DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 8

Section A : CPM PERT + Hydrology and Water Resource Engineering [All Topics]

Section B : Design of Steel Structure-1 (Part Syllabus) + Surveying and Geology-1 (Part Syllabus)

Section C : Solid Mechanics-2

1.	**(b)**	**16.**	**(a)**	**31.**	**(d)**	**46.**	**(a)**	**61.**	**(a)**
2.	**(b)**	**17.**	**(b)**	**32.**	**(d)**	**47.**	**(d)**	**62.**	**(a)**
3.	**(c)**	**18.**	**(b)**	**33.**	**(c)**	**48.**	**(a)**	**63.**	**(a)**
4.	**(a)**	**19.**	**(c)**	**34.**	**(d)**	**49.**	**(b)**	**64.**	**(a)**
5.	**(c)**	**20.**	**(d)**	**35.**	**(c)**	**50.**	**(c)**	**65.**	**(d)**
6.	**(a)**	**21.**	**(c)**	**36.**	**(c)**	**51.**	**(c)**	**66.**	**(b)**
7.	**(a)**	**22.**	**(c)**	**37.**	**(b)**	**52.**	**(d)**	**67.**	**(a)**
8.	**(d)**	**23.**	**(b)**	**38.**	**(c)**	**53.**	**(c)**	**68.**	**(a)**
9.	**(b)**	**24.**	**(a)**	**39.**	**(b)**	**54.**	**(a)**	**69.**	**(d)**
10.	**(d)**	**25.**	**(a)**	**40.**	**(c)**	**55.**	**(c)**	**70.**	**(d)**
11.	**(a)**	**26.**	**(a)**	**41.**	**(b)**	**56.**	**(b)**	**71.**	**(d)**
12.	**(d)**	**27.**	**(b)**	**42.**	**(b)**	**57.**	**(c)**	**72.**	**(a)**
13.	**(b)**	**28.**	**(d)**	**43.**	**(d)**	**58.**	**(c)**	**73.**	**(d)**
14.	**(c)**	**29.**	**(a)**	**44.**	**(c)**	**59.**	**(a)**	**74.**	**(a)**
15.	**(d)**	**30.**	**(b)**	**45.**	**(b)**	**60.**	**(d)**	**75.**	**(c)**

DETAILED EXPLANATIONS

Section A : CPM PERT + Hydrology & WRE

1. (b)

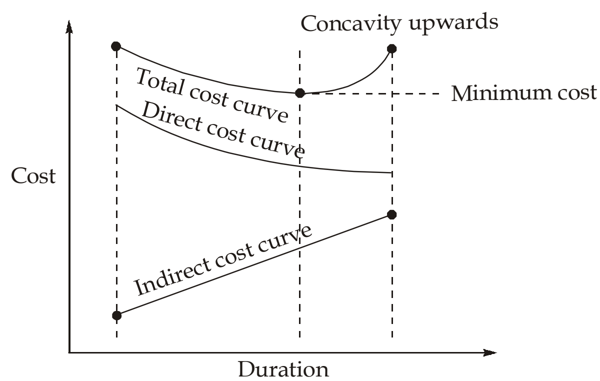
The contractor undertakes contract for the labour portion only, excluding the materials, in labour contract. The materials are arranged and supplied at the work site by the department or owner.

2. (b)

Though controlling can be better achieved with the help of milestone chart, it still possesses the same deficiency as that is contained by the bar chart since it does not show the inter dependencies between the activity. Gantt chart is also known as bar chart.

3. (c)

The indirect cost includes the expenditure related to administration and establishment charges, overhead, supervision, loss of revenue, penalty etc.



4. (a)

$$\text{Sinking fund factor} = \frac{i}{(1+i)^n - 1}$$

$$= \frac{0.05}{(1+0.05)^4 - 1} = \frac{0.05}{(1.1025)^2 - 1} = 0.232$$

5. (c)

$$\text{Injury severity rate} = \frac{\text{Number of days lost} \times 1000}{\text{Number of man hours worked}}$$

$$0.15 = \frac{\text{Number of days lost} \times 1000}{250 \times 48 \times 40}$$

Number of days lost = 72 days

6. (a)

Rolling resistance = 15 × 50 = 750 kg

$$\text{Grade resistance} = 15000 \times \frac{2}{100} = 300 \text{ kg}$$

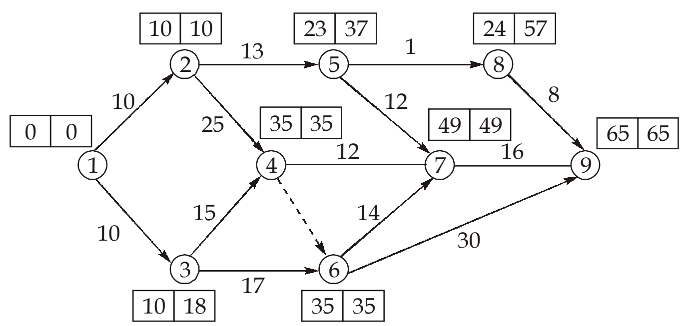
Pull available for towing the load = Maximum rimpull – rolling resistance – upgrade resistance
= 6300 – 750 – 300 = 5250 kg

7. (a)

In unit price contract, the total sum of money paid to the contractor for each item of work cannot be determined until completion of the contract, because payment is made only on the basis of the units of the work actually done and measured in the field.

9. (b)

The earliest start time and latest start times of the activities are as shown below:



For activity 5-8, latest expected finish time = 57

Earliest expected finish time = 24

∴ Interfering float for activity (5 – 8) = 57 – 24 = 33 days

11. (a)

Optimistic travel time, t_0 = 15 minutes

Pessimistic travel time, t_p = 45 minutes

Most likely travel time, t_m = 33 minutes

$$\text{Expected travel time} = \frac{15 + 4 \times 33 + 45}{6} = 32 \text{ minutes}$$

$$\text{Standard deviation of travel time} = \left(\frac{t_p - t_0}{6}\right) = \left(\frac{45 - 15}{6}\right) = 5 \text{ minutes}$$

14. (c)

Station	Normal rainfall	Rainfall in 2018
A	225 cm	175 cm
B	200 cm	–
C	185 cm	150 cm

Normal rainfall at station *B*, N_B = 200 cm

$0.9N_B$ = 0.9 × 200 = 180 cm

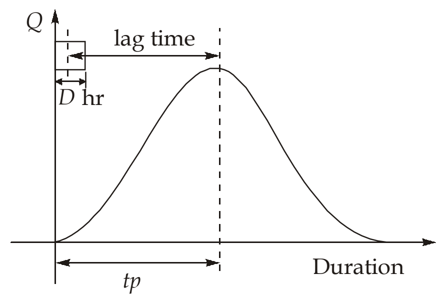
$$1.1N_B = 1.1 \times 200 = 220 \text{ cm}$$

Since the normal rainfall values vary more than 10%, the normal ratio method is adopted.

$$\therefore \quad P_B = \frac{200}{2} \times \left(\frac{175}{225} + \frac{150}{185}\right) = 158.86 \text{ cm} \simeq 159 \text{ cm (say)}$$

15. (d)

For a unit hydrograph.



$$\text{Peak time} = \text{Lag time} + \frac{D}{2}$$

$$= 42 + \frac{4}{2} = 44 \text{ hours}$$

16. (a)

$$\text{Compactness coefficient} = \frac{\text{Perimeter of the catchment}}{\text{Circumference of a circle}}$$

$\therefore$ Radius of circle having equal area,

$$\pi r^2 = 314 \text{ km}^2$$

$$\Rightarrow \quad r = \sqrt{\frac{314}{\pi}} \simeq 10 \text{ km}$$

$$\therefore \quad \text{Circumference} = 2\pi r = 2 \times \frac{22}{7} \times 10 = 62.86 \text{ km}$$

$$\therefore \quad \text{Compactness coefficient} = \frac{85}{62.86} = 1.35$$

17. (b)

The slope area method is extensively used in estimation of flood discharge based on high water marks. It is an indirect method of estimation of discharge.

18. (b)

An ephemeral stream does not have any base flow contribution.

The technique of predicting the runoff using the catchment response to a given rainfall input is called deterministic watershed simulation.

19. (c)

The hydraulic method of routing employ the continuity equation together with the equation of motion of unsteady flow.

21. (c)

Aridity index is defined as

$$AI = \frac{PET - AET}{PET} \times 100$$

$$= \frac{1736 - 295}{1736} \times 100 = 83\%$$

22. (c)

Trial 1: Assume $\phi < 1$ cm/hr

Total rainfall in 10 hours $= (2 \times 2) + (3 \times 2) + (6 \times 2) + (4 \times 2) + (1 \times 2) = 32$ cm

$$\therefore \quad \phi = \frac{32 - 20}{10} = 1.2 \text{ cm/hr} > 1 \text{ cm/hr}$$

Hence our assumption is incorrect.

Trial 2: Assume $1 \text{ cm/hr} < \phi < 2$ cm/hr

Total rainfall $= (2 \times 2) + (3 \times 2) + (6 \times 2) + (4 \times 2) = 30$ cm

$$\phi = \frac{30 - 20}{8} = 1.25 \text{ cm/hr} \qquad [< 2 \text{ cm/hr}]$$

Hence the ϕ index is 1.25 cm/hr.

Check :

Runoff = (2 – 1.25) × 2 + (3 – 1.25) × 2 + (4 – 1.25) × 2 = 20 cm which is same as given in question.

23. (b)

Rotating sprinklers used in sprinkler method of irrigation rotate in the horizontal plane and irrigate a circular area.

Zig-zag method is a controlled flooding method in which the agricultured area is sub-divided into small plots by low-bunds in a zig-zag manner.

24. (a)

The crop period is defined as the total period from the time of sowing of a crop to the time of harvesting it.

25. (a)

The quantity of water flowing continuously for one day at the rate of one cumec is known as one cumec day.

$$\therefore \quad 1 \text{ cumec-day} = \frac{1\,\text{m}^3}{\text{sec}} \times 24 \times 60 \times 60 \text{ sec}$$

$$= 24 \times 60 \times 60 \text{ m}^3$$

$$= 8.64 \text{ hectare metre}$$

26. (a)

Using the relation, $\Delta = \dfrac{8.64 \times B}{D}$

Discharge for Kharif crop,

Here, $\Delta = 60 \text{ cm} = 0.60 \text{ m}$

$B = 3 \text{ weeks} = 21 \text{ days}$

$\therefore \quad \text{Duty} = \dfrac{8.64 \times 21}{0.60} = 302.4 \text{ hectares/cumec}$

Area to be irrigated = 5000 ha

$\therefore \quad \text{Required discharge of channel} = \dfrac{5000}{302.4} = 16.53 \text{ cumec}$

Discharge for Rabi crop,

Here, $\Delta = 25 \text{ cm} = 0.25 \text{ m}$

$B = 4 \text{ weeks} = 28 \text{ days}$

$\therefore \quad \text{Duty} = \dfrac{8.64 \times 28}{0.25} = 967.68 \text{ ha/cumec}$

Area to irrigated = 4000 ha

$\text{Required discharge of channel} = \dfrac{4000}{967.68} = 4.134 \text{ cumec}$

So, the channel is to be designed for the maximum discharge of 16.53 cumec.

27. (b)

Available moisture = Field capacity – Permanent wilting point

= 35 – 22 = 13%

From, $$D_w = \frac{\gamma_d \times d}{\gamma_w} \times [FC - PWP]$$

$$= \frac{1.5 \times 0.70}{1} \times [0.35 - 0.22]$$

$\Rightarrow \quad D_w = 13.65 \text{ cm}$

$\therefore \quad \text{Frequency of irrigation, } f_w = \dfrac{13.65}{1.7} = 8.03 \text{ days} \simeq 8 \text{ days}$

28. (d)

Bandhara is a minor irrigation system suitable for irrigating isolated areas, up to 500 hectares. The bandhara is similar to weir which is constructed across a small stream to raise water level on the upstream side to divert the water through the canal.

In this system, the water is directly taken from the main canal and supplied to the agricultural land. The total area under a bandhara is known as *Thal*. Again it is divided into several zones, which are known as *Phad*.

29. (a)

When a dam is constructed across a river valley, to form storage reservoir then it is known as storage head works.

When a barrage is constructed across a river to raise the water level then it is known as diversion head works.

30. (b)

The limiting height of low gravity dam is

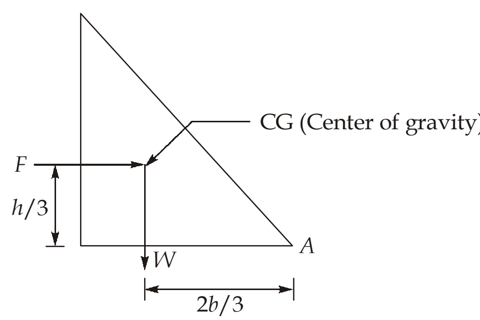
$$H = \frac{f}{\gamma_w(G - C + 1)}$$

$$\Rightarrow \quad H = \frac{f}{\gamma_w(G+1)} \qquad [c = 0 \text{ for no uplift}]$$

$$\Rightarrow \quad H = \frac{40 \times 10^4 \text{ kg/m}^2}{1000(2.6+1)}$$

$$\Rightarrow \quad H = 111.11 \text{ m} \simeq 111 \text{ m}$$

31. (d)



In limiting condition,

$$\Sigma M_A = 0$$

$$\Rightarrow \quad F \times \frac{h}{3} = W \times \frac{2b}{3}$$

$$\Rightarrow \quad \frac{\gamma_w h^2}{2} \cdot \frac{h}{3} = \frac{bh}{2}(2.56\gamma_w)\frac{2b}{3}$$

$$\Rightarrow \quad b^2 = 0.1953 \text{ h}^2$$

$$\Rightarrow \quad b = 0.44 \text{ h}$$

32. (d)

Lacey's equations do not include concentration of silt as variable.

33. (c)

Peak of FH = 1000 m^3/sec

Base flow = 30 m^3/sec

∴ Peak of DRH = 1000 – 30 = 970 m^3/sec

ϕ index = 1 cm/hr

$$\therefore \quad ER = (4 - 1) \times 12 = 36 \text{ cm}$$

$$\therefore \quad \text{Peak of 12 hr UH} = \frac{\text{Peak of DRH}}{ER(\text{in cm})} = \frac{970}{36} = 26.94 \text{ m}^3/\text{sec} \simeq 27 \text{ m}^3/\text{sec}$$

34. (d)

For a wide rectangular channel,

$$R \simeq y$$

$$\Rightarrow \quad R = 0.88 \text{ m}$$

$$\text{Average side boundary shear stress} = 0.75\,\gamma_w RS$$

$$= 0.75\left(9.81 \text{ kN/m}^3\right)(0.88 \text{ m})(0.005)$$

$$= 0.75 \times 9.81 \times 0.88 \times 0.005 \times 10^3$$

$$= 32.373 \text{ N/mm}^2$$

35. (c)

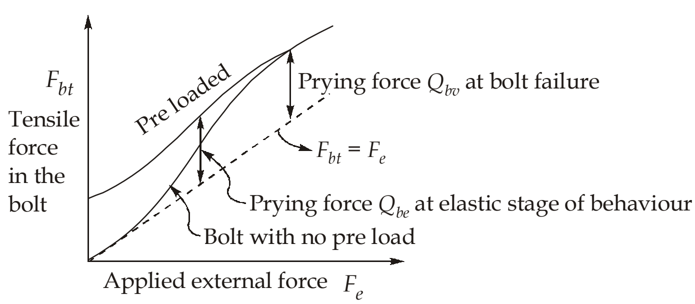
Higher tractive effort is available due to the concentration of total load on the same wheel axle.

36. (c)

Vapour pressure of solution (like sea water) is always less than that of pure water.

39. (b)

Relationship between external load and bolt force for a flexible T stub connection is shown below.



40. (c)

In a stiffened seat connection, the outstanding leg of stiffener angle must not exceed 14ε times the thickness (**Clause 8.7.1.2 of IS 800:2007**).

41. (b)

$$\text{Nominal diameter of bolt} = 24 \text{ mm}$$

$$\therefore \quad \text{Gross diameter of bolt hole } d_g = 24 + 2 = 26 \text{ mm}$$

As critical section contain single bolt hole,

Thickness of plate required for net section rupture,

$$\frac{0.9 f_u A_n}{\gamma_{m_1}} > 450$$

$$\frac{0.9 \times 410 \times (300 - 26) \times t}{1.25 \times 1000} > 450$$

$$t > 5.56 \text{ mm}$$

Thickness of plate required for gross section yielding,

$$\frac{A_g f_y}{\gamma_{m0}} > 450$$

$$\frac{300 \times t \times 250}{1000 \times 1.1} > 450$$

$$\Rightarrow \quad t > 6.6 \text{ mm}$$

So, provide a plate of thickness 8 mm.

42. (b)

- At point of contraflexure, bending moment changes its sign and thus point of minimum (or zero) bending moment.
- Diameter of bolt hole depends upon diameter of bolt.

For $d \leq 14$ mm $\quad d_0 = d + 1$ mm

For $14 \leq d \leq 24$ mm $\quad d_0 = d + 2$ mm

For $d > 14$ mm $\quad d_0 = d + 3$ mm

- Overall cost of bolted connection is less than that of rivet connection because of higher speed of fabrication, reduced labour, lower equipment costs and higher structural efficiency.

43. (d)

$$\lambda_{max} = 250$$

i.e. $$\frac{l_{eff}}{r} \leq 250$$

For given condition, $$l_{eff} = 0.85 \times L$$

$$= 0.85 \times 6 = 5.1 \text{ m}$$

$$\therefore \quad r \geq \left(\frac{l_{eff}}{250}\right) = \frac{5100}{250}$$

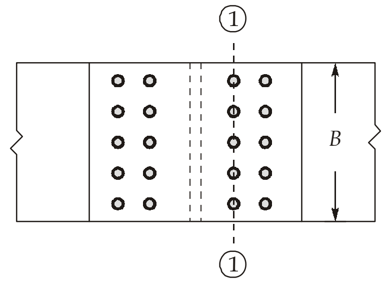
$$\Rightarrow \quad r \geq 20.4 \text{ mm}$$

44. (c)

- The radius of gyration of the combined column about the axis perpendicular to the plane of battens should be greater than the radius of gyration about the axis parallel to the plane of battens.
- The thickness of batten plates shall not be less than $\frac{1}{50^{th}}$ of the distance between the innermost connecting transverse bolts or welds.

45. (b)

- Fillet weld fails in shear



$$A_{net\,(1)\text{-}(1)} = (B - nd_0)t$$

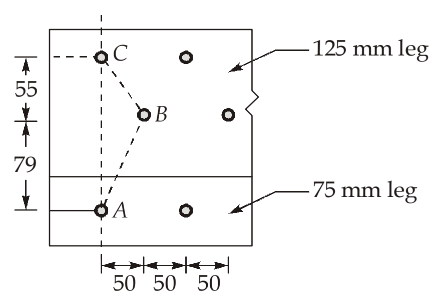
When n is more i.e. number of bolts at a section is large, net effective area reduces and hence its tensile force carrying capacity reduces.

- The permissible stresses in a weld are usually taken more than those of parent body.

46. (a)

- Fillet weld fails in shear.
- Block shear failure may also take place if bolts of very high shear strength are used.

47. (d)



$$g' = g_1 + g_2 - t = 45 + 40 - 6 = 79 \text{ mm}$$

Legs of the angle flattened into one plate is shown in above figure. This can be used for net area calculation. Also for M20 bolts, diameter of bolt hole = 22 mm

$$A_n = A_g - \Sigma d_h t + \Sigma\left(\frac{p^2}{4g}\right) \times t$$

Path AC:

$$\text{Net area, } A_n = (125 + 75 - 6) \times 6 - 2 \times 22 \times 6 = 900 \text{ mm}^2$$

Path ABC:

$$\text{Net area, } A_n = (125 + 75 - 6) \times 6 - 3 \times 22 \times 6 + \left(\frac{50^2}{4 \times 55} + \frac{50^2}{4 \times 79}\right) \times 6$$

$$= 883.65 \text{ mm}^2 \simeq 884 \text{ mm}^2$$

Thus net area of section is 884 mm^2.

48. (a)

In countries like the United States, Great Britain, India and other parts of the world, sexagesimal system is widely used

(a) Sexagesimal system

$$1 \text{ circumference} = 360° \text{ (degree of arc)}$$
$$1 \text{ degree} = 60' \text{ (minutes of arc)}$$
$$1 \text{ minute} = 60'' \text{ (seconds of arc)}$$

(b) Centisimal system

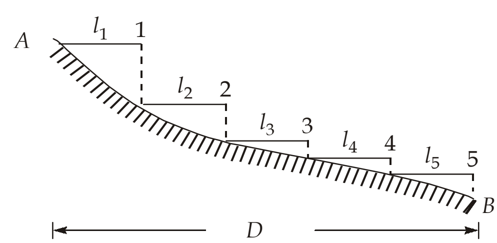
$$1 \text{ circumference} = 400^g \text{ (grads)}$$
$$1 \text{ grad} = 100^c \text{ (centigrads)}$$
$$1 \text{ centigrad} = 100^{cc} \text{ (centi-centigrads)}$$

(c) Hours system

$$1 \text{ circumference} = 24^h \text{ (hours)}$$
$$1 \text{ hour} = 60^m \text{ (minutes of time)}$$
$$1 \text{ minute} = 60^s \text{ (seconds of time)}$$

49. (b)

- In the direct method or the method of stepping, the distance is measured in small horizontal stretches or steps.



$$D = l_1 + l_2 + l_3 + l_4 + l_5$$

- Error due to bad ranging is cumulative positive.
- Degree of accuracy is highest for invar tape, less for steel tape and least for chaining.
- The Colby apparatus is a compensating and optical type rigid bar apparatus designed by Maj. Gen. Colby to eliminate the effects of changes of temperature upon measuring appliance.

50. (c)

- The essential difference between the dumpy level and the wye level is that in the former case, the telescope is fixed to the spindle while in the wye level, the telescope is carried in two vertical wye supports.
- Levelling staffs may be divided into two classes viz:

(1) Self reading staff : Which can be read directly by the instrument man through the telescope.

(2) A target staff : Which contains a moving target against which the reading is taken by staff man.

- In a tilting level, while taking the sight to a staff, the line of sight is made exactly horizontal by centering the bubble.

51. (c)

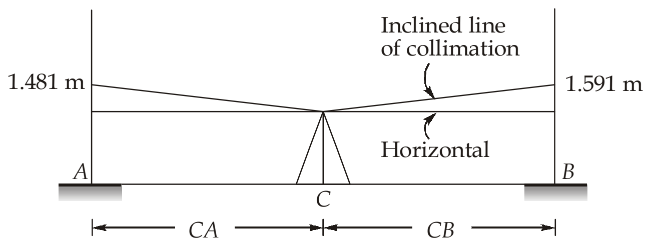
$$\text{Area} = 250 \times 600 = 150000 \text{ m}^2$$

$$E_{92} = \pm\sqrt{(250)^2 \times (0.04)^2 + (600)^2 \times (0.08)^2}$$

$$= \pm 49.03 \text{ m}^2 \simeq \pm 49 \text{ m}^2$$

52. (d)

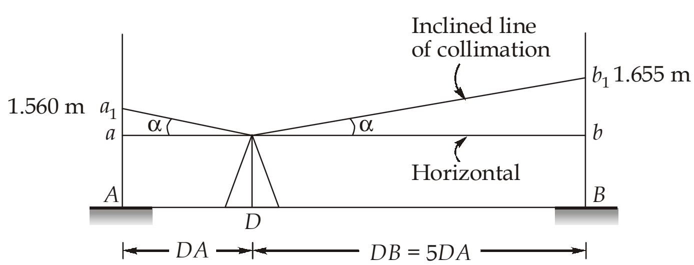
Case I : CA = CB



True difference of levels = 1.591 – 1.481 = 0.11 m

∴ A is at a higher level than B

Case II:



In the second set of readings, as angle α of line of collimation is constant and thus, if error on A is e, then on B it will be $5e$.

Hence, $Bb + 5e - (Aa + e) = 1.655 - 1.560$

⇒ $(Bb - Aa) + 4e = 0.095$ m

But $(Bb - Aa) =$ True difference in levels

$= 0.110$ m

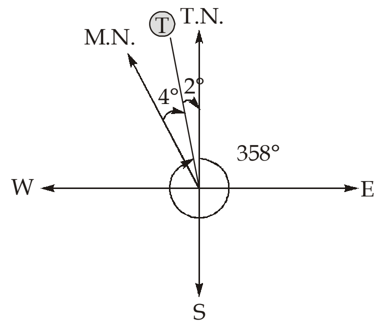
Hence, $4e = 0.095 - 0.11$ m

$= (-)\ 0.015$ m

or $e = (-)\ 0.00375 = -3.75$ mm

This indicates that the line of collimation is downward.

53. (c)



$$\begin{aligned}
\text{T.N.} &= \text{True North} \\
\text{M.N.} &= \text{Magnetic North} \\
\text{Declination} &= 4° + 2° = 6°\text{W} \\
\text{Backbearing of } AB &= 296° \\
\therefore \quad \text{Forebearing of } AB &= 296° - 180° = 116° \\
\text{Declination} &= 6°\text{W} \\
\therefore \quad \text{Correct forebearing of } AB &= 116° - 6° = 110°
\end{aligned}$$

Similarly, correct forebearing of AC = 346° – 180° – 6° = 160°

and correct forebearing of AD = 36° + 180° – 6° = 210°

54. (a)

$\dfrac{L_0}{r_{yy}}$ should be less than 0.7 × slenderness ratio of the built-up column.

where L_0 = Spacing of intermediate battens

and r_{yy} = Radius of gyration about y-axis

Hence, $$\frac{L_0}{r_{yy}} < 0.7\left(\frac{L}{r}\right)$$

$$\Rightarrow \quad L_0 < 0.7\left(\frac{L}{r}\right) \times r_{yy}$$

$$\lambda = \frac{L}{r} = \frac{1.1 \times 6.0 \times 10^3}{154} = \frac{L}{r} = 42.86$$

$$\therefore \quad L_0 < 0.7 \times 42.86 \times 28.2$$
$$< 846 \text{ mm}$$

Also $\dfrac{L_0}{r_{yy}}$ should be less than 50.

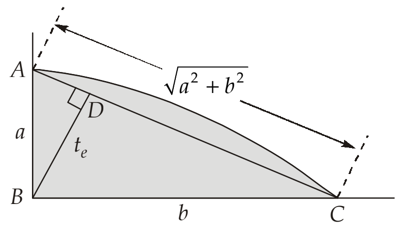
Therefore, $$\frac{L_0}{r_{yy}} < 50$$

$$\Rightarrow \quad L_0 < 50 \times 28.2$$
$$< 1410 \text{ mm}$$

Hence L_0 = Minimum [846 mm, 1410 mm] = 846 mm

So, maximum spacing between intermediate battens can be 846 mm.

55. (c)



The effective throat thickness is taken as the height of triangle inscribed inside the weld.

$$AD = \sqrt{a^2 - t_e^2}$$

$$DC = \sqrt{b^2 - t_e^2}$$

$$\therefore \quad AD + DC = AC$$

$$\Rightarrow \quad \sqrt{a^2 - t_e^2} + \sqrt{b^2 - t_e^2} = \sqrt{a^2 + b^2}$$

Solving above equation gives,

$$t_e = \frac{ab}{\sqrt{a^2 + b^2}}$$

Alternatively,

$$\frac{1}{2} \times a \times b = \frac{1}{2} \times t_e \times \sqrt{a^2 + b^2}$$

$$t_e = \frac{ab}{\sqrt{a^2 + b^2}}$$

56. (b)

On a topographic map, vertical distances are also representated by contour lines, hatching or other systems.

57. (c)

- Accuracy is the relationship between the value of a measurement and the true value of the dimension being measured, the greater the accuracy, the smaller the error.
- Precision describes the degree of refinement with which the measurement is made.

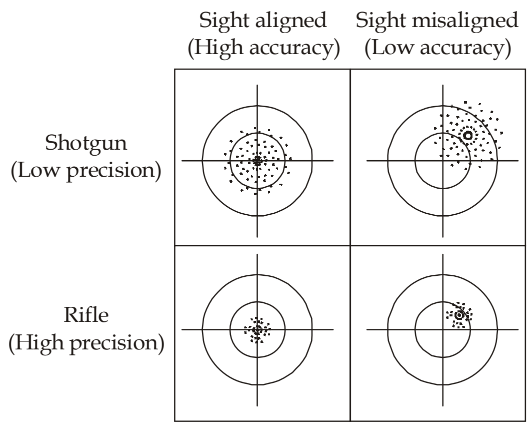


Fig. An illustration of the difference between accuracy and precision

58. (c)

$$\text{Maximum shear stress} \propto \frac{1}{I_P}$$

$\therefore$ $$\tau_s \propto \frac{1}{\pi r^4/2} \quad \text{...(i)}$$

and $$\tau_h \propto \frac{1}{\frac{\pi}{2}\left(r^4 - (0.6r)^4\right)} = \frac{1}{\frac{\pi}{2} r^4 (0.8704)} \quad \text{...(ii)}$$

Taking ratio of (ii) and (i)

$$\frac{\tau_h}{\tau_s} = 1.15$$

Since lengths of both circular and hollow shaft are same and so weight will be directly proportional to area of cross-section

$\therefore$ $$w_s \propto \pi r^2 \quad \text{...(i)}$$

and $$w_h \propto \pi r^2 - \pi \times (0.6r)^2$$

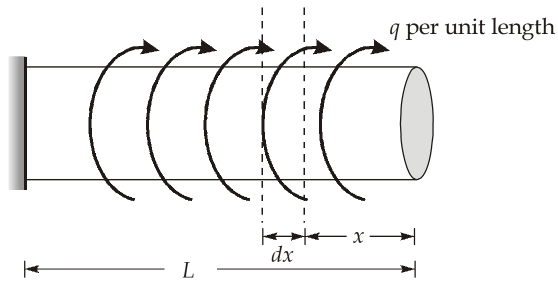
$\Rightarrow$ $$w_h \propto 0.64\pi r^2 \quad \text{...(ii)}$$

Taking ratio of (ii) and (i)

$$\frac{w_h}{w_s} = \frac{0.64\pi r^2}{\pi r^2}$$

$\Rightarrow$ $$\frac{w_h}{w_s} = 0.64$$

59. (a)



$$T_x = qx$$

We know that,
$$U = \int_0^L \frac{(T_x)^2\, dx}{2GI_P}$$

$$= \int_0^L \frac{(q.x)^2\, dx}{2GI_P} = \left.\frac{q^2x^3}{6GI_P}\right|_0^L$$

$$= \frac{q^2L^3}{6GI_P}$$

60. (d)

$$\text{Shear flow, } q = z \times t$$

$$= \frac{T}{2A_m} \quad [\textit{where } A_m = \text{Area of circle considering mean radius}]$$

$$\text{Mean radius,, } r_m = \frac{10+8}{2} = 9 \text{ mm}$$

$$\therefore \quad q = \frac{40\times10^3}{2\times\pi\times9^2} = 78.6 \text{ N/mm}$$

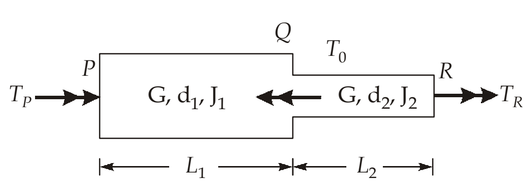
62. (a)

$$\text{Shear stress at NA} = \frac{4}{3}\times\frac{F}{\frac{1}{2}bh} = \frac{8}{3}\frac{F}{bh}$$

$$\text{Maximum shear stress} = \frac{3}{2}\times\frac{F}{\frac{1}{2}bh} = \frac{3F}{bh}$$

$$\text{Difference} = \frac{3F}{bh} - \frac{8F}{3bh} = \frac{F}{3bh}$$

63. (a)



$$\theta_{P/R} = 0$$

$$\frac{T_R L_2}{GJ_2} - \frac{(T_0 - T_R)L_1}{GJ_1} = 0$$

$$\frac{T_R L_2}{GJ_2} + \frac{T_R L_1}{GJ_1} = \frac{T_0 L_1}{GJ_1}$$

$$T_R = \frac{\dfrac{T_0 L_1}{GJ_1}}{\dfrac{L_2}{GJ_2} + \dfrac{L_1}{GJ_1}}$$

$$T_R = \frac{T_0 L_1 J_2}{L_2 J_1 + L_1 J_2}$$

64. (a)

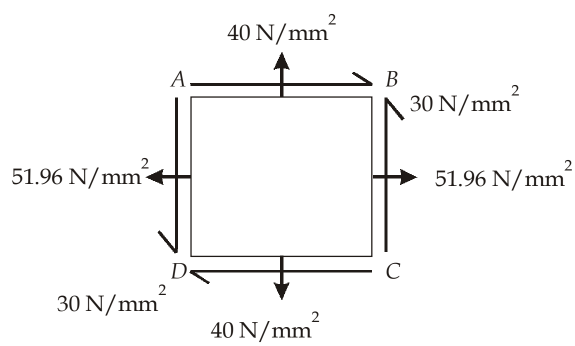
$$\tau_{\max} = \frac{9}{8}\tau_{avg}$$

$$= \frac{9}{8} \times \frac{S.F.}{\text{Area}} = \frac{9}{8} \times \frac{50 \times 10^3}{250 \times 250}$$

$$= 0.9 \text{ N/mm}^2$$

65. (d)

Resolving the stress acting on plane BC as shown below:

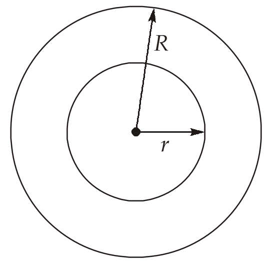


$$\tan 2\theta = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{2 \times 30}{51.96 - 40}$$

$\Rightarrow$ $$\tan 2\theta = 5.02$$

$\Rightarrow$ $$\theta = \frac{1}{2}\tan^{-1}(5.02)$$

66. (b)



For hollow circular cross-section,

$$\tau_{max} = \frac{4V}{3\pi}\left[\frac{R^2 + Rr + r^2}{R^4 - r^4}\right]$$

and
$$\tau_{mean} = \frac{V}{\pi\left(R^2 - r^2\right)}$$

$\therefore$
$$\frac{\tau_{max}}{\tau_{mean}} = \frac{4V\left(R^2 + Rr + r^2\right)}{3\pi\left(R^4 - r^4\right)} \times \frac{\pi\left(R^2 - r^2\right)}{V}$$

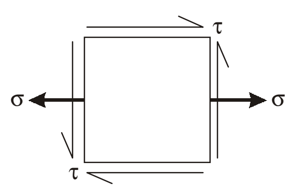
$$= \frac{4}{3} \times \left(\frac{R^2 + Rr + r^2}{R^2 + r^2}\right) \qquad [\because \; R = 3r]$$

$$= \frac{4}{3} \times \left(\frac{(3r)^2 + 3r.r + r^2}{(3r)^2 + r^2}\right)$$

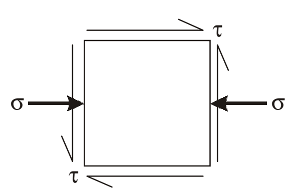
$$= \frac{4}{3} \times \left[\frac{9 + 3 + 1}{9 + 1}\right] = \frac{4}{3} \times \frac{13}{10} = 1.73$$

67. (a)

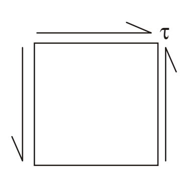
Stress block of B



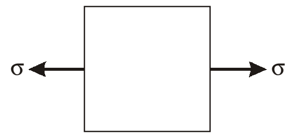
Stress block of D



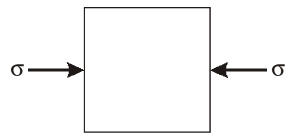
Stress block of C



Stress block of A



Stress block of E



68. (a)

$$\tau_{oct} = \frac{\sqrt{2}}{3}\left(\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2\right)^{1/2}$$

$$\tau_{oct} = \frac{\sqrt{2}}{3}\left(\sigma_y\right) / \text{FOS}$$

$$\therefore \quad \frac{\sqrt{2}}{3}\left(\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2\right)^{1/2} = \frac{\sqrt{2}}{3}\frac{\sigma_y}{\text{FOS}}$$

$$\Rightarrow \quad \left[(2.5\sigma)^2 + (-\sigma)^2 - 2.5\sigma(-\sigma)\right]^{1/2} = \frac{\sigma_y}{\text{FOS}}$$

$$\Rightarrow \quad 3.122\,\sigma = \frac{\sigma_y}{\text{FOS}}$$

$$\Rightarrow \quad \text{FOS} = \frac{\sigma_y}{3.122 \times \sigma}$$

$$\Rightarrow \quad \text{FOS} = \frac{250}{3.122 \times 50} = 1.60$$

70. (d)

- In rectangular sections maximum shear stress develops on the middle surface of longer side.
- Shear stress distribution is non-linear.

71. (d)

$$T = \frac{\pi}{16} \times \tau\left(\frac{D^4 - d^4}{D}\right)$$

$$= \frac{\pi}{16} \times 50\left(\frac{100^4 - 40^4}{100}\right)$$

$$= 3.045 \times 10^6\,\pi \text{ Nmm}$$

$$\therefore \quad \text{Power, } P = T \times \omega$$

$$= T \times 2\pi f$$

$$= 3.045 \times 10^6 \times 2 \times \pi \times \pi \times 2 \times 10^{-3} \text{ Watt}$$

$$= 120.2 \text{ kW}$$

72. (a)

Polar moment of inertia, $J = 2I$

$\Rightarrow$ $J = 2 \times 12 \times 10^6$

$= 24 \times 10^6 \text{ mm}^4$

Now, $$\frac{T}{J} = \frac{G\theta}{L}$$

$\Rightarrow$ $$T = \frac{70 \times 10^3 \times \frac{\pi}{180} \times 24 \times 10^6}{1.5 \times 1000} \quad \left(\theta = 1° = \frac{\pi}{180}\text{rad}\right)\text{radians}$$

$\Rightarrow$ $T = 19.5$ kNm

73. (d)

The plane of maximum and minimum normal stresses are at an angle of 180° to each other in a Mohr's circle.

75. (c)

If load passes through shear centre, the beam will not twist.

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