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ESE 2025 : 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.	(b)	**16.**	(d)	**31.**	(b)	**46.**	(a)	**61.**	(a)
2.	(c)	**17.**	(d)	**32.**	(c)	**47.**	(c)	**62.**	(d)
3.	(a)	**18.**	(b)	**33.**	(c)	**48.**	(b)	**63.**	(c)
4.	(a)	**19.**	(a)	**34.**	(c)	**49.**	(a)	**64.**	(d)
5.	(b)	**20.**	(a)	**35.**	(d)	**50.**	(d)	**65.**	(a)
6.	(b)	**21.**	(a)	**36.**	(c)	**51.**	(c)	**66.**	(d)
7.	(b)	**22.**	(a)	**37.**	(a)	**52.**	(a)	**67.**	(a)
8.	(d)	**23.**	(c)	**38.**	(d)	**53.**	(c)	**68.**	(a)
9.	(c)	**24.**	(d)	**39.**	(d)	**54.**	(a)	**69.**	(c)
10.	(b)	**25.**	(b)	**40.**	(a)	**55.**	(b)	**70.**	(a)
11.	(a)	**26.**	(c)	**41.**	(b)	**56.**	(d)	**71.**	(b)
12.	(c)	**27.**	(d)	**42.**	(b)	**57.**	(a)	**72.**	(a)
13.	(c)	**28.**	(d)	**43.**	(b)	**58.**	(d)	**73.**	(d)
14.	(c)	**29.**	(b)	**44.**	(a)	**59.**	(a)	**74.**	(b)
15.	(d)	**30.**	(b)	**45.**	(b)	**60.**	(c)	**75.**	(a)

Section A : Fluid Mechanics and Turbo Machinery

1. (b)

Applying energy conservation between A and D

$$\left(\frac{p}{\rho g}\right)_A = \left(\frac{p}{\rho g}\right)_D + h_{L,AD}$$

$$25.9 = 9 + 10Q_A^2$$

$$Q_A = \frac{13}{10}\text{m}^3/\text{s}$$

Applying energy conservation between B and D

$$\left(\frac{p}{\rho g}\right)_B = \left(\frac{p}{\rho g}\right)_D + h_{L,BD}$$

$$18 = 9 + 4Q_B^2$$

$$Q_B = \sqrt{\frac{9}{4}} = \frac{3}{2}\text{m}^3/\text{s}$$

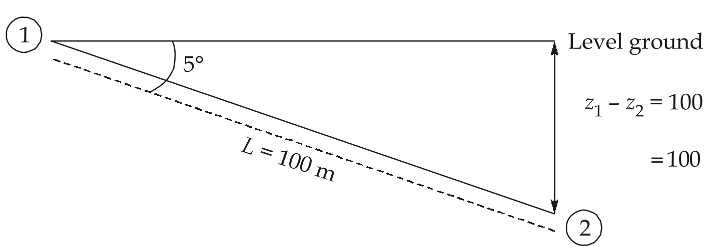
Applying energy conservation between D and C

$$\left(\frac{p}{\rho g}\right)_D = \left(\frac{p}{\rho g}\right)_C + h_{L,DC}$$

$$9 = \left(\frac{p}{\rho g}\right)_C + 1\left(\frac{3}{2} + \frac{13}{10}\right)^2$$

$$\left(\frac{p}{\rho g}\right)_C = 1.16 \text{ m}$$

2. (c)



$z_1 - z_2 = 100 \sin 5$

$= 100 \times 0.087 = 8.7$ m

Applying energy conservation between (1) and (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_{f,1\to 2}$$

$$z_1 - z_2 = \frac{fLV^2}{2gD} = \frac{fL}{D}.\frac{V^2}{2g}$$

$$f = (z_1 - z_2) \times \frac{D}{L} \times \frac{1}{\left(\frac{V^2}{2g}\right)}$$

$$= 8.7 \times \frac{0.2}{100} \times \frac{1}{0.5} = 0.0348 \simeq 0.35 \text{ m}$$

3. (a)

A = Ideal Bingham plastic eg. Drilling mud, Toothpaste, Ketchup
B = Pseudoplastic/shear-thining eg. Blood, Paint, Ink
C = Newtonian fluid eg. Water, Kerosene
D = Dilatant/shear-thickening eg. Wet sand, Silica suspension, Corn starch mixture

4. (a)

$$u = 500(0.5y - y^2)$$

$$\frac{du}{dy} = 500(0.5 - 2y)$$

$$\left.\frac{du}{dy}\right|_{y=0.1\text{ m}} = 150\text{s}^{-1}$$

$$\tau|_{y=0.1\text{m}} = \mu \left.\frac{du}{dy}\right|_{y=0.1\text{ m}}$$

$$= 0.001 \times 150 = 0.15 \text{ Pa}$$

5. (b)

$$F = \rho g \forall$$

$$= \rho g A H$$

$\forall$ = Volume between plate and its projection upto free surface

6. (b)

$$\rho_{\text{air}}\, gH = \rho_{Hg} \cdot g\left(h_{base} - h_{top}\right)$$

$$H = \frac{13600}{1}(750 - 600) \times 10^{-3}$$

$$= 2040 \text{ m}$$

7. (b)

- The center of pressure is always below the centroid for a submerged surface that is not horizontal.
- The hydrostatic force acting on a submerged plane surface is given by

$$F = \rho g A \bar{x}$$

$$= A(\rho g \bar{x})$$

where $\bar{x}$ is vertical distance between the free surface and centroid of the plane surface.

8. (d)

Given:

$$Q = f\{\Delta P, \rho, D\}$$
$$= f\{Q, \Delta P, \rho, D\}$$
$$\pi_1 = \Delta P\{Q, \rho, D\}$$
$$M^0L^0T^0 = ML^{-1}T^{-2}\{(L^3T^{-1})^a(ML^{-3})^b(L)^c\}$$

Equating exponent of M, T and L respectively.

$$0 = 1 + b \qquad \therefore\ b = -1$$
$$0 = -2 - a \qquad \therefore\ a = -2$$
$$0 = -1 + 3a - 3b + c \qquad \therefore\ c = 4$$
$$\pi_1 = \Delta P(Q^{-2}\rho^{-1}L^4)$$
$$Q = CD^2\sqrt{\frac{\Delta P}{\rho}}$$

9. (c)

Viscous flows can be irrotational, even if vorticity is zero, viscosity can still be present.

10. (b)

Boundary layer thickness is given by

$$\delta \propto \frac{x}{\sqrt{\text{Re}}}$$

Hence as Re no. decreases, boundary layer thickness increases.

11. (a)

$$\Delta P = \frac{8\mu l Q}{\pi R^4}$$

12. (c)

ψ exist i.e. flow is possible but not necessarily incompressible.

$\nabla^2\psi = 0$ means flow is irrotational.

13. (c)

$$V = \sqrt{2gx\left(\frac{\rho_w}{\rho_a} - 1\right)}$$
$$= \sqrt{2 \times 9.81 \times 0.05\left(\frac{1000}{1} - 1\right)}$$
$$= 31.3 \text{ m/s} \simeq 31 \text{ m/s}$$

14. (c)

For incompressible flow,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$5y + \frac{\partial v}{\partial y} = 0$$

$$v = -\frac{5y^2}{2} + f(x)$$

For irrotational flow,

$$\frac{\partial v}{\partial x} = \frac{\partial u}{\partial y}$$

$$f'(x) = 5x$$

$$f(x) = \frac{5x^2}{2} + C$$

$$V = -\frac{5y^2}{2} + \frac{5x^2}{2} + C$$

15. (d)

Navier stoke's equation in x-direction.

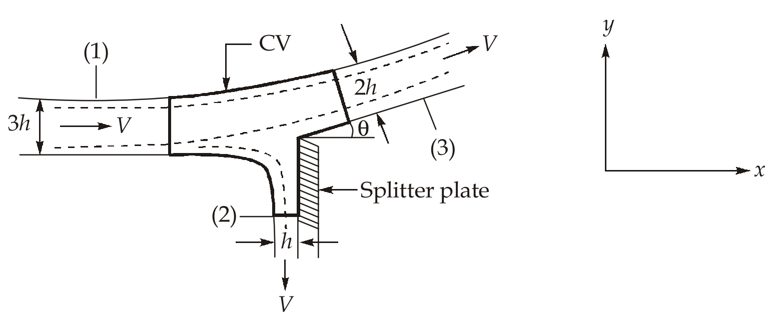
$$\rho a_x = -\frac{\partial P}{\partial x} + \mu \nabla^2 u + \rho g_x$$

Assume, inviscid flow,

$\Rightarrow$
$$\mu = 0$$
$$g_x = 0$$

$\therefore$
$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial x}$$

16. (d)



As the weight of water and friction along plate is neglected, so the force by jet on the plate in y-direction must be zero.

$$\Sigma F_y = \left[(\dot{m}v)_{out} - (\dot{m}v)_{in}\right]_{y-dir}$$

$$0 = \rho(2h \times 1)V \cdot V \sin\theta + \rho(h \times 1)V \cdot (-V) \qquad \left[\because (\dot{m}v)_{in} = 0\right]$$

$\therefore$
$$\theta = \sin^{-1}(0.5)$$

17. (d)

Applying mass conservation,

$$\frac{\partial \rho}{\partial t}+\frac{\partial \rho u}{\partial x}+\frac{\partial \rho v}{\partial y}+\frac{\partial \rho w}{\partial z} = 0$$

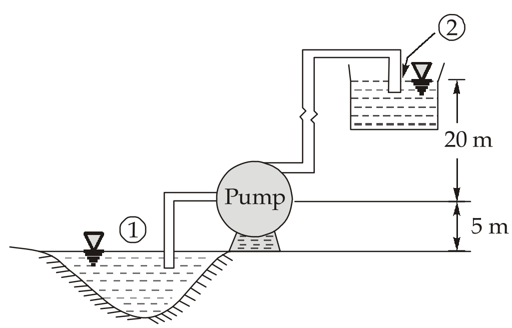
$$\Rightarrow \quad \frac{\partial \rho}{\partial t}+\rho\frac{\partial u}{\partial x}+u\frac{\partial \rho}{\partial x}+\rho\frac{\partial v}{\partial y}+v\frac{\partial \rho}{\partial y}+\rho\frac{\partial w}{\partial z}+w\frac{\partial \rho}{\partial z} = 0$$

$$\Rightarrow \quad \left(\frac{\partial \rho}{\partial t}+u\frac{\partial \rho}{\partial x}++v\frac{\partial \rho}{\partial y}++w\frac{\partial \rho}{\partial z}\right)+\rho\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right) = 0$$

$$\Rightarrow \quad \frac{D\rho}{Dt}+\rho\,\nabla\cdot\vec{V} = 0$$

$$\Rightarrow \quad \nabla\cdot\vec{V} = -\frac{1}{\rho}\frac{D\rho}{Dt} = -\frac{1}{2}\times 5 = -2.5\,s^{-1}$$

18. (b)



Applying energy conservation between (1) and (2)

$$H_p = 5 + 20 = 25 \text{ m}$$

$$\text{Power} = \frac{\rho Q g H_p}{\eta} = \frac{10^3\times 3\times 20\times 10^{-4}\times g\times 25}{0.75}\times 10^{-3}\,\text{kW}$$

$$= 2 \text{ kW}$$

19. (a)

Statement I is correct : This is Archimedes' principle, which states that the buoyant force on a submerged object equals the weight of the displaced fluid.

Statement II is correct : The buoyant force results from the pressure difference between the upper and lower surfaces of the submerged body, making it the net hydrostatic force.

20. (a)

Statement 3 is incorrect because Prandtl boundary layer theory does not assume viscous force dominate over inertial force. Instead, it assumes a balance between them within the boundary layer while inertial effects remain dominant in the outer flow.

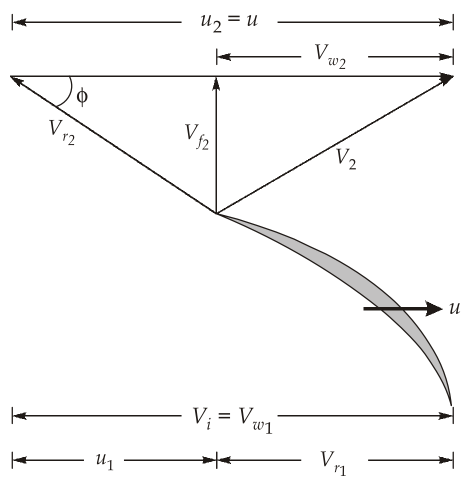
21. (a)

- Kaplan turbines are high head turbines meaning they rely on pressure difference rather than direct impulse force to generate power.
- The axial flow design works best under low-pressure conditions, which occur at low head sites with large flow rate.
- At high heads, the water velocity would be too high, leading to excessive mechanical stress.

22. (a)

$$RP = \eta(\rho Q g H)$$
$$= 0.9(10^3 \times 10 \times 9.81 \times 81) \times 10^{-3}$$
$$= 7151.49 \text{ kW}$$
$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{300\sqrt{7151.49}}{(3^4)^{\frac{5}{4}}} = 104.4$$

23. (c)



$$u = \frac{\pi DN}{60} = \frac{\pi \times 1 \times 764}{60} = 40 \text{ m/s}$$
$$V_{r_1} = V_{r_2} = V_1 - u$$
$$= 100 - 40 = 60 \text{ m/s}$$
$$\phi = 180 - \delta = 180° - 120° = 60°$$
$$V_{w_2} = V_{r_2}\cos\phi - u$$
$$= 40\cos 60° - 40 = -20 \text{ m/s}$$
$$\eta = \frac{\dot{m}(V_{w_1} - V_{w_2})u}{\frac{1}{2}\dot{m}V_1^2} = \frac{2(V_{w_1} - V_{w_2})u}{V_1^2}$$

$$= \frac{2 \times (100 - 20) \times 40}{100^2} = 0.64 \text{ or } 64\%$$

24. (d)

As flow rate increases frictional losses in the suction pipe increase, leading to higher NPSH requirement.

25. (b)

$$\begin{aligned} \text{Power} &= \eta_0(\rho Q g H) \\ &= 0.9(10^3 \times 50 \times 9.81 \times 81) \times 10^{-3} \\ &= 35757.45 \text{ kW or } 36 \text{ MW} \end{aligned}$$

26. (c)

Power available from a single turbine

$$\begin{aligned} P &= \left(\frac{N_s}{N}\right)^2 \times H^{5/2} = \left(\frac{225}{550}\right)^2 \times (81)^{5/2} \\ &= 9882.167 \text{ kW} \end{aligned}$$

$$\text{Number of turbines} = \frac{35757.45}{9882.167} = 3.62$$

Thus 4 turbines are to be installed.

27. (d)

- Centrifugal compressors are ideal for low mass flow, high-pressure ratio applications (e.g. turbo chargers, aircraft auxiliary power units). Axial compressors are used in high-flow applications (e.g. jet engines, gas turbines).
- Axial compressors are more compact for the same flow rate because they work in a continuous flow direction, unlike centrifugal compressors which require large radial space.
- The DOR, which defined the ratio of static pressure rise in the rotor to the total pressure rise in the stage, affects the efficiency of both compressors.

28. (d)

- Surge occurs at low flow rates, causing flow reversal and leading to pressure fluctuation.
- Centrifugal compressors experience surge but are less prone to rotating stall, as their flow patterns are different from axial compressor.

29. (b)

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

$$P \propto QH \quad \text{...(i)}$$

$$Q \propto D^2\sqrt{H} \quad \text{...(ii)}$$

$$u \propto \sqrt{H} \alpha DN \quad \text{...(iii)}$$

Putting (ii) and (iii) in equation (i),

$$P \propto \frac{H^{5/2}}{N^2}$$

$$\Rightarrow \quad \frac{PN^2}{H^{5/2}} = \text{Constant}$$

$$\left.\frac{PN^2}{H^{5/2}}\right|_P = \left.\frac{PN^2}{H^{5/2}}\right|_M$$

$$\frac{30\times100^2}{20^{2.5}} = \frac{40\times N_m^2}{20^{2.5}}$$

$$N_m = \sqrt{\frac{30}{40}}\times100 = 86.6 \text{ rpm} \simeq 87 \text{ rpm}$$

30. (b)

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1500\sqrt{2.25}}{(16)^{3/4}} = 281.25$$

31. (b)

- As clearance volume increases, more gas remains in the cylinder, reducing the fresh gas intake. This reduces the volumetric efficiency.
- In reality, compression in a reciprocating compressor is usually polytropic because heat transfer is not instantaneous. Even in ideal case, if the process are true isothermal, perfect heat exchange would be required, which is not practically possible.
- Increasing speed does not eliminate the clearance volume effect, it is a physical constraint even if speed increases, the trapped gas still remains in the clearance space. Increasing speed may slightly reduce re-expansion losses but does not eliminate clearance volume effects.

32. (c)

$$V_{r_1} = \sqrt{u_1^2 + v_1^2} = \sqrt{630^2 + 160^2} = 650 \text{ m/s}$$

$$M = \frac{V_{r_1}}{C_1} = \frac{650}{867} = 0.75$$

33. (c)

At $y = \delta$, $$\frac{dV_x}{dy} = 0$$

$$\frac{d}{dy}\left(0.5y - 0.5y^3\right) = 0$$

$$\Rightarrow \quad 0.5 - 1.5y^2 = 0$$

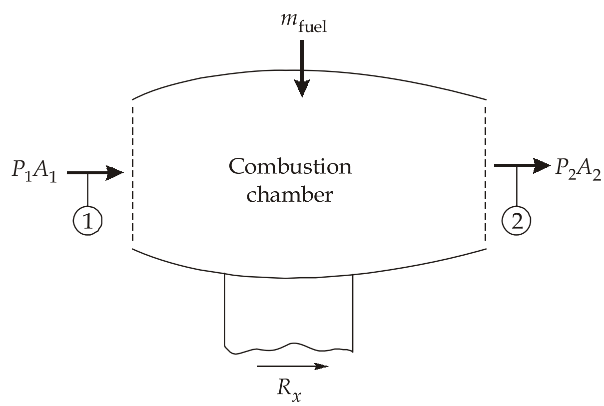
$$y = \frac{1}{\sqrt{3}} \text{ m}$$

$$\therefore \quad y = \delta = \frac{1}{\sqrt{3}} \text{ m}$$

34. (c)

$$W = \dot{m}\phi_s \cdot \phi_w u^2$$
$$= 30 \times 0.85 \times 1.05 \times 300^2 \times 10^{-3}$$
$$= 2409.75 \text{ kW or } 2.41 \text{ MW}$$

35. (d)



$$\Sigma F_x = (\dot{m}v)_{out} - (\dot{m}v)_{in}$$
$$R_x + P_1A_1 - P_2A_2 = \left(\dot{m}_a + \dot{m}_f\right)V_2 - \dot{m}_a V_1$$
$$R_x + 100(0.25 - 0.2) = 150\left[\left(1+\frac{1}{30}\right)2100 - 500\right]\times 10^{-3}$$
$$R_x + 5 = 250.5$$
$$R_x = 245.5 \text{ kN}$$

36. (c)

Centrifugal compressor

1. Radial flow machine.
2. Not preferred for multistage.
3. Wide operating range between surging and chocking limit and head capacity curve is flat and part load performance is better.
4. Low starting torque is required.
5. Suitable for low pressure ratios upto 4.

37. (a)

- Moisture content in steam turbines causes blade erosion, which is more severe in reaction turbines because reaction turbines operate at lower pressure in later stages, where condensation of steam occurs. In contrast, impulse turbines have higher pressure steam throughout reducing erosion risk.
- Reaction turbines are commonly used in large-scale, high speed applications like power plants because they provide continuous energy extraction. They are generally more efficient in large steam turbines due to better utilization of expansion energy.

Section B : Production Engineering & Material Science-1

38. (d)

Given : h = 450 mm, Q = 1728000 mm^3/s, g = 10000 mm/s^2

At the base of base of down sprue:

$$\text{Velocity, } V = \sqrt{2\times g\times h}$$
$$= \sqrt{2\times 10000\times 450} = \sqrt{9000000}$$
$$V = 3000 \text{ mm/s}$$

Area at the base of down sprue to maintain the flow rate

$$A = \frac{Q}{v} = \frac{1728000}{3000} = 576 \text{ mm}^2$$

39. (d)

40. (a)

Hot set = To cut hot metal

Fullers, top and bottom = To shape inside curves. To form corrugations for elongating metal

Swages, top and bottom = To shape convex surfaces and to give finish to round, square, hexagonal or octagonal shaped sections

Anvil = To forge art, bend and shape the work

Sewage block = To shape or bend the work to any form and to knock heads of bolts, etc.

Gouge = To cut plates to curves

41. (b)

$$V_{oc} = 78 \text{ V}; I_{sc} = 120 \text{ A}; L = 4 \text{ mm}; \eta = 80\%$$
$$V = 20 + 1.5L = 20 + 1.5 \times 4 = 26 \text{ Volts}$$

We know that,

$$\frac{V}{V_{oc}} + \frac{I}{I_{sc}} = 1$$
$$\frac{26}{78} + \frac{I}{120} = 1$$
$$\frac{1}{3} + \frac{I}{120} = 1$$
$$\frac{I}{120} = 1 - \frac{1}{3}$$
$$\frac{I}{120} = \frac{2}{3}$$
$$I = 80\text{A}$$

Power consumed = VI = 26 × 80 = 2080 Watt

Heat input to workpiece = 2080 × η

= 2080 × 0.80 = 1664 Watt

42. (b)

Flashes of fins are thin projections of metal not intended as a part of casting. These usually occur at the parting line of the mould or core section. These are caused by loose clamping of the mould, insufficient weight on the top part of the mould and excessive rapping of the pattern before it is withdrawn from the mould.

43. (b)

The split die opens horizontally to remove the forging.

44. (a)

Fixed automation is characterised by having the sequence of operations to manufacture or assemble a product fixed by the equipment configuration.

Programmable automation equipment is highly reprogrammable to accommodate high product variety but has low production rates relative to fixed automation.

45. (b)

The usual value of biting angle are

2° - 10° = For cold rolling of oiled sheet and strip

15° - 20° = For hot rolling of oiled sheet and strip

24° - 30° = For hot rolling of heavy fillets and blooms

46. (a)

We know that,

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

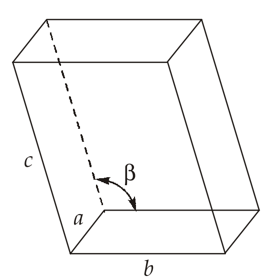
$$I = \sqrt{\frac{H}{Rt}} = \sqrt{\frac{2000}{400 \times 10^{-6} \times 0.4}}$$

$$I = 3535.53 \text{ A}$$

47. (c)

The source of heat in electroslag welding is the electrical resistance of molten flux and slag in the path of current flow. The process is basically used for vertical welding of thick plates.

48. (b)

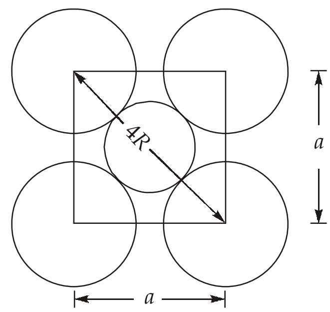


For monoclinic crystal system,

$a \neq b \neq c$, $\alpha = \gamma = 90° \neq \beta$

49. (a)

In FCC unit cell the atoms touch one another across a face diagonal the length of which is $4R$. Since the unit cell is a cube, its volume is a^3, where a is the cell edge length.



From the right angle on the face,

$$a^2 + a^2 = (4R)^2$$

$$a = 2\sqrt{2}R$$

$$\text{FCC unit cell volume, } V = a^3 = \left(2\sqrt{2}R\right)^3 = 16R^3\sqrt{2}$$

50. (d)

High carbon steel have higher tensile strength and are harder than other plain carbon steels. They also readily respond to heat treatment. These are used for making hand tools such as wrenches, chisels, punches etc.

51. (c)

The disadvantages of zinc are strong anisotropy exhibited under deformed conditions, lack of dimensional stability under ageing conditions, a reduction in impact strength at lower temperatures and the susceptibility to inter granular corrosion.

52. (a)

53. (c)

- Silicon steels are used for cores of electrical motors, generators and transformers.
- Chromium-Vanadium steels are used under heavy static or dynamic loading.
- Silicon-Manganese steels are used for leaf springs, coiled springs, chisel and punches.
- Molybdenum steels are used for transmission gears, bearing and axles.

54. (a)

Carbon as solid solution in BCC iron, is soft, ductile and magnetic material. Carbon as solid solution in FCC iron, is soft, moderately strong and non magnetic.

55. (b)

Quick lime : Caustic lime (CaO) : It has a great affinity for water and is caustic in nature.
Hydraulic lime : It is obtained from kinkar or by mixing clay with lime stone. When clay is added, it sets under water.
Lump lime : These are in the form of coarse powder lumps. It is difficult to preserve lump lime.
Fat lime : Calcium carbonate ($CaCO_3$) is known as fat lime.

56. (d)

Flexible automation is suitable for a planned workload, especially when there is a need for moderate production volumes with some variations in product design. It allows for automatic adjustments to accommodate different products without significant downtime, making it ideal for batch production or frequently changing designs.

Section C : Thermodynamics-2 + RAC-2

57. (a)

We know that,

For steady state,
$$\frac{dA}{dT} = \left(1-\frac{T_0}{T_r}\right)\dot{Q}-\left(1-\frac{T_0}{T_f}\right)\dot{Q}-\dot{W}-\dot{I} = 0$$

$\therefore$
$$\dot{I} = \left(1-\frac{T_0}{T_r}\right)\dot{Q}-\left(1-\frac{T_0}{T_f}\right)\dot{Q} \qquad \left[\text{As } \dot{W}=0\right]$$

$$\dot{I} = \left(1-\frac{300}{1200}\right)7.2-\left(1-\frac{300}{400}\right)7.2$$

$$\dot{I} = 5.4 - 1.8$$

$$\dot{I} = 3.6 \text{ kW}$$

58. (d)

$$\phi = U - U_0 + p_0(V - V_0) - T_0(S - S_0)$$
$$\phi = H - H_0 - V(p - p_0) - T_0(S - S_0) \qquad [\text{As } H = U + pV]$$

Since vacuum has zero mass,

$\therefore$ $U = 0, H = 0 \text{ and } s = 0$

If the vacuum was reduced to the dead state,

$$U_0 = 0, H_0 = s_0 = 0, \text{ and } V_0 = 0$$

The pressure p for the vacuum is zero,

But $p_0 = 1 \text{ bar} = 100 \text{ kPa and } V = 1 \text{ m}^3$

$$\phi = p_0V = 100 \times 1 = 100 \text{ kJ}$$

59. (a)

60. (c)

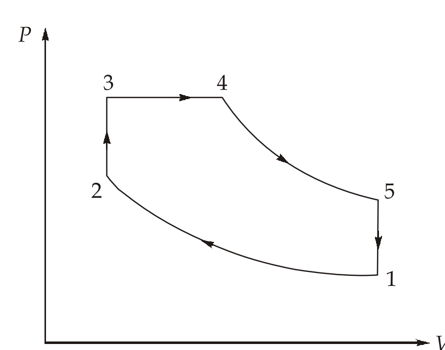
$$T_1 = 273 + 47 = 320 \text{ K}$$

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = (16)^{1.5-1}$$

$$\frac{T_2}{T_1} = (16)^{0.5}$$

$$T_2 = 4 \times 320 = 1280 \text{ K}$$

$$p_2 = p_1\left(\frac{v_1}{v_2}\right)^{\gamma} = 1\times(16)^{1.5} = 64 \text{ bar}$$



$$T_3 = T_2 \times \frac{p_3}{p_2} = 1280 \times \frac{70}{64} = 1400 \text{ K}$$

$$Q_{2\text{-}3} = C_v (T_3 - T_2) = 0.72\,(1400 - 1280)$$

$$Q_{2\text{-}3} = 86.4 \text{ kJ/kg}$$

61. (a)

The deviation of a gas from ideal gas behaviour is greatest in the vicinity of the critical point.

62. (d)

$$\text{Mass fraction of } CH_4 = \frac{\text{Mass of } CH_4}{\text{Total mass}} = \frac{8}{19} = 0.42$$

Mole fraction of CH_4,

$$n_{O_2} = \frac{4}{32} = 0.125$$

$$n_{N_2} = \frac{7}{28} = 0.25$$

$$n_{CH_4} = \frac{8}{16} = 0.5$$

$$n_{\text{Total}} = n_{O_2} + n_{N_2} + n_{CH_4}$$

$$= 0.125 + 0.25 + 0.5 = 0.875$$

$\therefore$

$$\text{Mole fraction of } CH_4 = \frac{n_{CH_4}}{n_{Total}} = \frac{0.5}{0.875} = 0.57$$

63. (c)

We know that,

Thermal efficiency of the cycle is given as,

$$\eta = 1 - \frac{T_1}{T_2}$$

$$\eta = 1 - \frac{310}{746.5} \qquad [T_1 = 273 + 37 = 310 \text{ K}, T_2 = 473.5 + 273 = 746.5 \text{ K}]$$

$$\eta = 0.5847 \text{ or } 58.47\%$$

64. (d)

The constant volume specific heat, C_v of a Vander Waals gas is not dependent on volume, and is therefore a function of temperature T alone.

We know that,

$$\left(\frac{\partial C_v}{\partial V}\right)_T = T\frac{\partial}{\partial T}\left[\left(\frac{\partial P}{\partial T}\right)_v\right]_v \qquad \text{...(i)}$$

From Vander Waals equation of state,

$$\left(\frac{\partial P}{\partial T}\right)_v = \frac{R}{v-b} \qquad \text{...(ii)}$$

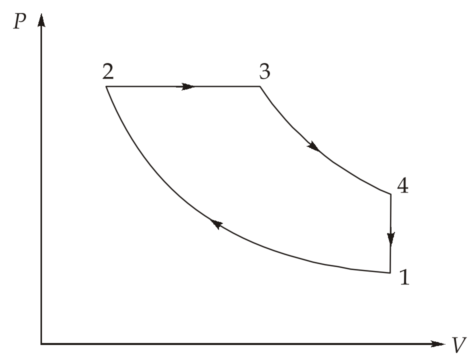
From equation (i) and (ii), we get

$$\left(\frac{\partial C_v}{\partial V}\right)_T = T\frac{\partial}{\partial T}\left(\frac{R}{v-b}\right)_v = 0$$

Hence, C_v is not dependent on the volume v.

65. (a)

$$T_2 = 600 + 273 = 873 \text{ K}$$
$$T_3 = 1480 + 273 = 1753 \text{ K}$$



$$\text{Cut off ratio } (r_c) = \frac{v_3}{v_2} = \frac{T_3}{T_2}$$

$$r_c = \frac{1753}{873} = 2.01$$

$$\text{Heat supplied, } Q = C_p\,(T_3 - T_2)$$
$$= 1.005(1753 - 873)$$
$$= 884.4 \text{ kJ/kg}$$

66. (d)

The exergy of a closed system is either positive or zero. It is never negative. Even a medium at low temperature and/ or low pressure contains exergy since a cold medium can serve as the heat sink to a heat engine that absorbs heat from the environment and an evacuated space makes it possible for the atmospheric pressure to move a piston and do useful work.

67. (a)

The adiabatic saturation temperature and the wet bulb temperature are taken to be equal for practical purposes.

68. (a)

$$h_a = 85.2 \text{ kJ/kg}, \; h_b = 42.4 \text{ kJ/kg}$$
$$h_c = 57.5 \text{ kJ/kg}, \; v_{sa} = 0.90 \text{ m}^3\text{/kg}$$

$$\text{The mass of air circulated per minute} = \frac{300}{0.9} = 333.3 \text{ kg/min}$$

$$\text{Sensible heat removed} = 333.3\,(h_c - h_b)$$
$$= 333.3(57.5 - 42.4)$$
$$= 5032.83 \simeq 5033 \text{ kJ/min}$$

69. (c)

$$\text{Latent heat removed} = 333.3\,(h_a - h_c) = 333.3(85.2 - 57.5) = 9232.41 \text{ kg/min}$$

$$\text{Sensible heat ratio (SHR)} = \frac{\text{Sensible heat}}{\text{Total heat}} = \frac{5032.83}{5032.83 + 9232.41} = 0.352$$

70. (a)

Clothing affects the effective temperature because the heat loss by convection and radiation depends upon the body surface temperature. The body surface temperature will be affected by the clothing as it comes in the way of heat transfer in the form of thermal resistance.

71. (b)

The air enters the tube tangentially and forms a free vortex.

72. (a)

$$h_1 = 2844 \text{ kJ/kg};\ h_{2'} = 2062 \text{ kJ/kg};\ h_4 = 2336 \text{ kJ/kg}$$

We know that,

$$\text{Entrainment efficiency } (\eta_e) = \frac{h_1 - h_4}{h_1 - h_{2'}} = \frac{2844 - 2336}{2844 - 2062}$$

$$\eta_e = 0.649 \simeq 0.65 \text{ or } 65\%$$

73. (d)

- An important advantage of this refrigeration system is the independence of COP on the size of thermo-electric refrigerator and this makes it particularly attractive to use Peltier cooling when the cooling capacity required is high.
- More power is needed to run the system.
- Low COP.
- Advantageous only for units of smaller quantity.

74. (b)

If unsaturated air passed through a spray of continuously recirculated water, the specific humidity will increase while DBT decreases. This is the process of adiabatic saturation or evaporative cooling.

75. (a)

The temperature of water when mixed from both wells.

$$T = \frac{700 \times 18 + 2000 \times 15}{700 + 2000} = 15.77°\text{C}$$

The heat extracted from the water in the evaporator per minute

$$= 2700 \times 4.2 \times (15.77 - 10) = 65431.8 \simeq 65432 \text{ kJ/min}$$

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