stress} = \left(\frac{\sigma_1 - \sigma_2}{2}\right) \times \sin 2\theta$$

$$= \left(\frac{1000-2000}{2}\right) \times \sin 30°$$

$$= -250 \text{ kg/cm}^2$$

4.15 (c)

Normal stress on the plane of maximum shear stress

$$= \frac{\sigma_1 + \sigma_2}{2} = \frac{100-50}{2}$$

$$= 25 \text{ MPa (tensile)}$$

4.16 (a)

As per maximum distortion theory, maximum shear strain energy in a body should be less than or equal to maximum shear strain energy under uniaxial loading.

$$\left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}\right]^{1/2} \leq 0$$

4.17 (b)

As per maximum shear stress theory, for no failure maximum shear stress should be less than half of yield stress.

$$\text{Max}\left[\left(\frac{\sigma_1 - \sigma_2}{2}\right), \left(\frac{\sigma_2 - \sigma_3}{2}\right), \left(\frac{\sigma_3 - \sigma_1}{2}\right)\right] \leq \frac{\sigma_0}{2}$$

Given that $\sigma_1 > \sigma_2 > \sigma_3$

$$\frac{\sigma_1 - \sigma_3}{2} = \frac{\sigma_0}{2}$$

4.18 (a)

When one of the principal stresses at a point is large in comparison to the other, the situation resembles uniaxial tension test. Therefore all theories give nearly same result.

4.19 (a)

For equal tensile stress on all the faces,

$$\sigma^2 + \sigma^2 + \sigma^2 - 6\,\sigma^2\mu = \sigma_y^2$$

$$3\sigma^2(1 - 2\mu) = \sigma_y^2$$

$$\therefore \quad \sigma = \frac{\sigma_y}{\sqrt{3(1-2\mu)}}$$

4.20 (c)

Principal stresses,

$$\sigma_1/\sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Since minimum principal stress is zero, therefore

$$\left(\frac{\sigma_x + \sigma_y}{2}\right)^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2$$

$$\tau_{xy} = \sqrt{\sigma_x \sigma_y}$$

4.21 (c)

The normal stress on planes having maximum

$$\text{shear stress} = \frac{p_1 + p_2}{2}$$

4.22 (c)

Let minor principal stress is σ_3.

$\therefore$ Maximum shear stress $= \left(\dfrac{200+\sigma_3}{2}\right)$

$$\therefore \quad \left(\frac{200+\sigma_3}{2}\right) = \frac{250}{2} \text{ at yielding}$$

$$\Rightarrow \quad \sigma_3 = 50 \text{ MPa}$$

4.23 (d)

Maximum principal stress = 150 MPa

Factor of safety $= \dfrac{300}{150} = 2$

4.24 (d)

The principal stresses will act on planes at 45° and 135°.

The values of principal stresses will be q and $-q$.

4.25 (b)

By stress invariant

$$\sigma_x + \sigma_y = \sigma_{p_1} + \sigma_{p_2} = \text{Constant}$$

$$32 + [-10] = 40 + \sigma_{p_2}$$

$$\sigma_{p_2} = 18$$

4.26 (b)

Minor principal stress $= C - r = 10$

Centre of circle $(C) = 10 + 20 = 30$ N/mm^2

Major principal stress $= C + r = 30 + 20$

$= 50$ N/mm^2

4.27 (a)

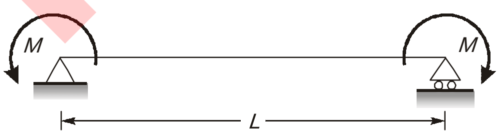
$$\text{Strain energy} = \frac{1}{2}(\sigma_1 \epsilon_1 + \sigma_2 \epsilon_2)$$

$$= \frac{1}{2E}(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2)$$

5. Deflection of Beams

5.1 (d)

The bending moment throughout the beam is M.



The beam deforms in the form of a circular arc with radius $R = \dfrac{EI}{M}$. The central deflection

$$= \frac{L^2}{8R} = \frac{ML^2}{8EI}$$

5.3 (c)

Strain energy due to bending

$$= \int \frac{M_x^2 dx}{2EI} = \frac{1}{2}W\delta$$

The deflection under the load,

$$\delta = \frac{WL^3}{48EI} = \frac{L^3}{48EI}$$

$\therefore$ Strain energy due to unit load

$$= \frac{1}{2} \times 1 \times \frac{L^3}{48EI} = \frac{L^3}{96EI}$$

5.4 (c)

The centre point deflection of fixed beam carrying central load is one-fourth of the centre point deflection of simply supported beam carrying point load.

$$\therefore \delta = \frac{1}{4}\left(\frac{WL^3}{48EI}\right) = \frac{WL^3}{192EI}$$

5.5 (c)

From Castigliano's theorem deflection at B

$$\delta_B = \int_0^L \frac{M}{EI}\left(\frac{\partial M}{\partial W}\right)dx$$

But $\quad M = Wx$

$$\therefore \quad \delta_B = \int_0^L \frac{Wx^2}{EI}dx$$

In conjugate beam, shear force at the fixed end is the slope at B and BM at fixed end is the deflection at B.

5.6 (c)

$$\delta_B = \delta_C + \theta_C \times (L - L_1)$$

$$\delta_C = \frac{PL_1^3}{3EI}$$

$$\theta_C = \frac{PL_1^2}{2EI}$$

$$\therefore \quad \delta_B = \frac{PL_1^3}{3EI} + \frac{PL_1^2}{2EI}(L - L_1)$$

$$= \frac{PL_1^2}{2EI}\left[L - L_1 + \frac{2}{3}L_1\right]$$

$$= \frac{PL_1^2}{2EI}\left(L - \frac{L_1}{3}\right)$$

5.7 (d)

The force in spring,

$$F = \frac{500 \times 2L}{L} = 1000 \text{ N}$$

Deflection in the spring,

$$\delta = \frac{F}{k} = \frac{1000}{50} = 20 \text{ mm}$$

Deflection at point B

$$= 2\delta = 40 \text{ mm downward}$$

5.8 (c)

For simply supported beam strain energy,

$$E_1 = \frac{W^2L^3}{240EI}$$

For cantilever beam strain energy,

$$E_2 = \frac{W^2L^3}{40EI}$$

$$\therefore \quad \frac{E_2}{E_1} = 6$$

5.9 (b)

The deflection is maximum at a point between load and mid span. The bending moment under the load is maximum and slope at nearest support is maximum.

5.10 (a)

Maximum bending moment, $M = \dfrac{WL}{4}$

Maximum deflection, $\delta = \dfrac{WL^3}{48EI}$

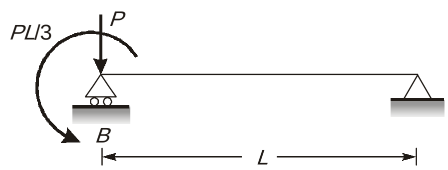
Maximum bending stress, $f = \dfrac{M}{Z}$

$$\therefore \quad \frac{\delta}{f} = \frac{L^2Z}{12EI} = \frac{L^2}{6Ed} \quad \left(as\ \frac{I}{Z} = \frac{d}{2}\right)$$

5.11 (c)

The over hanging part of the beam can be replaced by moment $\dfrac{PL}{3}$ and load P at point B. Slope at B

$$\theta_B = \left(\frac{PL}{3}\right)\frac{L}{3EI} = \frac{PL^2}{9EI}$$



If there was no load on overhanging part the deflection of load point would have been $\theta_B \times \dfrac{L}{3}$. However due to load the additional deflection $\dfrac{P(L/3)^3}{3EI} = \dfrac{PL^3}{81EI}$ is caused.

$\therefore$ Deflection under load,

$$\Delta_{Load} = \frac{PL^2}{9EI} \times \frac{L}{3} + \frac{PL^3}{81EI} = \frac{4PL^3}{81EI}$$

5.12 (c)

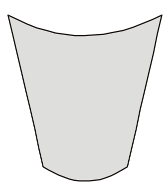
Macaulay's method is based on singularity function. It is applicable for prismatic beams only. While Mohr's moment area method can be used for prismatic and non prismatic beams.

6. Bending & Shear Stresses in Beams

6.1 (c)

The fibres above the neutral axis will be subjected to compression and fibres below the neutral axis will be subjected to tension due to bending. These bending stresses are axial in direction.

The transverse strain will also be there at all fibres cross-section due to Poisson's effect. Thus top fibres will laterally expand and bottom fibres will get compressed. Thus the deformed section will be as shown in figure (c).



6.2 (b, d)

Transform from steel to timber

Then $\quad I_t + mI_S$

Tranfrorm from timber to steel

Then $\quad \dfrac{I_t}{m} + I_s$

6.3 (d)

Section modulus of square section,

$$Z_1 = \frac{D^3}{6}$$

Section modulus of circular section,

$$Z_2 = \frac{\pi D^3}{32}$$

The moment carrying capacity $M = fZ$
where f is maximum permissible bending stress

$$\therefore \quad \frac{M_2}{M_1} = \frac{Z_2}{Z_1} = \frac{6\pi}{32} = \frac{3\pi}{16}$$

6.4 (c)

Maximum shear stress occurs at mid depth and the value is $\frac{3F}{bh}$. In triangular sections. At neutral axis the shear stress is $\frac{8F}{3bh}$.

6.5 (b)

Using bending formula

$$\frac{E}{R} = \frac{M}{I} = \frac{f}{y}$$

Given, $d = 20$ mm

So, $y_{max} = \frac{d}{2} = 10$ mm

$R = 10$ m $= 10{,}000$ mm

$E = 2 \times 10^6$ kg/cm^2

$$f_{max} = \frac{2 \times 10^6 \times 10}{10{,}000} = 2 \times 10^3 \text{ kg/cm}^2$$

6.6 (a)

The moment of inertia of a section is more if the area lies away from neutral axis. I-section has higher section modulus than that of rectangular section, therefore it is preferred to rectangular section.

6.7 (b)

For rectangular section, $\tau_{max} = 1.5\tau_{av}$

For circular section, $\tau_{max} = \frac{4}{3}\tau_{av} = 1.33\tau_{av}$

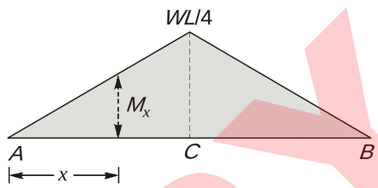
But, $\tau_{av} = \frac{V}{A}$

So for a given material, the maximum shear stress will be less in circular section when area of circular and rectangular section. Therefore circular section can resist greater shear force.

6.8 (c)

The bending moment diagram of the beam is BM at point x from simply supported end.

$$M_x = \frac{W}{2}x$$



Section modulus, $Z_x = \frac{bd_x^2}{6}$

But, $f = \frac{M_x}{Z_x}$

$$\therefore \quad d_x = \sqrt{\frac{3Wx}{bf}}$$

at $x = L/2$ $\quad d_{(L/2)} = \sqrt{\frac{3WL}{2bf}}$

6.9 (b)

The moment of inertia of both beams about their horizontal axis will be same.

i.e. $\quad I_A = I_B = \left(\frac{h^4}{12}\right)$

Deflection $\Delta \propto \frac{1}{EI}$ and since EI of beam A and B is same so deflection will be same. Therefore (1) is incorrect.

Maximum stress in beam having more section modulus will be less.

$$Z_A = \frac{I_A}{h/2} = \frac{2I_A}{h}$$

$$Z_B = \frac{I_B}{h/\sqrt{2}} = \left(\frac{\sqrt{2}I_B}{h}\right)$$

as $\quad Z_A > Z_B$ so $f_A < f_B$

The maximum stress in beam B is more than that in A, so (2) is correct.

The beam having higher section modulus will resist more load. So beam A can resist more load, so (3) is incorrect.

EI is called the flexural rigidity of the beam and it is same for both beams. Therefore (4) is correct.

6.10 (c)

At mid span of the beam, the beam is subjected to bending stresses only. These stress are zero at neutral axis or mid-depth so hole should be made at mid depth.

6.11 (c)

At a distance x from free end

$$M_x = \frac{wx^2}{2}$$

and $$Z_x = \frac{b_x d^2}{6}$$

Maximum bending stress,

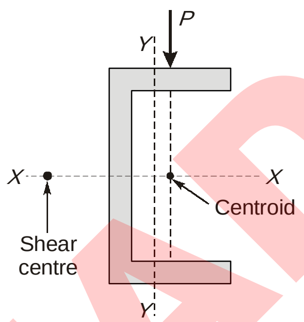
$$f = \frac{M_x}{Z_x}$$

$$\therefore \quad b_x = \frac{3wx^2}{fd^2}$$

The breadth is proportional to x^2.

6.12 (b)

Since the load does not pass through shear centre of the channel section, so the cross-section is subjected to torsion in addition to bending and shear



6.13 (d)

- In bending, maximum normal stress is known as modulus of rupture.
- Elongation ∝ Tensile stress
- Longitudinal stress is zero at neutral axis.
- At top fibre shear stress is zero as outermost surface shear stress is equal to zero.

6.14 (b)

The strain diagram is linear.

6.15 (d)

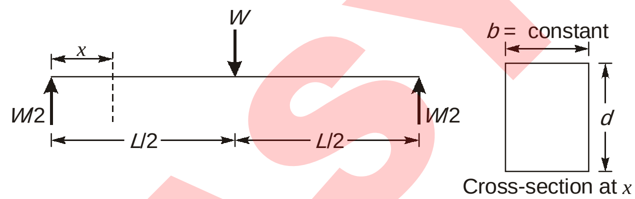
Flexural strength is proportional to sectional modulus of beams. For both beams moment of inertia will be same. Section modulus for first beam $Z_1 = \frac{2I}{a}$ (a = side of cross-section)

Section modulus for second beam,

$$Z_2 = \frac{\sqrt{2}I}{a}$$

$$\therefore \quad \frac{Z_1}{Z_2} = \sqrt{2}$$

6.16 (d)



For a beam of uniform strength

BM at distance x = Moment of resistance of beam

$$\frac{W}{2}x = \sigma Z$$

$$\frac{W}{2}x = \frac{fbd^2}{6}$$

$$d = \sqrt{\frac{3Wx}{fb}}$$

6.17 (c)

The diagonal is $B\sqrt{2}$. The location of maximum shear stress from neutral axis is $\frac{1}{8}$ length of diagonal i.e. $\frac{B}{4\sqrt{2}}$.

6.18 (b)

Two beams placed one over the other will bend about their respective geometrical axes. The total moment of resistance will be equal to the sum of moments of resistance of individual sections. In analyzing such cases, the assumption of plane section remain plane after bending is valid.

6.19 (b)

For strongest beam, the section modulus should be maximum.

$$\text{Breadth of beam} = \frac{D}{\sqrt{3}}$$

$$\text{Depth of beam} = \sqrt{\frac{2}{3}}D$$

$$\text{Section modulus} = \frac{D^3}{9\sqrt{3}}$$

$$\text{Moment of inertia} = \frac{D^4}{27\sqrt{2}}$$

6.20 (b)

For pure bending,

$$\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$$

$$y = \frac{0.5}{2} = 0.25 \text{ mm}$$

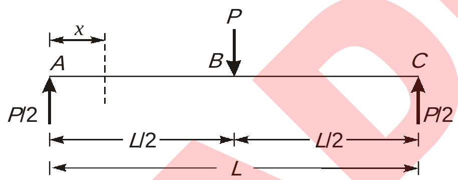
$$R = \frac{500}{2} = 250 \text{ mm}$$

$$\therefore \quad f = \frac{200 \times 0.25 \times 10^3}{250} = 200 \text{ MPa}$$

6.21 (a)

The moment capacity contributed by timber remains same in both cases. In the first case the steel plates are away from neutral axis (NA) so their contribution is more while in the second case the plate are vertical and their contribution is less. So $MR_1 > MR_2$.

6.22 (a)



Bending moment at a distance x (<L/2) from end,

$$M_x = \frac{p}{2}x$$

For a beam of uniform strength

BM at distance x = Moment of resistance of beam

$$\frac{p}{2}x = \sigma\frac{bd_x^2}{6}$$

$$d_x \propto x^{1/2}$$

6.23 (b)

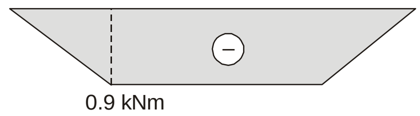
Using Bending Formula, $\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$

$$M = \frac{2 \times 10^5 \times \left(\frac{120 \times 10^3}{12}\right)}{10{,}000}$$

$$= 2 \times 10^5 \text{ N-mm}$$

6.24 (b)

BMD of beam



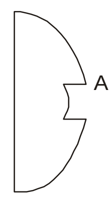
Upper fibers of the beam will be under tension since the maximum *BM* of 0.9 kN-m is hogging in nature. The maximum tensile stress

$$f = \frac{My_1}{I_{xx}} = \frac{0.9 \times 10^6 \times 70}{3 \times 10^6}$$

$$= \frac{9 \times 7}{3} = 21 \text{ N/mm}^2 = 21 \text{ MN/m}^2$$

6.25 (a)

In question figure Shear stress at point A is suddenly reduced. It shows sudden increase in width at point A, which is depicted by option (a)



6.26 (a)

For the same value of bending stress in timber, moment capacity of timber is same in both cases. In figure-I steel plates are away from the NA so more stress is generated in steel plates due to more strain. As they are away so lever arm is also large. Hence moment of resistance is more in figure-I.

6.27 (c)

The moment of inertia of timber beam equivalent is given $I_{xx} = 1250 \times 10^4$ mm^4

Stress at y = 20 mm

$$\sigma_{20} = \frac{1000 \times 10^3 \times 20}{1250 \times 10^4}$$

$$= 1.6 \text{ N/mm}^2 \text{ (Compressive)}$$

Stress at lower level of steel,

$$\sigma_s = m\sigma_{20} = 1.6 \times 20 = 32 \text{ N/mm}^2$$

Stress at lower level of timber at y = 80 mm

$$\sigma_t = \frac{1000 \times 10^3 \times 80}{1250 \times 10^4} = 6.4 \text{ N/mm}^2$$

Stress in timber is tensile. So it is positive.

7. Thick & Thin Cylinders and Spheres

7.1 (b)

Variation of hoop stress (f_x) and radial pressure (p_x) can be obtained by using Lame's equation i.e.

$$f_r - p_r = 2A$$

and $f_r + p_r + r\dfrac{d\,p_r}{dr} = 0$

$$\therefore \quad f_r = \frac{B}{r^2} + A, \qquad p_r = \frac{B}{r^2} - A$$

at $r = D_i$ we get $p_r = p$

$r = D_o$ we get $p_r = 0$

$$\therefore \quad p_r = p\left(\frac{D_0^2 - 4r^2}{D_0^2 - D_1^2}\right)\left(\frac{D_1^2}{4r^2}\right)$$

Radial pressure distribution is given by figure (b).

7.2 (d)

Hoop stress is more than longitudinal stress.

Hoop stress $= \dfrac{pd}{2t}$ = ultimate strength

Given, $d =$ 6 cm, t = 3 mm = 0.3 cm

$$\therefore \quad p = \frac{3600 \times 2 \times 0.3}{6} = 360 \text{ kg/cm}^2$$

7.3 (b)

Hoop stress for cylindrical shell $= \dfrac{pd}{2t}$

Hoop stress for spherical shell $= \dfrac{pd}{4t}$

So the ratio of hoop stress in the cylindrical to that of spherical shell is 2.

7.4 (a)

$$\frac{\text{Change in diameter}}{\text{Original diameter}} = \frac{\Delta D}{D}$$

$$= \frac{1}{E}[\sigma_1 - \mu\sigma_2]$$

$$= \frac{1}{E}\left[\frac{pD}{2t} - \frac{\mu pD}{4t}\right] = \frac{pD}{4tE}(2-\mu)$$

$$\therefore \Delta D = \frac{pD^2}{4tE}(2-\mu)$$

7.5 (b)

Hoop stress $= \dfrac{pd}{2t}$ = 20 MPa

$p =$ 200 m head of water

= 200 kPa = 2 MPa

$$\therefore \quad t = \frac{2 \times 1}{20 \times 2} = 0.05 \text{ m} = 50 \text{ mm}$$

7.6 (d)

The inner wall is subjected to radial pressure, and hoop stress only.

The stress on the outer wall element has hoop stress only and radial stress is zero.

8. Torsion in Shafts & Springs

8.1 (d)

Equivalent bending moment $= \dfrac{M + \sqrt{M^2 + T^2}}{2}$

Equivalent torsion $= \sqrt{M^2 + T^2}$

8.2 (d)

$$f_s = \frac{16}{\pi d^3}T$$

$$\therefore \quad d = \sqrt[3]{\frac{16T}{\pi f_s}}$$

8.3 (a)

For series combination of springs,

$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$$

$$\therefore \quad k = \frac{k_1 \times k_2}{k_1 + k_2}$$

8.4 (a)

Maximum bending stress, $\sigma_b = \dfrac{32M}{\pi d^3}$

Maximum shear stress, $\tau = \dfrac{16T}{\pi d^3}$

$$\frac{\sigma_b}{\tau} = \frac{2M}{T}$$

8.5 (d)

For series connection,

$$k_e = \frac{k \times 2k}{k + 2k} = \frac{2}{3}k$$

For parallel connection,

$$k_e' = k + 2k = 3k$$

$$\therefore \quad \frac{k_e}{k_e'} = \frac{2k/3}{3k} = \frac{2}{9}$$

8.6 (d)

Principal stresses,

$$\sigma_1/\sigma_2 = \frac{16}{\pi D^3}\left[M \pm \sqrt{M^2+T^2}\right]$$

Maximum principal stress is obtained by choosing '+' sign and minimum principal stress is obtained by '–' sign.

8.7 (a)

Maximum stress due to bending moment

$$\sigma_1 = \frac{32M}{\pi d^3}$$

Maximum shear stress due to torsion T

$$\tau = \frac{16T}{\pi d^3}$$

Maximum normal stress due to combined action of bending moment and torque

$$\sigma_{max} = \frac{\sigma_1}{2} + \sqrt{\left(\frac{\sigma_1}{2}\right)^2 + \tau^2}$$

$$= \frac{16}{\pi d^3}\left[M + \sqrt{M^2+\tau^2}\right]$$

According to maximum principal stress theory, for no failure

$$\sigma_{max} \le \text{Allowable stress}$$

$$d^3 \le \frac{16}{\pi\sigma}\left[M + \sqrt{(M)^2+\tau^2}\right]$$

8.8 (b)

Torsion formula is given as

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$$

Power = Torque × Rotational speed = $T\omega$

When diameter is doubled, the torque carrying capacity becomes 8 times the original. So power also increases 8 times.

8.10 (d)

Strain energy, $U = \frac{1}{2}T\theta$

and $\theta = \frac{TL}{GJ}$

$$\therefore \quad U = \frac{T^2L}{2GJ}$$

$$J = \frac{\pi d^4}{32}$$

$$\therefore \quad \frac{U_1}{U_2} = \left(\frac{d_2}{d_1}\right)^4$$

8.12 (c)

Angular twist in a spring is

$$\theta = \frac{32\,WRL}{\pi d^4 G}$$

where

d is diameter of wire of spring

G is modulus of rigidity

W is axial pull on spring

R is mean radius of coil

L is Length of spring

$$\therefore \quad \frac{\theta_2}{\theta_1} = \frac{W_2}{W_1} \times \frac{L_2}{L_1}$$

$$= \frac{W/2}{W} \times \frac{L/2}{L} = \frac{1}{4}$$

8.13 (c)

Power, $P = T\omega = 1500 \times \frac{2\pi \times 150}{60}$

$$= 7500\pi\ W = 7.5\pi\ \text{kW}$$

8.14 (c)

Polar modulus is also called polar section modulus or torsional section modulus.

$$\frac{I_P}{R} = \text{Polar modulus}$$

$$\therefore \quad \frac{I_{P_1}}{R_1} = \frac{I_{P_2}}{R_2}$$

$$\Rightarrow \frac{(\pi/32) \times (D_o^4 - D_i^4)}{D_o/2} = \frac{(\pi/32) \times D^4}{D/2}$$

$$\Rightarrow D_o^3\left[1 - \left(\frac{D_i}{D_o}\right)^4\right] = D^3$$

$$\Rightarrow 100^3\left[1 - \left(\frac{50}{100}\right)^4\right] = D^3$$

$$\Rightarrow D = 100\ \sqrt[3]{0.9375}$$

$$\Rightarrow D = 10\sqrt[3]{\frac{9375}{10}}$$

8.15 (b)

$$\frac{\theta_2}{\theta_1} = \frac{W_2L_2}{W_1L_1} = \frac{1}{4}$$

8.16 (b)

Maximum stress due to bending moment

$$\sigma = \frac{32M}{\pi d^3}$$

Maximum shear stress due to torsion T

$$\tau = \frac{16t}{\pi d^3}$$

Maximum normal stress due to combined action of bending moment and torque

$$\sigma_1, \sigma_3 = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \frac{16}{\pi d^3}\left[M \pm \sqrt{M^2 + \tau^2}\right]$$

9. Theoray of Columns and Retaining Walls

9.1 (d)

In order for Euler's formula to be applicable the critical stress must not exceed the proportional limit.

Now crushing stress in mild steel

$$= 3300\ \text{kg/cm}^2 = 330\ \text{N/mm}^2$$

But stress at proportional limit in mild steel

$$= 250\ \text{N/mm}^2$$

$$\text{Euler's buckling stress} = \frac{\pi^2 E}{\lambda^2}$$

$$\Rightarrow \quad 250 = \frac{\pi^2 \times 2 \times 10^5}{\lambda^2}$$

$$\Rightarrow \quad \lambda = 88.55 \approx 89$$

Thus slenderness ratio should be more than or equal to 89 ideally. Option (d) is the most close one.

9.2 (a)

For solid circular section, the maximum eccentricity for no tension is d/8.

$$\text{The stress} \quad \sigma_{c,t} = \frac{4P}{\pi d^2}\left[1 \pm \frac{8e}{d}\right]$$

for $\quad e = \dfrac{d}{4}$

$$\frac{\sigma_c}{\sigma_t} = \frac{\left(1 + \frac{8e}{d}\right)}{\left(1 - \frac{8e}{d}\right)} = \frac{3}{(-1)}$$

The minus sign is due to opposite nature of forces.

9.3 (b)

For no tensile stress to develop;

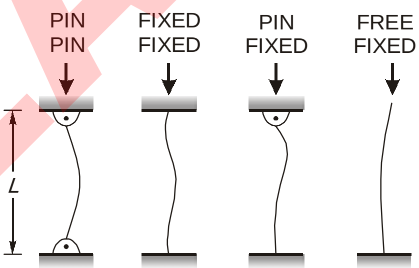
(i) For dead storage or empty condition

$$e = \frac{b}{6} \text{ for any } \frac{h}{b} \text{ ratio}$$

(ii) For full storage condition

$$e = \frac{b}{6} \text{ when } \frac{h}{b} = \sqrt{S}$$

9.4 (d)



Buckling Load	$\dfrac{\pi^2 EI}{L^2}$	$\dfrac{4\pi^2 EI}{L^2}$	$\dfrac{2\pi^2 EI}{L^2}$	$\dfrac{\pi^2 EI}{4L^2}$

9.5 (c)

Since the footing is rectangular and the load is eccentric about both X and Y axes respectively, the stresses at A and D are not equal.

The stress developed at point C is the combination of compressive stress due to load P, tensile stress due to eccentricity about X and Y axis respectively. So the final stress is compressive or not will depend upon the magnitude of tensile stresses. In exact terms we cannot say that the final stress at C is compressive however, option (c) is the most close among all the options.

9.6 (c)

Let area of column at the bottom be A_0.

$$\therefore \quad A = A_0\, e^{\rho H/p_0}$$

$$A_0 = A\, e^{-\rho H/p_0}$$

Also option (c) is the dimensionally correct one.

9.7 (c)

Slenderness ratio, $\lambda = \frac{l}{r}$

where r is the radius of gyration.

$$r = \frac{d}{4}$$

$$\therefore \quad \frac{l}{d} = \frac{160}{4} = 40$$

9.8 (b)

$$e_{max} = \frac{d^2 + D^2}{8D} = \frac{d^2 + (1.5d)^2}{8 \times 1.5d}$$

$$= \frac{3.25d^2}{12d} = \frac{13d}{48}$$

9.9 (b)

Kern is the region in which load can act but it does not produce tension anywhere in the cross-section.

Section	Kern
Rectangular	Rhombus
I-section	Rhombus
Hollow circular	Circle
Square	Square

9.10 (d)

Eddy's theorem is related to arches. It says that the BM at any section of an arch is proportional to the ordinate between the given arch and the linear arch.

9.11 (d)

The buckling load varies inversely with the square of effective length i.e.

$$P = \frac{\pi^2 EI}{l_e^2}$$

9.12 (b)

Moment about X-X axis = Py

Moment about Y-Y axis = Px

$$\therefore \text{ Stress at } A = \frac{P}{A} + \frac{Py}{I_{xx}}y_1 - \frac{Px}{I_{yy}}y_2$$

$$\text{Stress at } B = \frac{P}{A} + \frac{Py}{I_{xx}}y_1 + \frac{Px}{I_{yy}}y_2$$

$$\text{Stress at } C = \frac{P}{A} - \frac{Py}{I_{xx}}y_1 + \frac{Px}{I_{yy}}y_2$$

$$\text{Stress at } D = \frac{P}{A} - \frac{Py}{I_{xx}}y_1 - \frac{Px}{I_{yy}}y_2$$

9.13 (c)

For no tension, $\sigma_{min} \le 0$

$$\frac{P}{A} - \frac{My}{I} \le 0$$

$$\frac{W}{\frac{\pi}{4}\left(D_1^2 - D_2^2\right)} - \frac{We\frac{D_1}{2}}{\frac{\pi}{64}\left(D_1^4 - D_2^4\right)} \le 0$$

$$e \le \frac{\left(D_1^2 + D_2^2\right)}{8D_1}$$

9.14 (c)

Mean value of intensity of stress

$$= \frac{1000}{20 \times 10} = 5 \text{ N/mm}^2$$

Maximum value of intensity of stress

$$= 5\left[1 + \frac{6e}{d}\right] = 5\left[1 + \frac{6 \times 1}{10}\right]$$

$$= 8 \text{ N/mm}^2$$

% increase in stress

$$= \left(\frac{8-5}{5}\right) \times 100 = 60\%$$

9.15 (a)

Stress at any point

$$= \frac{P}{bd} + \frac{Pe_y \times y}{I_{xx}} + \frac{Pe_x \times x}{I_{yy}}$$

$$= \frac{P}{bd}\left[1 + \frac{12e_y \times y}{d^2} + \frac{12e_x \times x}{b^2}\right]$$

9.16 (b)

Assuming compressive stress as positive and tensile stress as negative.

Corner A and B will be in compression, whereas corner C and D will be in tension due to the eccentricity about XX-axis respectively. Corner A and D will be in compression whereas corner B and C will be in tension due to eccentricity about YY-axis respectively.

Point	Resultant stress (N/mm^2)
A	18 + 10 + 15 = 43
B	18 + 10 – 15 = 13
C	18 – 10 – 15 = – 7
D	18 – 10 + 15 = 23

9.17 (b)

The uniform compressive stress throughout the base due to load P is cancelled at one end due to moment and increased at other end due to some moment. So stress intensity at one end is zero and compressive at the other end with linear variation

9.18 (b)

For intermediate columns, the effect of both crushing and buckling is to be considered as none of these alone gives the satisfactory results.

Load by Rankine's formula is given as,

$$\frac{1}{P_R} = \frac{1}{P_e} + \frac{1}{P_c}$$

where, P_R is Rankine's load

P_c is crushing load and

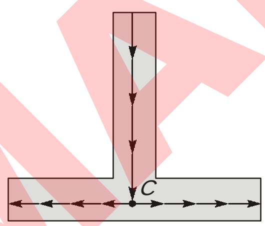
P_e is buckling load

So, Rankine's load considers the effect of both crushing and buckling, hence used for intermediate columns.

10. Shear Centre, Moment of Inertia & Principal Axes

10.1 (b)

The shear flow in the section is as shown in the figure.



The shear centre is the point about which the moment of the shear flows in all segments should be zero. So shear centre will lie at the intersection point of two axes.

10.2 (c)

For two axes of symmetry, the shear centre will coincide with the centroid.

10.3 (a)

Shear centre : The load at this point does not cause twisting.

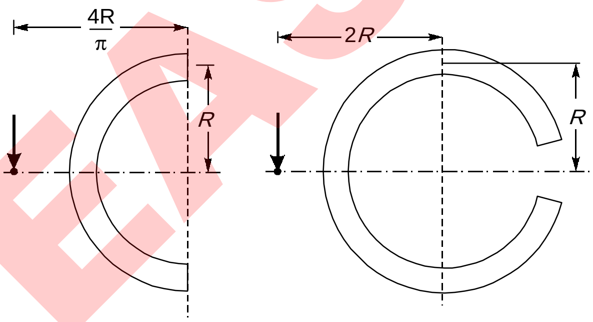
Principal plane : There is no shear stress on this plane.

Fixed end : It has zero slope

Middle third rule can be used to apply load such that there is no tension on a rectangular cross-section.

10.5 (c)

For semi circular arc the shear centre is at $\frac{4r}{\pi}$ from centre of the arc. In the case of circular tube made open by means of a cut the shear centre lies at a distance $2r$ from the centre of the circle.



10.6 (c)

$$e = \frac{b^2h^2t}{4I}$$

10.7 (c)

Shear centre coincides with Centre of gravity of open section only when section is doubly symmetric. If beam is singly symmetric then both shear centre and centroid lie on axis of symmetry but don't coincide each other.

11. Miscellaneous

11.1 (d)

$$F_3 \cos 45° = F_2 \quad \Rightarrow F_3 = 20\sqrt{2}\text{ kN}$$

$$F_3 \sin 45° = F_1 \quad \Rightarrow F_3 = 10\sqrt{2}\text{ kN}$$

Therefore the forces will not be in equilibrium for any value of F_3.

For equilibrium $F_3 = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

$$= 10\sqrt{5}\text{ kN}$$

F_3 should be at an angle $\tan\theta = \frac{1}{2}$ from horizontal.

11.2 (a)

The force R should be opposite to the resultant of $\vec{P}_1$ and $\vec{P}_2$.

Resultant of $\vec{P}_1$ and $\vec{P}_2 = \vec{P}_1 + \vec{P}_2$

$$\therefore \quad R = -\vec{P}_1 - \vec{P}_2$$

In other words, $\vec{R} + \vec{P}_1 + \vec{P}_2 = 0$. i.e. $\vec{R}, \vec{P}_1$ and $\vec{P}_2$ should form a closed triangle

11.4 (c)

First draw space diagram showing the system, point of application and line of action of the forces. Now force polygon can be drawn. Further polar diagram and funicular polygon can be drawn. Thus correct sequence is given in (c).

11.5 (b)

Equilibrium should close the force polygon. So (b) is the correct answer.

11.6 (a)

In the tensile test of specimen, the total elongation comprises -(i) uniform extension and (ii) local extension due to necking or waisting.

Uniform extension is proportional to gauge length and local extension is proportional to $\sqrt{A_o}$ i.e., independent of gauge length.

Total extension $D_T = aL_o + b\sqrt{A_o}$ [Unwin's formula]

Therefore it is necessary to specify gauge length.

$$L_o = 5.65\sqrt{A_o}$$

11.7 (a)

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

for $R = Q = P$

$$P^2 = 2P^2 + 2P^2\cos\theta$$

$$\Rightarrow \quad \cos\theta = -\frac{1}{2}$$

$$\therefore \quad \theta = 120^\circ$$

11.8 (b)

For a system to be in equilibrium force polygon and funicular polygon must close. If force polygon does not close then the forces will reduce to a resultant force. If funicular polygon does not close, then there is resultant moment on the system.

11.10 (d)

The forces are not concurrent so the resultant force and couple both may be present. Thus the best choice is that forces are not in equilibrium.

■■■■

UNIT

III

Structural Analysis

Syllabus

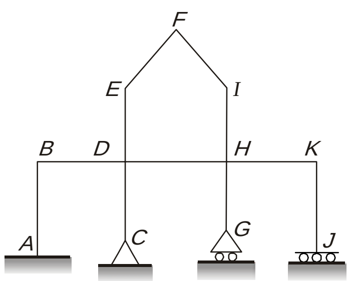
Basics of strength of materials, Types of stresses and strains, Bending moments and shear force, concept of bending and shear stresses; Analysis of determinate and indeterminate structures; Trusses, beams, plane frames; Rolling loads, Influence Lines, Unit load method & other methods; Free and Forced vibrations of single degree and multi degree freedom system; Suspended Cables; Concepts and use of Computer Aided Design.

Contents

3 Structural Analysis

1. Determinacy and Indeterminacy

1.1 Neglecting axial deformation, the kinematic indeterminacy of the structure shown in the figure below is



(a) 12 (b) 14
(c) 20 (d) 22

[ESE : 1998]

1.2 Match **List-I** (Type of structure) with **List-II** (Static indeterminacy) and select the correct answer using the codes given below the lists:
Number of members = m
Number of joints = n
Number of reaction elements = r

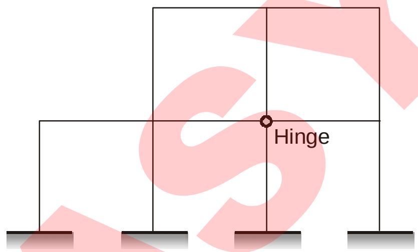
List-I		List-II	
A.	Plane frame	1.	$m + r - 3n$
B.	Space truss	2.	$6m + r - 6n$
C.	Space frame	3.	$6m + r - 3n$
		4.	$3m + r - 3n$

Codes:

	A	B	C
(a)	1	2	3
(b)	4	3	2
(c)	2	1	3
(d)	4	1	2

[ESE : 1999]

1.3 Total degree of indeterminacy (both internal and external) of the plane frame shown in the given figure is

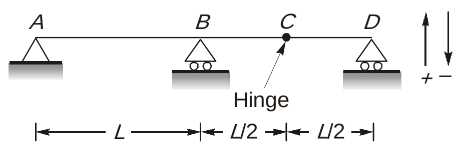


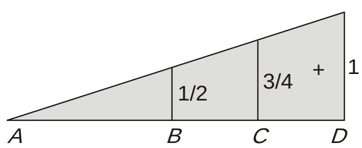
(a) 10 (b) 11
(c) 12 (d) 15

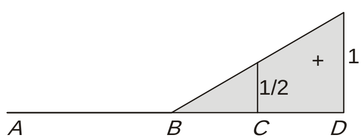
[ESE : 1999]

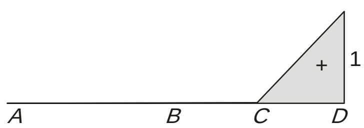
2. Influence Line Diagram and Rolling Loads

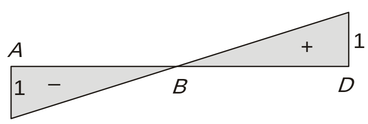
2.1 For the continuous beam shown in figure, the influence line diagram for support reaction at D is best represented as



(a)


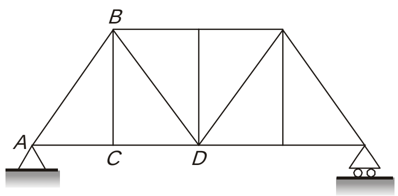
(b)


(c)


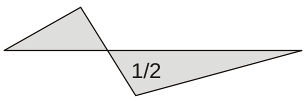
(d)


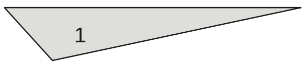
[ESE : 1995]

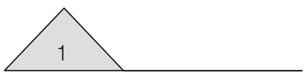
2.2 The given figure shows a portal truss:

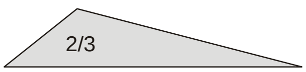


The influence line for force in member *BC* will be

(a) 

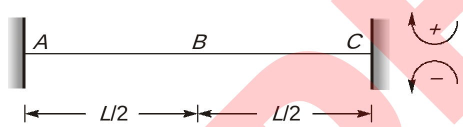
(b) 

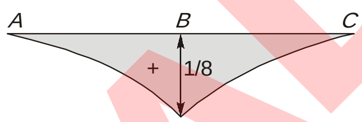
(c) 

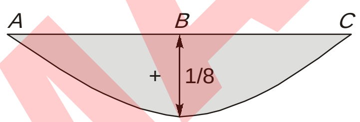
(d) 

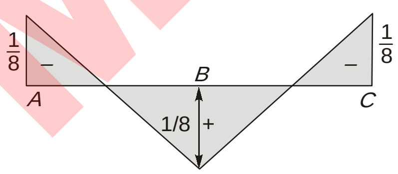
[ESE : 1995]

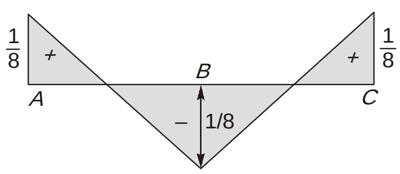
2.3 For the fixed beam shown in the figure, the influence line diagram for the bending moment at the mid-span of the beam is best represented as



(a) 

(b) 

(c) 

(d) 

[ESE : 1995]

2.4 **Assertion (A):** Whether it is maximum BM at a section or absolute maximum BM, the moving UDL should cover the entire span of a simple beam if span is less than load length.

Reason (R): Whether it is maximum BM at a section or absolute maximum BM, the moving UDL should be divided by the section in the same ratio in which the section divides the span, if the span is greater than load length.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

2.5 The maximum bending moment at the left quarter point of a simple beam due to crossing of UDL of length shorter than the span in the direction left to right, would occur after the load had just crossed the section by

(a) one-fourth of its length
(b) half of its length
(c) three-fourth of its length
(d) its full length

[ESE : 1997]

2.6 When a load crosses a through type Pratt truss in the direction left to right, the nature of force in any diagonal member in the left half of the span would

(a) change from compression to tension
(b) change from tension to compression
(c) always be compression
(d) always be tension

[ESE : 1997]

2.7 The influence line R_c for the beam shown in figure-I will be as in

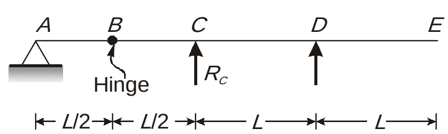
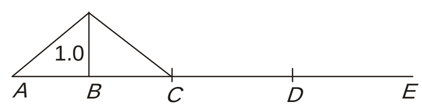
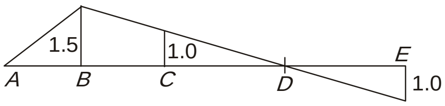
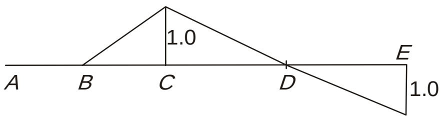
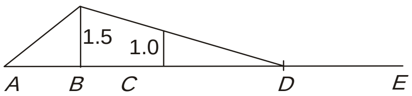


Figure-I

(a) 

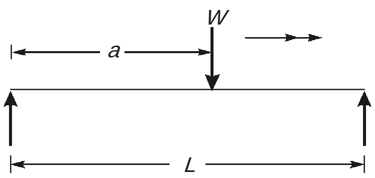
(b) 

(c) 

(d) 

[ESE : 1998]

2.8 **Assertion (A):** When a single load crosses a simple span of any length, the shear force under the loads to the right for all spans is constant, so long as the load maintains the same a/L ratio (see given figure)



Reason (R): When the load maintains the same a/L ratio in all spans, the reaction at the right hand support remains the same.

[ESE : 1998]

2.9 For beam shown in figure-I, an influence line diagram is shown in figure-II. This refers to

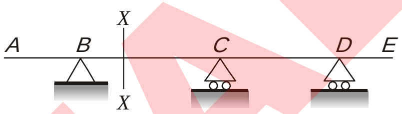


Figure-I

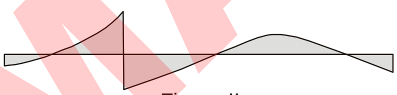


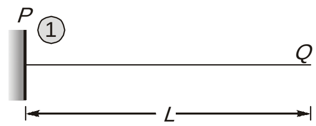
Figure-II

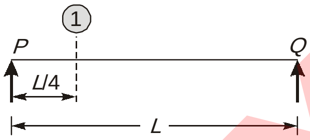
(a) reaction R_A
(b) shear force at support D
(c) BM at support B
(d) shear force at section XX

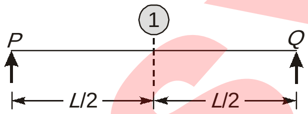
[ESE : 1999]

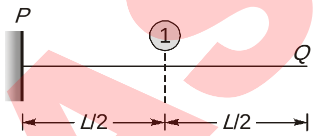
2.10 Match **List-I** (Beam) with **List-II** (Influence line for BM) and select the correct answer using the codes given below the lists:

List-I

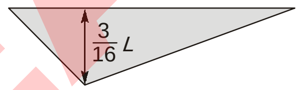
A. 

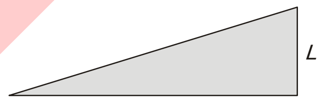
B. 

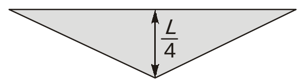
C. 

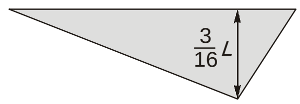
D. 

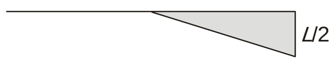
List-II

1. 

2. 

3. 

4. 

5. 

Codes:

	A	B	C	D
(a)	2	1	3	5
(b)	3	1	4	5
(c)	2	5	3	4
(d)	1	3	5	4

[ESE : 1999]

3. Arches and Suspension Bridges

3.1 A three-hinged parabolic arch rib of span L and crown rise 'h' carries a uniformly distributed superimposed load of intensity 'w' per unit length. The hinges are located on two abutments at the same level and the third hinge at a quarter span location from left hand abutment. The horizontal thrust on the abutment is

(a) $\frac{wL^2}{4h}$ (b) $\frac{wL^2}{6h}$

(c) $\frac{wL^2}{8h}$ (d) $\frac{wL^2}{12h}$

[ESE : 1995]

3.2 A two-hinged semicircular arch of radius R carries a concentrated load W at the crown. The horizontal thrust is

(a) $\frac{W}{2\pi}$ (b) $\frac{W}{\pi}$

(c) $\frac{2W}{3\pi}$ (d) $\frac{4W}{3\pi}$

[ESE : 1996]

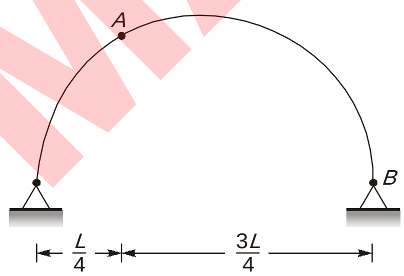
3.3 **Assertion (A):** The BM due to any load at all sections of an arch, is less than the BM at all sections of a simple beam having the same span of arch under the same load.

Reason (R): The moment due to horizontal thrust of the arch is hogging.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

3.4 For the semicircular two-hinged arch shown in the figure below, a moment of 50 t cm applied at B produces a displacement of 0.5 cm at A. If a concentrated load of 10 t is applied at A, the rotation at B in the arch will be



(a) 0.1 (b) 0.001
(c) 0.0001 (d) 0.01

[ESE : 1997]

3.5 A three-hinged semicircular arch of radius R carries a uniformly distributed load w per unit run over the whole span. The horizontal thrust is

(a) wR (b) $\frac{wR}{2}$

(c) $\frac{4wR}{3\pi}$ (d) $\frac{2wR}{3\pi}$

[ESE : 1997]

3.6 **Assertion (A):** In a parabolic symmetrical three hinged arch the bending moment at any section due to dead load is zero.

Reason (R): In influence line diagram for moment at a section of an arch, the simply supported moment diagram and 'H_{xy}' diagram have equal areas.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

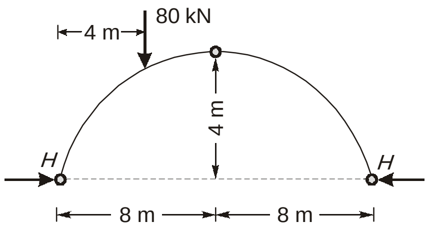
[ESE : 1997]

3.7 A circular three-pinned arch of span 40 m and a rise of 8 m is hinged at the crown and springings. It carries a horizontal load of 100 kN per vertical metre on the left side. The horizontal thrust at the right springing will be

(a) 200 kN (b) 400 kN
(c) 600 kN (d) 800 kN

[ESE : 1998]

3.8 The three-hinged arch shown in the given figure will have value of H as

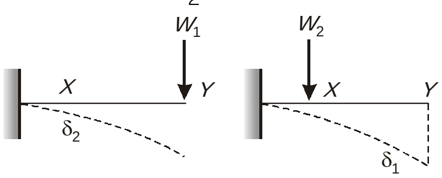


(a) 20 kN (b) 30 kN
(c) 40 kN (d) 50 kN

[ESE : 1999]

4. Methods of Structural Analysis

4.1 In the cantilever beam shown in the given figure, δ_2 is the deflection under X due to load W_1 at Y and δ_1 is the deflection under Y due to load W_2 at X. The ratio of $\frac{\delta_1}{\delta_2}$ is

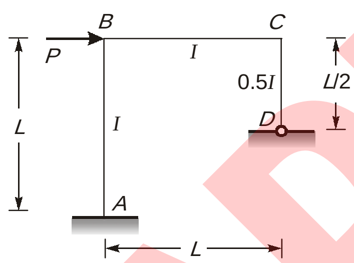


(a) $\frac{W_1}{W_2}$ (b) $\frac{W_2}{W_1+W_2}$

(c) $\frac{W_2}{W_1}$ (d) $\frac{W_1}{W_1+W_2}$

[ESE : 1995]

4.2 The given figure shows a portal frame with one end fixed and other hinged. The ratio of the fixed end moments $\frac{M_{BA}}{M_{CD}}$ due to side sway will be

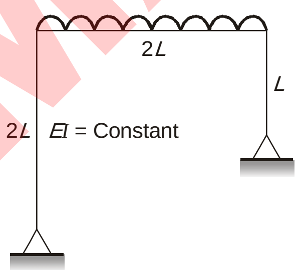


(a) 1.0 (b) 2.0

(c) 2.5 (d) 1.0

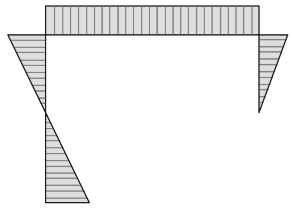
[ESE : 1995]

4.3 The given figure shows a portal frame with loads.

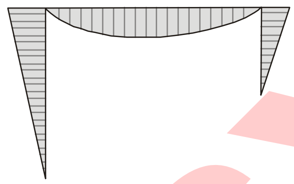


The bending moment diagram for this frame will be

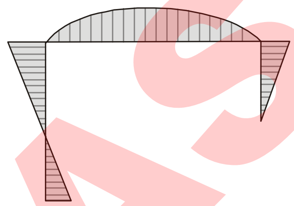
(a)



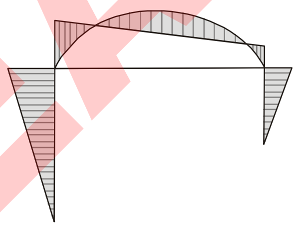
(b)



(c)

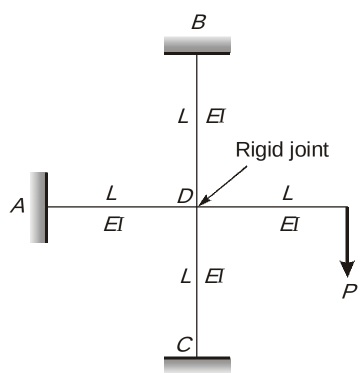


(d)



[ESE : 1995]

4.4 The given figure shows a frame loaded with a single concentrated load *P*. The fixed-end moment developed at support A will be

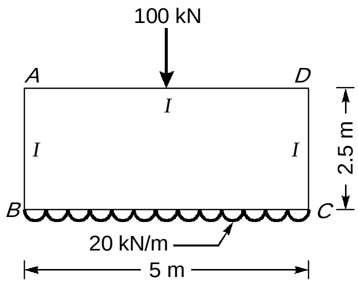


(a) $\frac{PL}{8}$ (b) $\frac{PL}{6}$

(c) $\frac{PL}{4}$ (d) $\frac{PL}{3}$

[ESE : 1995]

4.5 Which one of the following gives the distribution factors for members *AB* and *AD* of box section shown in the given figure?



(a) 0.5 and 0.5 (b) 0.33 and 0.67
(c) 0.67 and 0.33 (d) zero and 1

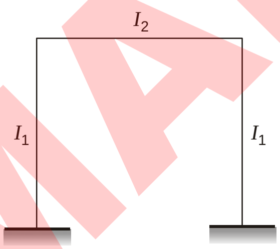
[ESE : 1995]

4.6 **Assertion (A):** The concept of strain energy can be used to analyze a statically indeterminate structure.

Reason (R): There is a direct relationship between strain energy of a structure and the slopes and deflection caused in it.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1995]

4.7 The rigid portal frame shown in the given figure will not have any side sway if



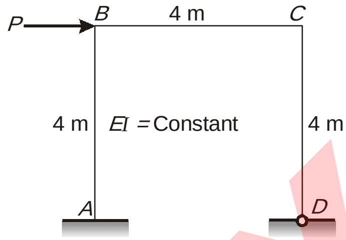
I_1 = the moment of inertia of the column cross-section

I_2 = the moment of inertia of the beam cross-section

(a) it is subjected to vertical loading only
(b) $I_2 = 2I_1$
(c) the loading is symmetrical about its centre line
(d) loaded in any manner

[ESE : 1996]

4.8 For the portal frame shown in the given figure, the shear equation is



(a) $\dfrac{M_{BC}+M_{CB}}{4}+P=0$

(b) $\dfrac{M_{BA}+M_{AB}}{4}+P=0$

(c) $\dfrac{M_{BA}+M_{AB}}{4}+\dfrac{M_{CD}}{4}+P=0$

(d) $\dfrac{M_{CD}}{4}+P=0$

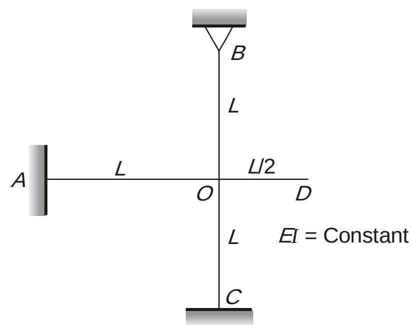
[ESE : 1996]

4.9 Due to some point load anywhere on a fixed beam, the maximum free bending moment is *M*. The sum of fixed end moments is

(a) M (b) 1.5M
(c) 2.0M (d) 3.0M

[ESE : 1996]

4.10 A steel frame is shown in the given figure.



If joint *O* of the frame is rigid, the rotational stiffness of the frame at point *O* is given by

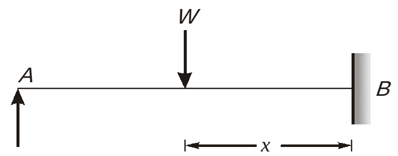
(a) $\dfrac{11EI}{L}$ (b) $\dfrac{10EI}{L}$

(c) $\dfrac{8EI}{L}$ (d) $\dfrac{6EI}{L}$

[ESE : 1996]

4.11 Consider the following statements:
In the beam shown in the given figure, for all positions of load W (except x = 0)

1. bending moment is maximum at B
2. bending moment is maximum under load
3. deflection is zero at A
4. deflection is zero at B



Which of these statements are correct?

(a) 1 and 3 (b) 2 and 4
(c) 1 and 4 (d) 1, 3 and 4

[ESE : 1996]

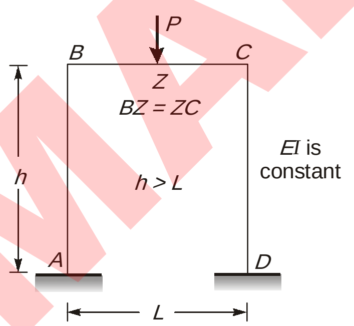
4.12 Assertion (A): In the analysis of rigid frames, the usual practice is to consider the strain energy due to flexure only.

Reason (R): The strain energies due to axial and shear forces are usually quite small compared to that of flexure.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

4.13 A symmetrical portal frame *ABCD* fixed at *A* and *D* carries a point load *P* as shown in the figure below.

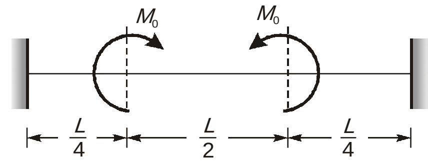


The number of points of contraflexure in the frame will be

(a) one (b) two
(c) three (d) four

[ESE : 1997]

4.14 A fixed beam is subjected to moment M_0 as shown in the figure below. The fixed end moments will be



(a) zero (b) M_0
(c) $M_0/2$ (d) $2M_0$

[ESE : 1997]

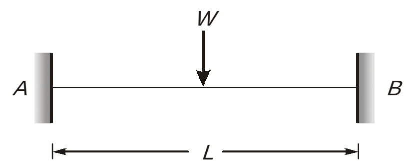
4.15 A fixed beam of uniform section is carrying a point load at its midspan. If the moment of inertia of the middle half length is now reduced to half its previous value, then the fixed end moments will

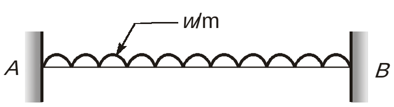
(a) increase
(b) decrease
(c) remain constant
(d) change their directions

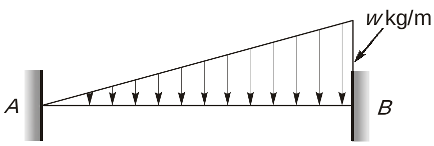
[ESE : 1997]

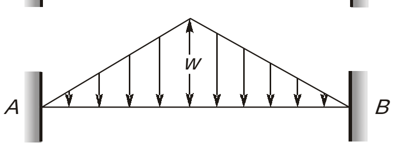
4.16 Match **List-I** (Fixed beam and various types of loading) with **List-II** (The moments at *A*) and select the correct answer using the codes given below the lists:

List-I

A. 

B. 

C. 

D. 

List-II

1. $\frac{5WL}{48}$ 2. $\frac{WL}{15}$

3. $\frac{WL}{12}$ 4. $\frac{WL}{8}$

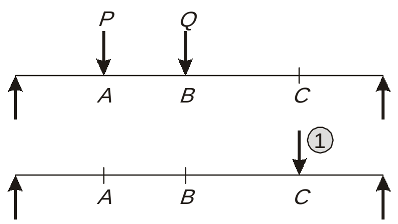
Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	1	2

(c) 4 3 2 1
(d) 3 4 2 1

[ESE : 1998]

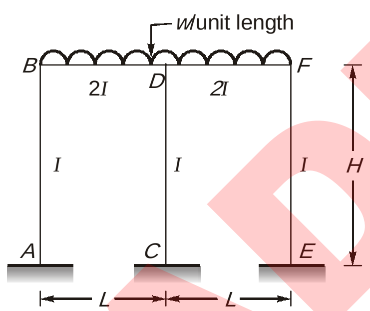
4.17 In the figures shown below x, y and z are the deflections under A, B and C due to loads P and Q. x', y' and z' are the deflection under A, B and C due to unit load at C. The deflection z would equal to



(a) $Px + Qy$ (b) $Px' + Qy'$
(c) $Py + Qx$ (d) $Py' + Qx'$

[ESE : 1998]

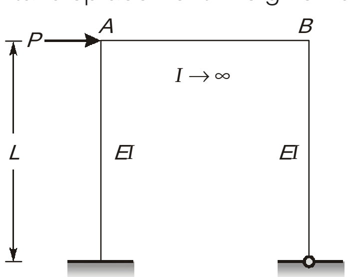
4.18 In the frame shown in the figure below, the value of M_{CD} will be



(a) $\frac{wL^2}{12}$ (b) $\frac{wL^2}{6}$
(c) $\frac{wH^2}{6}$ (d) zero

[ESE : 1998]

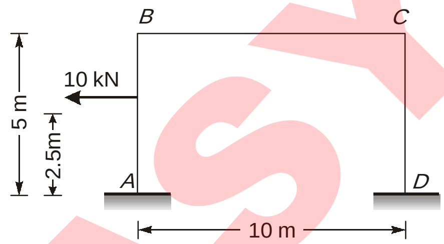
4.19 For the rigid frame shown in the figure below, the force required for moving the girder AB through a horizontal displacement Δ is given by



(a) $\frac{6EI\Delta}{L^3}$ (b) $\frac{8EI\Delta}{L^3}$
(c) $\frac{9EI\Delta}{L^3}$ (d) $\frac{15EI\Delta}{L^3}$

[ESE : 1998]

4.20 For the portal frame shown in the figure below, the final end moments are



M_{AB} = 15 kN-m
M_{BA} = 10 kN-m
M_{CD} = 20 kN-m
The end moment at M_{DC} will be
(a) 10 kN-m (b) 20 kN-m
(c) 30 kN-m (d) 40 kN-m

[ESE : 1998]

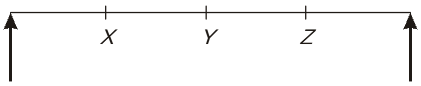
4.21 The moment at the indeterminate support of a two-span continuous beam of 6 m each with simple support at the ends carrying a udl of 20 kN/m over only the left span is (Flexural rigidity is the same for both the spans)
(a) 90 kN-m hogging (b) 45 kN-m hogging
(c) 45 kN-m sagging (d) zero

[ESE : 1998]

4.22 Assertion (A): In a built-in beam the area of fixed moment diagram equals the area of free moment diagram.
Reason (R): The first theorem of area-moment states that if the difference of slope between two points is zero, then the area of bending moment diagram enclosed between these points is also zero.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

4.23 The beam shown in the given figure carries loads of 20 kN and 40 kN at points *X* and *Y* respectively and produces a deflection of 6 mm at point *Z*.



To produce deflections of 8 mm and 5 mm at *X* and *Y* respectively, the load required at *Z* would be

(a) 20 kN (b) 40 kN
(c) 60 kN (d) 80 kN

[ESE : 1999]

4.24 A portal frame is shown in Figure-I. For EI constant, the deflected shape of the frame will be as in

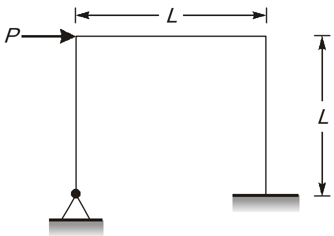
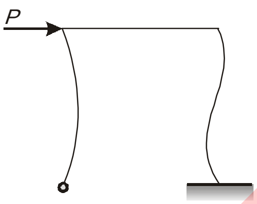
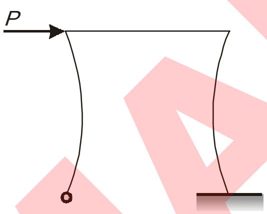
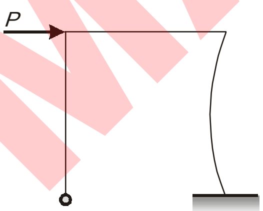
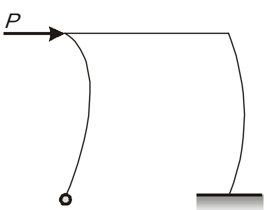


Figure-I

(a)


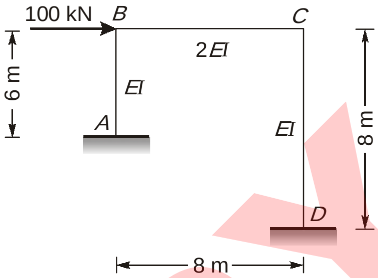
(b)


(c)


(d)


[ESE : 1999]

4.25 The slope-deflection equation at the end *B* of member *BC* for the frame shown in the given figure will be



(a) $M_{BC} = \dfrac{4EI}{8}(2\theta_C - \theta_B)$

(b) $M_{BC} = \dfrac{4EI}{8}(2\theta_B - \theta_C)$

(c) $M_{BC} = \dfrac{4EI}{8}(2\theta_B + \theta_C)$

(d) $M_{BC} = \dfrac{4EI}{8}(2\theta_C + \theta_B)$

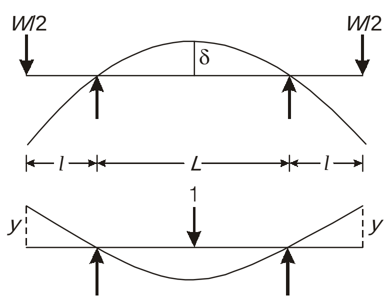
[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.26 Assertion (A): For the two systems of loads applied separately to the beam as shown in the figure below, the equation for the unknown deflection δ using reciprocal theorem is $\delta = Wy$.

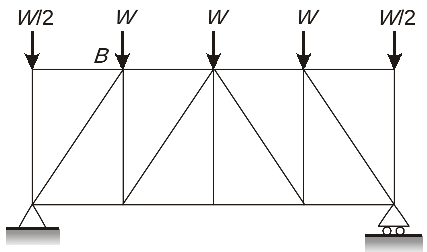


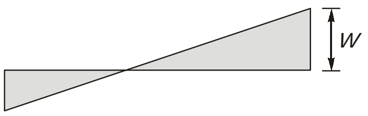
Reason (R): The equation for the unknown deflection δ from influence line diagram for deflection at mid-span is $\delta = Wy$.

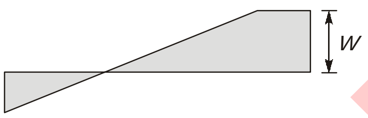
[ESE : 1999]

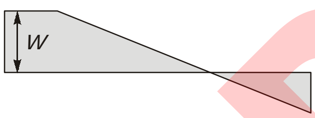
5. Trusses

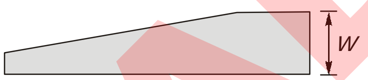
5.1 The correct shape of the force polygon for the joint *B* of the truss shown in the given figure is



(a)


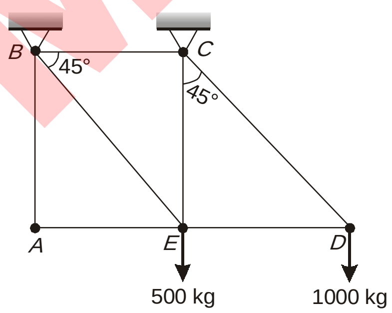
(b)


(c)


(d)


[ESE : 1996]

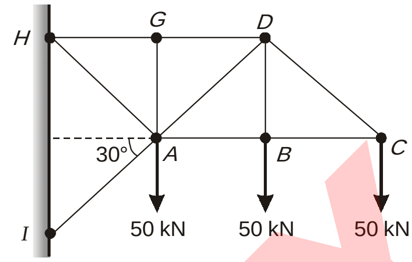
5.2 The cantilever frame shown in the given figure is supported by vertical links at *B* and *C* and carries loads as shown. The force in the bar *AE* is

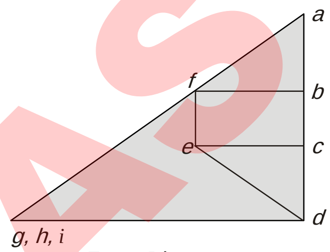


(a) 500 kg (b) 1000 kg
(c) zero (d) 2500 kg

[ESE : 1996]

5.3 In the figure below, force in member *AI* will be





Force Diagram

(a) zero
(b) 150 kN compression
(c) 300 kN compression
(d) 300 kN tension

[ESE : 1997]

5.4 What is the correct sequence of the following steps in the graphical determination of stresses in the members of a loaded plane truss?

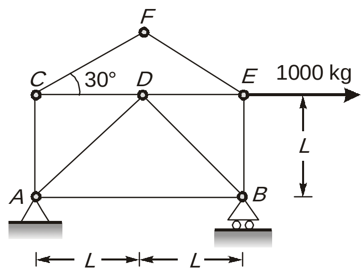
1. Vector diagram to determine the end reactions.
2. Space diagram.
3. Stress diagram.

Select the correct answer using the codes given below:

(a) 1, 2, 3 (b) 1, 3, 2
(c) 2, 1, 3 (d) 2, 3, 1

[ESE : 1997]

5.5 A plane pin-jointed truss is shown in the figure below. The force resisted by the member *AD* is



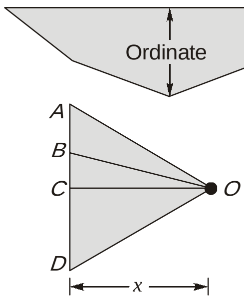
(a) zero

(b) $500\sqrt{2}$ kg (compression)

(c) $500\sqrt{2}$ kg (tension)

(d) $1000\sqrt{2}$ kg (tension) [ESE : 1997]

5.6 The below figures show funicular diagram and polar diagram of a beam subjected to vertical forces 'x' is the distance of the pole from the vector line. If 'x' is doubled, then the ordinate in the funicular diagram will be

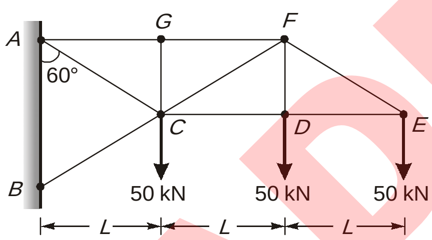


(a) doubled (b) halved

(c) unaffected (d) tripled

[ESE : 1997]

5.7 For the truss shown in the figure, the force in member AC is



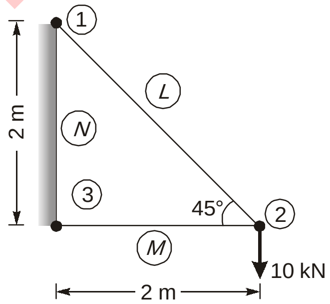
(a) 50 kN compression

(b) 50 kN tension

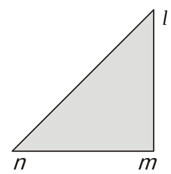
(c) $50\sqrt{\frac{3}{2}}$ kN tension

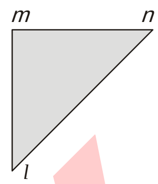
(d) zero [ESE : 1998]

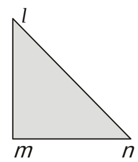
5.8 A cantilever truss with joints labelled as ①, ② and ③ is shown in the given figure. It carries a vertical load of 10 kN at joint ②

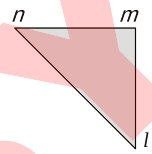


The force diagram drawn at joint ② is represented as

(a) 

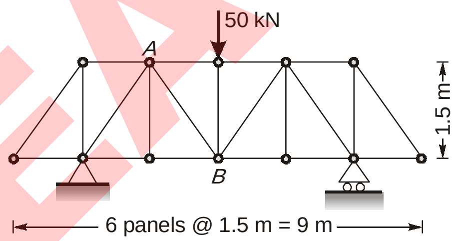
(b) 

(c) 

(d) 

[ESE : 1999]

5.9 The force in the member AB of the truss shown in the given figure is



(a) 25 kN compression

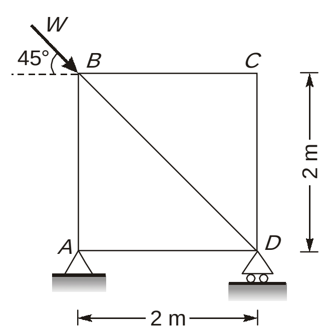
(b) $25\sqrt{2}$ kN tension

(c) $25\sqrt{2}$ kN compression

(d) 25 kN tension

[ESE : 1999]

5.10 Force in the member AB of the frame shown in the given figure will be



(a) zero (b) W

(c) $W\sqrt{2}$ (d) $\frac{W}{\sqrt{2}}$

[ESE : 1999]

Answers Structural Analysis

1.1 (b)	1.2 (d)	1.3 (c)	2.1 (c)	2.2 (c)	2.3 (a)	2.4 (a)	2.5 (c)	2.6 (a)
2.7 (b)	2.8 (a)	2.9 (d)	2.10 (a)	3.1 (c)	3.2 (b)	3.3 (a)	3.4 (a)	3.5 (b)
3.6 (a)	3.7 (a)	3.8 (c)	4.1 (c)	4.2 (a)	4.3 (d)	4.4 (b)	4.5 (c)	4.6 (a)
4.7 (c)	4.8 (c)	4.9 (a)	4.10 (a)	4.11 (d)	4.12 (a)	4.13 (d)	4.14 (c)	4.15 (a)
4.16 (c)	4.17 (b)	4.18 (d)	4.19 (d)	4.20 (b)	4.21 (b)	4.22 (a)	4.23 (c)	4.24 (a)
4.25 (c)	4.26 (a)	5.1 (a)	5.2 (c)	5.3 (c)	5.4 (c)	5.5 (c)	5.6 (b)	5.7 (d)
5.8 (d)	5.9 (b)	5.10 (a)						

Explanations Structural Analysis

1. Determinacy and Indeterminacy

1.1 (b)

Kinematic indeterminacy means degree of freedom of structure at various joints.

No rotation or translation is possible at A so degree of freedom at *A* is zero. There is a possibility of rotation at *C* but no translation so degree of freedom is one. At *G*, both rotation and translation is possible so degree of freedom is 2. At J no rotation but translation so d.o.f. is 1. At *B*, *D*, *H* and *K* there are 4 rotations and one translation so d.o.f. is 5. At *E*, *F* and *I* three rotations and two translations so d.o.f. is 5.

So kinematic indeterminacy

= 0 + 1 + 2 + 1 + 5 + 5 = 14

Alternate:

From direct formula

External reactions $r_e = 3 + 2 + 1 + 2 = 8$

Number of members (m) = 11

Number of rigid joints (j) = 9

Number of hinged joints (j') = 2

There are no internal hinges so number of releases is zero.

$$r_r = 0$$

Degree of kinematic indeterminacy

$$D_K = 3(j + j') - r_e + r_r - m$$
$$= 3 \times (9 + 2) - 8 - 11$$
$$= 33 - 19 = 14$$

1.2 (d)

Type of structure	No. of Unknowns	No. of equations	Degree of indeterminacy
Plane frame	3 m + r	3 n	3 m + r – 3 n
Space truss	m + r	3 n	m + r – 3 n
Space frame	6 m + r	6 n	6 m + r – 6 n

1.3 (c)

The degree of static indeterminacy

$$D_S = r_e + (3\,m - r_r) - 3(j + j')$$

Number of external reactions = r_e

$$= 3 + 3 + 3 + 3 = 12$$

Number of rigid joints,

$$j = 10$$

Number of joints at which releases are located,

$$j' = 1$$

Number of members,

$$m = 12$$

As the hinge is located at a point where 4 members meet. Hence it is equivalent to three hinges. Therefore number of releases, $r_r = 3$.

$$\therefore D_S = 12 + (3 \times 12 - 3) - 3(10 + 1)$$
$$= 12 + 33 - 33 = 12$$

2. Influence Line Diagram and Rolling Loads

2.1 (c)

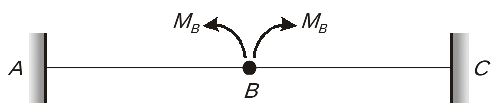
As per Muller Breslau's principle, the *ILD* for support reaction at *D* can be obtained by giving unit displacement in the positive direction of reaction. The deflected shape of beam will represent *ILD* as in figure (*c*)

2.2 (c)

Force in member *BC*, when the load is right of *D*, will be zero. When the load is between *A* and *D*, the tensile force with maximum value of 1 unit will develop. So correct diagram is as shown in figure (c).

2.3 (a)

The *ILD* for *BM* at mid span can be obtained by introducing a pinned connection at mid point and giving unit rotation at that point. The deflected shape of beam will give the *ILD*.



$$\theta_{BA} = \frac{M_B(L/2)}{EI}$$

and $$\theta_{BC} = \frac{M_B(L/2)}{EI}$$

$$\theta_{BA} + \theta_{BC} = 1.0$$

$$M_B = EI$$

Deflection at $B = \dfrac{M_B(L/2)^2}{2EI} = \dfrac{1}{8}$

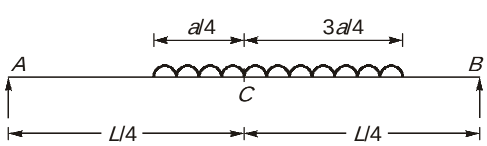
Slope at end *A* and end *C* will be zero. Therefore (a) will be the correct answer.

2.4 (a)

For the maximum BM at a section or absolute maximum BM, the moving UDL should be divided by the section in the same ratio in which the section divides the span. If length of UDL is more than the span, then for the same ratio it will cover the entire span.

2.5 (c)

Section should divide the load in the same ratio as it divides the span for maximum bending moment.



Length of UDL = *a*

Load crossed the section by $\dfrac{3a}{4}$

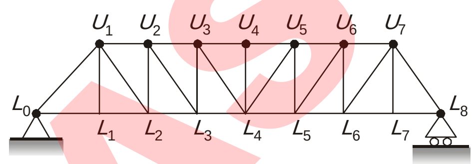
$$\Rightarrow \quad \frac{wa}{4 \times \frac{L}{4}} = \frac{w \times \frac{3}{4} a}{\frac{3L}{4}}$$

$$\Rightarrow \quad \frac{wa}{L} = \frac{wa}{L}$$

So average load on both sideis equal.

2.6 (a)

The figure shows Pratt truss.



When the load is at L_1, the force in U_1L_2 will be compressive and when the load is at L_2 the force in U_1L_2 will be tensile. This will happen for all diagonal members in left half. Reverse will be the case for diagonal members of right half.

2.7 (b)

By giving unit translation in the positive direction of support reaction at R_C, the deformed shape of beam is as shown in figure (b).

2.8 (a)

Reaction at right support = $\dfrac{Wa}{L}$. So shear force on the right for all spans is constant.

2.9 (d)

Since the diagram shows a displacement at *X–X*, so the figure represents *ILD* for shear force at section *X–X*.

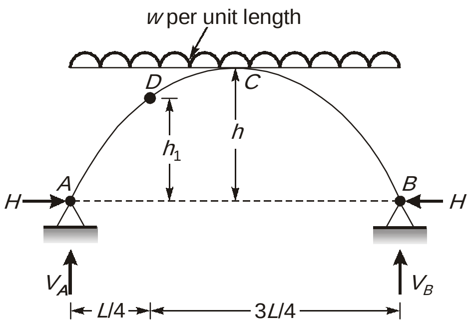
2.10 (a)

Introduce pinned connection at given section and given unit rotation at the section to find the *ILD* for *BM*.

3. Arches and Suspension Bridges

3.1 (c)

$$V_A = V_B = \frac{wL}{2}$$



$$\because \quad \frac{h}{(L/2)^2} = \frac{h-h_1}{(L/4)^2}$$

$$\Rightarrow \quad 4(h-h_1) = h$$

$$3h = 4h_1$$

$$h_1 = \frac{3h}{4}$$

Taking moment about hinge at D = 0

$$\Rightarrow \quad V_A \times \frac{L}{4} - H \times h_1 - \frac{wL}{4} \times \frac{L}{8} = 0$$

$$\Rightarrow \quad \frac{wL}{2} \times \frac{L}{4} - H \times \frac{3h}{4} - \frac{wL^2}{32} = 0$$

$$\therefore \quad H = \frac{wL^2}{8h}$$

3.2 (b)

For two hinged semi-circular arch with load W applied at any section, the radius vector corresponding to which makes an angle θ with the horizontal.

$$H = \frac{W}{\pi}\sin^2\theta$$

With load at crown,

$$\theta = \frac{\pi}{2}$$

So $$H = \frac{W}{\pi}$$

3.3 (a)

Moment in an arch = *BM* in beam − *Hy*

3.4 (a)

From Maxwell-Betti theorem

$$P_A\Delta_{AB} = M_{BA}\,\theta_{BA}$$

$$\therefore \quad \theta_{BA} = \frac{10 \times 0.5}{50} = 0.1 \text{ radians}$$

3.5 (b)

For three-hinged semicircular arch carrying udl of w the vertical reaction at hinges.

$$V_A = V_B = WR$$

So horizontal thrust

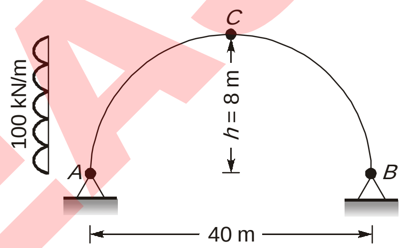
$$\therefore \quad H \times R = V_A \times R - \left(\frac{WR}{2}\right) \times \frac{R}{2}$$

$$H = V_A - \frac{WR}{2} = \frac{WR}{2}$$

3.6 (a)

A three hinged parabolic arch subjected to uniformly distributed load throughout the span, has zero bending moment everywhere because the beam bending moment and bending moment due to horizontal thrust are equal.

3.7 (a)



The vertical reaction at B is

$$V_B \times 40 = 100 \times 8 \times 4$$

$$V_B = 80 \text{ kN}$$

For horizontal thrust at *B* taking moment of right part about crown (*C*)

$$V_B \times 20 = H \times 8$$

$$\therefore \quad H = \frac{80 \times 20}{8} = 200 \text{ kN}$$

3.8 (c)

The vertical reaction at right springing

$$V_R = \frac{80 \times 4}{16} = 20 \text{ kN}$$

Horizontal thrust,

$$H = \frac{V_R \times 8}{4} = 40 \text{ kN}$$

4. Methods of Structural Analysis

4.1 (c)

Using Betti's theorem

i.e. $P_1\Delta_{12} = P_2\Delta_{21}$

$P_1 = W_1$ and $\Delta_{12} = \delta_1$

$P_2 = W_2$ and $\Delta_{21} = \delta_2$

$$\therefore \quad \frac{\delta_1}{\delta_2} = \frac{W_2}{W_1}$$

4.2 (a)

Due to sway, the deflection of point *B* will be equal to that of point *C*.

$$M_{BA} = \frac{6EI\Delta}{L^2}$$

$$M_{CD} = \frac{3E(0.5I)\Delta}{(L/2)^2} = \frac{6EI\Delta}{L^2}$$

$$\therefore \quad \frac{M_{BA}}{M_{CD}} = 1.0$$

Note: This question is not fully correct. If member *BC* is not rigid then rotation at *B* and *C* is different then equation of M_{BA} is not correct. *A* similar question was asked in 1998, which is correct.

4.3 (d)

Due to unsymmetrical nature of frame, the lateral translation will occur towards left. Therefore horizontal force of equal and opposite nature will develop on the supports. So correct bending moment diagram will be (d).

4.4 (b)

The eccentric load *P* can be replaced by a load *P* and moment *PL* at the joint *D*. The distribution factor for member *AD*, *BD* and *CD* will be $\frac{1}{3}$ for each.

$$\therefore \quad M_{DA} = \frac{PL}{3}$$

Carry over factor for the beam *AD* is $\frac{1}{2}$.

$$\therefore \quad M_{AD} = \frac{PL}{6}$$

4.5 (c)

Relative stiffness

$$K_{AB} = \frac{EI}{2.5}; \; K_{AD} = \frac{EI}{5}$$

Distribution factors

$$D_{AB} = \frac{K_{AB}}{K_{AB}+K_{AD}} = 0.67$$

$$D_{AD} = \frac{K_{AD}}{K_{AB}+K_{AD}} = 0.33$$

4.6 (a)

For analysis of indeterminate structures, the method of least work, (a special form of **Castigliano's Second Theorem**) is useful. If R_i is the reaction component, the corresponding displacement Δ_i is zero for a rigid support, then

$$\Delta_i = \frac{\partial U}{\partial R_i} = 0$$

This holds for each of the reaction components (force or moment) in the structure. This method can be used to solve indeterminate beams, trusses, arches and frames. Thus it is based on the relation of displacement (slope or deflection) with the strain energy.

4.7 (c)

The frame is symmetrical in shape and size about a central vertical line. Therefore symmetrical loading about the centre line will not cause any side sway.

4.8 (c)

$$\text{Shear in column } AB = \frac{M_{AB}+M_{BA}}{4}$$

$$\text{Shear in column } CD = \frac{M_{CD}}{4}$$

Shear equation will be

$$\frac{M_{AB}+M_{BA}}{4} + \frac{M_{CD}}{4} + P = 0$$

4.9 (a)

Due to point load, the free bending moment diagram will be triangle.

The fixed end moments M_1 and M_2 can be imposed on it. As the slope at the ends of fixed beam is zero. So the area of total B.M.D. (fixed end moment + free moment) will be zero.

$$\left(\frac{M_1+M_2}{2}\right)L - \frac{1}{2}ML = 0$$

$$\therefore \quad M_1 + M_2 = M$$

4.10 (a)

Rotational stiffness is the ratio of moment and rotation at *O*. In other words rotational stiffness is the moment required for unit rotation at *O*.

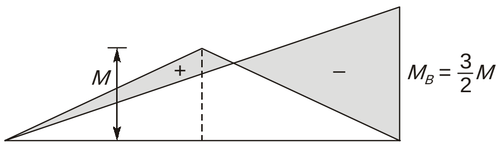
$$M = \frac{4EI}{L} + \frac{3EI}{L} + \frac{4EI}{L} = \frac{11EI}{L}$$

4.11 (d)

The propped cantilever beam shown in the figure will have zero deflection at points *A* and *B*. The slope will be zero at end *B*.

The bending moment will be zero at point *A*. The bending moment diagram of beam can be obtained by superimposing free moment diagram with fixed end moment diagram on the beam end *B*. Free moment under the load $M = \dfrac{W \times (L - x)}{L}$.

It is clear that maximum bending moment occurs at support *B*.



Moment under the load in the beam = $\dfrac{M}{4}$

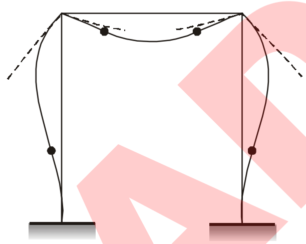
Moment at support $B = \dfrac{3}{2}M$

4.12 (a)

In analysis of rigid frames, strain energies due to shear and axial forces are neglected as strain energy due to flexure is much higher than strain energies due to shear and axial forces.

4.13 (d)

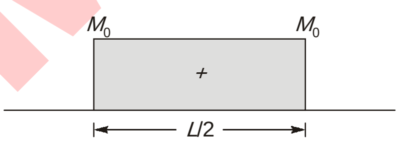
Deflected shape



There will be 1 point of contraflexure in each column and 2 points of contraflexure in beam.

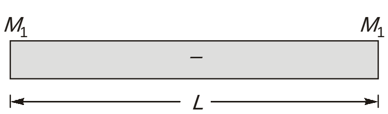
4.14 (c)

The free moment diagram of the beam is



Free moment diagram

Superimposing fixed end moment diagram and considering the fact that slopes at both end of the beam is zero.



Fixed moment diagram

Area under fixed moment diagram = Area under free moment diagram

$$M_1 L = M_o \frac{L}{2}$$

$$\therefore \quad M_1 = \frac{M_o}{2}$$

So the fixed end moments will be $M_0/2$.

4.15 (a)

Since the moment of inertia of middle half is reduced, so the redistribution of moment will occur in such a manner that less strong portion is subjected to less moment and more strong portion is subjected to more moment. From this argument, the fixed end moment will increase.

4.16 (c)

For case *D*, $M = \dfrac{5}{96} wL^2 = \dfrac{5}{48} WL$

4.17 (b)

From **Maxwell Betti's reciprocal theorem**

$P_1 \Delta_{1,2} = P_2 \Delta_{2,1}$

$P_1 \rightarrow$ load system 1 i.e. *P* and *Q* loads

$\Delta_{1,2} \rightarrow$ deflection at system 1 due to load at system 2. i.e., x′, y′ for *A* and *B* respectively.

$P_2 \rightarrow$ load system 2 i.e. load at *C*.

$\Delta_{2,1} \rightarrow$ deflection at system 2 due to load at system 1. i.e. *z* for point *C*.

$Px' + Qy' = 1 \times z$

$\therefore \quad z = Px' + Qy'$

4.18 (d)

The symmetry of the loading and frame does not allow any bending moment in column *CD*.

4.19 (d)

Both ends of left column are fixed, so shear in left column is

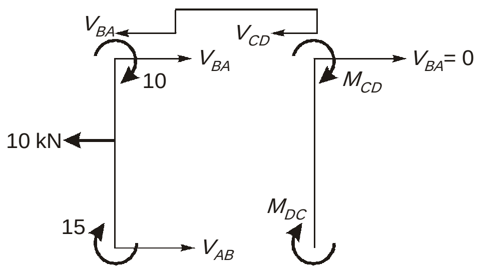
$$V_1 = \frac{12EI\Delta}{L^3}$$

For right column the top end is fixed, so shear in right column is

$$V_2 = \frac{3EI\Delta}{L^3}$$

$$P = V_1 + V_2 = \frac{15EI\Delta}{L^3}$$

4.20 (b)



For column AB, taking sum of moment about B is zero.

$$V_{AB} = \frac{M_{AB} + M_{BA}}{5} + 5$$

$= 10$ kN (towards right)

$\Sigma F_x = 0$ for AB

$\Rightarrow \quad V_{BA} = 0$

$\Sigma F_x = 0$ for BC

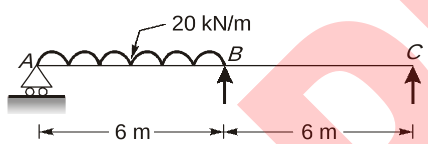
$\Rightarrow \quad V_{CD} = 0$

Now for column CD, taking sum of moment about C is zero.

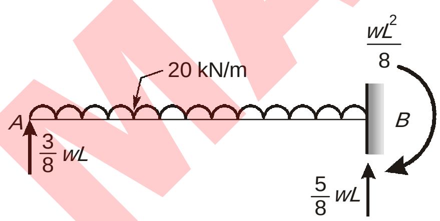
$$V_{CD} = \frac{M_{CD} + M_{DC}}{5} = 0$$

$\therefore \quad M_{DC} = -M_{CD} = -20$ kN-m

4.21 (b)



A two span continuous beam as above can be considered to be a propped cantilever beam for any span. So



So hogging moment at support

$$= \frac{wL^2}{8} = \frac{20 \times 6^2}{8}$$

$= 90$ kN-m hogging

When the load is on one span only the moment will be half i.e. 45 kN-m

4.23 (c)

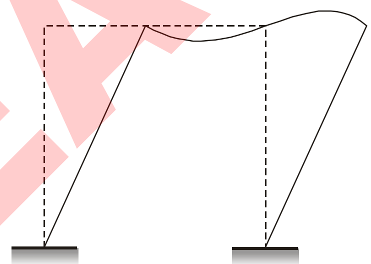
Using Maxwell-Betti's theorem

Load at $Z \times 6 = 20 \times 8 + 40 \times 5$

$$\therefore \text{ Load at } Z = \frac{160 + 200}{6} = \frac{360}{6} = 60 \text{ kN}$$

4.24 (a)

At the fixed support, there can be no angle but in all the options given in the question, the vertical member is shown at some angle with the fixed support. Also the horizontal member will not be horizontal after deflection unless it is a rigid member but it is given that EI is constant. So this is a faulty question. The true deflected shape will be



4.25 (c)

$$M_{BC} = \frac{2(2EI)}{8}(2\theta_B + \theta_C) = \frac{4EI}{8}(2\theta_B + \theta_C)$$

5.1 (a)

The force polygon will represent all forces at joint B. There are 4 members and load W at joint B. However force in horizontal member left of B is zero. Thus there are 3 members having non-zero force. So (a) is the force polygon showing 4 forces. Other figures show 5 forces.

5.2 (c)

There is no force at joint A, so forces in members AB and AE will be zero.

5.3 (c)

Member AI is inclined at 30° from horizontal. From the force diagram, forces in members GH and HI are zero. Force in member AI is compressive in nature.

$F_{AI} \sin 30° = 150$

$\therefore \quad F_{AI} = 300$ kN

5.4 (c)

The first step will be space diagram and then force polygon or vector diagram should be drawn to compute end reactions. Finally stress diagram can be drawn.

5.5 (c)

There is no force at joint F, so forces in member EF and CF is zero. Similarly forces in member CD and CA is zero.

$$R_A = \frac{1000 \times L}{2L} = 500 \text{ kg (downward)}$$

Joint equilibrium at A

$$F_{AD} \cos 45° = 500$$

$$F_{AD} = 500\sqrt{2} \text{ kg (tension)}$$

5.6 (b)

It is possible to draw infinite number of funicular polygons for any system of forces.

By choosing a new pole (O') having distance $2x$ from the force polygon, the ordinates in funicular polygon will be halved.

5.7 (d)

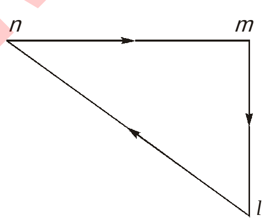
Cut a section through AG, AC and BC and take the moment of right part of the cut truss about F. The force in member AG and BC meet at point F itself so their moment is zero. The moment due to force in member AC is given by

$$L \cos 30° \times F_{AC} = -50 \times L + 50 \times 0 + 50 \times L = 0$$

So force in the member AC is zero.

5.8 (d)

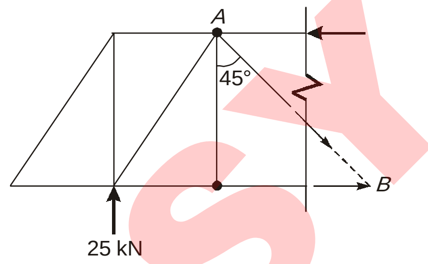
There will be tensile force in member L, N and compressive force in member N, M. Thus (d) represents the force polygon when we proceed in anticlockwise direction



5.9 (b)

The reaction at left support = 25 kN.

Cutting a section through member AB and other horizontal members of the same panel and considering left part of the cut section. The force in the member AB will be tensile.



$$\Sigma F_y = 0$$

$$F_{AB} \times \cos 45° = 25 \text{ kN}$$

$$\therefore \quad F_{AB} = 25\sqrt{2} \text{ kN (tension)}$$

5.10 (a)

$$\Sigma M_D = 0$$

$$R_A \times 2 = W \times 0$$

$$\Rightarrow \quad R_A = 0$$

At A, $\quad F_{AB} - R_A = 0$

$$\Rightarrow F_{AB} = 0$$

Similarly all other members will have zero force except member BD which has compressive force equal to W.

■■■■

UNIT

IV

Design of Steel Structures

Syllabus

Principles of Working Stress methods, Design of tension and compression members, Design of beams and beam column connections, built-up sections, Girders, Industrial roofs, Principles of Ultimate load design.

Contents

4 Design of Steel Structures

1. Structural Fasteners

1.1 Consider the following statements:
Aluminium is being increasingly used for structural purposes because
1. its modulus of elasticity is double that of steel
2. its coefficient of thermal expansion is half that of steel
3. it requires less maintenance
4. the strength to unit weight ratio of aluminium is high

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 4
(c) 1, 2 and 3 (d) 3 and 4
[ESE : 1995]

1.2 A steel plate is 30 cm wide and 10 mm thick. A rivet of nominal diameter 18 mm is driven. The net sectional area of the plate is
(a) 18.00 cm^2 (b) 28.20 cm^2
(c) 28.05 cm^2 (d) 32.42 cm^2
[ESE : 1995]

1.3 Which one of the following is the most important consideration in the design of a riveted joint between structural members when the centroid of the rivets does not coincide with the axis of the load?
(a) Direct shear force in each rivet is proportional to its radial distance from its centroid and the resultant force in each rivet should not exceed its rivet value.
(b) Shear force caused in each rivet due to eccentricity of the load is proportional to its radial distance from its centroid and the direct shear force in each rivet should be limited to half the rivet value.
(c) The shear force caused in each rivet due to eccentricity of the load is proportional to the radial distance of the rivet from the centroid of the rivet group and the maximum resultant force in any rivet should not exceed the rivet value.
(d) The shear force caused in the rivet due to eccentricity of load as well as direct shear force caused in the rivet should not exceed rivet value individually.
[ESE : 1995]

1.4 The common assumption that, 'all rivets share equally a non-eccentric load' is valid at a load
(a) below the working load
(b) equal to the working load
(c) above the working load
(d) equal to the failure load
[ESE : 1995]

1.5 A circular plate 100 mm diameter is welded to another plate by means of 6 mm fillet weld. If the permissible shearing stress in the weld equals 10 kg/mm^2, then the greatest twisting moment that can be resisted by the weld will be
(a) 424π kg-m (b) 300π kg-m
(c) 212π kg-m (d) 60π kg-m
[ESE : 1996]

1.6 A mild steel flat subjected to tensile force of 84 tonnes is connected to a gusset plate using rivets. If the forces required to shear a single rivet, to crush the rivet and to tear the plate per pitch length are 5000 kg, 8000 kg and 6000 kg respectively, then the number of rivets required is
(a) 12 (b) 14
(c) 16 (d) 17
[ESE : 1996]

1.7 In a fillet weld the weakest section is the
(a) smaller side of the fillet
(b) throat of the fillet
(c) side perpendicular to force
(d) side parallel to force
[ESE : 1996]

1.8 Which one of the following methods of design is not suitable for structures subjected to impact and fatigue?
(a) Simple design
(b) Semi-rigid design
(c) Rigid design
(d) Plastic design

[ESE : 1996]

1.9 **Assertion (A) :** In structural bearing type joints, each connection is assumed to transmit its proportional share of the applied load.
Reason (R) : Applied load passes through the centroid of the connector group.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

1.10 Upper yield point in the stress-strain curve in structural steel can be avoided by
(a) cold working (b) hot working
(c) quenching (d) galvanizing

[ESE : 1997]

1.11 In the design of framed connections, the rivets or bolts connecting the web of the beam with connecting angles are subject to
(a) single shearing and bearing on the web
(b) double shearing and bearing on the web
(c) double shearing and no bearing on the web
(d) no shearing but only bearing on the web

[ESE : 1997]

1.12 The effective length of the fillet weld is
(a) Total length $-2 \times$ throat size
(b) Total length $-2 \times$ weld size
(c) $0.7 \times$ total length
(d) Total length – (weld size/$\sqrt{2}$)

[ESE : 1997]

1.13 Consider the following statements:
1. To insert a 28 mm nominal diameter rivet, 29.5 mm rivet hole is made.
2. Provision is made to allow temperature expansion of the bolt.

Which of these statements are correct?
(a) Both 1 and 2 (b) 1 only
(c) 2 only (d) Neither 1 nor 2

[ESE : 1997]

1.14 In a diamond riveting, for a plate of width 'b' and rivet diameter 'd', the efficiency of the joint is given by
(a) $\dfrac{(b-d)}{b}$ (b) $\dfrac{(b-2d)}{b}$
(c) $\dfrac{(b-d)}{d}$ (d) $\dfrac{(b-2d)}{d}$

[ESE : 1997]

1.15 For two plates of equal thickness, full strength of fillet weld can be ensured if its maximum size, for square edge, is limited to
(a) 1.5 mm less than the thickness
(b) 75% of the thickness
(c) 80% of the thickness
(d) thickness of the plate

[ESE : 1998]

1.16 In a double-riveted double-covered butt joint, the strength of the joint per pitch length in shearing the rivets is n times the shear strength of one rivet in single shear, where 'n' is equal to
(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 1998]

1.17 A welded fillet joint of length L can be subjected to a maximum load of
(fs-fillet size and pss = permissible shear stress).
(a) $\dfrac{(fs \times L \times \text{pss})}{3}$ (b) $fs \times L \times pss$
(c) $(0.7)(fs \times L \times pss)$ (d) $2(fs \times L \times pss)$

[ESE : 1998]

1.18 Match **List-I** (Use) with **List-II** (Type of weld) and select the correct answer using the codes given below the lists:

List-I
A. Structural members
B. Joining two surfaces
C. A hole is made in one of
D. Pressure is applied

List-II

1. Slot weld subject to direct tension or compression
2. Seam weld approximately at right angles to each other
3. Fillet weld the components and welding is done around the periphery of the hole
4. Plug weld continuously
5. Butt weld

Codes:

	A	B	C	D
(a)	5	4	1	3
(b)	4	3	2	1
(c)	5	3	1	2
(d)	4	5	3	2

[ESE : 1999]

1.19 A welding detail is shown in figure-I

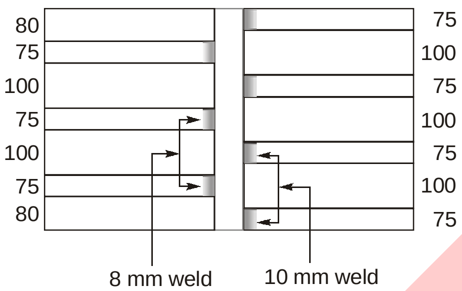
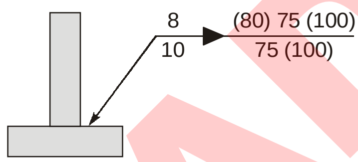
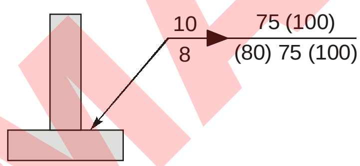
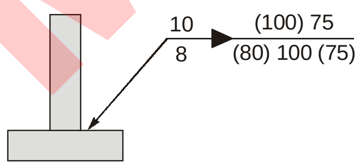


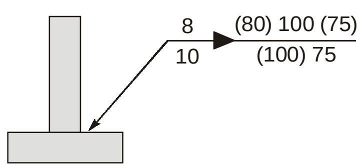
Figure-I

The welding notation for the figure is

(a)


(b)


(c)


(d)


[ESE : 1999]

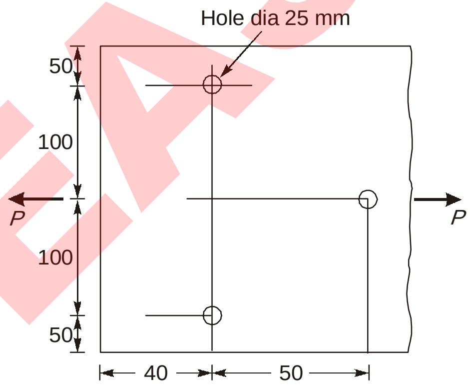
1.20 A structural member carrying a pull of 700 kN is connected to a gusset plate using rivets. If the pulls required to shear the rivet, to crush the rivet and to tear the plate per pitch length are respectively 60 kN, 35 kN and 70 kN, then the number of rivets required will be

(a) 22 (b) 20
(c) 18 (d) 12

[ESE : 1999]

2. Tension Member

2.1 What is the effective net width of plate shown in the given sketch, for carrying tension?



All dimensions are in mm

(a) 212.5 mm (b) 237.5 mm
(c) 250 mm (d) 275 mm

[ESE : 1996]

2.2 A single-angle tie of a welded steel truss in an industrial shed is required to be designed for an axial tension of 50 kN. If the permissible tensile stress is 150 MPa, then the most suitable section satisfying **IS : 800** codal requirements will be

(a) ISA 75 × 50 × 6
(b) ISA 60 × 40 × 5
(c) ISA 50 × 30 × 4
(d) ISA 45 × 30 × 5

[ESE : 1996]

2.3 Given that

A_e = effective area of the member and

σ_y = yield stress

In order to obtain the ultimate strength of a tension member, as per the plastic design concept, $A_e\sigma_y$ is to be multiplied by

(a) 1.1 (b) 0.95
(c) 0.85 (d) 0.75

[ESE : 1997]

2.4 The permissible stresses for main structural steel members under dynamic loads should be increased by

(a) 20% (b) 25%
(c) 30% (d) 33.33%

[ESE : 1999]

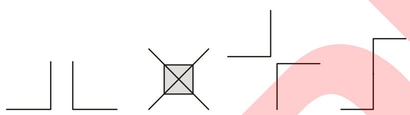
3. Compression Member

3.1 The most critical consideration in the design of rolled steel columns carrying axial loads is the

(a) percent elongation at yield and the net cross-sectional area
(b) critical bending strength and axial yield strength of the material
(c) buckling strength based on the net area of the section and percent elongation at ultimate load
(d) compressive strength based on slenderness ratio and gross cross sectional area of the member

[ESE : 1997]

3.2 Two equal angles form a compound column cross-section as shown in figures 1, 2, 3 and 4.



1 2 3 4

Among these, those which have the same axial compression load carrying capacity would include

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 and 4

[ESE : 1997]

3.3 In the case of structural steel sections, the MINIMUM ratio of thickness of elements in compression, in terms of their outstanding length is specified to prevent

(a) bending failure (b) shear failure
(c) local buckling (d) tension failure

[ESE : 1998]

3.4 In the case of an axially loaded column machined for full bearing, the fasteners connecting the column to the base plates in gusseted base are designed for

(a) 100% of the column load
(b) 50% of the column load
(c) 25% of the column load
(d) erection conditions only

[ESE : 1998]

3.5 The effective length of a structural steel compression member of length L effectively held in position and restrained against rotation at one end but neither held in position nor restrained against rotation at the other end, is

(a) L (b) $1.2L$
(c) $1.5L$ (d) $2.0L$

[ESE : 1998]

3.6 Which one of the following is the most critical set of considerations in the design of rolled steel columns carrying axial loads?

(a) Percent elongation at yield and the net cross-sectional area
(b) Critical bending strength and axial yield strength of the material
(c) Buckling strength based on the net area of the section and percent elongation at ultimate load
(d) Compressive strength based on slenderness ratio and gross cross-sectional area of the member

[ESE : 1999]

3.7 Consider the following statements:
A grillage base is checked for

1. bending
2. shear
3. compression
4. web crippling

Which of these statements are correct?

(a) 1 and 4 (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 2 and 4

[ESE : 1999]

4.Beams

4.1 A cantilever steel beam of 3 m span carries a uniformly distributed load of 20 kN/m inclusive of self weight. The beam comprises ISLB 200@198 N/mm flange100 mm × 7.3 mm, web thickness 5.4 mm

$I_{xx} = 1696.6 \text{ cm}^4$, $I_{yy} = 115.4 \text{ cm}^4$

Bending and shear stresses in the beam are respectively

(a) 530.47 N/mm^2 and 55.55 N/mm^2
(b) 3899.48 N/mm^2 and 82.19 N/mm^2

(c) 132.62 N/mm^2 and 41.1 N/mm^2
(d) 1949.74 N/mm^2 and 41.10 N/mm^2

[ESE : 1995]

4.2 The allowable shear stress in stiffened webs of mild steel beams decreases with
(a) decrease in the spacing of the stiffeners
(b) increase in the spacing of the stiffeners
(c) decrease in the effective depth
(d) increase in the effective depth

[ESE : 1997]

4.3 The rolled steel section used in a cased beam has width *B* mm and diameter *D* mm. The minimum width of the finished cased beam in mm is given by
(a) $(B + 50)$ (b) $(B + 100)$
(c) $(B + D + 100)$ (d) $2(B + D)$

[ESE : 1997]

4.4 Match **List-I** (Type of connection) with **List-II** (Type of beams) and select the correct answer using the code given below the lists:

List-I
A. Semi-rigid connection
B. Framed connection
C. Flexible connection
D. Seated connection

List-II
1. To permit large angles of rotation and to transmit negligible moment.
2. To allow small end rotation and transmit appreciable moment.
3. When a beam is connected to a beam or stanchion by means of an angle at the bottom of the beam which is shop-riveted to the beam and an angle at the top of which is field riveted.
4. When a beam is connected to a beam or stanchion by means of two angles riveted to them.

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	1	3
(c)	2	4	1	3
(d)	4	2	3	1

[ESE : 1998]

4.5 Racking force on a steel railway bridge is due to
(a) tractive effect of the driving well
(b) braking effect
(c) resistance offered by the bearing to the movement at the roller end
(d) lateral movement of the train when moving on a straight track.

[ESE : 1998]

4.6 **Assertion (A) :** Both transverse and longitudinal frames of a steel building are subjected to equal earthquake forces.
Reason (R) : Earthquake force is proportional to the mass of each floor.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

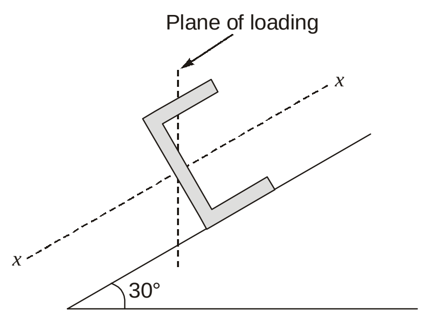
[ESE : 1998]

4.7 In a simply supported beam of span L each end is restrained against torsion, compression flange being unrestrained. According to **IS: 800**, the effective length of the compression flange will be equal to
(a) L (b) 0.85 L
(c) 0.75 L (d) 0.70 L

[ESE : 1999]

5. Plate Girders and Industrial Roofs

5.1 A channel section is placed in an inclined position carrying vertical loads as shown in the given figure. If the applied moment for the channel is 'M' due to vertical load, then M_{XX} is given by



(a) $\frac{\sqrt{3}}{2}M$ (b) $\frac{1}{2}M$
(c) $\frac{1}{\sqrt{2}}M$ (d) $2M$

[ESE : 1995]

5.2 Z-purlins may be fixed in either orientation *A* or *B* as shown in the given figure. Which one of the following statements is correct in this regard?

(a) Orientation *A* is structurally more efficient than orientation *B*.
(b) Orientation *B* is structurally more efficient than orientation *A*.
(c) Both the orientations are structurally equally efficient.
(d) Neither of the two orientation is structurally efficient.

[ESE : 1995]

5.3 Intermediate vertical stiffeners are provided in plate girders to
(a) eliminate web buckling
(b) eliminate local bucking
(c) transfer concentrated loads
(d) prevent excessive deflection

[ESE : 1995]

5.4 Consider the following systems:
1. Trusses and purlins
2. Suspension system
3. Flat grid roof
4. Shells

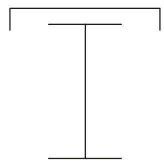
When these are used in single deck industrial structures, the correct sequence in increasing order of spans will be
(a) 3, 1, 2, 4 (b) 1, 3, 2, 4
(c) 3, 1, 4, 2 (d) 2, 4, 1, 3

[ESE : 1996]

5.5 The thickness of web for unstiffened plate girder with clear distance '*d*' between the flanges shall not be less than
(a) *d*/200 (b) *d*/85
(c) *d*/100 (d) *d*/160

[ESE : 1996]

5.6 The given figure shows a typical section of a crane girder. Consider the following statements in this regard:



The function of the top channel is to
1. increase moment of inertia about vertical axis
2. reduce moment of inertia about horizontal axis
3. increase torsional stiffness
4. increase lateral buckling strength

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 3 and 4

[ESE : 1996]

5.7 **Assertion (A) :** Portal bracing should be used in only through bridges where cross frames cannot be used.
Reason (R) : Portal bracing causes bending moment in the end frames.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

5.8 At a section along the span of a welded plate girder, where the web is spliced, the bending moment is *M*. If the girder has top flange, web and bottom flange plates of equal area, then the share of the bending moment which would be taken by the splice plates would be
(a) *M* (b) *M*/3
(c) *M*/7 (d) *M*/13

[ESE : 1997]

5.9 In the simplified design of angle iron purlins, which one of the following assumptions would NOT be valid?
(a) Load component acting normal to the slope is considered
(b) Bending moment about the minor axis is considered

(c) Allowable bending stress is not reduced
(d) Slope of the roof should not exceed 30°

[ESE : 1998]

5.10 The height at which wind force acts on a moving vehicle on a bridge deck is
(a) 1.2 m (b) 1.5 m
(c) 1.7 m (d) 2.0 m

[ESE : 1998]

5.11 If 'p' is the basic wind pressure, for buildings with large opening design pressure on a wall is taken as
(a) $0.5p$ (b) $0.7p$
(c) $1.0p$ (d) $1.2p$ [ESE : 1998]

5.12 According to Indian Railway Board, in respect of steel girders of single track span for metre/broad gauge, the impact factor for a span of 6 m is
(a) 0.5 (b) 0.75
(c) 1 (d) 1.25 [ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.13 **Assertion (A) :** Lateral bracing of adjacent trusses is necessary in industrial buildings.
Reason (R) : Wind forces acting along the ridge line are to be resisted.

[ESE : 1999]

5.14 **Assertion (A) :** The flange area method of design of plate girders is an approximate method.
Reason (R): Bending stresses in compression and tension flanges are assumed to be linearly distributed.

[ESE : 1999]

5.15 Consider the following statements regarding roofing of an industrial structure:
1. The canoidal shell is preferable to north-light steel trussed roof.
2. The ware-house flat slab construction is not suitable.
3. Loads other than self-weight have insignificant effect on the design.
4. Consideration of corrosive environment cannot be ignored as it affects the durability.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 2, 3 and 4
(c) 1 and 2 (d) 3 and 4

[ESE : 1999]

6. Plastic Analysis

6.1 In the plastic analysis which of the following pairs is/are correctly matched?

Geometry of steel section	Shape factor
1. Rectangle	2.0
2. Round	1.7
3. Square	1.0

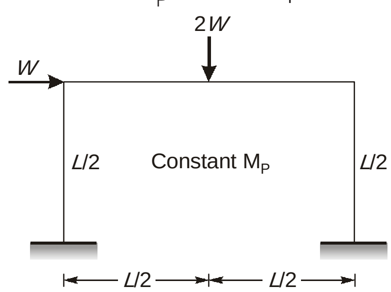
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 2 alone (d) 1 and 3

[ESE : 1995]

6.2 At the location of plastic hinge
(a) radius of curvature is infinite
(b) curvature is infinite
(c) moment is infinite
(d) flexural stress is infinite

[ESE : 1995]

6.3 Given figure shows a portal frame with loads. All members of frame have same plastic moment of resistance M_P. The collapse load W is



(a) $\frac{2M_P}{L}$ (b) $\frac{4M_P}{L}$

(c) $\frac{6M_P}{L}$ (d) $\frac{8M_P}{L}$

[ESE : 1995]

6.4 A rectangular steel section of width 'b' and depth 'h' has been stressed to yield point (σ_y) upto a depth of $h/4$ from both the top and bottom face under the action of a moment M. The magnitude of the moment M is

(a) $\frac{10}{24}bh^2\sigma_y$ (b) $\frac{1}{4}bh^2\sigma_y$

(c) $\frac{11}{48}bh^2\sigma_y$ (d) $\frac{13}{36}bh^2\sigma_y$

[ESE : 1995]

6.5 A simply supported beam of span L supports a concentrated load W at its midspan. If the cross-section of the beam is an I-section, then the length of elastic-plastic zone of the plastic hinge will be

(a) $L/8$ (b) $L/4$

(c) $L/2$ (d) $3L/4$

[ESE : 1995]

6.6 A continuous beam of constant M_P has three equal spans and carries total uniformly distributed load W on each span. The value of collapse load for the beam will be

(a) $\frac{12M_P}{L}$ (b) $\frac{8.65M_P}{L}$

(c) $\frac{11.656M_P}{L}$ (d) $\frac{4M_P}{L}$

[ESE : 1995]

6.7 For an I-beam, shape factor is 1.12. The factor of safety in bending is 1.5. If the allowable stress is increased by 20% for wind and earthquake loads, then the load factor is

(a) 1.10 (b) 1.25

(c) 1.35 (d) 1.40

[ESE : 1995]

6.8 Yield line theory results in

(a) elastic solution

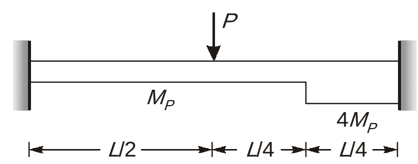
(b) lower bound solution

(c) upper bound solution

(d) unique solution

[ESE : 1995]

6.9 For the beam shown in the given figure, the collapse load P is given by



(a) $\frac{16M_P}{L}$ (b) $\frac{14M_P}{L}$

(c) $\frac{12M_P}{L}$ (d) $\frac{10M_P}{L}$

[ESE : 1996]

6.10 A fixed beam as shown in Figure 1 is loaded with a UDL over the entire span, the total load being W; when load was just increased to W_1, the deformed shape as shown in Figure 2 was seen. The value of W_1 (plastic moment of resistance $= M_P$) is

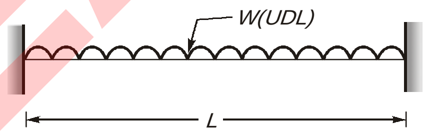


Figure 1

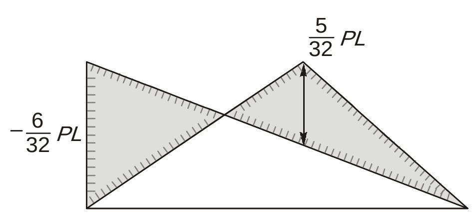
Figure 2

(a) $\frac{24M_P}{L}$ (b) $\frac{16M_P}{L}$

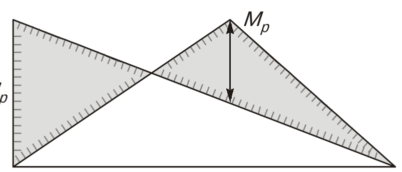
(c) $\frac{12M_P}{L}$ (d) $\frac{8M_P}{L}$

[ESE : 1996]

6.11 For a propped cantilever beam of span L with a central concentrated load P, the elastic and plastic moment diagrams are shown in the given figures:



Elastic



Plastic

From these diagrams, it is clear that

(a) maximum moments are distributed more advantageously in the elastic case
(b) maximum moments are distributed more advantageously in the plastic case
(c) bending moment distribution in both the cases is equally advantageous
(d) no definite conclusion can be drawn

[ESE : 1996]

6.12 Consider the following definitions:

1. collapse load/service load
2. (collapse load/service load) – 1
3. ultimate stress/permissible stress
4. (ultimate stress/permissible stress) – 1

Of these definitions, those which relate to 'margin of safety' would include

(a) 1 and 3 (b) 1 alone
(c) 2 and 4 (d) 3 alone

[ESE : 1996]

6.13 Assertion (A) : The shape factor of a circular section is less than that of a rectangular section.
Reason (R) : Compared to rectangular section, a circular section has more area near the neutral axis than at the extreme fibre.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

6.14 A ductile structure is defined as one for which the plastic deformation before fracture

(a) is smaller than the elastic deformation
(b) vanishes
(c) is equal to the elastic deformation
(d) is much larger than the elastic deformation

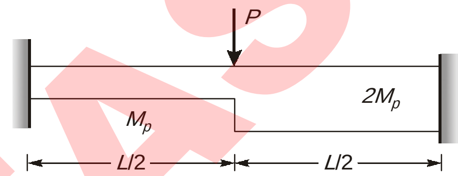
[ESE : 1996]

6.15 A simply supported beam of uniform cross-section has span L and is loaded by a point load P at its mid-span. The length of elastoplastic zone of the plastic hinge will be

(a) $\frac{L}{3}$ (b) $\frac{2L}{5}$
(c) $\frac{L}{2}$ (d) $\frac{3L}{4}$

[ESE : 1997]

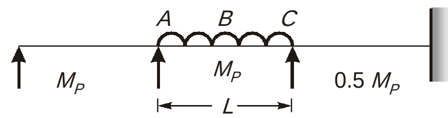
6.16 A fixed beam made of steel is shown in the figure below. At collapse, the value of load P will be equal to



(a) $\frac{10M_P}{L}$ (b) $\frac{12M_P}{L}$
(c) $\frac{16M_P}{L}$ (d) $\frac{20M_P}{L}$

[ESE : 1997]

6.17 A continuous beam with plastic moment capacities is shown in the given figure.



The correct sequence in which the plastic hinges will form in the beam is

(a) C, A, B
(b) A and C simultaneously, followed by B
(c) B, C, A
(d) B first then A and C simultaneously

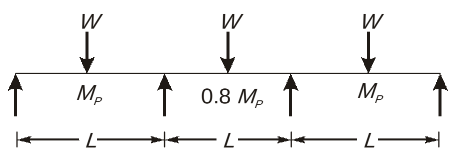
[ESE : 1997]

6.18 A thin hollow box section of 400 mm 600 mm deep (outer dimensions) with uniform plate thickness of 10 mm all-round is used for a beam. The plastic modulus of section (Z_P) and its shape factor will be

Z_P(in 10^5 mm^3)	Shape factor
(a) 36	7/6
(b) 36	6/7
(c) 42	6/7
(d) 42	7/6

[ESE : 1997]

6.19 The figure below shows a continuous beam loaded with concentrated loads W at the centre of each span. The value of W at collapse will be



(a) $3.2\ M_P/L$ (b) $4\ M_P/L$
(c) $5.6\ M_P/L$ (d) $6.4\ M_P/L$

[ESE : 1997]

6.20 A steel beam of rectangular cross-section is clamped at both ends. Deformation is just observed when the UDL on the beam is 10 kN/m. At the instant of collapse, the load on the beam will be

(a) 10 kN/m (b) 15 kN/m
(c) 20 kN/m (d) 30 kN/m

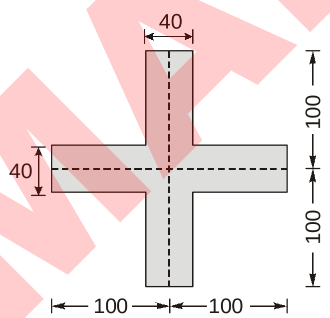
[ESE : 1998]

6.21 The ratio of collapse load of a propped cantilever of span L carrying a UDL throughout the span to that of a simply-supported beam carrying the same load is

(a) 1.457 (b) 1.500
(c) 2.000 (d) 3.000

[ESE : 1998]

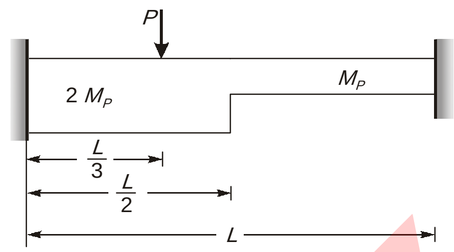
6.22 The shape factor of the section shown in the figure below is



(a) $\frac{139}{82}$ (b) $\frac{145}{86}$
(c) $\frac{150}{91}$ (d) $\frac{160}{97}$

[ESE : 1998]

6.23 A fixed beam is shown in the figure below. The plastic failure load for this beam is



(a) $10\ M_P/L$ (b) $12.5\ M_P/L$
(c) $15\ M_P/L$ (d) $16.5\ M_P/L$

[ESE : 1998]

6.24 To transform an indeterminate frame with a degree of indeterminacy 'r' into a determinate one, the number of plastic hinges required is

(a) $r + 2$ (b) $r + 1$
(c) r (d) $r - 1$

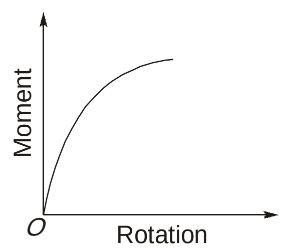
[ESE : 1998]

6.25 A propped cantilever of span L is subjected to a concentrated load at mid-span. If M_P is plastic moment capacity of the beam, then the value of the collapse load will be

(a) $\frac{12M_P}{L}$ (b) $\frac{8M_P}{L}$
(c) $\frac{6M_P}{L}$ (d) $\frac{4M_P}{L}$

[ESE : 1999]

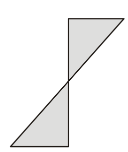
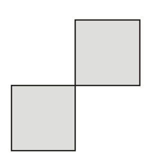
6.26 The moment rotation curve shown in the given figure is that of a

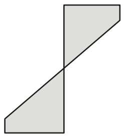


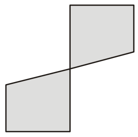
(a) rigid joint (b) flexible joint
(c) pin joint (d) semi-rigid joint

[ESE : 1999]

6.27 In a plastic hinge, the actual distribution of strain across the section will be as in

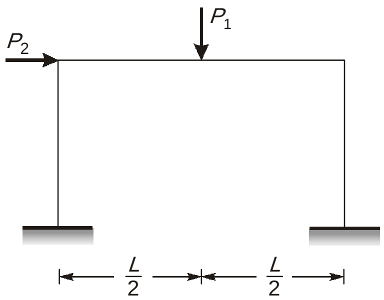
(a)  (b) 

(c) 

(d) 

[ESE : 1999]

6.28 Given figure shows a portal frame with load. All members have the same plastic moment of resistance M_P. The ratio P_1 to P_2 for beam and sway mechanism is



(a) 1
(b) 2
(c) 3
(d) 4

[ESE : 1999]

6.29 Which one of the following modes of failure is taken care of in plastic design of a steel beam?
(a) Plastic material deformation throughout the beam
(b) Lateral buckling of the beam
(c) Elastic buckling of the compression flange
(d) Hinge formation in the beam due to yielding of steel

[ESE : 1999]

■■■■

Answers Design of Steel Structures

1.1 (d)	1.2 (c)	1.3 (c)	1.4 (d)	1.5 (c)	1.6 (d)	1.7 (b)	1.8 (d)	1.9 (a)
1.10 (a)	1.11 (b)	1.12 (b)	1.13 (d)	1.14 (a)	1.15 (a)	1.16 (d)	1.17 (c)	1.18 (c)
1.19 (a)	1.20 (b)	2.1 (b)	2.2 (b)	2.3 (c)	2.4 (d)	3.1 (d)	3.2 (c)	3.3 (c)
3.4 (b)	3.5 (d)	3.6 (d)	3.7 (d)	4.1 (a)	4.2 (b)	4.3 (b)	4.4 (c)	4.5 (d)
4.6 (a)	4.7 (a)	5.1 (a)	5.2 (b)	5.3 (a)	5.4 (c)	5.5 (b)	5.6 (a)	5.7 (b)
5.8 (c)	5.9 (b)	5.10 (b)	5.11 (b)	5.12 (b)	5.13 (a)	5.14 (c)	5.15 (c)	6.1 (c)
6.2 (b)	6.3 (b)	6.4 (c)	6.5 (a)	6.6 (c)	6.7 (d)	6.8 (c)	6.9 (c)	6.10 (c)
6.11 (b)	6.12 (c)	6.13 (d)	6.14 (d)	6.15 (a)	6.16 (a)	6.17 (c)	6.18 (d)	6.19 (c)
6.20 (c)	6.21 (a)	6.22 (b)	6.23 (c)	6.24 (c)	6.25 (c)	6.26 (d)	6.27 (a)	6.28 (b)
6.29 (d)								

Explanations Design of Steel Structures

1. Structural Fasteners

1.1 (d)

Aluminium has greater strength to unit weight ratio compared to steel therefore they are being increasingly used for structural purposes.

The modulus of elasticity of aluminium is about one third that of steel while its coefficient of thermal expansion is double that of steel.

1.2 (c)

For a rivet with nominal diameter less than or equal to 25 mm, the hole diameter is taken 1.5 mm more than nominal diameter. For nominal diameter more than 25 mm, the hole diameter is 2 mm more than the nominal diameter. The rivet is heated uniformly from temperature 550°C to 1000°C and after placing it in the hole in the heated condition, its head is pressed on the rivet. Thus it fills the hole completely. However it can be cold driven also.

Diameter of rivet hole = 18 + 1.5 = 19.5 mm

The net cross-sectional area of plate

$= (30 - 1.95) \times 1.0 = 28.05 \text{ cm}^2$

1.3 (c)

For eccentric riveted connection,

Direct shear force,

$$R_p = \frac{P}{N}$$

$P \rightarrow$ Load with eccentricity e

$N \rightarrow$ Number of rivets

Shear force due to eccentricity,

$$R_m = \frac{Per}{\Sigma r^2}$$

$r \rightarrow$ radial distance of rivet from centroid.

Resultant $\vec{R} = \vec{R}_p + \vec{R}_m$

The magnitude of resultant should be less than rivet value.

1.5 (c)

The strength of weld (F)

$= 0.707 \times 10 \times 6 = 42.42$ kg/mm

Length of the weld, $l = \pi d = 100\pi$ mm

Twisting moment $= Fl \times \dfrac{d}{2}$

$= 42.42 \times 100\pi \times 50$

$= 212\ 100\pi$ kg-mm

$= 212.1\pi$ kg-m

1.6 (d)

Rivet value is minimum of 5000 kg, 8000 kg and 6000 kg.

$\therefore$ Rivet value = 5000 kg

Number of rivets $= \dfrac{84 \times 1000}{5000} = 16.8 \simeq 17$

1.7 (b)

Throat being the minimum section will carry maximum stress. Thus, it is weakest.

1.8 (d)

The connection, whether riveted, bolted or welded, can be designed as flexible, semi-rigid or rigid connections. Flexible connections are also known as simple connections. These connections are assumed to resist shear only. Rigid connections, also known as moment connections, can resist both shear and bending moments at the connections. Semi-rigid connections resist the bending moment in between the flexible and rigid connections.

Plastic or ultimate design considers complete mobilization of strength of material. This method does not take into consideration the effect of impact, fatigue, creep and shrinkage. The serviceability requirements of avoidance of excessive deflection and cracking are not considered.

1.10 (a)

Plastic deformation of metals below the re-crystallization temperature is known as cold working. In this process steel is loaded above elastic limit to have some plastic strain which in turn omits upper yield point later.

1.12 (b)

The effective length of fillet weld is taken equal to its overall length minus twice the weld size. The deduction is made to allow for craters to be formed at the ends of the welded length. The effective length of a fillet should not be less than 4 times the weld size.

1.13 (d)

For rivets with diameter ≤ 25 mm

Diameter of the hole = (d + 1.5) mm

For rivets with diameter ≥ 25 mm

Diameter of the hole = (d + 2) mm

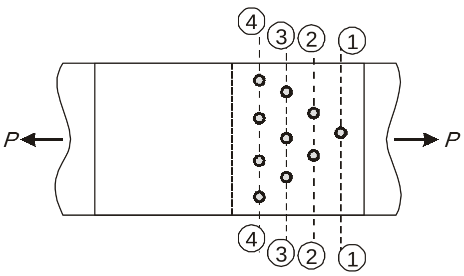
For 28 mm diameter, diameter of hole = (28 + 2) mm =30 mm

This provision is provided for ease of alignment of bolt.

1.14 (a)

Efficiency of riveted joint,

$$\eta = \frac{\text{Strength of riveted joint}}{\text{Strength of solid plate}} \times 100$$



The section 1 – 1 is most critical. The strength of joint at section 1 – 1 is $(b - d)\, t\, \sigma_{at}$.

The strength of solid plate is $b\, t\, \sigma_{at}$.

So $$\eta = \frac{b-d}{b} \times 100$$

1.15 (a)

The maximum size of a fillet weld is obtained by subtracting 1.5 mm from the thickness of the thinner member to be jointed. This specification limits the size of the fillet weld so that total strength may be developed without overstressing the adjacent metal.

1.16 (d)

Strength of one rivet in single shear

$$= P_s = \frac{\pi}{4} d^2 \tau_{vf}$$

Strength of double riveted double cover butt joint per pitch length = P_d

$$= 2 \times 2 \times \frac{\pi}{4} d^2 \tau_{vf}$$

But $P_d = nP_s$ (given)

$\Rightarrow$ $P_d = 4P_s$

1.17 (c)

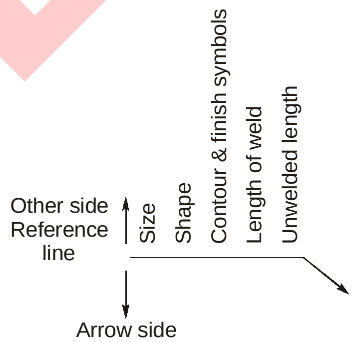
The strength fillet weld = 0.7 ($fs \times pss$) per unit length. So maximum load is strength of fillet weld × joint length (L).

1.18 (c)

In butt welds, the effective thickness is generally less than the plates connected so the joint has less than 100% efficiency. They are stronger than fillet welds and used most frequently. They are used when the members to be jointed are lined up. It is usually designed for direct tension or compression. Fillet welds are provided when two members to be jointed are in different planes.

If a sufficient length of fillet weld cannot be provided, the connection can be strengthened by the use of plug or slot welds. They are made by filling with weld metal in a circular (plug weld) or slotted (slot weld) hole cut in one of the parts to be joined.

1.19 (a)



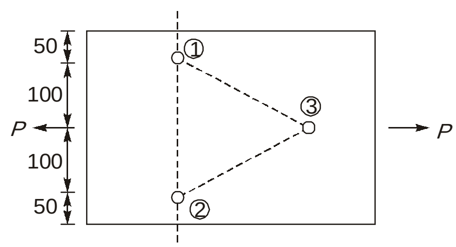
1.20 (b)

The rivet value R = 35 kN

Number of rivets required = $\frac{700}{35} = 20$

2. Tension Member

2.1 (b)



For section 1-3

Effective width = $(\beta - 2 \times d_0)$

where d_0 = hole diameter
β = total width of plate
$= (300 - 2 \times 25) = 275$ mm
For section 1-2-3

$$\text{Effective width} = \left(B - nd + \sum \frac{S_i^2}{4g}\right)$$

$n = n_0$ of bolt/rivet in section considered
S = pitch
g = gauge distance

$$= \left(300 - 3 \times 25 + \frac{2 \times 50^2}{4 \times 100}\right)$$

$= 237.5$ nn
Hence effective widt will be 237.5 mm

2.2 (b)
The net area required

$$= \frac{\text{Axial load}}{\text{Permissible stress}}$$

$$= \frac{50 \times 10^3}{150} = 333.33 \text{ mm}^2$$

For an angle of size ISA $a \times b \times t$
The area of connected leg with dimension 'a'
$A_1 = (a - t/2)t$
The area of outstand leg with dimension 'b'
$A_2 = (b - t/2)t$
It is better to connect larger leg and leave smaller leg as outstand.
Net effective area,
$A = A_1 + kA_2$

$$k = \frac{1}{1 + \frac{A_2}{3A_1}} = \frac{3A_1}{3A_1 + A_2}$$

Section	A_1(mm^2)	A_2(mm^2)	A(mm^2)
ISA75 × 50×6	432	282	663.60
ISA60 × 40×5	287.5	187.5	441.52
ISA 50×30×4	192	112	285.77
ISA 45×30 ×5	212.5	137.5	325.60

Thus ISA 60 × 40 × 5 is most suitable with net area 441.52 mm^2, which is more than required area of 333.33 mm^2 to resist the load.

2.3 (c)
The maximum load capacity of tension member is 0.85 $A_c f_y$
For compression member the load capacity is 1.7 $A_e \sigma_{ac}$
$\sigma_{ac} \rightarrow$ allowable compression
The maximum shear capacity of beam column is 0.55 $A_w f_y$ where A_w is the effective cross-sectional area resisting shear.

2.4 (d)
For structural steel and steel castings, the permissible stresses may be increased by $33\frac{1}{3}\%$.
For rivets, bolts and tension rods, the permissible stress may be increased by 25%.

3. Compression Member

3.1 (d)
For design of axially loaded compression member:
- A value of permissible compressive stress is assumed
- For this stress gross area is found.
- A trial section is chosen
- Maximum slenderness ratio for chosen section is found
- Load carrying capacity of chosen member is calculated
- The member is safe if load carrying capacity is equal or greater than the applied load.

Thus compressive strength based on slenderness ratio and cross-gross sectional area of member is most critical set of consideration.

3.2 (c)
The cruciform arrangement of double angle, in star section (figure-3) is most effective because of its approximately equal radii of gyration in two directions. The box section (figure-2) can be formed with welded connection. The least radius of gyration of the section shown in the figure-2 and figure-3 of two angles is same and it is more than that of the sections shown in figure-1. Therefore the permissible compressive stress for figure 2 and 3 will be same and compression load carrying capacity will be same.

3.3 (c)
The minimum ratio of thickness of elements in compression in terms of their outstanding length is specified in order to prevent local buckling of the element and hence to make the entire cross

section effective in compression.

3.4 (b)

When the end of the column is machined for complete bearing on the base plate, 50% of the axial column load is assumed to be transferred to the base plate by direct bearing and the remaining 50% of axial load will be transferred through the fastenings including the gusset plates, angle cleats, stiffeners etc. Where the end of the column shaft and the gusset plates not faced for complete bearing, the fastenings connecting to the base plate are designed to transmit all forces to which the base plate is subjected.

3.5 (d)

Degree of Restraint	Effective Length
(i) Effectively held in position and restrained against rotation at one end, and the other end restrained against rotation but not held in position.	1.2L
(ii) Effectively held in position and restrained against rotation at one end, and the other end is partially restrained against rotation but not held in position.	1.5L
(iii) Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position.	2.0L
(iv) Effectively held in position and restrained against rotation at one end but neither held in position nor restrained against rotation at the other end.	2.0L

3.6 (d)

For design of axially loaded compression member:

- A value of permissible compressive stress is assumed
- For this stress gross area is found.
- A trial section is chosen
- Maximum slenderness ratio for chosen section is found
- Load carrying capacity of chosen member is calculated
- The member is safe if load carrying capacity is equal or greater than the applied load.

Thus compressive strength based on slenderness ratio and cross-gross sectional area of member is most critical set of consideration

3.7 (d)

The grillage base essentially consists of steel beams encased in concrete. They are provided when

(i) The load on the column is very heavy

(ii) The bearing capacity of the soil on which the concrete block is to be placed may be poor.

They are designed for bending, shear and web crippling

4. Beams

4.1 (a)

The maximum bending moment,

$$M = \frac{wl^2}{2} = \frac{20 \times 3^2}{2} = 90 \text{ kN-m}$$

Section modulus of beam,

$$Z = \frac{I_{xx}}{(200/2)} = \frac{1696.6 \times 10^4}{100}$$

$$= 1696.6 \times 10^2 \text{ mm}^3$$

Bending stress,

$$\sigma = \frac{M}{Z} = \frac{90 \times 10^6}{1696.6 \times 10^2}$$

$$= 530.47 \text{ N/mm}^2$$

Maximum shear force,

$$V = wl = 20 \times 3 = 60 \text{ kN}$$

Shear stress, $\tau = \dfrac{V}{t_w d}$

Thickness of web,

$$t_w = 5.4 \text{ mm}$$

$$\therefore \quad \tau = 60 \times 10^3/(5.4 \times 200)$$

$$= 55.5 \text{ N/mm}^2$$

4.2 (b)

For unstiffened webs the permissible shear stress, $\tau_{va} = 0.4\, f_y$

For stiffened web:

(i) For webs where distance between vertical stiffeners (c) is less than 'd'

$$\tau_{va} = 0.4 f_y \left[1.3 - \frac{\sqrt{f_y}(c/t)}{4000\left\{1 + 0.5(c/d)^2\right\}} \right]$$

(ii) for webs where distance between vertical stiffeners (c) is more than 'd'

$$\tau_{va} = 0.4 f_y \left[1.3 - \frac{\sqrt{f_y}(d/t)}{4000\left\{1 + \frac{1}{2}(d/c)^2\right\}} \right]$$

Thus with increased spacing between vertical stiffeners, τ_{va} decreases.

4.3 (b)

In multistoreyed buildings (or tier buildings) consisting of steel stanchions and beam framing, it is advisable to encase the steel frame in concrete to make it fire resistant and more pleasing to eye. It is a composite beam. The minimum width of solid casing is (B + 100). The radius of gyration about yy-axis is 0.2 (B + 100).

4.4 (c)

The framed connection is made by two angles placed on the two sides of the web of the beam. The framed connection and seated connection are classified as flexible connections.
Seated connection consist of a horizontal angle with its horizontal leg at its top to receive the beam on it.

4.5 (d)

Due to small lateral movement of trains even when moving on straight track, lateral forces are applied by the train to the track. This horizontal lateral load (raking force) is taken equal to 5.88 kN/m and treated as a moving load.

4.6 (a)

Wind and earthquake forces are reversible and may be assumed to act along each axis of the building, once at a time. Wind pressure acts on the surface of the building exposed to it. Therefore the frames in the short direction of the building are usually more affected by wind than those in the long direction. But earthquake force is proportional to the mass of each floor and its magnitude changes little from short to long direction. Therefore both transverse and longitudinal frame may be equally affected by it and must be checked in every case.

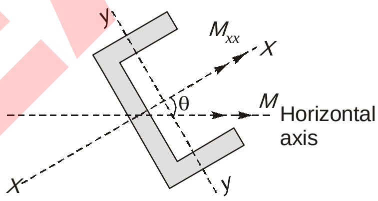
4.7 (a)

Type of member	End Condition of Bracing	Effective length l
Simply supported beams	Restrained against torsion	
	(i) unrestrained against lateral bending	L
	(ii) partially restrained against lateral bending	0.85 L
	(iii) fully restrained against lateral bending	0.7 L
All Members	Effective lateral bracing at intervals along the length	Distance between intersections of bracings with member

5. Plate Girders and Industrial Roofs

5.1 (a)

For vertical loading, the moment about horizontal axis is M. The angle between horizontal axis and $X - X$ axis is $\theta = 30°$.



$$\therefore \quad M_{xx} = M\cos\theta = \frac{\sqrt{3}}{2}M$$

$$M_{yy} = M\sin\theta = \frac{M}{2}$$

5.3 (a)

Web is relatively large in depth and thin. It is poor in compression and hence, the possibility of vertical and diagonal buckling is always there. Either the web is stiffened vertically as well as horizontally or the compressive stress in the web should be low enough to prevent buckling.

5.4 (c)

Flat grid roofs are used for small spans, Trusses and purlins are used for medium spans (20 m to 100 m), span length in shells is usually larger than in trusses and purlins and suspension system are used for very long spans (above 1000 m generally).

5.5 (b)

As per **IS:800-1984** Clause **6.7.3.1 (a)**, the thickness of the web plate for unstiffened web is the greater of $\frac{d\sqrt{\tau_{va,\,cal}}}{816}$ and $\frac{d\sqrt{f_y}}{1344}$ but not less than $\frac{d}{85}$ where $\tau_{va,cal}$ is calculated average stress in the web due to shear force.

5.6 (a)

Under normal circumstances, the crane girder is designed as laterally unsupported beam carrying vertical and horizontal load at the level of the top flange. The channel at top flange

(i) increases moment of inertia about vertical axis.

(ii) improves lateral buckling strength.

The channel used below the compression flange of the wide flange beam and is supported by brackets, increases the torsional stiffness of girder.

5.7 (b)

Assertion is correct as portal bracing are provided in situation where we can not provide cross (diagonal) bracing. The portal bracing transfer the reaction at abutment. They also provide lateral in plane rigidity. Due to rigidity bending moment will develope in end post hence reason is also correct but not a correct explanation to assertion.

5.8 (c)

$$M \propto I$$

$$I_w = \frac{tB^3}{12}$$

$$I = \frac{tB^3}{12} + 2\times\left[\cancelto{0}{\frac{Bt^3}{12}} + (Bt)\times\left(\frac{B}{2}\right)^2\right] = \frac{7tB^3}{12}$$

$$\frac{M_w}{M} = \frac{I_w}{I}$$

$$M_w = \frac{M}{7}$$

5.9 (b)

An angle iron purlin is unsymmetrical about both the axes. **IS:800-1984** permits the use of the angle section as a purlin, provided the slope of the roof truss is less than 30º. The vertical loads and wind loads are assumed to be normal to the roof truss. **The bending moment about minor axis is neglected.** The bending moment in a purlin may be taken as WL/10 where W is the total distributed load on the purlin including wind load. Under the calculated bending moment, the allowable bending stress is taken without lateral instability effect into account. Also, since the roof sheeting provides support against lateral buckling the allowable bending stress is not reduced on this account. For designing purlins, limiting deflection condition for beams is not applied.

5.10 (b)

Wind on moving load (vehicle) is assumed to be acting at 1.5 m above deck and it is 300 kg/m for ordinary high bridges.

5.11 (b)

Design pressure = $(C_{pe} - C_{pi})p$

Where $C_{pe}, C_{pi} \rightarrow$ external and internal pressure coefficients respectively.

Highly permeable buildings have more than 20% openings and $C_{pi} = \pm\, 0.7$

The external wind pressure coefficient depends upon

(i) height to width ratio of the building

(ii) length to width ratio of the building

(iii) angle of incidence

(iv) location of wall with respect to wind, such as windward side or leeward side.

In the absence of any such information (b) is the best option.

5.12 (b)

For broad and metre gauge with single track impact factor $= 0.15 + \frac{8}{6+L}$ subjected to maximum of 1.

For, $L = 6$ m

$$\text{Impact factor} = 0.15 + \frac{8}{12} = 0.15 + 0.67 = 0.82$$

However, there is no such option, therefore the closest answer 0.75 can be chosen.

5.13 (a)

The longitudinal wind force i.e. wind force along the ridge line is resisted by the lateral bracing. Thus lateral bracing of adjacent trusses is necessary in industrial buildings.

5.14 (c)

In the flange area method, the bending stress distribution in the tension and compression flange is assumed to be uniform.

$$M = Td_1 = A_f \sigma_{bt} d_1$$

$$\therefore \quad A_f' = \frac{M}{\sigma_{bt} d_1}$$

where $M \rightarrow$ bending moment

$A_f' \rightarrow$ net flange area

$\sigma_{bt} \rightarrow$ bending tensile stress

$d_1 \rightarrow$ effective depth of plate girder

5.15 (c)

Besides self weight; wind load, live load, impact load, snow load etc. are also considered in the design.

6. Plastic Analysis

6.1 (c)

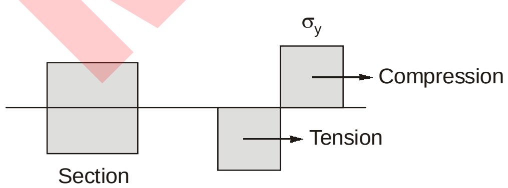
Shape factor for a section is the ratio of plastic moment (plastic section modulus) and the yield moment (elastic section modulus).

Shape	Shape factor
(i) Rectangle or square	1.5
(ii) Circle	1.7
(iii) Triangle	2.34
(iv) Diamond	2.0
(v) I-section	1.1 to 1.2

6.2 (b)

Curvature at plastic hinge is infinite and moment is equal to plastic moment capacity. It means that infinite rotation can occur at fully plastic section.

At the condition of plastic hinge stress distribution will be like



if we apply simple bending formula then

$$\frac{\sigma}{y} = \frac{E}{R}, \quad \text{at } y = 0$$

$$\frac{1}{R} = \frac{\sigma}{y \times E} = \infty$$

$$\Rightarrow \quad \frac{1}{R} = \text{Infinite}$$

Hence, curvature is infinite.

6.3 (b)

Number of hinges needed for failure

$= r + 1$

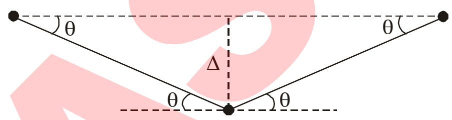
$= 3 + 1$

$= 4.$

$r \rightarrow$ degree of static indeterminacy.

The collapse load will be calculated using

(i) beam mechanism.

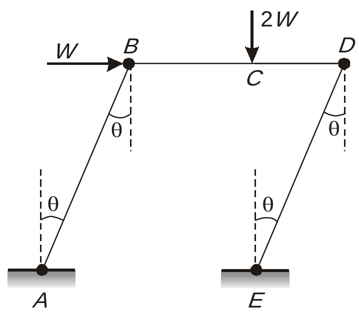


$$2W.\Delta = M_P(\theta) + M_P(2\theta) + M_P(\theta)$$

and $$\Delta = \frac{L\theta}{2}$$

$$\therefore \quad W = \frac{4M_P}{L}$$

(ii) Sway mechanism



$$W\Delta = M_P(\theta + \theta + \theta + \theta)$$

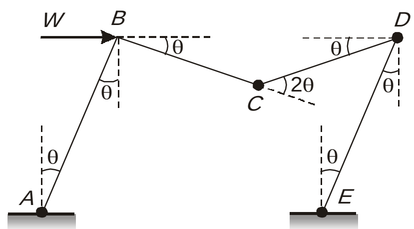
$$\Delta = \frac{L\theta}{2}$$

$$\therefore \quad W = \frac{8M_P}{L}$$

(iii) Combined mechanism

In this case hinges will form at A, C, D and E.

The other combination with hinges at A, B, C, E will give same load.



$$\therefore\ W\Delta_1 + 2W\Delta_2 = M_P(\theta + 2\theta + 2\theta + \theta)$$

$$\Delta_2 = \Delta_1 = \frac{L\theta}{2}$$

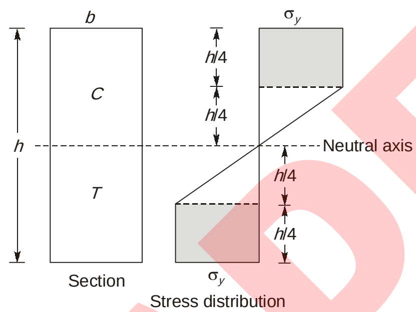
$$\frac{3WL\theta}{2} = 6\,M_P.\theta$$

$$W = \frac{4M_P}{L}$$

The lowest load $\dfrac{4M_P}{L}$ is collapse load

6.4 (c)

As per condition given by the questions stress distribution of section will be given as



Total moment capacity will be $M = M_1 + M_2$

Where M_1 = Moment due to shaded portion

M_2 = Moment due to unshaded portion

For M_1

M_1 = Force × Leverarm

$$= \sigma_y\left(\frac{bh}{4}\right)\times\left(\frac{3}{4}h\right) = \frac{3}{16}\sigma_y bh^2$$

$M_2 = \sigma_y Z$

Where Z = Section modulus of unshaded portion of section

$$= \sigma_y \times \left[\frac{b\left(\frac{h}{2}\right)^2}{6}\right]$$

$$= \left(\frac{1}{24}\right)\sigma_y bh^2$$

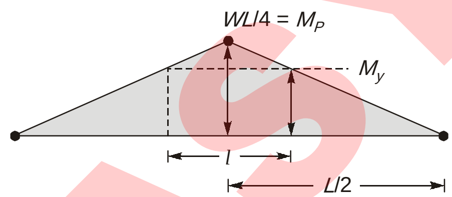
Hence total moment $M = M_1 + M_2$

$$= \frac{3}{16}\sigma_y bh^2 + \frac{1}{24}\sigma_y bh^2$$

$$= \frac{11}{48}\sigma_y bh^2$$

6.5 (a)

For I-section shape factor $\dfrac{M_P}{M_y}$ = 1.1 to 1.2



From the bending moment diagram

$$\frac{W}{2}\left[\frac{L}{2}-\frac{l}{2}\right] = M_y$$

Taking $\quad M_P = \dfrac{WL}{4}$

and $\quad M_y = \dfrac{M_P}{1.1}$

$$l = 0.09\text{ L} = \text{L}/11$$

Taking $\quad M_y = \dfrac{M_P}{1.2}$

$$l = L/6$$

So l varies between $\dfrac{L}{6}$ to $\dfrac{L}{11}$

Therefore $\dfrac{L}{8}$ is suitable choice

Alternative

Length of plastic hinge for beam having concentrated load $= L\left[1-\dfrac{1}{\text{Shape factor}}\right]$

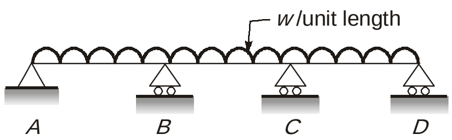
For I-section, shape, factor = 1.12

$$\therefore \text{Length of plastic hinge} = L-\left(1-\frac{1}{1.12}\right) = \frac{1}{10}$$

Closest option is (a)

Note: Length of plastic hinge for section carry uniformly distribution load is $\left[L\sqrt{1-\dfrac{1}{\text{S.F.}}}\right]$

6.6 (c)

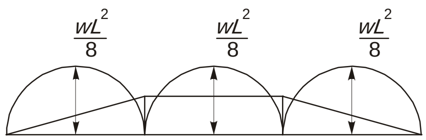


The degree of indeterminacy $r = 4 - 2 = 2$

Number of plastic hinges required for collapse

$= r + 1 = 3$

Using statical method



Moment diagram due to load and redundant forces

In the span AB, maximum moment occurs at support B and at $0.414L$ away from support A. Thus

$$\text{collapse load} = \frac{11.656M_P}{L^2}$$

Checking for this collapse load in span BC, the moment does not exceeds M_P anywhere.

Note: Although number of hinges required for collapse were 3, but formation of two hinges in span AB or CD gives collapse condition.

6.7 (d)

$$\text{Factor of safety} = \frac{\text{Yield stress}}{\text{Allowable stress}}$$

With increase in allowable stress, the factor of safety will reduce to $\frac{1.5}{1.2} = 1.25$.

$\therefore$ Load Factor = FOS × shape factor

$= 1.25 \times 1.12 = 1.40$

6.8 (c)

The yield line theory is the ultimate load theory for RCC slabs. Both the virtual work method as well as equilibrium method give the upper bound solution, i.e. the computed collapse load on the basis of an assumed yield line pattern is bound to be larger than the actual collapse load.

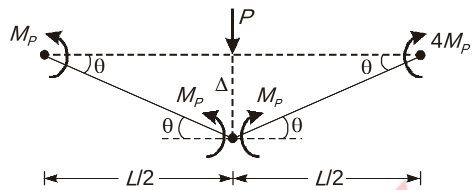
6.9 (c)

Degree of indeterminacy, $r = 2$

Number of plastic hinges needed for collapse

$= r + 1 = 3$

(i) Mechanism 1



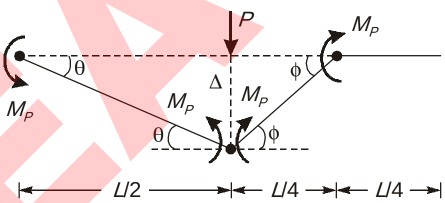
Using virtual work method, we get

$$M_P\theta + M_P(2\theta) + 4M_P\theta = P \times \frac{L}{2}\theta$$

$$\Rightarrow \quad 14M_P = PL$$

$$\Rightarrow \quad P = \frac{14M_P}{L}$$

(ii) Mechanism 2



$$\Delta = \frac{L}{2}\theta = \frac{L}{4}\phi$$

$$\therefore \quad \phi = 2\theta$$

Using virtual work method, we get

$$M_P\theta + M_P\theta + M_P\phi + M_P\phi = P \times \frac{L}{2}\theta$$

$$\Rightarrow 2M_P\theta + 2M_P\phi = P \times \frac{L}{2}\theta$$

$$\Rightarrow \quad 12\,M_P = PL$$

$$\Rightarrow \quad P = \frac{12M_P}{L}$$

Lower load among these mechanisms will be the collapse load.

$$\therefore \quad P = \frac{12M_P}{L}$$

6.10 (c)

$$\text{Fixed end moment} = \frac{w_1L^2}{12} = \frac{W_1L}{12} = M_P$$

$$\therefore \quad W_1 = \frac{12M_P}{L}$$

The plastic hinges are formed only at the ends and the beam has not collapsed yet.

At collapse, third hinge is formed in the middle and collapse load $W_2 = \frac{16M_P}{L}$

6.11 (b)

In the plastic case,

$$M_P + \frac{M_P}{2} = \frac{PL}{4}$$

$$M_P = \frac{PL}{6} = \frac{16PL}{96}$$

In the elastic case maximum moment is

$$\frac{6PL}{32} = \frac{18PL}{96}$$

Thus maximum moment in plastic case is less than elastic case. So the better distribution is obtained in plastic case.

6.12 (c)

$$\text{Margin of safety} = \frac{\text{Collapse load}}{\text{Service load}} - 1$$

$$= \frac{\text{Ultimate stress}}{\text{Permissible stress}} - 1$$

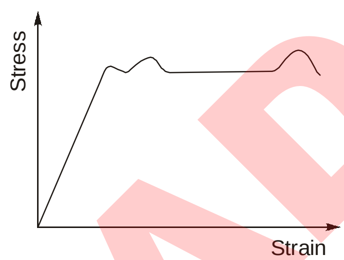
6.13 (d)

Shape factor for rectangular section = 1.5

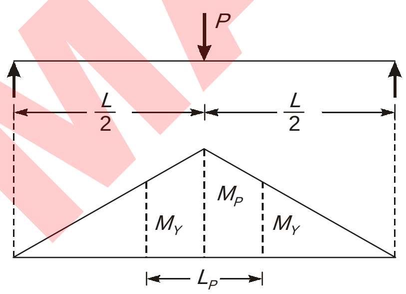
Shape factor for circular section = 1.7

6.14 (d)

Plastic deformation for a ductile structure before failure is much more than elastic deformation.



6.15 (a)



From similar triangles, we have

$$\frac{M_P}{M_Y} = \frac{L/2}{\frac{L}{2} - \frac{L_P}{2}}$$

$$\Rightarrow \quad \frac{L}{L - L_P} = \frac{3}{2}$$

$$\Rightarrow \quad L_P = \frac{L}{3}$$

Alternative:

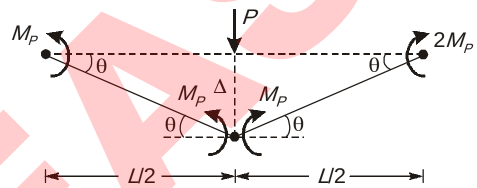
$$\text{Plastic hinge length} = L\left(1 - \frac{1}{\text{Shape factor}}\right)$$

$= L\left(1 - \frac{1}{1.5}\right)$ for rectantular section S.F. = 1.5

$$= \frac{L}{3}$$

6.16 (a)

Number of plastic hinges needed for collapse $= r + 1 = 3$.

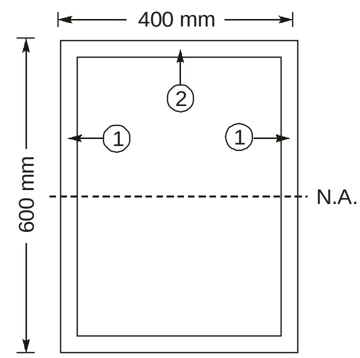


Using virtual work method, we get

$$M_P\theta + M_P(2\theta) + 2M_P\theta = \frac{PL\theta}{2}$$

$$\therefore \quad P = \frac{10M_P}{L}$$

6.18 (d)



Assuming the area as thin area,

$$Z_p = A_1y_1 + A_2y_2 + A_3y_3 + \text{etc.}$$

$$= 2 \times [(300 \times 10) \times (150 + 150)]$$

$$+[(400 \times 10) \times (300 + 300)]$$

$$= 42 \times 10^5 \text{ mm}^3$$

$$\text{Elastic section modulus} = \frac{I_{xx}}{300}$$

$$I_{xx} = \frac{400 \times 600^3}{12} - \frac{380 \times 580^3}{12}$$

$$= 1.021 \times 10^9 \text{ mm}^4$$

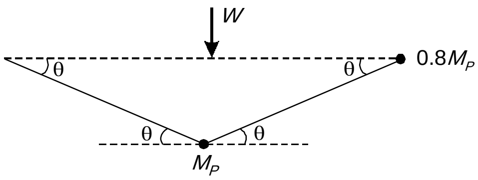
$$Z_y = 34.05 \times 10^5 \text{ mm}^3 \simeq 34 \times 10^5$$

Shape factor $= \dfrac{Z_p}{Z_y} = 1.187$

The shape factor is always greater than one.

6.19 (c)

Failure in the left/right span can be caused by formation of two hinges.



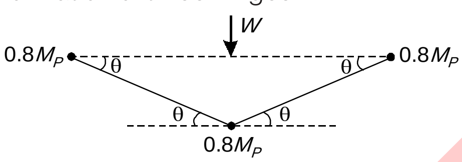
Left/Right span

Using virtual work method

$$W \times \frac{L\theta}{2} = M_P(2\theta) + 0.8M_P\theta$$

$$W = \frac{5.6M_P}{L}$$

The failure in the middle span will be caused by formation of three hinges.



$$\frac{WL\theta}{2} = 0.8M_P(\theta + 2\theta + \theta)$$

$$W = \frac{6.4M_P}{L}$$

The lower load $\dfrac{5.6M_P}{L}$ will be taken as the collapse load.

6.20 (c)

Shape factor $= \dfrac{M_p}{M_e}$

Let w_1 be collapse load, w be the yield load

For rectangular section, SF = 1.5

Now $\quad M_p = \dfrac{w_1 l^2}{16}$

$$M_y = M_e = \frac{wl^2}{12} = \frac{3}{4}\left(\frac{w_1}{w}\right)$$

Given $\quad w = 10$

$\therefore \quad w_1 = \dfrac{1.5 \times 10 \times 4}{3}$

$w_1 = 20$ kN/m

Now hinges at clamps will be formed at a load equal to w_2 = Shape Factor × w_1

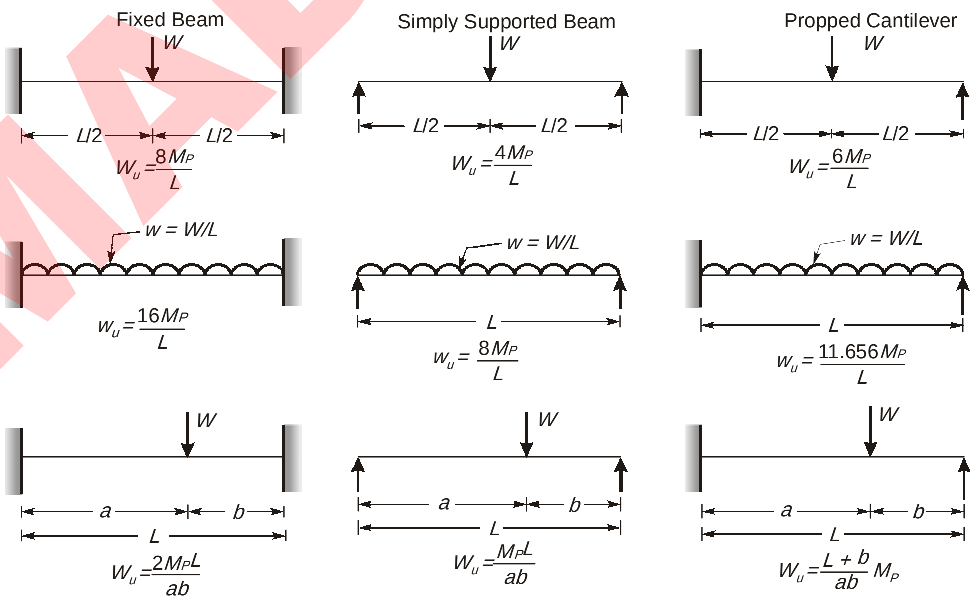
= 1.5 × 10 = 15 kN/m

Since beam is clamped at both the end, so it can be treated as fixed beam.

Load required to collapse the beam, after becoming two hinges at the fixed end is,

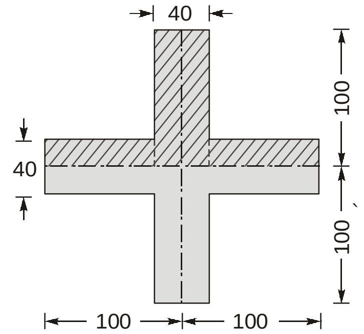
Collapse load, $w_u = \dfrac{4}{3} \times 15 = 20$ kN/m

6.21 (a)



Ratio of collapse load of propped cantilever beam to the simply supported beam is $\dfrac{11.656}{8} = 1.457$

6.22 (b)



$$Z_P = \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$$

$$= [(40 \times 100) \times (50 + 50)] + [(160 \times 20) \times (10 + 10)]$$

$$= 464000 \text{ mm}^3$$

$$Z = \frac{I_{xx}}{y}$$

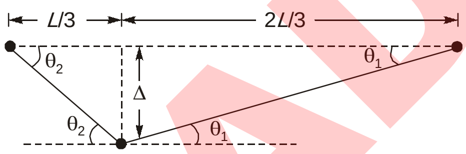
$$= \frac{\left[\frac{40 \times 200^3}{12} + \frac{160 \times 40^3}{12}\right]}{100}$$

$$= \frac{(40 \times 200^3) + (160 \times 40^3)}{1200}$$

$$\text{S.F.} = \frac{Z_p}{Z} = \frac{145}{86}$$

6.23 (c)

The plastic hinges will form at both fixed ends and under the load.

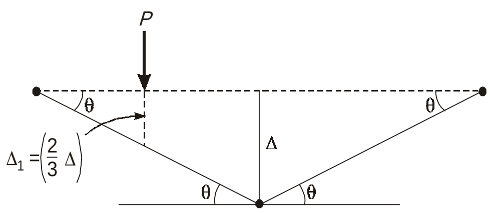


$$P\Delta = 2M_P\theta_2 + 2M_P(\theta_1 + \theta_2) + M_P\theta_1$$

$$= 2M_P \frac{3\Delta}{L} + 2M_P\left(\frac{3\Delta}{L} + \frac{3\Delta}{2L}\right) + M_P\left(\frac{3\Delta}{2L}\right)$$

$$P = \frac{16.5M_P}{L}$$

Considering hinges at both fixed ends and at section change.



$$\Delta = \theta L/2$$

$$\Delta_1 = \theta L/3$$

$$P\Delta_1 = 2M_P\theta + M_P 2\theta + M_P\theta = 5M_P\theta$$

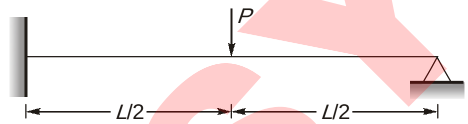
$$P = 15M_P/L$$

Lower load is the collapse load.

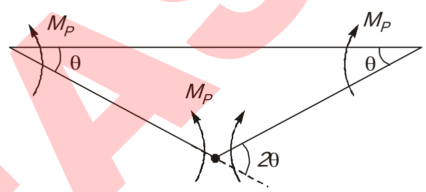
6.24 (c)

To convert indeterminate frame to determinate frame, the number of plastic hinges required is equal to the degree of static indeterminacy.

6.25 (c)



By Kinematic method



By virtue work principle:

$$\frac{PL\theta}{2} = M_p\theta + 2M_p\theta$$

$$P = \frac{6M_P}{L}$$

6.26 (d)

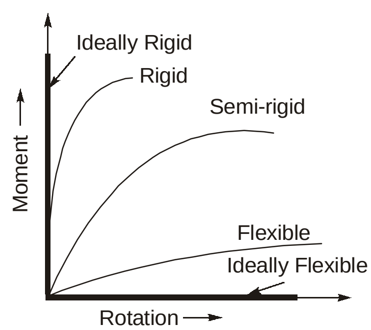
According to IS code based on connection rigidity joint can be defined as:

Rigid joint: These joint develope full moment capacity of connecting member and retain original angle between member under any joint rotation.

Simple/Flexible joint: No moment transfer takes place between connected part. Rotation movement of joint will be large in this case.

Semi rigid joint: These connection may not have sufficient rigidity to hold the original angles between the member and develope less than full moment capcity.

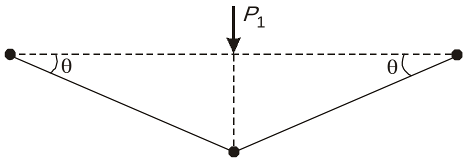
Graphical representation of connection are as:



6.27 (a)

Strain distribution across a section is linear is one of the basic assumption in plastic theory.

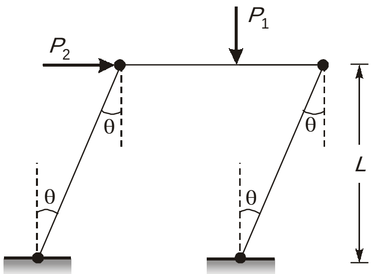
6.28 (b)



Beam mechanism

$$P_1 = \frac{8M_P}{L}$$

Sway mechanism



$$P_2 = \frac{4M_P}{L}$$

$$\therefore \quad \frac{P_1}{P_2} = 2$$

6.29 (d)

In Elastic buckling and lateral buckling the beam does not reach its yield strength and hence not considered for plastic design. A steel beam fails plastically by formation of hinges due to yielding of steel at point of maximum stress.

■■■■

UNIT

V

Design of Concrete & Masonry Structures

Syllabus

Limit state design for bending, shear, axial compression and combined forces; Design of beams, Slabs, Lintels, Foundations, Retaining walls, Tanks, Staircases; Principles of pre-stressed concrete design including materials and methods; Earthquake resistant design of structures; Design of Masonry Structure.

Contents

5 Design of Concrete & Masonry Structures

1. Fundamentals of RCC

1.1 Consider the following statements concerning both the working stress design and ultimate strength design of reinforced concrete:

1. Plane section before bending remains plane after bending
2. The tensile strength of concrete is ignored.

Which of these statements is/are correct?

(a) 1 alone (b) 2 alone
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 1995]

1.2 If f_{cu} and f_y are cube compressive strength of concrete and yield stress of steel respectively and E_s is the modulus of elasticity of steel for all grades of concrete, the ultimate flexural strain in concrete can be taken as

(a) 0.002 (b) $\frac{f_{cu}}{1000}$
(c) 0.0035 (d) $\frac{f_y}{1.15E_s} + 0.002$

[ESE : 1995]

1.3 Limit state of serviceability for deflection including the effects due to creep, shrinkage and temperature occurring after erection of partitions and application of finishes as applicable to floors and roofs is restricted to

(a) $\frac{\text{Span}}{150}$ (b) $\frac{\text{Span}}{200}$
(c) $\frac{\text{Span}}{250}$ (d) $\frac{\text{Span}}{350}$

[ESE : 1995]

1.4 In case of a composite construction, the effect of creep and shrinkage

(a) can be ignored even at the limit state of serviceability
(b) can be ignored at the ultimate limit state due to large inelastic strains induced
(c) can be completely eliminated if the props are removed after 28 days
(d) in the in-situ concrete has no interaction on the stresses in the pre-cast component at any stage **[ESE : 1995]**

1.5 The maximum strain in concrete at the outermost compression fiber in the limit state design of flexural member is (as per **IS:456-1978**)

(a) 0.0020 (b) 0.0035
(c) 0.0065 (d) 0.0050

[ESE : 1996]

1.6 Deflection can be controlled by using the appropriate

(a) aspect ratio (b) modular ratio
(c) span/depth ratio (d) water/cement ratio

[ESE : 1996]

1.7 In limit state approach, spacing of main reinforcement controls primarily

(a) collapse (b) cracking
(c) deflection (d) durability

[ESE : 1996]

1.8 Unequal top and bottom reinforcement in a reinforced concrete section leads to

(a) creep deflection
(b) shrinkage deflection
(c) long-term deflection
(d) large deflection **[ESE : 1996]**

1.9 The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from as cast level of supports of floors, roofs and all other horizontal members should NOT exceed

(a) span/350 (b) span/300
(c) span/250 (d) span/200

[ESE : 1997]

1.10 High yield deformed bars have a
(a) definite yield value
(b) chemical composition different from mild steel
(c) percentage elongation less than that of mild steel
(d) percentage elongation more than that of mild steel
[ESE : 1998]

1.11 The limiting compressive strain of concrete in bending is
(a) 0.0035 (b) 0.0015
(c) 0.0025 (d) 0.015
[ESE : 1998]

1.12 When assessing the strength of a structure as per the limit state of collapse, the value of partial safety factor for steel is taken as
(a) 2.0 (b) 1.5
(c) 1.15 (d) 1.00
[ESE : 1998]

1.13 Combination of partial safety factors for loads under limit state of collapse and limit state of serviceability will be
(a) 1.5 ($DL + LL$) or 1.5 ($DL + WL$) or 1.2 ($DL + LL + WL$) and DL + 0.8 ($LL + WL$)
(b) 1.5 ($DL + LL$) and DL + 0.8 ($LL + WL$)
(c) 1.5 ($DL + LL$) or 1.5 ($DL + WL$) or 1.2 ($DL + LL + WL$) and 1.0 ($DL + LL$) or 1.0 ($DL + WL$) or DL + 0.8 ($LL + WL$)
(d) 1.2 ($DL + LL + WL$) and 1.0 ($DL + LL$) or 1.0 ($DL + WL$) or DL + 0.8 ($LL + WL$)
[ESE : 1998]

1.14 The assumption that the plane sections normal before bending remain normal after bending is used
(a) only in the working stress method of design
(b) only in the limit-state method of design
(c) in both working stress and limit-state methods of design
(d) only in the ultimate load method of design
[ESE : 1998]

1.15 In the limit state method of design, the failure criterion for reinforced concrete beams and columns is
(a) maximum principal stress theory
(b) maximum principal strain theory
(c) maximum shear stress theory
(d) maximum strain energy theory
[ESE : 1998]

1.16 As per **IS:456-1978**, the ratio of stress in concrete to its characteristic strength at collapse in flexure for design purposes is taken as
(a) 0.67 (b) 0.576
(c) 0.447 (d) 0.138
[ESE : 1999]

1.17 In limit state design of reinforced concrete, deflection is computed by using
(a) initial tangent modulus
(b) secant modulus
(c) tangent modulus
(d) short-and long-term values of Young's modulus
[ESE : 1999]

2. Beams and Slabs

2.1 In case of 2-way slab, the limiting deflection of the slab is
(a) primarily a function of the long span
(b) primarily a function of the short span
(c) independent of long or short spans
(d) dependent on both long and short spans
[ESE : 1995]

2.2 From limiting deflection point of view, use of high strength steel in RC beam results in
(a) reduction in depth
(b) no change in depth
(c) increase in depth
(d) increase in width [ESE : 1995]

2.3 A slab-beam floor system may be supported on brick walls or framed into a system of RC columns. The floor thickness (slab + beam web) for the same span will be
(a) less when framed into a system of RC columns
(b) less when supported on brick walls
(c) the same in both the cases
(d) equal to the wall thickness or size of column
[ESE : 1995]

2.4 For maximum sagging bending moment at support in a continuous RC beam, live load should be placed on

(a) spans adjacent to the support plus alternate spans
(b) all the spans except the spans adjacent to the support
(c) spans next to the adjacent spans of the support plus alternate spans
(d) spans adjacent to supports only

[ESE : 1995]

2.5 Design of one-way RC slabs for concentrated load is done by

(a) using Pigeaud's moment coefficients
(b) taking slab strip of unit width containing the load
(c) taking slab strip of width effective in resisting the deflection
(d) taking orthogonal slab strips of unit width containing the load

[ESE : 1995]

2.6 The main reinforcement of a RC slab consists of 10 mm bars at 10 cm spacing. If it is desired to replace 10 mm bars by 12 mm bars, then the spacing of 12 mm bars should be

(a) 12 cm (b) 14 cm
(c) 14.40 cm (d) 16 cm

[ESE : 1995]

2.7 Shrinkage deflection in case of rectangular beams and slabs can be eliminated by putting

(a) compression steel equal to tensile steel
(b) compression steel more than tensile steel
(c) compression steel less than tensile steel
(d) compression steel 25% greater than tensile steel

[ESE : 1995]

2.8 A T-beam roof section has the following particulars:

Thickness of slab : 100 mm
Width of rib : 300 mm
Depth of beam : 500 mm
Centre to centre distance of beams : 3.0 m
Effective span of beams : 6.0 m
Distance between points of contraflexure : 3.60 m

The effective width of flange of the beam is

(a) 3000 mm (b) 1900 mm
(c) 1600 mm (d) 1500 mm

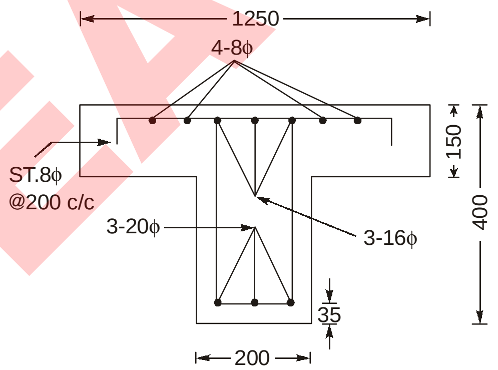
[ESE : 1996]

2.9 A simply supported isotropically reinforced square slab of side 4 m is subject to a service load of 6 kPa. The thickness of the slab is 120 mm. The moment of resistance required as per yield line theory is

(a) 9 kN-m (b) 9 kNm/m
(c) 13.2 kN-m (d) 13.2 kNm/m

[ESE : 1996]

2.10 For the section of the beam shown in the given figure, span of the beam = 6.0 m, concrete = *M* 20, steel = Fe 415.



If the section is checked for serviceability limit state of deflection, then it will be found that

(a) the section is unsafe
(b) the section needs revision
(c) the section is safe
(d) it cannot be judged from the given data

[ESE : 1996]

2.11 Given that *d* = effective depth, *b* = width and *D* = overall depth, the maximum area of compression reinforcement in a beam is

(a) 0.04 bd (b) 0.04 bD
(c) 0.12 bd (d) 0.12 bD

[ESE : 1997]

2.12 A reinforced concrete slab is 75 mm thick. The maximum size of reinforcement bar that can be used is

(a) 12 mm diameter (b) 10 mm diameter
(c) 8 mm diameter (d) 6 mm diameter

[ESE : 1997]

2.13 In the design of two-way slab restrained at all edges, torsional reinforcement required is
(a) 0.75 times the area of steel provided at midspan in the same direction
(b) 0.375 times the area of steel provided at midspan in the same direction
(c) 0.375 times the area of steel provided in the shorter span
(d) nil

[ESE : 1997]

2.14 Side face reinforcement is provided in a beam when the depth of web exceeds
(a) 300 mm (b) 450 mm
(c) 500 mm (d) 750 mm

[ESE : 1997]

2.15 Drops are provided in flats slabs to resist
(a) bending moment (b) thrust
(c) shear (d) torsion

[ESE : 1997]

2.16 **Assertion (A)** : The behaviour of an over reinforced beam is more ductile than that of an under reinforced beam.
Reason (R) : Over reinforced beam contains more steel and steel is more ductile than concrete.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.17 Flexural collapse in over reinforced beams is due to
(a) primary compression failure
(b) secondary compression failure
(c) primary tension failure
(d) bond failure

[ESE : 1997]

2.18 A square slab 4 m × 4 m is isotropically reinforced at the bottom. If it is subjected to a working load of 12 kPa (including self-weight), the moment capacity required as per yield line theory is
(a) 6 kN-m/m (b) 8 kN-m/m
(c) 10 kN-m/m (d) 12 kN-m/m

[ESE : 1997]

2.19 A reinforced cantilever beam of span 4 m, has a cross-section of 150 mm × 500 mm. If checked for lateral stability and deflection, the beam will
(a) fail in deflection only
(b) fail in lateral stability only
(c) fail in both deflection and lateral stability
(d) satisfy the requirements of deflection and lateral stability

[ESE : 1997]

2.20 In an RCC beam, side face reinforcement is provided if its depth exceeds
(a) 300 mm (b) 500 mm
(c) 700 mm (d) 750 mm

[ESE : 1998]

2.21 The bending moment coefficients for continuous *RC* slabs in **IS: 456-1978** code is based on
(a) Pigeaud's method
(b) Marcus's method
(c) Yield-line theory
(d) Westergaard's mathematical analysis

[ESE : 1998]

2.22 The sum of nodal forces at any yield line intersection in a slab is
(a) zero
(b) infinity
(c) independent of the reinforcement
(d) indeterminate

[ESE : 1998]

2.23 For a composite steel-beam and RCC-slab floor construction
(a) the grade of concrete has to be M20 for the composite action to be satisfactory
(b) the longitudinal reinforcement of the slab has to be welded to the beam to develop monolithicity
(c) a notch is made in the slab to house the upper flange of the beam
(d) shear connectors are provided to develop the composite action

[ESE : 1998]

2.24 The effective width 'b_f' of flange of a continuous T-beam in a floor system is given by

$$b_f = \frac{L_o}{6} + b_w + 6D_f$$

where L_0 represents the

(a) distance between points of contraflexure in a span
(b) effective span of beams
(c) clear span of beams
(d) spacing between beams

[ESE : 1999]

2.25 Beam sections of reinforced concrete designed in accordance with ultimate strength or limit state design approach, as compared to sections designed by working stress method for the same conditions of load and span, and the same width, usually have
(a) a larger depth and smaller amount of reinforcement
(b) the same depth and same reinforcement
(c) smaller depth and more reinforcement
(d) same depth as that of a deep beam

[ESE : 1999]

2.26 A doubly reinforced beam is considered less economical than a singly reinforced beam because
(a) tensile steel required is more than that for a balanced section
(b) shear reinforcement is more
(c) concrete is not stressed to its full value
(d) compressive steel is under-stressed

[ESE : 1999]

2.27 As per IS:456-1978 the vertical deflection limit for beams may generally be assumed to be satisfied provided that the ratio of span to effective depth of a continuous beam of span up to 10 m is not be greater than
(a) 35 (b) 26
(c) 20 (d) 18

[ESE : 1999]

2.28 Negative moment in reinforced concrete beams at the location of supports is generally much higher than the positive span moment. This is primarily due to curvature at the supports being
(a) very high (b) very low
(c) zero (d) of reversing nature

[ESE : 1999]

2.29 In an RCC beam of breadth '*b*' and overall depth *D* exceeding 750 mm, side face reinforcement required and the allowable area of maximum tension reinforcement shall be respectively
(a) 0.2% and 0.02 bD
(b) 0.3% and 0.03 bD
(c) 0.1% and 0.04 bD
(d) 0.4% and 0.01 bD

[ESE : 1999]

3. Shear, Bond, Torsion and Development Length

3.1 Torsion resisting capacity of a given *RC* section
(a) decreases with decrease in stirrup spacing
(b) decreases with increase in longitudinal bars
(c) does not depend upon stirrup and longitudinal steels
(d) increases with the increase in stirrup and longitudinal steels

[ESE : 1995]

3.2 If the nominal shear stress (τ_v) at a section does not exceed the permissible shear stress (τ_c)
(a) minimum shear reinforcement is still provided
(b) shear reinforcement is provided to resist the nominal shear stress
(c) no shear reinforcement is provided
(d) shear reinforcement is provided for the difference of the two

[ESE : 1995]

3.3 In limit state design, permissible bond stress in the case of deformed bars is more than that in plain bars by
(a) 60% (b) 50%
(c) 40% (d) 25%

[ESE : 1995]

3.4 Shear span is defined as the zone where
(a) bending moment is zero
(b) shear force is zero
(c) shear force is constant
(d) bending moment is constant

[ESE : 1996]

3.5 The safe shear resistance of an anchor connector is given by (K is a coefficient and other symbols have the usual meanings)

(a) $V = Kf_{sy}A_t$ (b) $V = Kf_{sy}^2A_t$

(c) $V = Kf_{sy}^{1/2}A_t$ (d) $V = Kf_{sy}^{1/2}A_t^{1/2}$

[ESE : 1998]

3.6 Consider the following statements:

1. At a point of inflection, the embedment length need not exceed the development length L_d.
2. The condition that $L_d \le \left(\frac{M_1}{V} + L_0\right)$ need not be checked for negative reinforcement.
3. At least one-third of the total negative reinforcement provided must extend beyond the point of inflection for a distance not less than 'd' or 12ϕ or clear-span whichever is larger.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2

(c) 1 and 3 (d) 2 and 3

[ESE : 1999]

3.7 Match **List-I** (Stress) with **List-II** (Nature) and select the correct answer using the codes given below the lists:

List-I

A. Bond stress

B. Thermal stress

C. Hoop stress

D. Torsional stress

List-II

1. Zero at centre of cross-section

2. Circumferential stress

3. Linear stress

4. Longitudinal shear stress

5. Zero on the surface

Codes:

	A	B	C	D
(a)	5	2	4	1
(b)	4	3	2	1
(c)	4	5	2	3
(d)	1	3	4	5

[ESE : 1999]

3.8 **Assertion (A) :** The development length for HYSD Fe 415 bars is less than that for mild steel plain bars.

Reason (R) : The permissible bond stress for HYSD Fe 415 bars is more than that for mild steel plain bars.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1999]

4. Walls, Columns and Footings

4.1 Minimum clear cover (in mm) to the main steel bars in slab, beam, column and footing respectively are

(a) 10, 15, 20, 25 (b) 15, 25, 40, 40

(c) 20, 25, 30, 40 (d) 20, 35, 40, 75

[ESE : 1995]

4.2 Which one of the following statements is correct?

(a) Maximum longitudinal reinforcement in an axially loaded short column is 6% of gross sectional area

(b) Columns with circular section are provided with transverse reinforcement of helical type only

(c) Spacing of lateral ties cannot be more than 16 times the diameter of the tie bar

(d) Longitudinal reinforcement bar need not be in contact with lateral ties

[ESE : 1995]

4.3 Match **List-I** (Condition of support) with **List-II** (Effective length of load bearing wall) and select the correct answer using the codes given below the lists (L = the length of wall between centres of piers, buttresses or cross walls):

List-I

A. Wall is continuous and supported by cross walls or buttresses and there is no opening within one eighth of the wall height

B. Wall is supported by a buttress or cross wall at one end and continues with buttress or cross wall supported at other end.

C. Wall is supported at each end by a buttress or a cross wall

D. Wall is free at one end and supported by a buttress or cross wall at the other end

List-II

1. 2.0L
2. 0.8L
3. 0.9L
4. 1.0L

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	4	1
(c)	3	2	4	1
(d)	2	3	1	4

[ESE : 1996]

4.4 The limits of percentage 'p' of the longitudinal reinforcement in a column is

(a) 0.15% to 2% (b) 0.8% to 4%
(c) 0.8% to 6% (d) 0.8% to 8%

[ESE : 1996]

4.5 Match **List-I** with **List-II** regarding the minimum concrete cover to reinforcing steel and select the correct answer using the codes given below the lists:

List-I

A. For longitudinal reinforcement in columns of size 200 mm and less, with 12 mm diameter bars as longitudinal steel.

B. For longitudinal reinforcement in beams.

C. For longitudinal bars in slabs.

D. For longitudinal bars in columns of size more than 200 mm.

List-II

1. 40 mm or diameter of bar whichever is more
2. 15 mm or diameter of bar whichever is more
3. 25 mm or diameter of bar whichever is more
4. 25 mm

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	2	3	4
(c)	1	3	2	4
(d)	4	2	3	1

[ESE : 1996]

4.6 The load carrying capacity of a column designed by working stress method is 500 kN. The collapse load of the column is

(a) 500.0 kN (b) 662.5 kN
(c) 750.0 kN (d) 1100.0 kN

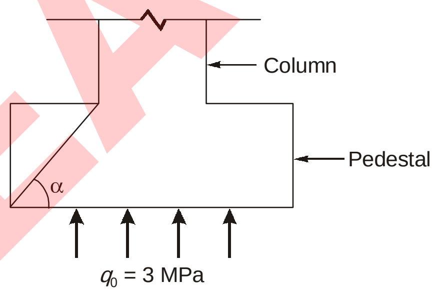
[ESE : 1996]

4.7 Design of foundation for a large generator is guided, primarily, by

(a) frequency (b) deformation
(c) strength (d) stiffness

[ESE : 1996]

4.8 A concrete pedestal made of M20 mix is shown in the figure below. The tanα value in this case will be



(a) not less than 3.5
(b) less than or equal to 3.6
(c) greater than 3.6
(d) greater than or equal to 3.6

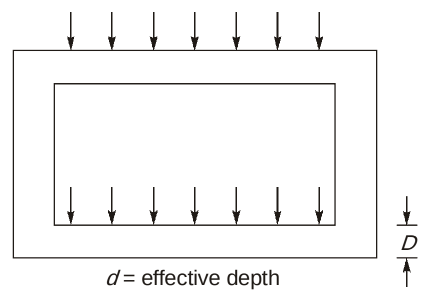
[ESE : 1997]

4.9 The reduction coefficient of a reinforced concrete column with an effective length of 4.8 m and size 250 mm × 300 mm is

(a) 0.80 (b) 0.85
(c) 0.90 (d) 0.95

[ESE : 1997]

4.10 A box girder section is subjected to loads as shown in the figure below. The critical section for shear in the bottom slab will occur at



(a) D from the face of the wall
(b) 'd' from the face of the wall
(c) '$d/2$' from the face of the wall
(d) the face of the wall

[ESE : 1997]

4.11 The maximum spacing of vertical reinforcement in RCC wall should **NOT** exceed
(a) the thickness of wall
(b) 1.5 times the thickness of wall
(c) 2 times the thickness of wall
(d) 3 times the thickness of wall

[ESE : 1998]

4.12 In a reinforced concrete retaining wall, a shear key is provided, if the
(a) shear stress in the vertical stem is excessive
(b) shear force in the toe slab is more than that in the heel slab
(c) retaining wall is not safe against sliding
(d) retaining wall is not safe against overturning

[ESE : 1998]

4.13 In an underground warehouse, the external walls
(a) are designed as curtain walls
(b) are designed as retaining walls with or without surcharge
(c) are designed only for vertical loads imposed by the upper floors
(d) do not share any dynamic loads caused by the movement of trucks and fork-lift vehicles.

[ESE : 1998]

5. Prestress Concrete

5.1 If a simply supported concrete beam, prestressed with a force of 2500 kN is designed by load balancing concept for an effective span of 10 m and to carry a total load of 40 kN/m, the central dip of the cable profile should be
(a) 100 mm (b) 200 mm
(c) 300 mm (d) 400 mm

[ESE : 1995]

5.2 In case of pre-tensioned RC beams
(a) shrinkage of concrete is of the order of 3×10^{-4}
(b) relaxation of steel can be ignored
(c) only one wire can be stretched at a time
(d) even mild steel can be used for prestressing

[ESE : 1995]

5.3 For prestressed structural elements, high strength concrete is used primarily because
(a) both shrinkage and creep are more
(b) shrinkage is less but creep is more
(c) modulus of elasticity and creep values are higher
(d) high modulus of elasticity and low creep

[ESE : 1995]

5.4 Prestressed concrete is more desirable in case of
(a) cylindrical pipe subjected to internal fluid pressure
(b) cylindrical pipe subjected to external fluid pressure
(c) cylindrical pipe subjected to equal internal and external fluid pressures.
(d) cylindrical pipe subject to end pressures

[ESE : 1995]

5.5 **Assertion (A) :** Losses in prestress of pretensioned beam are more than the losses in post-tensioned beam.
Reason (R) : This is partially due to the effect of elastic shortening.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

5.6 In a load-balanced prestressed concrete beam under self load the cross-section is subjected to
(a) axial stress
(b) bending stress
(c) axial and shear stress
(d) axial and bending stress

[ESE : 1996]

5.7 Which one of the following statements is correct?
(a) Web shear cracks start due to high diagonal tension in case of beams with their webs and high prestressing force.

(b) Shear design for a prestressed concrete beam is based on elastic theory.
(c) In the zone where bending moment is dominant and shear is insignificant, cracks occur at 20° to 30°.
(d) After diagonal cracking, the mechanism of shear transfer in a prestressed concrete member is very much different from that in reinforced concrete members.

[ESE : 1996]

5.8 A prestressed concrete beam 150 mm × 300 mm supports a live load of 5 kN/m over a simple span of 8 m. It has a parabolic cable having an eccentricity of 75 mm at mid-span and zero at the ends. The prestressing force required to maintain the net resultant stress at the bottom fibre at mid-span as zero under the action of *DL* + *LL* + prestress is
(a) 239 kN (b) 293 kN
(c) 302 kN (d) 392 kN

[ESE : 1996]

5.9 A partially prestressed member is one in which
(a) tensile stresses and cracking are permitted under service loads
(b) no tensile stresses are permitted under service loads
(c) mild steel is used in addition to prestressing steel
(d) tensile stresses are permitted but not cracking at service loads

[ESE : 1996]

5.10 For a prestressed concrete continuous beam, it is true that the concordant cable profile
(a) is not unique in any given statically indeterminate beam but it is located within a certain narrow zone
(b) may be selected so that it causes no secondary stresses ignoring economy
(c) may be chosen as a compromise between the secondary stresses and the working stress based on economy
(d) should be chosen consistent with all the statements made in (a), (b) and (c)

[ESE : 1996]

5.11 For ultimate load design of prestressed concrete girders used for bridges, combination of load factors used is (where *DL* and *LL* are dead and live loads respectively)
(a) 1.5 *DL* + 2.5 *LL* (b) 1.0 *DL* + 2.5 *LL*
(c) 1.0 *DL* + 2.0 *LL* (d) 2.0 *DL* + 2.0 *LL*

[ESE : 1996]

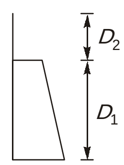
5.12 The prestress profile in mass-produced pretensioned slab units of 2.8 m span for normal residential buildings would generally be
(a) axial along centroidal axis
(b) parabolic below centroidal axis with zero eccentricity at ends
(c) straight along top kern
(d) straight along bottom kern

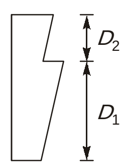
[ESE : 1996]

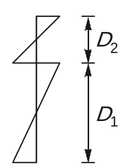
5.13 For a pretensioned rectangular plank the uplift at centre on release of wires from anchors due to pretensioning only (force *P*, eccentricity *e*) will be
(a) $\dfrac{PeL^2}{6EI}$ (b) $\dfrac{Pe^2L}{6EI}$
(c) $\dfrac{PeL^2}{8EI}$ (d) $\dfrac{Pe^2L}{8EI}$

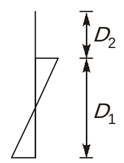
[ESE : 1996]

5.14 A pretensioned plank (depth D_1) is placed over simple supports and additional in situ concrete (depth D_2) is laid on top. What is the probable shape of stress block on hardening of in situ concrete?

(a)


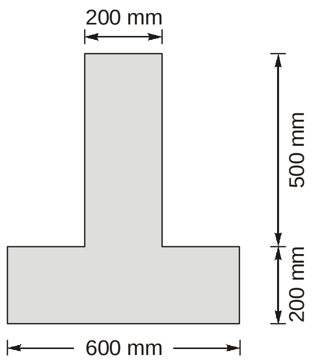
(b)


(c)


(d)


[ESE : 1996]

5.15 A culvert is constructed with pretensioned inverted *T* section and subsequent in situ concrete. Concrete grade corresponds to σ_c = 7 MPa. For the section shown in the given figure, the maximum prestressing force will be



(a) 620 kN (b) 890 kN
(c) 970 kN (d) 1060 kN

[ESE : 1996]

5.16 At the time of initial tensioning, the maximum tensile stress in tendon immediately behind the anchorage shall NOT exceed

(a) 50% of the ultimate tensile strength of the wire or bar or strand
(b) 80% of the ultimate tensile strength of the wire or bar or strand
(c) 40% of the ultimate tensile strength of the wire or bar or strand
(d) 60% of the ultimate tensile strength of the wire or bar or strand

[ESE : 1997]

5.17 The cable for a prestressed concrete simply supported beam subjected to uniformly distributed load over the entire span should ideally be

(a) placed at the centre of cross-section over the entire span
(b) placed at some eccentricity over the entire span
(c) varying linearly from the centre of cross-section at the ends to maximum eccentricity at the middle section
(d) parabolic with zero eccentricity at the ends and maximum eccentricity at the centre of the span

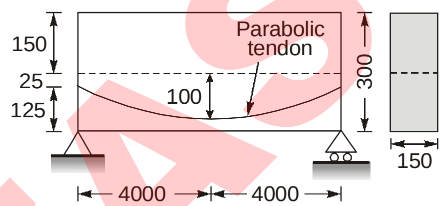
[ESE : 1997]

5.18 For a prestressed concrete bridge beam, a minimum clear spacing of the cable or group of cables should be

(a) 25 mm
(b) 25 mm or 6 mm plus the largest size of the aggregate
(c) 40 mm
(d) 50 mm

[ESE : 1997]

5.19 In the PSC beam shown, f_{ck} = 45 MPa and it supports a UDL of 15 kN/m including self weight. It is prestressed by a parabolic cable carrying an effective prestress of 200 kN. The shear resistance of uncracked section at the support will be



All dimensions are in mm

(a) 93.8 kN (b) 94.5 kN
(c) 94.2 kN (d) 95.4 kN

[ESE : 1997]

5.20 In the case of a P.S.C. beam, to satisfy the Limit State of Serviceability in cracking, match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Class 1 structure
B. Class 2 structure
C. Class 3 structure

List-II

1. No visible cracking $\sigma_1 < 3$ N/mm^2
2. Concrete section uncracked; crack width to be calculated to check
3. No cracking under service loads

Codes:

	A	B	C
(a)	1	2	3
(b)	2	1	3
(c)	3	1	2
(d)	3	2	1

[ESE : 1997]

5.21 In a composite construction,

(a) interface slipping is prevented by using shear connectors
(b) differential shrinkage is overcome by using the same grade of concrete for both the components

(c) precast member is always designed to carry the weight of in-situ concrete without props
(d) the in-situ concrete cannot be prestressed

[ESE : 1997]

5.22 The magnitude of loss of prestress due to relaxation of steel is in the range of
(a) zero to 1% (b) 2 to 8%
(c) 8 to 12% (d) 12 to 14%

[ESE : 1998]

5.23 In the design of prestressed concrete structure, which of the following limit states will come under the limit states of serviceability?
1. Flexure 2. Shear
3. Deflection 4. Cracking

Select the correct answer using the codes given below :
(a) 1 and 4 (b) 3 and 4
(c) 2, 3 and 4 (d) 2 and 3

[ESE : 1998]

5.24 In pre-tensioning scheme, pre-stress load is transferred in
(a) a single stage process
(b) multi stage process
(c) either single stage or multi-stage process depending upon the magnitude of load transfer
(d) the same manner as in post-tensioning scheme

[ESE : 1999]

5.25 In the conventional prestressing, the diagonal tension in concrete
(a) increases
(b) decreases
(c) does not change
(d) may increase or decrease

[ESE : 1999]

5.26 The ultimate moment resisting capacity of a simply supported prestressed concrete beam is obtained by using
(a) force and moment equilibrium equations
(b) stress-strain relationship of concrete and steel
(c) moment equilibrium and compatibility condition
(d) force equilibrium equation alone

[ESE : 1999]

5.27 The ultimate strength of the steel used for prestressing is nearly
(a) 250 N/mm^2 (b) 415 N/mm^2
(c) 500 N/mm^2 (d) 1500 N/mm^2

[ESE : 1999]

6. Masonry Structures and Earthquake Engineering

6.1 For masonry built in 1:1:6 cement-lime-sand mix mortar or equivalent, the horizontal shear stress permissible on the area of a mortar bed joint is
(a) 0.15 MPa (b) 0.125 MPa
(c) 0.1 MPa (d) 0.075 MPa

[ESE : 1999]

6.2 Direct load carrying capacity of a brick masonry wall standing freely as against when it supports RC slab will be
(a) more
(b) less
(c) the same in both the cases
(d) 100% more

[ESE : 1995]

6.3 A brick masonry wall of nominal thickness 200 mm carries an axial load of 26 kN/m and another load of 19 kN/m acting at an eccentricity of 45 mm. The resultant eccentricity and eccentricity ratio are respectively
(a) 19 mm, 0.095 (b) 19 mm, 0.1
(c) 22 mm, 0.11 (d) 24 mm, 0.12

[ESE : 1996]

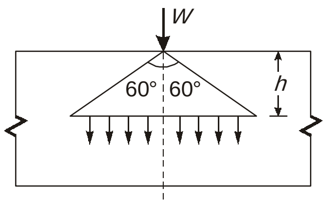
6.4 A 200 mm thick wall made of modular bricks is 5 m long between cross walls and 3.8 m clear height between RCC slabs at top and bottom. The slenderness ratio of the wall is
(a) 15 (b) 19
(c) 20 (d) 25

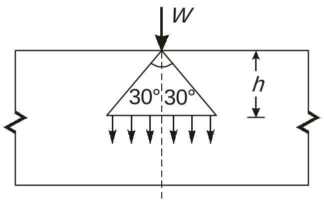
[ESE : 1997]

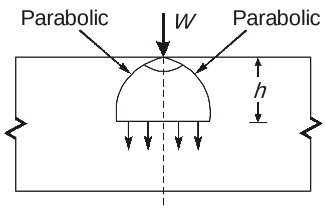
6.5 A 200 mm thick brick masonry wall made of modular bricks carries an axial load of 30 kN/m from wall above and an eccentric load of 20 kN/m from RCC floor acting at a distance of 47.5 mm from the centre line of the wall. The resultant eccentricity ratio is
(a) 0.090 (b) 0.095
(c) 0.100 (d) 0.105

[ESE : 1997]

6.6 Which one of the following figures shows the permitted dispersion of concentrated load in masonry structures?

(a)


(b)


(c)


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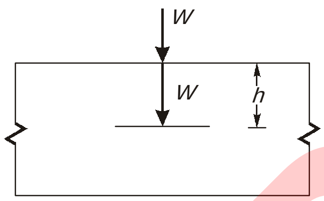


[ESE : 1997]

6.7 In brick masonry, arch action is possible only when the minimum height of wall above the top of lintel is X times the height of triangular distribution, where X is

(a) 1.00 (b) 1.25
(c) 1.50 (d) 1.75

[ESE : 1998]

6.8 The basic stress in masonry unit having height to width ratio of 1.5 may be increased by a factor of

(a) 1.2 (b) 1.4
(c) 1.6 (d) 2.0

[ESE : 1998]

6.9 Given that 'ϕ' is the angle of internal friction 'p' is the safe bearing capacity and 'γ' is the unit weight of soil, the minimum depth of foundation of a masonry footing is given by

(a) $\dfrac{p}{\gamma}\left(\dfrac{1+\sin\phi}{1-\sin\phi}\right)$ (b) $\dfrac{p}{\gamma}\left(\dfrac{1-\sin\phi}{1+\sin\phi}\right)$

(c) $\dfrac{p}{\gamma}\left(\dfrac{1+\sin\phi}{1-\sin\phi}\right)^2$ (d) $\dfrac{p}{\gamma}\left(\dfrac{1-\sin\phi}{1+\sin\phi}\right)^2$

[ESE : 1999]

7. Miscellaneous

7.1 In Pigeaud's coefficient method for the analysis of an interior panel of a T-beam bridge

(a) notation for coefficients as αx_4 and αy_4 includes suffix 4 since the panel is continuous on all the four edges
(b) Poisson's ratio of concrete has no contribution
(c) the applicability is restricted to the case when the wheel load is centrally placed
(d) dispersion of load as considered through the wearing coat only.

[ESE : 1995]

7.2 The "effective width method" requires the

(a) wheel load to be dispersed through the wearing coat as well as deck slab in the transverse direction
(b) wheel load to be dispersed through the wearing coat as well as the deck slab in the longitudinal direction
(c) overlap to be considered in the transverse direction only
(d) impact factor to be considered for the dead load as well

[ESE : 1996]

7.3 Consider the following measures:

1. Keeping cement content within the range of 330 kg/m^3 to 530 kg/m^3.
2. Using well-graded aggregate with water-cement ratio less than 0.5.
3. Controlling the permissible stress in steel by the strain and crack widths rather than the strengths.
4. Providing minimum steel of any grade amounting to 0.3 per cent.

Which of these measures have been recommended by **IS:3370-1970** for the design of leak-proof liquid containers of impervious concrete?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1 and 4

[ESE : 1999]

7.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Deck slab bridge
B. Balanced cantilever
C. Arch bridge
D. Rigid frame culvert

List-II

1. Used for long spans
2. Used for bridge medium spans
3. Statically determinate structure
4. Used for small drains

Codes :

	A	B	C	D
(a)	3	2	4	1
(b)	2	3	1	4
(c)	3	2	1	4
(d)	1	2	3	4

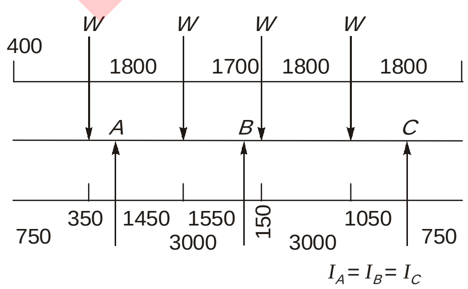
[ESE : 1995]

7.5 For a bridge-deck the most economical section shall be

(a) a double-tee section
(b) an I-section
(c) a box section
(d) a channel section

[ESE : 1995]

7.6 The given figure shows the position of concentrated wheel loads on a bridge deck. For determining the bending moments in the girders by Courbon's theory, the reaction factors are respectively



(a) 1.80 W, 1.33 W and 0.87 W
(b) 1.73 W, 1.28 W and 0.99 W
(c) 2.00 W, 1.50 W and 0.50 W
(d) 2.00 W, 1.25 W and 0.75 W

[ESE : 1997]

7.7 Elastomeric bearing pads are

(a) flat solid metal plates
(b) preferable to steel roller bearing since they do not require any periodical maintenance.
(c) not as satisfactory for concrete bridges as they are for steel bridges
(d) made of thermo-plastic material

[ESE : 1997]

7.8 The notching in a simply-supported timber beam of span L and depth 'd' should be restricted to the region

(a) L/6 from the support
(b) L/6 from the mid-span
(c) L/6 or 3d from the mid-span, whichever is less
(d) L/6 or 3d from the supports, whichever is less

[ESE : 1998]

7.9 To ensure adequate ductility for preventing failures during earthquakes, the percentage tension reinforcement 'p' on any face at any section in beams and girders should **NOT** exceed which one of the following values, when M15 concrete and mild steel bars are used for the construction of beams or girders (p_c is the percentage compression reinforcement and f_{ck} and f_{sy} have their usual meanings)?

(a) $p \le p_c + 0.011\dfrac{f_{ck}}{f_{sy}}$

(b) $p \le p_c + 0.19\dfrac{f_{ck}}{f_{sy}}$

(c) $p \le p_c + 0.15\dfrac{f_{ck}}{f_{sy}}$

(d) $p \le p_c + 0.11\dfrac{f_{ck}}{f_{sy}}$

[ESE : 1998]

7.10 A six-storey 4-bay RC frame subjected to lateral loads would structurally behave

(a) more as a cantilever than as a portal frame

(b) more as a portal frame than as a cantilever
(c) neither as a cantilever nor as a portal frame
(d) as a cantilever or as a portal frame depending upon the load intensity

[ESE : 1998]

7.11 Which one of the following components of the bridge deck is analyzed by using Courbon's method?
(a) Slabs (b) Diaphragms
(c) Cross-beams (d) Girders

[ESE : 1999]

7.12 **Assertion (A) :** Bridges designed for class-AA loading should be checked for class-A loading also.
Reason (R) : Under certain conditions, heavier stresses may be obtained for class-A loading
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

7.13 In a spherical dome subjected to a uniformly distributed load the meridional force induced is
(a) compressive throughout
(b) zero at the crown
(c) tensile below the plane of rupture
(d) compressive for heavier loads, while being tensile for lower loads

[ESE : 1995]

7.14 Minimum percentage area of HYSD reinforcement in a 150 mm thick water tank wall is
(a) 0.16 (b) 0.20
(c) 0.23 (d) 0.24

[ESE : 1996]

7.15 In a deep grain container
(a) only the horizontal pressure on walls approaches a limit
(b) only the vertical pressure on the bottom approaches a limit
(c) both vertical and horizontal pressures approach the limits
(d) the vertical pressure increases continuously while the horizontal pressure approaches a limit

[ESE : 1997]

7.16 In chimneys, the allowable axial compression reduces with the ratio ***d/t*** (***d*** being the diameter and ***t*** being the plate thickness) and NOT with the ratio ***l/r*** as in columns. This is to take into account the action of
(a) hoop compressive strain produced by axial compression
(b) temperature gradient due to hot gases
(c) shell buckling
(d) axial strain produced by hoop tension

[ESE : 1997]

7.17 The ratio of the lateral pressure of the bulk storage material at the time of emptying to that at the time of filling is
(a) less than one
(b) equal to or less than one
(c) equal to one
(d) greater than one

[ESE : 1998]

7.18 IRC prescribes Coulomb's theory of earth pressure for the design of abutments and wing walls. The ratio of height of center of pressure above the bottom to the height of the wall is equal to
(a) 0.33 (b) 0.36
(c) 0.39 (d) 0.42

[ESE : 1998]

7.19 In chimneys, the allowable axial compression reduces with the ratio ***d/t***, (diameter ***d*** and plate thickness ***t***) and not with the ratio ***l/r*** as in columns. This is to recognize the
(a) hoop compressive strain produced by axial compression
(b) temperature gradient caused by hot gases
(c) shell buckling
(d) axial strain produced by hoop tension

[ESE : 1999]

Answers Design of Concrete & Masonry Structures

1.1 (c)	1.2 (c)	1.3 (d)	1.4 (b)	1.5 (b)	1.6 (c)	1.7 (b)	1.8 (b)	1.9 (c)
1.10 (c)	1.11 (a)	1.12 (c)	1.13 (c)	1.14 (c)	1.15 (b)	1.16 (c)	1.17 (d)	2.1 (b)
2.2 (c)	2.3 (a)	2.4 (c)	2.5 (a)	2.6 (c)	2.7 (a)	2.8 (d)	2.9 (b)	2.10 (d)
2.11 (b)	2.12 (c)	2.13 (d)	2.14 (d)	2.15 (c)	2.16 (d)	2.17 (a)	2.18 (d)	2.19 (c)
2.20 (d)	2.21 (c)	2.22 (a)	2.23 (d)	2.24 (a)	2.25 (c)	2.26 (d)	2.27 (b)	2.28 (a)
2.29 (c)	3.1 (d)	3.2 (a)	3.3 (a)	3.4 (c)	3.5 (a)	3.6 (b)	3.7 (b)	3.8 (d)
4.1 (b)	4.2 (a)	4.3 (b)	4.4 (c)	4.5 (a)	4.6 (c)	4.7 (a)	4.8 (c)	4.9 (b)
4.10 (d)	4.11 (d)	4.12 (c)	4.13 (b)	5.1 (b)	5.2 (a)	5.3 (d)	5.4 (a)	5.5 (a)
5.6 (a)	5.7 (b)	5.8 (d)	5.9 (a)	5.10 (d)	5.11 (d)	5.12 (d)	5.13 (c)	5.14 (b)
5.15 (c)	5.16 (b)	5.17 (d)	5.18 (c)	5.19 (b)	5.20 (c)	5.21 (a)	5.22 (b)	5.23 (b)
5.24 (a)	5.25 (b)	5.26 (a)	5.27 (d)	6.1 (c)	6.2 (b)	6.3 (a)	6.4 (a)	6.5 (b)
6.6 (b)	6.7 (b)	6.8 (a)	6.9 (d)	7.1 (c)	7.2 (a)	7.3 (b)	7.4 (b)	7.5 (c)
7.6 (a)	7.7 (b)	7.8 (d)	7.9 (c)	7.10 (a)	7.11 (d)	7.12 (a)	7.13 (a)	7.14 (c)
7.15 (d)	7.16 (a)	7.17 (d)	7.18 (a)	7.19 (a)				

Explanations Design of Concrete & Masonry Structures

1. Fundamentals of RCC

1.1 (c)

Both assumptions are correct as per IS code 456 : 2000 Pr. 38.1 in limit state method as well as in WSM (Pr. 31.3).

It is to be noted both assumptions are true, both for limit state and working stress method. As per IS 456 : 2000, clause 38, limit state of collapse in flexure shall be based on the assumptions:

1. Plane sections remain plane after bending.
2. Maximum strain in concrete at outermost compressed fibre is taken as 0.0035.
3. The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola r any other shape which results in satisfactory agreement with results of test.
4. Tensile strength of concrete is ignored.
5. The stresses in reinforcement are derived from representative stress-stain curve for the type of steel used. Partial safety factor used = 1.15.
6. Maximum strain in tension reinforcement at failure shall not be less than $\left(\dfrac{f_y}{1.15E_s}+0.002\right)$.

1.2 (c)

The strain in steel shall not be less than $\dfrac{f_y}{1.15E_s}+0.002$ to ensure ductility and ultimate flexural strain in concrete is 0.0035.

1.3 (d)

The deflection shall generally be limited to the following:

(i) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the support of floors, roofs and all other horizontal members shall not normally exceed span/250.

(ii) The deflection including the effects of temperature, creep and shrinkage occurring after the erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

1.4 (b)

Creep is elastic strain and partly recoverable. However in ultimate limit state both creep and shrinkage effects can be ignored due to plastic flow.

1.5 (b)

As per Clause 38.1(b) of **IS 456 : 2000**, Maximum strain at outermost compression fiber is taken as 0.0035.

1.6 (c)

As per Clause 23.2.1 of **IS 456 : 2000**, the vertical deflection limits may be controlled by limiting the span/depth ratio.

1.7 (b)

The code specifies minimum and maximum limits for the spacing between parallel reinforcing bars in a layer. The minimum limits are necessary to ensure that the concrete can be placed easily in between and around the bars during the placement of fresh concrete. The maximum limits are specified for bars in tension for the purpose of controlling crack-widths and improving bond.

1.8 (b)

When there is unequal top and bottom reinforcement in RC section, differential strains are induced across the cross-section with the location with having reinforcement shrinking more than locations with high reinforcement, leading to shrinkage deflection.

1.9 (c)

As per **IS 456 : 2000** clause 23.2, Final deflection due to loads including effect of temperature, creep, shrinkage and measured from cast level of supports of floors, roofs and all other horizontal members should not exceed span/250.

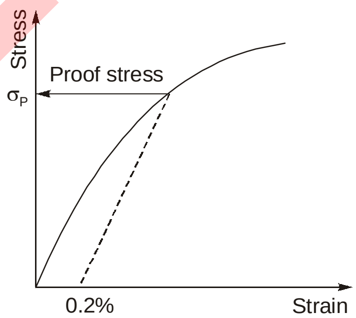
1.10 (c)

Mild steel has definite yield point and the plastic strain may extend upto a strain of 0.15. Cold worked high strength deformed bars do not have a definite yield point and the characteristic strength refers to 0.2% proof stress. Their plastic strain is less than that of mild steel bars.

Proof stress: In some ductile materials like, Aluminium, copper, the yield point can not be clearly defined during tension test, therefore yield stress is unknown. For such metals design stress called proof stress is calculated using offset method.

Measurement Steps:

1. Draw line of best fit (if the initial portion is also not straight.)
2. Calculate required strain (0.2%) and mark on x-axis.
3. Draw parallel line.
4. Note point of intersection.
5. Project a line back to vertical axis which is the proof stress.



1.11 (a)

As per Clause 38.1(b) of **IS 456 : 2000**, Maximum strain at outermost compression fiber is taken as 0.0035.

1.12 (c)

Partial material safety factor

(i) for concrete 1.5

(ii) for steel 1.15

1.13 (c)

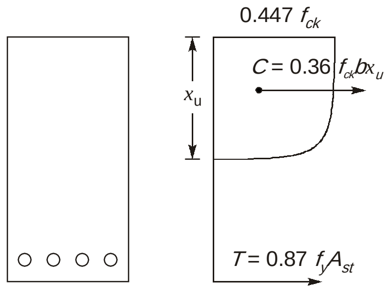
As per clause 18.2.3.1, 36.4.1 and B 4.3

Load combinations	Limit state of collapse			Limit state of serviceability (for short term effects only)		
DL + IL	DL	IL	WL	DL	IL	WL
DL + WL	1.5	–	1.0	1.0	1.0	–
	1.5 or 0.9	–	1.5	1.0	–	1.0
DL + IL + WL	1.2	–	1.2	1.0	0.8	0.8

1.14 (c)

The assumption that plane sections normal before bending remain plane after bending i.e the strain variation is linear and holds good for both working stress and limit state methods of design.

1.16 (c)



The compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor of 1.5 shall be applied in addition to this.

Thus stress in concrete at collapse

$$= \frac{0.67}{1.5} f_{ck} = 0.447 f_{ck}$$

1.17 (d)

The short term deflections may be calculated using methods for elastic deflections using the short term modulus of elasticity of concrete E_c and effective moment of inertia.

For long term deflections, the long term modulus

$E_{ce} = \dfrac{E_c}{1+\theta}$ is used where θ is creep coefficient

2. Beams and Slabs

2.1 (b)

The strip of a two way slab may be checked for deflection control against shorter span to effective depth ratios.

Span to effective depth ratio

Type of slab	Type of reinforcement	
	Mild Steel	Fe 415 grade steel
Simply supported	35	28
Continuous	40	32

2.2 (c)

The effective span to depth ratio for beam with different type of tension steel are obtained by multiplying the basic values of effective span to depth ratio with modification factor.

For higher grade of steel modification factor value shall be less as per figure no. 4/IS 456, thus depth of member required will be more.

$$\text{Effective depth} = \frac{\text{span}}{\text{A - value} \times \text{MF}}$$

2.3 (a)

Beam column will make the slab either fixed or continuous for which less slab thickness is required. In case of slab supported on brickwork the slab will be simply supported for which higher thickness is required.

- When beam slab is supported on masonry walls, it is like simply supported beam/slab.

  Hence bending moment at mid span $= \dfrac{wl^2}{8}$.
- When it is framed bending moment at mid span $= \dfrac{wl^2}{24}$; which is 3 times less. Hence thickness of floor for the span will be less when framed into a system of RC columns.

2.4 (c)

The maximum moment or shear force at a section depends on the position of the live load.

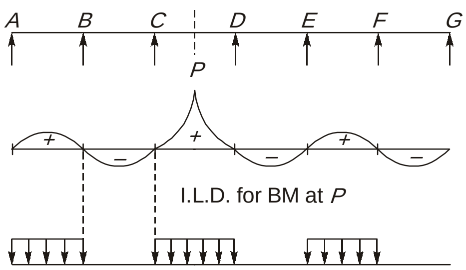
(i) For maximum positive span moment at mid point, load that span and all other alternate spans.

(ii) For maximum positive support moment, unload the spans on either side of the support and load the next spans.

(iii) For maximum negative span moment at mid point, load the adjacent spans on either side of the span and all other alternate spans.

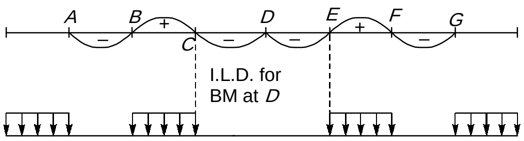
(iv) For maximum negative moment at support, load the two spans next to adjacent span and all other alternate spans.

For case (i)



Position of load for maximum positive moment at P.

For case (iv)



Position of load for maximum positive moment at *D*.

2.5 (a)

Pigeaud's moment coefficients can be used for computing bending moments in a panel freely supported along four edges with restrained corners and carrying symmetrically placed load distributed over small area i.e. a concreted load. Pigeaud derived these curves for thin plates, using elastic theory of flexure, and assuming Poisson's ratio of 0.15.

2.6 (c)

The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm whichever is smaller. The total reinforcement in the slab should remain same. By replacing 10 mm bars by 12 mm bars, the spacing will increase as

$$\left(\frac{d_2}{d_1}\right)^2 \times S_1 = \left(\frac{12}{10}\right)^2 \times 10 = 14.4 \text{ cm}$$

2.7 (a)

The bond between concrete and steel restrains shrinkage. Therefore, the shrinkage curvature is influenced by the area of tension and compression reinforcement equally.

The shrinkage curvature

$$\phi_{sh} = \beta e_{sh}/D$$

$e_{sh} \rightarrow$ free shrinkage = 0.0003

$D \rightarrow$ Overall depth of beam

$$\beta = 0.72 \frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0$$

for $0.25 \leq P_t - P_c \leq 1$

$$= 0.65 \frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0$$

for $P_t - P_c \geq 1$

$P_c, P_t \rightarrow$ percentage of compression and tension steel respectively

Thus shrinkage deflection can be eliminated by making compression steel equal to tension steel.

2.8 (d)

Effective width

(i) For T-beams $b_f = \frac{L_0}{6} + b_w + 6D_f \not> b$

(ii) For inverted *L*-beam

$$b_f = \frac{L_0}{12} + b_w + 3D_f \not> b$$

(iii) For isolated T-beam.

$$b_f = \frac{L_0}{\left(\frac{L_0}{b}\right) + 4} + b_w$$

(iv) For isolated L-beam

$$b_f = \frac{0.5L_0}{\left(\frac{L_0}{b}\right) + 4} + b_w$$

$b_f \rightarrow$ effective width of flange

$L_0 \rightarrow$ distance between points of zero moments (points of contraflexure) which may be taken as 0.7 times the effective span for continuous beams and for beams in frames

$b_w \rightarrow$ breadth of web

$D_f \rightarrow$ thickness of flange

$b \rightarrow$ actual width of flange which is equal to breadth of web plus half the sum of the clear distance between the beams on either side.

$$b = 300 + 2700 = 3000 \text{ mm}$$
$$L_0 = 3600 \text{ mm}$$
$$b_w = 300 \text{ mm}$$
$$D_f = 100 \text{ mm}$$

$$\therefore \; b_f = \frac{3600}{6} + 300 + 6 \times 100 = 1500 \text{ mm}$$

2.9 (b)

$$\text{Moment of resistance} = \frac{w_u L^2}{24}$$

Self weight of slab = 0.12 × 25 = 3 kN/m^2

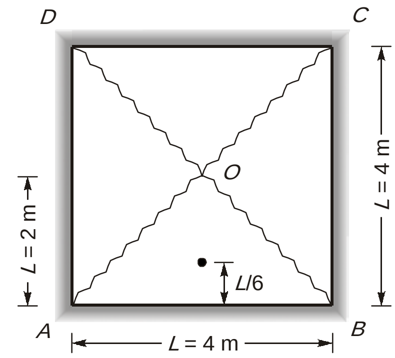
Service load = 6 kN/m^2

Ultimate load = 1.5 × (6 + 3) = 13.5 kN/m^2

Ultimate moment capacity

$$= \frac{13.5 \times 4^2}{24} = 9 \text{ kN-m/m}$$

Note proof:



- Suppose *W* load is acting per unit area.
- Hence the force on any triangular slab at 0.
- Location of C.G. from the edge

$$= \left(\frac{L}{2}\right) \times \frac{1}{3} = \frac{1}{6}$$

$$\because \qquad \Sigma M_{AB} = 0$$

$$\frac{1}{4} \times [WL \times L] \times \frac{L}{6} - M \times L = 0$$

$$\therefore \qquad M = \frac{WL^2}{24}$$

2.10 (d)

Minimum 'd' $= \dfrac{\text{space}}{\text{(A) value}}$

The final deflection is limited to span/250 or 20 mm whichever is less.

So limiting deflection = 17.1 mm

Type of beam is not mentioned (cantilever/simply supported/continuous). (A) value cannot be found.

Therefore it can not be judged from the given data.

2.11 (b)

As per **IS:456-2000** maximum area of compression or tension reinforcement shall not exceed 0.04bD.

Common Mistake:

Minimum tension reinforcement $A_{st} = \dfrac{0.85}{f_y} \times bd$

Minimum tension/compression reinforcement $A_{sc} = 0.04bD$.

Note the difference here of total depth and effective depth.

2.12 (c)

The diameter of the bars shall not exceed one eight of the total thickness of the slab.

$\therefore$ Maximum size $= \dfrac{75}{8} = 9.375$ mm

So the diameter will be 8 mm.

2.13 (d)

For restrained slab, the area of reinforcement in each of the four corner layers shall be three-quarters of the area required for the maximum mid span moment in the slab simply supported on both edges meeting at that corner. If the corner contained by edges over only one of which the slab is continuous, torsion reinforcement equal to 0.375 times the area of reinforcement provided the mid-span in shorter span direction shall be provided. If both edges are continuous, no torsion reinforcement shall be provided.

Support condition are not specified. Considering edges continuous option (d) is correct.

Option (a) is wrong due to same direction.

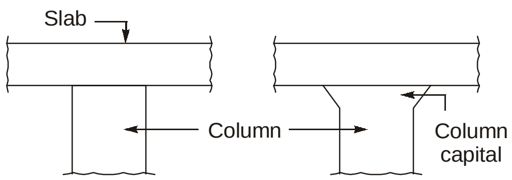
It should be 0.75 times the area of steel provided in the shorter span.

2.14 (d)

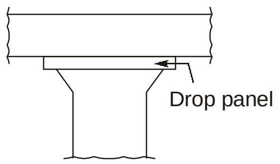
As per IS 456 : 2000, cl. 26.5.1.3, where the depth of web in a beam exceeds 750 mm, the side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall not exceed 0.1% of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.

2.15 (c)

The slabs supported directly on columns without beams are know as flat slabs. In such slabs, large bending moments and shear forces are induced in the vicinity of columns. Therefore the columns are flared at the top called column heads or column capitals and slab are thickened around the column capitals called drops for reducing the stresses due to moments and shears. The drops primarily resist shear.



Flat slab with column capital



Flat slab with column capital and drop panel

2.16 (d)

In under-reinforced beam, the reinforcement failure occurs first while in over-reinforced beam the concrete failure occurs first. Thus under-reinforced beam is ductile and over-reinforced beam shows sudden failure i.e., brittle.

2.17 (a)

Failure of over reinforced section occure due to primary compression failure.
Under reinforced sections fails due to secondary compression.

2.18 (d)

The term isotropically reinforced means the moment capacity per unit length, M is the same, no matter which is the direction. Hence the yield line in such slab has no torsional strength.
Ultimate load (w_u) = 1.5 × 12 = 18 kPa

$$\text{Moment capacity} = \frac{w_u L^2}{24} = \frac{18 \times 4^2}{24} = 12\ \text{kN-m/m}$$

2.19 (c)

$$\frac{\text{Span}}{\text{Effective depth}} = \frac{4000}{500} = 8 > 7$$

So the beam will fail in deflection.
For stability, the clear distance from the free end of the cantilever the lateral restraint shall not exceed $25b$ or $\frac{100b^2}{d}$ whichever is less.

Consider nominal cover = 40 mm

Effective depth = 500 – 40 = 460 mm
Clear Distance = 25 × 150 = 3750 mm

or $\frac{100 \times (150)^2}{(460)} = 4891.3$ mm

Thus clear distance between the lateral restraints shall be 3750 mm. However the span is 4 m. So the beam fails from lateral stability consideration also.

2.20 (d)

As per **IS 456 : 2000** (clause 26.5.1.3), Where depth of web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces.

2.21 (c)

IS 456 : 2000 has adopted moment coefficients derived by Rankine-Grashoff for the analysis of simply supported rectangular slab without any provision for torsion as in Table 27.
However, for continuous RC slab, coefficient of Table 26 is based on yield line theory.

2.22 (a)

The total force acting on segment at intersection of two adjacent straight portions of yield line is known as nodal force. The shear force acting on each side of yield line should be equal and opposite for equilibrium. Thus sum of nodal forces as junction of yield line is zero.

2.23 (d)

Shear connectors prevent separation between steel girder and in-situ concrete slab by transferring horizontal shear force along contact surface without slip. Thus they are important structural element for composite steel beam and RCC slab floor construction.

2.24 (a)

As per Clause 23.1.2. In effective width formula for T-beam L_o represents distance between points of zero moment in beam.

2.25 (c)

LSM and ULM follow non linear stress-strain curve of steel and concrete i.e. utilize the strength in plastic zone. So sections designed have lesser depth in comparison to member designed by WSM. For the same load, bending moment is more in case of LSM compared to WSM due to provisions for partial safety factors. As depth decreases in LSM, lever arm decreases and hence larger area of reinforcement is required as compared to WSM.

2.26 (d)

The doubly reinforced beam section is needed

(i) when depth of the section is restricted and the strength available from a singly reinforced section is inadequate

Actual stress in compression steel is found less than its strength so high area of steel is required to be provided due to which doubly reinforced section become uneconomical.

2.27 (b)

Span to effective depth ratios for spans upto 10 m.

Cantilever	–	7
Simply supported	–	20
Continuous	–	26

Note: *For span greater than 10 m, the values may be multiplied by 10 × span in meters.*

2.28 (a)

Where curvature at the supports is very high, It shows more moment.

$$\frac{M}{I} = \frac{E}{R}$$

Curvature $\dfrac{1}{R} = \dfrac{M}{EI}$

(Curvature ∝ Moment)

2.29 (c)

As per Clause 26.5.1.1 and 26.5.1.3. The maximum area of tension reinforcement should not exceed 0.04bD and total area of side reinforcement should not be less than 0.1% bD and it should be distributed equally on two faces at spacing not exceeding 300 mm or web thickness whichever is less.

3. Shear, Bond, Torsion and Development Length

3.1 (d)

The amount of torsion in a member depends upon the magnitude of the torsional stiffness of the member itself in relation to the stiffness of the interconnecting members. In reinforced concrete structures, the stiffness decreases considerably after the formation of cracks if the continuity at the joint are not considered in the design.

The presence of reinforcement in the form of longitudinal and transverse steel increases the torsional moment carrying capacity of beams.

3.2 (a)

If the calculated shear stress (τ_v) is

(i) less than allowable shear stress (τ_c) but more than $0.5\tau_c$, the minimum shear reinforcement in the form of stirrups shall be provided such that

$$\frac{A_{sv}}{bS_v} \geq \frac{0.4}{0.87 f_y}$$

(ii) more than τ_c, shear reinforcement shall be provided in the form of vertical stirrups or bent up bars with stirrups or inclined stirrups to resist $V_{us} = V_u - \tau_c bd$. Here $\tau_v < \tau_{c,\max}$

(iii) If $\tau_v > \tau_{c,\max}$ redesign the section.

3.3 (a)

As per **IS 456 : 2000, clause 26.2.1**, for deformed bars, the bond stress shall be increased by 60% of the values for plain bars in tension. For bars in compression, the values of bond stress for bars in tension shall be increased by 25%.

3.4 (c)

The shear strength of a beam without shear reinforcement depends upon shear span/effective depth ratio, where shear span is defined by the ratio M/V. The shear force is constant over the shear span.

3.5 (a)

$$V = K\, f_{sy}\, A_f$$

V = ultimate shear resistance of each connector

f_{sy} = ultimate tensile strength of steel of anchorage connector

A_f = cross-section area of each connector

3.6 (b)

The development length $L_d = \dfrac{\phi\sigma_s}{4\tau_{bd}}$

$\phi \rightarrow$ nominal diameter of the bar.

$\phi_s \rightarrow$ stress in bar at the section considered at design load.

$\tau_{bd} \rightarrow$ design bond stress

At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that

$$L_d \leq \frac{M_1}{V} + L_o$$

This condition need not to be checked for negative reinforcement.

Third statement is wrong because the 1/3rd of total negative reinforcement provided must extend beyond the point of inflexion for a distance not less than '*d*' or 12ϕ or one-sixteenths of clear span, whichever is larger.

3.7 (b)

Thermal stresses are developed due to restriction of free length. These are linear with respect to change in temperature.

1. Bond stress is also known as longitudinal shear stress.
2. Thermal stress are developed due to restriction of free length. These are linear with respect to change in temperature.
3. Hoop stress is circumferential stress.
4. There are no torsional stresses at centre of any cross-section.

3.8 (d)

The development length $L_d = \dfrac{\phi\sigma_s}{4\tau_{bd}}$.

Design bond stress (τ_{bd}) in HYSD bars is 60% more than that for mild steel plain bars.

But development length of HYSD bars is found more than that of mild steel.

For mild steel,

$$L_d = \frac{0.87 \times 250 \times \phi}{4 \times \tau_{bd}} = 50.38\frac{\phi}{\tau_{bd}}$$

For HYSD bars,

$$L_d = \frac{0.87 \times 415\phi}{4 \times \tau_{bd} \times 1.6} = 56.41\frac{\phi}{\tau_{bd}}$$

4. Walls, Columns and Footings

4.1 (b)

In **IS:456-1978**, the clear covers are specified as:

(i) For a longitudinal reinforcing bar in a column, not less than 40 mm, or less than the diameter of such bar.

(ii) For longitudinal reinforcing bar in a beam, not less than 25 mm, or less than the diameter of such bar.

(iii) For tensile, compressive, shear or other reinforcement in a slab, not less than 15 mm, or less than the diameter of such bar.

(iv) In other cases the clear cover to the reinforcement bars shall not be less than 40 mm or diameter of such bar whichever is more.

The minimumm clear cover should not exceed 75mm in any case.

According to **IS 456:2000** nominal cover shall not be less than the diameter of bar. The nominal cover is specified to meet durability requirement in Table 16 on page 47 of the IS Code. To meet specified period of fire resistance the clear covers are given in Table 16A on page. 47.

For longitudinal reinforcing bars the nominal cover shall not be less than 40 mm.

For footings minimum cover shall be 50 mm.

4.2 (a)

In columns,

(a) the minimum longitudinal reinforcement = 0.4% of gross cross-sectional area.

(b) the maximum longitudinal reinforcement = 6% of gross cross-sectional area.

(c) the pitch of the transverse reinforcement shall not be more than the least of the following:

  (i) The least lateral dimension of the compression members

  (ii) 16 times the smallest diameter of the longitudinal reinforcement bar to be tied

  (iii) 300 mm

4.4 (c)

As per **IS : 456-2000** the cross-sectional area of the longitudinal reinforcement in columns, shall not be less than 0.8% nor more than 6% of the gross cross-sectional area of the column.

Note: The use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete; hence lower percentage recommended. Where bars from the column below have to be Lapped with those in the column under consideration, the percentage of steel shall usually not exceed 4 percent.

4.5 (a)

For column, the longitudinal bar shall not have a cover less than 40 mm or the diameter of the bar whichever is more. In case of columns of minimum dimension of 200 mm or less, whose reinforcing bars do not exceed 12 mm diameter, a cover of 25 mm may be provided.

4.6 (c)

$$\text{Collapse Load} = \text{Load factor x Working load}$$
$$= 1.5 \times 500 = 750 \text{ kN}$$

4.7 (a)

Design of foundation for large generator is guided by frequency to avoid the occurrence of resonance (when natural frequency coincides with operating frequency).

4.8 (c)

According to **IS : 456-2000** the angle between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and horizontal plane shall be governed by the expression

$$\tan\alpha \not< 0.9\sqrt{\frac{100q_0}{f_{ck}}+1}$$

Given $q_0 = 3$ MPa

$f_{ck} = 20$ MPa

$\therefore \tan\alpha > 3.6$

4.9 (b)

In the working stress method the design of a long column is made by considering reduced stresses obtained by multiplying the permissible stresses by a coefficient,

$$C_r = 1.25 - \frac{l_{eff}}{48D} \text{ or } 1.25 - \frac{l_{eff}}{48B}$$

whichever is smaller

$$\therefore C_r = 1.25 - \frac{4800}{48\times 250} \text{ or } 1.25 - \frac{4800}{48\times 300}$$

$$= 0.85 \text{ or } 0.92$$

So the reduction coefficient is 0.85.

4.10 (d)

We know from **IS 456 : 2000, clause 22.6.2** when the support exert compressive reaction to the beam, the critical section for shear is at '*d*' from face of support, else at the face of the support.

Hence the bottom slab, critical section is the face of the wall.

4.11 (d)

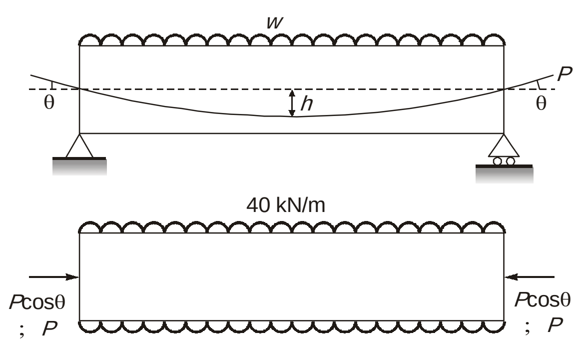
The vertical reinforcement in walls shall be spaced not farther apart than three times the wall thickness nor 450 mm.

4.12 (c)

If the retaining wall is found unsafe against sliding, a shear key is provided.

5. Prestress Concrete

5.1 (b)



$$w = w_b = \frac{8Ph}{L^2}. \quad \text{So } h = \frac{wL^2}{8P}$$

Central dip,

$$h = \frac{wl^2}{8P} = \frac{40\times(10)^2}{8\times 2500} = 0.2 \text{ m} = 200 \text{ mm}$$

5.2 (a)

As per IS 1343, the shrinkage of concrete is given to be 3×10^{-4}. Shrinkage of concrete in pre-stressed members results in shortening of tension wires and contributes to loss of prestress.

The losses in a pre-tensioned member are due to

1. Shrinkage
2. Creep of concrete

3. Relaxation of steel
4. Elastic shortening of concrete.
   - Relaxation of steel also result in losses so it cannot be ignored.
   - It pre-tensioned members many wires can be stretched at a time.
   - Mild steel cannot be used. If PSC only high strength steel are used due to large losses occurring at later stage

5.3 (d)

High strength concrete is less liable to shrinkage cracks and has a higher modulus of elasticity and smaller ultimate creep strain, resulting in a smaller loss of prestress in steel. The use of high strength concrete results in a reduction in the cross-sectional dimensions of prestressed concrete structural elements. With a reduced dead weight of the material, longer spans become technically and economically practicable.

5.4 (a)

When cylindrical pipe is subjected to internal fluid pressure the hoop stress is tensile in nature and when cylindrical pipe is subjected to external fluid pressure the hoop stress is compressive in nature. Prestressing is required when cylindrical pipe is subjected to internal fluid pressure as the concrete is weak in tension.

5.5 (a)

Causes	Percentage Loss Post-tensioned	Pre-tensioned
(i) Shrinkage of concrete	6	7
(ii) Creep of concrete	5	6
(iii) Relaxation in steel	3	2
(iv) Elastic shortening and bending of concrete	1	3
Total	**15**	**18**

5.6 (a)

In load balancing method, the applied load is balanced by the cable profile. Thus bending moment and shear forces do not exist. Only axial stresses exists.

5.7 (b)

- Prestressing force reduces the principal diagonal tension by inducing compressive normal strains. Hence option (a) is wrong.
- We know, elastic theory is applicable even in prestressed structures. Option (b) is correct.
- Cracks develop perpendicularly in the region where BM is significant and shear force is very example mid span. Option (c) is wrong.
- Diagonal cracking is PSC beam is somewhat restrained but once started, it is similar normal RCC member. Option (d) is wrong.

5.8 (d)

Area, $A = 45 \times 10^3\ \text{mm}^2$

Section modulus,

$$Z = \frac{Bd^2}{6} = \frac{150 \times 300^2}{6}$$

$$= 2.25 \times 10^6\ \text{mm}^2$$

$$\text{Dead load} = 0.15 \times 0.30 \times 1 \times 25$$

$$= 1.125\ \text{kN/m}$$

For bottom fibre stress to be zero

$$\frac{P}{A} + \frac{Pe}{Z} = \frac{M_{DL} + M_{LL}}{Z}$$

$$M_{DL} + M_{LL} = \frac{(1.125 + 5) \times 8^2}{8}$$

$$= 49\ \text{kN-m}$$

$$e = 75\ \text{mm}$$

$$\therefore \quad P = \frac{49 \times 10^6}{2.25 \times 10^6 \left[\dfrac{1}{45 \times 10^3} + \dfrac{75}{2.25 \times 10^6}\right]}$$

$$= 392\ \text{kN}$$

5.9 (a)

Partially PSC members are class-III type.

In partially prestressed members, limited tensile stresses are permitted in concrete under service loads with control on the maximum width of cracks. The untensioned reinforcement is required in the cross-section for various reasons such as to resist differential shrinkage, temperature effects and handling stresses.

5.10 (d)

Secondary moments are developed due to redundant reactions at indeterminate supports when statistically indeterminate structures are prestressed. The tendon profile which does not induce secondary moments at support is referred to as concordant profile.

5.11 (d)

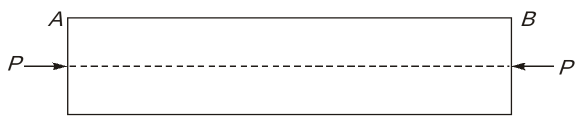
In ultimate load design concept for prestressed concrete girder used for bridges, the load factor taken for both L.L and D.L is 2.

Ultimate load = 2.0 Dead Load + 2.0 Live Load

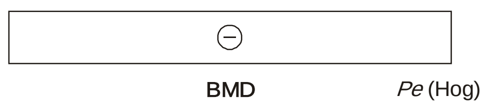
5.12 (d)

The use of straight cable is necessary while pretensioning the slabs especially in mass production. For normal residential building we have tension at bottom. Thus cable profile used is straight.

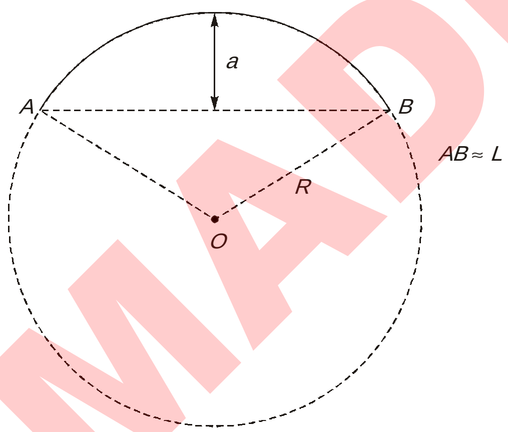
5.13 (c)



Bending moment will be constant throughout = Pe



Assuming the beam to curved in the shape like below. (Due to constant moment the beam is bent with constant curvature).



From basic flexure equation,

$$\frac{M}{I} = \frac{E}{R}$$

(The beam is subjected to a constant moment $M = Pe$)

Hence, $R = \dfrac{EI}{M}$

We know, for Circles's property,

$$\frac{L}{2} \times \frac{L}{2} = a \times (2R - a)$$

$$\therefore \quad \frac{L^2}{4} = 2aR - a^2$$

Neglecting higher powers of a; since it is already a small quantity

$$\therefore \quad \frac{L^2}{4} = 2aR$$

$$a = \frac{L^2}{8R}$$

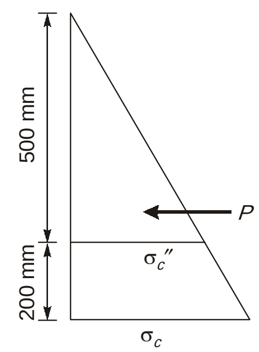
$$a = \frac{L^2 M}{8EI} = \frac{PeL^2}{8EI} \qquad [\text{as } M = Pe]$$

5.14 (b)

Pretensioned prestressed plank can resist both compressive and tensile stresses. However, pretensioning is done to keep the stresses compressive throughout the beam.

5.15 (c)

The stress varies from zero at one extreme fiber to σ_c at other extreme fiber. Maximum prestressing force will be obtained if stress diagram is as shown in figure.

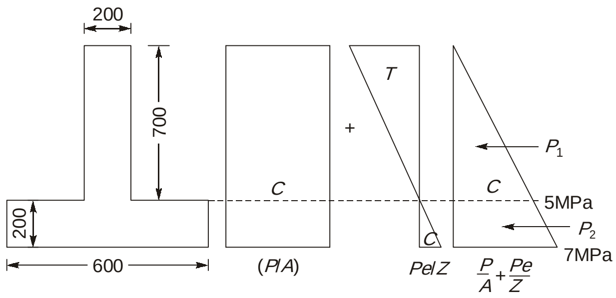


Resultant stress diagram

$$\sigma_c'' = \frac{5}{7}\sigma_c = 5 \text{ MPa}$$

$$P_0 = \left[\frac{600 \times 200 \times \left(\frac{5+7}{2}\right) + 200 \times 500 \times \frac{5}{2}}{1000}\right]$$

$= 970$ kN



5.16 (b)

As per IS 1343:1980(clause 18.5.1) the maximum tensile stress f_{pi} immediately behind the anchorage shall not exceed 80 percent of ultimate tensile strength of wire or bar or stand at the time of initial tensioning. (However this provision has been revised to 76% of ultimate tensile strength in **IS 1343: 2012**)

5.17 (d)

The load balancing concept is used to decide the cable profile. The shape of B.M.D. forms the basis for cable profile.

In the case of udl, the BMD is parabolic so cable profile will also be parabolic.

5.18 (c)

As per **IS 1343 : 1980, clause 11.1.8**. The minimum clear spacing between groups of cables or ducts of grouped cables shall be greater of the following:

(i) 40 mm

(ii) 5 mm plus maximum size of the aggregate.

5.19 (b)

Slope of the cable at supports,

$$\theta = \frac{4(e_0 - e_s)}{L}$$

$$e_0 = 100 \text{ mm}$$

$$e_s = 25 \text{ mm}$$

$$\therefore \quad \theta = \frac{4 \times (100 - 25)}{8000}$$

$$= 0.0375 \text{ radians}$$

Vertical component of prestressing force at support

$= 200 \times 0.0375 = 7.5$ kN

As per **IS:1343-1980** the ultimate resistance of a section uncracked in flexure is

$$V_{co} = 0.67bD\sqrt{f_t^2 + 0.8f_{cp}f_t}$$

Maximum principal tensile stress,

$$f_t = 0.24\sqrt{f_{ck}} = 0.24 \times \sqrt{45} = 1.61 \text{ N/mm}^2$$

$$b = 150 \text{ mm}$$

$$D = 300 \text{ mm}$$

Compressive stress at centroidal axis,

$$f_{cp} = \frac{P}{bD} = \frac{200 \times 10^3}{150 \times 300} = 4.44 \text{ N/mm}^2$$

$$\therefore \quad V_{co} = 0.67 \times 150 \times 300 \times \sqrt{(1.61)^2 + 0.8 \times 1.61 \times 4.44}$$

$$= 86918 \text{ N} = 86.9 \text{ kN}$$

$\therefore$ Shear resistance = 86.9 + 7.5

= 94.4 kN

5.20 (c)

IS 1343:1980 (clause 19.3.2) gives serviceability limit states.

Class 1 structures- no cracking under service loads.

Class 2 structures- no visible cracking when $\sigma < 3$ N/mm^2.

Class 3 structures- concrete section uncracked. Tensile stress and cracking both are allowed.

5.21 (a)

In a composite construction, precast prestressed members are used in conjunction with the concrete cast-in situ, so that the members behave as monolithic unit under service loads. The high strength prestressed concrete is used in the tension zone, while cast-in situ concrete of relatively lower compressive strength is used in the compression zone of the composite members. The composite action between the two components is achieved by roughening the surface of prestressed unit on to which the concrete is cast in situ, thus given a better frictional resistance, or by stirrups protruding from the prestressed unit into the added concrete.

In the design of shear connection, it generally assumed that the natural bond at the interface contribution a part of the required shear resistance. Any extra shear resistance over and above this should be provided by shear connectors.

5.22 (b)

As per IS 13.43 : 1980, clause 18.5.2.3 the relaxation stress losses in prestressing steels vary with

- Type of steel
- Initial prestress value
- Age
- Temperature

It is experimentally determined. Its value roughly lies between 2-8% of initial prestress.

5.23 (b)

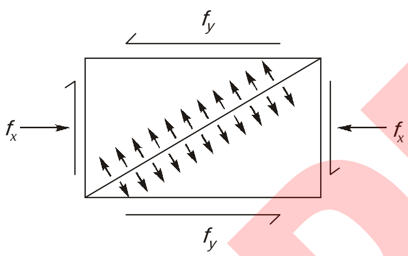
Limit state of deflection and cracking comes under serviceability limits.

5.24 (a)

In the pretensioning system, the tendons are first tensioned between rigid anchor blocks prior to the casting of concrete is the moulds. The pretensioned wires are released by either cutting or releasing jacking pressure. The high tensile wires tend to shorten but are checked by the bond between concrete and steel. Thus prestress load is transferred in single stage.

5.25 (b)

General case of the concrete member under going prestressing shown.



$$f_1/f_2 = \left(\frac{f_x + f_y}{2}\right) \pm \sqrt{\left(\frac{f_x + f_y}{2}\right)^2 + \tau_{xy}^2}$$

Due to the presence of compressive f_x and f_y, the magnitude of principal tensile stress is considerably reduced risk of diagonal tension is miminised to great extent.

5.27 (d)

Total loss in prestress is in range of 200 N/mm^2 to 300 N/mm^2. Thus high tensile steel having strength in range of 1200-1500 N/mm^2 is to be used so that even after there is loss there is sufficient prestress left in the concrete.

6.Masonry Structures and Earthquake Engineering

6.1 (c)

For masonry built in M_1 mortar or equivalent, a horizontal shear stress f_s may be permitted on the area of mortar bed joint as given by

$f_s = 0.1 + f_d/6 \leq 0.5$ N/mm^2

Where f_d is the actual compressive stress on the section due to dead loads.

Since the height of wall or column is not given so assume $f_d = 0$.

$\therefore \quad f_s = 0.1$ N/mm^2

6.2 (b)

The slenderness ratio of free standing wall will be more than that when it supports RC slab. So the load carrying capacity will be less.

6.3 (a)

Resultant load = 26 + 19 = 45 kN/m

Resultant moment = 26 × 0 + 19 × 45

= 855 kN-mm/m

Resulting eccentricity, $e = \frac{855}{45} = 19$ mm

Eccentricity ratio = $\frac{e}{t} = \frac{19}{200} = 0.095$

Eccentricity ratio can have maximum value as 0.50.

6.4 (a)

The slenderness ratio of a wall is lesser of the

$\frac{h}{t}$ eff. and $\frac{l}{t}$

$$\frac{h_{eff}}{t} = 0.75 \times \frac{h}{t}$$

$$= 0.75 \times \frac{3800}{200} = 14.25 \text{ say } (15)$$

$$\therefore \quad \frac{l}{t} = \frac{5000}{200} = 25$$

6.5 (b)

Resultant eccentricity

$$e = \frac{30 \times 0 + 20 \times 47.5}{30 + 20} = 19 \text{ mm}$$

Eccentricity ratio = $\frac{e}{t} = \frac{19}{200} = 0.095$

6.6 (b)

The angle of dispersion is normally taken to be 45° for good masonry. For poor masonry it is taken 30° to vertical. If the height of the wall above the opening is less than 1.25 times the height of the triangle, full rectangular load over the lintel is transferred.

6.7 (b)
For the transfer of load to the sides by arch action, it is necessary that the height of the wall above the opening is 1.25 times the height of triangle of masonry load transferred on the lintel and the length of the wall on each side of the opening is equal to at least half of the effective span of the lintel.

6.8 (a)
Modifying factor for shape of masonry units.

Height to width ratio	Modification factor for shape K_u for strength of units in N/mm^2			
	5.0	7.5	10.0	15
1.0	1.2	1.1	1.1	1.0
1.5	1.5	1.3	1.2	1.1

So for height to width ratio 1.5 K_u = 1.2

6.9 (d)
As per IS 1080 : 1980, all types of foundation must have a minimum depth of 500 mm. The minimum depth is required to ensure the availability of soil having the safe bearing capacity assumed in the design. The foundation must be placed below the natural or finished ground level so that it is not affected by swelling or shrinkage of soil. Rankine's formula gives the preliminary estimate of depth of foundation.

$$d_{min} \le \frac{q}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

It doesn't take into consideration the loads acting on the foundation.

7. Miscellaneous

7.1 (c)
Bending moment in the panel of a bridge can be computed via Pigeaud's curves. Elastic theory of flexure is used and the Poisson's ratio is taken as 0.15. It was initially for steel plates and then conceptualized for concrete slabs as well. Pigeaud's curves are only applicable to a single wheel load placed centrally.

7.2 (a)
As per **IS 456 : 2000 clause 24.3.2** for a single concentrated load on solid slab supported on two edges, effective with b_{ef} is given by

$$b_{ef} = kx\left[1-\frac{x}{l_{ef}}\right]+a$$

b_{ef} = Effective width of slab
k = Constant from table 14
x = Distance of centroid of concentrated load from nearer support
l_{ef} = Effective span
a = Width of contact area of the concentrated load from nearer support measured parallel to support edge.

7.3 (b)
IS:3370 says

Thickness of section	Mild bar reinforcement	HYSD reinforcement
≤ 100 mm	0.3%	0.24%
100-450 mm	Linearly from 0.3-0.2%	Linearly from 0.24 - 0.16%
≥ 450 mm	0.2%	0.16%

7.4 (b)
- Deck slab bridge: It is simplest type of construction used for culverts with spans less than 9 m.
- Arch bridge: Where beams becomes uneconomical, they are used. Dead load moments can be greatly minimised in this, if properly designed.
- Balanced cantilever bridge: It is used for 20-30 m lengths.
- Rigid frame culvert: It is used for small drain only.

7.5 (c)
Box section has higher torsional resistance. So it is most economical.

7.6 (a)
Courbon's theory of distribution of live loads on longitudinal beams is applicable when the following conditions are satisfied:
(i) The span to width ratio is greater than 2 and less than 4.

(ii) There are at least five symmetrical cross-girders or diaphragms connecting the longitudinal girders.

(iii) The depth of the cross girders is at least $\frac{3}{4}$th of the depth of longitudinal girders.

When the live loads are eccentrically placed with respect to the axis of the bridge, then reaction factor R_x for any given girder at a distance x from the bridge axis is

$$R_x = \frac{\Sigma P}{n}\left[1+\frac{nex}{\Sigma x^2}\right]$$

Number of girder

$$n = 3$$

$$\Sigma P = W + W + W + W = 4W$$

x is measured from the bridge axis.

The bridge axis from left kerb.

$$l_c = \frac{400+1800+1700+1800+1800}{2}$$

$$= 3750 \text{ mm} = 3.75 \text{ m}$$

Girder	A	B	C
$x(m)$	3.0	0	–3

$\Sigma x^2 = (3.0)^2 + (0)^2 + (3.0)^2 = 18 \text{ m}^2$

Eccentricity,

$$e = \frac{W\times(3.35+1.55-0.15-1.95)}{4W} = 0.7$$

$$R_A = \frac{4W}{3}\left[1+\frac{3\times0.7\times3}{18}\right] = 1.80W$$

$$R_B = \frac{4W}{3}[1+0] = 1.33W$$

$$R_C = \frac{4W}{3}\left[1-\frac{3\times0.7\times3}{18}\right] = 0.87\text{W}$$

7.7 (b)

Since metallic bearings are expensive in the initial cost and required periodical oiling and greasing, the recent trend is to favour elastomeric bearing, which are easy to install, low in initial cost and require practically no maintenance. An elastomer is any member of a class of polymeric substances obtained after vulcanization and possessing characteristic similar to rubber, especially the ability to regain shape almost completely after deformation.

7.8 (d)

Where notching or cutting slots or holes are required in timber beam, the net section remaining after notching should be safe for bending and shearing stresses.

Within a length equal to $L/6$ or $3d$ whichever is less, measured from the supports, notches may be cut in the top or bottom fibers upto a maximum depth of $d/5$. Holes having diameter less than $d/4$ may be made in the middle third portion of depth and span of beam.

7.9 (c)

To ensure adequate ductility

$$p - p_c \le \left[\frac{\epsilon_u}{\epsilon_u + \mu_s\,\epsilon_y}\right]\frac{0.36f_{ck}}{0.87f_{sy}}$$

$$\epsilon_u = 0.0035$$

$$\epsilon_y = 0.002+\frac{0.87f_y}{E_s} = 0.0031$$

$$\mu_s = 2.0 \text{ for M15}$$

$$\therefore \quad p - p_c \le 0.15\frac{f_{ck}}{f_{sy}}$$

$$p \le p_c + 0.15\frac{f_{ck}}{f_{sy}}$$

7.10 (a)

For cantilever action,

$$\frac{\text{Number of storey}}{\text{Number of bay}} = \frac{6}{4} = 1.5 > 1$$

So the behaviour of frame subjected to lateral loads will be more like a cantilever than as a portal frame.

For $\frac{\text{Number of storey}}{\text{Number of bay}} < 1$, the behaviour will be like a portal frame .

7.11 (d)

Courbon's theory is used for distribution of live loads on longitudinal beams (girders). The other methods for the same purpose are - Henry - Jaegar method; and Morice and Little version of Guyon and Massonet method.

Courbon's method of analysis is an old method of bridge deck analysis. It is highly popular due to its simplicity. According to this method, reaction factor for individual longitudinal girders is given by

$$P_1 = \frac{P}{n}\left[1+\frac{\eta e d_i}{\Sigma d_i^2}\right]$$

where P = Total load, e = eccentricity, n = no. of girders, d_i = distance of girders from bridge's axis.

7.12 (a)

IRC class *AA* loading is to be adopted within certain municipal limits in certain existing or contemplated industrial area, in other specified areas and along certain specified highways.

IRC class *A* loading is most common type of loading adopted for prominent bridges and culverts.

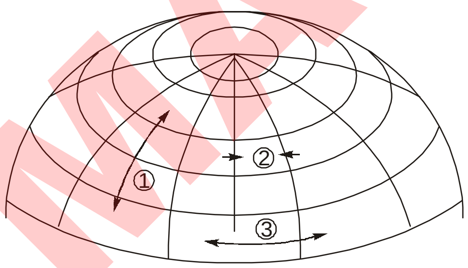
IRC class *B* loading is adopted for temporary structures and for bridges in specified areas. The structures with timber spans are regarded as temporary structures.

The live loadings considered are:

(i) Class AA tracked vehicles
(ii) Class AA wheeled vehicles
(iii) Class A loading

7.13 (a)

The primary stresses induced in the dome are (i) a compressive force acting along the meridian, called the meridional thrust and (ii) a force compressive or tensile in nature, acting along a horizontal circle on the dome called the hoop tension or hoop compression.



1. Meridional stress (Compressive)
2. Circumferential Hoop stress (Compressive)
3. Circumferential Hoop stress (Tensile)

7.14 (c)

As per IS 3370 (Part-II) : 1965 clause 7.1, the minimum steel is walls, floors and roofs in each of two directions at right angles shall have an area of 0.3% of concrete section in that direction for sections upto 100 mm thickness. For thickness greater than 100 mm and less than 450 mm the minimum reinforcement in each of the directions shall be linearly reduced from 0.3% for 100 m thick section to 0.2% for 450 mm thick.

If thickness > 450 mm, minimum reinforcement of 0.2% is to be provided in each of the two directions.

The minimum reinforcement for water tanks is

(i) 0.24% of the concrete section for section upto 100 mm thick.

(ii) $\left[0.24-\frac{0.08(t-100)}{350}\right]$% for section thickness 100-450 mm.

(iii) 16% for section thickness more than 450 mm

∴ For 150 mm, the minimum reinforcement

$$0.24-\frac{0.08\times 50}{350} = 0.23\%$$

7.15 (d)

Bunkers and silos are used for storage of materials like grain, cereals, coal, cement etc. The approximate methods for the analysis of these structures was suggested by Janssen and Airy. Airy's theory is based on Coulomb's wedge theory of earth pressure.

For deep bins the maximum horizontal pressure condition is to be satisfied and vertical load on the wall is $P_w = \mu' P_h$

$\mu' \rightarrow$ friction between material and wall.

Thus horizontal pressure approaches a limit and vertical pressure increases continuously.

7.16 (a)

Axial compression is induced in chimneys due to self-weight but buckling tendency becomes critical due to lateral wind pressure, which cause hoop compressive strain and buckling tendency increases with increase in d/t ratio.

7.17 (d)

The lateral pressure during filling $= \frac{Wr}{\mu_f}$

The lateral pressure during emptying $= \frac{Wr}{\mu_e'}$

$\therefore$ Ratio of lateral pressure during emptying to that at the time of filling is = $\dfrac{\mu_f'}{\mu_e'}$

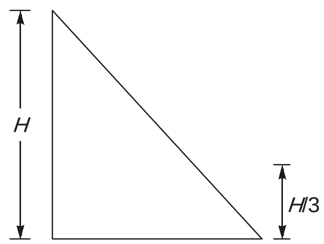
μ_f' $\rightarrow$ friction coefficient during filling.

μ_e' $\rightarrow$ friction coefficient during emptying

Since $\mu_e' > \mu_f'$ so ratio is greater than one

7.18 (a)

Earth pressure distribution will be as:



The centre of pressure will lie at H/3 from bottom of retaining wall.

7.19 (a)

Axial compression is induced in chimneys due to self-weight but buckling tendency becomes critical due to lateral wind pressure, which cause hoop compressive strain and buckling tendency increases with increase in d/t ratio.

■■■■

UNIT

VI

Construction Practice, Planning & Management

Syllabus

Construction-Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare.

Contents

6 Construction Practice, Planning & Management

1. Basics of Construction Management

1.1 Functional organization system of working was introduced by

(a) F.W. Taylor (b) Henry Gantt
(c) M.R. Walker (d) J.E. Kelly

[ESE : 1995]

1.2 Match **List-I** (Indications of terms) with **List-II** (Terms) and select the correct answer using the codes given below the lists:

List-I

A. Used for recording instructions given by the Executive Engineer at site
B. Used widely for civil engineering construction
C. One of the principles of organization
D. One of the functions of management

List-II

1. Co-ordination
2. Unity of command
3. Line organization
4. Site order book

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	4	2	3	1
(c)	2	4	1	3
(d)	4	1	2	3

[ESE : 1996]

1.3 Preliminary project report for a road project must contain

(a) the detailed estimated cost based on detailed design
(b) the several alternatives of the project that have been considered
(c) the soil survey, traffic survey, concept design and approximate cost
(d) the contract documents for inviting tenders

[ESE : 1999]

1.4 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Translates policy into a method of achieving the objective set out
B. Consists of defining the responsibilities of employees
C. Transmits all the information to the supervising staff
D. The organizational setup is aided to operate efficiently with flow of information, decisions and results in all directions

List-II

1. Co-ordinating
2. Planning
3. Organizing
4. Directing

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	1	4
(c)	3	2	4	1
(d)	2	3	4	1

[ESE : 1999]

1.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. To allocate the resources among competing projects and to determine whether or not the returns from investment are adequate.
B. To see that adequate and timely funds are made available for investment including that for operation and maintenance
C. To analyze various aspects of a project such as process, design, size, layout, capacity, etc.
D. To find the effects of fiscal, monetary, wage, exchange rate, etc. policies

List-II
1. Technical analysis
2. Macroeconomic analysis
3. Financial analysis
4. Feasibility analysis
5. Economic analysis

Codes :

	A	B	C	D
(a)	5	4	2	1
(b)	4	3	1	2
(c)	3	5	2	1
(d)	5	3	1	2

[ESE : 1999]

2. Element of Network

2.1 Consider the following activities in a building construction:
1. Concreting of roof slabs.
2. Brick-jelly lime concrete terracing.
3. Erection of formwork for slab.
4. Construction of parapet wall in terrace.

The correct sequence of these activities is
(a) 1, 3, 2, 4 (b) 3, 1, 4, 2
(c) 3, 1, 2, 4 (d) 1, 3, 4, 2

[ESE : 1995]

2.2 The network rules are common to all activity-on-arrow networking systems. The use of computers for making computations may impose certain rules. Which of the following basic rules of network logic are correct?
1. Before an activity may begin, all the activities preceding it must be complete
2. Any two events may be directly connected by no more than one activity.
3. Event numbers must not be duplicated in a network.

Select the correct answer using the codes given below :
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 1998]

3. PERT & CPM

Part-1 : PERT

3.1 Consider the following features/factors:
1. Projects are the non-repetitive type.
2. Time requirement need not be known.
3. Time required is known precisely.
4. Events have been established for planning.
5. Emphasis given to activities of project.

PERT is preferred for planning because of
(a) 1, 2 and 4 (b) 3, 4 and 5
(c) 1, 3 and 4 (d) 1, 2 and 5

[ESE : 1995]

3.2 Given that
t = the duration of various jobs
t_m = mean time of different durations
n = number of observations
The standard deviation is given by
(a) $\frac{\Sigma t}{n}$ (b) $t - t_m$
(c) $\frac{\Sigma(t-t_m)^2}{n}$ (d) $\sqrt{\frac{\Sigma(t-t_m)^2}{n}}$

[ESE : 1995]

3.3 For a given activity, the optimistic time, pessimistic time and the most probable estimates are 5, 17 and 8 days respectively. The expected time is
(a) 8 days (b) 9 days
(c) 10 days (d) 15 days

[ESE : 1995]

3.4 The optimistic, most likely, and pessimistic estimates of time for an activity are 4 days, 11 days and 12 days respectively. The expected completion time of this activity is
(a) 8 days (b) 9 days
(c) 10 days (d) 11 days

[ESE : 1997]

3.5 The time estimates obtained from four contractors P, Q, R and S for executing a particular job are as under:

Contractor	Optimistic time, t_o	Most likely time, t_L	Pessimistic time, t_P
P	5	10	13
Q	6	9	12
R	5	10	14
S	4	10	13

Which one of these contractors is more certain about completing the job in time?

(a) P (b) Q
(c) R (d) S

[ESE : 1997]

3.6 The optimistic, the most likely duration and the pessimistic time estimates in a network are 4, 5 and 8 months respectively. The expected time is
(a) 4.00 months (b) 5.33 months
(c) 5.67 months (d) 7.00 months

[ESE : 1998]

3.7 The probability distribution taken to represent the completion time in PERT analysis is
(a) gamma distribution
(b) normal distribution
(c) beta distribution
(d) log-normal distribution

[ESE : 1998]

Part-2 : CPM

3.8 Match **List-I** (Description of activity floats) with **List-II** (Names of the floats) and select the correct answer using the codes given the lists:

List-I
A. Earliest start time of successor activity minus earliest activity in question minus the duration
B. Time available for an activity performance minus the duration of the activity
C. Excess of minimum available time over the required activity duration
D. Difference between total and free float of an activity

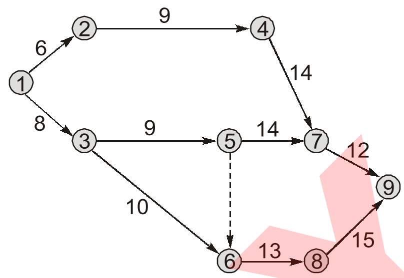
List-II
1. Total
2. Free
3. Interfering
4. Independent float

Codes :

	A	B	C	D
(a)	1	2	3	4
(b)	1	2	4	3
(c)	2	1	3	4
(d)	2	1	4	3

[ESE : 1995]

3.9 The flow net of activities of a project is given in the following figure. The duration of activities are indicated along the arrows.



The critical path of the activities is along
(a) 1 – 2 – 4 – 7 – 9
(b) 1 – 3 – 5 – 7 – 9
(c) 1 – 3 – 6 – 8 – 9
(d) 1 – 3 – 5 – 6 – 8 – 9

[ESE : 1995]

3.10 Match **List-I** (Item) with **List-II** (Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. Activity
B. Event
C. Dummy
D. Float

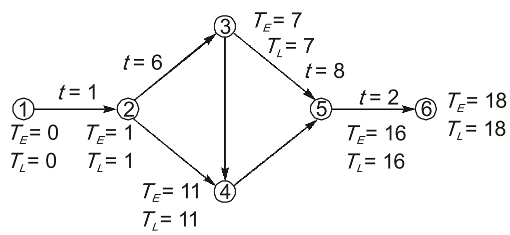
List-II
1. Resourceless element
2. Resource consuming element
3. Spare time
4. Instantaneous stage

Codes :

	A	B	C	D
(a)	1	4	3	2
(b)	2	1	4	3
(c)	2	4	1	3
(d)	3	4	1	2

[ESE : 1995]

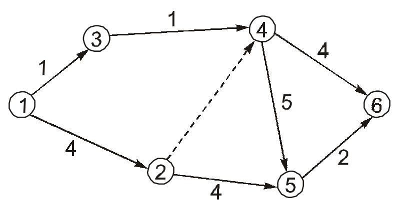
3.11 The following diagram shows the details necessary for the CPM network analysis:



The critical path will be

(a) 1 – 2 – 3 – 5 – 6
(b) 1 – 2 – 3 – 4 – 5 – 6
(c) 1 – 2 – 4 – 5 – 6
(d) 1 – 2 – 4 – 3 – 5 – 6 [ESE : 1995]

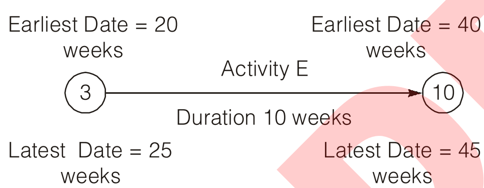
3.12 From the network shown in the figure below (the number on each arrow denotes the time duration of activity in days), the earliest start time, in days for activity 5–6 is



(a) 8 (b) 7
(c) 9 (d) 11

[ESE : 1997]

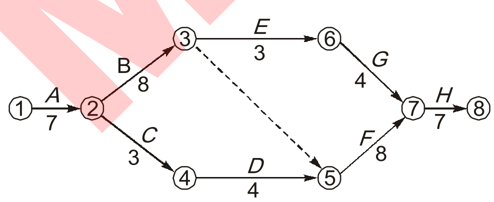
3.13 The earliest date and the latest date of events 3 and 10 are given in the figure below. Activity E is connecting both the events and its duration is 10 weeks. The independent float of the activity is



(a) 5 weeks (b) 10 weeks
(c) 15 weeks (d) 20 weeks

[ESE : 1998]

3.14 The flow net of the activities of a project are shown in the network given below indicating the duration of the activities along their arrows.



The critical path of the activities is along

(a) $1 \to 2 \to 4 \to 5 \to 7 \to 8$
(b) $1 \to 2 \to 3 \to 6 \to 7 \to 8$
(c) $1 \to 2 \to 3 \to 5 \to 7 \to 8$
(d) $1 \to 2 \to 4 \to 5 \to 3 \to 6 \to 7 \to 8$

[ESE : 1998]

3.15 Consider the following pairs:

1. Difference between total float and free float : **Interfering float**
2. Sum of independent float and tail slack : **Free float**
3. Sum of independent float, tail slack and interfering float : **Total float**

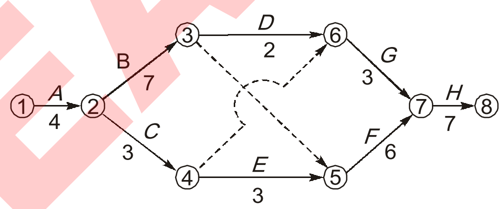
Which of these pairs are correctly matched?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1999]

3.16 Consider the *AOA* network of a project shown in the given figure. (Activities are designated by alphabets and durations are shown around the stem of the arrow)

The critical path will be



(a) 1-2-3-6-7-8 (b) 1-2-3-5-7-8
(c) 1-2-4-5-7-8 (d) 1-2-4-6-7-8

[ESE : 1999]

3.17 Consider the implicit details between, before and after successive steps in/within the order while doing time computations on a *CPM* network (*FP* ⇒ Forward Pass; *BP* ⇒ Backward Pass; *LET* ⇒ Late Event Time; *EET* ⇒ Early Event Time; *TF* ⇒ Total Float; *PD* ⇒ Project Duration; *AD* ⇒ Activity Duration)

The correct sequence of computation would be

(a) *EET*, *PD*, *LET*, *TF*
(b) *EET*, *PD*, *LET*, *AD*
(c) *AD*, *EET*, *BP*, *PD*
(d) *FP*, *EET*, *TF*, *PD*

[ESE : 1999]

4. Time Cost-Models, Crashing

4.1 Three activities implementable in parallel, have the following time-cost relationships for direct cost component in each:

Activity A:

10 days-800 units; 9 days-900 units;

8 days-1000 units

Activity B:

11 days-1200 units; 10 days-1350 units; 9 days-1500 units

Activity C:

7 days-500 units; 6 days-700 units; 5 days-900 units

The feasible range of total direct cost component for the three activities together is

(a) 2500 to 3400 units
(b) 2650 to 3200 units
(c) 2500 to 2900 units
(d) 2600 to 3100 units

[ESE : 1995]

4.2 Cost-benefit studies are essential to

(a) assess the total cost of the work
(b) ascertain the relevant escalation in prices
(c) monitor the expenditure
(d) evaluate the viability and worthwhileness of taking up the project

[ESE : 1996]

4.3 Consider the following statements:

Crashing a project in terms of its duration would result in

1. an increase in the indirect cost
2. a decrease in the indirect cost
3. a decrease in the direct cost
4. an increase in the direct cost

Which of these statements are correct?

(a) 1 and 4 (b) 2 and 3
(c) 1 and 3 (d) 2 and 4

[ESE : 1998]

4.4 In the time-cost optimization, using CPM method for network analysis, the crashing of the activities along the critical path is done starting with the activity having

(a) longest duration
(b) highest cost slope
(c) least cost slope
(d) shortest duration

[ESE : 1998]

4.5 Activity *P* is followed by Activity *Q* which in turn, is followed by Activity *R*. The direct cost of these activities in relation to the choice of feasible durations table is given below:

	Activity P			Activity Q			Activity R		
Duration in days	7	6	5	8	7	6	9	8	7
Direct Cost Rs. '000	12	14	15	20	23	27	40	42	45

For all the three activities taken together the minimum possible direct cost for a total duration of 21 days will be

(a) Rs. 81,000 (b) Rs. 79,000
(c) Rs. 78,000 (d) Rs. 77,000

[ESE : 1999]

5. AON Network, Resource Allocation, Charts etc.

5.1 In resources levelling

(a) total duration of project is reduced
(b) total duration of project is increased
(c) uniform demand of resources is achieved
(d) cost of project is controlled

[ESE : 1995]

5.2 The following table contains data on four activities, A, B, C and D:

Activity	Starts at Week number	Ends with Week number	Resources needed per week
A	9th	16th	6
B	11th	20th	4
C	15th	22th	3
D	13th	24th	7

The maximum total resource load in any week will be

(a) 20 (b) 17
(c) 16 (d) 14

[ESE : 1995]

5.3 Gantt charts indicate

(a) comparison of actual progress with the scheduled progress
(b) balance of work to be done
(c) progressive costs of project
(d) inventory costs

[ESE : 1997]

5.4 Consider the following statements:
Resource levelling means
1. economical utilization of resources
2. gradual increase in resources
3. adjustment of resources to have the least variations.
4. complete revamping of resources to suit the requirements
5. validating network depending on resource constraints

Which of these statements are correct?
(a) 1 and 2 (b) 2, 3 and 4
(c) 3 and 5 (d) 1, 2, 3, 4 and 5
[ESE : 1997]

5.5 Which of the following are the possible changes during the updating of the project network?
1. Change in the duration of an activity.
2. Addition or deletion of an activity.
3. Change in the logical relationship among the activities

Select the correct answer using the codes given below :
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE : 1998]

5.6 **Assertion (A) :** In resource levelling, the project completion time is not extended even though there is constraint in the availability of resources.
Reason (R) : There is generally a constraint against exceeding the project duration time.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

6. Cost Estimation and Valuation

6.1 The original cost of an equipment is Rs. 10,000. Its salvage value at the end of its total useful life of five years is Rs. 1,000. Its book value at the end of two years of its useful life (as per straight line method of evaluation of depreciation) will be
(a) Rs. 8,800 (b) Rs. 7,600
(c) Rs. 6,400 (d) Rs. 5,000
[ESE : 1995]

6.2 Consider the following statements:
A floating floor construction can
1. efficiently absorb impact noise
2. efficiently insulate against impact noise
3. efficiently insulate against airborne noise

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE : 1996]

6.3 Window sills in residential houses are normally kept at
(a) 83 to 90 cm above the floor level
(b) 80 to 90 cm above the floor level
(c) 78 to 88 cm above the floor level
(d) 75 to 85 cm above the floor level
[ESE : 1996]

6.4 In a mass-haul diagram, the distance (D) of the centre of mass of excavation or embankment from the line representing the volume to be hauled over is given by
(a) D = Area × Horizontal scale × Vertical scale/Volume ordinate
(b) D = Area × Volume ordinate/(Horizontal scale × Vertical scale)
(c) D = Area × Volume ordinate
(d) D = Area × Horizontal scale/Vertical scale
[ESE : 1996]

6.5 With the usual notations, sinking fund factor is given by
(a) $(1 + i)^n$ (b) $\dfrac{i}{(1+i)^n - 1}$
(c) $\dfrac{1}{(1+i)^n}$ (d) $\dfrac{i(1+i)^n}{(1+i)^n - 1}$
[ESE : 1998]

6.6 Capital recovery factor at 15% p.a. discrete compounding for 4 years is 0.35. Rs. 10,000 deposited now at 15% p.a. discrete compounding will yield an amount X at the end of each 4 year period in perpetuity. The value of X is
(a) Rs. 7,500 (b) Rs. 6,666
(c) Rs. 6,000 (d) Rs. 5,000
[ESE : 1999]

6.7 A machine costs Rs. 16,000. By constant rate of declining balance method of depreciation, its salvage value after an expected life of 3 years is Rs. 2,000. The rate of depreciation is

(a) 0.25 (b) 0.30
(c) 0.40 (d) 0.50

[ESE : 1999]

7. Productivity and Operation, Site Investigation

7.1 The profits and the associated probability of making the profits are given below in respect of four projects:

Project	Profit	Probability of making the profit
1	15%	0.5
2	10%	0.8
3	12%	0.7
4	11%	0.6

When the motive is maximization of expected profit, the correct order of preference of these projects would be

(a) 1, 3, 4, 2 (b) 2, 3, 4, 1
(c) 3, 2, 1, 4 (d) 3, 4, 2, 1

[ESE : 1997]

7.2 The issue rate of an item stocked in stores is

(a) permanently fixed
(b) fixed at the beginning of each year
(c) a rate less than the market rate
(d) the rate revised during the year when there is an appreciable variation in the rates of the items

[ESE : 1997]

7.3 **Assertion (A) :** The point of minimum total cost of equipment occurs when the inventory procurement cost is equal to the inventory holding cost.

Reason (R) : The inventory procurement cost is inversely proportional to the size of the lot, and the inventory holding cost is directly proportional to the size of the lot.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

7.4 It is desired to purchase four different types of construction equipment from three different manufactures. The optimal order for the equipment and the minimal cost are to be determined. The most appropriate model for this purpose would be

(a) Waiting line model
(b) Inventory model
(c) Transportation model
(d) Assignment model [ESE : 1998]

7.5 Cost of owning an equipment would include

(a) cost of depreciation, maintenance and repair, and fuel
(b) cost of investment, wages of the crew, and fuel
(c) cost of fuel, lubricating oil, investment, and depreciation
(d) cost of investment, major repairs, and depreciation

[ESE : 1998]

7.6 Sensitivity analysis is a study of

(a) comparison of profit and loss
(b) comparison of assets and liabilities
(c) changes in output due to change in input
(d) economics of costs and benefits of the project

[ESE : 1998]

7.7 Two events *K* and *L* can cause delay in construction activity when occurring either each independently or both together, but the two events are not statistically independent of each other. The probability that at least one of the events occurs is 0.75 and the probability that each one occurs by itself is 0.45. The critical probability for occurrence of delay in the activity is

(a) $\frac{0.75}{0.45+0.75}$ (b) $\frac{0.75-0.45}{0.75}$

(c) $\frac{2\times0.45-0.75}{0.75}$ (d) $\frac{2\times0.45-0.75}{0.45}$

[ESE : 1999]

7.8 In a project, the contractor is paid on the basis of the running bill for a month. The rate contract for concerning is Rs. 1000 per m^3 of concrete. The consumption of number of cement bags of weight 50 kg is 527. The mix proportion for the concrete is 1:1.4:2.75 with w/c ratio of 0.52. The approximate billing amount of the month will be
(a) Rs. 5,27,000 (b) Rs. 1,49,404
(c) Rs. 62,252 (d) Rs. 26,350
[ESE : 1999]

7.9 The outgo of investment in a project is estimated at 2000 units of money at year zero. The following four alternatives of revenue earning schemes are considered as possibilities, each at 6% ROR
1. 600 units of money at the end of each of the year 1st to 5th.
2. 800 units at the end of year 1, reducing at the rate of 100 units each year, ending with 400 units at the end of year 5.
3. 400 units at the end of year 1, increasing at the rate of 100 units each year, ending with 800 units at the end of year 5.
4. 400 units at the end of each of year 1 and year 2; with 600 units at the end of year 3; and with 800 units at the end of each of year 4 and year 5.

From the investor's point of view, the correct sequence in decreasing order of preference will be
(a) 2, 1, 4, 3 (b) 2, 4, 3, 1
(c) 3, 4, 2, 1 (d) 3, 1, 2, 4
[ESE : 1999]

8. Construction Equipments

8.1 Consider the following operations:
1. Drilling 2. Blasting
3. Mucking 4. Placing Steel
5. Placing concrete

The correct sequence of these operations in tunnel construction is
(a) 1, 2, 4, 3, 5 (b) 1, 3, 2, 4, 5
(c) 1, 2, 3, 4, 5 (d) 1, 3, 4, 2, 5
[ESE : 1995]

8.2 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Derick
B. Claw-hammer
C. Chain-Lewis
D. Drop-hammer

List-II
1. Stone masonry work
2. Wood work
3. Steel work
4. Concrete compaction
5. Pile foundation

Codes :

	A	B	C	D
(a)	1	3	5	4
(b)	2	3	4	5
(c)	3	1	5	2
(d)	3	2	1	5

[ESE : 1996]

8.3 The maximum rimpull in the first gear of a tractor while towing a load is 6300 kg. The tractor weighs 12 tonnes and is operating along a 2 per cent upgrade and the rolling resistance is 45 kg/tonne. Pull available for towing the load is
(a) 3425 kg (b) 5515 kg
(c) 4350 kg (d) 2975 kg
[ESE : 1996]

8.4 The probable output per hour of a 34° double-drum paving mixer in cum/hour, is
(a) 1.5 to 2.5 (b) 2.0 to 2.5
(c) 2.0 to 3.25 (d) 2.5 to 3.0
[ESE : 1996]

8.5 The tipping load of a crane refers to
(a) lifted weight together with all attached handling tackle and hoist rope, with grounded attached outriggers
(b) lifted weight together with all attached handling tackle but excluding hoist rope, with specifying the radius horizontally, with grounded outriggers
(c) lifted weight alone, with specifying the radius for the lifted weight and also for the counter weight without grounding the outriggers
(d) lifted weight alone, at specified horizontal radius without grounding the outriggers
[ESE : 1996]

8.6 Consider the following statements:
A concrete mixer is specified by the
1. volume of the mixing drum
2. horse power of the prime mover
3. volume of mixed concrete discharged
4. mixer drum speed
5. feeding arrangement
Which of these statements are correct?
(a) 1, 2 and 5 (b) 1, 3 and 4
(c) 3 and 5 (d) 2 and 4
[ESE : 1997]

8.7 Reinforced concrete door and window frames can be compacted using
1. needle vibrator 2. plate vibrator
3. form vibrator 4. tamping
The correct sequence of these equipment in order of preference (from the best to the worst) is
(a) 2, 3, 4, 1 (b) 3, 2, 1, 4
(c) 2, 3, 1, 4 (d) 3, 2, 4, 1
[ESE : 1997]

8.8 Which of the following types of pumps can be used for concreting?
1. Piston operated
2. Pneumatically operated
3. Centrifugally operated, with straight blades
4. Screw type
Select the correct answer using the codes given below :
(a) 1 and 3 (b) 1 and 2
(c) 1, 3 and 4 (d) 2 and 4
[ESE : 1997]

8.9 Grader is used mainly for
(a) trimming and finishing
(b) shaping and trimming
(c) finishing and shaping
(d) finishing, shaping and trimming
[ESE : 1997]

8.10 Which one of the following is **NOT** an excavating and moving type of equipment?
(a) Bulldozer (b) Clamshell
(c) Scraper (d) Dump truck
[ESE : 1997]

8.11 The most suitable type of equipment for compacting of cohesive soils is
(a) smooth-wheeled rollers
(b) vibratory rollers
(c) sheep foot rollers
(d) tampers
[ESE : 1997]

8.12 For excavating utility trenches with precise control of depth, the excavation equipment used is
(a) hoe (b) shovel
(c) dragline (d) none of these
[ESE : 1997]

8.13 The basic action involved in sheep foot rolling is
(a) kneading (b) pressing
(c) tamping (d) vibration
[ESE : 1997]

8.14 **Assertion (A) :** Single scaffolding consists of a single framework of standards, ledgers and put-logs constructed parallel to the wall.
Reason (R) : Putlogs are placed at both ends on frames when it is difficult to provide holes in the wall.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1997]

8.15 Match **List-I** (Types of work) with **List-II** (Type of contract most appropriate) and select the correct answer using the codes given below the lists:

List-I
A. Specified architectural work
B. House construction
C. Repainting of house
D. Dewatering foundations

List-II
1. Cost plus
2. Lumpsum
3. Item rate
4. Price work

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	4	1
(c)	2	3	1	4
(d)	3	2	4	1

[ESE : 1997]

8.16 Consider the following statements:
Wheeled tractors are replacing crawler tractors because
1. wheeled tractors travel faster
2. crawler tractors are more expensive
3. track parts of a crawler tractor wear out quickly
4. crawler tractors have stick control

Which of these statements are correct?
(a) 1, 3 and 4 (b) 2, 3 and 4
(c) 1, 2 and 3 (d) 1, 2 and 4
[ESE : 1998]

8.17 Match **List-I** (Nature of work) with **List-II** (Machine required) and select the correct answer using the codes given below the lists:

List-I		List-II
A. Excavation and moving	**1.**	Derrick
B. Pure excavation	**2.**	Dump truck
C. Pure transportation	**3.**	Power shovel
D. Pure hoisting	**4.**	Drag line

Codes :

	A	B	C	D
(a)	1	3	2	4
(b)	3	4	2	1
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1998]

8.18 The rated loads of lifting cranes, as percentage of tipping loads at specified radius, for crawler-mounted, and pneumatic tyre mounted machines would be respectively
(a) 80 and 90 (b) 90 and 80
(c) 85 and 75 (d) 75 and 85
[ESE : 1998]

8.19 **Assertion (A) :** The hoe is not very advantageous in digging trenches and basements.
Reason (R) : In a hoe, the digging action results from the drag of the bucket.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true [ESE : 1999]

8.20 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Cube specimen
B. Pavement slab
C. Heavily reinforced column
D. Mass concrete in bridge piers

List-II
1. Pin vibrator
2. Form vibrator
3. Table vibrator
4. Screed vibrator
5. Manual compaction

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	2	3	4	5
(c)	3	4	2	1
(d)	3	4	1	5

[ESE : 1999]

8.21 Consider the following statements regarding use of mechanical vibrator:
1. It can be used for small as well as large volumes of concrete.
2. The mix can have high value of slump.
3. Density of concrete can be high.

The advantages of a mechanical vibrator include
(a) 2 and 3 (b) 1 and 3
(c) 1, 2 and 3 (d) 1 and 2
[ESE : 1999]

8.22 A centrifugal pump is required to lift 2.8 m^3/s of water to a height of 7.5 m. If the total loss of head in the pipe system is 0.25 m and the efficiency of the pump is 80%, then the brake horse power will be

(a) $\frac{1000\times2.8\times7.5\times0.8}{75}$

(b) $\frac{1000\times2.8\times7.75}{0.8}$

(c) $\frac{1000\times2.8\times7.75}{0.8\times75}$

(d) $\frac{1000\times2.8\times0.8}{75}$

[ESE : 1999]

Answers Construction Practice, Planning & Management

1.1	(a)	1.2	(a)	1.3	(c)	1.4	(d)	1.5	(d)	2.1	(c)	2.2	(d)	3.1	(a)	3.2	(d)
3.3	(b)	3.4	(c)	3.5	(b)	3.6	(b)	3.7	(b)	3.8	(d)	3.9	(c)	3.10	(c)	3.11	(b)
3.12	(c)	3.13	(a)	3.14	(c)	3.15	(c)	3.16	(b)	3.17	(a)	4.1	(a)	4.2	(d)	4.3	(d)
4.4	(c)	4.5	(d)	5.1	(c)	5.2	(a)	5.3	(a)	5.4	(c)	5.5	(a)	5.6	(a)	6.1	(c)
6.2	(d)	6.3	(b)	6.4	(a)	6.5	(b)	6.6	(a)	6.7	(d)	7.1	(c)	7.2	(d)	7.3	(a)
7.4	(a)	7.5	(d)	7.6	(a)	7.7	(d)	7.8	(c)	7.9	(a)	8.1	(c)	8.2	(d)	8.3	(b)
8.4	(d)	8.5	(a)	8.6	(c)	8.7	(a)	8.8	(b)	8.9	(c)	8.10	(d)	8.11	(c)	8.12	(a)
8.13	(a)	8.14	(b)	8.15	(d)	8.16	(d)	8.17	(c)	8.18	(d)	8.19	(d)	8.20	(c)	8.21	(b)
8.22	(c)																

Explanations Construction Practice, Planning & Management

1. Basics of Construction Management

1.1 (a)

Henry Gantt introduced Bar Chart.

1.2 (a)

Site order book is register maintained by contractor to record instructions given by executive engineer. Line organization is oldest and simplest form of organization adopted in construction projects specifying line of authority and responsibilities. Unity of command is one of the principles of organization. Co-ordination, planning, organizing etc are the function of organization.

1.3 (c)

Preliminary project report contains topographic details and soil survey along alternate alignments, consideration of geometric design and other requirements of alignment, preparation of plans and comparison of alternate routes, economic analysis and selection of final alignment.

1.4 (d)

In planning phase, strategies are set-out while considering company's policies and rules. Organizing is dividing work and assigning task to people. Directing is transferring all information to supervising staff. Coordinating is making people work together with flow of information, decisions and results in all directions.

2. Element of Network

2.1 (c)

First for work is erected and steel is placed over form work. Then concrete is poured and compacted in formation of slab. After that brick-jelly lime concrete is provided over casted slab for water proofing and thermal insulation. Lastly parapet wall is constructed.

3. PERT & CPM

3.1 (a)

PERT is probabilistic in nature and it is event based. It is used for non-repetitive type of projects. CPM is activity based and time for completion is known precisely.

3.3 (b)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$= \frac{5 + 4 \times 8 + 17}{6}$$

$$= 9 \text{ days}$$

3.4 (c)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$= \frac{4 + 4 \times 11 + 12}{6}$$

= 10 days

3.5 (b)

The standard deviation,

$$\sigma = \left(\frac{t_p - t_o}{6}\right)$$

Contractor's Standard deviation in estimates

$P \rightarrow (13 - 5)/6 = 4/3 = 1.33$

$Q \rightarrow (12 - 6)/6 = 1$

$R \rightarrow (14 - 5)/6 = 1.5$

$S \rightarrow (13 - 4)/6 = 1.5$

Since the time estimates of contractor Q has least standard deviation, so work can be completed by him in most certain manner.

3.6 (b)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$= \frac{4 + 4\times 5 + 8}{6}$$

= 5.33 months

3.7 (b)

The distribution curve for the time taken to complete each activity of a project resembles a β-distribution curve and the distribution curve for the time taken to complete entire project (consisting of several activities) in general resembles a normal distribution curve.

3.8 (d)

Total float is the excess of maximum available time over the activity time.

$$F_T = \left(T_L^j - T_E^i\right) - t^{ij}$$

$$= LST - EST$$

$$= LFT - EFT$$

Free float is the excess of available time over the activity time when all jobs start as early as possible.

$$F_F = \left(T_E^j - T_E^i\right) - t^{ij}$$

$$= F_T - S_j$$

Independent float is the excess of minimum available time over the activity time.

$$F_{ID} = \left(T_E^j - T_L^i\right) - t^{ij}$$

$$= F_F - S_i$$

Interfering float is the difference between total float and free float

$$F_{IN} = F_T - F_F = S_j$$

3.9 (c)

The critical path should have maximum duration.

Path	Duration
1 – 2 – 4 – 7 – 9	6 + 9 + 14 + 12 = 41
1 – 3 – 5 – 7 – 9	8 + 9 + 14 + 12 = 43
1 – 3 – 5 – 6 – 8 – 9	8 + 9 + 0 + 13 + 15 = 45
1 – 3 – 6 – 8 – 9	8 + 10 + 13 + 15 = 46

Maximum duration is for path 1 – 3 – 6 – 8 – 9, so this is the critical path.

3.10 (c)

Activity: It is resource consuming element of the project

Event: It is stage or instant of time at which some milestone of project is achieved.

Dummy: Special type of activity which does not consume any resource and time.

Float: Time by which finish or start of activity can be delayed without affecting project completion time.

3.11 (b)

In CPM networks, critical path is the path traced by critical activities. Critical activities are those activities which have zero total float i.e.

$$F_T = \left(T_L^j - T_E^i\right) - t^{ij}$$

F_T for 1 – 2 = (1 – 0) – 1 = 0

F_T for 2 – 3 = (7 – 1) – 6 = 0

F_T for 3 – 5 = (16 – 7) – 8 = 1

F_T for 5 – 6 = (18 – 16) – 2 = 0

Thus activity 3 – 5 is not critical. The duration of activities 2 – 4, 3 – 4 and 4 – 5 are not provided. Since 3 – 5 is not critical the only available path is 1– 2 – 3 – 4 – 5 – 6.

It may be noted that in the given network slack ($T_L - T_E$) at each event is zero. And we know that events hving zero slack are critical events. The path traced by critical events is the critical path. But, this theory applies for a PERT network. Thus if this network happens to be a PERT network then there might have been three critical paths. viz. (i) 1 – 2 – 3 – 5 – 6, (ii) 1 – 2 – 4 – 5– 6 and (iii) 1 – 2 – 3 – 4 – 5 – 6.

3.12 (c)

Using forward pass, the earliest start time of any activity can be found. Starting with event 1 with earliest occurrence time (EOT) as zero, the EOT of other head events are assigned by adding activity times and choosing such maximum time obtained from all paths.

Event	1	2	3	4	5	6
EOT (days)	0	4	1	4	9	11

EOT of tail event = EST of activity

$\therefore \quad EST_{5-6} = 9$ days

3.13 (a)

Independent float $= (EOT)_{10} - (LOT)_3 - t_{3-10}$
$= 40 - 25 - 10 = 5$ weeks

3.14 (c)

Path	Time taken
1 – 2 – 4 – 5 – 7 – 8	7 + 3 + 4 + 8 + 7 = 29
1 – 2 – 3 – 5 – 7 – 8	7 + 8 + 0 + 8 + 7 = 30

The path 1 – 2 – 4 – 5 – 3 – 6 – 7 – 8 is not possible. Hence, critical path is
1 – 2 – 3 – 5 – 7– 8

3.15 (c)

Time scale for an activity:

Independent Float (*IF*) is the excess of minimum available time over activity time.

Free Float (*FF*) is the excess of available time over the activity time when all jobs start as early as possible.

So $FF = IF +$ Tail slack.

Interfering Float $= TF - FF =$ Head slack

$\therefore$ $TF =$ Int. $F + FF =$ Int. $F + IF +$ Tail slack

Or $TF = IF +$ Head slack + Tail slack

3.16 (b)

Path	Total duration
1 – 2 – 3 – 6 – 7 – 8	4 + 6 + 2 + 3 + 7 = 23
1 – 2 – 3 – 5 – 7 – 8	4 + 7 + 0 + 6 + 7 = 24
1 – 2 – 4 – 5 – 8	4 + 3 + 3 + 6 + 7 = 23
1 – 2 – 4 – 6 – 7 – 8	4 + 3 + 0 + 3 + 7 + 17

Critical path is the path with maximum total duration i.e. 1 – 2 – 3 – 5 – 7 – 8

3.17 (a)

The sequence is

AD – FP – EET – PD – BP – LET – TF

4. Time Cost-Models, Crashing

4.1 (a)

The minimum cost for normal duration of all activities = 800 + 1200 + 500 = 2500 units.

The maximum cost for crash duration of all activities = 1000 + 1500 + 900 = 3400 units.

4.3 (d)

Crashing reduces duration and therefore indirect cost decreases while direct cost increase.

4.5 (d)

The activity with least cost slope is to crashed first. So for one day crash, the cost slope of activities are :

Activity	Cost slope (Rs. 000)
P	2
Q	3
R	2

So crashing *R* by one day first, and then *P* by one day. Now the direct costs of each activity and duration will be

Activity	Duration	Direct Cost Rs. 000
P	6	14
Q	8	20
R	8	42
Total	**22**	**76**

Now one day crashing is required to reach at desirable duration of 21 days. The activity P has least cost slope of Rs. 1000. So

Activity	Duration	Direct cost Rs. 000
P	5	15
Q	8	20
R	8	42
Total	21	77

5. AON Network, Resource Allocation, Charts etc.

5.1 (c)

In resource levelling the total project duration is not changed but some of the activity start times are shifted by their available float so that more or less uniform resource demand is guaranteed.

In resource smoothening, the activity start times are so rescheduled that the peak demand does not exceed the available limit of resource. If it does not give desirable result by consideration of floats, the total project duration to minimum extent may be extended.

5.2 (a)

15th - 16th week demands most resources because four activities A,B,C,D will run in parallel in that week.

Resource load = 6+4+3+7=20

5.3 (a)

Gantt charts give comparison of actual progress with scheduled progress i.e. it gives idea about physical progress of project but not about financial aspect.

5.4 (c)

In resource levelling the activities are so rescheduled that the maximum or peak demand for the resources does not exceed the available resources. Thus in resource levelling the main constraint is on the resources. However, the resources cannot be less than the maximum amount needed for any activity of the project.

5.5 (a)

In updating sometimes it becomes imperative to change the original network as the work progress. Such an alteration may be due to several reasons such as the change in time schedule because of say, changes in the supply of materials, non-availability of additional labour during the project. Thus activity durations are changed and some activities may be added and those activities which are already complete may be deleted.

Due to change in the company's policy of execution the interdependence of some operations may change i.e. logical relationship among activities may change.

5.6 (a)

In resource levelling, the project completion time is not extended even though there is constraint in the availability of resources.

6. Cost Estimation and Valuation

6.1 (c)

$$\text{Annual depreciation} = \frac{P - C_s}{n}$$

$$= \frac{10000 - 1000}{5} = 1800$$

$\therefore$ Book value at the end of two years

$$= 10,000 - 2 \times 1800 = 6400$$

6.2 (d)

Impact noise or structure-borne noise is developed in solid structures and it is then transmitted as air-borne noise. The closing of doors, vibrations of machines etc. set up vibrations in solid materials of the structure which result in the transmission of noise to the receiving room.

The air-borne noise has less power, continues for a long time and is confined to places near its origin. The impact noise has more power, continues for a short duration and is often propagated over long distances.

In floating floor construction, the floor is separated from the structural floor by a layer of resilient material such as quilted mineral or glass wool. It can insulate against air-borne noise and can reduce the impact noise. So 1 and 3 are correct.

6.3 (b)

Window sills are provided to give a suitable finish to the window opening and to protect the external wall below such opening.

6.4 (a)

The mass-haul diagram is a curve plotted on a distance base with the ordinate at any point on the curve representing the algebraic sum of the volume of earthwork up to that point.

6.5 (b)

The various factors used in calculation of depreciation are :

(i) Uniform series present worth factor

$$= \frac{(1+i)^n - 1}{i(1+i)^n}$$

(ii) Capital recovery factor = $\dfrac{i(1+i)^n}{(1+i)^n - 1}$

(iii) Uniform series compound amount factor

$$= \frac{(1+i)^n - 1}{i}$$

(iv) Sinking fund factor = $\dfrac{i}{(1+i)^n - 1}$

6.6 (a)

Capital Recovery factor (CRF) = 0.35; $i = 0.15$

$$X = P\left[(1+i)^4 - 1\right]$$

$$= \frac{P \times i}{\text{Sinking Fund Factor } (SFF)}$$

$$S.F.F. = CRF - i$$

$$= 0.35 - 0.15 = 0.20$$

$$\therefore \quad X = \frac{10{,}000 \times 0.15}{0.20} = 7500$$

6.7 (d)

Rate of depreciation

$$r_D = 1 - \left(\frac{C_s}{C_i}\right)^{1/n}$$

Initial cost, $C_i = 16000$

Salvage value, $C_s = 2000$

$n = 3$

$$\therefore \quad r_D = 1 - \left(\frac{2000}{16000}\right)^{1/3} = 0.50$$

7. Productivity and Operation, Site Investigation

7.1 (c)

Both the probability and profit should be considered for evaluating the preference.

The ranking should be decided by multiplying profit and probability.

Project	Profit × probability	Ranking
1.	0.075	Third
2.	0.080	Secod
3.	0.084	First
4.	0.066	Fourth

So the correct order is 3 – 2 – 1 – 4

7.2 (d)

Issue rate denotes cost per unit fixed on the article of stock for the purpose of calculating the amount creditable to the subhead concerned of stock account when issued from stock. An issue rate is fixed for each article of stock on the basis of actual cost plus other expenses including storage charges. So this rate should be revised when there is variation in the rates of the item.

7.3 (a)

The inventory procurement cost = $\dfrac{DF}{Q}$

The carrying cost = $\dfrac{QC}{2}$

Total cost = $\dfrac{DF}{Q} + \dfrac{QC}{2}$

Where, $D \rightarrow$ Demand in units per year.

$Q \rightarrow$ Order quantity

$C \rightarrow$ Carrying or holding cost (per unit per year)

$F \rightarrow$ Fixed order cost

For minimum total cost,

$$\frac{DF}{Q} = \frac{QC}{2}$$

∴ Economic Order Quantity (EOQ)

$$Q = \sqrt{\frac{2DF}{C}}$$

7.4 (a)

Waiting line model is used for ensuring that resources required by numerous activities are adequate.

7.5 (d)

The most significant factors affecting ownership cost are :

(i) Purchase expense or initial cost.

(ii) Salvage value

(iii) Tax saving from depreciation

(iv) Major repairs and overhauls

(v) Property taxes

(vi) Insurance

(vii) Storage and miscellaneous

The operating cost includes fuel or energy cost and lubrication oil cost.

7.6 (a)

A sensitivity analysis involves explicit consideration of the economic impact of changes in the values of one or more parameter. The objective is to determine how sensitive the selection decision is to the values of the parameters used in the analysis. It can be done using

(i) Present worth method

(ii) Future worth method

(iii) Internal rate of return method

(iv) Annual worth method

7.7 (d)

$P(K \cap L) = P(K) + P(L) - P(K \cup L)$

$\therefore P(K \cap L) = 2 \times 0.45 - 0.75$

Critical probability for delay in activity

$$\therefore P(K/L) = \frac{P(K \cap L)}{P(L)} = \frac{2 \times 0.45 - 0.75}{0.45}$$

7.8 (c)

From Rule of Thumb:

1 bag of cement (50 kg) contains 0.035 m^3 of cement.

Yield of concrete of proportion (1:1.4:2.75)

$$= \frac{2}{3} \times 0.035 \times (1 + 1.4 + 2.75)$$

$$= 0.023 \times 5.15 = 0.12 \text{ m}^3$$

So concrete from 527 bags of cement will be

$$= 527 \times 0.12 = 63.24 \text{ m}^3$$

Therefore approximate billing

$$= 63.24 \times 1000 = 63240$$

The most close option is (c).

7.9 (a)

Alternative 1 : Annual earning,

$A_1 = 600$ units

Alternative 2: Equivalent annual earning,

$$A_2 = 800 - \frac{100}{i} [1 - n \times SFF]$$

Alternative 3: Equivalent annual earning,

$$A_3 = 400 + \frac{100}{i} [1 - n \times SFF]$$

Alternative 4: Equivalent annual earning,

$$A_4 = CRF \times \left[\frac{400}{(1+i)} + \frac{400}{(1+i)^2} + \frac{600}{(1+i)^3} + \frac{800}{(1+i)^4} + \frac{800}{(1+i)^5} \right]$$

For $i = 6\%$ $n = 5$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} = 0.24$$

$$\therefore SFF = 0.24 - 0.06 = 0.18$$

$$\therefore A_2 = 800 - \frac{100}{0.06} (1 - 5 \times 0.18)$$

$$= \text{Rs. } 633.33$$

$$A_3 = 400 + \frac{100}{0.06} \times (1 - 5 \times 0.18)$$

$$= \text{Rs. } 566.67$$

$$A_4 = 0.24 \times \left[\frac{400}{1.06} + \frac{400}{(1.06)^2} + \frac{600}{(1.06)^3} + \frac{800}{(1.06)^4} + \frac{800}{(1.06)^5} \right]$$

$$= \text{Rs. } 592.47$$

The higher earning means, better choice. So correct decreasing order preference 2–1–4–3.

8. Construction Equipments

8.2 (d)

Drop hammer is used to drive a pile.

Claw hammer is used to drive nails in wood.

Chain Lewis is used for lifting stone blocks.

8.3 (b)

Rolling resistance = 12 × 45 = 540 kg

$$\text{Grade resistance} = 12000 \times \frac{2}{100} = 240 \text{ kg}$$

$\therefore$ Pull available for towing the load

= Maximum rimpull – Rolling resistance – Grade resistance

= 6300 – 540 – 240 = 5520 kg

8.4 (d)

Double drum paving mixer is used for mixing concrete for road or pavement construction. It consists of a long drum divided into two parts by a central diaphragm. Both parts are operated in series. The concrete is initially mixed upto a certain time in the first compartment of the drum and then transferred to the section compartment for the remaining operation of mixing. Thus mixing capacity can be doubled with the same batching equipment and supervisory staff. Standard size of double compartment mixers are 16E(16°) and 34E(34°) as per ASTM specification, where E stands for paving mixer and the number indicates nominal volume of mixed concrete in ft^3 in one batch.

Capacity of 34° double-drum mixer per batch = $34 \times (0.3048)^3 = 0.963$ m^3

Assuming time loss per hour for cleaning drum, chutes, starting and oiling engine and taking rest for labourers = 15 min.

Actual operating time per hour = 60 – 15
= 45 min.

As per Indian standards cycle time per batch of 0.2 m^3 = 3 min.

∴ Cycle time for 0.963 m^3

$$= \frac{0.963}{0.2} \times 3 = 14.45 \text{ min.} = 15 \text{ min. (Approx.)}$$

Number of batches per hour = $\frac{45}{15} = 3$

∴ Probable output per hour
= $0.963 \times 3 = 2.89$ m^3

8.5 (a)

When a crane lifts a load attached to the hoist line that passes over a sheave located at the boom point of the machine, there is a tendency to tip the machine over.

The tipping load is the load that produces a tipping condition at a specified radius. The load includes the weight of the item being lifted plus the weights of hooks, hook blocks, slings and any other items used in hoisting the load, including the weight of the hoist rope located between the boom point sheave and the item being lifted.

8.6 (c)

As per **IS:1791-1985**, concrete mixers are designated by a number representing its nominal mixed batch capacity in litres such 85T, 100T, 200NT, 200R, etc. T, NT and R denote tilting, non-tilting and reversing respectively. Thus, these letters indicate feeding arrangement.

8.7 (a)

Plate vibrator is used for manufacture of large prefabricated elements such as electric poles, railway sleepers, prefabricated roof element, door and window frames, etc. Form vibrators can also be used, but their efficiency is low. Needle vibrators will create problem due to congested reinforcement and it is better to compact by hand otherwise reinforcement may get disturbed. So needle vibrators should be the last choice.

8.8 (b)

There are three types of concrete pumps viz. piston pumps, pneumatic pumps and squeeze pressure pumps. Most piston pumps currently contain two pistons, with one retracting during the forward stroke of the other to give a more continuous flow of concrete. The pneumatic pumps normally use a reblending discharge box at the discharge end to bleed off the air and to prevent segregation and spraying. In the case of squeeze pressure pumps, hydraulically powered rollers rotate on the flexible hose within the drum and squeeze the concrete out at the top. The vacuum keeps a steady supply of concrete in the tube from receiving hopper.

8.9 (c)

Graders are multipurpose machines used for finishing, shaping, bank sloping and ditching.

8.10 (d)

Scraper is a self sufficient machine which can dig, load, haul and discharge the material in uniformly thick layers.

Dump trucks are fitted with automatic unloading devices and they are used for moving the excavated material. The loading is normally done by loading shovels or loaders.

8.11 (c)

Material	Impact	Pressure	Vibration	Kneading
Gravel	Poor	No	Good	Very good
Sand	Poor	No	Excellent	Good
Silt	Good	Good	Poor	Excellent
Clay	Excellent with Confinement	Very good	No	Good

Sheepfoot rollers compact by tamping and kneading. Therefore they are suitable for silt and clay i.e. cohesive soils.

8.12 (a)

Hoe may be used to

(i) excavate below the natural surface of the ground on which the machine rests.

(ii) dig trenches, footings or basements and general grading work which requires precise control of depths.
(iii) penetrate easily into toughest materials to be dug.

8.13 (a)

The primary action is kneading in sheep foot roller.

8.14 (b)

When it is difficult to leave holes in the wall to provide bearing for the putlogs, then two frames of standards, ledgers and braces are used. One frame is placed close to the wall and the other at a distance of 1.5 m from the first one. Put logs are then supported on both the frames. This arrangement is called Mason's Scaffold. Thus, the Mason's Scaffold is entirely independent of the wall.

8.15 (d)

For specified architectural work, specific items/ materials are used. Hence, item rate type of contract is most appropriate.

For construction of house, large number of quantity of materials is required, thus many a time it is lumpsum type of contract.

Price work contract is related to a particular work for which the price is to be paid like repainting of house which is done after some years of use of house.

In cost plus a fixed sum contract, the contractor will honestly endeavour to perform the work in the shortest possible time, with the best workmanship and for the least cost, in order to win high business prestige. This is ideally suited for war emergency when compensation is no consideration and also on works relating to subsoil conditions which cannot be correctly estimated for bidding.

8.16 (d)

Wheel tractor possesses speed upto 3 to 4 times higher than a crawler tractor.

A wheel tractor has steering wheel which is easy to operate and control while a crawler tractor is provided with stick control which is not easy to control.

Crawler tractors are more costly initially than wheel tractors. Operation, maintenance and repair cost is less in wheel tractor than in crawler tractor.

8.18 (d)

A partial safety factor with respect to tipping is introduced by PCSA (Power Creane and Shovel Association) rating standards that state that the rated load of a lifting crane shall not exceed the following percentages of tipping loads at specified radii.

(i) Crawler mounted cranes, 75%
(ii) Rubber-tyre-mounted machines, 85%
(iii) Machines on outriggers, 85%

8.19 (d)

Hoe is advantageous for digging trenches, footings or basements and general grading work which requires precise control of depths.

8.21 (b)

When mechanical vibrators are used, the mix should not have high slump.

8.22 (c)

Total head against which work will be done,

$H = 7.5 + 0.25 = 7.75$ m

$$\therefore BHP = \frac{wQH}{75\eta} = \frac{1000 \times 2.8 \times 7.75}{0.8 \times 75}$$

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