DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 24

Full Syllabus Test-8 (Paper-II)

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

NOTE: Change in [Q.109, 111, 118(A. Key), Q.111, 118(Solution)]

DETAILED EXPLANATIONS

2. (a)

Waste gate limits the maximum boost pressure to prevent detonation in SI engines and the maximum pressure and engine damage. It is a diaphragm operated valve that can bypass part of the gases around the turbine wheel when manifold pressure is quite high.

3. (b)

Ignition delay in a CI engine decreases with increasing fuel air ratio.

5. (b)

$$\text{Swept volume, } V_s = \frac{\pi}{4}d^2 l = \frac{\pi}{4}\times 10^2 \times 12 = 300\pi \text{ cm}^3$$

$$\text{Compression ratio, } r = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c} = 1 + \frac{300\pi}{50\pi} = 7$$

$$\eta_{\text{air-std.}} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(7)^{0.4}} = 54.08\%$$

6. (a)

As engine is running at constant speed with all cylinder working, the frictional and pumping looses remains constant. We know that,

$$IP_{(1+2+3+4)} = BP_{(1+2+3+4)} + FP_{(1+2+3+4)}$$

If cylinder '1' is cut off,

$$IP_{(2+3+4)} = BP_{(2+3+4)} + FP_{(1+2+3+4)}$$

Now,

$$IP_1 = BP_{(1+2+3+4)} - B_{(2+3+4)} = 20 - 14.6 = 5.4 \text{ kW}$$

$$IP_2 = BP_{(1+2+3+4)} - BP_{(1+3+4)} = 20 - 14.3 = 5.7 \text{ kW}$$

$$IP_3 = BP_{(1+2+3+4)} - B_{(1+2+4)} = 20 - 14.4 = 5.6 \text{ kW}$$

$$IP_4 = BP_{(1+2+3+4)} - B_{(1+2+3)} = 20 - 14.1 = 5.9 \text{ kW}$$

$$\eta_{\text{mech}} = \frac{BP_{(1+2+3+4)}}{IP_1 + IP_2 + IP_3 + IP_4} = \frac{20}{5.4 + 5.7 + 5.6 + 5.9}$$

$$\eta_{\text{mech}} = \frac{20}{22.6} = 0.88495 \approx 88.5\%$$

7. (a)

1. According to Fluid flim theory, the lubricant is supposed to act like mass of globulous, rolling between two surfaces. It produces a rolling effect, which reduces friction.
2. According to Boundary layer theory, the lubricant is soaked in rubbing surfaces and forms oily surface over it. Thus the sliding surfaces are kept apart from each other, thereby reducing friction.

8. (d)

$$\eta = 1-\frac{1}{(r)^{\gamma-1}} = 1-\frac{1}{(8)^{\frac{5}{3}-1}} = 0.75$$

$$\eta_{act} = 0.75 \times 0.6 = 0.45$$

$$\frac{W_{act}}{Q_{in}} = 0.45$$

$$\Rightarrow \quad W_{net} = 0.45 \times 40 = 18 \text{ kW}$$

Now, we know that,

$$P_m = \frac{\text{Work done}}{\text{Swept volume}} = \frac{18\times10^3}{7200\times10^{-6}}$$

$$P_m = \frac{18}{7.2}\times10^6 = 2.5 \text{ MPa}$$

9. (b)

$$\eta_{mech} = \frac{BP}{IP}$$

$$\text{IP} = \frac{20}{0.8} = 25 \text{ kW}$$

Indicated thermal efficiency,

$$\eta_{ith} = \frac{IP}{V_g\times C.V.} = \frac{25}{\left(\frac{20000}{3600}\right)\times 20} = \frac{25\times3600}{20000\times20}$$

$$= \frac{25\times36}{200\times20} = \frac{36}{160} = \frac{9}{40} = 0.225 = 22.5\%$$

$$\eta_{relative} = \frac{\eta_{ith}}{\eta_{air\ std.}} = \frac{22.5}{50} = 45\%$$

12. (b)

Ideal extrusion force,

$$F_i = \sigma A_o \ln\frac{A_o}{A_f}$$

$$F_i = 200\times\frac{\pi}{4}\times0.1^2\ln\left(\frac{100}{50}\right)^2 = 2.17\times10^6 \text{ N}$$

Total force,

$$F = F_i + 0.35\,F_i + 0.3F$$

$$F = \frac{1.35F_i}{0.7} = \frac{1.35\times2.17\times10^6}{0.7} = 4.2 \text{ MN}$$

13. (d)

Largest resistance at the contact between the two workpiece to be joined is because of non continuity of material and trapment of air. Air is having low thermal conductivity and induces high resistance between the workpiece.

14. (b)

Choke area is given as:

$$A = \frac{\rho_{CI} \times V_m}{\rho_m t C\sqrt{2gh}} = \frac{250 \times 250 \times 250 \times 7.86 \times 10^{-6}}{6.9 \times 10^{-6} \times 20 \times 0.78 \times \sqrt{2 \times 10 \times 1000 \times 200}}$$

$$= 570.4 \text{ mm}^2$$

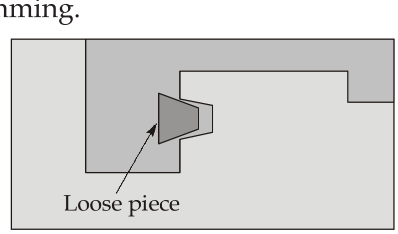
Where, C = Efficiency factor which depends on gating system

15. (b)

In locating by holes, one of the pins has to be diamond shaped to accomodate tolerance on the pins distance between the holes and their diameters.

16. (c)

1. **Gated pattern:** This is an improvement over the simple pattern where the gating and runner system are integral with the pattern. This would eliminate handcutting of the runner and gates and help in improving the productivity of a moulder.
2. **Skeleton pattern:** This type of pattern is used generally for very large castings, required in small quantities where large expense on the complete wooden pattern is not justified.
3. **Loose-piece pattern:** When one piece solid pattern has projection or back drafts which lies above or below the parting plane, it is impossible to with draw if from the mould so the projection are made with help of loose piece pattern. the drawback is possibility of shifting of loose pattern during ramming.



4. Sweep pattern used for generating large shapes which are axi-symmetrical or prismatic in nature such as bell shaped. This greatly reduces the cost of three-dimensional pattern.

17. (b)

This unique process is characterized mainly by very slow work speed but very large depth or infeed (d) which not only enables large stock removal and high MRR but also provides longer life of the grits and better surface finish.

19. (a)

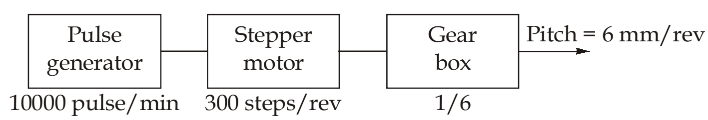
$$\text{Flatness error} = \frac{(n_2 - n_1)}{2} \times \frac{\lambda}{2} = \frac{(20-12)}{2} \times \frac{0.5}{2} = 1\,\mu\text{m}$$

20. (d)

Manufacturing companies that are agile tend to exhibit the following four principles or characteristics of agility:

1. Organize to master change: In an agile company, the human and physical resource can be rapidly reconfigured to adapt to a changing environment and new market opportunities, thus allowing the company to flourish amid uncertainty.
2. Leverage the impact of people and information: In an agile company, knowledge is valued, innovation is rewarded, and authority is distributed to the appropriate level in the organization. Management provides the resources that personnel need. The organization has an entrepreneurial spirit.
3. Cooperate to enhance competitiveness: The objective of an agile company is to bring new products to market as rapidly as possible using whatever resources and competencies are required, wherever they exists. This may involve partnering with other companies, possibly even competitors, to form what are called virtual enterprises.
4. Enrich the customer: The products of an agile company are perceived by their customers as solutions to problems. Pricing of a product may be based on the value of the solution rather than on manufacturing cost.

21. (b)



1 min - 10000 pulses

$$\text{Rotation speed of stepper motor} = \frac{10000}{300} = \frac{100}{3} \text{ rev/ min}$$

$$\text{Rotation speed of lead screw} = \frac{1}{6} \times \frac{100}{3} = \frac{100}{18} \text{ rev/ min}$$

$$\text{Table translation speed} = \text{Pitch} \times \frac{100}{18} = 6 \times \frac{100}{18} = \frac{100}{3} \text{ mm/ min}$$

$$\text{Basic length unit} = \frac{\text{Table translation speed}}{\text{Pulse rate}}$$

$$= \frac{100}{3 \times 10000} = 3.33\ \mu\text{m}$$

22. (c)

$$R_i = 10\ \Omega$$

$$\text{Sensitivity} = \frac{\Delta R}{F} = 0.05 \Omega / \text{N}$$

$$F = 100\ \text{N}$$

$$\Delta R = 5\ \Omega$$

$$R_f - R_i = 5\ \Omega$$

$$R_f = 10 + 5 = 15\ \Omega$$

Total initial resistance $(R_{\text{total}})_{\text{initial}} = 100\ \Omega + 10\ \Omega = 110\ \Omega$

$$I_i = \frac{V}{(R_{\text{Total}})_{\text{Initial}}} = \frac{23}{110}\text{ Amp}$$

Total final resistance $(R_{\text{total}})_{\text{final}} = 100 + 15 = 115\ \Omega$

$$I_f = \frac{V}{(R_{\text{Total}})_{\text{Final}}} = \frac{23}{100+15} = \frac{23}{115}\text{ Amp}$$

Change in current, $I_f - I_i = 23\left[\frac{1}{115} - \frac{1}{110}\right]$

$$-\frac{1}{110} = -9.09 \times 10^{-3}\text{ Amp}$$

23. (a)

Cylindrical configuration offers good mechanical, stiffness and the wrist positioning accuracy decreases as the horizontal stroke increases. It is suitable to access narrow horizontal cavities and hence useful for machine loading operation.

24. (d)

Variability of the robot is also repeatability of the robot which is defined as how accurately the same position can be reached if the motion is repeated many times.

25. (b)

$$P_{xyz} = \text{Trans }(4, -3, 7)\text{ Rot }(y, 90°)\text{ Rot}(z, 90°)\ P_{uvw}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 90° & 0 & \sin 90° & 0 \\ 0 & 1 & 0 & 0 \\ -\sin 90° & 0 & \cos 90° & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 90° & -\sin 90° & 0 & 0 \\ \sin 90° & \cos 90° & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 6 \\ 4 \\ 3 \\ 1 \end{bmatrix}$$

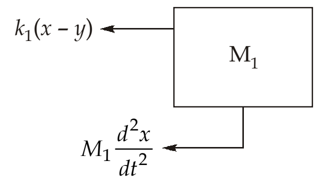
$$= \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 6 \\ 4 \\ 3 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -4 \\ 6 \\ 3 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 6 \\ 4 \\ 1 \end{bmatrix} = \begin{bmatrix} 7 \\ 3 \\ 11 \\ 1 \end{bmatrix}$$

26. **(b)**

We will draw the free body diagram of M_1 as options are given in terms of M_1.



From D'alembert principle,

$$M_1\frac{d^2x}{dt^2}+k_1(x-y) = 0$$

Solving differential equation using Laplace transformation,

$$M_1\,[s^2X(s) - sX(0) - X'(0)] + k_1X(s) - k_1Y(s) = 0$$

$$M_1\,[s^2X(s) - 0 - 0] + k_1X(s) - k_1Y(s) = 0$$

$$(M_1s^2 + k_1)\,X(s) = k_1Y(s)$$

$$X(s) = \frac{k_1}{M_1s^2+k_1}Y(s)$$

$$\text{Transfer function} = \frac{Y(s)}{X(s)} = \frac{M_1s^2+k_1}{k_1} = \frac{M_1}{k_1}s^2+1$$

27. **(b)**

Steady state error is the difference between the steady state value and input value. Which is arise from the configuration of the system and the type of input signal. It is a measure of the accuracy of a control system.

28. **(b)**

MP has no internal memory.

MP is used for general purpose whereas, MC is used for specific purpose.

29. **(a)**

For Bingham plastic fluid, $\tau = \tau_y + \mu\frac{du}{dy}$

The minimum value of τ is τ_y and $\tau_y = 0.6\ \text{N/m}^2$.

By force balance, $\tau_y \times (\pi DL) = \Delta P \times \frac{\pi}{4}D^2$

$$\Delta P = \frac{4\tau_y L}{D} = \frac{4\times0.6\times3}{15\times10^{-3}} = \frac{4\times6\times3\times1000}{15\times10}$$

$$\Delta P = 480\ \text{Pa}$$

30. (b)

$$V = 2t^2\left(1-\frac{x}{2L}\right)$$

Given: $x = 0.5$, $L = 0.8$ and $t = 45$

Total acceleration = Local acceleration + Convective acceleration

$$\text{Local accelerationl } a_t = \frac{dV}{dt} = 2\times 2t\left(1-\frac{x}{2L}\right) = 4\times 4\left(1-\frac{0.5}{2\times 0.8}\right) = 11\text{ m/s}^2$$

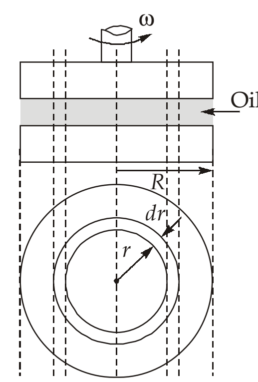
$$\text{Convective acceleration, } a_c = V\frac{\partial V}{\partial x} = 2t^2\left(1-\frac{x}{2L}\right)\times 2t^2\left(-\frac{1}{2L}\right)$$

$$a_c = -\frac{4t^4}{2L}\left(1-\frac{x}{2L}\right) = -\frac{2\times 4^4}{0.8}\times\left(1-\frac{0.5}{2\times 0.8}\right) = -\frac{2\times 256}{0.8}\times\frac{11}{16}$$

$$= -440\text{m/s}^2$$

$$\text{Total acceleration} = 11 - 440 = -429\text{ m/s}^2$$

31. (a)



Considering the strip as shown in figure.

$$dA = 2\pi r dr, \quad V = \omega r$$

$$\text{From Newton's law of viscosity, } \tau = \mu\frac{V}{h} = \frac{\mu(\omega r)}{h}$$

$$dF = \tau dA = \frac{\mu(\omega r)}{h}\times 2\pi r dr$$

$$\text{Torque required, } T = \int_0^R dF\times r = \int_0^R \frac{\mu\omega r}{h}\times 2\pi r dr\times r$$

$$T = \frac{2\pi\mu\omega}{h}\int_0^R r^3 dr = \frac{\pi\mu\omega R^4}{2h}$$

$$\text{Power, } P = T\omega = \frac{\pi\mu\omega^2 R^4}{2h}$$

$$\therefore \quad \mu = \frac{2Ph}{\pi\omega^2 R^4}$$

33. (b)

For flow to be irrotational, stream function should satisfy Laplace equation which is

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0$$

when, $\psi = 2xy$, $\quad \dfrac{\partial^2\psi}{\partial x^2} = 0$ and $\dfrac{\partial^2\psi}{\partial y^2} = 0$

So, $\quad \dfrac{\partial^2\psi}{\partial x^2} + \dfrac{\partial^2\psi}{\partial y^2} = 0$

34. (d)

Given: P = 100 kPa = 100 × 10^3 Pa = 10^5 Pa

$$(\rho_{Hg})_{T\,=\,40°C} = 13600 - 2.5 \times 40 = 13500\ \text{kg/m}^3$$

$$(\rho_{Hg})_{T\,=\,-40°C} = 13600 - 2.5 \times (-40) = 13700\ \text{kg/m}^3$$

$$\text{Column height, } h = \frac{P}{\rho g}$$

$$h_{summer} = \frac{10^5}{13500 \times 10} = \frac{100}{135} = \frac{20}{27} = 0.74\ \text{m}$$

$$h_{winter} = \frac{10^5}{13700 \times 10} = \frac{100}{137} = 0.73\ \text{m}$$

$$\Delta h = 0.74 - 0.73 = 0.01\ \text{m}$$

35. (b)

$$\frac{\text{Re}_2}{\text{Re}_1} = \frac{\left(\frac{\rho VD}{\mu}\right)_2}{\left(\frac{\rho VD}{\mu}\right)_1} = \frac{V_2 d_2}{V_1 d_1}$$

From continuity, $$A_1V_1 = A_2V_2$$

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

$$\Rightarrow \quad \frac{V_2}{V_1} = \frac{d_1^2}{d_2^2}$$

$$\therefore \quad \frac{\text{Re}_2}{\text{Re}_1} = \frac{d_1^2}{d_2^2} \times \frac{d_2}{d_1} = \frac{d_1}{d_2} = \frac{r_1}{r_2}$$

$$\frac{\text{Re}_2}{\text{Re}_1} = \frac{r_o e^{-\alpha x_1}}{r_o e^{-\alpha x_2}} = \frac{1}{e^{-\alpha(x_2 - x_1)}} = \frac{1}{e^{-\alpha \Delta x}}$$

$$\frac{\text{Re}_2}{\text{Re}_1} = e^{\alpha \Delta x} = e^{0.5 \times 2} = 2.718$$

36. (c)

$$I_{CG} = \frac{1 \times L^3}{12}\ \text{m} \qquad L\sin\theta = h, \qquad \text{Area, } A = L \times 1 = L$$

Hydrostatic force on the gate, $$F = \rho g A h_{CG} = \frac{\rho g A h}{2} = \frac{\rho g L h}{2}$$

Centre of pressure, $$y_{CP} = h_{CG} + \frac{I_{CG}\sin^2\theta}{A h_{CG}} = \frac{h}{2} + \frac{\frac{1 \times L^3}{12} \times \sin^2\theta}{1 \times L \times \frac{h}{2}} = \frac{h}{2} + \frac{L^2 \sin^2\theta}{6h}$$

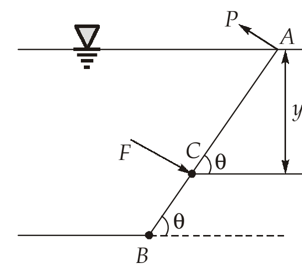
$$y_{CP} = \frac{h}{2} + \frac{h^2}{6h} = \frac{3h+h}{6} = \frac{2h}{3} \qquad [L\sin\theta = h]$$

$$BC = AB - AC = L - \frac{y_{CP}}{\sin\theta} = L - \frac{2h}{3\sin\theta} = L - \frac{2}{3}L$$

$$BC = \frac{L}{3}$$

$$\Sigma M_B = 0$$

$$PL - F \times \frac{L}{3} = 0$$



$$P = \frac{\rho g L h \times L}{2 \times L \times 3} = \frac{\rho g L h}{2 \times 3} = \frac{\rho g h^2}{6\sin\theta}$$

37. (c)

Losses in mechanical energy after result from the unconfined mixing as the flow stream decelerates again to fill the pipe. There is no loss of head during acceleration of fluid upto the vena-contracta (only pressure head is converted into velocity head)

38. (b)

$$\alpha = 4.8 \times 10^{-5}\ \text{atm}^{-1} = \frac{4.8\times10^{-5}}{101.325}\ \text{kPa}^{-1}$$

Now,

$$\alpha = \frac{1}{K} = -\frac{1}{v}\left(\frac{dv}{dp}\right)_T = \frac{1}{\rho}\left(\frac{d\rho}{dp}\right)_T$$

$$\frac{4.8\times10^{-5}}{101.325} = \frac{1}{1000}\times\left(\frac{\Delta\rho}{\Delta p}\right)_T$$

$$\Delta\rho = \frac{4.8\times10^{-5}}{101.325}\times1000\times(5100-100)$$

$$\Delta\rho = \frac{240}{101.325} = 2.36$$

$$\rho_f - \rho_i = 2.36$$

$$\rho_f = 1000 + 2.36 = 1002.36\ \text{kg/m}^3$$

39. (a)

Given: $Q = 0.81\ l/s = 0.81 \times 10^{-3}\ m^3/s$.

$$A_1 = 900\ \text{mm}^2 = 900\times10^{-6}\ \text{m}^2,\ C_d = 0.9,\ \frac{A_1}{A_2} = 4$$

For venturimeter,

$$Q = \frac{C_d A_1 \sqrt{2g\Delta h}}{\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

$$0.81 \times 10^{-3} = \frac{0.9 \times 900 \times 10^{-6}\sqrt{2g\Delta h}}{\sqrt{4^2 - 1}}$$

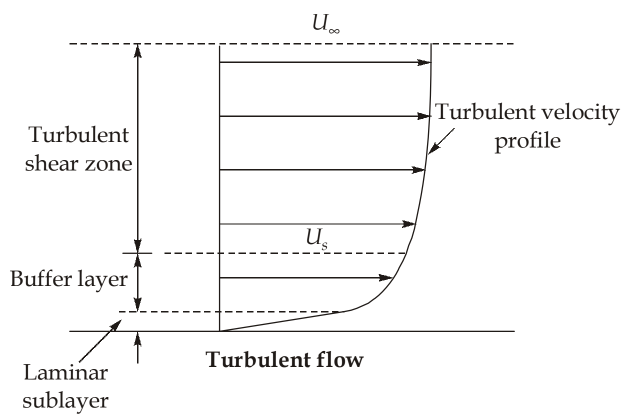
$$\frac{0.81 \times 10^{-3}\sqrt{15}}{0.9 \times 900 \times 10^{-6}} = \sqrt{2g\Delta h}$$

$$15 = 2g\Delta h$$

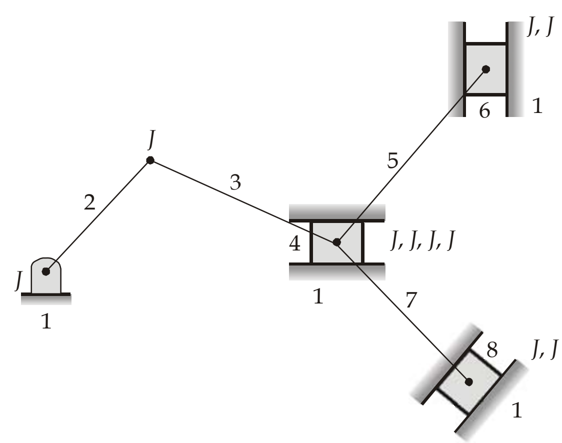
$$g\Delta h = \frac{15}{2}$$

$$\Delta P = \rho g\Delta h = 1000 \times \frac{15}{2} = 7500 \text{ Pa}$$

40. (a)



41. (b)



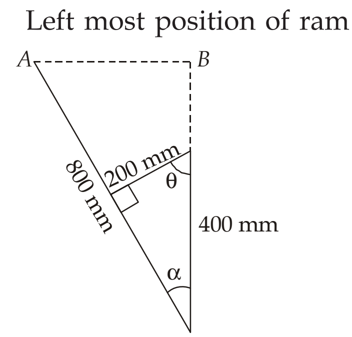
$$\text{Number of links, } l = 8$$

$$\text{Number of revolute joints, } j = 10$$

$$\text{Degrees of freedom, } n = 3(l - 1) - 2j$$

$$= 3 \times (8 - 1) - 2 \times 10 = 1$$

42. (b)



$$\cos\theta = \frac{200}{400} = \frac{1}{2}$$

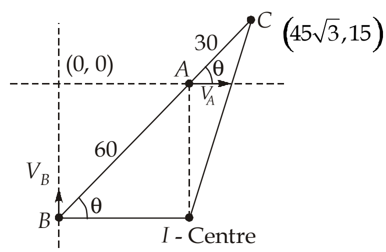
$\Rightarrow$ $\theta = 60°$

$\Rightarrow$ $\alpha = 30°$

$$\text{Stroke} = 2AB = 2 \times (800 \sin\alpha)$$

$$= 2 \times 800 \times \frac{1}{2} = 800 \text{ mm}$$

43. (c)

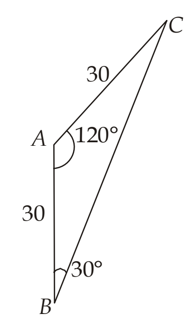


Using $$\left(\frac{x}{90}\right)^2 + \left(\frac{y}{30}\right)^2 = 1$$

BC = 90 cm and AC = 30 cm

$\Rightarrow$ AB = 60 cm

We can write x coordinate of C as



$$90 \cos\theta = 45\sqrt{3} \text{ cm}$$

$\Rightarrow$ $$\cos\theta = \frac{\sqrt{3}}{2}$$

$\Rightarrow$ $\theta = 30°$

In ΔABI, $$AI = 60 \sin 30° = 60 \times \frac{1}{2} = 30 \text{ cm}$$

Using ΔAIC, $$IC = 2(30\cos 30°) = 2 \times 30 \times \frac{\sqrt{3}}{2} = 30\sqrt{3} \text{ cm}$$

$$\text{Velocity of } C = \omega(IC) = 2 \times 30\sqrt{3} = 60\sqrt{3} \text{ cm/s}$$

44. (c)

Prime circle is the smallest circle that can be drawn (with its centre at the cam centre) so as to be tangential to the pitch curve.

Trace point of a knife-edge follower is at the knife edge.

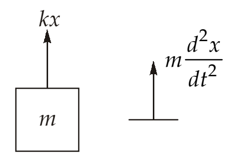
45. **(c)**

Drawing FBD of mass

$$\Rightarrow \quad m\frac{d^2x}{dt^2} + kx = 0$$

$$\Rightarrow \quad \frac{d^2x}{dt^2} + \frac{kx}{m} = 0$$

$$\Rightarrow \quad \frac{d^2x}{dt^2} + \omega_n^2 x = 0$$



The general solution of this equation is

$$x = A\cos(\omega_n t + \phi)$$

Here, $\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{1080}{1.2}} = 30$

At, $t = 0$, $x = 5$ mm

So, $5 = A\cos(\phi)$ ... (i)

At $t = 0$, $\dot{x} = 0$ mm/s

So, $\dot{x} = -A\omega_n \sin(\omega_n t + \phi)$

$\Rightarrow$ $0 = -A\omega_n \sin(\phi)$

As $A\omega_n \neq 0$

so, $\phi = 0$ ... (ii)

Putting value of ϕ in equation (i), we get, $A = 5$ mm

So, $x = 5\cos(30t)$

47. **(a)**

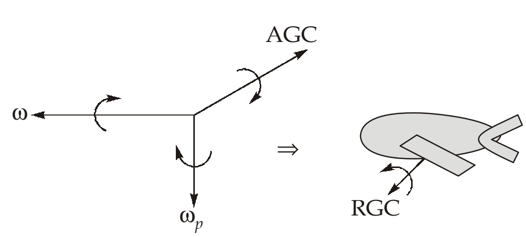
Undercutting decrease chances of interference as involute part does not come in contact with non-involute part.

There is no change in contact ratio as arc of contact and circular pitch remain unchanged due to undercutting. There is decrement in strength as we reduce the base by undercutting.

48. **(d)**

When the hands in a pair of spiral gears are same then the angle between the shafts is the sum of the helix angles of the two gears. Since the shaft angle is less than the helix angle of the right-handed spiral gear, the hands of the two gears must be opposite. Thus, the other spiral gear of the pair must be left handed and its helix angle is 10° – 5° = 5°.

49. **(a)**

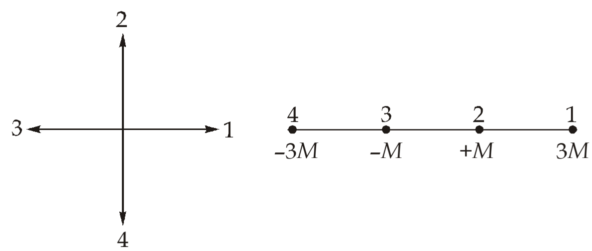


50. **(a)**

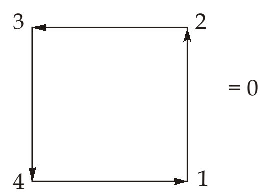
Friction at sleeve mass tends to decrease sensitivity and increase stability.

51. **(c)**

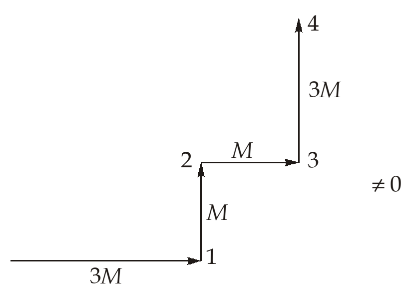
Primary cranks



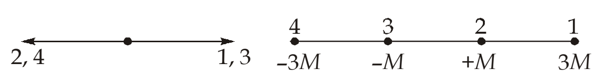
1. Primary forces



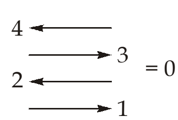
2. Primary force moments



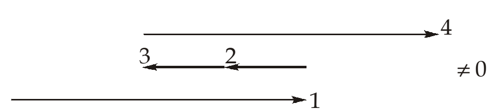
Secondary cranks



1. Secondary forces



2. Secondary force moments



52. **(c)**

$$\Delta E = I\omega^2 C_s$$

As ΔE and I remain constants,

$$C_s \propto \frac{1}{\omega^2}$$

$$\Rightarrow \quad \frac{C_{s2}}{C_{s1}} = \frac{\omega_1^2}{\omega_2^2} = \frac{1}{4}$$

53. (d)

For a gas contained in piston-cylinder arrangement,

$$\text{Availability function, } \phi = U - T_o S + p_o V$$

54. (b)

Triple point of water is 0.01°C or (273.15 + 0.01) K, i.e. 273.16 K. Specific volume of ice is more than that of liquid water at 0°C.

56. (a)

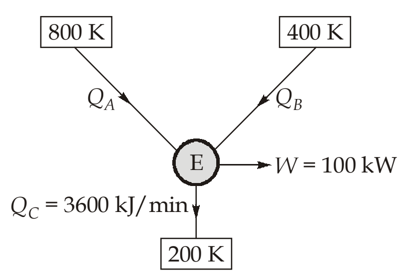
$$\text{Work done against atmosphere, } W = p_o(V_2 - V_1) = p_o\left(\frac{mRT_2}{p_2} - \frac{mRT_1}{p_1}\right)$$

$$= p_o mR\left(\frac{T_2}{p_2} - \frac{T_1}{p_1}\right) = 100 \times 2 \times 0.287 \times \left(\frac{300}{100} - \frac{400}{800}\right)$$

$$= 2 \times 28.7 \times \left(3 - \frac{1}{2}\right) = 2 \times 28.7 \times \frac{5}{2}$$

$$= 143.5 \text{ kJ}$$

57. (b)



I[st] law of thermodynamics,

$$Q_A + Q_B = Q_C + W$$

$$\Rightarrow \quad Q_A + Q_B = \frac{3600}{60} + 100 = 160 \text{ kW} \quad \text{... (i)}$$

$$\text{Clausius's inequality, } \oint \frac{đQ}{T} = 0$$

$$\Rightarrow \quad \frac{Q_A}{800} + \frac{Q_B}{400} = \frac{60}{200}$$

$$Q_A + 2Q_B = 240 \text{ kW} \quad \text{... (ii)}$$

Solving (i) and (ii):

$$Q_B = 80 \text{ kW}$$

Putting this value in equation (i):

$$Q_A + 80 = 160$$
$$Q_A = 80 \text{ kW}$$

So, $$\frac{Q_A}{Q_B} = \frac{80}{80} = 1$$

58. (c)

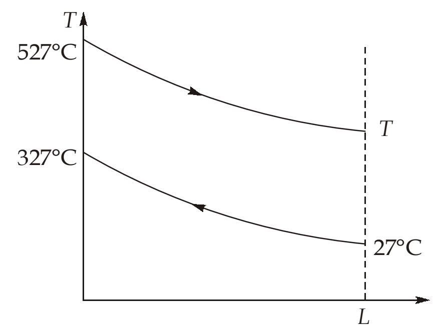
Heat required by hot water = Heat taken by cold water

$$\Rightarrow \quad \dot{m}_h c_{ph}(527 - T) = \dot{m}_c c_{pc}(327 - 27)$$

$$\Rightarrow \quad 0.75 \times 4.2 \times (527 - T) = 1 \times 4.2\,(327 - 27)$$

$$527 - T = \frac{300}{0.75} = 400$$

$$T = 527 - 400 = 127°\text{C}$$



Entropy generation rate, $\dot{S}_{gen} = \Delta\dot{S}_{univ}$

$$= \Delta\dot{S}_{sys} + \Delta\dot{S}_{surr} = \Delta\dot{S}_{sys} \quad [\because \Delta\dot{S}_{surr} = 0 \text{ (insulated)}]$$

$$= \Delta\dot{S}_h + \Delta\dot{S}_c$$

$$= \dot{m}_h c_{ph} \ln\frac{T_{hf}}{T_{hi}} + \dot{m}_c c_{pc} \ln\frac{T_{cf}}{T_{ci}}$$

$$= 0.75 \times 4.2 \ln\frac{400}{800} + 1 \times 4.2 \ln\frac{600}{300}$$

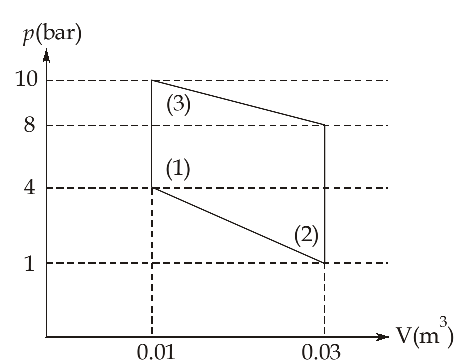
$$= 4.2\,[-0.75 \ln 2 + \ln 2]$$

$$= 4.2 \times 0.25 \times 0.7 = 0.735 \text{ kW/K}$$

59. (b)

Compresibility chart is plotted between compressibility factor (Z) and reduced pressure. At very low pressure, Z approaches 1 and gases behave like ideal gas.

60. (b)



Net work, $W_{net} = A_1 + A_2 + A_3$

$$= [(8-4)\times(0.03-0.01)+\frac{1}{2}\times(0.03-0.01)\times(4-1)+\frac{1}{2}\times(0.03-0.01)\times(10-8)]\times 100 \text{ kJ}$$

$$= 0.02\,[4 + 1.5 + 1] \times 100$$

$$W_{net} = 13 \text{ kJ} = p_m \times (0.03 - 0.01)$$

$$p_m = \frac{13}{0.02} = 650 \text{ kJ} = 6.5 \text{ bar}$$

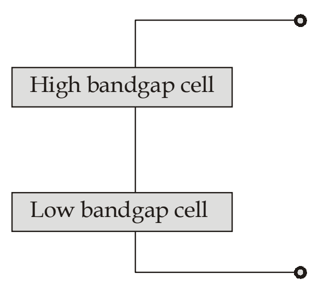
61. **(a)**

Czochralski process is the technique used to make single crystal silicon. Multiple steps like melting of polycrystalline silicon and adding of dopants, introduction of seed crystal, growth of crystal of formation of crystal are involved in Czochralski process.

62. **(d)**

Shockley-Quiesser limit states that in unconcentrated, AM 1.5, solar radiation with a band gap of 1.34 eV, 33.4% efficiency is obtained. AM coefficient or air mass coefficient is optical path length relative to path length vertically upward. AM 1.5 is typically used for evaluating panels. Tandem solar cells can overcome these limitations.

Tandem cells:



63. **(a)**

- Defects in crystal does not increase efficiency of solar cells. Defects create dangling band which will trap electrons and holes. Hence single crystal is preferred to work with solar cell as it is most effective to capture solar energy, compared to polycrystalline and amorphous crystal.

65. **(a)**

$$E = \frac{-\Delta G}{nF},$$

F = Faraday's constant = 96500 Coulombs per gram mole.

$$n = 2$$

$$E = \frac{237000}{2\times 96500} = \frac{1185}{965} = 1.23 \text{ V}$$

66. (d)

$$\text{Concentration ratio, CR} = \frac{1}{\sin\phi_{max}}$$

$$2\phi_{max} = \text{Acceptance angle} = 15°$$

$$\phi_{max} = 7.5°$$

$$\therefore \quad CR = \frac{1}{\sin\phi_{max}} = \frac{1}{\sin 7.5°} = 7.7$$

67. (b)

The wavelength of a travelling wave can be shown to be,

$$\lambda = \frac{2\pi g}{\omega^2}, \quad \omega = \frac{2\pi}{T}$$

$$\therefore \quad \lambda = \frac{2\pi g}{\omega^2}, \quad \omega = \frac{2\pi}{8} = 0.78 \text{ rad/s}$$

$$\lambda = \frac{2\pi \times 9.81}{0.17853^2} = 100 \text{ m}$$

68. (a)

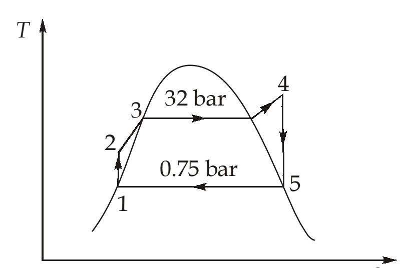
$$\text{Wind power, } P = \frac{1}{2}\dot{m}V^2 = \frac{1}{2}(\rho AV)V^2 = \frac{1}{2}\rho AV^3$$

$$P \propto V^3$$

69. (b)

Methane-forming bacteria works best in temperature range of 20 -55°C.

70. (d)



$$Q_{added} = h_4 - h_2$$

$$h_2 - h_1 = W_{pump} = v_f(P_{boiler} - P_{condenser})$$

$$= 0.001037(3200 - 75) = 3.24 \text{ kJ/kg}$$

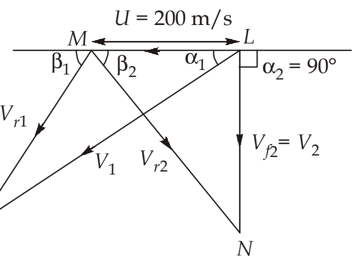
$$\therefore \quad h_2 - h_f = 3.24 \text{ kJ/kg}$$

$$h_2 = 3.24 + 384.36 = 387.6 \text{ kJ/kg}$$

$$h_4 = 3663 \text{ kJ/kg}$$

$$Q_{added} = 3663 - 387.6 = 3275.4 \text{ kJ/kg}$$

71. (c)



Given: V_1 = 600 m/s, U = 200 m/s,

$$\text{Diagram efficiency, } \eta_0 = \frac{2U(V_{w1}+V_{w2})}{V_1^2} \quad \text{... (i)}$$

$$V_{w1} = V_1 \cos\alpha_1 = 600 \times \cos 20° = 600 \times 0.9$$

$$V_{w2} = 0$$

Now, from equation (i),

$$\eta_o = \frac{2\times 200(600\times 0.9+0)}{600^2} = \frac{2\times 200\times 600\times 0.9}{600\times 600}$$

$$\eta_o = 60\%$$

72. (a)

$$\dot{m} = 314 \text{ kg/s} = \rho\times\frac{\pi}{4}D^2\cdot V\cdot n \text{ (where, } n = \text{Number of tubes)}$$

$$314 = 1000\times\frac{3.14}{4}\times\left(\frac{25}{1000}\right)^2\times 80\times n$$

$$n = 8 \text{ tubes}$$

$$\text{Heat transfer area, } A = (\pi DL)\times np$$

$$62.83 = \pi\times\frac{25}{1000}\times 2\times 8\times P$$

$$P = \frac{62.83\times 40}{3.14\times 2\times 8} = 50 \text{ passes}$$

73. (b)

$$\text{Temperature distribution, } T = T_s + \frac{q_G R^2}{6k}\left(1-\frac{r^2}{R^2}\right)$$

One dimensional conduction equation in polar coordinates:

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dT}{dr}\right)+\frac{q_G}{k} = 0$$

74. (c)

$$\dot{m} = 0.6 \text{ kg/s}$$

$$\text{Heat transfer rate, } q = \dot{m}c_p\Delta T = 0.6\times 4.2\times 10^3 \times 30 = 75600$$

Now,

$$q = h(\text{PL})(\text{LMTD})$$

$$75600 = 4614.2\times\frac{2(1.5+3.5)}{100}\times 6\times(LMTD)$$

$$\frac{75600\times 10}{6\times 4614.2} = (\text{LMTD})$$

$$\text{LMTD} = 27.307°\text{C}$$

75. (b)

$$\text{Controllability matrix, } \phi = [\text{B} \quad \text{AB}]$$

$$= \begin{bmatrix} 1 & 5 \\ 1 & \beta+12 \end{bmatrix}$$

$$\text{For not-controllable, } |\phi| = 0$$

$$\begin{vmatrix} 1 & 5 \\ 1 & \beta+12 \end{vmatrix} = 0$$

$$\beta + 12 - 5 = 0$$

$$\beta = -7$$

76. (c)

The matrix equation representing transformation is

$$P_{xyz} = R_a(90°)\cdot T(4, -3, 7)\cdot R_o(90°)\cdot P$$

$$= \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 7 \\ -3 \\ 1 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 \\ -3 \\ -7 \\ 1 \end{bmatrix}$$

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

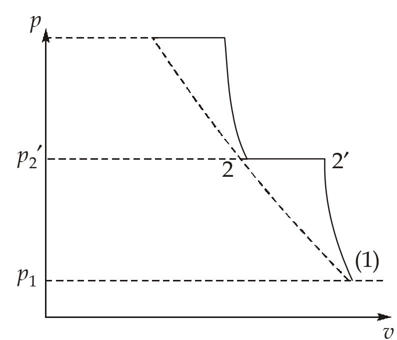
77. **(b)**

$$F_1 = P_1A_1$$
$$F_1 = P_2A_2$$
$$\Rightarrow \quad F_1 = F_2$$
$$P_1A_1 = P_2A_2$$
$$P_2 = P_1\left(\frac{A_1}{A_2}\right) = 477.464\left(\frac{4^2}{6^2}\right) = 212.206 \text{ N/cm}^2$$

78. **(c)**

As given data: p_1 = 1 bar, T_1 = 15 + 273 = 288 K, P_{N+1} = 256 bar, T_2' = 303 + 273 = 576 K

From 1 - 2′



$$\frac{T_2'}{T_1} = \left(\frac{p_2'}{p_1}\right)^{\frac{n-1}{n}} = k^{\frac{n-1}{n}}$$
$$\left(\frac{576}{288}\right) = k^{\frac{0.25}{1.25}}$$
$$k = (2)^{\frac{1.25}{0.25}} = 2^5 = 32$$
$$\frac{P_{N+1}}{P_1} = k^N$$
$$\frac{256}{1} = (32)^N$$
$$N \ln(32) = \ln(256)$$
$$N = \frac{\ln(2^8)}{\ln(2^5)} = \frac{8}{5} = 1.6 \approx 2 \text{ stages}$$

79. **(c)**

$$\rho = 4.8 \text{ g/cm}^3 = \frac{nA}{V_C N_A}$$

Where,
n = Number of atoms in each unit cell
A = Atomic mass = 48 g/mol
V_C = Volume of unit cell
N_A = Avogadro's number (6.023 × 10^{23} atoms/mol)

As titanium has HCP Crystal structure, so
n = 6 for HCP.

Now,
$$\rho = 4.8 \text{ g/cm}^3 = \frac{6 \times 48}{V_C \times 6.023 \times 10^{23}}$$

$$V_C = \frac{6\times 48}{4.8\times 6.023\times 10^{23}} = 9.96\times 10^{-23} \approx 10^{-22}\ \text{cm}^3$$
$$= 10^{-22} \times 10^{-6}\ \text{m}^3 = 0.1 \times 10^{-27}\ \text{m}^3$$
$$= 0.1\ \text{nm}^3$$

81. (a)

- Upon cooling hypereutectoid alloy cementite phase will begin to form on austenite grain boundries and this cementite is called proeutectoid cementite.
- Proeutectoid cementite has same appearance as proeutectoid ferrite due to this there is some difficulty in distinguishing between hypoeutectoid and hypereutectoid steels on the basis of microstructure.

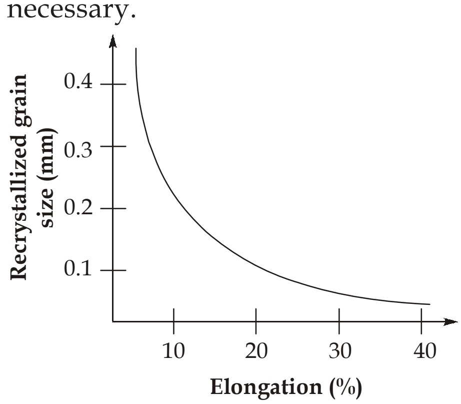
84. (a)

There is no significant change in modulus of elasticity for tungsten where the temperature is below recrystallization temperature.

85. (b)

The driving force for microstructural transformation of cementite plates into cementite spheroids in spheroidizing is the reduction in interfacial energy.

86. (a)

- To restore isotropy, a temperature higher than that required for recrystallization may be necessary.
- 

87. (c)

- Capillary tube is used as expansion device in both, refrigerator and air-conditioner.
- As temporary range of domestic refrigerator is large, its COP will be less,

$$\text{COP} = \frac{T_L}{T_H - T_L}$$

88. (a)

- Volumetric efficiency, $\eta_{vol} = 1 + C - C\left[\frac{P_H}{P_L}\right]^{1/n} = 1 - C\left[\left(\frac{P_H}{P_L}\right)^{1/n} - 1\right]$

As the clearance volume decrease, clearance ratio decrease and hence volumetric efficiency will increase.

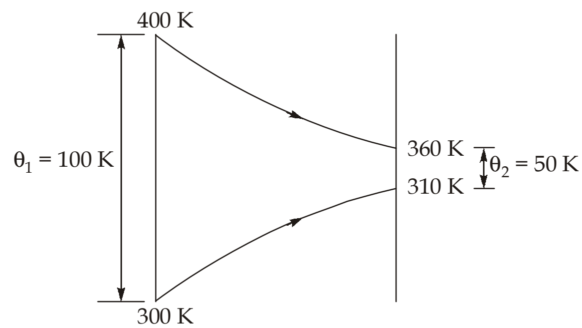
- Clearance ratio have no impact on the power consumption of the compressor.

89. (c)

As expander, compressor and motor are connected on same shaft,

$$\because \quad \dot{W}_{\text{net, input}} = \frac{\dot{W}_{\text{motor}}}{\eta_{\text{mech}}} = \frac{10}{1} = 10\text{ kW}$$

For a liquid cooled parallel flow air cooler,



Logarithmic mean temperature difference,

$$\theta_M = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)} = \frac{100-50}{\ln 2} = \left(\frac{50}{\ln 2}\right)$$

So, Heat rejected by air $(\theta_{rej}) = UA\theta_M$

$$= 0.5 \times 0.693 \times \frac{50}{\ln 2} = 25\text{ kW}$$

So, Heat absorbed by evaporator, $Q_{abs} = Q_{rej} - W_{\text{net, in}}$

$$= 25 - 10 = 15\text{ kW}$$

$$\text{COP of system} = \frac{Q_{abs}}{Q_{\text{net,in}}} = \frac{15}{10} = 1.5$$

90. (b)

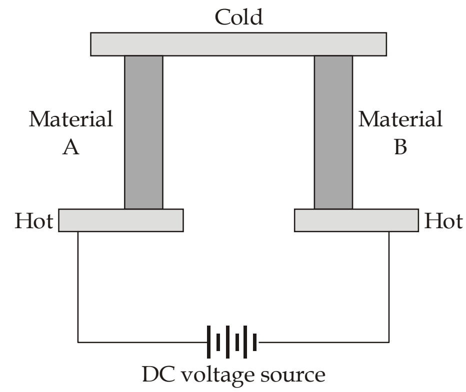
If the mean surface temperature of water is equal to the DBT of air then enthalpy of air increases due to humidification. Hence the water is required to be externally heated as its enthalpy decreases.

91. (d)

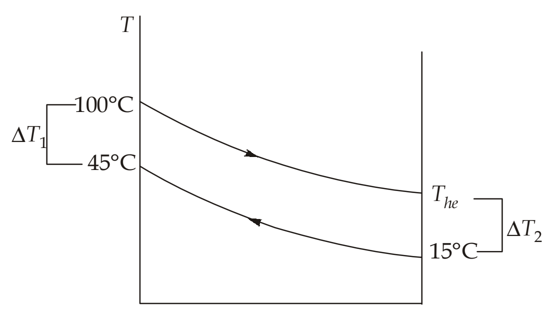
$$\begin{aligned} Q_{\text{total}} &= Q_{\text{sensible}} + Q_{\text{latent}} \\ &= \text{cmm } (0.0204\Delta t + 50\Delta\omega)\text{ kW} \\ &= 1000 \times (0.0204 \times 20 + 50 \times 7 \times 10^{-3}) \\ &= 1000 \times (0.408 + 0.350) \\ &= 758\text{ kW} \end{aligned}$$

92. (b)

- Material must be a very poor conductor of heat because heat must be absorbed at one end and rejected at the other.
- Basic principle for thermo-electric refrigeration is peltier effect.



93. (a)



$$\dot{q} = \dot{m}_h c_{ph}(T_{hi} - T_{he}) = \dot{m}_c c_{pc}(T_{ce} - T_{ci})$$

$$\Rightarrow \quad 2.1 \times 1(100 - T_{he}) = 0.5 \times 4.2\,(45 - 15)$$

$$2.1\,(100 - T_{he}) = 63 \text{ kW}$$

$$T_{he} = 70°\text{C}$$

Here,

$$\Delta T_1 = 100 - 45 = 55°$$

$$\Delta T_2 = 70 - 15 = 55°$$

$$\therefore \quad \text{LMTD} = 55°\text{C}$$

$$\dot{q} = 63 \times 1000 \text{ W} = \text{UA (LMTD)}$$

$$A = \frac{63000}{1000 \times 55} = \frac{63}{55} = 1.145 \text{ m}^2$$

94. (d)

Although the radiation emitted by a blackbody is a function of wavelength and temperature, it is independent of direction. That is, the blackbody is a diffuse emitter.

95. (d)

Given: $h = 15$ W/m^{2}K, $T_\infty = 127°$C

$$(q_{net})_{loss} = 700 \text{ W/m}^2$$

$$q_{conv} + 500 + 1200 - 2500 = 700$$

$$q_{conv} = 1500 \text{ W/m}^2$$

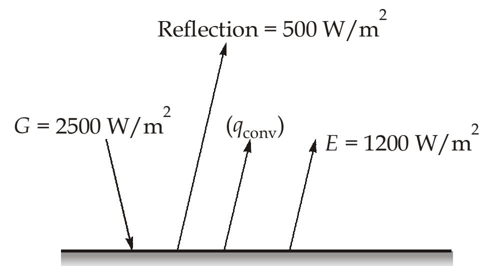
$$h\Delta T = 1500 \text{ W/m}^2$$

$$\Delta T = \frac{1500}{15} = 100°\text{C}$$

$$T_s - T_\infty = 100$$

$$T_s = 127 + 100 = 227°\text{C}$$

$$T_s = 500 \text{ K}$$



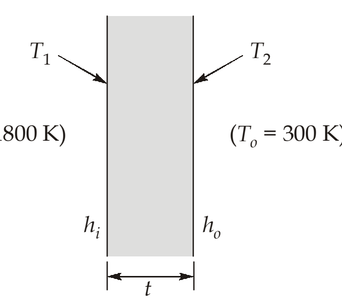
96. (c)

$$(\Delta T)_{\text{across slab}} \propto \frac{1}{k}$$

97. (c)

Given: $t = 0.2$ m, $h_i = 40$ W/m²K, $h_o = 10$ W/m²K, $k = 0.8$ W/m-K

$$\text{Heat flux, } q = \frac{T_i - T_o}{\frac{1}{h_i} + \frac{t}{k} + \frac{1}{h_o}} = \frac{T_i - T_1}{\frac{1}{h_i}} = \frac{T_2 - T_0}{\frac{1}{h_o}}$$



$$\Rightarrow \quad \frac{1800 - 300}{\frac{1}{40} + \frac{0.2}{0.8} + \frac{1}{10}} = \frac{1800 - T_1}{\frac{1}{40}} = \frac{T_2 - 300}{\frac{1}{10}}$$

$$\therefore \quad 4000 = \frac{1800 - T_1}{\frac{1}{40}} \text{ and } 4000 = \frac{T_2 - 300}{\frac{1}{10}}$$

$$T_1 = 1700 \text{ K, and } T_2 = 700 \text{ K}$$

98. (d)

$$h = 1.2 \text{ m of water} = \frac{flV_m^2}{2gD}$$

where, f = Friction factor,

$$f = \frac{1.2 \times 2 \times 10 \times 2.5 \times 10^{-2}}{6 \times 3^2} = \frac{12 \times 2 \times 10 \times 25}{6 \times 9 \times 100 \times 100} = \frac{1}{90}$$

$$\text{Friction coefficient, } C_f = \frac{f}{4} = \frac{1}{4 \times 90} = \frac{1}{360}$$

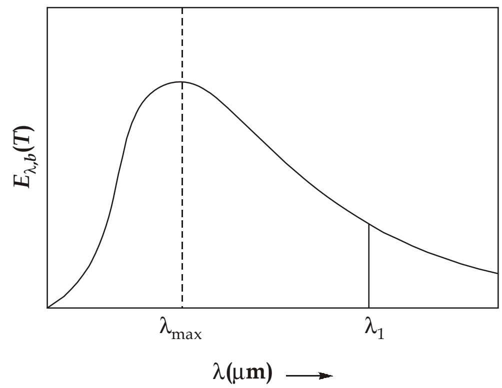
By Reynolds analogy,

$$St_d = \frac{h}{\rho V_m c_p} = \frac{C_f}{2}$$

$$h = \frac{1000 \times 3 \times 4.2}{2 \times 360} = 17.5 \text{ kW/m}^2\text{K}$$

99. (b)

The wavelength λ_1 corresponds to the lower limit of spectral band ($\lambda_1 \to \infty$) containing 10% of emitted radiation.



$$F_{(\lambda_1 \to \infty)} = 1 - F_{(o \to \lambda_1)} = 0.1 \text{ (or 10\%)}$$
$$F_{o - \lambda_1} = 0.9$$

It follows from table given in question that $\lambda_1 T = 9382$

$$\therefore \quad \lambda_1 = \frac{9382}{2000} = 4.69\,\mu m$$

101. (b)

$$\text{Speed, } V = \sqrt{2gH}$$
$$V \propto H^{1/2}$$
$$\text{Discharge, (Q)} = A.V = \frac{\pi}{4}D^2 \times \sqrt{2gH}$$
$$Q \propto H^{1/2}$$
$$\text{Power, (P)} = \rho Q g H$$
$$P \propto \sqrt{H} \cdot H$$
$$P \propto H^{3/2}$$

102. (c)

As per given information:

Work done per second by the jet on the plate = $F_x \times u$

The normal thrust on a moving flat plate is given as

$$F_x = \dot{m}\left[(v-u)-0\right]$$
$$= \rho A\,(v-u)[(v-u)-0]$$
$$\text{Work done per second} = F_x \times u$$
$$= \rho A\,(v-u)^2 \times u$$
$$\text{Kinetic energy of the issuing jet} = \frac{1}{2}\dot{m}v^2 = \frac{1}{2}(\rho A v)(v)^2 = \frac{1}{2}\rho A v^3$$

$$\text{Efficiency of jet, } \eta = \frac{\text{Work done per second}}{\text{Kinetic energy of issuing set}}$$

$$= \frac{\rho A(v-u)^2 u}{\frac{1}{2}\rho A v^3} = \frac{2u(v-u)^2}{v^3}$$

103. (c)

As per given data:

$\eta_o = 0.90$, $\rho = 1000$ kg/m^3, $Q = 9$ m^3/s, $g = 10$ m/s^2, $H = 25$ m

$$\text{Power} = \eta_o \times \rho Q g H$$
$$= 0.9 \times 1000 \times 9 \times 10 \times 25$$

$$\text{Power} = \frac{9 \times 9 \times 100 \times 25 \times 10}{1000} \text{ kW}$$

$$\text{Specific speed, } N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{200\sqrt{\left(\frac{9 \times 9 \times 100 \times 25 \times 10}{1000}\right)}}{25^{5/4}} = \frac{200 \times 45}{25^{5/4}}$$

$$= \frac{200 \times 45}{55.9} = 161.00$$

104. (b)

Due to finite number of vanes on a rotor the air trapped between the impeller vanes is reluctant to move round with the impeller and this results in a higher static pressure on the leading face of a vane than on the trailing face. It also prevents the air acquiring a whirl velocity equal to impeller speed. This effect is known as slip. Because of slip, we obtain $V_{w2} < U_2$. The slip factor σ is

$$\sigma = \frac{V_{w2}}{U_2}$$

The value of σ lies between 0.9 to 0.92. The energy transfer per unit mass in case of slip becomes

$$\frac{E}{m} = V_{w2}U_2 = \sigma U_2^2$$

105. (b)

As per given data: As the 22% of hydraulic losses

$$\text{hydraulic efficiency, } \eta_h = 1 - 0.22 = 0.78$$

For radial discharge,
$$\eta_H = \frac{V_{w1}u_1 \times \rho Q}{\rho Q g H} = \frac{V_{w1}u_1}{gH} \quad \text{... (i)}$$

As we know,
$$H = 8 \text{ m}$$
$$u_1 = 12.03 \text{ m/s}$$

$$V_{f1} = 4.51 \text{ m/s}$$

From equation (i),
$$0.78 = \frac{V_{w1} \times 12.03}{10 \times 8}$$

$$V_{w1} = \frac{0.78 \times 10 \times 8}{12.03} = \frac{62.4}{12.03} = 5.18 \text{ m/s}$$

106. (c)

Stop valve: It regulates the flow of steam from the boiler. This is generally mounted on highest part of boiler shell and performs function of regulating the flow of steam from boiler. Stop valve generally has main body of cast steel; valve, valve seat and nut etc. are of brass.

Statement 2 is correct for feed check valve.

107. (c)

As per given data:

Cofficient of friction, $k = 1$, $u = 12$ m/s, $Q = 0.9$ m^3/s, $H = 100$ m

$$v_1 = \sqrt{2 \times 9.81 \times 100} = 10\sqrt{19.62}$$
$$= 4.42 \times 10 = 44.20 \text{ m/s}$$
$$\phi = 180° - 160° = 20°$$

Power developed,
$$P = u(v - u)\,[1 + k\cos\phi]\rho Q$$
$$= 12(44.20 - 12)\,[1 + \cos 20°] \times 10^3 \times 0.9$$
$$= 12 \times 32.20\,[1 + 0.93] \times 0.9 \text{ kW}$$
$$= 12 \times 32.20 \times 1.93 \times 0.9 \text{ kW}$$
$$= 12 \times 32.20 \times 1.737 \text{ kW}$$
$$= 671.2 \text{ kW}$$

108. (a)

Given: Height of chimney, $H = 20$ m, Flue gas temperature, $T_g = 380 + 273 = 653$ K, Ambient temperature, $T_a = 27 + 273 = 300$ K

For maximum discharfge condition,

$$\frac{T_g}{T_a} = 2\left(\frac{m+1}{m}\right)$$

$$2\left(\frac{m+1}{m}\right) = \frac{653}{300}$$

$$\Rightarrow \quad 2m + 2 = 2.176 \text{ m}$$

$$m = \frac{2}{0.176} = 11.36$$

$$m = 11.36 \text{ kg air per kg of fuel}$$

$$\text{Air supplied} = 11.36 \text{ kg/kg of fuel}$$

110. (d)

- Ejector condenser has water jet discharging through the series of guide cones which guide steam on to the surface of water jet. Discharge of water through these convergent nozzles causes partial vacuum due to conversion of potential energy into kinetic energy.
- Subsequently water jet enters the diffuser nozzle where kinetic energy is converted into the pressure head and water is discharged against the vacuum pull.
- Ejector condensers are well suited for moderate vacuum only.
- Steam is injected in condenser with non-return valve in between and is condensed by the mixing with cooling water. Condensation of steam further increases vacuum.
- Ejector condenser does not require air pump because of air entraining effect of water jet itself.

111. (*)

As per given data:

Turbine 1

$$P_1 = 130 \text{ kW}$$
$$N_1 = 230 \text{ rpm}$$
$$H_1 = 16 \text{ m}$$
$$D_1 = 1 \text{ m}$$

Turbine 2

$$P_1 = 660 \text{ kW}$$
$$H_2 = 25 \text{ m}$$
$$D_2 = ?$$

From similarity relationship,

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

$$\frac{130}{D_1^2 (16)^{3/2}} = \frac{660}{D_2^2 (25)^{3/2}}$$

$$\left(\frac{D_2}{D_1}\right)^2 = \frac{660 \times 16^{3/2}}{130 \times 25^{3/2}}$$

$$\frac{D_2}{D_1} = \left(\frac{660 \times 16^{3/2}}{130 \times 25^{3/2}}\right)^{1/2} = 1.6$$

$$\Rightarrow \quad D_2 = 1.6 \text{ m}$$

112. (d)

Velocity compounded impulse turbine offers advantages such as less number of stages compared to pressure compounding and so less cost. It also requires less space and is relatively more reliable and easy to start. In multi stage velocity compounded impulse turbine the first stage has large pressure drop and remaining turbine stages are subjected to constant low pressure, thus lesser number of stages. In velocity compounded impulse turbine since pressure drop occurs in nozzle itself so the rest of turbine and its' casing need not be manufactured very strong. But the efficiency is low due to large frictional losses due to large initial velocity and 'non optimum value of ratio of blade velocity to steam velocity for all blade rings'.

113. (c)

$$\rho = 8000 \text{ kg/m}^3$$
$$\omega = 20 \text{ rad/s}$$
Flywheel radius, $R = 0.3$ m

Tangential velocity, $V = R\omega = 0.3 \times 20 = 6$ m/s

As we know,

In case of disk flywheel,

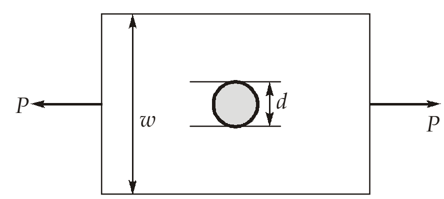
$$\sigma_{r\ max} = \frac{\rho V^2}{8}(\mu + 3) = \frac{8000 \times 6^2}{8} \times (0.3 + 3)$$
$$= 1000 \times 36 \times 3.3 \text{ N/m}^2$$
$$= \frac{1000 \times 36 \times 3.3}{10^6} = 0.118 \text{ MPa}$$

114. (b)

Corrected indurance limit, $S_e = k_a k_b k_c k_d\, S_e^*$

$$= 0.6 \times 0.5 \times 0.8 \times \frac{1}{2} \times (0.5 \times 400)$$
$$S_e = 24 \text{ MPa}$$

For axial load, $(S_e)_a = 0.7 \times 24 = 16.8$ MPa



For safe design, $$\frac{P}{(w-d)t} \le \frac{(S_e)_a}{N}$$

$$\Rightarrow \quad \frac{30 \times 10^3}{(40-10) \times t} \le \frac{16.8}{2}$$

$$\Rightarrow \quad t \ge \frac{2000}{16.8} \text{ mm}$$
$$t \ge 119.05 \text{ mm}$$

115. (b)

$\because$ Joint stiffness factor, (c) $= \dfrac{k_b}{k_m + k_b} = 0.3$

where, k_b = Stiffness of bolts

k_m = Stiffness of member

For joint to be leak proof,

$$F_{member} \ge 0$$

$$\Rightarrow \quad F_{pre} - \frac{k_m}{k_m + k_b} \times W \ge 0$$

$$\Rightarrow \quad F_{pre} \ge W(1 - c)$$

$\because$ Load applied (W) $= p \times \frac{\pi}{4} D^2 = 6 \times \frac{\pi}{4} \times 200^2$ N

So, Pretensioning per bolt $= \frac{F_{pre}}{n} = \frac{W(1-c)}{6} = \frac{6 \times \frac{\pi}{4} \times 200^2}{6} \times 0.7$

$= 22000$ N $= 22$ kN

116. (b)

$$\because \quad T_{mean} = \frac{\int_0^{4\pi} T \cdot d\theta}{4\pi} = \frac{\int_0^{4\pi} (375 + 100\sin 2\theta - 50\cos\theta)\, d\theta}{4\pi} = 375 \text{ N-m}$$

For clutch, $T_{transmit} = T_{mean} = 375$ N-m

According to UWT, $T_{transmit} = \frac{\mu p_{per} d}{8 \sin\alpha}(D^2 - d^2)$

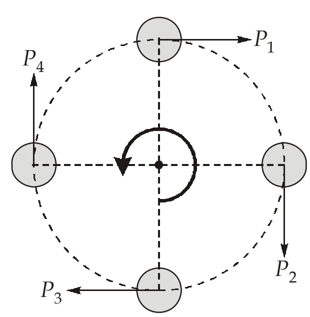
where, d = Inner diameter

D = Outer diamater

$$\Rightarrow \quad 375 = \frac{\mu \times 0.2164 \times \frac{150}{1000}(250^2 - 150^2)}{8 \sin 12.5°}$$

$$\mu = \frac{375 \times 8 \times 0.2164 \times 1000}{0.2164 \times 150 \times 400 \times 100} = 0.5$$

117. (d)



$\therefore \quad P_1 r + P_2 r + P_3 r + P_4 r - T = 0$

By symmetry

$P_1 = P_2 = P_3 = P_4$

$4Pr = T$

$$P = \frac{T}{4r} = \frac{T}{4 \times \frac{50}{1000}} = \frac{100T}{20} = 5T$$

$$\text{Shear stress} = \frac{P}{A} = \frac{5T}{20} = 40$$

$T = 160$ Nm

118. (a)

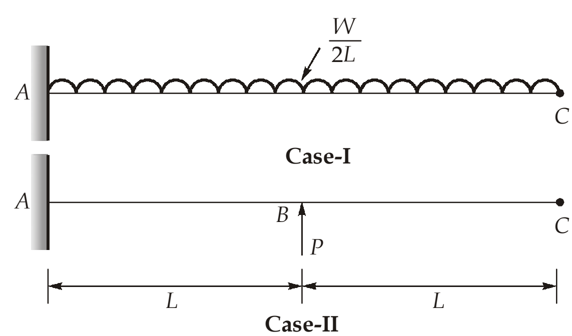
$$(\sigma_x)_{max} = 70\text{ N/mm}^2, \quad (\sigma_y)_{max} = 80\text{ N/mm}^2$$
$$(\sigma_x)_{min} = 30\text{ N/mm}^2, \quad (\sigma_y)_{min} = 20\text{ N/mm}^2$$
$$\sigma_{xm} = 50\text{ N/mm}^2, \quad \sigma_{ym} = 50\text{ N/mm}^2$$
$$\sigma_{xa} = 20\text{ N/mm}^2, \quad \sigma_{ya} = 30\text{ N/mm}^2$$

Using maximum distortion energy theory of failure,

$$\sigma_m = \sqrt{\sigma_{xm}^2 - \sigma_{xm} \times \sigma_{ym} + \sigma_{ym}^2}$$
$$= \sqrt{50^2 - 50 \times 50 + 50^2} = \sqrt{5000 - 2500} = 50\text{ N/mm}^2$$
$$\sigma_a = \sqrt{\sigma_{xa}^2 - \sigma_{xa} \times \sigma_{ya} + \sigma_{ya}^2}$$
$$= \sqrt{20^2 - 20 \times 30 + 30^2} = \sqrt{900 + 400 - 600}$$
$$\sigma_a = \sqrt{700} = 26.45\text{ N/mm}^2$$
$$\text{Amplitude ratio} = \frac{26.45}{50} = 0.53$$

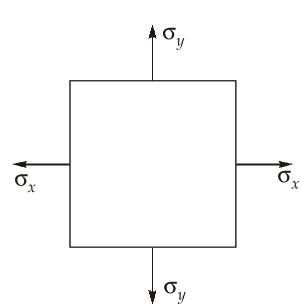
119. (c)

Slope at C is zero, i.e.



$$\theta_C = 0$$
$$\theta_{cI} = \theta_{cII}$$
$$\Rightarrow \quad \frac{\left(\frac{W}{2L}\right)(2L)^3}{6EI} = \left(\frac{PL^2}{2EI}\right)$$
$$\Rightarrow \quad \frac{4W}{3} = P$$
$$\Rightarrow \quad \frac{W}{P} = \frac{3}{4}$$

120. (c)



As we know, $$\varepsilon_x = \frac{1}{E}\left[\sigma_x - \mu\sigma_y\right] = \frac{1}{E}\left[\sigma_x - \mu \times 2\sigma_y\right] = \frac{\sigma_x}{E}(1-2\mu)$$

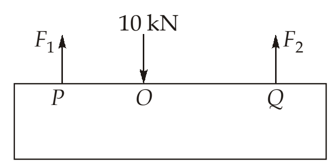
And, $$\varepsilon_y = \frac{1}{E}\left[\sigma_y - \mu\sigma_x\right] = \frac{1}{E}\left[2\sigma_x - \mu\sigma_x\right] = \frac{\sigma_x}{E}(2-\mu)$$

So, $$\frac{\varepsilon_x}{\varepsilon_y} = \frac{\frac{\sigma_x}{E}[1-2\mu]}{\frac{\sigma_x}{E}[2-\mu]} = \frac{1-2\mu}{2-\mu}$$

121. (b)

For equilibrium, $$\Sigma M_P = 0$$

$\Rightarrow$ $$F_2 \times (50 + 150) = 10 \times 50$$



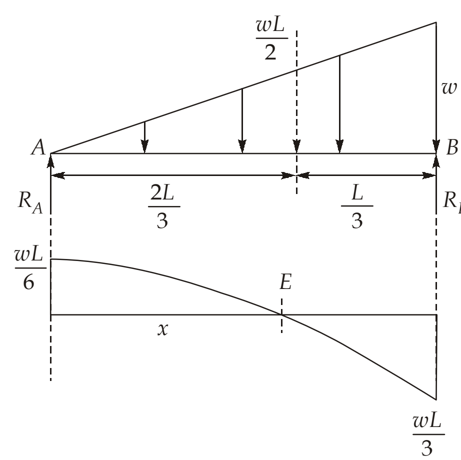
$$F_2 = \frac{10 \times 50}{200} = 2.5\text{ kN}$$

So, force in bar 2, $$F_2 = 2.5\text{ kN (Tensile)}$$

$$\Delta_2 = \frac{F_2 L}{AE} = \frac{2.5 \times 1000 \times 500}{250 \times 200 \times 10^3} = 0.025\text{ mm}$$

122. (b)

For Equilibrium, $\Sigma F_y = 0$



$\Rightarrow$ $$R_A + R_B = \frac{wL}{2}$$

$\Sigma M_A = 0,$ $$\frac{wL}{2} \times \frac{2L}{3} - R_B \times L = 0$$

$\Rightarrow$ $$R_B = \frac{wL}{3}$$

$$R_A = \frac{wL}{2} - \frac{wL}{3} = \frac{wL}{6}$$

Shear force diagram, $$SF_A = R_A = \frac{wL}{6}$$

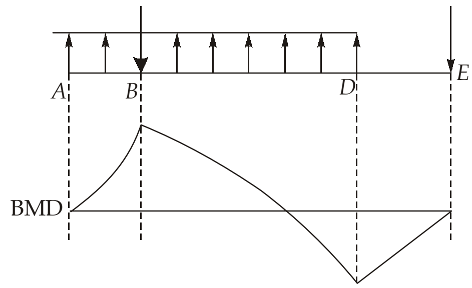
$$SF_B = -R_B = -\frac{wL}{3}$$

Since load intensity increases from point A to B, slope of SFD will increase.

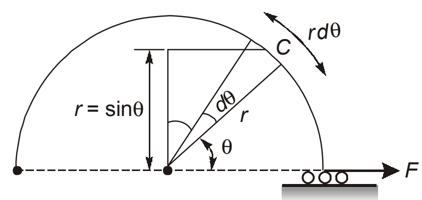
$$SF_E = \frac{wL}{6} - \frac{1}{2}\left(\frac{wx}{L}\right)x = \frac{wL}{6} - \frac{wx^2}{2L} = 0$$

$$\frac{wL^2}{3} = wx^2 \Rightarrow x = \frac{L}{\sqrt{3}}$$

123. (b)



124. (a)



$$M \text{ at } C = F \times \text{perpendicular distance}$$
$$= F \times r\sin\theta$$

$\therefore$
$$M = F \times r\sin\theta$$

$$\frac{dM}{dF} = r\sin\theta$$

By Castigliano's theorem

$$\delta = \int_0^l \frac{M}{EI} \times \frac{\partial M}{\partial F} \times dx = \int_0^\pi \frac{Fr\sin\theta}{EI} \times r\sin\theta \times rd\theta$$

$$= \int_0^\pi \frac{Fr^3\sin^2\theta d\theta}{EI} = \frac{Fr^3}{EI} \times \int_o^\pi \sin^2\theta d\theta$$

$$= \frac{Fr^3}{EI} \times \int_o^\pi \left(\frac{1-\cos 2\theta}{2}\right) d\theta = \frac{Fr^3}{2EI}\left[\pi - \left[\frac{\sin 2\theta}{2}\right]_0^\pi\right]$$

$$= \frac{Fr^3}{2EI}\left[\pi - \left\{\frac{\sin 2\pi}{2} - \frac{\sin 0}{2}\right\}\right]$$

$$= \frac{\pi F r^3}{2EI} = \frac{\pi \times 10 \times 10^3 \times 0.5 \times 0.5 \times 0.5}{2 \times 1250} = \frac{\pi}{2} \text{ m}$$

125. (b)

$$\varepsilon_x = \varepsilon_{0^\circ} = 200 \ \mu\text{m/m}$$
$$\varepsilon_y = \varepsilon_{90^\circ} = 300 \ \mu\text{m/m}$$

$$\varepsilon_{45^\circ} = 150\,\mu\text{m/m}$$

$$\varepsilon_n = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

$$600 = \frac{200+300}{2} + \frac{200-300}{2}\cos(90^\circ) + \frac{\gamma_{xy}}{2}\sin(90^\circ)$$

$$600 = 250 + \frac{\gamma_{xy}}{2} \Rightarrow \gamma_{xy} = 700\,\mu\text{m/m}$$

126. (a)

$$\sigma_1 = \frac{16}{\pi d^3}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\sigma_2 = \frac{16}{\pi d^3}\left[M - \sqrt{M^2 + T^2}\right]$$

According to Maximum shear stress theory

$$\tau_{\max} \le S_{ys}$$

$$\frac{\sigma_1 - \sigma_2}{2} \le \frac{\sigma_{yt}}{2}$$

$$\sigma_1 - \sigma_2 \le \sigma_{yt}$$

$$\frac{16}{\pi d^3}\left[M + \sqrt{M^2 + T^2}\right] - \frac{16}{\pi d^3}\left[M - \sqrt{M^2 + T^2}\right] = \sigma_e$$

$$\Rightarrow \frac{32}{\pi d^3}\sqrt{M^2 + T^2} = \sigma_e$$

$$\Rightarrow \frac{32 \times 10^6}{\pi d^3}\sqrt{5^2 + 12^2} = 160$$

$$\frac{32 \times 10^6 \times 13}{\pi d^3} = 160$$

$$d^3 = \frac{32 \times 10^6 \times 13}{\pi \times 160}$$

$$d^3 = \frac{10^6 \times 13}{5\pi}$$

127. (c)

$$\left(\frac{P}{V}\right)_{\text{ratio}} = \frac{\text{Sales cost/ unit} - \text{Variable cost/ unit}}{\text{Sales cost/ unit}}$$

$$0.25 = \frac{40 - \text{Variable cost/ unit}}{40}$$

$$\text{Variable cost/unit} = (40 - 40 \times 0.25) = ₹30/\text{unit}$$

128. (c)

$$\text{Reorder level} = \text{Safety stock} + \text{Consumption during normal lead time}$$

$$= 400 + \frac{12000}{300} \times 14 = 400 + 560 = 960 \text{ units}$$

129. (b)

In work sampling, number of observation is given by,

$$n = \frac{Z^2}{L^2} \times \frac{(1-P)}{P}$$

Where, n = Number of observation

P = Proportional or fraction occurance of an activity

L = Limit of accuracy

Z = Standard normal variant whose value depends upon confidence level required.

$$Z = 1.96,\ L = 0.05,\ P = \frac{15}{20} = \frac{3}{4}$$

$$n = \frac{1.96^2}{(0.05)^2} \times \frac{(1-3/4)}{3/4} = 512.2133 = 513$$

130. (d)

Min Ai ≥ Max. Bi

Min Ci ≥ Max. Bi

	Xi	Yi
~~1~~	~~9~~	~~13~~
2	15	16
~~3~~	~~11~~	~~8~~
~~4~~	~~9~~	~~10~~
5	9	13

Sequence is 4 - 1 - 5 - 2 - 3 or 4 - 5 - 1 - 2 - 3

132. (a)

Unit A and B are in parallel connection

∴ $R_{AB} = 1 - (1 - R_A)(1 - R_B)$

where, $R_A = R_B = R_C = 0.35$

∴ $R_{AB} = 1 - (1 - 0.35)(1 - 0.35)$

∴ $R_{AB} = 1 - 0.65 \times 0.65$

$= 0.5775$

∴ $R_{system} = R_{AB} \times R_C$

$= 0.5775 \times 0.35$

133. (b)

$$kE_A = kE_B$$

$$\Rightarrow \quad \frac{1}{2}m_A V_A^2 = \frac{1}{2}m_B V_B^2$$

$$\Rightarrow \quad \frac{m_A}{m_B} = \left(\frac{V_B}{V_A}\right)^2$$

$$\Rightarrow \quad \sqrt{\frac{1}{9}} = \frac{V_B}{V_A} \Rightarrow V_B = \frac{V_A}{3}$$

Ratio of linear momentums, $$\frac{P_A}{P_B} = \frac{m_A V_A}{m_B V_B} = \frac{1}{9} \times 3 = \frac{1}{3}$$

134. (c)

Torsional stiffness, $$k = \frac{GJ}{L}$$

$$\frac{k_h}{k_s} = \frac{GJ_h / L_h}{GJ_s / L_s} \qquad [\because \text{Material is same}]$$

$$\frac{k_h}{k_s} = \frac{J_h}{J_s} \times \frac{L_s}{L_h} = \frac{\frac{\pi}{32}\left(D^4 - d^4\right)}{\frac{\pi}{32}D^4} \times \frac{L_s}{L_h}$$

$$\frac{k_h}{k_s} = \left[1 - \left(\frac{d}{D}\right)^4\right]\frac{L_s}{L_h}$$

136. (c)

From symmetry

$$R_D = R_E = P + \frac{wl}{2} \qquad \text{...(i)}$$

$$M = P \cdot x - \left(P + \frac{wl}{2}\right)(x - l) + w(x - l)\frac{(x - l)}{2}$$

$$= P \cdot x - \left(P + \frac{wl}{2}\right)(x - l) + \frac{w}{2}(x - l)^2$$

$$M \text{ at } x = \frac{3l}{2}$$

$$= \frac{3Pl}{2} - \left(P + \frac{wl}{2}\right)\frac{l}{2} + \frac{w}{2}\left(\frac{l}{2}\right)^2$$

$$= \frac{3Pl}{2} - \frac{Pl}{2} - \frac{wl^2}{2} + \frac{wl^2}{8} = Pl - \frac{3l^2}{8}$$

$$P = \frac{wl}{8}$$

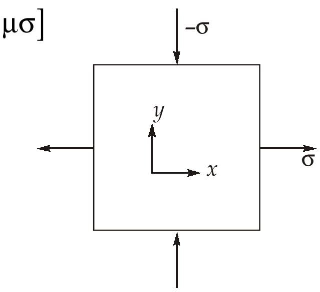
137. **(d)**

For thermal stress, along with temperature gradient, restriction on expansion is also required.

138. **(d)**

Stress in z-direction,

$$\varepsilon_z = \frac{1}{E}\left[\sigma_z - \mu\sigma_y - \mu\sigma_x\right] = \frac{1}{E}[0 + \mu\sigma - \mu\sigma]$$



$\varepsilon_z = 0$, i.e. plane strain condition,

As we know,

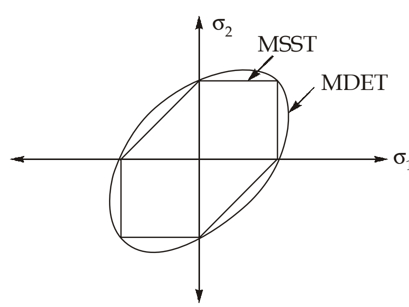
$$\text{Volumetric strain, } \varepsilon_v = \frac{1-2\mu}{E}\left[\sigma_x + \sigma_y + \sigma_z\right]$$

$$\varepsilon_v = \frac{1-2\mu}{E}\left[\sigma_x + \sigma_y + \sigma_z\right]$$

Since, $\sigma_x + \sigma_y + \sigma_z = 0, \varepsilon_v = 0$

139. **(c)**

The region of safety of MSST is a hexagon which is less than region of safety of MDET i.e. MSST gives larger safe dimensions than MDET.



$$\text{Safe dimension} \propto \frac{1}{\text{Region of safety}}$$

140. **(d)**

Dropwise condensation is much desirable because of its higher heat transfer rates. However, it hardly occurs on a cooling surface. When the surface is coated with some promoter like teflon, mercaptan, oleic acid and so on, drop condensation can occur for some time.

141. **(d)**

Vortex tube is a device which uses only compressed air and discharges hot and cold steams simultaneously.

142. **(d)**

Liquification of Helium is not possible at atmospheric pressure. It is liquified at very high pressure and low temperature.

147. (d)

$$\text{Entropy change, } \Delta S = \oint \frac{đQ}{T} + S_{gen}$$

For reversible process, $S_{gen} = 0$

So, $$\Delta S = \oint \frac{đQ}{T}$$

If process is isothermal expansion, heat will be added to system. Hence, entropy change of system will be positive. If process is isothermal compression, heat will be rejected. Hence entropy change of the system will be negative.

148. (d)

Stepper motor highly preffered for the open loop control system.

149. (c)

In fixture, a setting block is used to locate the cutting tool in relation to workpiece surface to be produced. So statement 2 is wrong.

150. (a)

The size of in gate are normally increased from to to bottom such that metal enters the mould cavity from the bottom most gate and then progressively moves to the higher gate. This gives the sound casting without any mould erosion.