DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 20

Full Syllabus Test-2 (Paper-II)

1.	(b)	23.	(b)	45.	(a)	67.	(b)	89.	(c)	111.	(c)	133.	(c)
2.	(a)	24.	(c)	46.	(b)	68.	(d)	90.	(a)	112.	(c)	134.	(c)
3.	(d)	25.	(b)	47.	(b)	69.	(c)	91.	(d)	113.	(a)	135.	(c)
4.	(d)	26.	(d)	48.	(b)	70.	(d)	92.	(d)	114.	(b)	136.	(d)
5.	(a)	27.	(c)	49.	(d)	71.	(b)	93.	(c)	115.	(c)	137.	(a)
6.	(a)	28.	(a)	50.	(d)	72.	(c)	94.	(b)	116.	(c)	138.	(d)
7.	(a)	29.	(d)	51.	(c)	73.	(a)	95.	(b)	117.	(b)	139.	(b)
8.	(a)	30.	(a)	52.	(a)	74.	(a)	96.	(d)	118.	(a)	140.	(d)
9.	(b)	31.	(c)	53.	(a)	75.	(d)	97.	(c)	119.	(c)	141.	(b)
10.	(b)	32.	(c)	54.	(c)	76.	(a)	98.	(b)	120.	(a)	142.	(d)
11.	(b)	33.	(d)	55.	(c)	77.	(c)	99.	(c)	121.	(c)	143.	(a)
12.	(b)	34.	(b)	56.	(b)	78.	(b)	100.	(c)	122.	(b)	144.	(a)
13.	(c)	35.	(d)	57.	(d)	79.	(b)	101.	(b)	123.	(a)	145.	(a)
14.	(b)	36.	(c)	58.	(c)	80.	(c)	102.	(c)	124.	(c)	146.	(a)
15.	(c)	37.	(d)	59.	(d)	81.	(c)	103.	(b)	125.	(c)	147.	(d)
16.	(d)	38.	(a)	60.	(b)	82.	(c)	104.	(b)	126.	(c)	148.	(b)
17.	(d)	39.	(b)	61.	(a)	83.	(c)	105.	(a)	127.	(a)	149.	(c)
18.	(d)	40.	(c)	62.	(b)	84.	(b)	106.	(a)	128.	(c)	150.	(b)
19.	(c)	41.	(c)	63.	(a)	85.	(b)	107.	(c)	129.	(d)		
20.	(a)	42.	(c)	64.	(c)	86.	(c)	108.	(b)	130.	(c)		
21.	(b)	43.	(b)	65.	(d)	87.	(c)	109.	(a)	131.	(d)		
22.	(a)	44.	(a)	66.	(b)	88.	(d)	110.	(c)	132.	(d)		

Answer Key changed for Q.19

DETAILED EXPLANATIONS

1. (b)

$$\text{Static deflection in } k_1, \Delta_1 = \frac{mg}{k_1}$$

$$\text{Static deflection in } k_2, \Delta_2 = \frac{mgl_1}{l_2 k_2}$$

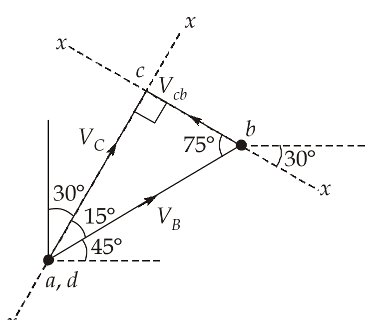
$$\text{Net static deflection in } m, \Delta = \Delta_1 + \frac{\Delta_2 l_1}{l_2} = \frac{mg}{k_1} + \frac{mgl_1^2}{k_2 l_2^2}$$

$$\text{Natural frequency, } \omega_n = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{1}{m\left(\frac{1}{k_1} + \frac{l_1^2}{k_2 l_2^2}\right)}} = \sqrt{\frac{k_1 k_2 l_2^2}{m\left(k_2 l_2^2 + k_1 l_1^2\right)}}$$

2. (a)

$$V_B = \omega_{\text{input}} \times AB = \sqrt{2} \times 4\sqrt{2}$$

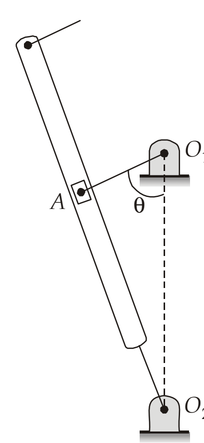
$$= 8 \text{ cm/s}$$



From velocity diagram, $V_C = V_B \cos 15° = 8 \times 0.966 = 7.728$ cm/s

$$\omega_{CD} = \frac{V_C}{CD} = 1.288 \text{ rad/ s}$$

3. (d)



As $\dfrac{\text{Cutting time}}{\text{Return time}} = 3$

$\Rightarrow$ $\dfrac{360° - 2\theta}{2\theta} = 3$

$\Rightarrow$ $\theta = 45°$

$$O_1O_2 = \frac{O_1A}{\cos 45°} = \frac{120}{\left(\frac{1}{\sqrt{2}}\right)} = 169.7 \simeq 170 \text{ mm}$$

4. **(d)**

$$\text{Path of approach, } AB = AC - BC$$

$$AC = \sqrt{OA^2 - OC^2} = \sqrt{5^2 - 3^2} = 4 \text{ cm}$$

As, $$AB = AC - BC = 4 - 2 = 2 \text{ cm}$$

5. **(a)**

The Scotch Yoke (also known as slotted link mechanism) is a reciprocating motion mechanism, converting the linear motion of a slider into rotational motion, or vice versa. The piston or other reciprocating part is directly coupled to a sliding yoke with a slot that engages a pin on the rotating part.

6. **(a)**

$$\text{Maximum velocity of sliding} = \omega \times d$$

$$= 2 \times \frac{22}{7} \times \frac{630}{60} \times 0.02 = 66 \times 0.02$$

$$= 1.32 \text{ m/s}$$

7. **(a)**

As side thrust reduces, jamming tendency decreases.

8. **(a)**

Given: $m = 5$ kg, $J = 150$ kg-cm^2,

Let m_1 and m_2 be the equivalent point masses placed at a_1 and a_2 distance from G.

For dynamically equivalent system, three conditions are :

$$m_1 a_1 = m_2 a_2 \quad \dots \text{(i)}$$

$$m_1 a_1^2 + m_2 a_2^2 = J \quad \dots \text{(ii)}$$

$$m_1 + m_2 = m \quad \dots \text{(iii)}$$

From equation (iii) $$m_1 + m_2 = 5$$

$\Rightarrow$ $$m_1 = 5 - m_2$$

From equation (i) $$m_1 4 = m_2 a_2$$

$\Rightarrow$ $$(5 - m_2)4 = m_2 a_2$$

$\Rightarrow$ $$20 = m_2 (4 + a_2)$$

$\Rightarrow$ $$m_2 = \frac{20}{4 + a_2}$$

As $$m_1 = 5 - m_2$$

$$= 5 - \frac{20}{4 + a_2} = \frac{5a_2}{4 + a_2}$$

From equation (ii),

$$\left(\frac{5a_2}{4 + a_2}\right)16 + \left(\frac{20}{4 + a_2}\right)a_2^2 = 150$$

$$\Rightarrow \quad 80a_2 + 20a_2^2 = 600 + 150a_2$$
$$\Rightarrow \quad 20a_2^2 - 70a_2 - 600 = 0$$
$$\Rightarrow \quad 2a_2^2 - 7a_2 - 60 = 0$$
$$a_2 = \frac{7 \pm \sqrt{49+480}}{4} = \frac{7 \pm \sqrt{529}}{4}$$
$$= \frac{30}{4} \text{ or } -\frac{16}{4} = 7.5 \text{ or } -4$$

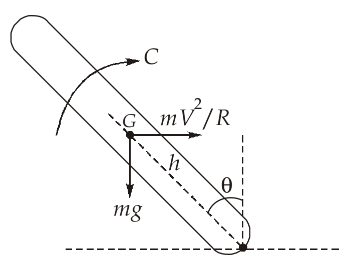
As –4 cm would mean both m_1 and m_2 are on same side, therefore 7.5 cm is correct.

9. **(b)**

- Pressure angle varies from maximum at the beginning of engagement, reduces to zero at the pitch point and again increases to maximum at the end of engagement resulting in less smooth running of the gears.
- Exact centre-distance is required in case of cycloidal teeth profile.
- Cycloidal teeth involves double curve, epycycloid and hypocycloid. This complicates the manufacturing process and hence increases the manufacturing cost.
- The cycloidal teeth have spreading flanks and thus are stronger for the same pitch of involute teeth.

10. **(b)**

Given, $r = 0.2$ m, $I_w = 1$ kg-m^2, $m = 180$ kg, $h = 0.5$ m, $I_E = 0.3$ kg-m^2, $\omega_E = 3.5\ \omega_\omega$, $V = 20$ m/s, $R = 80$ m



$$mgh\sin\theta = \frac{mV^2}{R}h\cos\theta + (2I_w\omega_\omega\cos\theta + I_E\omega_E\cos\theta)\omega_P$$
$$mgh\sin\theta = \frac{mV^2h\cos\theta}{R} + (2I_w + 3.5I_E)\frac{V}{r}\times\frac{V}{R}\cos\theta$$
$$\tan\theta = \frac{\left[mh + (2I_\omega + 3.5I_E)\frac{1}{r}\right]V^2}{mghR}$$
$$= \frac{\left[180\times0.5 + (2\times1 + 3.5\times0.3)\frac{1}{0.2}\right]\times 20^2}{180\times10\times0.5}$$
$$= \frac{103.5\times400}{900\times80} = \frac{1.035\times5}{9} = \frac{5.175}{9} = 0.575$$
$$\theta \approx 30° \text{ as } \tan30° = 0.577$$

11. (b)

Taking moment about 10 kg mass plane,

$$B_1 \times 40 \times 50 = B_2 \times 50 \times 80$$

$$\Rightarrow \quad B_1 = 2B_2$$

$$\text{Balancing force, } 10 \times 39 = B_1 \times 40 + B_2 \times 50$$

$$\Rightarrow \quad 390 = 2 \times B_2 \times 40 + B_2 \times 50$$

$$\Rightarrow \quad B_2 = \frac{390}{130} = 3\text{ kg}$$

12. (b)

$$\eta_{air} = 1 - \frac{1}{(r)^{\gamma_{air}-1}} = 1 - \frac{1}{(8)^{1.4-1}} = 1 - \frac{1}{(8)^{0.4}}$$

$$= 0.564 = 56.4\%$$

$$\eta_{helium} = 1 - \frac{1}{(r)^{\gamma_{helium}-1}} = 1 - \frac{1}{(8)^{5/3-1}} = 1 - \frac{1}{(8)^{2/3}} = 1 - \frac{1}{4}$$

$$= 0.75 = 75\%$$

So, change $\eta_{helium} - \eta_{air} = 75 - 56.4 = 18.6\%$

It can be solved by checking options we know that

$$8^{0.33} \text{ or } 8^{1/3} = 2$$

So, $1 - \frac{1}{(8)^{1/3}} = 50\%$

Change in efficiency is given by:

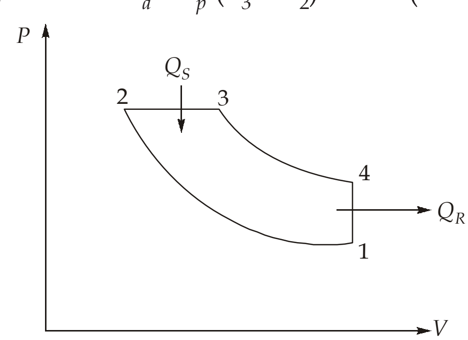
So, change $\eta_{helium} - \eta_{air} = \frac{1}{(8)^{0.4}} - \frac{1}{(8)^{2/3}}$

If first term is like $\frac{1}{(8)^{0.33}} = 0.5,$ then difference will be 0.25 (25%), so the value is greater than 0.333 i.e. 0.4, the difference will be less than 25%. In option, only one option i.e. (b) is less than 25%.

13. (c)

Heat addition at constant pressure, $Q_s = (m_a + m_f) \times c_p (T_3 - T_2)$

$$m_f \times CV = m_a \times c_p (T_3 - T_2) \qquad (\because m_a + m_f \approx m_a)$$



$$CV\times\frac{m_f}{m_a} = c_p\,(T_3 - T_2)$$

$$\frac{CV}{AFR\times c_p} = (T_3 - T_2) \qquad \text{[where, AFR is air fuel ratio]}$$

$$T_3 = T_2 + \frac{CV}{AFR\times c_p} = 800 + \frac{40\times10^3}{25\times1} = 2400\text{ K}$$

$$\text{Cut-off ratio, } \rho = \frac{T_3}{T_2} = \frac{2400}{800} = 3$$

14. (b)

For C.I. engines fuel most preferred are paraffins and for S.I. engines fuel most preferred are aromatics.

15. (c)

$$\text{Brake power, BP} = T_{max}\times\omega = 270\times\omega$$

$$bmep = \frac{BP}{V_s\times N'} = \frac{270\times\omega\times1000\times2}{3\times N} \qquad \left[N' = \frac{N}{2}\right]$$

$$= \frac{270\times2\pi\times N\times1000\times2\times10^{-5}}{3\times N} = 3.6\pi\text{ bar}$$

$$imep = \frac{bmep}{\eta_m} = \frac{3.6\pi}{0.9} = 4\pi\text{ bar}$$

16. (d)

In high speed engines, to take the advantage of ram effect during compression, intake valve closing is delayed for a greater period of time after BDC (≃ 60°).

17. (d)

1. Power output per unit displacement represents a rough comparision of the space requirements of the engine types. The SI engine requires less space for the same power output.
2. The efficiency of the SI engine reduces rapidly at part load and idling due to throttling of mixture. The reduction in the efficiency of the CI engine is less due to absense of throttling. This factor makes the CI engine inherently more suitable for all driving vehicles, as they mostly operate at part load.

21. (b)

$$\delta \le \delta_{max}$$

As we know, $$\frac{Pl}{E(a-b)t}\ln\frac{a}{b} \le \delta_{max}$$

$$t \geq \frac{Pl}{E(a-b)\delta_{max}} \ln\frac{a}{b}$$

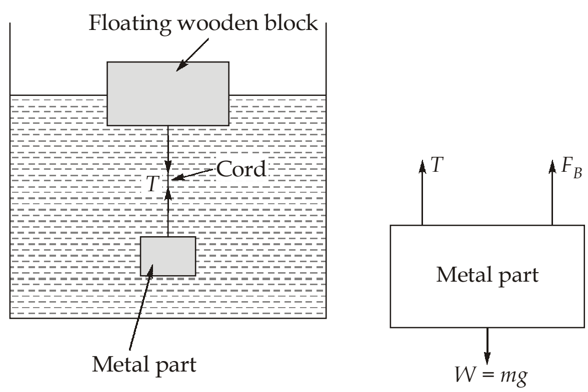
$$\geq \frac{40 \times 10^3 \times 3000}{200 \times 10^3 \times (100-50) \times 0.5} \ln\left(\frac{100}{50}\right)$$

$$\geq 24 \ln 2 \geq 24 \times 0.693$$

$$t \geq 16.64 \text{ mm}$$

22. (a)

$$V_m = 6600 \text{ mm}^3, \quad V_w = 25000 \text{ mm}^3$$



From FBD of metal part

$$mg = T + F_B$$

$$F_B = \rho_{water} \times V_m g = 1000 \times 6600 \times 9.81 \times 10^{-9} \text{ N}$$

$$= 6.468 \times 10^{-2} \text{ N}$$

$$= 0.06468 \text{ N}$$

$\therefore$ $$mg = 0.11 + 0.06468 = 0.17468 \text{ N}$$

$$m = \frac{0.17468}{9.81} \text{kg} = \frac{0.17468}{9.81} \times 1000 \text{ gram}$$

$$m = 17.82 \text{ gram}$$

23. (b)

$$\gamma_A = 12 \text{ N/m}^3 \text{ and } \gamma_{water} = 10^4 \text{ N/m}^3$$

Gauge pressure at B, $P_B(\text{gauge}) = (P_B)_{abs} - P_{atm} = 0$

Now, $$P_{atm} + \gamma_A h\cos(50°) = P_B + \gamma_{water} (1.8 - 0.8) \cos(50°) \times 10^{-3}$$

$$12 \times h \cos(50°) = 10^4 \times 1\cos(50°) \times 10^{-3}$$ $[\because (P_B)_{abs} = P_{atm}]$

$$h = \frac{10}{12} = 0.833 \text{ m} = 83.3 \text{ cm}$$

24. (c)

Since the flow is incompressible and two-dimensional the area of the fluid element must remain constant (volumetric strain must be zero in an incompressible flow).

The area of the fluid particle is S^2. Hence the horizontal dimension of fluid particle at the later time must be $\frac{S^2}{0.5S} = 2S.$

Since the particle shrinks by a factor of two in y-direction, it stretches by factor of two in x-direction.

25. **(b)**

The EGL is always a distance $\frac{V^2}{2g}$ above the HGL. These two curves approach each other as velocity decreases and they diverse as the velocity increases. The height of HGL decreases as the velocity increases and vice-versa.

26. **(d)**

The standard continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \left(\rho \vec{V}\right) = 0 \quad \text{... (i)}$$

If flow is steady and incompressible then

$\frac{\partial \rho}{\partial t} = 0,$ $\quad \rho = \text{Constant}$

$$\therefore \quad \nabla \cdot \vec{V} = 0$$

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

$$\dot{\varepsilon}_{xx} + \dot{\varepsilon}_{yy} + \dot{\varepsilon}_{zz} = 0 \qquad [\dot{\varepsilon} = \text{Linear strain rate}] \quad \text{... (ii)}$$

From (i)

$$\left(\frac{\partial \rho}{\partial t} + \vec{V} \cdot \nabla \rho\right) + \rho \nabla \cdot \vec{V} = 0$$

$$\frac{D\rho}{Dt} + \rho\left(\nabla \cdot \vec{V}\right) = 0 \quad \text{... (iii)}$$

In polar form,

$$\frac{\partial V_r}{\partial r} + \frac{V_r}{r} + \frac{1}{r}\frac{\partial V_\theta}{\partial \theta} + \frac{\partial V_z}{\partial z} = 0 \quad \text{... (iv)}$$

27. **(c)**

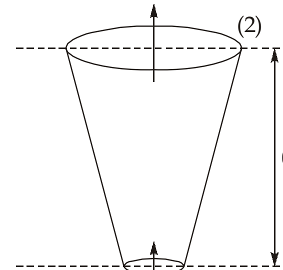
Production flow analysis (PFA) is an approach to part family identifying and machine cell formation. It is a method of identifying part families and associated machine grouping that uses the information contained on production route sheets rather than part drawings. Work parts with identical or similar routings are classified into part families. These families can then be used to form logical machine cells in a group-technology layout. Since PFA uses manufacturing data rather than design data to identify part families, it can overcome two possible anomalies that can occur in part classification and coding. First, parts whose basic geometry is quite different may nevertheless require similar or even identical process routings. Second, parts whose geometry is quite similar may neverthless require process routings.

28. (a)

The surface at the boundary layer interface is rather fictitious, dividing rotational and irrotational flow.

29. (d)

Applying Bernoulli's equation between (1) and (2)



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{4^2}{2g} - (Z_2 - Z_1) = \frac{V_2^2}{2g}$$

$$V_2 = \sqrt{16 - 2 \times 10 \times 0.35} = 3$$

From continuity equation, $A_1V_1 = A_2V_2$

$$\frac{\pi}{4}d_1^2 \times V_1 = \frac{\pi}{4}d_2^2 \times V_2$$

$$15^2 \times 4 = d_2^2 \times 3$$

$$d_2 = \sqrt{300} = 17.32 \text{ mm}$$

30. (a)

- Most flow-meter manufacturers recommend installing their flow meter at least 10 to 20 pipe diameters downstream of any elbows or valves. This allows the swirling turbulent eddies generated by the elbow or valve to largely disappear and the velocity profile to become fully developed before entering the flow meter.
- In some cases, minor losses may be greater than the major losses. This is the case, for example, in systems with several turns and valves in a short distance.

31. (c)

Articulated configuration of arm having two revolute and one prismatic joint.

32. (c)

Inverse of transformation matrix (T^{-1})

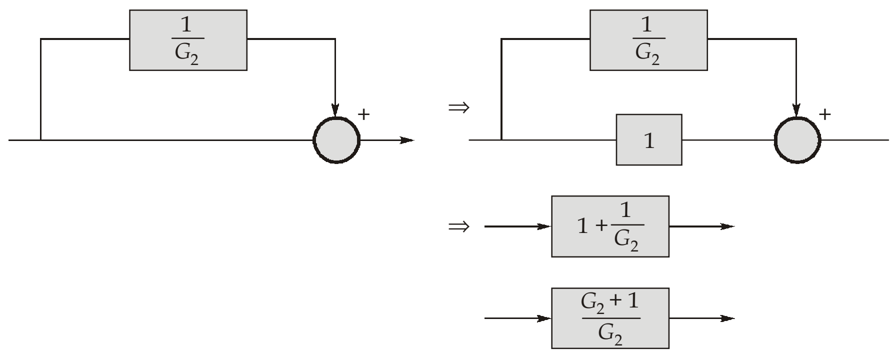
$$T^{-1} = \begin{bmatrix} n_x & n_y & n_z & -d \cdot n \\ o_x & o_y & o_z & -d \cdot o \\ a_x & a_y & a_z & -d \cdot a \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & 0.7 & 0 & -(0.5 \times 1 + 0.7 \times 2 + 0 \times 3) \\ 0 & 0 & 1 & -3(0 \times 1 + 00 \times 2 + 1 \times 3) \\ 0.7 & -0.5 & 0 & -(0.7 \times 1 + (-0.5 \times 2) + (0 \times 3)) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

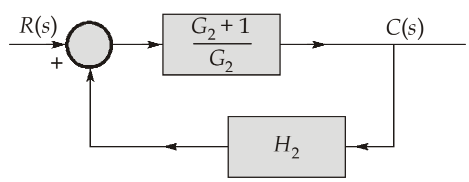
$$= \begin{bmatrix} 0.5 & 0.7 & 0 & -1.9 \\ 0 & 0 & 1 & -3 \\ 0.7 & -0.5 & 0 & 0.3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

33. (d)

Step 1:



Step 2:



Error ratio of positive feedback closed loop system

$$\frac{E(s)}{R(s)} = \frac{1}{1 - G(s)H(s)}$$

$$G(s) = \frac{G_2 + 1}{G_2}$$

$$H(s) = H_2$$

$$\text{Error ratio} = \frac{E(s)}{R(s)} = \frac{1}{1 - \left(\frac{G_2 + 1}{G_2}\right)(H_2)} = \frac{G_2}{G_2 - H_2(1 + G_2)}$$

34. (b)

Statement 1 and 3 are absolutely correct. For statement 2 sensitivity has no unique units, it has a wide range of units which are dependent upon the instrument or measuring system.

35. (d)

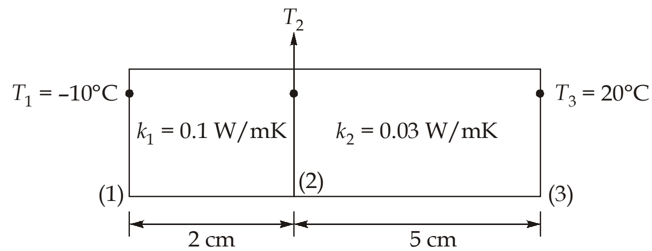
$$\text{Sensitivity of LVDT} = \frac{\text{Output current}}{\text{Displacement}} = \frac{3 \times 10^{-3}}{0.75} = \frac{300}{75} \times 10^{-3} \text{ A/ mm}$$

$$= 4 \times 10^{-3} \text{ A/mm}$$

$$\text{Sensitivity of instrument} = \text{Amplification factor} \times \text{Sensitivity of LVDT}$$

$$200 \times 4 \times 10^{-3} = 0.8 \text{ A/mm}$$

36. (c)



$$q_{12} = q_{23}$$

$$\frac{k_1(T_1 - T_2)}{L_{12}} = \frac{k_2(T_2 - T_3)}{L_{23}}$$

$$\frac{0.1(-10 - T_2)}{0.02} = \frac{0.03(T_2 - 20)}{0.05}$$

$$5\,(-10 - T_2) = 0.6\,(T_2 - 20)$$

$$50 - 5T_2 = 0.6T_2 - 12$$

$$T_2 = -6.78°\text{C}$$

37. (d)

$$\text{Nu} = 6$$

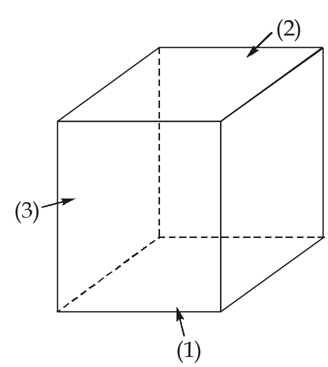
$$\frac{hD}{k} = 6, \qquad h = \frac{6k}{D}$$

Now, $\text{Power} = VI = hA\,(T_s - T_w)$

$$110 \times I = \frac{6k}{D} \times (\pi DL) \times (120 - 35)$$

$$I = \frac{6 \times 0.61 \times \pi \times 0.65 \times 85}{110} = 5.77\text{ A}$$

38. (a)



$$F_{12} = F_{21} = 0.2\ (A_1 = A_2)$$

$$F_{11} + F_{12} + F_{13} = 1$$

$$F_{13} = 1 - F_{12} = 1 - 0.2 = 0.8 \qquad (F_{11} = 0)$$

By reciprocity theorem: $A_1F_{13} = A_3F_{31}$

$$F_{31} = \frac{1 \times 1 \times 0.8}{4 \times (1 \times 1)} = 0.2$$

$$\begin{aligned}(q_{net})_{bottom} &= \sigma A T^4 - (F_{31} \times J_3) \times (4A) - F_{21} J_2 A \qquad [\text{where } A = 1 \times 1 = 1 \text{ m}^2]\\ &= (5.67 \times 10^{-8} \times 1000^4 - 0.2 \times 3200 \times 4 - 0.2 \times 7500) \times A\\ &= (56700 - 2560 - 1500) \times 1 = 52640 \text{ W}\\ &= 52.64 \text{ kW}\end{aligned}$$

39. (b)

By energy balance we get:

$$-\rho V c \frac{dT}{dt} = h A_s (T_i - T_\infty)$$

$$\frac{dT}{dt} = -\frac{h A_s (T_i - T_\infty)}{\rho V c} = -\frac{h (T_i - T_\infty)}{\rho \left(\frac{V}{A_s}\right) c}$$

$$\frac{dT}{dt} = -\frac{120 \times (625 - 25)}{7800 \times \left(\frac{18 \times 10^{-3}}{6}\right) \times 475} = -\frac{120 \times 600 \times 1000}{7800 \times 3 \times 475}$$

$$= -\frac{1600}{247} = -6.47^\circ\text{C/s}$$

(Negative sign signifies that there is decrease in temperature)

40. (c)

For film condensation on vertical plate,

$$h_x = \left[\frac{g \rho_l (\rho_l - \rho_v) k_l^3 h_{fg}}{4 \mu_l (T_{sat} - T_s) x}\right]^{1/4}$$

$$\therefore \qquad h_x \propto \frac{1}{(T_{sat} - T_s)^{1/4}}$$

Heat transfer, $q_s'' = h_x (T_{sat} - T_s)$

$$q_s'' \propto \frac{1}{(T_{sat} - T_s)^{1/4}} \times (T_{sat} - T_s)$$

$$q_s'' \propto (T_{sat} - T_s)^{1 - \frac{1}{4}} \propto (T_{sat} - T_s)^{3/4}$$

$$\therefore \qquad k = \frac{3}{4}$$

41. (c)

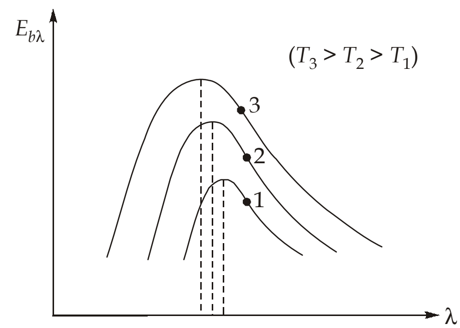
$(\Delta T)_{lm} < (\Delta T)_{am}$, so statement 1 is incorrect.

42. (c)

For a circular tube characterized by uniform surface heat flux with laminar, fully developed conditions, the Nusselt number is a constant (Nu = 4.36); independent of Re_D, Pr and axial location.

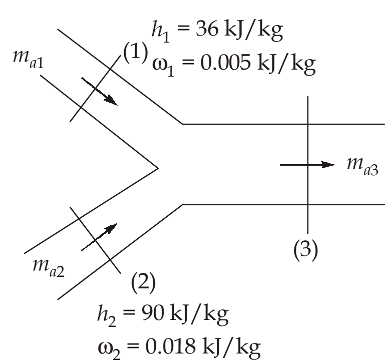
43. (b)

By Wien's displacement law,



The radiation emitted by the sun, which is considered to be a blackbody at 5780K, reaches its peak in visible region of spectrum. Therefore, the sun is in tune with our eyes. On the other hand, surfaces at $T \leq 800$K emit almost entirely in infrared region and thus are not visible to eye unless they reflect light coming from other sources.

44. (a)



Let, 1 at 20°C and 2 at 40°C

$$m_{a3} = m_{a1} + m_{a2} = 1 \text{ kg} + 2 \text{ kg} = 3 \text{ kg}$$

$$\omega_3 = \frac{m_{a1}\omega_1 + m_{a2}\omega_2}{m_{a3}} = \frac{1 \times 0.0057 + 2 \times 0.018}{3}$$

$$= 0.0139 \text{ kg/kg of d.a.}$$

$$h_3 = \frac{m_{a1}h_1 + m_{a2}h_2}{m_{a3}} = \frac{1 \times 36 + 2 \times 90}{3}$$

$$= 72 \text{ kJ/kg of d.a.}$$

46. (b)

Torque to be transmitted, $T = \frac{P}{\omega} = \frac{10 \times 1000}{200} = 50$ N-m (i = initial, f = final)

For input shaft (1), $\omega_{1,f} = \omega_{1,i} - \alpha t$

$$\omega_{1,f} = \omega_1 - \frac{T}{I_1}t = 200 - \frac{50}{0.1}t$$

For output shaft (2),
$$\omega_{2,f} = \omega_{2,i} + \alpha t$$
$$\omega_{2,f} = 0 + \frac{T}{I_2}t = \frac{50}{0.4}t$$
$$\omega_{1,f} = \omega_{2,f}$$
$$\Rightarrow \quad 200 - \frac{50}{0.1}t = \frac{50}{0.4}t$$
$$200 = 50\left(\frac{1}{0.1} + \frac{1}{0.4}\right)t = 50\left(\frac{0.4 + 0.1}{0.04}\right)t$$
$$t = \frac{200 \times 0.04}{50 \times 0.5} = 0.32 \text{ s}$$

47. (b)

Power loss using uniform pressure theory (UPT)
$$P_{UPT} = (T_f)_{UPT}\omega \qquad \text{... (i)}$$
Power loss using uniform wear theory (UWT)
$$P_{UWT} = (T_f)_{UWT}\omega \qquad \text{... (ii)}$$
Dividing (ii) by (i):
$$\frac{P_{UWT}}{P_{UPT}} = \frac{(T_f)_{UWT}\,\omega}{(T_f)_{UPT}\,\omega} = \frac{(T_f)_{UWT}}{(T_f)_{UPT}}$$
$$= \frac{(\mu W)\frac{R}{2}}{(\mu W)\left(\frac{2}{3}R\right)} = \frac{3}{4}$$
$$P_{UWT} = \frac{3}{4} \times P_{UPT}$$
$$\Rightarrow \quad P_{UWT} = \frac{3}{4} \times 4 = 3 \text{ kW}$$

48. (b)

In Hermatically sealed compressor, compressor and motor are inside a welded steel shell. Motor cannot get natural cooling, so it is cooled by the suction vapour which decreases the COP of the system,
$$\because \quad \text{HRR} = 1 + \frac{1}{\text{COP}}$$
So, HRR is highest for hermatically sealed compressor.

49. (d)

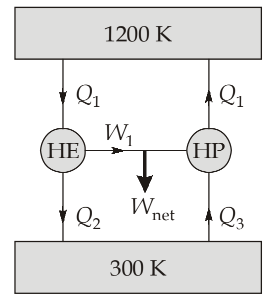
COP of cascade refrigeration system does not depend on the intemediate temperature of the cycle.

50. (d)

$$\eta_{HE} = 1 - \frac{300}{1200} = \frac{3}{4} = \frac{W_1}{Q_1}$$

$$\because \quad (COP)_{HP} = \frac{Q_1}{W_1 - W_{net}} = \frac{T_H}{T_H - T_L} = \frac{1200}{1200 - 300} = \frac{1200}{900}$$

$$\frac{Q_1}{W_1 - W_{net}} = \frac{4}{3}$$



$$\Rightarrow \quad \frac{W_1 - W_{net}}{Q_1} = \frac{3}{4}$$

$$\Rightarrow \quad \frac{W_1}{Q_1} - \frac{W_{net}}{Q_1} = \frac{3}{4}$$

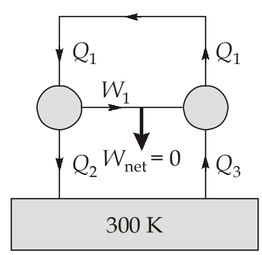
$$\Rightarrow \quad \frac{3}{4} - \frac{W_{net}}{Q_1} = \frac{3}{4}$$

$$\Rightarrow \quad \frac{W_{net}}{Q_1} = \frac{3}{4} - \frac{3}{4} = 0$$

$$\Rightarrow \quad W_{net} = 0$$

Alternate solution:

As combined system of work absorbing and work producing is interacting with one reservoir only. Hence, according to Kelvin-Plank statement.



$$W_{net} = 0$$

51. (c)

If air will be trapped inside the condensor, it will increase the pressure and temperature of the refrigerant in condensor, so more heat will be transferred to cooling water. Hence the exit temperature of cooling water will increase.

As the condensor pressure will increase, the pressure ratio will increase,

$$\because \quad \eta_{volumetric} = 1 + C - C\left[\frac{P_2}{P_1}\right]^{1/n}$$

So the volumetric efficiency of compressor will decreases.

53. (a)

It does not contain any moving part. Due to which chances of leakage of ammonia, a toxic gas is very low. Hence it is used for domestic purposes.

The pressure in condensor and evaporator is approximately same. The flow happens due to difference in partial pressure of NH_3 in condensor and evaporator.

54. **(c)**

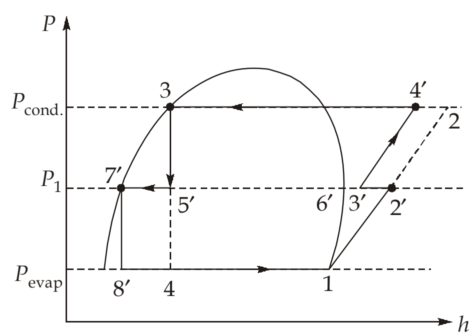
Steam Jet Refrigeration system contains an evaporator, a steam jet ejector, condensor and 2 stage ejectors non-condensable pump. The are suited for large volume flows. It is necessary to reject 2 to 3 times the amount of heat in condensor than a conventional mechanical refrigeration cycle would require because it also condenses the steam which energizes the ejector. Hence, higher cooling water flow rate is required.

The steam jet ejector is heart of the system. It has major effect on operating cost of system and site of base condensor and evaporator.

55. **(c)**

1 - 2 - 3 - 4 $\rightarrow$ simple VCRS

1 - 2′ - 3′ - 4′ - 3 - 5′ - 7′ - 8′ $\rightarrow$ VCRS with flash chamber



As two compressors (1 - 2′ and 3′ - 4′) are used and two 2 throttling devices (3 - 5′ and 7′ - 8′) are used the cost of equipment will increases. For same size of evaporator, the mass flow rate through evaporator will be same so refrigeration effect has been increased from $(h_1 - h_4)$ to $(h_1 - h_{8'})$

At intermediate pressure the vapour at stage 5′ is not throttled this eliminates the undesirable throttling of vapour at intermediate pressure.

56. **(b)**

$$\because \qquad \text{HRR} = 1 + \frac{1}{\text{COP}}$$

$$1.33 = 1 + \frac{1}{\text{COP}}$$

$$\Rightarrow \qquad (\text{COP})_{ref} = 3$$

$$\because \qquad (\text{COP})_{\text{heat pump}} = 1 + (\text{COP})_{ref.} = 1 + 3 = 4$$

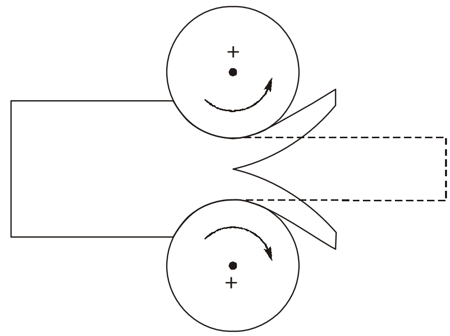
57. **(d)**

R-717 (NH_3) has high compressor discharge temperature because of higher superheat horn. It reacts with coppper so it is never used with copper.

In presence of sulphur, NH_3 gives white fumes. Hence sulphur test or ribbon method is used for detection of ammonia.

It is a toxic gas and it is extremely soluble in water.

58. (c)



Alligatoring: Rolled object split open in the middle due to friction and high forces at roll surface.

59. (d)

$$\text{Shrinkage allowance} = \alpha l(\theta_f - \theta_o) = 1.2 \times 10^{-5} \times 32\,(1530 - 30) = 0.576 \text{ mm}$$

$$\text{Pattern dimension} = 32 + 0.576 = 32.576 \text{ mm}$$

60. (b)

$$\text{Permeability number, } PN = \frac{VH}{PAt}$$

V = Volume of air = 2000 cm^3

H = Height of specimen = 2 inches = 5.08 cm

$$A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 5.08^2 = 20.268 \text{ cm}^2$$

t = Time in minutes, P = Pressure in g/cm^2 = 5 g/cm^2

$$PN = \frac{2000 \times 5.08}{20.268 \times P \times t} = \frac{501.282}{5 \times 2} = 50.12$$

$$PN = 50$$

61. (a)

Indexing jig is used to drill holes which are spaced equally along a circle.

62. (b)

Autogeneous welding is the welding in which no filler material is used.

63. (a)

- Chills are provided in the mould so as to increase the heat-extraction capability of sand mould. A chill provides a steeper temperature gradient so that directional solidification as required in a casting can be obtained.
- Porosity in casting may be caused by shrinkage or gases or both. Due to shrinkage, porosity can by reduced by internal and external chills.

65. (d)

$$N_{max} = \frac{1000V_{max}}{\pi D_{min}} \text{ rpm}$$

$$N_{min} = \frac{1000V_{min}}{\pi D_{max}}$$

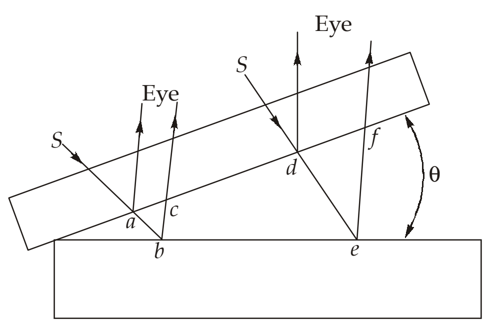
$$\frac{N_{max}}{N_{min}} = \frac{V_{max}}{V_{min}} \times \frac{D_{max}}{D_{min}}$$

$$R_N = R_V \times R_D$$

where, R_N = Speed ratio, R_V = Velocity ratio and R_D = Diamater ratio

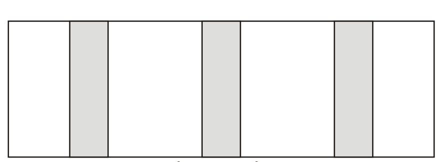
So, $$R_N = \frac{320}{40} \times \frac{150}{50} = 24$$

66. (b)



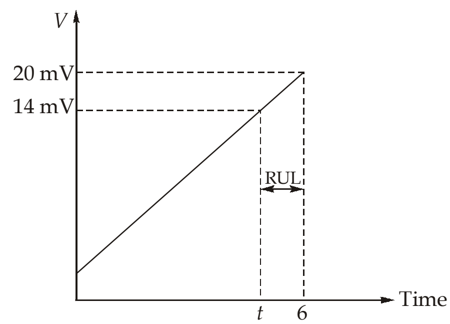
The two reflected components of the light ray are collected and recombined by the eye, having travelled two different paths whose length differs by an amount 'abc'. if 'abc' = $\frac{\lambda}{2}$, where λ is the wavelength of the monochromatic light source, then the condition for complete interference has been satisfied. The eye is now able to see a distinct patches of darkness termed a as fringe. For second point the length 'def' equals $\frac{3\lambda}{2}$, then also total inteference occurs and similar fringe (dark) is obtained. That means for odd values of $\frac{\lambda}{2}$ dark fringe will be obtained.

However at an intermediate point between the two fringes, the path difference between two reflected portion of the light ray will be an even number of half wavelength and a light band will be seen



Interference fringes

67. (b)



Equation of line can be obtained,

$$V = mt + b$$

where, V is in mV and t is in minutes

at $t = 0$, $V = 2$ mV

So, $V = 0 \times m + b$

$2 = b$

and at = 6 min, $V = 20$ mV

$20 = m \times 6 + 2$

$18 = m \times 6$

$m = 3$

So, equation of line is $V = 3 \times t + 2$

at $V = 14$ mV, $14 = 3 \times t + 2$

$12 = 3t$

$t = 4$ min

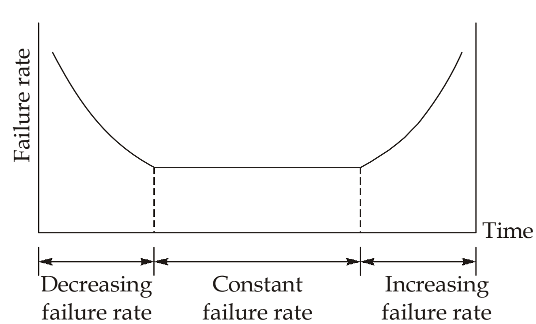
Remaining useful life of a machine (RUL) = 6 – 4 = 2 min

68. (d)

$$\text{System availability, } A = \frac{MTBF}{MTBF + MTTR + MTWS}$$

$$A = \frac{100}{100 + 30 + 20} = \frac{100}{150} = \frac{2}{3} = 0.67 = 67\%$$

69. (c)



$$\text{Reliability, } R(t) = e^{-\lambda t}$$

where, failure rate 'λ' is constant

70. (d)

Dislocation do not move with same degree of ease on all crystallographic planes of atoms and in all crystallographic directions. Ordinarily there is preferred plane and in that plane there are specific directions along which disclocation motion occurs. This plane is known as slip plane; it follows that the direction of movement is called slip direction.

71. (b)

The reduction in strength and hardness that occurs after long time period is called overaging.

72. (c)

- Option (b) will be the microstructure at point *d*.

73. (a)

Top-down and bottom-up methods are two types of approaches used in nanofabrication. The bottom-up approach is more advantageous than the top-down approach because the former has a better chance of producing nanostructures with less defects, more homogenous chemical composition, and better short- and long-range ordering.

74. (a)

The austenitic stainless steel is the most corrosion resistant because of the high chromium content and also the nickel additions.

76. (a)

Gold has FCC strucrture, so it has 4 atoms/unit cell.

$$\text{Number of unit cell per nucleus} = \frac{\frac{4}{3}\pi r^3}{a^3} = \frac{\frac{4}{3}\pi \times 1.32^3}{0.44^3} = \frac{4}{3}\pi\left(\frac{1.32}{0.44}\right)^3$$

$$= \frac{4}{3}\pi \times 27 = 36\pi \text{ unit cells}$$

$$\text{Total number of atoms per nucleus} = (36\pi)\frac{\text{Unit cells}}{\text{Nucleus}} \times \frac{4\,\text{Atoms}}{\text{Unit cells}}$$

$$= 452.389 \text{ atoms/nucleus}$$

77. (c)

Quality or dryness fraction,

$$x = \frac{m_g}{m_f + m_g} = \frac{1}{\frac{m_f}{m_g} + 1}$$

$$= \frac{1}{\frac{V_f / v_f}{V_g / v_g} + 1} = \frac{1}{\frac{V_f}{V_g} \times \frac{v_g}{v_f} + 1}$$

As given in question,

Volume in liquid form, $V_f = \frac{1}{10}V$

So, volume in vapour form $V_g = V - \frac{1}{10}V = \frac{9}{10}V$

Also, $v_g = 81\, v_f$

$$x = \frac{1}{\frac{\frac{1}{10}V}{\frac{9}{10}V} \times \frac{81 v_f}{v_f} + 1} = \frac{1}{\frac{1}{9}\times 81 + 1} = \frac{1}{10}$$

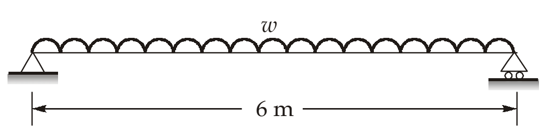
$= 0.1 = 10\%$

78. **(b)**

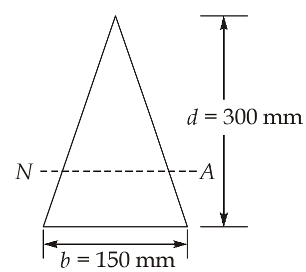
Intenal energy and entropy of saturated water are arbitrarily chosen to be zero at the triple point.

Since $h = u + pv$, the enthalpy of saturated water at 0.01°C (triple point) is slightly positive.

79. **(b)**



As we know, maximum bending moment in simply supported beam with uniformly distributed load of intensity 'w',



$$M_{max} = \frac{wL^2}{8}$$

$$I = \frac{bd^3}{36}$$

Bending equation, $$\frac{M_{max}}{I} = \frac{\sigma_{per}}{y_{max}}$$

$$\Rightarrow \frac{\frac{wL^2}{8}}{\frac{bd^3}{36}} = \frac{\sigma_{per}}{2d/3}$$

$$\Rightarrow w = \frac{\sigma_{per} bd^2}{3L^2} = \frac{150 \times 150 \times 300^2}{3 \times (6000)^2}$$

$$w = \frac{5 \times 15 \times 9 \times 10^6}{36 \times 10^6} = 18.75 \text{ N/mm}$$

80. (c)

Maximum shear stress, $\tau_{max} = \frac{T}{J} \times R = \frac{T}{\frac{\pi}{32} D^4} \times \frac{D}{2} = \frac{16T}{\pi D^3}$

Shear stress at radius, 'r',

$$\tau = \frac{T/2}{\frac{\pi}{32} d^4} \times \frac{d}{2} = \frac{8T}{\pi d^3}$$

As we know, $\tau \propto r$

$$\frac{\tau}{\tau_{max}} = \frac{r}{R} = \frac{d/2}{D/2} = \frac{d}{D}$$

$$\tau = \frac{d}{D} \times \tau_{max}$$

$$\frac{8T}{\pi d^3} = \frac{d}{D} \times \frac{16T}{\pi D^3}$$

$\Rightarrow$ $2d^4 = D^4$

$\Rightarrow$ $d = \frac{1}{2^{1/4}} D = 0.84D$

Alternate Solution:

As we know, $\frac{T}{J} = \frac{G\theta}{l}$

$$T \propto J$$

$\Rightarrow$ $\frac{T/2}{T} = \frac{\frac{\pi}{32} d^4}{\frac{\pi}{32} D^4}$

$\Rightarrow$ $\frac{1}{2} = \left(\frac{d}{D}\right)^4$

$\Rightarrow$ $d = \frac{1}{2^{1/4}} D = 0.84D$

81. (c)

Comparator's is combination of diodes and operational amplifiers generally used in Analogue to Digital Convertor (ADC) and Digital to Analogue Convertor (DAC). Which compares the voltage input or current input at its two terminal and gives output in the form of digital signal. Second statement correct for encoders.

83. (c)

Non returning type control valve also belongs to directional type control valve. These are three type:

1. Check valve
2. Shuttle valve
3. Dual pressure valve

In which the fluid flow only in one-direction and blocks the flow in opposite direction. Solenoid valve- electrically actuated valve and the amount of flow rate of fluid depends on magnitude of the current.

84. (b)

$$P^A = \text{Trans }(5, 3, 6)\text{ Rot }(x, 90°), \text{Rot z}, 90°)\ P^B$$

$$P^A = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos 90° & -\sin 90° & 0 \\ 0 & \sin 90° & \cos 90° & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 90° & -\sin 90° & 0 & 0 \\ \sin 90° & \cos 90° & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ 5 \\ 1 \end{bmatrix}$$

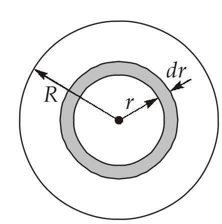
$$= \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ 5 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -3 \\ 2 \\ 5 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -3 \\ -5 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ -2 \\ 8 \\ 1 \end{bmatrix} = [2, -2, 8, 1]^T$$

85. (b)

Shear stress acting on an element at a distance 'r',



$$\tau = \tau_{max}\frac{r}{R}$$

$$\text{Strain energy absorbed, } U = \int \frac{\tau^2}{2G} dV = \int_0^R \frac{\left(\tau_{max}\frac{r}{R}\right)^2}{2G} \times 2\pi r dr L$$

$$= \frac{\tau_{max}^2}{2GR^2} \times 2\pi L \int_0^R r^3 dr$$

$$= \frac{\tau_{max}^2}{2GR^2} \times 2\pi L\left[\frac{R^4}{4}\right] = \frac{\tau_{max}^2}{G} \times \frac{\pi R^2 L}{4}$$

$$U = \frac{\tau_{max}^2 V}{4G}$$

86. (c)

For a shaft subjected to bending moment 'M' and torque, 'T',

$$\text{Equivalent bending moment, } M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\text{Equivalent torque, } T_e = \sqrt{M^2 + T^2}$$

$$\text{Maximum shear stress, } \tau_{max} = \frac{16T_e}{\pi d^3} = \frac{16\sqrt{M^2 + T^2}}{\pi d^3}$$

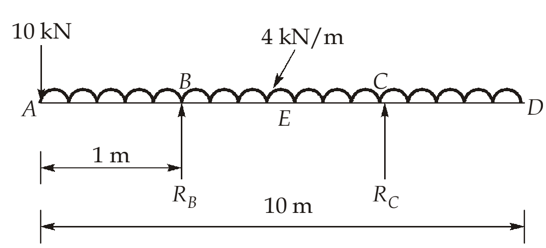
$$\text{Major principal stress, } \sigma_1 = \frac{32M_e}{\pi d^3} = \frac{32 \times \frac{1}{2}\left(M + \sqrt{M^2 + T^2}\right)}{\pi d^3}$$

$$= \frac{16\left(M + \sqrt{M^2 + T^2}\right)}{\pi d^3}$$

$$\frac{\tau_{max}}{\sigma_1} = \frac{\dfrac{16\left(\sqrt{M^2 + T^2}\right)}{\pi d^3}}{\dfrac{16\left(M + \sqrt{M^2 + T^2}\right)}{\pi d^3}} = \frac{\sqrt{M^2 + T^2}}{M + \sqrt{M^2 + T^2}}$$

$$= \frac{\sqrt{(2T)^2 + T^2}}{(2T) + \sqrt{(2T)^2 + T^2}} = \frac{T\sqrt{5}}{T\left[2 + \sqrt{5}\right]} = \frac{1}{\frac{2}{\sqrt{5}} + 1} = 0.53$$

87. (c)



$$R_B + R_C = 10 + 4 \times 10 = 50 \text{ kN}$$

$$\Rightarrow \quad R_B + R_C = 50 \text{ kN} \quad \text{... (i)}$$

Since point E is point of contraflexure,

$$\text{BM}_E = 0 \text{ (Taking moment of all the forces on left side)}$$

$$-10\times5-\frac{4\times5^2}{2}+R_B\times4 = 0$$

$$\Rightarrow \quad R_B = \frac{50+50}{4} = 25\text{ kN} \quad \text{... (ii)}$$

From (i) and (ii), $R_C = 25$ kN

88. (d)

Abrasive wear is due to foreign particle in lubricant so it can be remedied by provision of oil fillers.

Corrosive wear is caused by corrosive elements which can be remedied by providing complete enclosure to gear.

Pitting is a surface fatigue failure, which occurs when the load on gear tooth exceeds the surface endurance strength.

Scoring is a stick-slip phenomenon in which alternate shearing and welding take place rapidly due to breakdown of oil film.

89. (c)

For a given load, power loss and frictional torque will be same for any number of collars in collar bearing.

- Conical bearing is not prefered as it gives more power loss than flat colar bearing.
- Friction circle radius depends on radius of shaft and the coefficient of friction between shaft and bearing.

90. (a)

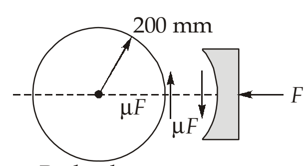
Deep groove ball bearing - Noise-less bearing

Spherical roller bearing - Acts like hinge support

Taper roller bearing - Maximum load bearing capacity

Cylindrical roller bearing - Maximum radial load bearing capacity

91. (d)



Brake drum

$$\Rightarrow \quad \text{Power lost in brake, } P_{\text{brake}} = \left(\mu F\times\frac{200}{1000}\right)\times\frac{2\pi N_{\text{drum}}}{60}$$

∵Power transferred through gears,

$$P_t = \left(5000\times\frac{150}{1000}\right)\times\frac{2\pi N_2}{60}$$

∵ The energy transferred by gear to pinion will be completely absorber by brake.

$$\Rightarrow \quad P_{\text{brake}} = P_t$$

$$\Rightarrow \quad \left(\mu F\times\frac{200}{1000}\right)\times\frac{2\pi N_1}{60} = \left(5000\times\frac{150}{1000}\right)\times\frac{2\pi N_2}{60}$$

$$\because \quad G = 3 = \frac{\text{Speed of pinion}\left(N_{drum} = N_1\right)}{\text{Speed of gear}\left(N_2\right)}$$

$$\Rightarrow \quad N_1 = 3N_2$$

$$\Rightarrow \quad 0.2 \times F \times 200 \times 3 = 5000 \times 150$$

$$F = \frac{5000}{0.8}$$

$$F = 6250 \text{ N}$$

94. (b)

$\dot{m}$ is the mass flow rate of fluid through the rotor.

The torque exerted by the rotor on the fluid,

$$T = \dot{m}\,(V_{w2}r_2 - V_{w1}r_1)$$

The rate of energy transfer to the fluid is given by

$$\text{Power, } P = T.\omega = \dot{m}\left[V_{w2}r_2 - V_{w1}r_1\right]\omega = \dot{m}\left[V_{w2}U_2 - V_{w1}U_1\right] \quad \text{... (i)}$$

Equation (i) is known as Euler's equation in relation to fluid machines.

Equation (i) can also be written in terms of head it gained by fluid.

$$H = \frac{V_{w2}U_2 - V_{w1}U_1}{g} = \frac{1}{2g}\left[\left(V_2^2 - V_1^2\right) + \left(U_2^2 - U_1^2\right) + \left(V_{r1}^2 - V_{r2}^2\right)\right]$$

95. (b)

- For pelton wheel in practice the deflection is limited to about 165° so that the water leaving a bucket may not hit the back of the following bucket. Therefore, the camber angle of the buckets is made as approximate 165°.
- The number of jets is not more than two for horizontal shaft turbines and is limited to six for vertical shaft turbines.
- The flow partly fills the buckets and the fluid remains in contact with the atmosphere. Therefore, once the jet is produced by the nozzle, the static pressure of the fluid remains atmospheric throughout the machine.

96. (d)

In centrifugal compressor

- The pressure rise per stage is high and the volume flow rate tends to be low. The pressure rise per stage is generally limited to 4 : 1 for smooth operations.
- Blade geometry is relatively simple and small foreign particle does not affect much on operational characteristics.
- Centrifugal impellers have lower efficiency compared to axial impellers

98. (b)

As per given data:

Diameter at the tip of impeller, $D = 0.5$ m

$$N = 7000 \text{ rpm}$$

$$\text{Speed, } u_2 = \frac{\pi DN}{60} = \frac{22}{7} \times \frac{0.5 \times 7000}{60} = 183.33 \text{ m/s}$$

$T_{01} = 290$ K

$$\text{Slip factor, } \sigma = 1$$

$$\text{Power input factor, } \psi = 1$$

$$c_p = 1.005 \text{ kJ/kgK}$$

$$\text{Specific heat ratio} = \gamma = 1.4$$

$$\text{Work} = \psi\sigma u_2^2$$

$$= 1 \times 183.33^2 = 33.609 \text{ kJ/kg}$$

$$\text{Work} = c_p (T_{02} - T_{01}) = 33.609$$

$$1.005 (T_{02} - 290) = 33.609$$

$$T_{02} = 33.44 + 290 = 323.44 \text{ K}$$

$$\frac{T_{03}}{T_{01}} = \frac{T_{02}}{T_{01}} = \left(\frac{P_{03}}{P_{01}}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{P_{03}}{P_{01}} = \left(\frac{T_{03}}{T_{01}}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{323.44}{290}\right)^{\frac{1.4}{0.4}}$$

99. **(c)**

Air is sucked into the impeller eye and whirled outwards at high speed by the impeller. At any point in the flow of air through the impeller, the centripetal acceleration is obtained by pressure head so that the static pressure of the air increases from the eye to the tip of the impeller. The remainder of the static pressure rise is obtained in the diffuser, where the very high velocity of air leaving the impeller tip is reduced to almost the velocity with which the air enters the impeller eye.

100. **(c)**

General expression of blade efficiency

$$\eta_D = \frac{2(V_1 \cos\alpha - u)(1 + k_b)u}{V_1^2}$$

$$\text{Velocity ratio, } \rho = \frac{u}{V_1}$$

$$\eta_D = 2\rho^2\left[\frac{\cos\alpha}{\rho} - 1\right](1 + k_b) = 2\left(\rho\cos\alpha - \rho^2\right)(1 + k_b)$$

$$\frac{d\eta_\rho}{d\rho} = 0$$

$$\rho_{\text{optimum}} = \frac{\cos\alpha}{2}$$

$$(\eta_D)_{\max} = 2\left[\frac{\cos^2\alpha}{2} - \frac{\cos^2\alpha}{4}\right](1 + k_b) = \left(\frac{1 + k_b}{2}\right)\cos^2\alpha$$

101. **(b)**

In two stage velocity compounded stage, power ratio in first and second stage is 3 : 1.

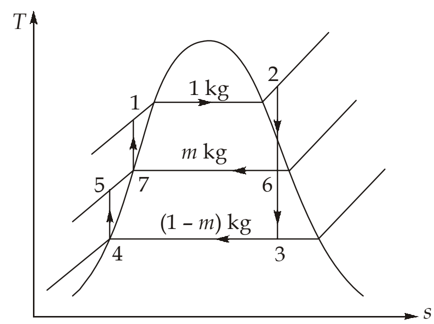
Hence in first stage power developed = $\frac{3}{4}$ total power.

In second stage power developed = $\frac{1}{4}$ total power .

2nd stage power developed = $\frac{750}{4}$ kW = 187.5 kW

102. (c)

For the given regenerative steam cycle obtained T-S diagram is:



For the regenerative steam cycle considered, with unit mass of steam leaving boiler and 'm' kg of steam bled out for feed water heating:

$$\text{Steam turbine work} = (h_2 - h_6) + (1 - m) \times (h_6 - h_3)$$

$$\text{Pump work} = (1 - m) \times (h_5 - h_4) + 1 \times (h_1 - h_7)$$

$$\text{Net work} = \{(h_2 - h_6) + (1 - m) \times (h_6 - h_3)\} - \{(1 - m) \times (h_5 - h_4) + (h_1 - h_7)\}$$

103. (b)

The theoretical discharge of the pump,

$$Q_{th} = \frac{2ALN}{60} = \frac{2 \times 0.1 \times 0.3 \times 45}{60}$$

$$= 0.045 \text{ m}^3/\text{s}$$

$$\text{Actual discharge, } Q_a = \frac{2.4}{60} = 0.04 \text{ m}^3/\text{s}$$

$\therefore$ Slip of the pump $= (Q_{th} - Q_a)$

$$= (0.045 - 0.04)$$

$$= 0.005 \text{ m}^3/\text{s}$$

104. (b)

i. In externally fired boilers heat addition is done externally i.e. furnace is outside the boiler unit, such as Lanchashire boiler, Locomotive boiler etc.

ii. In internally fired boilers heat addition is done internally i.e. furnace is within the boiler unit, such as Cochran boiler, Babcock Wilcox boiler etc.

iii. In fire tube boilers the hot gases inside the tube and water is outside surrounding them. e.g. Cornish boiler, Cochran boiler, Lancashire boiler, Locomotive boiler etc.

iv. In water tube boilers water flowing inside the tubes and hot gases surround them. e.g. Babcock-Wilcox boiler, Stirling boiler, La-Mont boiler, Benson boiler etc.

105. (a)

Comparison of forced and induced draught system:

- Power requirement is more in case of induced draught fan blower as compared to forced draught because of hot flue gases being handled by induced draught fan and atmospheric air being handled by forced draught fan.
- Induced draught fan size may be up to twice of the fan size in forced draught. Material of induced draught fan should be capable of handling hot gases laden with solid particles (ash).
- As the induced draught fan/blower withstands high temperature, so the fan cooling requirements are very stringent as compared to forced draught.
- Maintenance is easy in forced draught fan as compared to induced draught due to their locations.

106. (a)

As we know,

$$\text{For turbine, } \frac{P_1}{D_1^2 H_1^{3/2}} = \frac{P_2}{D_2^2 H_2^{3/2}}$$

$$\frac{144}{D_1^2 (16)^{3/2}} = \frac{576}{D_2^2 (25)^{3/2}}$$

$$\frac{D_2}{D_1} = \left[\frac{576 \times 16^{3/2}}{144 \times 25^{3/2}}\right]^{1/2} = \left[\frac{576 \times 4^3}{144 \times 5^3}\right]^{1/2} = \frac{4^2}{5^{3/2}}$$

$$= \frac{16}{(2.23)^3} = \frac{16}{11.18} = 1.43$$

107. (c)

As the vapourizing capacity of wet air is less as compared to dry air. So the performance of evaporative condenser deteriorates when humidity in atmosphere is high.

108. (b)

In PAFC Phosphoric acid is used as a electrolyte and operating temperature varies between 175°C - 200°C.

109. (a)

The rate of energy loss in respiration is much less as compared to the rate of energy gain during photosynthesis which results in net gain of oxygen and fixation of carbon in the form of biomass.

110. (c)

Two and three-bladed HAWTs are the most commonly used wind turbines for electricity generation. Three-blade rotors operate more smoothly and more quietly than two-blade rotors. Single-blade rotors, with a counterweight, have been field tested at full scale, but the asymmetry produces too many difficulties for commercial prospects. Gearing and generators are usually at the top of the tower in a nacelle. Multi-blade rotors, having large starting torque in light winds, are used for water pumping and other low-frequency mechanical power.

111. (c)

The quantum efficiency (Q.E.) is the ratio of the number of carriers collected by the solar cell to the number of photons of a given energy incident on the solar cell. During the carrier collection processes, some minority carrier are lost due to recombination. In order to minimize these losses, the active surface must be properly treated by suitable anti-reflection coating or by having textured structure. Generally, PV cell are designed with significantly less than the carrier diffusion length. Higher diffusion lengths are indicative of materials with longer lifetimes and it is important quality to consider with semiconductor materials.

112. (c)

$$\text{Declination, } \delta = 23.45 \sin\left[\frac{360}{365}(284+n)\right] \text{degree}$$

n, number of days.

113. (a)

Zenith angle is the angle between sun beam and surface normal to the horizontal plane.

114. (b)

Flat plate collectors have glass on top and have blackened metallic absorbers inside and riser tubes to carry water.

Evacuated tube collectors are made of a glass tube where the outer covering absorbs the solar radiation and the heat generated is transferred to the flowing water.

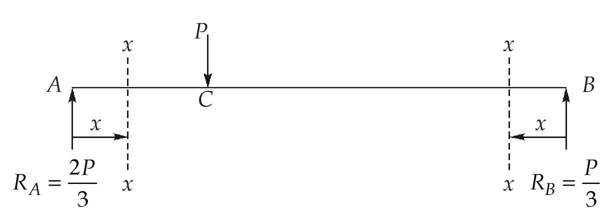
115. (c)

Capacity factor is the ratio of the energy delivered in a specified period to the energy deliverable at full capacity in that period.

116. (c)

In Pyrolysis zone up to the temperature of 200°C only water is driven off. Between 200° and 280°C carbon dioxide, acetic acid and water are given off. The real pyrolysis, which takes place between 280° and 500°C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some methyl alcohol is also formed. Between 500° and 700°C the gas production is small and contains hydrogen.

117. (b)



Strain energy, $U_{AB} = U_{AC} + U_{CB}$

$$= \int_0^{L/3} \frac{M_x^2 dx}{2EI} + \int_0^{2L/3} \frac{M_x^2 dx}{2EI}$$

$$= \int_0^{L/3} \frac{\left(\frac{2P}{3}x\right)^2 dx}{2EI} + \int_0^{2L/3} \frac{\left(\frac{P}{3}x\right)^2 dx}{2EI}$$

$$= \frac{1}{2EI}\left[\frac{4}{9}P^2\left(\frac{x^3}{3}\right)_0^{L/3} + \frac{1}{9}P^2\left(\frac{x^3}{3}\right)_0^{2L/3}\right]$$

$$= \frac{P^2}{18EI \times 3}\left[4\left(\frac{L^3}{27} - 0\right) + \left(\frac{8L^3}{27} - 0\right)\right]$$

$$U_{AB} = \frac{P^2}{18EI \times 3}\frac{12L^3}{27} = \frac{2P^2L^3}{27 \times 9}$$

$$\delta_C = \frac{\partial U_{AB}}{\partial P} = \frac{2 \times 2PL^3}{27 \times 9EI} = \frac{4PL^3}{243EI}$$

Alternate solution:

$$\delta_C = \frac{Pa^2b^2}{3EIL} = \frac{P\left(\frac{L}{3}\right)^2\left(\frac{2L}{3}\right)^2}{3EIL}$$

$$= \frac{4PL^4}{243EIL} = \frac{4PL^3}{243EI}$$

118. (a)

Let, thickness be 't'

Outer diameter, D_o = 750 mm

Inner diameter, D_i = $(750 - 2t)$

$$\text{Permissible stress, } \sigma_{per} = \frac{\sigma_{ut}}{N} = \frac{400}{4} = 100 \text{ MPa}$$

$$\text{Strength criterion, } \sigma_{max} = \frac{pD_i}{4t} \le \sigma_{per}$$

$$\frac{4 \times (750 - 2t)}{4t} \le 100$$

$$750 - 2t \le 100t$$

$$750 \ge (100 + 2)t$$

$$t \ge \frac{750}{102}$$

$$t \ge 7.35 \text{ mm}$$

The closest option to the answer is 7.43 mm.

119. (c)

Free expansion of rod,

$$\Delta = L\alpha\Delta T = 20 \times 12 \times 10^{-6} \times (60 - 20)$$

$$\Delta = 9.6 \times 10^{-3} \text{ m} = 9.6 \text{ mm}$$

$$\text{Thermal strain} = \frac{\lambda}{L} = \frac{6}{20 \times 1000} = 3 \times 10^{-4}$$

$$\text{Expansion prevented} = \Delta - \lambda = 9.6 - 6 = 3.6 \text{ mm}$$

So, $$\text{Thermal strain resisted, } \varepsilon_{th} = \frac{\text{Expansion prevented}}{\text{Original length}} = \frac{3.6}{20 \times 1000}$$

$$= 1.8 \times 10^{-4}$$

120. (a)

In-plane τ_{max} and absolute τ_{max} are equal in magnitude under following state of stress conditions:

1. Uni-axial state of stress condition (In-plane τ_{max} = *Abs* $\tau_{max} = \frac{\sigma_1}{2}$)
2. Bi-axial state of stress when both stresses are unlike in nature (In-plane τ_{max} = *Abs* $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$)

121. (c)

$$\Sigma F_y = 400 - 800 = -400 \text{ N} = 400\,\text{N}(\downarrow)$$

$$\Sigma M_A = 400 \times 1 + 600 \times 1 = 1000 \text{ N-m}$$

The distance along x-axis from point A,

$$x = \frac{\Sigma M_A}{\Sigma F_y} = \frac{1000}{400} = 2.5 \text{ m}$$

122. (b)

From the impulse-momentum principle,

$$I = \int_1^2 F dt = F_{av} \cdot \Delta t = m(v_2 - v_1)$$

$$0.002 F_{av} = 0.001\ (0 - 1000)$$

$$F_{av} = -\frac{1}{0.002} = -500 \text{ N}$$

which implies that a resistance force of 500 N acts opposite to the direction of motion of the bullet.

By the work-energy principle,

$$\int_{r_1}^{r_2} F \cdot dr = \frac{1}{2} m\left(v_2^2 - v_1^2\right)$$

or $$-500 \times \text{Distance penetrated} = \frac{1}{2} \times 0.001 \times \left(0^2 - 1000^2\right)$$

$$\text{Distance penetrated} = 1 \text{ m}$$

123. (a)

$$\delta Q = dE + \delta W, \qquad dE = \delta Q - \delta W$$

Since, energy is a point function, dE is an exact differential.

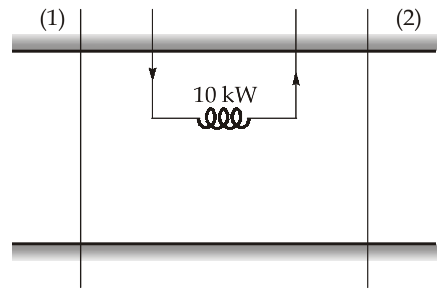
For isothermal process, $\delta Q = \delta W$

Hence, statement 3 is wrong.

124. (c)

$c_p = 1.005$ kJ/kgK, $\dot{Q} = 0$ (Insulated), $\dot{W} = -10$ kW (External agent)

Applying steady flow energy equation,



$$\dot{m}h_1 + \dot{Q} = \dot{m}h_2 + \dot{W}$$

$$\dot{m}h_1 + 0 = \dot{m}h_2 - \dot{W}$$

$$\dot{m}(h_2 - h_1) = \dot{W}$$

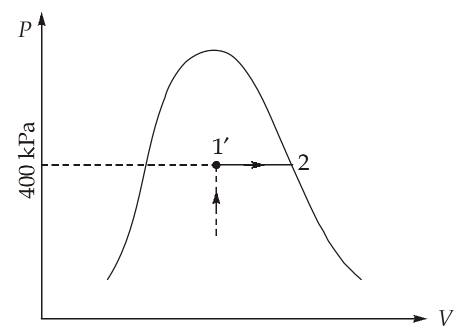
$$\dot{m}c_p(T_2 - T_1) = \dot{W}$$

$$T_2 - T_1 = \frac{\dot{W}}{\dot{m}c_p}$$

$$T_2 = T_1 + \frac{\dot{W}}{\dot{m}c_p} = 55 + \frac{10}{1.005 \times 2} = 60°\text{C}$$

125. (c)

Initial volume, $v_1 = 0.1 \text{ m}^3$



At 400 kPa, $v_2 = v_g = 0.4625 \text{ m}^3/\text{kg}$

Final volume $v_2 = 0.4625 \times 2 = 0.925 \text{ m}^3$

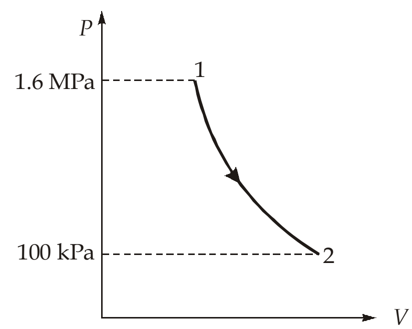
Work done, $W = W_{1-1'} + W_{1'-2}$ ($\because W_{1-1'}$ is constant volume process)

$= 0 + P_2(v_2 - v_1)$

$= 400 \times (0.925 - 0.1) = 400 \times (0.825)$

$= 330$ kJ

126. (c)



For triatomic gas, $\gamma = 1.33 = \frac{4}{3}$

Process 1 - 2(Isentropic)

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_2}{1000} = \left(\frac{100}{1.6\times1000}\right)^{\frac{4/3-1}{4/3}} = \left(\frac{1}{16}\right)^{1/4}$$

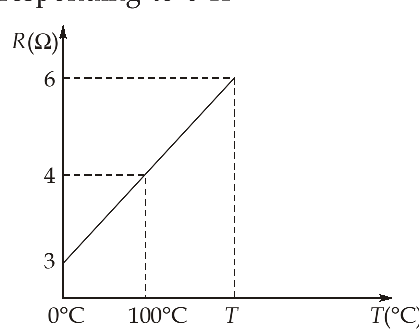
$$T_2 = 1000\times\frac{1}{2} = 500\text{ K}$$

Work done during process, $W = \frac{p_1V_1 - p_2V_2}{\gamma-1} = \frac{mR(T_1-T_2)}{\gamma-1}$

$$= \frac{1\times0.19\times(1000-500)}{\frac{4}{3}-1} = 3\times0.19\times500 = 285\text{ kJ}$$

127. (a)

Let 'T' be the temperature corresponding to 6 Ω



Since linear relation, the slope will be same,

$$\frac{6-4}{T-100} = \frac{4-3}{100-0}$$

$\Rightarrow$ $T - 100 = 2\times100$

$$T = 200 + 100 = 300°\text{C}$$

128. (c)

As we know, $E = 2.42 \text{ eV}$

E, energy available in a photon,

$$E = \frac{1.24}{\lambda}(\text{eV})$$

$$\lambda \times E = 1.24$$

$$\lambda = \frac{1.24}{2.42} = 0.512\ \mu\text{m}$$

129. (d)

$\because$ Lead time = 4 weeks

So, average demand during lead time = 4 × 100 = 400 units/lead time

Standard deviation of demand during lead time = $\sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2}$

$$= \sqrt{15^2 + 15^2 + 15^2 + 15^2}$$

= 30 units/lead time

So, Reorder level = Average demand during lead time + Safety stock

$\Rightarrow$ $420 = 400 + z \cdot 30$

$z = 0.67$

Service level = 75%

130. (c)

PERT and CPM are tools used in Active phase of planning. In prior planning phase forecasting, order writing and product design is done.

Critial path has zero float and zero slack.

131. (d)

$$\because \quad \text{Margin of safety in \%} = \frac{\text{Margin of safety}}{\text{Total sales}} \times 100$$

$$\Rightarrow \quad \text{MOS} = 100000 \times \frac{50}{100} = \text{Rs. } 50000$$

$$\because \quad \left(\frac{P}{V}\right) \text{ratio} = \frac{\text{Profit}}{\text{Margin of safety}}$$

$\Rightarrow$ Profit = Rs. 50000 × 40%

= Rs. 20000

132. (d)

Representative time = 0.5 min

Observed rating factor = 110%

Total allowances = 8 + 2 = 10%

$$\text{Normal time (Basic time)} = 0.5 \times \frac{110}{100} = 0.55 \text{ min}$$

$$\text{Standard time} = 10\% \text{ of normal time} + \text{Normal time}$$

$$= 0.55 \times \frac{10}{100} + 0.55 = 0.605 \text{ min}$$

133. (c)

There are three inputs of a MRP system:

1. Master production schedule (MPS).
2. Bill of material (BOM).
3. Inventory status file.

It is not a total company system, it does not provide a link with other areas of business, such as finance and marketing etc.

MRP-II is a total company system, in which functional groups interact commonly and formally and make joint decisions.

134. (c)

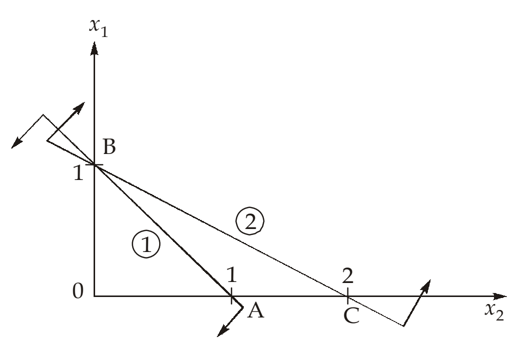
A Kanban system is a system of inventory and production control which uses Kanbans as principal information transmission device. At the same time, it promotes quality control, as fine-tuned steady production processes facilitate better product quality. Normally production is more defect free and of an even and superior quality.

There are 2 types of Kanban system:

1. Withdrawl Kanban
2. Production Kanban

Kanban is a visual signal that's used to trigger an action. The word kanban is Japanese and roughly translated means "card you can see."

135. (c)



$x_1 + x_2 \leq 1$

$2x_1 + x_2 \geq 1$

$x_1, x_2 \geq 0$

For these set of constraints, point B will be the feasible region.

If during solution, there is a tie for leaving variable then solution is termed degenerate.

In Big-M method, if artificial variable is one of the basic variable in the final solution, then there is no solution of the problem.

136. (d)

$$\text{Number of arrivals/hr, } \lambda = \frac{60}{4} = 15$$

$$\text{Number of customers serviced/hr, } (\mu) = \frac{60}{2} = 30$$

$$\rho = \frac{\lambda}{\mu} = \frac{15}{30} = 0.5$$

$$\text{Waiting time in system} = \frac{\rho}{\lambda(1-\rho)} = \frac{1}{15} \times \frac{0.5}{0.5} = \frac{1}{15} \text{ min}$$

Probability that waiting time in queue is more than $\left(\frac{4}{60}\right)$ min is

$$= \rho e^{-t/w_s} = 0.5e^{\frac{-4}{60 \times \frac{1}{15}}} = \frac{e^{-1}}{2}$$

137. (a)

For steady flow,

$$S_e - S_i = \oint \frac{dQ}{T} + S_{gen}$$

$$S_e = S_i + S_{gen} \qquad \left[\because \oint \frac{dQ}{T} = 0 \text{ for adiabatic process}\right]$$

For irreversible flow, $S_{gen} > 0$

So, $S_e > S_i$

Thus, entropy of fluid increases during steady state irreversible adiabatic flow.

138. (d)

Circulation ratio is the ratio of flow rate of saturated water in downcomers to the flow rate steam released from drum.

140. (d)

Statement I is correct with respect to degeneracy.

142. (d)

In a polytropic process [$1 < n < \gamma$], temperature decreases when heat is added to the system because the work done by the system is more than the heat added.

143. (a)

Ions are not electrically neutral so they have charge. For slip in some directions, ions of like charge are bought into close proximity to one another; because of electrostatic repulsion, this mode of slip is very restricted, to the extent that plastic deformation in ceramics is rarely measurable at room temperature.

144. **(a)**

The surfaces are in such close proximity that there is molecular adhesion of high magnitude that creates a high adhesion force.

145. **(a)**

Statements I is correct and statement II is correct expansion of I. In wide freezing range alloys during the process of solidification the dendrities are spread over a much larger part and thus reduces the flow of the metal, decreasing the fluidity.

146. **(a)**

During cooling, forging tends to shrink towards its centre and as a result, the external surfaces are likely to be seperated whereas the internal surface tend to cling to the die more strongly. So internal surfaces require more draft than external surface.

147. **(d)**

$$\text{Thermal diffusivity, } \alpha = \frac{k}{\rho c_p} = \frac{\text{Heat conduction}}{\text{Heat storage}}$$

A small value of thermal diffusivity means that heat is mostly absorbed by the material and a small amount of heat is conducted further. So, statement 1 is incorrect.

148. **(b)**

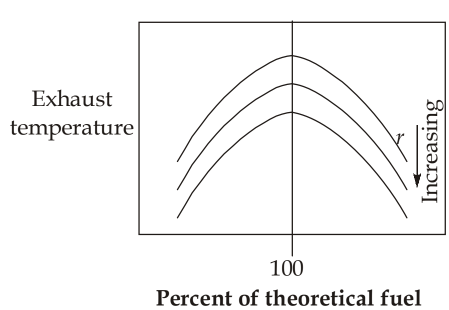
Methanol vaporizes at boiling point of 69°C. Quantity of evaporated fuel in the temperature range of 60-80°C will be more in blended fuels which will lead to better cold starting.

Addition of methanol has got a good response on octane number. Each 5 percent addition results in an increase of 3.0 to 3.4 octane units.

149. **(c)**

The exhaust gas temperature is maximum at the chemically correct mixture. The exhaust gas temperature varies with fuel-air ratio in same manner as maximum temperature except that maximum exhaust gas temperature is at the chemically correct fuel-air ratio in place of slightly rich fuel-air ratio (6%) as in case of maximum temperature. However behaviour of exhaust gas temperature with compression ratio is different from that of maximum temperature.

The exhaust gas temperature is lower at high compression ratios, because the increased expansion causes the gas to do more work on the piston leaving less heat to be rejected at the end of the stroke.



150. **(b)**

Statement I is correct explanation for statement II.