



POSTAL BOOK PACKAGE 2027

MECHANICAL ENGINEERING

OBJECTIVE PRACTICE SETS **VOLUME - II**

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FLUID MECHANICS AND HYDRAULIC MACHINES

OBJECTIVE PRACTICE SETS

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Fluid Properties

MCQ and NAT Questions

Q.1 A fluid is said to be Newtonian fluid when the shear stress is

- (a) directly proportional to the velocity gradient
- (b) inversely proportional to the velocity gradient
- (c) independent of the velocity gradient
- (d) none of these

Q.2 Which one of the following is the bulk modulus K of a fluid? (Symbols have the usual meaning)

- (a) $\rho \frac{dp}{d\rho}$
- (b) $\frac{dp}{\rho d\rho}$
- (c) $\rho \frac{d\rho}{dp}$
- (d) $\frac{d\rho}{\rho dp}$

Q.3 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) $\frac{K (\rho - \rho_0)}{g (\rho + \rho_0)^2}$
- (c) $\frac{K}{g} \left(\frac{1}{\rho_0} - \frac{1}{\rho} \right)$
- (d) $\frac{K (\rho \rho_0)}{g (\rho + \rho_0)}$

Q.4 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 plane lamina is

- (a) $\frac{\epsilon \cos \alpha}{\mu W A}$
- (b) $\frac{\epsilon \mu W}{A \sin \alpha}$
- (c) $\frac{\epsilon W \cos \alpha}{A \mu}$
- (d) $\frac{\mu W \sin \alpha}{\epsilon A}$

Q.5 A 50 mm diameter and 0.1 m long cylindrical body slides vertically down in a 52 mm diameter cylindrical tube. The space between the cylindrical body and

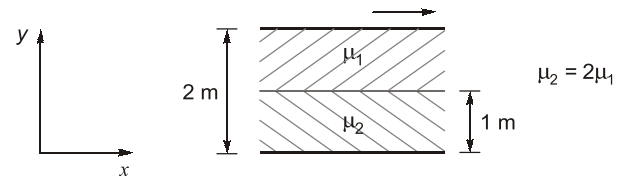
tube wall is filled with oil of dynamic viscosity 1.9 Ns/m². The velocity of fall if its weight is 16 N will be

- (a) 0.536 m/s
- (b) 0.268 m/s
- (c) 0.804 m/s
- (d) 0.638 m/s

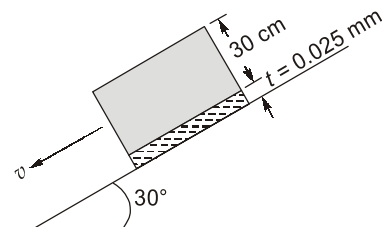
Q.6 Two immiscible, incompressible, viscous fluids having same densities but different viscosities are contained between two infinite horizontal parallel plates, 2 m apart as shown below. The bottom plate is fixed and the upper plate moves to the right with a constant velocity of 3 m/s. With the assumptions of Newtonian fluid, steady, and fully developed laminar flow with zero pressure gradient in all directions, the momentum equations simplify to

$$\frac{d^2 u}{dy^2} = 0$$

If the dynamic viscosity of the lower fluid, μ_2 , is twice that of the upper fluid, μ_1 , then the velocity at the interface (round off to two decimal places) is _____ m/s.



Q.7 As shown in the figure, a cubical block of 30 cm side and of 30 kg weight is allowed to slide down along a plane inclined at 30° to the horizontal on which there is a film of oil having viscosity of 2×10^{-3} N-s/m². The film thickness is 0.025 mm. The terminal velocity of the block is



- (a) 12.44 m/s
- (b) 16.89 m/s
- (c) 20.44 m/s
- (d) 22.22 m/s

Q.8 The 4 m³ of a certain oil weighs 30 kN. The relative density of oil is

- (a) 0.765 (b) 0.813
(c) 0.872 (d) 0.965

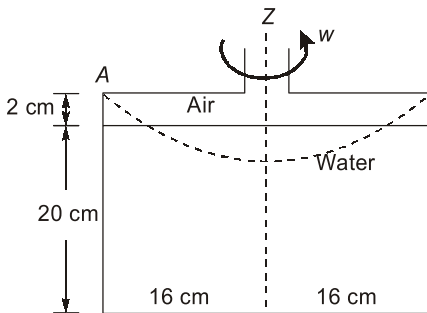
Q.9 A plate 0.03 mm distant from a fixed plate, moves at 80 cm/s and requires a force of 4 N per unit area to maintain this speed. The fluid viscosity between the plates is

- (a) 1.5×10^{-4} poise (b) 2.5×10^{-3} poise
(c) 1.5×10^{-3} poise (d) 2.5×10^{-4} poise

Q.10 The equation of a velocity profile over a plate is $V = 7y^2 + y$ (where V is the velocity in m/s). The viscosity of the liquid is 8.35 poise. The shear stress at $y = 7.5$ cm is

- (a) 1.71 N/m² (b) 3.42 N/m²
(c) 4.62 N/m² (d) 4.78 N/m²

Q.11 A cylinder is rotated about the central axis as shown in figure. The force (in N) on the bottom of the cylinder, when the rotation speed is such that the water just touches the point A will be



- (a) 157.8 (b) 187.5
(c) 142.1 (d) 117.5

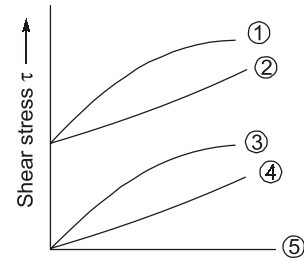
Q.12 The shear stress in a fluid may be expressed as:

$$\tau \propto \left(\frac{dv}{dy}\right)^n$$

where $\frac{dv}{dy}$ is the velocity gradient and n is constant. The n value for Newtonian and Non-newtonian fluids will be respectively

- (a) $n = 1$ and $n > 1$ (b) $n < 1$ and $n > 1$
(c) $n = 1$ and $n < 1$ (d) $n = 1$ and $n \neq 1$

Q.13 Which of the curves labelled as ①, ②, ③, ④, & ⑤ in the given figure represent the Newtonian and the ideal fluid respectively?



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

Q.14 Classify the fluid based upon the following results of a test on their rheological behaviour

Shear rate, $\frac{\partial u}{\partial y}$	0	0.50	1.0	1.5	2.0
Shear stress, τ	1	2	3	4	5

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

Q.15 The dynamic viscosity of fluid is 0.5 poise and its specific gravity is 0.5. The kinematic viscosity of this fluid (in stokes) is:

- (a) 0.25 (b) 0.5
(c) 1.0 (d) 1.5

Q.16 Kinematic viscosity of air at 20°C is given to be 1.6×10^{-5} m²/s. Its kinematic viscosity at 70°C will be varying approximately

- (a) 2.2×10^{-5} m²/s (b) 1.6×10^{-5} m²/s
(c) 1.2×10^{-5} m²/s (d) 3.2×10^{-5} m²/s

Q.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 $\mu = 8.60$ poise, the shear stress at a point 15 cm from the boundary is

- (a) 1.72 N/m² (b) 1.46 N/m²
(c) 14.62 N/m² (d) 17.20 N/m²

Q.18 Consider the following statements related to the fluid properties:

- Vapour pressure of water at 373 K is 101.5×10^3 N/m².
- Capillary height in cm for water in contact with glass tube and air is (tube diameter)/0.268.
- 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

Q.19 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

Q.20 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

Q.21 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/m² (b) 2.77 kN/m²
(c) 3.77 kN/m² (d) 4.77 kN/m²

Q.22 The work done in blowing a soap bubble of diameter 20 cm is _____ $\times 10^{-3}$ Nm.

[Assume the surface tension of soap solution as 0.040 N/m.]

- (a) 14.88 (b) 10.05
(c) 6.01 (d) 4.32

Q.23 In an experiment, the tip of a glass tube with an internal diameter of 2 mm is immersed to a depth of 1.5 cm into a liquid of specific gravity 0.85. Air is forced into the tube to form a spherical bubble just at the lower end of the tube. If the air pressure in the bubble is 200 N/m², then the surface tension of the liquid will be

- (a) 0.018 N/m (b) 0.025 N/m
(c) 0.037 N/m (d) 0.042 N/m

Q.24 The surface tension at air-water interface is 0.088 N/m. The pressure difference between inside and outside of a water bubble of diameter 0.02 mm in air is

- (a) 9.8 kN/m² (b) 11.9 kN/m²
(c) 17.6 kN/m² (d) 21.2 kN/m²

Q.25 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

Q.26 Mercury (density = 13600 kg/m³, $\sigma = 0.49$ N/m; $\theta = 0^\circ$) is contained in a wide beaker. A 2 mm internal diameter open ended capillary tube is inserted in the middle of the beaker into the mercury. The meniscus in tube will be below the external mercury surface by how much distance?

- (a) 4.2 mm (b) 5.7 mm
(c) 6.8 mm (d) 7.3 mm

Q.27 A clean tube of internal diameter 3 mm is immersed in a liquid with a coefficient of surface tension of 0.48 N/m. The angle of contact of the liquid with the glass can be assumed to be 130°. The density of the liquid is 13600 kg/m³. What would be the level of the liquid in the tube relative to the free surface of the liquid outside the tube? [Take $\sin 40^\circ = 0.643$]

- (a) 1.54 mm (b) -1.54 mm
(c) 3.08 mm (d) -3.08 mm

Q.28 Consider the following statements:

1. In thixotropic fluid, viscosity decreases at higher shear stress.
2. Viscosity of Rheopectic fluid decreases at higher shear stress.
3. In thixotropic fluid, viscosity increases at higher shear stress.
4. Viscosity of Rheopectic fluid increases at higher shear stress.

Which of the above statements are CORRECT?

- (a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) None of the above

- Q.29** Oil in a hydraulic cylinder is compressed from an initial volume 2 m^3 to 1.96 m^3 . If the pressure of oil in the cylinder changes from 40 MPa to 80 MPa during compression, the bulk modulus of elasticity of oil is
(a) 1000 MPa (b) 2000 MPa
(c) 4000 MPa (d) 8000 MPa

- Q.30** A Newtonian fluid fills the clearance between a shaft and a sleeve, when a force 800 N is applied to the shaft, parallel to the sleeve, the shaft attains a speed of 1.5 cm/sec. If a force of 2.4 kN is applied instead, the shaft would move with a speed of :
(a) 1.5 cm/sec (b) 13.5 cm/sec
(c) 0.5 cm/sec (d) 4.5 cm/sec

Directions (Q.31 to Q.34): Each of the next items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. Examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

- (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

- Q.31 Statement (I) :** The mercury level inside the tube shall rise above the level of mercury outside.

Statement (II) : The cohesive force between the molecules of mercury is greater than the adhesive force between mercury and glass.

- Q.32 Statement (I):** In general, viscosity in liquids increases and in gases it decreases with rise in temperature.

Statement (II): 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.

- Q.33 Statement (I):** The kinematic viscosity of both air and water decreases as the temperature increases.

Statement (II): The kinematic viscosity of liquids and gases at a given pressure is a function of temperature.

- Q.34 Statement (I):** In 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.

Multiple Select Questions (MSQ)

- Q.35** Calculate the capillary effect in mm in a glass tube of 4 mm diameter when immersed in water and mercury respectively.
Temperature of the liquid = 20°C
Surface tension of water in contact with air = 0.073 N/m
Surface tension of mercury in contact with air = 0.51 N/m
Angle of contact for water is zero and for mercury is 130°
Density of water = 998 kg/m^3
(a) Capillary rise of 2.46 mm for mercury
(b) Capillary depression of 7.46 mm for water
(c) Capillary depression of 2.46 mm for mercury
(d) Capillary rise of 7.46 mm for water.



Answers Fluid Properties

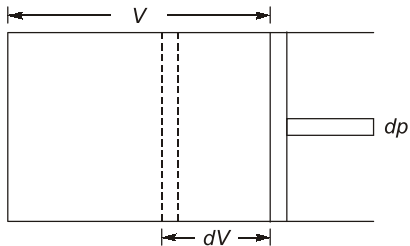
1. (a) 2. (a) 3. (c) 4. (c) 5. (a) 6. (1) 7. (c) 8. (a) 9. (c) 10. (a)
11. (a) 12. (d) 13. (d) 14. (c) 15. (c) 16. (a) 17. (b) 18. (a) 19. (a) 20. (d)
21. (c) 22. (b) 23. (c) 24. (c) 25. (c) 26. (d) 27. (d) 28. (b) 29. (b) 30. (d)
31. (d) 32. (d) 33. (d) 34. (a) 35. (c, d)

Explanations Fluid Properties

2. (a)

Bulk modulus,

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



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

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

3. (c)

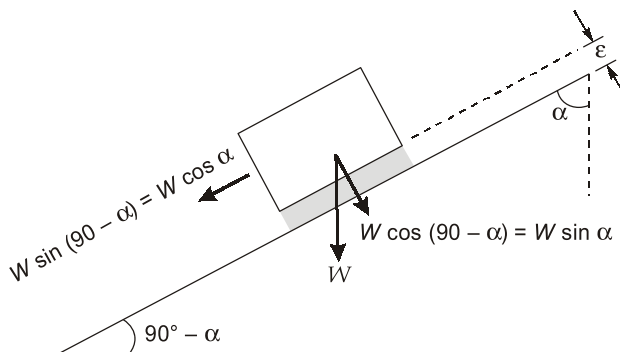
$$K = \frac{\rho dp}{d\rho}$$

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

$$\left[\frac{-1}{\rho} \right]_p^{p_0} = \frac{gh}{K}$$

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

4. (c)



For zero acceleration,

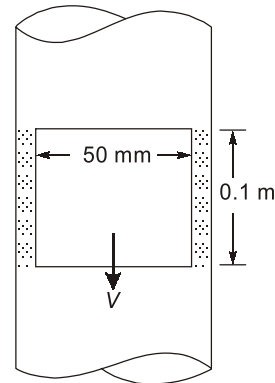
$$W \cos \alpha = \text{Drag force}$$

Here, Drag force = Shear force = $\mu A \frac{V}{\epsilon}$

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

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

5. (a)

Let V be its terminal velocity of fallShear stress τ will be

$$\begin{aligned} \tau &= \mu \frac{dv}{dy} = 1.9 \times \frac{V}{1 \times 10^{-3}} \\ &= 1.9 \times 10^3 V \text{ N/mm}^2 \end{aligned}$$

The shear stress will act on the surface of the cylinder.

Hence, Total force, $F = \tau \times A$

$$\begin{aligned} &= 1.9 \times 10^3 \times V \times 3.142 \times 50 \times 10^{-3} \times 0.1 \\ &= 29.849 U \end{aligned}$$

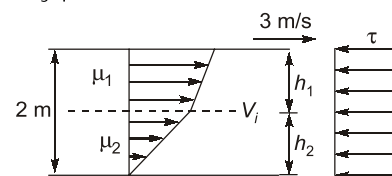
Under equilibrium condition, the weight will be balanced by total shear force. Hence,

$$16 = 29.849 U$$

$$\text{or } U = 0.536 \text{ m/s}$$

6. (1)

Velocity profile is laminar in both fluids



$$\frac{d^2 u}{dy^2} = 0$$

$$\frac{du}{dy} = c_1$$

$$u = c_1 y + c_2$$

i.e. we can assume linear velocity profile.

If velocity profile is linear shear stress will be constant in gap everywhere i.e. in fluid (1) and fluid (2). Also at the interface shear stress will be constant.

$$\tau_1 = \tau_2$$

$$\mu_2 \frac{V_i}{h_2} = \mu_1 \frac{(V - V_i)}{h_1}$$

where V_i is velocity at the interface.

$$2\mu_1 \frac{V_i}{1} = \frac{\mu_1(3 - V_i)}{1}$$

$$2V_i = 3 - V_i$$

$$3V_i = 3$$

$$V_i = 1 \text{ m/s}$$

7. (c)

Weight of block = 25 kg

Block dimensions = $30 \times 30 \times 30 \text{ cm}^3$

Driving force along the plane,

$$F = W \sin 30^\circ$$

$$= 30 \times 9.81 \times 0.5$$

$$= 147.15 \text{ N}$$

$$\text{Shear force, } \tau = \frac{F}{A} = \frac{147.15}{(0.3)^2} = 1635 \text{ N/m}^2$$

Contact area, $A = 0.3 \times 0.3 \text{ m}^2$

$$\text{Also, } \tau = \mu \frac{dv}{dy}$$

$$\Rightarrow 1635 = 2 \times 10^{-3} \times \frac{V}{0.025 \times 10^{-3}}$$

$$\Rightarrow V = \frac{1635 \times 0.025}{2} = 817.5 \times 0.25 = 20.44 \text{ m/s}$$

8. (a)

Specific weight,

$$\gamma = \frac{\text{Weight}}{\text{Volume}} = \frac{30 \text{ kN}}{4 \text{ m}^3} = 7.5 \text{ kN/m}^3$$

Mass density,

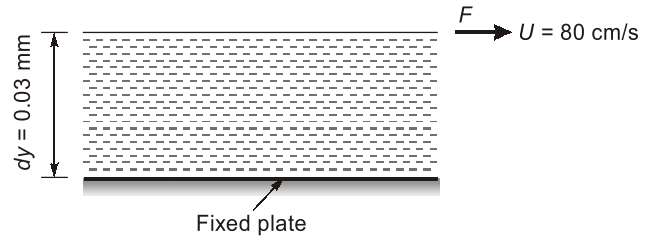
$$\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{W/g}{V} = \frac{7.5 \times 10^3 (\text{N/m}^3)}{9.81 (\text{m/s}^2)}$$

$$= 764.53 \text{ kg/m}^3$$

$$\therefore \text{Relative density of oil} = \frac{\text{Density of oil}}{\text{Density of water}}$$

$$= \frac{764.53}{1000} = 0.76453 \approx 0.765$$

9. (c)



Distance between plates,

$$dy = 0.03 \text{ mm} = 3 \times 10^{-5} \text{ m}$$

Velocity of upper plate,

$$u = 80 \text{ cm/s} = 0.8 \text{ m/s}$$

Force on upper plate,

$$F = 4 \text{ N/m}^2$$

This is the value of shear stress i.e. τ

Let the fluid viscosity between the plates is μ

$$\Rightarrow \tau = \mu \frac{du}{dy}$$

$$4.0 = \mu \times \frac{0.80}{3 \times 10^{-5}}$$

$$\mu = \frac{4 \times 3 \times 10^{-5}}{80} = \frac{3 \times 10^{-5}}{20} = 0.15 \times 10^{-5}$$

$$= 1.5 \times 10^{-4} \times 10 \text{ poise}$$

$$= 1.5 \times 10^{-3} \text{ poise}$$

10. (a)

Velocity profile,

$$V = 7y^2 + y$$

Coefficient of dynamic viscosity,

$$\mu = 8.35 \text{ poise} = 8.35 \times 10^{-1} \text{ Ns/m}^2$$

Velocity gradient,

$$\frac{dv}{dy} = 14y + 1$$

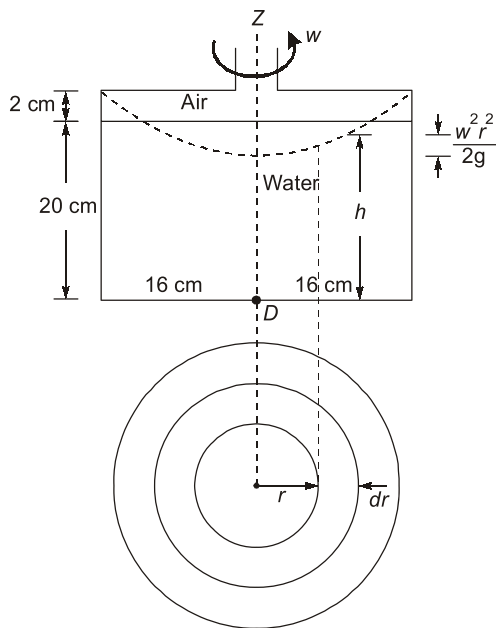
$$\tau = \mu \frac{dv}{dy} = \mu(14y + 1)$$

At $y = 7.5 \text{ cm} = 0.075 \text{ m}$

$$\tau = 8.35 \times 10^{-1} \times (14 \times 0.075 + 1)$$

$$= 1.71 \text{ N/m}^2$$

11. (a)



\therefore Water just touches point A

$$\therefore 0.04 = \frac{w^2(0.16)^2}{2g}$$

$$dF = \text{Pressure} \times \text{Area}$$

$$= \rho gh \times 2\pi r dr$$

$$\therefore F = \int dF$$

$$= \int \rho g \left(0.18 + \frac{w^2 r^2}{2g} \right) \times 2\pi r dr$$

$$\Rightarrow F = 2\pi \rho g \int_0^{0.16} \left(0.18 + \frac{w^2 r^2}{2g} \right) r dr$$

$$= 2\pi \rho g \left[\frac{0.18 r^2}{2} + \frac{w^2}{2g} \times \frac{r^4}{4} \right]_0^{0.16}$$

$$= 2\pi \rho g \left[0.09(0.16)^2 + \frac{w^2(0.16)^2}{2g} + \frac{(0.16)^2}{4} \right]$$

$$= 157.8 \text{ N}$$

13. (d)

Ideal fluid is inviscid so there will be zero shear stress at all values of rate of shear strain. Thus it is represented by (5)

For Newtonian fluid $\tau = \mu \left(\frac{du}{dy} \right)$ means that shear stress is linearly proportional to rate of shear strain. Thus it is represented by curve (4).

Curve

Fluid

(1) Thixotropic fluid ($n < 1$)

(2) Ideal Bingham plastic

(3) Pseudoplastic ($n < 1$)

(4) Newtonian

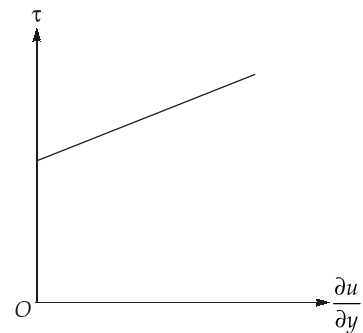
(5) Ideal

14. (c)

Given fluid has linear shear stress vs shear rate

behaviour, however at $\frac{\partial u}{\partial y} = 0$, the shear stress is 1 unit. Hence the fluid is classified as Bingham plastic. A general relationship between shear stress and velocity gradient (rate of shear strain) for non-newtonian fluid is

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



At $\tau = 1$ and $\frac{du}{dy} = 0$

$B \neq 0$ and also, $n = 1$

\Rightarrow Fluid is Bingham plastic.

15. (c)

Poise is the unit of dynamic viscosity (μ) in C.G.S. system. Stokes is the unit of kinematic viscosity (ν) in C.G.S. system.

$$\text{Specific gravity } G = \frac{\rho}{\rho_w} = \frac{(\mu/\nu)}{\rho_w}$$

$$\therefore \nu = \frac{0.5}{0.5} = 1 \text{ stokes}$$

16. (a)

Dynamic viscosity of gases increase with increase in temperature,

$$\text{i.e., } \mu \propto \sqrt{T}$$

and density of gases decrease with increase in temperature at constant pressure.

$$\text{i.e., } \rho \propto \frac{1}{T}$$

HEAT TRANSFER

OBJECTIVE PRACTICE SETS

Page No. 137 - 231

Introduction and Basic Concepts

MCQ and NAT Questions

- Q.1** Heat transmission is directly linked with the transport of medium itself, i.e., there is actual or bulk motion of heated particles during
- conduction only
 - convection only
 - radiation only
 - conduction as well as radiation
- Q.2** Choose the correct statement
- Thermal conductivity for metals decreases with increase in temperature
 - Thermal conductivity for gases and insulating material decreases with increase in temperature
 - Thermal conductivity is not a function of temperature
 - Thermal conductivity increases with increase in temperature irrespective of material
- Q.3** Arrange the following substance in increasing order of thermal conductivity.
- | | |
|-----------|--------------|
| 1. Copper | 2. Aluminium |
| 3. Water | 4. Air |
- Which one of the following sequence is correct?
- 4-3-2-1
 - 4-3-1-2
 - 3-4-2-1
 - 3-4-1-2
- Q.4** The inner surface of a plane brick wall is at 50°C and the outer surface is at 25°C. The rate of heat transfer per m² of the surface area of the wall, which is 220 mm thick is (the thermal conductivity of the bricks is 0.51 W/m K).
- 20.65 W/m²
 - 32.75 W/m²
 - 47.62 W/m²
 - 57.95 W/m²
- Q.5** All the three modes of heat transmission are involved in
- melting of ice
 - cooling of a small metal casting in a quenching bath
 - heat flow through the walls of a refrigerator
 - automobile engine equipped with a thermo-syphon cooling system
- Q.6** For a composite wall made of three layers, of three layers, *A*, *B* and *C* of different material wall thickness and temperature difference across the wall faces of layer *A*, *B* and *C* are 20cm and 100°C, 15cm and 180°C, 25cm and 100°C respectively. Which one of the following is correct? (assume area of each layer is same).
- Layer *A* has highest thermal conductivity (*k*)
 - Layer *B* has highest thermal conductivity (*k*)
 - Layer *C* has highest thermal conductivity (*k*)
 - All layers have equal thermal conductivity.
- Q.7** The heat conducted through a wall of thickness δ is given by
- $$Q = -kA \frac{dT}{dx} = -kA \left(\frac{T_2 - T_1}{\delta} \right)$$
- which amongst the following is not a correct statement?
- the term (δ/kA) is called thermal resistance
 - the term (kA/δ) is called thermal conductance
 - the factor (Q/A) is called thermal loading
 - the temperature gradient (dT/dx) is positive
- Q.8** Heat conduction in gases is due to
- electromagnetic waves
 - motion of electrons
 - mixing motion of the different layers of the gas
 - elastic impact of molecules
- Q.9** Thermal diffusivity is
- a dimensionless parameter
 - function of temperature
 - a physical property of the material
 - none of these
- Q.10** Your finger sticks to an ice tray just taken from the refrigerator, Which factor has more effect on this phenomenon?
- The inside temperature of the freezer (Suppose it's working properly)
 - The humidity of the air

- (c) The heat capacity of both your finger and the tray
- (d) The thermal conductivity of the tray

Q.11 A cold liquid is stored in spherical vessel in order to

- (a) reduce rate of heat transfer
- (b) increase rate of heat transfer
- (c) prevent the liquid from freezing
- (d) none of these

Q.12 Which one of the following is correct, in context of thermal diffusivity (α) of liquid and gas

- (a) $\alpha_{\text{gas}} > \alpha_{\text{liquid}}$
- (b) $\alpha_{\text{gas}} < \alpha_{\text{liquid}}$
- (c) $\alpha_{\text{gas}} = \alpha_{\text{liquid}}$
- (d) Depend on other factors

Q.13 The unit of thermal diffusivity is

- (a) $\text{m}^2/\text{hr}^\circ\text{C}$
- (b) $\text{kJ}/\text{m}^2\text{hr}$
- (c) $\text{m}/\text{hr}^\circ\text{C}$
- (d) m^2/hr

Q.14 The ratio of thermal conductivity to electrical conductivity is equal to

- (a) Prandtl number
- (b) Schmidt number
- (c) Lorentz number
- (d) Lewis number

Q.15 Hot coffee in a cup is allowed to cool. Its cooling rate is measured and found to be greater than the value calculated by conduction, convection and radiation measurement. The difference is due to

- (a) properties of coffee changing with temperature
- (b) currents of air flow in the room
- (c) underestimation of emissivity of coffee
- (d) evaporation

Q.16 The Fourier law of heat conduction is valid for

- (a) One dimensional only
- (b) Two dimensional only
- (c) Three dimensional only
- (d) None of these

Q.17 Match the property with their units

Property	Units
A. Bulk modulus	1. W/s
B. Thermal conductivity	2. N/m^2
C. Heat transfer coefficient	3. N/m^3
D. Heat flow rate	4. W
	5. W/mK
	6. $\text{W}/\text{m}^2\text{K}$

Codes:

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

Q.18 In a case of one dimensional heat conduction in a medium with constant properties, T is the temperature at position x , at time t . Then $\frac{\partial T}{\partial t}$ is proportional to

- (a) $\frac{T}{x}$
- (b) $\frac{\partial T}{\partial x}$
- (c) $\frac{\partial^2 T}{\partial x \partial t}$
- (d) $\frac{\partial^2 T}{\partial x^2}$

Q.19 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

- A. Momentum transfer
- B. Mass transfer
- C. Heat transfer

List-II

- 1. Thermal diffusivity
- 2. Kinematic viscosity
- 3. Diffusion coefficient

Codes:

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

3

Multiple Select Questions (MSQ)

Q.20 Which of the following statements is/are correct with respect to conduction heat transfer?

- (a) Heat transfer takes place by molecular lattice vibrational energy and due to free electron transfer in solids.
- (b) If all other factors remains same (i.e. area, temperature gradients same), then conduction heat transfer by brass will be more than copper.
- (c) All electrically good conductor are in general good conductors of heat also.
- (d) Diamond is having the highest thermal conductivity among all known materials.

- Q.21** Which of the following statements is/are correct?
 (a) Thermal conductivity is a thermophysical property of a material.
 (b) Heat conduction occurs in gases by molecular momentum transfer.
 (c) With increase in temperature thermal conductivity of gases decreases.
 (d) Liquids are better conductors of heat than gases.
- Q.22** Which of the following statements is/are correct about a black body?
 (a) A black body is considered as an ideal emitter.
 (b) A black body is considered as a perfect absorber.
 (c) A black body is considered as non-diffusive in nature.
 (d) Snow and Ice are also considered as black body.
- Q.23** Which of the following statements is/are correct?
 (a) In free convection heat transfer the motion of the fluid occurs naturally due to buoyancy forces.
 (b) Radiation heat transfer does not require any material medium for its propagation.
 (c) All bodies at all temperature emit thermal radiation except the body at 0 K.
 (d) Radiation heat transfer dominates over conduction and convection when the temperature difference is sufficiently large.


Answers Introduction and Basic Concepts

1. (b) 2. (a) 3. (a) 4. (d) 5. (d) 6. (c) 7. (d) 8. (d)
 9. (c) 10. (d) 11. (a) 12. (a) 13. (d) 14. (c) 15. (d) 16. (a)
 17. (b) 18. (d) 19. (a) 20. (a, c, d) 21. (a, b, d) 22. (a, b, d) 23. (a, b, c, d)

Explanations Introduction and Basic Concepts

1. (b)

Actual movement of particles of the medium is present in convection only.

2. (a)

For gases thermal conductivity increases with increase in temperature and decrease with increase in molecular weight.

3. (a)

Substance	k (w/m-K)
Copper	386
Aluminium	175.6
Water	0.51
Air	0.022

4. (d)

$$q = k \frac{\Delta T}{\Delta x} = \frac{0.51 \times 25}{0.22} = 57.95 \text{ W/m}^2$$

5. (d)

In syphon cooling system all modes conduction, convection and radiation takes place. Since it has high temperatures therefore radiation heat transfer is also significant.

6. (c)

$$\therefore Q = \frac{k_1 A_1 \Delta t_1}{L_1} = \frac{k_2 A_2 \Delta t_2}{L_2} = \frac{k_3 A_3 \Delta t_3}{L_3}$$

$$\therefore A_1 = A_2 = A_3 = A$$

$$\therefore Q = \frac{k_1 \cdot \Delta t_1}{L_1} = \frac{k_2 \cdot \Delta t_2}{L_2} = \frac{k_3 \cdot \Delta t_3}{L_3}$$

$$\therefore Q = \frac{k_1 (100)}{20} = \frac{k_2 (180)}{15} = \frac{k_3 (100)}{25}$$

$$\therefore 5k_1 = 12k_2 = 4k_3$$

$$\therefore \boxed{k_3 > k_1 > k_2}$$

7. (d)

$\frac{\delta}{kA}$ in thermal resistance

$\frac{Q}{A}$ in thermal loading

$\frac{dT}{dx}$ is negative in the direction of heat flow

8. (d)

Heat conduction in gases is due to collision of gases molecules. It is due to its elastic impact of molecules.

10. (d)

Due to high temperature difference between your finger and the tray, some heat will be transferred to the tray, depending on its capacity for thermal conductivity.

Since the surface of your skin is naturally moisturized (it's not a function of the air humidity), the loss of heat will cause a thin layer of ice to form on the skin which in turn sticks to the tray.

No matter how dry is the air and how cold is the freezer, your finger will not stick to a wooden tray whose thermal conductivity is low. So the most important factor is the thermal conductivity of the tray.

11. (a)

Spherical vessel to reduce heat transfer as it offers the maximum thermal resistance.

12. (a)

Since thermal diffusivity, $\alpha = \frac{k}{\rho C}$

$$\begin{aligned} (\rho C)_{\text{liquid}} &> (\rho C)_{\text{gas}} \\ (\alpha)_{\text{gas}} &> (\alpha)_{\text{liquid}} \end{aligned}$$

13. (d)

Thermal diffusivity, $\alpha = \frac{k}{\rho C}$

Hence its unit = m²/hr or m²/sec

Note that unit of thermal diffusivity and kinematic viscosity is same.

14. (c)

The ratio of thermal conductivity to electrical conductivity is always constant for all the conductors at the given temperature. This is known as Wideman and Frange law.

i.e. $\frac{k}{\sigma T} = \text{constant}$

The constant is known as Lorentz number (Lo) whose value is equal to $2.045 \times 10^{-8} \text{ W}/\mu\text{K}^2$.

15. (d)

Some heat is also lost in evaporation. The vapours of water is not accounted in these 3 modes of heat transfer.

16. (a)

While deriving Fourier law of heat conduction some assumptions are made, which are

1. Steady state condition
2. One-directional heat transfer
3. No heat generation
4. Material is homogeneous and isotropic

18. (d)

The equation of heat transfer in Cartesian coordinates without heat generation is

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{\rho C_p}{k} \frac{\partial T}{\partial t}$$

For one dimensional heat transfer,

$$\frac{\partial^2 T}{\partial x^2} = \frac{\rho C_p}{k} \frac{\partial T}{\partial t}$$

i.e., $\frac{\partial T}{\partial t} \propto \frac{\partial^2 T}{\partial x^2}$

19. (a)

Momentum transfer — Kinematic viscosity

Kinematic viscosity: $\nu = \frac{\mu}{\rho}$

Mass transfer — diffusion coefficient

Molecular diffusion is governed by Fick's law

$$N_A = \frac{m_A}{A} = -D_{AB} \frac{dc_A}{dx}$$

where, N_A = mass flux of species A

D_{AB} = diffusion coefficient

$$\frac{dc_A}{dx} = \text{concentration of gradient for species A.}$$

Heat transfer — Thermal diffusivity

Thermal diffusivity: $\alpha = \frac{k}{\rho C_p}$

20. (a, c, d)

1. 30% of conduction heat transfer takes place by molecular lattice vibrational energy transfer and 70% of conduction heat transfer takes place by free electron transfer in solids.
2. Thermal conductivity of pure metal is more than its alloys.
3. All electrically good conductors are in general good conductor of heat also because of the presence of abundant number of free electrons.

POWER PLANT ENGINEERING

OBJECTIVE PRACTICE SETS

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Steam Generators

Q.1 Which of the following statements are true in the context of Lancashire boiler?

1. It is a fire tube boiler.
 2. It employs two flue tubes and three passes.
 3. It is a water tube boiler.
 4. It makes use of external pump for circulation
- (a) 1, 2 (b) 2, 3
(c) 1, 4 (d) 3, 4

Q.2 The major shortcoming of fire tube boiler is:

- (a) size and pressure limitation inherent in design
- (b) high cost
- (c) requirement of high draught
- (d) need of highly skilled labour for operation

Q.3 Which of the following is/are functions of a steam drum?

- (a) to ensure moisture free steam going to the superheater
- (b) to secure bubble-free water going to the downcomer
- (c) to aid in steam formation at the desired rate
- (d) Both (a) and (b)

Q.4 Match **List-I (Method for separation of steam-water mixture)** with **List-II (Mechanism of separation of mixture)** and select the correct answer:

List-I	List-II
A. Baffles	1. Centrifugal force
B. Cyclone separators	2. Gravity
C. Steam Washing	3. Fabric Filters
D. Screens	4. Pure Feedwater

Codes:

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

Q.5 Match **List-I (Name of Boiler)** with **List-II (Type)** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Stirling	1. Bent water tube
B. Cochran	2. Once through flow
C. Lancashire	3. Vertical fire tube
D. Benson	4. Inclined water tube
	5. Horizontal fire tube

Codes:

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

Q.6 Performance of mechanical draft cooling tower is superior to natural draft with

- (a) increase in air wet bulb temperature
- (b) decrease in air wet bulb temperature
- (c) increase in air dry bulb temperature
- (d) increase in recirculation of air

Q.7 Consider the boiler accessories:

1. Superheater
2. Air preheater
3. Economizer
4. I D fan

What is the correct sequence of the flow of flue gases through the above accessories of a natural circulation high pressure boiler?

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

Q.8 In a boiler, the subcooled liquid enters at enthalpy 200 kJ/kg and exits at 10 bar pressure with quality of steam as 0.9. Enthalpy of saturated liquid and saturated vapour at 10 bar is 700 kJ/kg and 1700 kJ/kg respectively. What will be the efficiency of boiler ?

Take steam generation rate = 6.3 tonne/hr

Coal consumption = 0.7 tonne/hr

Calorific value of coal = 30 MJ/kg

- (a) 70% (b) 62%
(c) 50% (d) 42%

Q.9 Minimum circulation ratio in riser tubes to avoid overheating is:

- (a) 8 (b) 25
(c) 6 (d) 10

Q.10 Which is a correct statement in the context of difference between a Lancashire boiler and a Cornish boiler?

- (a) Lancashire boiler is a fire tube boiler whereas Cornish boiler is a water tube boiler.
(b) Lancashire boiler has two flue tubes and the Cornish boiler has one flue tube.
(c) Lancashire is horizontal and Cornish boiler is vertical in placement.
(d) Lancashire boiler is externally fired and the Cornish boiler is internally fired.

Q.11 The mass flow rate of steam released from the drum is 2 kg/s and the mass flow rate of saturated water at riser exit is 18 kg/s. The circulation ratio is

- (a) 9 (b) 10
(c) 8 (d) 6

Q.12 Find the INCORRECT statement from the following:

- (a) Downcomers are fewer in number
(b) Downcomers are bigger in diameter to reduce frictional losses
(c) Risers make use of large diameter to accelerate heat transfer rate from furnace.
(d) Risers are larger in number compared to downcomers

Q.13 The erosion rate from flash in the flue gas varies with gas velocity (V_g) as:

- (a) Directly proportional to V_g
(b) Directly proportional to V_g^2
(c) Directly proportional to V_g^3
(d) Directly proportional to V_g^4

Q.14 Which of the following fitting is a boiler mounting?

- (a) superheater (b) economiser
(c) feed check valve (d) spring type

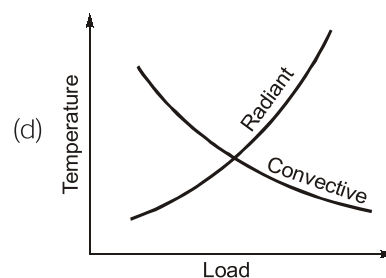
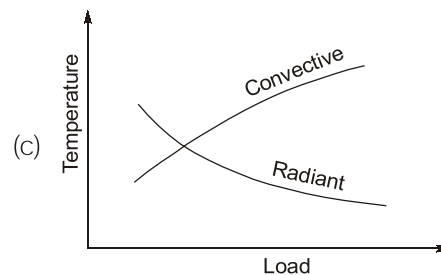
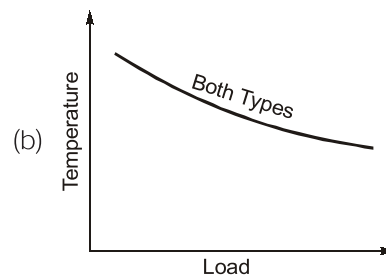
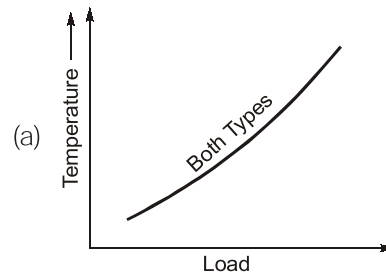
Q.15 In thermal power plants, the deaerator is used mainly to

- (a) remove air from condenser
(b) increase feed water temperature
(c) reduce steam pressure
(d) remove dissolved gases from feed water

Q.16 Which one of the following boiler accessories does NOT need "flue-gas" for its operation?

- (a) Economizer (b) Preheater
(c) Injector (d) Superheater

Q.17 The variation of superheater outlet temperature with variation of load in case of convective type and radiative type superheaters is best represented as:



Q.18 Once-through boilers will not have

- (a) Drums, headers and pumps
(b) Drums, steam separators and pumps
(c) Drums, headers and steam separators
(d) Drums, headers, steam separators and pumps

Q.19 Water-tube boilers are preferred for

- (a) high pressure and high output
(b) high pressure and low output

- (c) low pressure and high output
- (d) low pressure and low output

Q.20 A super critical boiler consists of only economizer and superheater and it does not have an evaporator because

- (a) Water temperature can be raised to critical temperature in the economizer itself
- (b) High evaporation rate is achieved through forced circulation of water through tubes
- (c) Enthalpy of evaporation becomes zero at critical pressure or above that
- (d) Flue gas used to run rotary compressor supply high pressure air to the furnace

Q.21 Which device is used in thermal power plants to reduce level of pollution?

- (a) Electrostatic precipitator
- (b) Draught fan
- (c) Chimney
- (d) Deaerator

Q.22 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Boiler mounting	1. Fusible plug
B. Boiler accessory	2. Steam trap
C. Benson boiler	3. Indirect heating
D. Loeffler boiler	4. No drum

Codes:

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

Q.23 The distinguishing feature of velox boiler is that:

- (a) It is drumless
- (b) It uses supersonic flow
- (c) It operates under supercritical pressure
- (d) It uses indirect heating

Q.24 In a condenser test the following observations were made, vacuum = 70 cm of Hg, Barometer reading = 76 cm of Hg, Mean temperature of condensation = 35°C, the partial pressure of steam corresponding to 35°C is 4.21 cm of Hg then the vacuum efficiency of condenser is

- (a) 97.5%
- (b) 87.27%
- (c) 95.1%
- (d) 92.5%

Q.25 The air pre-heater of a boiler is located between

- (a) Forced draft fan and furnace
- (b) Furnace and economizer
- (c) Economizer and chimney
- (d) Superheater and furnace

Q.26 Maximum amount of energy lost in the boiler is due to

- (a) incomplete combustion
- (b) flue gases
- (c) unburnt carbon in ash
- (d) ash content

Q.27 Which of the following statements are correct?

1. In fire tube boiler, hot flue gases flow through tubes surrounded by water in a shell.
2. In water boiler, hot flue gases flow over tubes carrying water.
3. In water tube boiler, water from a drum flows through the shell carrying tubes through which flue gases flow.
4. Fire tube boilers have the capability to meet large and sudden load demands with small pressure changes

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

Q.28 Which of the following are disadvantages of straight-tube boilers?

1. Less accessibility and poorer inspection capability
2. Imperfect fabrication of handhole caps leading to leakage
3. Sluggish circulation due to low head
4. Inadequate separation of steam and water leading to reduced steam rate

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

Q.29 Which of the following statements are correct with respect to boiling in riser tube?

1. Wetted surface is desirable for effective heat transfer rate
2. Nucleate boiling should persist and film boiling is avoided
3. Vapour film has a much lower thermal conductivity than a liquid film and offers large thermal resistance.
4. Bubble formation is not desirable as it increases the resistance to heat transfer.

bed on the grate. The total draught developed by the force draught fan is

- (a) 250 N/m² (b) 300 N/m²
(c) 305 N/m² (d) 310 N/m²

Q.52 A chimney of height 40 m has mean flue gas temperature of 327°C. The temperature of outside air is 30°C. The air fuel ratio is 14.3. Draught produced in mm of water column is

- (a) 2026 mm H₂O (b) 21.42 mm H₂O
(c) 23.26 mm H₂O (d) 24.61 mm H₂O

Q.53 Consider the following statements:

1. The amount of volatile matter indicates whether the coal will burn with a short or long flame and whether it will tend to produce smoke.
2. Proximate Analysis gives the percentage of moisture, ash and volatile matter.
3. Ultimate Analysis gives the chemical elements that comprise the coal substance.

4. Higher rank coals are characterised by a greater oxygen content that aids ignition.

Which of these statements are correct?

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

Q.54 Consider the following statements with respect to draught system in a thermal power plant:

1. It is used to supply to the furnace the required quantity of air for complete combustion of fuel.
2. The term 'draught' is used to define the static pressure in the furnace.
3. Natural draught is provided by the use of induced draught fans
4. Forced draught fans are normally located at the foot of the stack and handle hot combustion gases.
5. Forced draught fans maintain the entire system up to stack entrance under positive gauge pressure.

Which of these statements are correct?

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

Answers Steam Generators

- | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (a) | 2. (a) | 3. (d) | 4. (b) | 5. (b) | 6. (d) | 7. (a) | 8. (d) | 9. (c) |
| 10. (b) | 11. (b) | 12. (c) | 13. (c) | 14. (c) | 15. (d) | 16. (c) | 17. (c) | 18. (c) |
| 19. (a) | 20. (c) | 21. (a) | 22. (c) | 23. (b) | 24. (a) | 25. (c) | 26. (b) | 27. (a) |
| 28. (d) | 29. (a) | 30. (c) | 31. (a) | 32. (c) | 33. (b) | 34. (c) | 35. (d) | 36. (a) |
| 37. (b) | 38. (c) | 39. (b) | 40. (d) | 41. (b) | 42. (a) | 43. (a) | 44. (a) | 45. (a) |
| 46. (b) | 47. (a) | 48. (a) | 49. (c) | 50. (c) | 51. (d) | 52. (b) | 53. (b) | 54. (b) |

Explanations Steam Generators

1. (a)

Lancashire boiler is a stationary, horizontal, natural circulation fire tube boiler having two flue tubes and three passes.

2. (a)

The major shortcoming of a fire-tube boiler is that definite size and pressure limitations are inherent in its basic design i.e. the maximum size of the unit and the maximum operating pressure are limited.

3. (d)

Steam formation takes place inside the boiler.

4. (b)

Mechanical separators like baffles, screens and cyclones are housed inside drum for separation of steam-water mixture.

6. (d)

Performance of mechanical draft cooling tower is superior to natural draft with increase in recirculation of air.

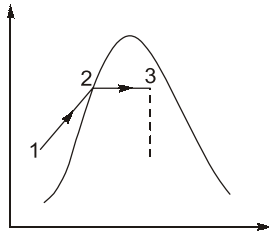
7. (a)

Flow of flue gases is :

Superheater-Economizer-Air preheater-ID fan

8. (d)

Energy added to water in boiler,



$$Q_s = h_3 - h_1$$

$$h_3 = h_f + xh_{fg}$$

$$= 700 + 0.9(1700 - 700)$$

$$= 1600 \text{ kJ/kg}$$

$$Q_s = h_3 - h_1 = 1600 - 200$$

$$Q_s = 1400 \text{ kJ/kg}$$

Mass of steam/kg of fuel

$$= \frac{6.3}{0.7} = 9 \text{ kg steam/kg of fuel}$$

Now, boiler efficiency,

$$\eta_B = \frac{m_s \times (h_3 - h_1)}{m_f \times CV} \times 100\%$$

$$= \frac{9 \times 1400}{30000} \times 100\% = 42\%$$

9. (c)

The circulation ratio in a natural circulation boiler varies from one riser tube to another. However the circulation ratio in any tube should not be less than 6, otherwise tube will get over-heated and fail prematurely and not be higher than 25 for effective utilization of the tube in steam generator.

10. (b)

- (i) Both are fire tube boilers
- (ii) Both have horizontal placement
- (iii) Lancashire boiler has two flue tubes
- (iv) Cornish boiler is of mono flue tube type

11. (b)

Circulation Ratio

$$= \frac{\text{Flow rate of saturated water in downcomers}}{\text{Flow rate of steam released from the drum}}$$

$$= \frac{2+18}{2} = 10$$

12. (c)

Risers absorb heat from the furnace. For the same total cross-sectional area, smaller the diameter,

larger the surface area exposed to hot gases for heat transfer.

13. (c)

Rate of erosion $\propto V_g^3$, where V_g is gas velocity.

14. (c)

Various boiler mounting are as under:-

1. Pressure gauge
2. Water level indicator
3. Fusible plug
4. Safety valve
 - 4.1 Lever safety valve
 - 4.2 Spring loaded safety valve
5. Steam stop valve
6. Feed check valve
7. Blow off cock

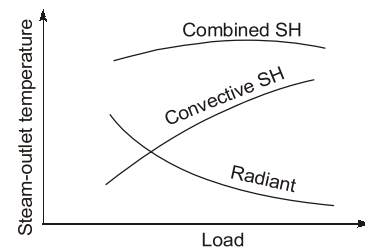
15. (d)

In thermal power plants, the deaerator is used for removal of dissolved gases, mainly O_2 and CO_2 . Presence of dissolved oxygen in feed water is responsible for corrosion of metal tube.

16. (c)

Injector is the boiler accessory which does not need "flue-gas" for its operation.

17. (c)



18. (c)

Benson boiler is a typical high pressure, drum less, water tube, forced circulated once through boiler. It has a unique characteristic of absence of drum entire process of heating, steam formation and superheating is done in a single continuous tube. Feed pumps feeds water to economiser from where it goes to radiant heating section.

19. (a)

Water tube boilers are high capacity boilers and preferred for high pressure and high output.