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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 6

Section A : Fluid Mechanics and Turbo Machinery [All Topics]
Section B : Production Engineering & Material Science-1 [Part Syllabus]
Section C : Thermodynamics-2 + Refrigeration and Air-Conditioning-2 [Part Syllabus]

Answer Key

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

Section A : Fluid Mechanics & Turbo Machinery

1. (d)

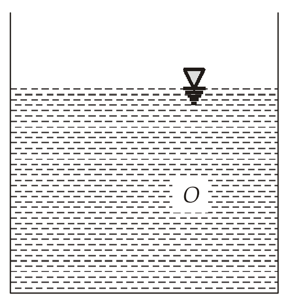
Property	Unit	Dimension
Momentum diffusivity	m^2/s	$[M^0L^2T^{-1}]$
Specific volume	m^3/kg	$[M^{-1}L^3T^0]$
Shear strain rate	$1/s$	$[M^0L^0T^{-1}]$
Bulk modulus	N/m^2	$[M^1L^{-1}T^{-2}]$

$$N \rightarrow kgm/s^2 \rightarrow [MLT^{-2}]$$

Strain $\rightarrow$ unitless

2. (b)

Given : P_i = ?; P_o = 150 kPa; σ = 0.073 N/m; d = 1.46 mm; R = 0.73 mm



$$\Delta P = \frac{2\sigma}{R} = \frac{2 \times 0.73}{0.73 \times 10^{-3}}$$

$$\Delta P = 200 \text{ Pa} = 0.2 \text{ kPa} \quad \{\text{Pressure at concave side will be more}\}$$

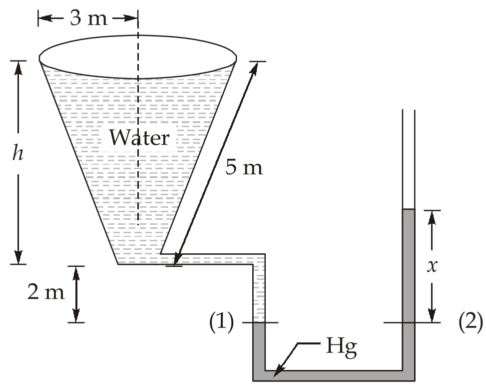
$$P_i - P_o = 0.2$$

$$P_i = 150.2 \text{ kPa}$$

3. (c)

Vapour pressure : The vapour molecules exert a partial pressure in the space above the liquid, known as vapour pressure. The vapour pressure of a given liquid is a function of temperature only and equal to the saturation pressure for boiling corresponding to that temperature. Hence, the vapour pressure increases with the increase in temperature. The boiling can be achieved by either raising the temperature or the liquid, or by lowering the pressure of the ambience (surrounding gas) to the liquid's vapour pressure at the existing temperature.

4. (c)



Considering the equilibrium,

$$\because \quad \frac{\rho_{Hg}}{\rho H_2O} = 13.6$$

$$h = \sqrt{5^2 - 3^2} = 4 \text{ m}$$

$$\because \quad P_1 = P_2$$

$$P_{atm} + (1000 \times 9.81 \times (4 + 2)) = P_{atm} + (13600 \times 9.81 \times x)$$

$$\Rightarrow \quad x = \frac{6}{13.6} = 0.4412 \text{ m}$$

$$\text{or} \quad x = 44.12 \text{ cm}$$

5. (c)

For equilibrium, Weight of body = Total buoyancy acting on it

Let, A = Cross-section area of block

ρ_m = Density of metallic block

h = Height above top surface of block

Pressure at top surface = $P_{atm} + \rho_w g h$

Pressure at bottom surface = $P_{atm} + \rho_w g h + \rho_w g x + \rho_{Hg} g y$

Buoyancy = Pressure difference = $(\rho_w x + \rho_{Hg} y) g$

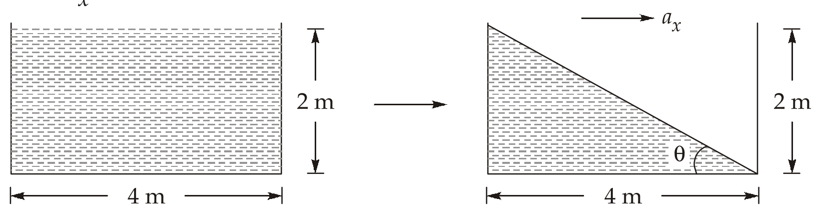
Therefore, x and y remains same and do not depend on height or water level above top surface.

$\therefore \quad x : y$ remains same.

6. (a)

Given : Tank base area = 4 m × 4 m; Height = 2 m

Let acceleration = a_x



Initially

$$V_i = 4 \times 4 \times 2 \text{ m}^3 \qquad V_f = \frac{1}{2} \times (4 \times 4 \times 2)$$

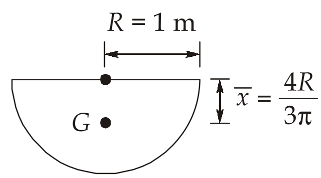
$$\tan\theta = \frac{a_x}{g} = \frac{2}{4}$$

$$\Rightarrow \quad a_x = \frac{g}{2}$$

7. (d)

The horizontal force will be calculated by taking projection.

Projection is semi circular disc,



$$F_H = \rho g A \bar{x} = 1000 \times 9.81 \times \frac{\pi(1)^2}{2} \times \frac{4(R=1)}{3\pi}$$

$$= 6540 \text{ N} = 6.54 \text{ kN}$$

8. (c)

Given : $\vec{V} = (5 - y)\hat{j} + 2z\hat{k}$.

For steady flow, stream line and streak line are same.

∴ Equation for streamline,

$$\frac{dy}{v} = \frac{dz}{w}$$

$$v = (5 - y),\ w = 2z$$

$$\Rightarrow \quad \int \frac{dy}{5-y} = \int \frac{dz}{2z}$$

$$\Rightarrow \quad -\ln(5 - y) = \frac{1}{2}\ln z + \ln c$$

$$\Rightarrow \quad \ln(z) + 2\ln(5 - y) + 2\ln c = 0$$

$$\Rightarrow \qquad z(5-y)^2 = c_1$$

Passing through (1, 1, 2)

$$\therefore \qquad 2(4)^2 = c_1$$

$$\Rightarrow \qquad c_1 = 32$$

$$\therefore \qquad z(5-y)^2 = 32$$

9. (d)

The continuity equation, $\nabla\cdot\left(\rho\vec{V}\right)+\frac{\partial\rho}{\partial t}=0$ in three-dimensions for a general fluid flow since

(i) ρ variations taken into account.
(ii) Temporal variations taken into account.
(iii) Viscosity does not enter into equation since viscosity implies the existence of stresses which are not related to mass.

10. (d)

Reynolds Transport Equation : It shows that the rate of change of N (extensive property) for a system equals the sum of the efflux of N across the control surface and the rate of change of N within the control volume.

$$\frac{DN}{Dt} = \int_{CS} n(\rho U\cdot dA)+\frac{\partial}{\partial t}\int_{CV} n(\rho\cdot dA)$$

If N is mass it will become continuity equation by conservation of mass.

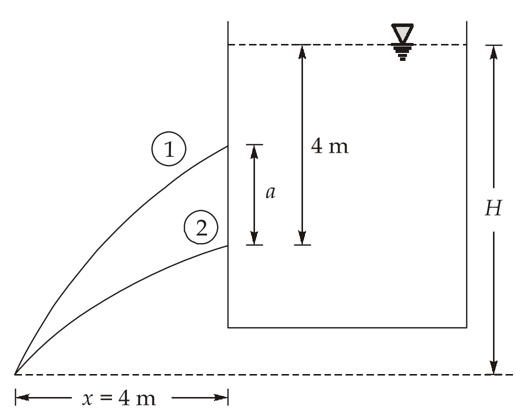
11. (c)

Free vortex flows are the plane circular vortex flows where the total mechanical energy remains constant in the entire flow field. There is neither any energy interaction between an outside source and the flow, nor is there any dissipation of mechanical energy within the flow. The mechanical energy does not vary from streamline to streamline.

The superimposition of a radial flow with a free vortex flow gives rise to a spiral free vortex flow.

12. (c)

Given : $C_{V_1} = C_{V_2} = 0.6$; $h_1 = 4$ m; $h_2 = (x + 4)$



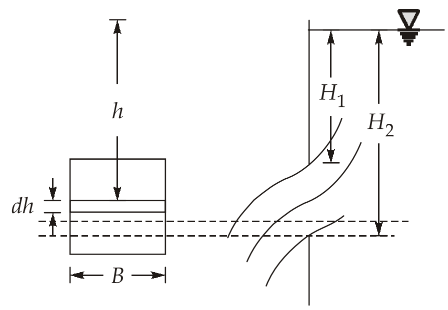
For orifice 2,
$$C_V = \frac{x}{\sqrt{4y_2h_2}}$$
$$0.64 = \frac{4}{\sqrt{4\times(H-4)\times 4}}$$
$$16(H-4) = \frac{1}{0.0256}$$
$$H = 6.44 \text{ m}$$

13. (d)

Given : $C_{V_1} = C_{V_2} = 0.6$; $h_1 = 4$ m; $h_2 = (x + 4)$

As
$$C_{V_1} = C_{V_2}$$
$$\frac{x}{\sqrt{4y_1h_1}} = \frac{x}{\sqrt{4y_2h_2}}$$
$$y_1h_1 = y_2h_2$$
$$(H-4+a)(4-a) = (H-4)4$$
$$4H - 16 + 4a - aH + 4a - a^2 = 4H - 16$$
$$a^2 - 8a + aH = 0$$
$$a[a-8+H] = 0$$
$$a = 0 \text{ [Not possible]}$$
$$a = 8 - H = 8 - 6.44 = 1.56 \text{ m}$$

14. (c)



Discharge through elemental strip $= c_d$ (Area) × Velocity
$$= c_d(Bdh)\sqrt{2gh}$$

$\therefore$ Discharge through entire orifice
$$= c_dB\sqrt{2g}\int_{H_1}^{H_2}\sqrt{h}\,dh$$
$$= \frac{2}{3}c_dB\sqrt{2g}\left(H_2^{3/2} - H_1^{3/2}\right)$$

15. (b)

Given : U_∞ = 1.44 m/s; L = 0.36 m; b = 4 m; $\nu = 1 \times 10^{-6}$ m^2/s, ρ = 1000 kg/m^3

$$\text{Re}_L = \frac{U_\infty L}{\nu}$$

$$\text{Re}_L = \frac{1.44 \times 0.36}{10^{-6}} = 5.184 \times 10^5$$

Using Blasius equation,

$$c_d = \frac{1.328}{\sqrt{\text{Re}_L}} = \frac{1.328 \times 10^{-3}}{\sqrt{1.44 \times 0.36}}$$

$$c_d = \frac{1.328 \times 10^{-3}}{1.2 \times 0.6} = 1.844 \times 10^{-3}$$

$$F_D = c_d \times \frac{1}{2} \times A\rho U_\infty^2$$

$$= 1.844 \times 10^{-3} \times \frac{1}{2} \times (0.36 \times 4) \times 1000 \times (1.44)^2$$

$$F_D = 2.75 \text{ N}$$

16. (c)

Given : U_∞ = 16 m/s; x = 3 m; $\nu = 1.5 \times 10^{-5}$ m^2/s

$$\text{Re}_x = \frac{U_\infty x}{\nu} = \frac{16 \times 3}{1.5 \times 10^{-5}} = 32 \times 10^5 > 5 \times 10^5$$

$\therefore$ For turbulent flow, $$\delta = \frac{0.37x}{(\text{Re}_x)^{1/5}} = \frac{0.37 \times 3}{\left(32 \times 10^5\right)^{1/5}}$$

$$\delta = \frac{0.37 \times 3}{2 \times 10} = 0.0555 \text{ m}$$

or $$\delta = 5.55 \text{ cm}$$

17. (d)

Given : H = 20 m; Q = 1 m^3/s; h_f = ?

Power available at exit $= \rho g Q(H - h_f)$

$\Rightarrow$ $98.1 \times 10^3 = 1000 \times 9.81 \times 1(20 - h_f)$

$\Rightarrow$ $h_f = 10$ m

18. (b)

Given : f = 0.00981

Pipe BC, $q = 10^{-5}$ m^3/s/m

L = 3000 m, d = 0.1 m

$Q_{BC} = 10^{-5} \times 3000 = 0.03$ m^3/s

Head loss in pipe when uniform discharge through length take place.

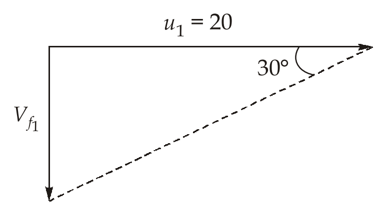
$$h_f = \frac{1}{3}\frac{fLV^2}{2gd}, \; V = \frac{4Q}{\pi d^2} = \frac{4\times 0.03}{\pi\times 0.01} = \frac{12}{\pi} \text{ m/s}$$

$$h_f = \frac{1}{3}\times 0.00981\times\frac{3000\times 12^2}{2g\times 0.1\times\pi^2} = \frac{720}{\pi^2} = 72.95 \text{ m}$$

$\therefore$ $$(h_f)_{BC} = 72.95 \text{ m}$$

19. (b)

Given : Centrifugal pump, u_1 = 20 m/s; β_1 = 30°; b_1 = 0.8, r_1 = 1 m; V_{w_1} = 0



$$Q = 2\pi r_1 b_1 V_{f1} = 2\pi r_1 b_1 (u_1 \tan 30°)$$

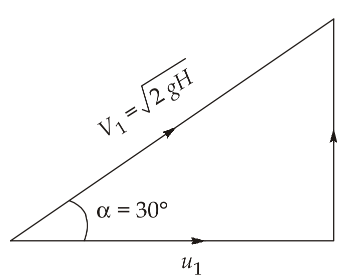
$$= 2\pi\times 1\times 0.8\times 20\times\frac{1}{\sqrt{3}} \simeq 58 \text{ m}^3/\text{s}$$

20. (c)

The shutoff head is the net head that occurs when the volume flow rate is zero and is achieved when the outlet port of the pump is blocked off. Under these conditions, head is large but volume flow rate is zero, the pump efficiency will be zero.

21. (c)

Given : d_1 = 1.2 m; θ = 90°, α = 30°; H = 36 m



$$V_1 = \sqrt{2gH} = \sqrt{2g\times 36} = 6\sqrt{2g} \text{ m/s}$$

$$u_1 = V_1\cos 30°$$

$$= 6\sqrt{2g}\times\frac{\sqrt{3}}{2} = 3\sqrt{6g} \text{ m/s}$$

$\therefore$ $$u_1 = \frac{\pi d_1 N}{60}$$

$\Rightarrow$ $$N = \frac{3\sqrt{6\times 9.81}\times 60}{\pi\times 1.2} = 366.31 \text{ rpm} \simeq 366 \text{ rpm}$$

22. (d)

Given : $n = 16$; $N = 180000$ rpm; $r_2 = 0.2$ m; $\psi = 1.08$; $\dot{m} = 1.5$ kg/s

$$P = \dot{m}\sigma\psi u_2^2$$

$$u_2 = \frac{2\pi r_2 N}{60} = \frac{2\pi \times 0.2 \times 18000}{60} = 120\pi = 377 \text{ m/s}$$

$$P = 1.5 \times 0.875 \times 1.08 \times (377)^2 \times 10^{-3} \text{ kW} = 201.46 \text{ kW}$$

23. (c)

Vaneless diffuser : The diffusion is directly proportional to the diameter ratio. This leads to a relatively large-sized diffuser which is a serious disadvantage of the vaneless type. In some cases the overall diameter of the compressor may be impractically large. This is a serious limitation which prohibits the use of vaneless diffusers in aeronautical applications.

24. (c)

Given : $P = 8829$ kW; $\eta_0 = 0.9$; $H = 360$ m

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

$$\Rightarrow \quad 8829 \times 10^3 = 0.9 \times 10^3 \times 9.81 \times Q \times 360$$

$$\Rightarrow \quad Q = \frac{1000}{360} \simeq 2.78 \text{ m}^3/\text{s}$$

25. (d)

Given : $H = 36$ m; $N = 180$ rpm; $h_0 = 0.9$; $Q = 8$ m^3/s

$$P = \rho g Q H \cdot \eta$$

$$= 1000 \times 9.81 \times 8 \times 36 \times 0.9 \times 10^{-3} \text{ kW}$$

$$= 2542.752 \text{ kW}$$

For head, $H_2 = 16$ m

$$\frac{P}{D^2 H^{3/2}} = c \qquad \left\{\text{Unit power} = \frac{P}{H^{3/2}}\right\}$$

$$\Rightarrow \quad P \propto H^{3/2}$$

$$\Rightarrow \quad P_2 = 2542.752 \times \left(\frac{16}{36}\right)^{1.5} = 753.41 \text{ kW}$$

26. (c)

Machines	Characteristics
Centrifugal pump	Priming required volute casing
Reciprocating pump	Air vessels
Axial flow pumps	High discharge, high specific speeds
Pelton wheel	Work at atmospheric pressure
Kaplan turbine	Adjustable runner vanes and high part load efficiency

27. (c)

The ramjet engine consists of
- Supersonic diffuser
- Subsonic diffuser section
- Combustion chamber
- Discharge nozzle

The pulse jet engine consists of
- A diffuser
- A valve grid
- A combustion chamber
- A spark plug
- A discharge nozzle

28. (b)

Effect of variation of turbine inlet temperature and pressure ratio:

As turbine inlet temperature increases, the thermal efficiency increases and for each value of turbine inlet temperature there is an optimum pressure ratio for maximum thermal efficiency. For lower value of inlet temperature efficiency first increases and after reaching maximum value it decreases rapidly. The optimum pressure ratio for maximum work is at lower value as compared to for maximum efficiency at the same inlet temperature. For higher value of turbine inlet temperature the peaks of the curves are flatter gives greater range of optimum value of pressure ratio.

29. (b)

Given : W_T = 360 kJ/kg; W_{net} = 180 kJ/kg

$$\text{Air rate} = \frac{3600}{W_{net}} = \frac{3600}{180} = 20 \text{ kJ/kWh}$$

$$\text{Work ratio} = \frac{W_{net}}{W_T} = \frac{180}{360} = 0.5 \text{ or } 50\%$$

30. (d)

In the first stage blades, the steam enters with velocity V_1 and the certain portion of this kinetic energy is utilized in the blades, a small portion is absorbed by friction and the remainder comes out with the absolute velocity V_2.

- Carry-over coefficient : The fraction of the kinetic energy corresponding to V_2 which will be available for utilization in the nozzles of the succeeding stages.

The following are the results when carry-over is taken into account:

- The maximum gross stage efficiency of any stage of multi-stage impulse turbine is greater than the single stage turbine for same nozzle.
- For the same nozzle angle the optimum value of ρ is higher.

31. (c)

Given : P = 1152 kW; SSC = 8.25 kg/kWh

$$\because \qquad \text{SSC} = \frac{\dot{m}_f}{\text{Power}} \times 3600$$

$$\dot{m}_f = \frac{(SSC) \times Power}{3600} = \frac{8.25 \times 1152}{3600} = 2.64 \text{ kg/s}$$

32. (a)

Given : h_1 = 2718 kJ/kg; h_2 = 2593 kJ/kg; η_e = 0.9; η_g = 0.96

$$\Delta h_{i,\text{sen}} = h_1 - h_2 = 125 \text{ kJ/kg}$$

$$\text{SSC} = \frac{3600}{\eta_e \eta_g \times 125} = \frac{3600}{0.9 \times 0.96 \times 125}$$

$$\Rightarrow \qquad \text{SSC} = 33.33 \text{ kg/kWh}$$

33. (c)

Reciprocating pump:

The pressure head in the cylinder during suction stroke, is constant and equal to the suction head which is below atmospheric pressure.

The absolute pressure at beginning of stroke should not fall below the vapour pressure so that separation does not take place.

$$h_{\text{sep}} = H_{\text{atm}} - (h_s + h_{as})$$

$$h_{\text{as}} = \frac{l_s}{g} \cdot \frac{A}{a_s} \cdot \omega^2 r$$

h_s : suction pipe length

∴ Higher suction pipe length or high speed can cause separation.

34. (a)

Given : P_v = 2.943 kPa; h_s = 3.5 m; h_f = 1.2 m

$$\text{NPSH} = \frac{P_{atm}}{\rho g} - \frac{P_v}{\rho g} - h_s - h_f$$

$$= \frac{101.325\times10^3}{1000\times9.81} - \frac{2.943\times10^3}{1000\times9.81} - 3.5 - 1.2$$

$$= \frac{101.325}{9.81} - 0.3 - 3.5 - 1.2 = 5.33 \text{ m}$$

35. (b)

Given : D = 0.1 m; L = 0.2 m, N = 60 rpm; $Q^{th} = \frac{ALN}{60}$; Q_{act} = 1.5 l/s

$$Q_{th} = \frac{\pi}{4}(0.1)^2 \times 0.2 \times \frac{60}{60} = 1.571\times10^{-3}\text{ m}^3/\text{s}$$

or $$Q_{th} = 1.571\ l/\text{s}$$

$\therefore$ $$\%\text{Slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

$$= 4.51\%$$

36. (a)

Arranging dissimilar pipes in series may create problems because the volume flow rate through each pump must be the same, but the overall pressure raise is equal to the pressure rise of one pump plus that of the other. If the pumps have widely different performance curves, the smaller pump may be forced to operate beyond its free delivery flow rate, where upon its acts like a head loss, reducing the total volume flow rate. In such case, the power supplied to the smaller pump would be wasted.

37. (a)

Entry flow in a duct:

At the entrance region, the velocity gradient is steeper at the wall, causing a higher value of shear stress as compared to a developed flow. In addition, momentum flux across any section is the entrance region is higher than that typically at the inlet due to the change in shape of the velocity profile. Arising out of these, an additional pressure drop is brought about at the entrance region as compared to the pressure drop in the fully developed region.

38. (a)

Casting defects:

Dross : Lighter impurities appearing on top surface.

Rat-Tail: long shallow angular depression normally found in thin casting.

Misrun: Solidification before reaching farthest position.

Hot Tear: Crack developed due to high residual stress.

39. (d)

Casting : 100 mm × 200 mm × 300 mm

For casting to be of final dimensions of 100 × 200 × 300 mm pattern should be made larger to compensate solid shrinkage.

$$\text{Pattern} = \left(100+\frac{20}{1000}\times 100\right)\times\left(200+\frac{20}{1000}\times 200\right)\times\left(300+\frac{20}{1000}\times 300\right)$$

$$= 102 \text{ mm} \times 204 \text{ mm} \times 306 \text{ mm}$$

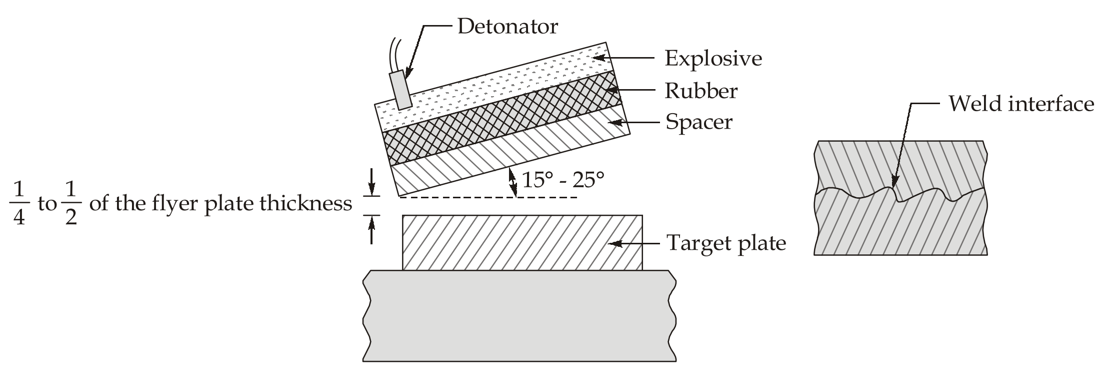
40. (c)

Chills are used to increase local rate of heat transfer in casting :

- To avoid uneven thermal deformation during cooling.
- To achieve desired directional solidification.

41. (c)

Explosive Welding : The explosive welding process is used to join two plates, face to face. One of the workpieces, called the target plate, is held fixed. The other one, called the flyer plate, is kept at an angle to the target plate.



Explosive welding

The minimum distance between the two plates is of the order of $\frac{1}{4}$ to $\frac{1}{2}$ of the flyer plate thickness.

An explosive charge is kept on the top of the flyer plate with an intervening layer of rubber spacers. When the explosive charge is detonated, the flyer plate comes and hits the target plate with a huge velocity and the two plates are welded face to face. This process can be used to join dissimilar materials.

42. (c)

Initial	Final
$R_1 = R$	R_2
t_1	t_2

$$\text{Initial volume} = \text{Final volume}$$

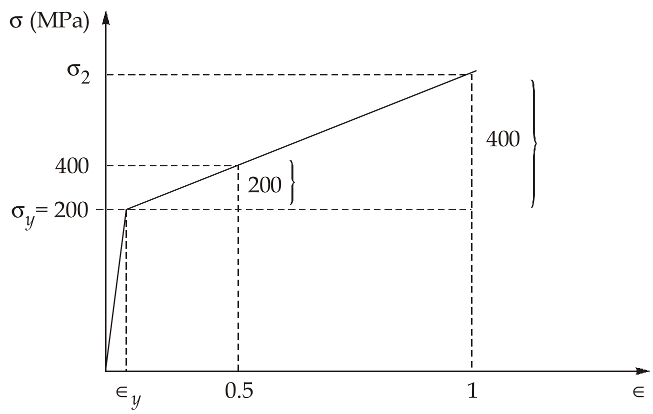
$$\pi R^2 t_1 = \pi R_2^2 t_2$$

$$R_2 = \sqrt{\frac{t_1}{t_2}}\, R$$

$$\text{Sticking radius } (R_S) = R_2 - \frac{h_2}{2\mu}\ln\left(\frac{1}{\sqrt{3}\mu}\right)$$

$$= R\sqrt{\frac{t_1}{t_2}} - \frac{t_2}{2\mu}\left(\ln\frac{1}{\sqrt{3}\mu}\right)$$

43. (c)



$$\text{Strain } (\in) = \ln\left(\frac{A_1}{A_2}\right) = 2\ln\left(\frac{d_1}{d_2}\right)$$

$$\in = \ln\left(\frac{2.72}{1}\right) \simeq 1$$

Since yield strain for steel << 0.5

$$\sigma_{mean} = \frac{\text{Area } (\sigma - \in)}{\text{Strain}} \simeq \frac{\sigma_y + \sigma_2}{2}$$

$$= \frac{200 + 600}{2} = 400 \text{ MPa}$$

44. (c)

$$\text{Maximum draft} = \mu^2 R = (0.125)^2\left(\frac{200}{2}\right) = \frac{25}{16} \text{ mm}$$

$$\Delta t = 10 - 0.6 = 9.4 \text{ mm}$$

$$\text{Number of passes} = \frac{9.4}{25/16} = \frac{9.4 \times 16}{25} = 6.016 > 6$$

Minimum number of passes required is 7.

45. (d)

Maximum thickness reduction per pass = $\mu^2 R$

$$= (0.125)^2 \times 100 = \frac{25}{16} \text{ mm} = 1.5625 \text{ mm}$$

Maximum thickness reduction in two passes

$$= 2 \times 1.5625$$
$$= 3.125 \text{ mm}$$

46. (c)

$$\text{Corner radius, } r = 1 \text{ mm}$$
$$\text{Cup diameter, } d = 40 \text{ mm}$$
$$\text{Cup height, } h = 90 \text{ mm}$$
$$20r = 20 \text{ mm} < d$$

So, blank diameter is given by $\sqrt{d^2 + 4dh}$

$$= \sqrt{40^2 + 4 \times 40 \times 90} = \sqrt{40(40+360)}$$
$$= \sqrt{40 \times 400} = 40\sqrt{10} = 126.49 \text{ mm}$$

47. (d)

CAPP has the following advantages :

1. It can reduce the skill required of a process planner.
2. It can reduce the process planning time.
3. It can reduce both process-planning and manufacturing costs.
4. It can increase productivity.

48. (b)

Crystal structure of materials at room temperature
FCC : Ca, Ni, Cu, Ag, Pt, Au, Pb, A*l*
BCC : Na, K, V, Mo, Ta, W
HCP : Be, Mg, Zn, Cd, Te, Co

49. (d)

- **Sulphur :** Iron forms with sulphur, iron sulphide, FeS, which solidifies along the grain boundaries making the steel brittle and lowers its hot working properties. If an equal amount of manganese is present in the steel then manganese sulphide, MnS forms and the harmful effects of sulphur are reduced. It is generally recommended that manganese should at least be three times that of sulphur. However very small quantities (0.075 to 0.15%) that are generally present contribute to better machinability.
- **Phosphorous :** Phosphorous in small amounts increases the strength and hardness of steels. Most of the steels contain a very small percentage of about 0.05% phosphorous.
- **Silicon :** Silicon in very small amounts of the order of less than 0.2% do not have any effect. When it is between 0.2 and 0.4%, it raises the elastic limit and ultimate strength of the steel without greatly reducing the ductility. More than this percentage will reduce the ductility.

50. (a)

Aluminium : 85% to 95% reflectivity
Copper : Bronze
Zinc : Galvanizing
Magnesium : High strength to weight ratio

51. (d)

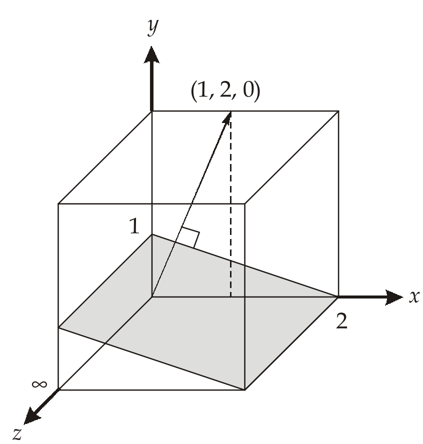
Fused silica is a type of glass with > 99.5% of SiO_2.

52. (a)

Vulcanization

The crosslinking process in elastomers is called vulcanization, which is achieved by a nonreversible chemical reaction, ordinarily carried out at an elevated temperature. In most vulcanizing reactions, sulfur compounds are added to the heated elastomer; chains of sulfur atoms bond with adjacent polymer backbone chains and crosslink them.

53. (a)



Miller indices of plane is $\frac{1}{2}, \frac{1}{1}, \frac{1}{\infty}$

$0.5, 1, 0$

$(1, 2, 0)$

54. (a)

Since the martensitic transformation does not involve diffusion, it occurs almost instantaneously; the martensite grains nucleate and grow at a very rapid rate-the velocity of sound within the austenite matrix. Thus the martensitic transformation rate, for all practical purposes, is time independent.

Martensite grains take on a plate-like or needle-like appearance. The white phase in the micrograph is austenite (retained austenite) that did not transform during the rapid quench. As already mentioned, martensite as well as other microconstituents (e.g., pearlite) can coexist.

55. (c)

NC machining has least level of automation among CNC, DNC and FMS machining.

56. (a)

Mode of transfer depends on the intersection of these forces and governs the ability of welding in various positions. The major forces which take part in this process are those due to (i) gravity, (ii) surface tension, (iii) electromagnetic interaction, and (iv) hydrodynamic action of plasma.

The force of gravity may be a retaining or a detaching force, depending on whether the electrode is pointing upward or downward. But the surface tension always tends to retain the liquid drop at the tip of the electrode. This force depends on the radius of the electrode, the capillarity constant, and the density of the liquid metal. The electromagnetic force, known as the Lorentz force, is set up due to the interaction of the electric current with its own magnetic field. This force acts in the direction of the current when the cross-section of the conductor is increasing in the direction of the current. Similarly, the force acts in the direction opposite to that of the current if the cross-section of the conductor is reducing in the direction of the current.

57. (a)

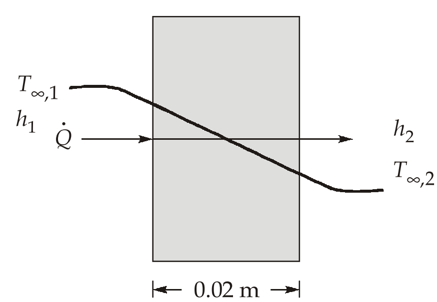
1. Exergy is a measure of departure of the state of a system from that surrounding.
2. Exergy is an attribute of both system and surrounding.
3. Value of Exergy is always positive.

58. (c)

Given : $k = 0.05$ W/mK; $h_1 = h_2 = 40$ W/mK; $\Delta x = 0.02$ m

$T_{\infty,1} = 1000$ K, $T_{\infty,2} = 300$ K

Since no useful work is obtained in the process.



$\Rightarrow$ All useful work is destroyed during process irreversibility.

$\Rightarrow$ Rate of exergy destroyed per unit wall area = $\dfrac{\dot{Q}}{1}\left(1-\dfrac{T_{\infty,2}}{T_{\infty,1}}\right)$

$$= \frac{T_{\infty,1} - T_{\infty,2}}{\dfrac{1}{h_1 A} + \dfrac{1}{kA} + \dfrac{1}{h_2 A_2}}\left(1-\frac{T_{\infty,2}}{T_{\infty,1}}\right)$$

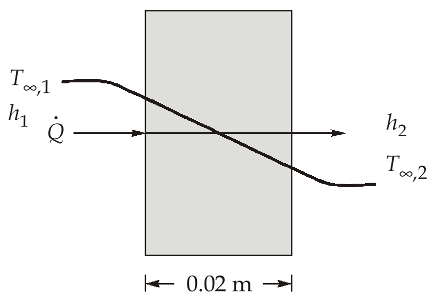
$$= \frac{(1000-300)}{\frac{1}{40\times 1}+\left(\frac{0.02}{0.05}\right)+\frac{1}{40\times 1}}\left(1-\frac{300}{1000}\right)$$

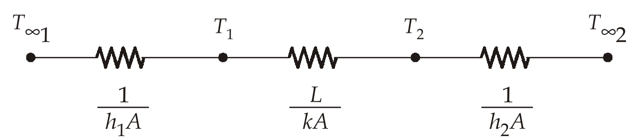
$$= \frac{20}{9}(700)(0.7) \simeq 1088.9 \text{ kJ/m}^2\text{kg}$$

59. (d)

Given :

$$k = 0.05 \text{ W/mK}; h_1 = h_2 = 40 \text{ W/mK}; \Delta x = 0.02 \text{ m}$$
$$T_{\infty,1} = 1000 \text{ K}, T_{\infty,2} = 300 \text{ K}$$





$$\dot{Q} = \frac{T_{\infty,1}-T_{\infty,2}}{\frac{1}{hA}+\frac{L}{kA}+\frac{1}{hA}} = \frac{T_{\infty,1}-T_1}{\frac{1}{hA}} = \frac{T_2-T_{\infty,2}}{\frac{1}{hA}}$$

$$T_1 = T_{\infty,1} - \frac{T_{\infty,1}-T_{\infty,2}}{2+\frac{Lh}{k}} = 1000 - 38.89 = 961.111$$

$$T_2 = T_{\infty,2} + \frac{T_{\infty,1}-T_{\infty,2}}{2+\frac{Lh}{k}} = 300 - 38.89 = 338.889 \text{ K}$$

$$\frac{I_{Wall}}{I_{Total}} = \frac{Q\left(1-\frac{T_2}{T_1}\right)}{Q\left(1-\frac{T_{\infty,2}}{T_{\infty,1}}\right)} = \frac{\left(1-\frac{338.889}{961.111}\right)}{\left(1-\frac{300}{1000}\right)}$$

$$\simeq 0.924855 = 92.48\%$$

60. (d)

Energy $\rightarrow$ Extensive Property

Exergy $\rightarrow$ Extensive Property

Specific volume $\rightarrow$ Intensive Property

Entropy generation $\rightarrow$ Path function

61. (b)

$$\eta_{Otto} = 1-\frac{1}{r_c^{\gamma-1}} = 1-\frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

Given, $$\frac{P_2-P_1}{P_1}\times 100\% = 800\%$$

$$\frac{P_2}{P_1} = 8+1 = 9$$

$$r_p = 9$$

$$\eta_{otto} = 1-\frac{1}{r_p^{\frac{\gamma-1}{\gamma}}} = 1-\frac{1}{9^{\frac{0.5}{1.5}}} = 1-\frac{1}{\sqrt[3]{9}}$$

$$= 0.51925 = 51.925\%$$

62. (a)

Cubic capacity / Stroke volume / Swept volume (V_s)

$$\text{Over square ratio} = \frac{d}{L_s} = 1.2$$

$$\Rightarrow \quad L_s = \frac{d}{1.2}$$

$$\therefore \quad V_s = \frac{\pi}{4}d^2L_s = \frac{\pi}{4}d^2\left(\frac{d}{1.2}\right)$$

$$\Rightarrow \quad 654.5 = \frac{\pi}{4}\times\frac{d^3}{1.2}$$

$$d^3 = 1000.002$$

$$d \simeq 10 \text{ cm}$$

63. (c)

The relation among the reduced properties, p_r, T_r and v_r, is known as the law of corresponding states. It can be derived from the various equations of state, such as those of van der Waals, Berthelot, and Dieterici. For a van der Waals gas,

$$\left(p+\frac{a}{v^2}\right)(v-b) = RT$$

where, a, b, and R are the characteristic constants of the particular gas.

$$\therefore \quad p = \frac{RT}{v-b}-\frac{a}{v^2}$$

or $$pv^3-(pb+RT)v^2+av-ab = 0$$

64. (c)

We know that,

$$P_C = \frac{a}{27b^2},\ T_C = \frac{8a}{27Rb},\ V_C = 3b$$

$$Z = \frac{P_C V_C}{RT_C} = \frac{a}{27b^2} \times \frac{3b \times 27Rb}{R \times 8a} = \frac{3}{8}$$

65. (b)

$$R_m = x_1R_1 + x_2R_2 \quad ...(i)$$

$$x = \text{mass fraction}$$

$$mR = n\bar{R} \quad ...(ii)$$

$$R_m = x_1\left(\frac{n_1\bar{R}}{m_1}\right) + x_2\left(\frac{n_2\bar{R}}{m_2}\right)$$

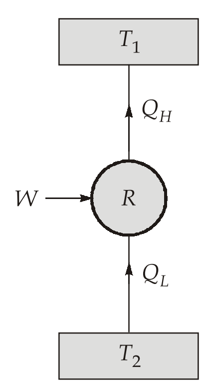
$$R_m = \bar{R}\left[\frac{x_1n_1}{m_1} + \frac{x_2n_2}{m_2}\right] = \bar{R}\left[\frac{x_1}{m_1} + \frac{x_2}{m_2}\right]$$

$$R_m = [8.314]\left[\left(\frac{0.25}{20} + \frac{0.75}{30}\right)\right] = 0.311 \text{ kJ/kgK}$$

66. (c)

Vortex tube refrigeration	:	Working theory given by Van Deemter
Vapour jet refrigeration	:	Uses Vacuum chamber
Thermoelectric refrigerator	:	Based on Peltier effect
Thermoelectric generator	:	Based on Seebeck effect

67. (c)



$$\text{COP} = \frac{Q_L}{W}$$

$$0.1 = \frac{mc(T_1 - T_2)}{W}$$

$$W = \frac{(1\times0.5)(4)(25-5)}{0.1} = 400 \text{ kJ}$$

68. (b)

$$\mu = 0.7,\ \phi = 0.9$$

$$\mu = \frac{\omega}{\omega_s} = \frac{P_v}{P_{vs}}\left(\frac{P-P_{vs}}{P-P_v}\right)$$

and $$\phi = \frac{P_v}{P_{vs}}$$

$\Rightarrow$ $$P_v = 0.9P_{vs}$$

$$0.7 = 0.9\left(\frac{100-P_{vs}}{100-P_v}\right)$$

$$700 - 7P_v = 900 - 9P_{vs}$$

$$9P_{vs} - 7P_v = 200$$

$$9P_{vs} - 7(0.9P_{vs}) = 200$$

$$P_{vs} = \frac{200}{2.7} = 74.07$$

$$\begin{aligned} P_{vs} - P_v &= P_{vs} - 0.9P_{vs} \\ &= P_{vs}(1-0.9) \\ &= 0.1\ P_{vs} \\ &= 0.1 \times 74.07 = 7.407 \text{ kPa} \end{aligned}$$

69. (c)

Absolute humidity : The weight of water vapour present in unit volume of air.

Specific humidity/ humidity Ratio (ω) : The mass of water vapour present per kg of dry-air.

Degree of saturation (μ) : Ratio of specific humidity to specific humidity of air saturated at same temperature.

Relative humidity (ϕ) : Ratio of mass of water vapour in given volume to mass of water vapour of saturated at same temperature.

70. (b)

$$M_v = 21 \text{ kg/kmol};\ M_a = 30 \text{ kg/kmol};\ P_v = 4 \text{ kPa};\ P = 100 \text{ kPa}$$

$$\text{Humidity ratio } (\omega) = \frac{m_v}{m_a}$$

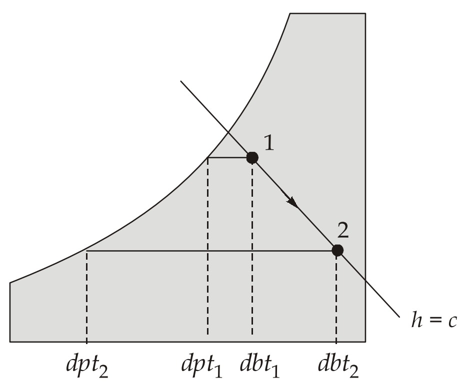
$$\omega = \left(\frac{R_a}{R_v}\right)\left(\frac{P_v}{P_a}\right) = \frac{\dfrac{\bar{R}}{M_a}}{\dfrac{\bar{R}}{M_v}}\left(\frac{P_v}{P-P_v}\right)$$

$$\omega = \frac{M_v}{M_a}\left(\frac{P_v}{P-P_v}\right) = \frac{21}{30}\left(\frac{4}{100-4}\right)$$

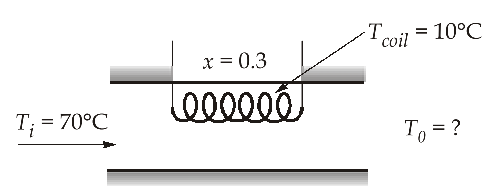
$$= 0.7 \times \frac{1}{24} = 0.029$$

71. (c)

Adiabatic Chemical Dehumidification: When the high humid air is passed through the solid absorbent bed or through a liquid absorbent spray, part of the water vapour will be absorbed reducing the vapour content in the air as shown in figure below. The latent heat liberated is absorbed by the air increasing its dry-bulb temperature and the total heat of the air remains constant, so that the process of chemical dehumidification follows the path along constant enthalpy line.



72. (c)



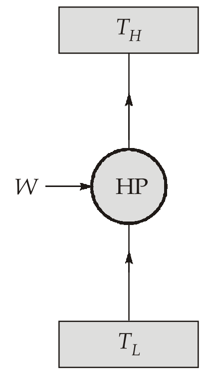
$$x = \frac{T_o - T_{coil}}{T_i - T_{coil}}$$

$$x = \frac{T_o - 10}{70-10}$$

$$0.3 = \frac{T_o - 10}{60}$$

$$T_o = 18 + 10 = 28°\text{C}$$

73. (c)



$$COP_{HP} = \frac{T_H}{T_H - T_L} = 3$$

$$T_H = 3T_H - 3T_L$$

$$T_H = 1.5\ T_L \quad \text{...(i)}$$

$$COP_{HP} = \frac{(T_H - 50)}{(T_H - 50) - T_L} = 5$$

$$\Rightarrow \quad 0.2 = 1 - \frac{T_L}{T_H - 50}$$

$$\Rightarrow \quad T_L = 0.8(T_H - 50)$$

$$\Rightarrow \quad \frac{T_H}{1.5} = 0.8(T_H - 50)$$

$$\Rightarrow \quad 0.2T_H = 60$$

$$\Rightarrow \quad T_H = 300\text{ K}$$

74. (d)

1. Exergy of a system does not depend on process path followed by the system state to dead state. Exergy is a property of system.
2. Extent of irreversibility during process leads to Exergy distruction.

75. (b)