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ESE 2019

UPSC ENGINEERING SERVICES EXAMINATION

Preliminary Examination

Mechanical Engineering

Topicwise **Objective** Solved Questions

Volume-I

Topicwise Presentation	***Thoroughly Revised and Updated***

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ESE-2018 : Preliminary Examination
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12th Edition: 2018

Director's Message

B. Singh (Ex. IES)

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a carrier option.

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power"*. To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

Contents

Mechanical Engineering

Volume-I

Objective Solved Questions

of UPSC Engineering Services Examination

UNIT

I

Fluid Mechanics and Fluid Machinery

Syllabus

Fluid Mechanics: Basic Concepts and Properties of Fluids, Manometry, Fluid Statics, Buoyancy, Equations of Motion, Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes.
Fluid Machinery: Reciprocating and Rotary pumps, Pelton wheel, Kaplan and Francis Turbines, velocity diagrams, Impulse and Reaction principles.

Contents

1 Fluid Properties

1.1 Match **List-I** (Properties of fluids) with **List-II** (Definition/Results) and select the correct answer using the codes given below the lists:

List-I

A. Ideal fluid
B. Newtonian fluid
C. μ/ρ
D. Mercury in glass

List-II

1. Viscosity does not vary with rate of deformation
2. Fluid of zero viscosity
3. Dynamic viscosity
4. Capillary depression
5. Kinematic viscosity
6. Capillary rise

Codes:

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

[ESE : 1995]

1.2 Match **List-I** (Fluid properties) with **List-II** (Related terms) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Capillarity	**1.** Cavitation
B. Vapour pressure	**2.** Density of water
C. Viscosity	**3.** Shear force
D. Specific gravity	**4.** Surface tension

Codes:

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

[ESE : 1996]

1.3 **Assertion (A):** In fluid, the rate of deformation is far more important than the total deformation itself.
Reason (R): A fluid continues to deform so long as the external forces are applied.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

[ESE : 1996]

1.4 Which one of the following is the bulk modulus *K* of a fluid? (Symbols have the usual meaning)
(a) $\rho\dfrac{dp}{d\rho}$ (b) $\dfrac{dp}{\rho d\rho}$
(c) $\rho\dfrac{d\rho}{dp}$ (d) $\dfrac{d\rho}{\rho dp}$

[ESE : 1997]

1.5 The dimensions of surface tension are
(a) N/m^2 (b) J/m
(c) J/m^2 (d) W/m **[ESE : 1997]**

1.6 Which of the following forces act on a fluid at rest?
1. Gravity force
2. Hydrostatic force
3. Surface tension
4. Viscous force

Select the correct answer using the codes given below:
(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 2 and 4 (d) 1, 3 and 4

[ESE : 1998]

1.7 Surface tension is due to
(a) viscous forces
(b) cohesion
(c) adhesion
(d) the difference between adhesive and cohesive forces

[ESE : 1998]

1.8 Newton's law of viscosity depends upon the
(a) stress and strain in a fluid
(b) shear stress, pressure and velocity
(c) shear stress and rate of strain
(d) viscosity and shear stress
[ESE : 1998]

1.9 The normal stress is the same in all directions at a point in a fluid only when
(a) the fluid is frictional
(b) the fluid is frictionless and incompressible
(c) the fluid has zero viscosity and is at rest
(d) one fluid layer has no motion relative to an adjacent layer
[ESE : 1998]

1.10 If the surface tension of water-air interface is 0.073 N/m, the gauge pressure inside a rain drop of 1 mm diameter will be
(a) 0.146 N/m^2 (b) 73 N/m^2
(c) 146 N/m^2 (d) 292 N/m^2
[ESE : 1999]

1.11 **Assertion (A):** If a cube is placed in a liquid with two of its surfaces parallel to the free surface of the liquid, then the pressures on the two surfaces which are parallel to the free surface, are the same.
Reason (R): Pascal's law states that when a fluid is at rest, the pressure at any plane is the same in all directions.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true
[ESE : 2000]

1.12 The shear stress developed in a lubricating oil, of viscosity 9.81 poise, filled between two parallel plates 1 cm apart and moving with relative velocity of 2 m/s is
(a) 20 N/m^2 (b) 196.2 N/m^2
(c) 29.62 N/m^2 (d) 40 N/m^2
[ESE : 2001]

1.13 A capillary tube is inserted in mercury kept in an open container.
Assertion (A): The mercury level inside the tube shall rise above the level of mercury outside.
Reason (R): The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true
[ESE : 2001]

1.14 In the phenomenon of cavitation, the characteristic fluid property involved is
(a) surface tension
(b) viscosity
(c) bulk modulus of elasticity
(d) vapour pressure
[ESE : 2002]

1.15 The capillary rise at 20°C in clean glass tube of 1 mm diameter containing water is approximately
(a) 15 mm (b) 50 mm
(c) 20 mm (d) 30 mm
[ESE : 2002]

1.16 Match **List-I** (Type of fluid) with **List-II** (Variation of shear stress) and select the correct answer using the codes given below the lists:

List-I
A. Ideal fluid
B. Newtonian fluid
C. Non-Newtonian fluid
D. Bingham plastic

List-II
1. Shear stress varies linearly with the rate of strain
2. Shear stress does not vary linearly with the rate of strain
3. Fluid behaves like a solid until a minimum yield stress beyond which it exhibits a linear relationship between shear stress and the rate of strain
4. Shear stress is zero

Codes:

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

[ESE : 2002]

1.17 The equation of a velocity distribution over a plate is given by $u = 2y - y^2$ where u is the velocity in m/s at a point y meter from the plate measured perpendicularly. Assuming μ = 8.60 poise, the shear stress at a point 15 cm from the boundary is
(a) 1.72 N/m^2 (b) 1.46 N/m^2
(c) 14.62 N/m^2 (d) 17.20 N/m^2
[ESE : 2002]

1.18 **Assertion (A):** In general, viscosity in liquids increases and in gases it decreases with rise in temperature.
Reason (R): Viscosity is caused by intermolecular forces of cohesion and due to transfer of molecular momentum between fluid layers; of which in liquids the former and in gases the later contribute the major part towards viscosity.
(a) Both **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true [ESE : 2002]

1.19 Match **List-I** (Rheological equation) with **List-II** (Types of fluids) and select the correct answer using the codes given below the lists:
List-I
A. $\tau = \mu\left(\frac{du}{dy}\right)^n, n = 1$
B. $\tau = \mu\left(\frac{du}{dy}\right)^n, n < 1$
C. $\tau = \mu\left(\frac{du}{dy}\right)^n, n > 1$
D. $\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^n, n = 1$
List-II
1. Bingham plastic
2. Dilatant fluid
3. Newtonian fluid
4. Pseudo-plastic fluid
Codes:

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

[ESE : 2003]

1.20 Match **List-I** (Flows over or inside the systems) with **List-II** (Type of flow) and select the correct answer using the codes given below the lists:
List-I
A. Flow over a sphere
B. Flow over a long circular cylinder
C. Flow in a pipe bend
D. Fully developed flow in a pipe at constant flow rate
List-II
1. Two dimensional flow
2. One dimensional flow
3. Axisymmetric flow
4. Three dimensional flow
Codes:

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

[ESE : 2003]

1.21 An oil of specific gravity 0.9 has viscosity of 0.28 stokes at 38°C. What will be its viscosity in Ns/m^2?
(a) 0.2520 (b) 0.0311
(c) 0.0252 (d) 0.0206
[ESE : 2004]

1.22 Consider the following statements:
1. Viscosity 2. Surface tension
3. Capillarity 4. Vapour pressure
Which of the above properties can be attributed to the flow of jet of oil in an unbroken stream?
(a) 1 only (b) 2 only
(c) 1 and 3 (d) 2 and 4
[ESE : 2005]

1.23 A vertical clean glass tube of uniform bore is used as a piezometer to measure the pressure of liquid at a point. The liquid has a specific weight of 15 kN/m^3 and a surface tension of 0.06 N/m in contact with air. If for the liquid, the angle of contact with glass is zero and the capillary rise in the tube is not to exceed 2 mm, what is the required minimum diameter of the tube?
(a) 6 mm (b) 8 mm
(c) 10 mm (d) 12 mm
[ESE : 2006]

1.24 When the pressure on a given mass of liquid is increased from 3.0 MPa to 3.5 MPa, the density of the liquid increases from 500 kg/m^3 to 501 kg/m^3. What is the average value of bulk modulus of liquid over the given pressure range?

(a) 700 MPa (b) 600 MPa
(c) 500 MPa (d) 250 MPa

[ESE : 2006]

1.25 If the relationship between the shear stress τ and the rate of shear strain $\left(\frac{du}{dy}\right)$ is expressed as

$$\tau = \mu\left(\frac{du}{dy}\right)^n$$

then the fluid with exponent $n > 1$ is known as which one of the following?

(a) Bingham plastic
(b) Dilatant fluid
(c) Newtonian fluid
(d) Pseudoplastic fluid

[ESE : 2007]

1.26 What are the dimensions of kinematic viscosity of a fluid?

(a) LT^{-2} (b) L^2T^{-1}
(c) $ML^{-1}T^{-1}$ (d) $ML^{-2}T^{-2}$

[ESE : 2007]

1.27 Assertion (A): Blood is a Newtonian fluid.

Reason (R): The rate of strain varies non-linearly with shear stress for blood.

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

[ESE : 2007]

1.28 In an experiment, the following shear stress-time rate of shear strain values are obtained for a fluid:

Time rate of shear strain (1/s)	:	0	2	3	4
Shear stress (kPa)	:	0	1.4	2.6	4

How can the fluid be classified?

(a) Newtonian fluid (b) Bingham plastic
(c) Pseudo plastic (d) Dilatant

[ESE : 2008]

1.29 Consider the following statements related to the fluid properties:

1. Vapour pressure of water at 373 K is 101.5×10^3 N/m^2.
2. Capillary height in cm for water in contact with glass tube and air is (tube diameter)/0.268.
3. Blood is a Newtonian fluid.

Which of these statements is/are correct?

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

[ESE : 2008]

1.30 What is the unit of dynamic viscosity of a fluid termed 'poise' equivalent to?

(a) dyne/cm^2 (b) gm-s/cm^2
(c) dyne-s/cm^2 (d) gm-cm/s

[ESE : 2008]

1.31 What is the pressure difference between inside and outside of a droplet of water?

(a) $\frac{2\sigma}{d}$ (b) $\frac{4\sigma}{d}$
(c) $\frac{8\sigma}{d}$ (d) $\frac{12\sigma}{d}$

Where σ is surface tension and d is the diameter of the droplet. **[ESE : 2008]**

1.32 What is the pressure inside a soap bubble, over the atmospheric pressure if its diameter is 2 cm and the surface tension is 0.1 N/m?

(a) 0.4 N/m^2 (b) 4.0 N/m^2
(c) 40.0 N/m^2 (d) 400.0 N/m^2

[ESE : 2008]

1.33 The capillary rise or depression in a small diameter tube is

(a) directly proportional to the specific weight of the fluid
(b) inversely proportional to the surface tension
(c) inversely proportional to the diameter
(d) directly proportional to the surface area

[ESE : 2008]

1.34 Match **List-I** (Variable) with **List-II** (Dimensional expression) and select the correct answer using the codes given below the lists :

List-I

A. Dynamic viscosity
B. Moment of momentum
C. Power
D. Volume modulus of elasticity

List-II
1. ML^2T^{-3}
2. $ML^{-1}T^{-2}$
3. $ML^{-1}T^{-1}$
4. ML^2T^{-2}
5. ML^2T^{-1}

Codes:

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

[ESE : 2008]

1.35 What is the capillary rise in a narrow two-dimensional slit of width *w*?
(a) Half of that in a capillary tube of diameter *w*
(b) Two-third of that in a capillary tube of diameter *w*
(c) One-third of that in a capillary tube of diameter *w*
(d) One-fourth of that in a capillary tube of diameter *w*

[ESE : 2009]

Direction: Each of the next questions 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 **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

1.36 Assertion (A) : In a fluid, the rate of deformation is far more important than the total deformation itself.

Reason (R) : A fluid continues to deform so long as the external forces are applied.

[ESE : 2009]

1.37 Assertion (A) : A narrow glass tube when immersed into mercury causes capillary depression, and when immersed into water causes capillary rise.

Reason (R) : Mercury is denser than water.

[ESE : 2009]

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

List-I
A. Lubrication
B. Rise of sap in trees
C. Formation of droplets
D. Cavitation

List-II
1. Capillary
2. Vapour pressure
3. Viscosity
4. Surface tension

Codes:

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

[ESE : 2010]

1.39 Consider the following statements:
1. A small bubble of one fluid immersed in another fluid has a spherical shape.
2. The droplets of a fluid move upward or downward in another fluid due to unbalance between gravitational and buoyant forces.
3. Droplets of bubbles attached to a solid surface can remain stationary in a gravitational fluid if the surface tension exceeds buoyant forces.
4. Surface tension of a bubble is proportional to its radius while buoyant force is proportional to the cube of its radius.

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

[ESE : 2010]

1.40 The annular space between two coaxial vertical cylinders, of equal length, is filled with an incompressible liquid of constant viscosity. The outer cylinder is held fixed and the inner cylinder is slowly rotated about its axis at a uniform rotational speed. Assuming that Newton's law of viscosity holds good
(a) the tangential velocity of liquid varies linearly across the gap
(b) viscous shear stress in liquid is uniform across the gap
(c) the tangential velocity of liquid varies non-linearly across the gap
(d) viscous shear stress in liquid varies linearly across the gap

[ESE : 2010]

1.41 A thin plane lamina, of area A and weight W, slides down a fixed plane inclined to the vertical at an angle α and maintains a uniform gap ε from the surface of the plane, the gap being filled with oil of constant viscosity μ. The terminal velocity of the plane is

(a) $\frac{\varepsilon \cos\alpha}{\mu WA}$ (b) $\frac{\varepsilon\mu W}{A\sin\alpha}$

(c) $\frac{\varepsilon W\cos\alpha}{A\mu}$ (d) $\frac{\mu W\sin\alpha}{\varepsilon A}$

[ESE : 2010]

1.42 In a quiescent sea, density of water at free surface is ρ_0 and at a point much below the surface density is ρ. Neglecting variation in gravitational acceleration g and assuming a constant value of bulk modulus K, the depth h of the point from the free surface is

(a) $\frac{K}{g}\left(\frac{1}{\rho_0}+\frac{1}{\rho}\right)$ (b) $\frac{K}{g}\frac{(\rho-\rho_0)}{(\rho+\rho_0)^2}$

(c) $\frac{K}{g}\left(\frac{1}{\rho_0}-\frac{1}{\rho}\right)$ (d) $\frac{K}{g}\left(\frac{\rho\rho_0}{\rho+\rho_0}\right)$

[ESE : 2010]

1.43 Pseudo plastic is a fluid for which

(a) dynamic viscosity decreases as the rate of shear increases
(b) Newton's law of viscosity holds good
(c) dynamic viscosity increases as the rate of shear increases
(d) dynamic viscosity increases with the time for which shearing forces are applied

[ESE : 2010]

1.44 If angle of contact of a drop of liquid is acute then

(a) adhesion is more than cohesion
(b) cohesion is more than adhesion
(c) cohesion is equal to adhesion
(d) adhesion and cohesion have no bearing with angle of contact

[ESE : 2010]

1.45 With increase in pressure, the bulk modulus of elasticity

(a) Decreases (b) Increases
(c) Remains constant (d) None of the above

[ESE : 2011]

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

	List-I		List-II
A.	Capillarity	**1.**	Cavitation
B.	Vapour pressure	**2.**	Density of water
C.	Viscosity	**3.**	Shear forces
D.	Specific gravity	**4.**	Surface tension

Codes:

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

[ESE : 2011]

1.47 Newton's law of viscosity relates

(a) Velocity gradient and rate of shear strain
(b) Rate of shear deformation and shear stress
(c) Shear deformation and shear stress
(d) Pressure and volumetric strain

[ESE : 2011]

1.48 In an experiment to determine the rheological behaviour of a material, the observed relation between shear stress, τ, and rate of shear strain, $\frac{du}{dy}$, is $\tau = \tau_0 + c\left(\frac{du}{dy}\right)^{0.5}$. The material is

(a) A Newtonian fluid
(b) A thixotropic substance
(c) A Bingham plastic
(d) An ideal plastic

[ESE : 2011]

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

List-I
A. Coaxial cylinder viscometer
B. Capillary tube viscometer
C. Saybolt viscometer
D. Falling sphere viscometer

List-II
1. Hagen Poiseuille equation
2. Stokes law
3. Newton's law of viscosity
4. Efflux viscometer

Codes:

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

[ESE : 2011]

Direction: Each of the next questions 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 **A** and **R** are individually true and **R** is the correct explanation of **A**
(b) Both **A** and **R** are individually true but **R** is not the correct explanation of **A**
(c) **A** is true but **R** is false
(d) **A** is false but **R** is true

1.50 **Assertion (A) :** In non-Newtonian fluids, the shear stress at any point is not a linear function of normal distance from the surface.
Reason (R) : This behaviour usually arises because the fluid molecules are very large, like polymers or proteins.
[ESE : 2011]

1.51 **Assertion (A) :** The mercury level inside the tube shall rise above the level of mercury outside.
Reason (R) : The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.
[ESE : 2011]

1.52 The vapour pressure is the characteristic fluid property involved in the phenomenon of
(a) water hammer in a pipe flow
(b) cavitation
(c) rise of sap in a tree
(d) spherical shape of rainwater drop
[ESE : 2012]

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

List-I (Fluids)
A. Ideal fluid
B. Newtonian fluid
C. Inviscid fluid
D. Real fluid

List-II (Viscosity equal to)
1. Zero
2. Non-zero
3. $\mu \frac{du}{dy}$

Code:

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

[ESE : 2012]

1.54 The unit of the following property is not m^2/s
(a) thermal diffusivity
(b) kinematic viscosity
(c) dynamic viscosity
(d) mass diffusivity
[ESE : 2013]

1.55 **Statement (I):** In a fluid, the rate of deformation is far more important than the total deformation itself.
Statement (II): A fluid continues to deform so long as the external forces are applied.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is **NOT** the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true.
[ESE : 2013]

1.56 Unlike the viscosity of liquids, the viscosity of gases increases with increasing temperature. This is due to
(a) Increased cohesive force between the molecules
(b) Increased momentum transfer in the molecules
(c) Decreased momentum transfer in the molecules
(d) Increases in both cohesive force and momentum transfer
[ESE : 2014]

1.57 The pressure inside a soap bubble of 50 mm diameter is 25 N/m^2 above the atmospheric pressure. The surface tension in soap film would be
(a) 0.156 N/m (b) 0.312 N/m
(c) 0.624 N/m (d) 0.078 N/m
[ESE : 2014]

1.58 **Statement (I) :** A small insect can sit on the free surface of a liquid though insect's density is higher than that of the liquid.

Statement (II): Liquids have viscosity.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is **NOT** the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true.

[ESE : 2014]

1.59 Which of the following fluids exhibit a certain shear stress at zero shear strain rate followed by a straight line relationship between shear stress and shear strain rate?

(a) Newtonian fluids
(b) Ideal Bingham plastic fluids
(c) Pseudo-plastic fluids
(d) Dilatant fluids

[ESE : 2015]

1.60 If angle of contact of a drop of liquid is acute, then

(a) cohesion is equal to adhesion
(b) cohesion is more than adhesion
(c) adhesion is more than cohesion
(d) both adhesion and cohesion have no connection with angle of contact

[ESE : 2016]

1.61 A spherical waterdrop of 1 mm in diameter splits up in air into 64 smaller drops of equal size. The surface tension coefficient of water in air is 0.073 N/m. The work required in splitting up the drop is

(a) 0.96×10^{-6} J (b) 0.69×10^{-6} J
(c) 0.32×10^{-6} J (d) 0.23×10^{-6} J

[ESE : 2017]

1.62 A 150 mm diameter shaft rotates at 1500 rpm within a 200 mm long journal bearing with 150.5 mm internal diameter. The uniform annular space between the shaft and the bearing is filled with oil of dynamic viscosity 0.8 poise. The shear stress on the shaft will be

(a) 1.77 kN/m^2 (b) 2.77 kN/m^2
(c) 3.77 kN/m^2 (d) 4.77 kN/m^2

[ESE : 2018]

1.63 The normal stresses within an isotropic Newtonian fluid are related to

1. Pressure
2. Viscosity of fluid
3. Velocity gradient

Which of the above are correct?

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

[ESE : 2018]

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Answers Fluid Properties

1.1 (d)	1.2 (d)	1.3 (a)	1.4 (a)	1.5 (c)	1.6 (b)	1.7 (b)	1.8 (c)	1.9 (d)
1.10 (d)	1.11 (d)	1.12 (b)	1.13 (d)	1.14 (d)	1.15 (d)	1.16 (d)	1.17 (b)	1.18 (d)
1.19 (c)	1.20 (c)	1.21 (c)	1.22 (b)	1.23 (b)	1.24 (d)	1.25 (b)	1.26 (b)	1.27 (d)
1.28 (d)	1.29 (a)	1.30 (c)	1.31 (b)	1.32 (c)	1.33 (c)	1.34 (b)	1.35 (a)	1.36 (a)
1.37 (b)	1.38 (d)	1.39 (a)	1.40 (c)	1.41 (c)	1.42 (c)	1.43 (a)	1.44 (a)	1.45 (b)
1.46 (d)	1.47 (b)	1.48 (b)	1.49 (b)	1.50 (c)	1.51 (d)	1.52 (b)	1.53 (c)	1.54 (c)
1.55 (a)	1.56 (b)	1.57 (a)	1.58 (b)	1.59 (b)	1.60 (c)	1.61 (b)	1.62 (c)	1.63 (d)

Explanations Fluid Properties

1.1 (d)

A Newtonian fluid is a fluid whose stress versus strain rate curve is linear and passes through origin. The constant of proportionality is known as the viscosity.

In fluid mechanics, the term (μ/ρ) is observed frequently and hence for convenience, it is called as kinematic viscosity.

The depression of the meniscus of a liquid contained in a tube where the liquid does not wet walls of container, as in mercury barometer, the meniscus has a convex shape, resulting in a depression.

1.2 (d)

Viscosity: It is a measure of resistance of a fluid which is being deformed by either shear stress or tensile stress.

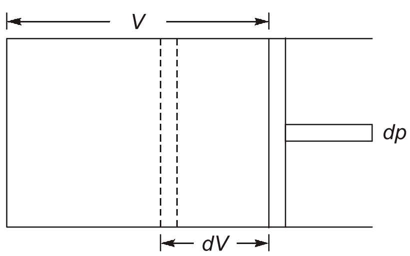
Specific gravity: It is the ratio of density of fluid to the density of standard fluid.

Capillarity: It is the ability of liquid to flow against gravity combination of surface tension and adhesion act to lift the liquid.

1.4 (a)

Bulk modulus,

$$K = -\frac{dp}{dv/v} \quad \ldots \text{(i)}$$



Specific volume,

$$v = \frac{1}{\rho} = \rho^{-1}$$

Taking $\log_e$ both sides, we get

$\log_e v = -\log_e \rho$

On differentiating

$$\frac{dv}{v} = -\frac{d\rho}{\rho}$$

Substituting $\frac{dv}{v} = -\frac{d\rho}{\rho}$ in Eq (i), we get

$$K = \frac{-dp}{-d\rho/\rho} = \rho\frac{dp}{d\rho}$$

1.5 (c)

The property of the liquid surface film to exert a tension is called the surface tension. It is the force required to maintain unit length of the film in equilibrium. In SI units surface tension is expressed in N/m or J/m^2. In metric gravitational system of units it is expressed in kgf/cm or kgf/m.

1.6 (b)

For a fluid at rest, there can be no shear force (i.e. viscous force), The only forces acting on the free body are the normal pressure forces, exerted by the surrounding fluid on the plane surface and the weight of the element.

1.7 (b)

Surface tension is due to cohesion between liquid particles at the surface, where as capillarity is due to both cohesion and adhesion.

The property of cohesion enables a liquid to resist tensile stress, while adhesion enables it to stick to another body.

1.8 (c)

Newton's law of viscosity

$$\tau = \mu\frac{du}{dy} \quad \text{where } \tau = \text{shear stress,}$$

$$\frac{du}{dy} = \text{rate of strain}$$

1.9 (d)

The pressure at any point in a fluid at rest has the same magnitude in all directions. In other words, when a certain pressure is applied at any point in a fluid at rest, the pressure is equally transmitted in all the direction and to every other point in the fluid. It is known as Pascal's law.

1.10 (d)

Pressure intensity inside a droplet,

$$p = \frac{4\sigma}{d} = \frac{4 \times 0.073}{10^{-3}} \text{ N/m}^2 = \mathbf{292\ N/m^2}$$

1.11 (d)

Pressure on the two surfaces which are parallel to free surface are not same.

1.12 (b)

$$\tau = \mu \frac{du}{dy} = 0.981 \times \frac{2}{10^{-2}} = \mathbf{196.2\ N/m^2}$$

1.13 (d)

Assertion is true but reason is false because, for capillary rise adhesive force is greater than the cohesive force.

1.14 (d)

Vapour pressure plays very important role in cavitation.

1.15 (d)

At 20°C surface tension of water (contact with air) = 0.0736 N/m

∴ Capillary rise,

$$h = \frac{4 \times 0.0736}{9.81 \times 10^3 \times 10^{-3}} = 0.030 \text{ m} = \mathbf{30\ mm}$$

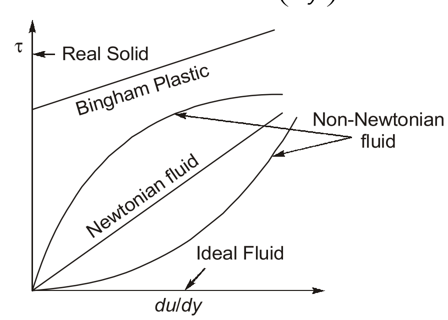
1.16 (d)

$$\tau = \mu \frac{du}{dy}, \text{ Newtonian fluid}$$

$$\tau = \mu \left(\frac{du}{dy}\right)^n, \text{ Non-newtonian fluid}$$

$\tau = 0$, Ideal fluid

$$\tau = \text{constant} + \mu \left(\frac{du}{dy}\right), \text{ Binghamplastic}$$



1.17 (b)

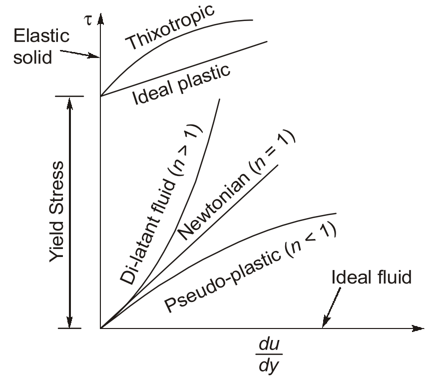
$$\frac{du}{dy} = 2 - 2y; \quad \left.\frac{du}{dy}\right|_{y=0.15} = 1.7$$

$$\tau = \mu \frac{du}{dy} = 0.86 \times 1.7 = \mathbf{1.46\ N/m^2}$$

1.18 (d)

In liquid, viscosity is due to cohesion with rise in temperature, volume of liquid increases, the distance between molecules increases, thus decreasing the cohesion. Therefore the viscosity of liquid decreases with rise in temperature.
In case of gases, viscosity is due to molecular momentum exchange with rise in temperature of gas, kinetic energy of molecules increases, thus increasing the molecular momentum exchange. Therefore, the viscosity of gases increases with rise in temperature.

1.19 (c)



1.21 (c)

Dynamic viscosity,

$$\mu = \rho\nu = (0.9 \times 1000) \times (0.28 \times 10^{-4})$$
$$= \mathbf{0.0252\ Ns/m^2}$$

1.22 (b)

By waver number similarity can be checked. So surface tension will be the answer.

1.23 (b)

Capillary rise,

$$h = \frac{4\sigma\cos\theta}{wd} \quad (w = \rho g)$$

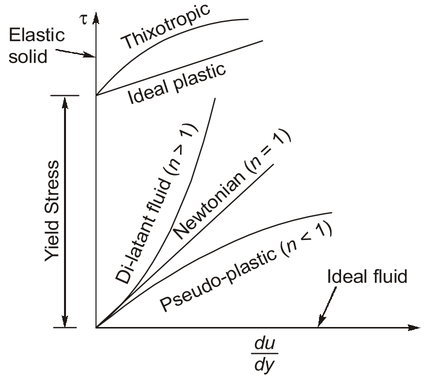
$$\text{or} \quad d = \frac{4 \times 0.06 \times \cos\theta}{15 \times 1000 \times 2 \times 10^{-3}} = \mathbf{8\ mm}$$

1.24 (d)

Bulk modulus,

$$K = \frac{\rho dp}{d\rho} = \frac{500 \times (3.5 - 3.0)}{501 - 500} = \mathbf{250\ MPa}$$

1.25 (b)



1.26 (b)

Kinematic viscosity,

$$\nu = \frac{\text{Dynamic viscosity } (\mu)}{\text{Mass density } (\rho)} = \frac{\mu}{\rho} = \frac{ML^{-1}T^{-1}}{ML^{-3}}$$

$= L^2T^{-1}$

1.27 (d)

$$\tau = A\left(\frac{du}{dy}\right) + B$$

(i) $B = 0$ and $n < 1$

$\Rightarrow$ Pseudo Plastic e.g. Blood and Milk

(ii) $B = 0$ and $n > 1$

$\Rightarrow$ Dilatent Fluid e.g. Rich starch, sugar in water

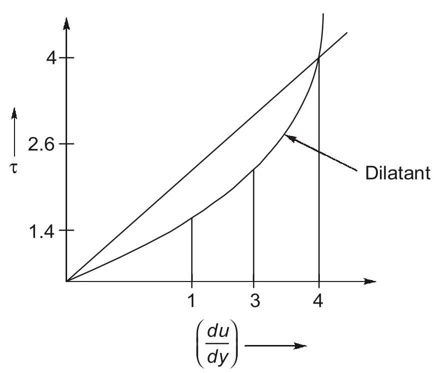
(iii) $B \neq 0$ and $n = 1$

$\Rightarrow$ Bingham plastic e.g. Tooth paste

(iv) $B = 0$ and $n = 1$

$\Rightarrow$ Newtonian Fluid e.g. water.

1.28 (d)



1.29 (a)

Only first statement is correct.

(i) Vapour pressure of water at 373 K is $101.5 \times 10^3 \times N/m^2$

(ii) Capillary height in cm for water in contact with glass tube $= \frac{0.3}{d}$

(iii) Blood is a pseudoplastic fluid.

1.30 (c)

Poise is a C.G.S unit of dynamic viscosity equivalent to dyne s/cm^2

1 poise = 1 dyne s/cm^2 = 10^{-5+4} Ns/m^2

= 10^{-1} Ns/m^2 = **0.1 Ns/m^2**

1.31 (b)

Pressure difference between inside and outside of a droplet of water $= \frac{4\sigma}{d}$

$\because$ Bursting force $= p \times \frac{\pi d^2}{4}$

Resisting force $= \sigma \times \pi d$

Bursting force = Resisting force

$$p \times \frac{\pi d^2}{4} = \sigma \times \pi d$$

or $$p = \frac{4\sigma}{d}$$

1.32 (c)

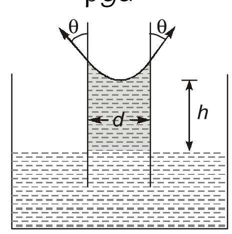
$$\text{Pressure} = \frac{8\sigma}{d} = \frac{8 \times 0.1}{2 \times 10^{-2}}$$

$= 0.4 \times 100 =$ **40 N/m^2**

1.33 (c)

Capillary rise is given by

$$h = \frac{4\sigma\cos\theta}{wd} = \frac{4\sigma\cos\theta}{\rho gd}$$



1.34 (b)

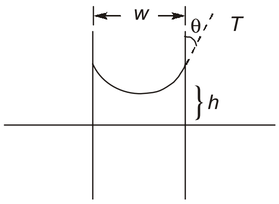
Dynamic viscosity : $M\,L^{-1}\,T^{-1}$

Moment of momentum : $M\ L^2\ T^{-1}$

Power : $M\ L^2\ T^{-3}$

Volume modulus of elasticity : $M\ L^{-1}\ T^{-2}$

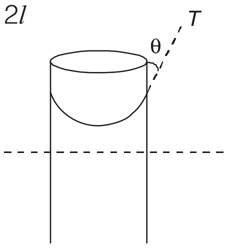
1.35 (a)



For narrow slit → weight of fluid = surface tension force

$$(w \times h \times l) \times \rho_g = T\cos\theta \times 2l$$

$$\therefore \quad h = \frac{2T\cos\theta}{w\rho g}$$



For capillary tube

$$T\cos\theta \times (w\,\pi) = \frac{\pi w^2}{4} h\rho g$$

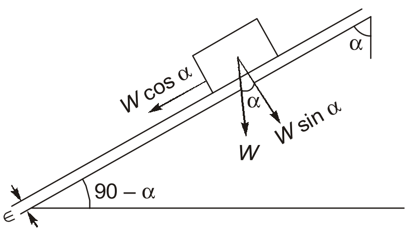
$$h = \frac{4T\cos\theta}{w\rho g}$$

1.38 (d)

Capillarity: It is the ability of a liquid to flow against gravity where liquid spontaneously rises in narrow space such as thin tube (e.g. rise of water in trees)

Cavitation: It will only occur if the pressure declines to some point below the saturated vapour pressure.

1.41 (c)



For zero acceleration

$$W\sin\alpha = \text{drag force}$$

Here

$$\text{Drag force} = \text{shear force} = \mu A\frac{V}{\in}$$

$$W\cos\alpha = \mu A\frac{V}{\in}$$

$$\therefore \quad V = \frac{\in W\cos\alpha}{\mu A}$$

1.42 (c)

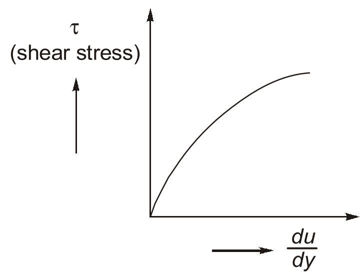
$$K = \frac{\rho\, dp}{d\rho}$$

$$\frac{d\rho}{\rho} = \frac{\rho g dh}{K}$$

$$\left[-\frac{1}{\rho}\right]_{\rho}^{\rho_0} = \frac{gh}{K}$$

$$h = \frac{K}{g}\left[\frac{1}{\rho_0} - \frac{1}{\rho}\right]$$

1.43 (a)



1.44 (a)

When adhesion force is more than cohesion force then fluid will wet the surface and angle of contact between fluid and surface will be less than 90° (acute).

1.45 (b)

$$\text{Bulk modulus: } K = \frac{dp}{\left(-\frac{dv}{v}\right)}$$

∴ Bulk modulus increase with increases in pressure.

1.46 (d)

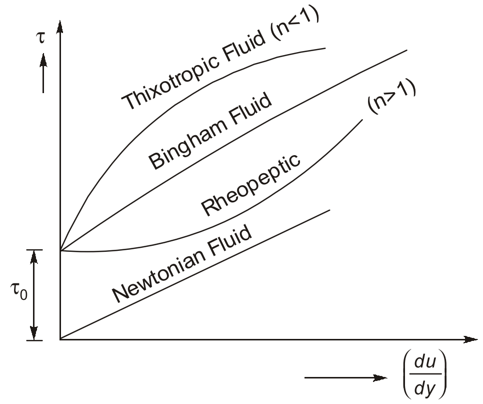
Capillarity	–	Surface tension
Vapour pressure	–	Cavitation
Viscosity	–	Shear forces
Specific gravity	–	Density of water.

1.47 (b)

$$\tau \propto \left(\frac{du}{dy}\right) \propto \frac{d\theta}{dt}$$

∴ Above equation shows the relation between rate of angular deformation and shear stress.

1.48 (b)



Example of Thixotropic fluid : Paint

1.49 (b)

According to Stokes law, the drag force, F, on a sphere of radius r moving through a fluid of viscosity μ at speed V is given by

$$F = 6\pi r\mu V$$

The efflux viscometer, also known as flaw cup, type ford is a traditional instrument used world wide for the determination of kinematic viscosity.

1.51 (d)

Cohesive force is the action or property of like molecules sticking together, being mutually attractive. Mercury has large adhesion force with most container materials and strong cohesive forces. This causes the depression in mercury level inside the tube.

1.52 (b)

Water hammer — Sudden closure of valve
Cavitation — Vapour pressure
Rise of sap in tree — Capillarity
Spherical shape of rainwater drop — Surface tension

1.53 (c)

Ideal fluid is inviscid *i.e.*, it has zero viscosity.
For Newtonian fluid,

$$\text{Shear stress: } \tau = \mu\frac{du}{dy}$$

For real fluid viscosity is non zero.

1.54 (c)

$$\text{Thermal diffusivity: } \alpha = \frac{k}{\rho c_p} \text{ m}^2/\text{s}$$

$$\text{Kinematic viscosity: } \nu = \frac{\mu}{\rho} \text{ m}^2/\text{s}$$

Dynamic viscosity, μ has unit **Pa.s**
Mass diffusivity has also unit of **(m^2/s)**

1.55 (a)

A fluid is a substance that deforms continuously under the application of shear stress no matter how small the shear stress may be. Fluid can be any substance which cannot resist a shear stress when at rest.
So, statement (II) is wrong.

1.56 (b)

For gases, viscosity increases with increase in temperature while for liquids it decreases with increase in temperature. In liquid, the viscosity is governed by the cohesive forces between the molecular of the liquid, whereas in gases, the molecular activity plays a dominant role.

1.57 (a)

Pressure intensity inside a soap bubble,

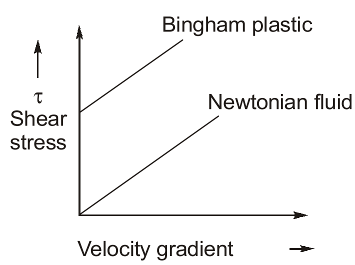
$$p = \frac{4\sigma}{r}$$

$$\therefore \quad \sigma = \frac{pr}{4}$$

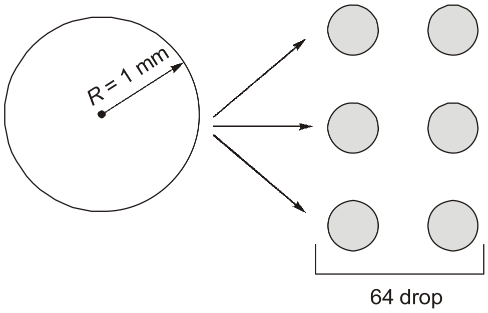
$$= \frac{25\times25\times10^{-3}}{4}$$

$$= \mathbf{0.15625\ N/m}$$

1.59 (b)



1.61 (b)



Volume before splitting = Volume after splitting

$$\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$$

$$r = \frac{R}{n^{1/3}} = \frac{0.5}{(64)^{1/3}} = \frac{0.5}{4} = 0.125 \text{ mm}$$

$$W = \sigma\,(\Delta A)$$

$$= 0.073 \times (n \times 4\pi r^2 - 4\pi R^2)$$

$$= 0.073 \times 4\pi\,[64 \times (0.125)^2 - (0.5)^2]$$

$$= 0.073 \times 4\pi\,[64 \times (0.125)^2 - (0.5)^2] \times 10^{-6}$$

$$= 0.69 \times 10^{-6} \text{ J}$$

1.62 (c)

Using Newtons law of viscosity

$$\tau = \frac{zv}{h} = \frac{2v}{c_1}$$

$$z = 0.8 \text{ poise} = 0.08 \text{ Pa-s}$$

$$v = \frac{\pi DN}{60} = \pi(0.15) \times \frac{1500}{60}$$

$$= 11.781 \text{ m/s}^2$$

$$h = G = \text{Radial clearance} = \frac{D_1 - D}{2}$$

$$= 0.25 \text{ mm}$$

$$= 0.25 \times 10^{-3} \text{ m}$$

$$\tau = 3769.92 \text{ N/m}^2 \simeq 3.77 \text{ kN/m}^2$$

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