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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 8

Section A : Heat Transfer + IC Engines
Section B : Fluid Mechanics and Turbo Machinery-1
Section C : Production Engineering & Material Science-2

Answer Key

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

Section A : Heat Transfer + IC Engines

1. (a)

Process	h (W/m$^2\cdot$K))
Free convection Gases	2 – 25
Liquids	50 – 1000
Forced convection Gases	25 – 250
Liquids	100 – 20000
Convection with phase change Boiling or condensation	2500 – 100000

2. (b)

$$Q_{\text{radiation}} = \sigma \in A\left(T_s^4 - T_{surr}^4\right)$$

and also $$Q_{\text{radiation}} = h_{\text{radiation}} \times A \times (T_s - T_{\text{surr}})$$

$\Rightarrow$ $$h_{\text{radiation}} = \sigma \in A\left(T_s + T_{surr}\right)\left(T_s^2 + T_{surr}^2\right)$$

$$= \left(\frac{5.67}{10^8}\right) \times 0.5(400+300)\left(400^2 + 300^2\right)$$

$$= \frac{(5.67)(0.5)(7)(5^2)}{100} = \frac{5.67 \times 5 \times 7 \times 25}{1000}$$

$$= 4.96125 \text{ W/m}^2\text{K}$$

3. (d)

Materials	Thermal conductivity, k (W/m-deg)
Metals	
Aluminium	225
Brass	107
Copper	385
Cast iron	55-65
Steel	20-45
Silver	410
Construction Materials	
Concrete	1.20
Brick (masonary)	0.65
Brick (first clay)	0.75 -1.75
Earth	0.138
Furnace or boiler slag	0.30
Glass (window)	0.75
Plaster	0.75-0.95
Insulating Materials	
Asbestos sheet	0.17
Cork, felt	0.05-0.10
Glass wool	0.03
Saw dust	0.07
Wood (Balsa)	0.052
Miscellaneous	
Air	0.024
Ash	0.12
Ice (ρ = 925 kg/m^3)	2.25
Water	0.55 -0.7
Freon	0.0083

4. (d)

Fourier's Law helps to define thermal conductivity of the conducting medium.
Fourier's Law is valid for all material i.e. solid, liquid or gaseous.
Fourier's Law cannot be derived from first principles.

$$q_x^n = -k\frac{\partial T}{\partial x}; \quad q_y^n = -k\frac{\partial T}{\partial y}; \quad q_z^n = -k\frac{\partial T}{\partial z}$$

Each of these expressions relates the heat flux across a surface to the temperature gradient in a direction perpendicular to the surface. It is also implicit that the medium in which the conduction occurs is isotropic. For such a medium the value of the thermal conductivity is independent of the coordinate direction.

Fourier's law is the cornerstone of conduction heat transfer, and its key features are summarized as follows. It is not an expression that may be derived from first principles; it is instead a generalization based on experimental evidence. It is an expression that defines an important material property, the thermal conductivity. In addition, Fourier's law is a vector expression indicating that the heat flux is normal to an isotherm and in the direction of decreasing temperature. Finally, note that Fourier's law applies for all matter, regardless of its state (solid, liquid, or gas).

5. (c)

From energy equation and Fourier's law

$$\left[\frac{\partial^2 T}{\partial x^2}\right] = \left[\frac{q_g}{k}\right] = \left[\frac{1}{\alpha}\frac{\partial T}{\partial t}\right]$$

$$[\alpha] = \frac{\left[\frac{\partial T}{\partial t}\right]}{\left[\frac{\partial^2 T}{\partial x^2}\right]} = \frac{\left[T^{-1}\theta\right]}{\left[\theta \cdot L^{-2}\right]} = [L^2 T^{-1}]$$

Note : Thermal diffusivity α and Momentum diffusivity ν both have some dimension and their ratio results in a dimensionless parameter known as 'Prandtl Number' (Pr) = $\frac{\nu}{\alpha}$.

6. (d)

From energy equation for 1-D heat transfer,

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) = \rho c_p\left(\frac{\partial T}{\partial t}\right)$$

For k, ρ and c_p to be constant with temperature

$$\frac{\partial T}{\partial t} = \alpha\frac{\partial^2 T}{\partial x^2}$$

$$\frac{\partial T}{\partial t} = \alpha\frac{\partial^2\left(ax^2 + bx + c\right)}{\partial x^2}$$

$$\frac{\partial T}{\partial t} = 2a\alpha$$

7. (c)

$$\frac{\partial T}{\partial t} = 2a\alpha = \text{is independent of space, time and temperature}$$

$$m = 2a\alpha$$

$$a = \frac{m}{2\alpha}$$

8. (d)

$$\alpha + \gamma + \tau = 1$$

$$\alpha = 1 - (\gamma + \tau) = 1 - (0.5 + 0.2) = 0.3$$

$$\frac{G_a}{G} = 0.3$$

$$G = \frac{G_a}{0.3} = \frac{300}{0.3} = 1000 \text{ W/m}^2$$

9. (d)

$$\frac{d^2T}{dx^2} + \left(\frac{1}{A_c}\frac{dA_c}{dx}\right)\frac{dT}{dx} - \left(\frac{1}{A_c}\frac{h}{k}\frac{dA_s}{dx}\right)(T - T_\infty) = 0 \qquad (A_c = \text{constant}) \quad \frac{dA_c}{dx} = 0$$

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0$$

10. (a)

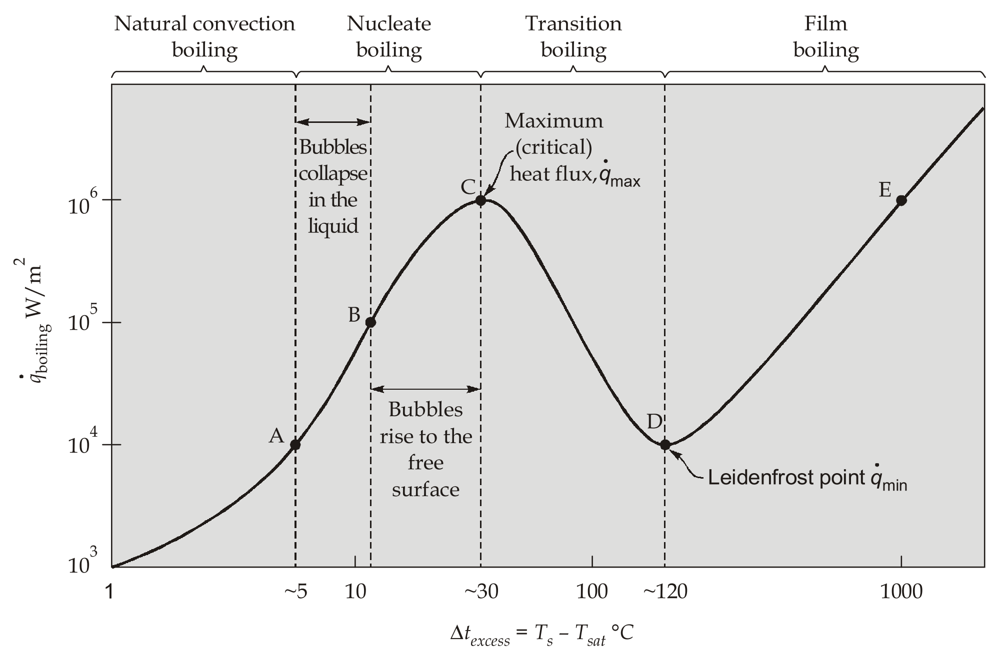


Figure: Typical boiling curve for water at 1 atm pressure

Film Boiling (beyond Point (D): In this region the heater surface is completely covered by a continuous stable vapor film. Point (D), where the heat flux reaches a minimum, is called the **Leidenfrost point**, in honor of J. C. Leidenfrost, who observed in 1756 that liquid droplets on a very hot surface jump around and slowly boil away. The presence of a vapor film between the heater surface and the liquid is responsible for the low heat transfer rates in the film boiling region. The heat transfer rate increases with increasing excess temperature as a result of heat transfer from the heated surface to the liquid through the vapor film by radiation, which becomes significant at high temperatures.

11. (c)

For film condensation over a flat vertical plate the liquid film thickness 'δ' at location 'x' from the top edge varies as

$$\delta(x) = \left[\frac{4\mu_l k_l (T_{sat} - T_s) x}{g\rho_l(\rho_l - \rho_v) h_{fg}}\right]^{1/4}$$

12. (c)

$$\text{NTU} = \frac{UA}{c_{\min}} = \frac{20}{2} = 10$$

and for a balanced counterflow heat exchange,

$$R = \frac{c_{\min}}{c_{\max}} = 1$$

and

$$\in = \frac{NTU}{NTU+1} = \frac{10}{11}$$

13. (b)

14. (b)

From Wein's displacement law,

$$\lambda_{max} \cdot T = 2897.8\ \mu\text{m.K}$$

$$(5\mu\text{m})\,T = 2897.8\ \mu\text{m.K}$$

$$T = \frac{2897.8}{5} = 579.56\ \text{K}$$

$$T = 306.56°\text{C}$$

15. (d)

$$\frac{q_{shield}}{q_{without\,shield}} = \frac{1}{N+1}$$

N = Number of shields employed in between plates which are having same emissivity as that of plate surfaces

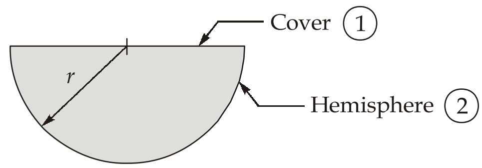
$$\%\text{Reduction in heat transfer rate} = \frac{q_{without\,shield} - q_{shield}}{q_{without\,shield}} \times 100\%$$

$$= \left(1 - \frac{q_{shield}}{q_{without\,shield}}\right) 100\%$$

$$= \left(1 - \frac{1}{N+1}\right) \times 100 = \left(1 - \frac{1}{10}\right) \times 100\%$$

$$= 90\%$$

16. (b)



$$A_1 = \pi r^2$$
$$A_2 = 2\pi r^2$$
$$F_{11} = 0 \text{ and } F_{12} = 1$$
$$A_1 F_{12} = A_2 F_{21}$$

$\Rightarrow$
$$F_{21} = \frac{A_1}{A_2}(F_{12}) = \frac{\pi r^2}{2\pi r^2}(1) = \frac{1}{2}$$

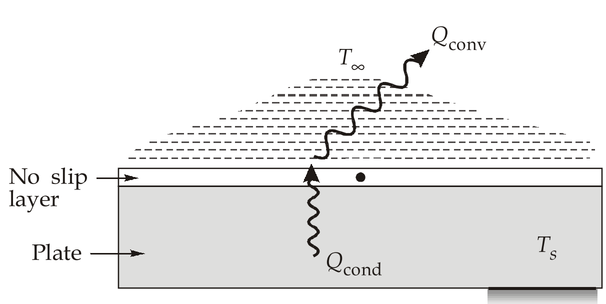
Also,
$$F_{21} + F_{22} = 1$$
$$\frac{1}{2} + F_{22} = 1$$
$$F_{22} = \frac{1}{2} = 0.5$$

17. (c)

Grashof Number (Gr) indicates the relative strength of the buoyant to viscous forces. From its mathematical formulation,

$$\text{Gr} = \frac{l^3\rho^2\beta g\Delta T}{\mu^2}$$
$$= \left(\rho l^3\beta g\Delta T\right)\frac{\rho}{\mu^2} = \left(\rho l^3\beta g\Delta T\right)\times\frac{\rho V^2 l^2}{(\mu V l)^2}$$
$$= \left(\text{Buoyant force}\right)\times\frac{\text{Inertia force}}{(\text{Viscous force})^2}$$

18. (b)

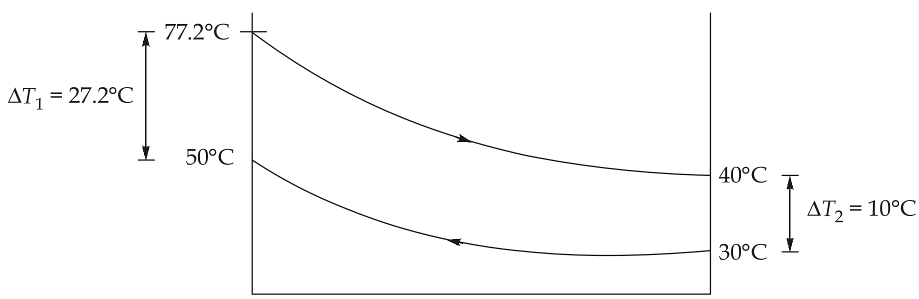


$$q'' = h(T_s - T_\infty) = -k\left(\frac{dT}{dy}\right)_{y=0}$$

$$\Rightarrow \quad h = \left(\frac{1}{T_s - T_\infty}\right)(-k)(-2b + 6cy)_{y=0}$$

$$\Rightarrow \quad h = \frac{2kb}{T_s - T_\infty}$$

19. (c)



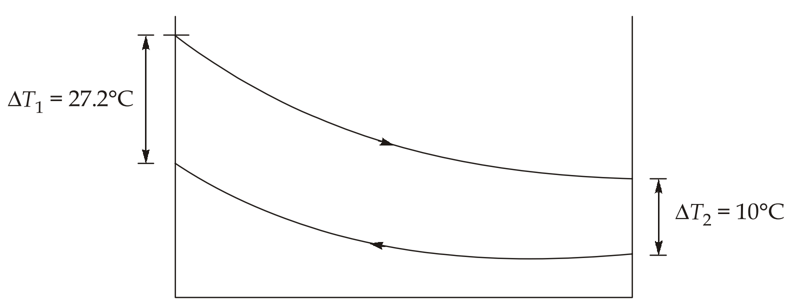
$$Q_{hot} = Q_{cold}$$

$$\dot{C}_h\left(77.2 - T_{h_o}\right) = \dot{C}_c(50 - 30)$$

$$T_{h_o} = 77.2 - \left(\frac{\dot{C}_c}{\dot{C}_h}\right)(50 - 30)$$

$$T_{h_o} = 40°C$$

20. (b)



$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{27.2 - 10}{\ln\left(\frac{27.2}{10}\right)} \simeq 17.2°C \qquad \{\because \ \ln(2.72) \simeq \ln(e) = 1\}$$

21. (a)

$$Q_{\text{dirty}} = 0.8\ Q_{\text{clean}}$$

$\Rightarrow$

$$U_{\text{dirty}} = 0.8\ U_{\text{clean}}$$

$$R_f = \frac{1}{U_{dirty}} - \frac{1}{U_{clean}}$$

$$= \frac{1}{0.8U_{clean}} - \frac{1}{U_{clean}}$$

$$= \frac{1}{4U_{clean}} = \frac{1}{1000} = 0.001\ \text{m}^2\,°\text{C/W}$$

22. (c)

$$\eta_m = \frac{b.p.}{i.p.} = 0.9 \quad \text{...(i)}$$

$$i.p. - b.p. = f.p = 30 \quad \text{...(ii)}$$

From (i) and (ii),

$$i.p. - 0.9\ i.p. = 30$$

$$i.p. = \frac{30}{0.1} = 300\ \text{kW}$$

23. (a)

Rate of fuel consumption, $\dot{m}_f = \dfrac{B.P.}{\eta_{B_{th}} \cdot CV}$

$$\dot{m}_f = \frac{100 \times 10^{-3}}{0.2 \times 50} = 10 \times 10^{-3}\ \text{kg/s}$$

$$\dot{m}_f = 0.01\ \text{kg/s}$$

24. (d)

$$\text{B.P.} = p_{bm}\ LAnK$$

$$p_{bm} = \frac{B.P.}{L.A.n.K} = \frac{100}{\left(2 \times 10^{-3}\right) \times \frac{2400}{2 \times 60} \times 1}$$

$$p_{bm} = 25 \times 10^2\ \text{kPa}$$

$$= 25\ \text{bar}$$

25. (c)

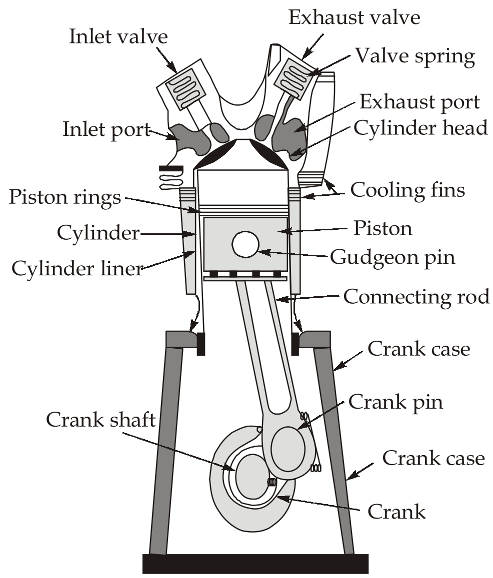


Figure : Components of an internal combustion engine

26. (d)

1. Time loss factor i.e. loss due to time required for mixing of fuel and air and also for combustion.
2. Heat loss factor i.e. loss of heat from gases to cylinder walls.
3. Exhaust blowdown factor i.e. loss of work on the expansion stroke due to early opening of the exhaust valve.

27. (c)

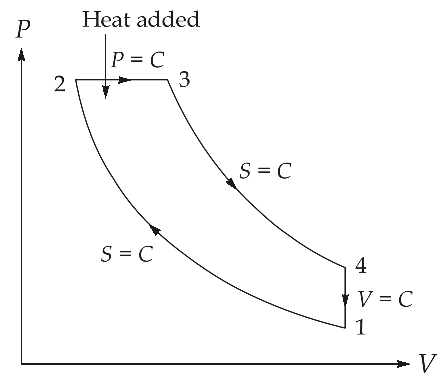
$$\eta_{diesel} = 1 - \frac{1}{r_c^{\gamma-1}}\left\{\frac{\alpha^{\gamma}-1}{\gamma(\alpha-1)}\right\}; \; r_c = \text{compression ratio}, \alpha = \text{cutoff ratio}$$

$$= 1 - \frac{1}{16^{1.5-1}}\left\{\frac{2.25^{1.5}-1}{1.5(2.25-1)}\right\}$$

$$= 1 - \frac{1}{4}\left\{\frac{\frac{27}{8}-1}{1.5(1.25)}\right\} = 1 - \left(\frac{1}{4}\right)\left(\frac{19}{8}\right)\left(\frac{2}{3}\right)\left(\frac{4}{5}\right)$$

$$= 1 - \frac{19}{60} = \frac{41}{60} = 0.6833 \text{ or } 68.33\%$$

28. (c)



$$\eta_{th} = 1-\frac{Q_R}{Q_A} = 1-\frac{C_v(T_4-T_1)}{C_p(T_3-T_2)}$$

$$= 1-\frac{1}{\gamma}\left(\frac{x}{2x}\right) = 1-\frac{1}{2\times 1.4} = 1-\frac{1}{2.8}$$

$$= 0.6428 \text{ or } 64.28\%$$

29. (b)

The morse test consists of obtaining indicated power of the engine without any elaborate equipment. The test consists of making inoperative, in turn, each cylinder of the engine and noting the reduction in brake power developed. With a gasoline engine each cylinder is rendered inoperative by shorting the spark plug of the cylinder; with a diesel engine by cutting off the supply of fuel to each cylinder. It is assumed that pumping and friction losses are the same when the cylinder is inoperative as well as during firing. This test is applicable only to multi cylinder engines.

Net indicated power per cylinder = $gp - pp$

30. (b)

William's line method : Fuel rate extrapolation method.

Morse test : Used to find indicated power without any elaborative equipment.

Motoring test : Uses swinging field type electric dynamometer.

Retardation test : Engine made to run at no load and fuel supply is cutoff. Time of fall in speed is recorded.

31. (a)

Rating of SI engine fuels	Rating of CI engine fuels
Octane number zero (C_7H_{14}) Normal heptane	Cetane number zero ($C_{11}H_{10}$) Alpha methyl Napthelene
Octane number 100 (C_8H_{18}) Iso-octane	Cetane number 100 ($C_{16}H_{34}$) Normal cetane

32. (c)

B2 contains

2% Biodiesel and 98% petrol-diesel

33. (a)

Catalytic converters are chambers mounted in the flow system through which the exhaust gases pass through. These chambers contain catalytic material, which promotes the oxidation of the emissions contained in the exhaust flow. Generally, they are called three-way converters because they are used to reduce the concentration of CO, HC, and NO_x in the exhaust.

34. (b)

Comparison of Various Methods

The Willan's line method and Morse tests are comparatively easy to conduct. However, both these tests give only an overall idea of the losses whereas motoring test gives a very good insight into the various causes of losses and is a much more powerful tool. As far as accuracy is concerned, the *ip* - *bp* method is the most accurate if carefully done. Motoring method usually gives a higher value for *fp* as compared to that given by the Willan's line method. Retardation method, though simple, requires accurate determination of the load torque and the time for the fall in speed for the same range.

35. (c)

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_d} \quad \text{...(i)}$$

It is to be noted that irrespective of the engine whether SI, CI or gas engine, volumetric rate of air flow is what to be taken into account and not the mixture flow.

If ρ_a is taken as the atmospheric air density, then η_v is the pumping performance of the entire inlet system. If it is taken as the air density in the inlet manifold, then η_v is the pumping performance of the inlet port and valve only.

The normal range of volumetric efficiency at full throttle for SI engines is between 80 to 85% where as for CI engines it is between 85 to 90%. Gas engines have much lower volumetric efficiency since gaseous fuel displaces air and therefore the breathing capacity of the engine is reduced.

For supercharged/turbocharged engines $\eta_v > 100\%$.

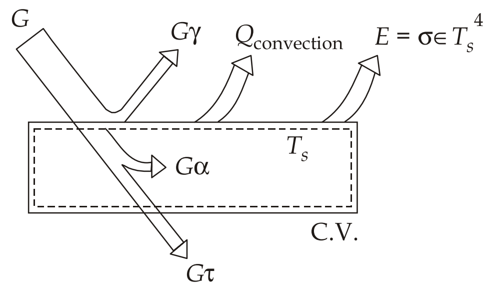
36. (d)

Contrary to the common belief that addition of insulating material on a surface always brings about a decrease in the heat transfer rate, there are instances when the addition of insulation to the outside surfaces of cylindrical or spherical walls (geometries which have non-constant cross-sectional areas) does not reduce the heat loss. In fact, under certain circumstances, it actually increases the heat flow upto a certain thickness of insulation.

37. (b)

Emitted radiation reduces thermal energy of matter and absorbed radiation increases the thermal energy of matter.

Reflected and transmitted radiation have no effect on thermal energy of matter.



38. (a)

Given : $H = 245$ m; $P = 15696$ kW; $N = 180$ rpm; $\eta_0 = 0.9$, $C_V = 1$; $V_1 = C_V\sqrt{2gH} = 69.33$ m/s

$$P = \eta_0 \times \rho g Q H$$

$$\Rightarrow \quad 15696 \times 10^3 = 0.9 \times 10^3 \times 9.81 \times Q \times 245$$

$$\Rightarrow \quad Q = \frac{15696}{0.9 \times 9.81 \times 245} = 7.26 \text{ m}^3/\text{s}$$

39. (b)

Given : $H = 245$ m; $P = 15696$ kW; $N = 180$ rpm; $\eta_0 = 0.9$, $C_V = 1$; $V_1 = C_V\sqrt{2gH} = 69.33$ m/s

$$u = \rho V_1 = \rho C_V\sqrt{2gH} = 0.45\sqrt{2 \times 9.81 \times 245}$$

$$u \simeq 31.2 \text{ m/s}$$

$$u = \frac{\pi D N}{60}$$

$$\Rightarrow \quad D = \frac{60 \times 31.2}{\pi \times 180} = 3.31 \text{ m}$$

$$d = \frac{D}{12} = 0.276 \text{ m}$$

$$Q = N_J \times \frac{\pi}{4} d^2 V_1$$

$$\Rightarrow \quad 7.26 = \frac{\pi}{4} \times (0.276)^2 \times 69.33 N_j$$

$$\Rightarrow \quad N_J = 1.75 \simeq 2$$

40. (c)

Reaction turbine :

Ex. : Kaplan turbine, Propeller turbine

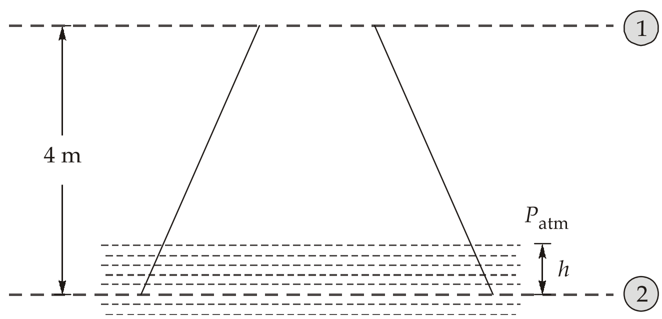
The reaction turbines are efficient under smaller heads.

Reaction turbine works at high specific speeds and high discharge.

Propeller turbine don't have adjustable runner vanes and hence they are efficient only at design load.

41. (c)

Given : d_1 = 2.5 m, Q = 25 m^3/s; z_2 = 0; z_1 = 4 m; V_2 = 1.5 m/s; P_1 = –5 + 10.3 = 5.3 m



$$P_{atm} = 10.3 \text{ m}$$

$$V_1 = \frac{Q}{\frac{\pi}{4}d^2} = \frac{25}{\frac{\pi}{4}\times 2.5^2} = 5.093 \text{ m/s}$$

Applying Bernoulli's equation between 1 and 2,

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_f \qquad \{\because \; h_f = 0\}$$

$$h = 5.3+\frac{5.093^2-1.5^2}{2\times 9.81}+4-10.3 \qquad \left\{\frac{P_2}{\rho g}=\frac{P_{atm}}{\rho g}+h\right\}$$

$$= 0.2074 \text{ m} \simeq 20.74 \text{ cm}$$

42. (d)

For 50% reaction turbine,

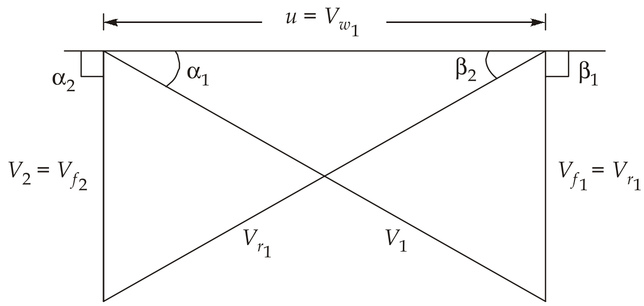
$$\alpha_1 = \beta_2, \quad \beta_1 = \alpha_2$$

$$V_1 = V_{r_2}, \; V_2 = V_{r_1}$$

For fully utilization (or V_2 is minimum)

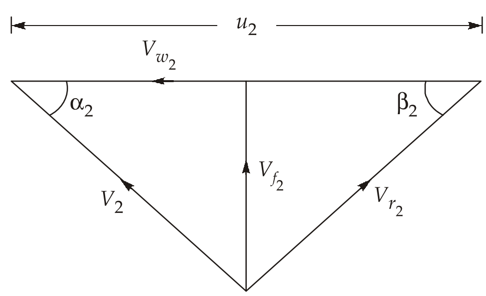
$$\beta_1 = 90° = \alpha_2, \; V_{w_2} = 0$$

$$V_{f_1} = V_{f_2}$$



43. (a)

Given : d_2 = 1 m; N = 240 rpm; H_m = 4 m; β_2 = 30°; V_{f_2} = $1.5\sqrt{3}$ m/s



$$u_2 = \frac{\pi d_2 N}{60} = \frac{\pi \times 1 \times 240}{60} = 4\pi \text{ m/s}$$

$$\tan\beta_2 = \frac{V_{f2}}{u_2 - V_{w2}}$$

$$\Rightarrow \quad 4\pi - V_{w_2} = \frac{1.5\sqrt{3}}{\tan 30°} = 4.5$$

$$\Rightarrow \quad V_{w_2} = 4\pi - 4.5 = 8.066 \text{ m/s}$$

$$\eta_m = \frac{gH_m}{V_{w_2} u_2} = \frac{9.81 \times 4}{8.066 \times 4\pi} = 0.3871 \text{ or } 38.7\%$$

44. (c)

Parameters	Formular / Unit	Dimensional formula
Power	J/s	ML^2T^{-3}
Force	N	MLT^{-2}
Energy	Nm or J	ML^2T^{-2}
Coefficient of elasticity	N/m^2	$ML^{-1}T^{-2}$
Discharge (Q)	m^3/s	L^3T^{-1}
Head (H)	m	L
Specific speed of turbine	$\frac{N\sqrt{P}}{H^{5/4}}$	$[M^{1/2}L^{-1/4}T^{-5/2}]$
Specific speed of pump	$\frac{N\sqrt{Q}}{H^{3/4}}$	$[L^{3/4}T^{-3/2}]$

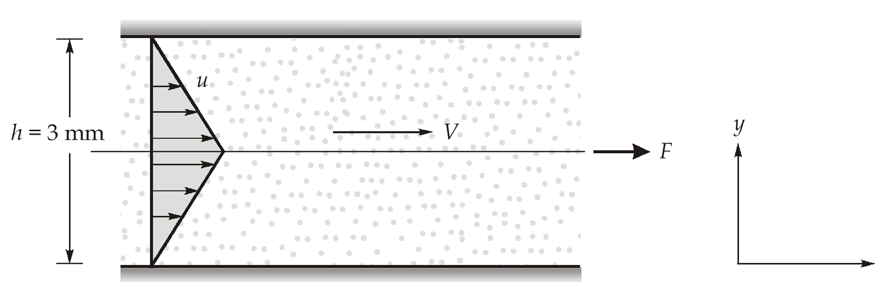
45. (c)

Fluid Machines
- → Rotodynamic type
- → Positive displacement type

- The working of a positive displacement machine is based on the change of volume occupied by a certain amount of fluid within the machine. The reciprocating pump is a positive displacement type of pump.
- The reciprocating pump consists primarily of a piston or a plunger executing reciprocating motion inside a close fitting cylinder. The motion of the piston outwards causes a reduction of pressure in the cylinder and therefore liquid flow into the cylinder through the inlet valve. Usually, the operation of the valve is controlled automatically by the pressure in the cylinder.

46. (b)

Given : h = 3 mm; μ = 0.03 Pa.s; A = 300 mm × 300 mm; V = 4 m/s



$$F = \mu A \frac{du}{dy} = 2\mu A \frac{V-0}{\left(\frac{h}{2}\right)}$$

$$F = 2 \times 0.03 \times 0.3 \times 0.3 \times \frac{4}{1.5 \times 10^{-3}} = 14.4 \text{ N}$$

47. (c)

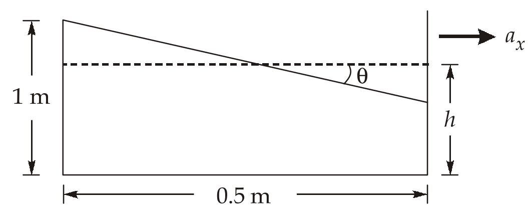
Given : σ = 0.072 N/m; θ = 30°; ρ = 1000 kg/m^3; d = 0.003 mm

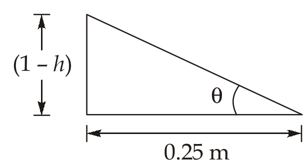
$$h = \frac{4\sigma\cos\theta}{\rho g d} = \frac{4 \times 0.072 \times \left(\frac{\sqrt{3}}{2}\right)}{1000 \times 9.81 \times 0.003 \times 10^{-3}}$$

$$= 8.475 \text{ m} \simeq 8.5 \text{ m}$$

48. (a)

Given : A = 0.5 m × 0.5 m; h = 1 m





$$a_x = \frac{72 - 0}{10} \times \left(\frac{1}{3.6}\right) = 2 \text{ m/s}^2$$

$$h = \text{Initial height}$$

$$\tan\theta = \frac{a_x}{g} = \frac{2}{g}$$

or $$\tan\theta = \frac{1-h}{0.25}$$

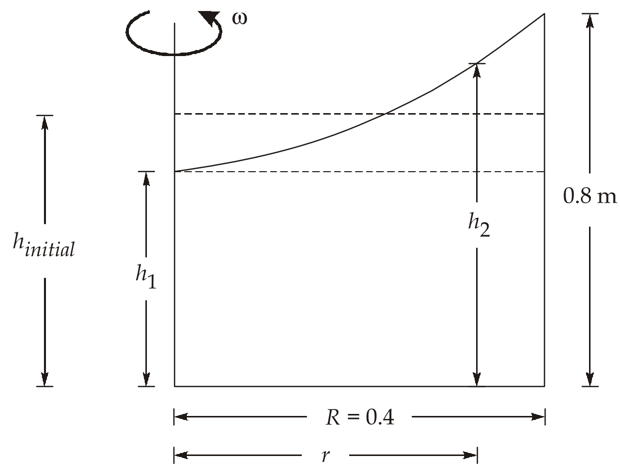
$\Rightarrow$ $$\frac{1-h}{0.25} = \frac{2}{g}$$

$\Rightarrow$ $$h = 0.949 \text{ m}$$

or $$h \simeq 0.95 \text{ m}$$

49. (d)

Given : d_{tank} = 40 cm = 0.4 m; H = 80 cm = 0.8 m; ω = 7 rad/s



$$\Delta h \text{ or } (h_2 - h_1) = \frac{\omega^2 r^2}{2g}$$

For $R = 0.4$

$\Delta h = 0.4$ m

$\Rightarrow$ $h_2 = 0.8$ m

$\Rightarrow$ $h_1 = 0.4$ m

$$h_i = \frac{h_1 + h_2}{2} = 0.6 \text{ m} = 60 \text{ cm}$$

50. (c)

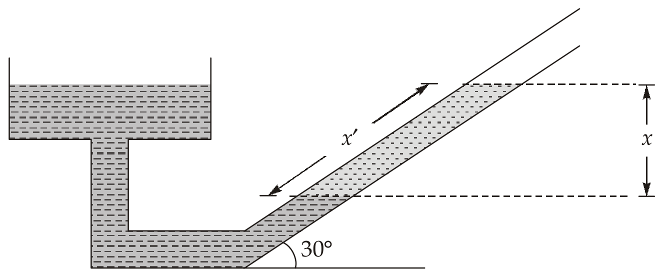
Given : $V = 5\ m^3$; $W = 40$ kN

$$\text{Specific volume, } v_s = \frac{V}{m} = \frac{V}{\left(\frac{W}{g}\right)} = \frac{V \times g}{W}$$

$$= \frac{5 \times 9.81}{(40 \times 10^3)} = 1.22625 \times 10^{-3}\ m^3/kg \simeq 1.23 \times 10^{-3}\ m^3/kg$$

51. (c)

Given : x = 50 cm



$$x' = \frac{x}{\sin 30°} = \frac{50}{0.5} = 100\,\text{cm}$$

52. (d)

If the floating body is bottom-heavy and thus the centre of gravity G is directly below the B, the body is always stable. But unlike immersed bodies, a floating body may still be stable when G is directly above B.

A measure of stability for floating bodies in the metacentric height (GM). A floating body is stable if GM is positive. The length of metacentric height is measure of stability. The larger it is, the more stable is the floating body.

53. (c)

The rate of increase of volume of a fluid element per unit volume is called the volumetric strain rate or bulk strain rate. Another synonym of volumetric strain rate is rate of volumetric dilatation.

$$\dot{\varepsilon}_v = \frac{1}{V}\frac{DV}{Dt} = \frac{1}{V}\frac{dV}{dt}$$

$$= \dot{\varepsilon}_{xx} + \dot{\varepsilon}_{yy} + \dot{\varepsilon}_{zz}$$

54. (a)

The HGL and EGL are defined as follows:

$$\text{EGL} = \frac{P}{\rho g} + \frac{V^2}{2g} + z;\; HGL = \frac{P}{\rho g} + z$$

- For stationary bodies such as reservoirs or lakes, the EGL and HGL coincide with the free surface of the liquid.
- The EGL is always $\frac{V^2}{2g}$ above the HGL. These two curves approach each other as the velocity decreases, and they diverge as the velocity increases. The height of the HGL decreases as the velocity increases, and vice versa.
- At the pipe exit, P_{gauge} = 0 and thus HGL coincides with the pipe outlet.

55. (d)

Given : $\psi = x^2 + y^2$

$$u = \frac{\partial \psi}{\partial y} = 2y$$

$$v = -\frac{\partial \psi}{\partial x} = -2x$$

At point (2, 1.5), u = 3 units

v = –4 units

$$v = \sqrt{u^2 + v^2} = \sqrt{3^2 + (-4)^2} = 5 \text{ units}$$

56. (b)

- The centrifugal pumps are classified according to type of casing which are volute casing, vortex casing and diffuser casing.
- In a vortex casing a circular chamber is introduced between the impeller and the casing. The efficiency of this type of casing is more compared to the simple volute casing because loss of head due to eddies is reduced considerably.

Section C : Production Engineering & Material Science-2

57. (d)

Resistance to corrosion depends on the composition of the material and on the particular environment.

- Two dissimilar metals may from a galvanic cell, that is two electrodes in a electrolyte in a corrosive environment that includes moisture and cause galvanic corrosion. Two-phase always are more susceptible to galvanic corrosion.
- Cold worked metals are likely to have residual stresses, hence they are more susceptible to corrosion than hot-worked or annealed metals.
- In stainless steel, because of chromium present in the alloy develop a protective film on their surface.

58. (c)

- The measures that may be taken to prevent, or at least reduce, corrosion include material selection, environmental alteration, the use of inhibitors, design changes, application of coatings, and cathodic protection.
- Forms of metallic corrosion
  Uniform attack, galvanic corrosion, crevice corrosion, pitting, intergranular corrosion, selective leaching, erosion-corrosion and stress corrosion.

59. (c)

Increasing the temperature generally has the following effects on mechanical properties of carbon steel:

- The ductility and toughness increase, and

- The yield stress and modulus of elasticity decrease.
- The strain hardening exponent decreases with increasing temperature.

60. (d)

Compression : For brittle materials such as ceramics and glasses, a disc test has been developed.

Bending : A commonly used test method for brittle material is the flexural test.

Hardness test : The knoop test is a micro-hardness test, it is suitable for very small or very thin specimen and for brittle materials such as carbides, ceramics and glasses.

Impact test : Impact tests are particularly useful in determining the ductile brittle transition temperature of materials.

61. (d)

Two necessary conditions for forming interstitial solutions:

1. The solvent atom must have more than one valence electron, and
2. The atomic radius of the solute atom must be less than 59% of the atomic radius of the solvent atom.

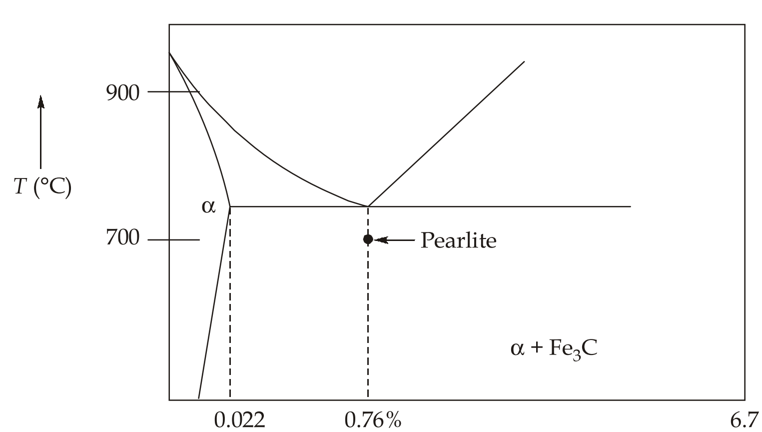
Two conditions (known as Hume-Rothery rules) are generally required to form complete substitutional solid solutions.

1. The two metals must have similar crystal structures, and
2. The differences in their atomic radii should be less than 15%.

62. (b)

- HSLA steels have low carbon content and plates, bars and structural shapes are made from these steels.
- The main application of ultra-high-strength-steels is for crashworthy design of automobiles such as bumpers and roof supports.
- Typical applications of stainless steel include cutlery, kitchen equipment, healthcare and surgical equipment, and applications in the chemical, food processing and the petroleum industries.
- Shock-resisting steels (type of die steel) are designed for impact toughness and are used in applications such as header dies, punches and chisels.

63. (c)

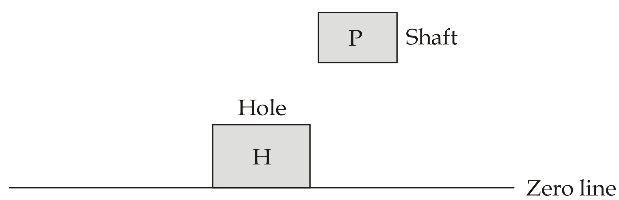


Mass fraction of Fe_3C, $m_{Fe_3C} = \dfrac{0.76-0.022}{6.7-0.022} \times 100 = 11.05\%$

64. (c)

CMMs are very versatile and capable of recording measurements of complex profiles with high resolution (0.25 μm) and high speed. They are built rigidly and ruggedly to resist environmental effects in manufacturing plants, such as temperature variations and vibrations. They can be placed close to machine tools for efficient inspection and rapid feedback, that way, processing parameters are corrected before the next part is made.

65. (d)



Therefore, H_7 - P6 is a interference fit.

66. (b)

Given : 1 MSD = 1 mm; MSR = 12 mm

$$1 \text{ V.D.} = \frac{19}{20} \text{ mm} = 0.95 \text{ mm}$$

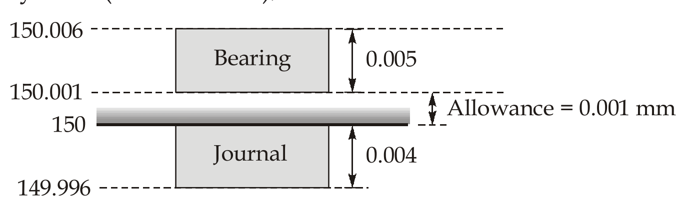
$\therefore$ L.C. = 1 – 0.95 = 0.05 mm

$\therefore$ Reading = MSR + VR

= 12 + 0.05 × 5 = 12.25 mm

67. (b)

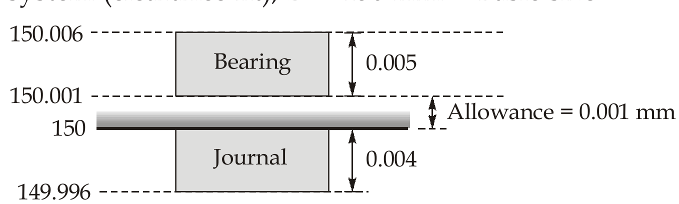
Given : Shaft basis system (clearance fit), D = 150 mm = Basic size



$\therefore$ Upper limit of journal = Basic size = 150 mm

68. (d)

Given : Shaft basis system (clearance fit), D = 150 mm = Basic size



Lower limit of bearing = 150.001 mm

69. (c)

Given : $\alpha = 15°, \phi = 60°$

$$\gamma = \cot\phi + \tan(\phi - \alpha)$$
$$= \cot 60° + \tan 45°$$
$$= \frac{1}{\sqrt{3}} + 1 = \frac{\sqrt{3}+1}{\sqrt{3}} = 1.577$$

70. (a)

Given : $F_c = 800$ N; $F_t = 600$ N; $\beta = 30°$

$$R = \sqrt{F_c^2 + F_t^2} = \sqrt{600^2 + 800^2} = 1000 \text{ N}$$
$$F = R\sin(\beta) = 1000 \sin 30°$$
$$F = 500 \text{ N}$$

71. (c)

CBN : At elevated temperature, CBN is chemically inert to iron and nickel. Its resistance to oxidation is high thus it is particular suitable for cutting hardened ferrous and high-temperature alloys and for high speed machining operations. Furthermore, in order to avoid chipping and cracking due to thermal shock, machining generally should be performed dry (i.e. cutting fluids should be avoided) particularly in interrupted cutting operations (such as milling), which repeatedly subject to the tool to thermal cycling.

72. (d)

Given : $d = 12$ mm; $N = 720$ rpm; $f = 0.2$ mm/rev

$$\text{MRR} = \frac{\pi}{4}(d^2)\left(\frac{fN}{60}\right)$$
$$= \frac{\pi}{4}(12)^2\left(\frac{0.2\times720}{60}\right)$$
$$= 86.4\,\pi \text{ mm}^3/\text{s} = 271.43 \text{ mm}^3/\text{s}$$

73. (a)

Given : $f = 0.2$ mm/tooth $\{f_m = fzN\}$; $d = 3$ mm; $D = 48$ mm $(\because D >> d)$; $z = 12$; $N = 120$

$$t_{\max} = \frac{2f_m}{Nz}\sqrt{\frac{d}{D}} = 2f\sqrt{\frac{d}{D}}$$
$$= 2\times0.2\sqrt{\frac{3}{48}} = 0.1 \text{ mm}$$

74. (d)

Given : $A = 2 \times 2 = 4\ \text{cm}^2$; $h = 0.35$ mm = 0.035 cm; r = 4 Ωcm

$$\therefore \qquad R_{gap} = \frac{\rho h}{A} = \frac{4 \times 0.035}{4} = 0.035\,\Omega$$

$$\text{or} \qquad R_{gap} = 35\ \text{m}\Omega$$

75. (a)

Nanoparticles have a very high surface area to volume ratio, thus affecting their behaviour in processes such as diffusion and agglomeration. Because the synthesis of nanomaterials is done at atomic levels, their purity (on the order of 99.9999%), their homogeneity, and the uniformity of their micro-structures are highly controlled. As a result, their mechanical, electrical, magnetic, optical and chemical properties also can be controlled precisely.

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