DETAILED SOLUTIONS

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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 6

Section A : Fluid Mechanics and Turbo Machinery
Section B : Production Engineering & Material Science-1
Section C : Thermodynamics-2 + Refrigeration and Air-Conditioning-2

Answer Key

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

DETAILED EXPLANATIONS

2. (d)

$$\text{Dynamic viscosity, } \mu = 0.006 \text{ poise} = 6 \times 10^{-4} \text{ Pa.s}$$
$$\text{Specific gravity, SG} = 0.75$$
$$\text{Density of liquid, } \rho = (SG) \times \rho_{water} = 0.75 \times 1000 = 750 \text{ kg/m}^3$$

Kinematic viscosity is given as:

$$\nu = \frac{\mu}{\rho} = \frac{6 \times 10^{-4}}{750} = 8 \times 10^{-7} \text{ m}^2\text{/s} = 8 \times 10^{-3} \text{ stokes}$$

Note : 1 stokes = 10^{-4} m^2/s; 1 Poise = 0.1 Pa.s

3. (b)

$$P_i = 1 \text{ MPa}; P_f = 5 \text{ MPa}, \frac{d\rho}{\rho_i} = 5\% = 0.05$$

Bulk modulus is given by,

$$k = \frac{dP}{\left(\frac{d\rho}{\rho_i}\right)} = \frac{P_f - P_i}{\left(\frac{d\rho}{\rho_i}\right)} = \frac{5-1}{0.05} = 80 \text{ MPa} = 0.08 \text{ GPa}$$

4. (a)

Given : $P = 6 \text{ N/cm}^2 = 6 \times 10^4 \text{ Pa}$, $\rho_{Hg} = 13600 \text{ kg/m}^3$

Pressure is given as, $P = \rho_{Hg} \cdot g \cdot H$

$$6 \times 10^4 = 13600 \times 9.81 \times H$$

$\Rightarrow$ $H = 0.44972$ m $= 449.75 \text{ mm} \simeq 450 \text{ mm}$

5. (b)

$$\psi = x^2 - 3xy^2$$

The velocity in x-direction is given as:

$$u = \frac{-\partial\psi}{\partial y} = -[0 - 6xy] = 6xy$$

The velocity in y-direction is given as:

$$v = \frac{\partial\psi}{\partial x} = 2x - 3y^2$$

$$\text{Resultant velocity, } V = \sqrt{u^2 + v^2} = \sqrt{(6xy)^2 + (2x - 3y^2)^2}$$

$$V_{(1,2)} = \sqrt{(6\times1\times2)^2 + \left(2\times1-3\times2^2\right)^2}$$

$$= \sqrt{12^2 + (-10)^2} = 15.62 \text{ units}$$

6. (a)

$$\text{Velocity field, } \vec{V} = x^2\hat{i} - y^2\hat{j}$$

Hence, $u = x^2$ and $v = -y^2$

The equation of stream line is given as:

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\Rightarrow \quad \frac{dx}{x^2} = \frac{dy}{-y^2}$$

$$\Rightarrow \quad \frac{dy}{dx} = \frac{-y^2}{x^2}$$

7. (a)

The momentum thickness (δ**) is given as

$$\delta^{**} = \int_0^\delta \frac{u}{U}\left(1-\frac{u}{U}\right)\cdot dy$$

$$= \int_0^\delta \left(\frac{3y}{2\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right)\left(1 - \frac{3y}{2\delta} + \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right)\cdot dy$$

$$= \int_0^\delta \left(\frac{3y}{2\delta} - \frac{9y^2}{4\delta^2} + \frac{3y^4}{4\delta^4} - \frac{y^3}{2\delta^3} + \frac{3y^4}{4\delta^4} - \frac{y^6}{4\delta^6}\right)\cdot dy$$

$$= \left(\frac{3y^2}{4\delta} - \frac{3y^3}{4\delta^2} + \frac{3y^5}{20\delta^4} - \frac{y^4}{8\delta^3} + \frac{3y^5}{20\delta^4} - \frac{y^7}{28\delta^6}\right)_0^\delta$$

$$= \delta\left(\frac{3}{4} - \frac{3}{4} + \frac{3}{20} - \frac{1}{8} + \frac{3}{20} - \frac{1}{28}\right)$$

$$= \frac{39}{280}\delta$$

$$\Rightarrow \quad \frac{\delta^{**}}{\delta} = \frac{39}{280}$$

8. (c)

The displacement thickness (δ*) is given as:

$$\delta^* = \int_0^\delta \left(1-\frac{u}{U}\right)\cdot dy$$

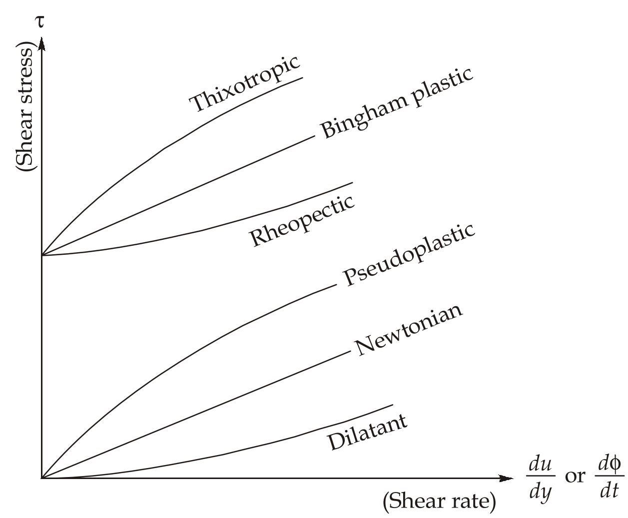
$$= \int_0^{\delta}\left(1-\frac{3y}{2\delta}+\frac{y^3}{2\delta^3}\right)\cdot dy$$

$$= \left(y-\frac{3y^2}{4\delta}+\frac{y^4}{8\delta^3}\right)_0^{\delta}$$

$$= \delta\left(1-\frac{3}{4}+\frac{1}{8}\right)=\frac{3}{8}\delta$$

$$\Rightarrow \qquad \frac{\delta^*}{\delta} = \frac{3}{8}$$

9. (b)



- For Rheopectic fluids, with increase in shear stress the slope of the curve increases. Hence, the viscosity increases.
- For Pseudoplastic fluids, with increase in shear stress the slope of the curve decreases. Hence, the viscosity decreases.

Examples of Rheopectic fluid : Gypsum in water, printer ink, etc.
Examples of Thixotropic fluid : Ice cream, crude coil, etc.

10. (d)

Given : d = 200 mm, f = 0.025, L = 1000 m, Q = 0.2 m^3/s
Frictional head loss is given as,

$$h_f = \frac{fLv^2}{2gd} = \frac{fL\left(\dfrac{Q}{\frac{\pi}{4}d^2}\right)^2}{2gd}$$

$$= \frac{1}{12.1}\frac{fLQ^2}{d^5}$$

$$h_f = \frac{1}{12.1} \times \frac{0.025 \times 1000 \times (0.2)^2}{(0.2)^5} = 258.26 \text{ m}$$

11. (b)

Given : $SG = 0.7$, $\nu = 0.01$ stokes $= 1 \times 10^{-6}$ m^2/s, $D = 80$ mm, Re = 2000

Reynolds number is given as,

$$\text{Re} = \frac{\rho v D}{\mu} = \frac{vD}{\nu}$$

$$2000 = \frac{v \times 0.080}{(1 \times 10^{-6})}$$

$$\Rightarrow \quad v = \frac{2000 \times 10^{-6}}{0.080} = 0.025 \text{ m/s}$$

12. (d)

Given : $C_v = 1$, $\rho = 1.2$ kg/m^3, $p_s = 6$ kPa, $p_0 = -6$ kPa

In a pitot tube,

$$\Delta h = \frac{p_s}{\rho g} - \frac{p_0}{\rho g} = \left(\frac{p_s - p_0}{\rho g}\right)$$

$$V_0 = C_v\sqrt{2g\Delta h} = C_v\sqrt{2g\left(\frac{p_s - p_0}{\rho g}\right)}$$

$$\Rightarrow \quad V_0 = C_v\sqrt{2\left(\frac{p_s - p_0}{\rho}\right)} = 1 \times \sqrt{2\left(\frac{6-(-6)}{1.2}\right) \times 1000}$$

$$= \sqrt{2} \times 100 = 141.42 \text{ m/s}$$

13. (b)

$W_{\text{real}} = 500$ N, $W_{\text{apparent}} = 400$ N, $\rho g = 9810$ N/m^3

Considering volume of block to be V, Buoyant force acting on the block when in water is given by,

$$\text{Buoyant force, } F = \rho g V$$

$$W_{\text{real}} - W_{\text{apparent}} = \rho g V \quad \text{...(i)}$$

also,

$$W_{\text{real}} = \rho_{\text{metal}} \cdot g \cdot V \quad \text{...(ii)}$$

From equation (i) and (ii),

$$\frac{W_{real}}{W_{real} - W_{apparent}} = \frac{\rho_{metal} \cdot g \cdot V}{\rho \cdot g \cdot V} = \frac{\rho_{metal}}{\rho}$$

$$\Rightarrow \quad \frac{500}{500 - 400} = \frac{\rho_{metal}}{\rho}$$

$$\Rightarrow \quad \frac{\rho_{metal}}{\rho} = \text{Relative density} = 5$$

14. (b)

For laminar flow between two fixed horizontal parallel plates:

- The wall shear stress varies directly as the distance from the mid plane.
- The maximum velocity of flow is three-halves of the average velocity of the flow.

15. (c)

Given : R = 0.5 mm = 0.5 × 10^{-3} m, σ = 0.072 N/m

Pressure difference across on air bubble is given as:

$$\Delta p = \frac{2\sigma}{R} = \frac{2 \times 0.072}{0.5 \times 10^{-3}} = 288 \text{ N/m}^2$$

16. (b)

With increase in temperature, the molecular collision between the gas molecules increases, resulting in increase in viscosity of gases with increasing temperature.

17. (d)

Euler's equation of motion represents the conservation of momentum for an inviscid fluid.

18. (d)

(SG) = 2, ρ = 2000 kg/m^3, h = 50 cm = 0.50 m

$$P_{\text{absolute}} = P_{\text{gauge}} + \rho g h$$
$$= 91 + (2000 \times 9.81 \times 0.50) \times 10^{-3}$$
$$= 91 + 9.81$$
$$= 100.81 \text{ kPa} \simeq 101 \text{ kPa}$$

19. (c)

Velocity flow field: $\vec{V} = (-x^2 + 3y)\hat{i} + (2xy)\hat{j}$

$\Rightarrow$ $u = -x^2 + 3y$ and $v = 2xy$

(i) For an incompressible flow $\vec{\nabla} \cdot \vec{V}$ must be zero

$$\vec{\nabla} \cdot \vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = (-2x) + (2x) = 0$$

Hence, the flow is an incompressible flow.

(ii) For an irrotational flow $\vec{\nabla} \times \vec{V}$ must be zero

$$\vec{\nabla} \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ -x^2 + 3y & 2xy & 0 \end{vmatrix} = 0 + 0 + (2y - 3)\hat{k} \neq 0$$

Hence, the flow is not an irrotational flow.

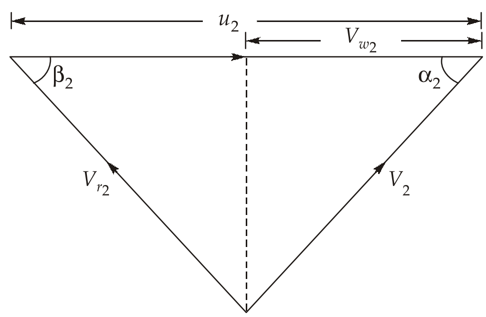
(iii) Since, there is no temporal term in the velocity flow field $\left(\frac{\partial \vec{V}}{\partial t} = 0\right)$.

So, steady flow field

(iv) The equipotential line and stream lines are always orthogonal to each other.

20. (d)

Refer outlet velocity triangle,



Velocity triangle (outlet)

Now, $$U_2 = \frac{\pi DN}{60} = \frac{\pi \times 0.3 \times 1200}{60} = 18.85 \text{ m/s}$$

Manometric efficiency is

$$\eta_{mano} = \frac{gH}{V_{w_2} U_2}$$

or $$V_{w_2} = \frac{9.81 \times 30}{0.9 \times 18.85} = 17.35 \text{ m/s}$$

21. (c)

Discharge is given by, $$Q = \pi D_2 B_2 V_{f_2}$$

∴ $$V_{f_2} = \frac{Q}{\pi D_2 B_2} = \frac{0.4}{\pi \times 0.3 \times 0.05} = 8.48 \text{ m/s}$$

22. (d)

With air vessel : Average velocity,

$$V_{avg} = \frac{Q}{A_d} = \frac{ALN}{60 \times A_d}$$

Now, head loss in delivery pipe

$$h_{fd_1} = \frac{f L_d V_{avg}^2}{2 g d_d}$$

$$h_{fd_1} = \frac{f L_d}{2 g d_d}\left(\frac{A}{A_d} \cdot \frac{LN}{60}\right)^2$$

$\therefore$ Work done, $P_1 = mg\,h_{fd_1}$ ...(i)

Without air vessel, maximum head loss,

$$h_{fd_{max}} = \frac{f L_d}{2g d_d}\left(\frac{A}{A_d}\cdot r\omega\right)^2$$

or $$h_{fd_{max}} = \frac{f L_d}{2g d_d}\left(\frac{A}{A_d}\cdot\frac{L}{2}\cdot\frac{2\pi N}{60}\right)^2$$

or $$h_{fd_{max}} = \pi^2 h_{fd_1}$$

$\therefore$ Time averaged loss, $$h_{fd_2} = \frac{2}{3}\times h_{fd_{max}} = \frac{2}{3}\pi^2 h_{fd_1}$$

$\therefore$ Work done, $$P_2 = \frac{2}{3}\pi^2 \times P_1 \quad \text{...(ii)} \quad [\because\ P_1 = mgh_{fd_1}]$$

$\therefore$ Saving in work, $$\frac{P_2 - P_1}{P_2} = \frac{\frac{2}{3}\pi^2 - 1}{\frac{2}{3}\pi^2} = 0.848 \text{ or } 84.8\%$$

23. (d)

Given : $P = 400$ kW, $H = 100$ m, $\eta_{hyd} = 0.9$, $\eta_{mech} = 0.85$

Overall efficiency, $\eta_0 = \eta_{hyd} \times \eta_{mech}$

$\eta_0 = 0.9 \times 0.85 = 0.765$

Hence, discharge, $$Q = \frac{P}{\eta_0 \times \rho g h} = \frac{400\times 10^3}{0.765\times 10^3 \times 9.81\times 100}$$

$$= 0.53 \text{ m}^3/\text{s}$$

24. (b)

Flow ratio, $$\psi = \frac{V_{f_1}}{\sqrt{2gH}}$$

$\Rightarrow$ $$V_{f_1} = 0.2\times\sqrt{2\times 9.81\times 100} = 8.86 \text{ m/s}$$

Now, Discharge, $0.53 = (1 - k)\pi D_1 B_1 \times V_{f_1}$

or $0.53 = 0.9 \times \pi \times D_1 \times 0.1 \times D_1 \times 8.86$

$\therefore$ $$D_1^2 = \frac{0.53}{0.9\times\pi\times 0.1\times 8.86}$$

$\Rightarrow$ $D_1 = 0.46$ m

25. (d)

Air vessel on delivery side:

(i) Almost constant delivery discharge is obtained.

(ii) Reduction in friction loss and hence saving in power.

26. (c)

$$\text{Unit power, } P_u = \frac{P}{H^{3/2}}$$

or
$$\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$$

$\therefore$
$$P_2 = P_1 \times \left(\frac{H_2}{H_1}\right)^{3/2} = 9000 \times \left(\frac{16}{25}\right)^{3/2}$$

$$P_2 = 4608 \text{ kW}$$

27. (b)

$$\text{Power per wheel} = \frac{5000}{2} = 2500 \text{ kW}$$

$\therefore$
$$\text{Power, } P = \eta_0 \cdot \rho g Q H$$

$\therefore$
$$Q = \frac{P}{\eta_0 \cdot \rho g H} = \frac{2500 \times 10^3}{0.8 \times 10^3 \times 9.81 \times 300}$$

$$Q = 1.06 \text{ m}^3/\text{s}$$

28. (c)

$$\text{Power, } P = \eta_0 \cdot \rho g Q H$$

$\therefore$
$$Q = \frac{P}{\eta_0 \cdot \rho g H} = \frac{10000 \times 10^3}{0.9 \times 10^3 \times 9.81 \times 40}$$

$$Q = 28.3 \text{ m}^3/\text{s}$$

Also,
$$Q = \frac{\pi}{4}\left(D_0^2 - D_b^2\right) \times V_{f_1}$$

$\Rightarrow$
$$28.3 = \frac{\pi}{4}\left(2^2 - 1^2\right) \times V_{f_1}$$

$$V_{f_1} = \frac{4 \times 28.3}{\pi \times 3} = 12.01 \text{ m/s}$$

29. (d)

For homologous pumps, the specific speed of the pump is the same,

Hence,
$$N_{s_A} = N_{s_B}$$

$$\frac{N_A\sqrt{Q_A}}{H_A^{3/4}} = \frac{N_B\sqrt{Q_B}}{H_B^{3/4}}$$

or
$$\frac{\sqrt{4}}{(81)^{3/4}} = \frac{\sqrt{2}}{(H_B)^{3/4}} \qquad (\because \ N_A = N_B)$$

$\therefore$
$$(H_B)^{3/4} = \frac{\sqrt{2}}{\sqrt{4}} \times (81)^{3/4}$$

$$H_B = 19.09^{4/3} = 51 \text{ m}$$

30. (d)

In centrifugal compressor, since the pressure differential will make the air to flow around the space between the impeller and the casing, this naturally results in a loss of efficiency. Therefore, the clearance must be kept as small as possible to reduce such a loss.

31. (a)

At large values of the incidence, the flow separation occurs on the suction side of the blades which is referred to as positive stalling. Negative stall is due to the separation of flow occurring on the pressure side of the blade due to large values of negative incidence.

32. (a)

The pulse jet engine, consists essentially of the following parts:

(i) a diffuser
(ii) a valve grid which contains springs that close on their own spring pressure
(iii) a combustion chamber
(iv) a spark plug
(v) a tail pipe or discharge nozzle

33. (d)

Back pressure or topping turbine rejects the steam after expansion to the lowest possible pressure at which it is used for heating purpose. The back pressure turbine supplies power as well as heat energy. It is generally used in sugar industries.

34. (c)

Given : $V_{f_1} = 120$ m/s; $V_{f_2} = 90$ m/s; $\dot{m}_s = 10$ kg/s

Axial thrust is given by,

$$F_a = \dot{m}_s\left(V_{f_1} - V_{f_2}\right)$$
$$= 10(120 - 90)$$
$$= 300 \text{ N}$$

35. (b)

As per given data,

$$u = \frac{\pi DN}{60} = \frac{\pi \times 0.1 \times 12000}{60} = 62.83 \text{ m/s}$$

$\therefore$ Power developed,
$$P = \frac{mV_{w_1} \cdot u}{1000} = \frac{10 \times 350 \times 62.83}{1000}$$
$$P = 219.9 \text{ kW} \simeq 220 \text{ kW}$$

36. (c)

Blade efficiency,
$$\eta_{\text{blade}} = \frac{2uV_{w_1}}{V_1^2}$$

$$\because \qquad \rho = \frac{u}{V_1} = 0.25$$

$$\Rightarrow \qquad V_1 = \frac{62.83}{0.25} = 251.32 \text{ m/s}$$

$$\therefore \qquad \eta_{\text{blade}} = \frac{2 \times 62.83 \times 350}{251.32^2} \times 100$$

$$= 69.63\%$$

38. (c)

Platinum occupies face centred cubic structure.

39. (c)

Given : Thickness of plates, t_1 = 1 mm; Welding current, I = 5000A; Current flow time, t = 0.1s; Electrode diameter, d = 5 mm; Effective resistance, $R = 200 \times 10^{-6}\,\Omega$; Height of weld nugget, h = 1.5 mm

Assumption:

1. Heat generated is fully transferred into the melting the metal without any losses.
2. The weld nugget formed is cylindrical.

$$\text{Heat generated, } Q = I^2Rt$$

$$Q = (5000)^2 \times 200 \times 10^{-6} \times 0.1$$

$$Q = 500 \text{ J}$$

$$\text{Weld nugget volume, } V_n = \frac{\pi}{4}d^2h = \frac{\pi}{4} \times 5^2 \times 1.5 \simeq 30 \text{ mm}^3$$

Since heat required to melt 1 mm^3 is 10 J,

$$\therefore \qquad \text{Heat required in melting} = 10 \times V_n$$

$$= 10 \times 30 = 300 \text{ J}$$

Thus, heat dissipated into the metal surrounding the nugget is 500 – 300 = 200 J.

40. (a)

When cast iron is slowly cooled, the cementite decomposes into iron and carbon in form of graphite which is called graphitisation. Cast irons where a large percentage of cementite is decomposed by graphitisation are called grey cast irons. Cast iron in which graphitisation has not taken place i.e. all the carbon is in the combined form, is called white cast iron. The graphitisation process requires time and therefore, when liquid cast iron is cooled rapidly, white cast iron would result.

41. (c)

Nickel, silicon and aluminium do not form any carbide, whereas manganese, chromium, tungsten, molybdenum, vanadium, titanium and niobium have increasing carbide stability in that order.

42. (c)

The shrinkage allowance is always added to linear dimensions. Even in case of internal dimensions (e.g. internal diameters), the material has a tendency to contract towards the centre and thus the dimensions are to be increased.

$\therefore$ For dimension 200 mm allowance is $200 \times \frac{21}{1000}$ i.e. 4.20 mm. Hence, the pattern dimension becomes 204.2 mm

and, for dimension 80 mm, allowance is $80 \times \frac{21}{1000}$ i.e. 1.68 mm. Hence, the pattern dimension becomes 81.68 mm.

43. (d)

- Metals and alloys with high melting temperatures are difficult to cast by hot chamber process, because gooseneck of the hot chamber machine is continuously in contact with the molten metal.
- The main difference between hot and cold chamber die casting is that in hot chamber, the holding furnace for the liquid metal is integral with the die casting machine, whereas in the cold chamber machine, the metal is melted in a separate furnace and then poured into the machine with a ladle for each casting cycle which is also called "shot".
- Since the metal is ladled into the cold chamber machine from the separate furnace, it may lose the superheat and sometimes may cause defects like cold shuts.

44. (d)

Given : h_0 = 25 mm; h_1 = 20 mm

If V_r is the roller speed then,

$$\text{Forward slip} = \frac{V_1 - V_r}{V_r}$$

$$= \frac{V_1}{V_r} - 1 = \frac{1.5}{100}$$

$$= \frac{V_1}{V_r} = \frac{101.5}{100} \quad \text{...(i)}$$

Since, width of plate is a assumed to be constant,

$$V_r h_n = V_1 h_1 \quad \text{...(ii)}$$

Thus, from (i) and (ii)

$$h_n = h_1 \times \frac{101.5}{100} = 20 \times \frac{101.5}{100}$$

$$= 20.3 \text{ mm}$$

45. (b)

- **Cold shut :** It appears as a small crack at the corners of the forging. This is caused mainly by the improper design of the die wherein the corner and fillet radii are small as a result of which the metal do not flow properly into the corner and ends up as a cold shut.
- **Scale pits :** This is seen as irregular depressions on the surface of the forging. This primarily caused because of the improper cleaning of the stock used for forging. The oxide and scale present on the stock surface gets embedded into the finished forging surface. When the forging is cleaned by pickling, there are seen as depressions on the forging surface.

- **Die shift :** This is caused by the misalignment of the two die halves, making the two halves of the forging to be of improper shape.
- **Flakes :** These are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exteriors to cool quickly causing internal fractures.

46. (b)

Only constant cross-section components can be made by extrusion process.

47. (d)

- In going from P to Q, the motion is clockwise, hence G02 code should be used.
- (X, Y) are the coordinates of the destination i.e. point Q.
- (I, J) are the distances, along the reference axes of the centre of arc from the starting point of the arc.

48. (b)

Heat input to weldment, $H = \dfrac{VI}{V_w}$

For GTAW, $H = \dfrac{12 \times 125 \times 60}{26 \times 10}$ J/m = 346 J/mm

For PAW, $H = \dfrac{18 \times 75 \times 60}{34 \times 10}$ J/m = 238 J/mm

In addition to higher welding speed in PAW, the lower heat input provides less stress in welded components.

49. (b)

It is given that the packing efficiency is 0.68, thus the given element occupies BCC lattice.

The closest distance between the neighbouring atoms is the diameter of atoms.

$\therefore$ $2r = 1.5 \text{Å}$

Also, for BCC $4r = a\sqrt{3}$

$$a = \frac{4r}{\sqrt{3}} = \frac{2(2r)}{\sqrt{3}}$$

$$a = \frac{2(1.5)}{\sqrt{3}} = \frac{3}{\sqrt{3}} = \sqrt{3} \text{Å}$$

Since, $\rho = \dfrac{nM}{a^3 A_0}$

where, n : Number of atoms in the unit cell

M : Mass of one atom or atomic weight

a : Edge length

A_0 : Avogadro's number

Thus, $$10000 = \frac{2 \times M}{\left(\sqrt{3} \times 10^{-10}\right)^3 \times 6 \times 10^{23}}$$

$$M = \frac{10000\left(\sqrt{3}\times 10^{-10}\right)^3 \times 6\times 10^{23}}{2}\text{kg}$$

$$M = \frac{1000\times 10000\times 3\sqrt{3}\times 10^{-30}\times 6\times 10^{23}}{2}g$$

$$M = 9\sqrt{3}g \simeq 15.6g$$

50. (d)

- In ionic crystals, the formation of point imperfections (whether Frenkel or Schottky) is subject to requirement that the overall electrical neutrality is maintained.
- An ion displaced from a regular site to an interstitial site is called a Frenkel imperfection. As cations are generally the smaller ions, it is possible for them to get displaced into the void space. Anions do not get displaced like this, as the void space is just too small for their size.

51. (c)

Using tie line rule, the fraction of the liquid in alloy is,

$$f_l = \frac{75-40}{75-35} = 0.875 \text{ or } 87.5\%$$

52. (a)

Alloying elements like chromium, Nickel, Mn, Mo and V are known to improve hardenability.

53. (b)

Fibreglass and concrete are examples of composite materials.

54. (b)

- Additives which are used to improve tensile and compressive strengths, abrasion resistance, toughness, dimensional and thermal stability are called fillers.
- Additives which are used to improve flexibility, ductility and toughness are called plasticizers.
- Additives that counter act deteriorative processes are called stabilizers.
- Copolymers are polymers made up of two or more monomer species combined during the copolymerization process to produce a polymer with distinct properties not present in individual monomers.

55. (a)

- Elastomers are a family of polymers that exhibit large elastic deformation, which may exceed 500%, under relatively low stresses.
- These are amorphous polymers that exit at an ambient temperature above their glass transition temperature, so that they are soft and deformable when stretched, with a small modulus of elasticity.

57. (a)

- At very low pressure, Z approaches unity, as a real gas approaches the ideal gas behaviour.
- The value of Z at the critical state of a Vander Waals gas is 0.375. $\left[\text{Since } R = \frac{8}{3}\frac{P_c V_c}{T_c}\right]$

58. (c)

- Exergy is a property and the value of a property does not change unless the state changes. Therefore, the exergy change of a system is zero if the state of the system or the environment does not change during the process.
- The exergy of a closed system is either positive or zero. It is never negative.
- The total exergy transfer is zero for an isolated systems since they involve no heat, work or mass transfer.

59. (c)

$$n_1 = \frac{9.2}{22.4} = 0.4107$$

$$n_2 = \frac{13.2}{22.4} = 0.5893$$

The mole fraction of oxygen, $x_1 = \frac{n_1}{n_1 + n_2} = 0.4107$

The mole fraction of hydrogen, $x_2 = \frac{n_2}{n_1 + n_2} = 0.5893$

∴ The entropy change for the process,

$$\Delta s = -\bar{R}(n_1 \ln x_1 + n_2 \ln x_2)$$

$$= -8.314 \times [0.4107 \times \ln(0.4107) + 0.5893 \times \ln(0.5893)]$$

$$= 5.63 \text{ J/K}$$

60. (c)

The decrease of exergy principle can be summarized as follows:

$$X_{\text{destroyed}} = \begin{cases} > 0, & \text{Irreversible process} \\ = 0, & \text{Reversible process} \\ < 0, & \text{Impossible process} \end{cases}$$

61. (a)

$$\Delta S_{\text{uni}} = \Delta S_{sys} + \cancelto{0}{\Delta S_{surro}} \qquad [\because \text{ Insulated tank}]$$

∴ Exergy destroyed $= T_0 \times \Delta S_{uni} = T_0 \times \Delta S_{sys} = T_0 \times mc_v \ln\left(\frac{T_2}{T_1}\right)$

$$= 290 \times 0.5 \times 0.72 \times \ln\left(\frac{330}{300}\right)$$

$$= 9.95 \text{ kJ}$$

62. (a)

The reversible work, which represents the minimum work input is given by,

$$W_{\text{rev}} = (U_2 - U_1) - T_0(S_2 - S_1)$$

$$= m \cdot c_v (T_2 - T_1) - T_0 \times mc_v \ln\left(\frac{T_2}{T_1}\right)$$

$$= 0.5 \times 0.72 \times (57 - 27) - 290 \times 0.5 \times 0.72 \times \ln\left(\frac{330}{300}\right)$$

$$= 10.80 - 9.95$$

$$= 0.85 \text{ kJ}$$

63. (c)

$$\frac{\text{Weight}}{\text{Volume}}\left(\frac{W}{V}\right) = 20 \text{ N/m}^3$$

$$\Rightarrow \quad \frac{m}{V} = \frac{20}{10} = 2$$

$$PV = mRT$$

$$\Rightarrow \quad R = \frac{PV}{mT} = \frac{0.3 \times 10^6 \times 1}{2 \times 300}$$

$$= 500 \text{ Nm/kgK}$$

64. (d)

The change in availability,

$$\psi_1 - \psi_2 = (h_1 - h_2) - T_0 (s_1 - s_2)$$

$$= (h_1 - h_2) + T_0 (s_2 - s_1)$$

$$= c_p (T_1 - T_2) + T_0 \left\{ c_p \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{P_1}{P_2}\right) \right\}$$

$$= 1.005 \times (527 - 327) + 300 \left\{ 1.005 \times \ln\left(\frac{600}{800}\right) + 0.287 \times \ln\left(\frac{500}{100}\right) \right\}$$

$$= 1.005 \times 200 + 300 \times 0.173 = 201 + 51.9$$

$$= 252.90 \text{ kJ/kg}$$

65. (c)

$$\text{Irreversibility, } I = T_0 \times s_{gen}$$

$$= T_0 \times (s_{exit} - s_{inlet})$$

$$= T_0 \times \left\{ (s_2 - s_1) + \frac{Q}{T_0} \right\}$$

$$= T_0 \times \left[\left\{ c_p \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{P_1}{P_2}\right) \right\} + \frac{Q}{T_0} \right]$$

$$= 300 \times \left[\left\{ 1.005 \times \ln\left(\frac{600}{800}\right) + 0.287 \times \left(\frac{500}{100}\right) + \frac{30}{300} \right\} \right]$$

$$= 81.84 \text{ kJ/kg}$$

66. (c)

From figure,

$$h_1 = 29.3 \text{ kJ/kg}; h_2 = h_3 = 42.3 \text{ kJ/kg}; t_{db_2} = 24.5°\text{C}$$

Now, $$\dot{m}_a = \frac{0.30 \times 50}{0.82} = 18.3 \text{ kg/min}$$

∴ $$Q_{coil} = \dot{m}_a(h_2 - h_1) = \frac{18.3 \times (42.3 - 29.3)}{60}$$

∴ $$Q_{coil} = 3.96 \text{ kW}$$

67. (d)

By pass factor is given by

$$BF = \frac{t_{db_4} - t_{db_2}}{t_{db_4} - t_{db_1}}$$

$$0.3 = \frac{t_{db_4} - 24.5}{t_{db_4} - 12}$$

$$0.3\, t_{db_4} - 3.6 = t_{db_4} - 24.5$$

∴ $$t_{db_4} = 29.85°\text{C}$$

68. (b)

Capacity of the humidifier is given by

$$= \frac{m_a(\omega_3 - \omega_1)}{1000} \times 60$$

$$= \frac{18.3(8.6 - 6.8) \times 60}{1000} = 1.98 \text{ kg/h}$$

69. (c)

$$RSH = 82000 \text{ kJ/h}; RLH = 18000 \text{ kJ/h}$$

∴ $$RSHF = \frac{82000}{18000 + 82000} = 0.82$$

71. (c)

The effective temperature corresponds to the dry bulb temperature of the saturated air at which a given percentage of people feel comfortable.

73. (d)

Given : p_t = 1.01325 bar, w = 0.0095 kg/kgd.a.

Specific humidity is given by

$$w = \frac{0.622 p_v}{p_t - p_v}$$

$$0.0095 = \frac{0.622 p_v}{1.01325 - p_v}$$

$$\therefore \quad \frac{0.0095 \times 1.01325}{0.622 + 0.0095} = p_v$$

$$\therefore \quad p_v = 0.01524 \text{ bar}$$

74. (b)

Seebeck and Peltier effect are reversible in nature.

75. (d)

Vortex tube consists of the following parts:

1. Nozzle
2. Diaphragm
3. Cold air side
4. Hot air side and
5. Throttling valve