DETAILED SOLUTIONS

MADE EASY

India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Lucknow, Bhubaneswar, Pune, Kolkata, Patna

ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 10

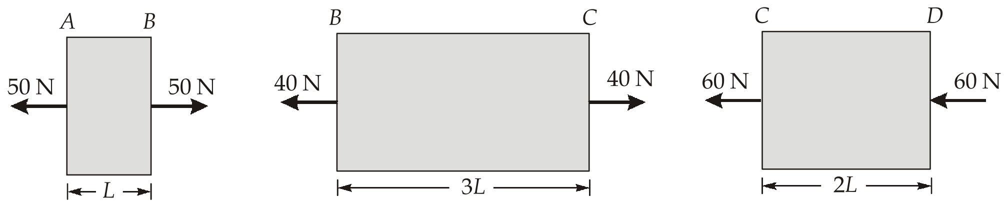
Section A : Strength of Materials & Engineering Mechanics [All Topics]
Section B : Heat Transfer-1 + IC Engines-1 [Part Syllabus]
Section C : Fluid Mechanics and Turbo Machinery-2 [Part Syllabus]

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

DETAILED EXPLANATIONS

1. (b)

The total elongation of the wire will be the sum of the elongations of the individual sections *AB*, *BC* and *CD*. Considering FBDs of these sections,



Therefore, total elongation of the bar is given by

$$\Delta L = \Delta L_{AB} + \Delta L_{BC} + \Delta L_{CD}$$

$$= \left(\frac{PL}{AE}\right)_{AB} + \left(\frac{PL}{AE}\right)_{BC} + \left(\frac{PL}{AE}\right)_{CD}$$

$$= \frac{4 \times 50 \times L}{\pi D^2 E} + \frac{4 \times 40 \times 3L}{\pi D^2 E} + \frac{4 \times 60 \times 2L}{\pi D^2 E}$$

$$= \left(\frac{4L}{\pi D^2 E}\right)(50 + 120 + 120)$$

$$= \frac{1160L}{\pi D^2 E}$$

Now, the maximum stress will be in the portion where the maximum force is acting as the diameters of all three portions are same.

$$\therefore \quad \sigma_{max} = \left(\frac{P}{A}\right)_{CD} = \frac{4 \times 60}{\pi D^2} = \frac{240}{\pi D^2}$$

2. (b)

The strain in any direction of the cube will be given as:

$$\in_x = \frac{\sigma_x}{E} - \frac{v\sigma_y}{E} - \frac{v\sigma_z}{E} \quad \text{...(i)}$$

where, $\sigma_x = \sigma_y = \sigma_z = -300$ MPa (as pressure is a compressive stress)

Putting the given values in equation (i),

$$\in_x = \frac{-300 \times 10^6}{100 \times 10^9} - \frac{1}{4}\frac{(-300 \times 10^6)}{100 \times 10^9} - \frac{1}{4}\frac{(-300 \times 10^6)}{100 \times 10^9}$$

$$\in_x = -3 \times 10^{-3} + 0.75 \times 10^{-3} + 0.75 \times 10^{-3}$$

$$\in_x = -1.5 \times 10^{-3}$$

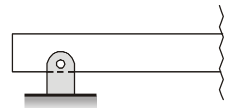
$$\therefore \quad \text{Change in dimension, } \Delta = \in_x L_x$$

$$= -1.5 \times 10^{-3} \times 100$$

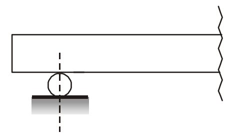
$$= -0.15 \text{ mm}$$

3. **(c)**

A pinned support is capable of resisting a force in any direction of the plane.



A roller support is capable of resisting a force in only one specific line of action.



4. **(d)**

The torque in the shaft can be expressed as $T = tx$, where t = 40 kN-m/m. Using the expression for the torque, the angle of twist can be calculated as

$$\phi = \int_0^L \frac{T}{JG} dx = \frac{t}{JG}\int_0^L x\, dx = \frac{tL^2}{2GJ}$$

If the angle of twist must be limited to 0.05 rad, the minimum polar moment of inertia is given by

$$J = \frac{tL^2}{2\phi G} = \frac{40000 \times 10^2}{2 \times 0.05 \times 40 \times 10^9}$$

$$J = 10^{-3} \text{ m}^4 = 10^9 \text{ mm}^4$$

$$J = 1000 \times 10^6 \text{ mm}^4$$

6. **(c)**

Block slides itself if inclination of plane is greater than angle of repose else it has to be pushed down.

7. **(c)**

Applying energy conservation equation between A and B.

$$E_A = E_B$$

$$\Rightarrow \quad mg \times 2 = \frac{1}{2} m v_B^2$$

$$\Rightarrow \quad v_B = 2\sqrt{g} \text{ m/s}$$

Using 3rd equation of kinematics between B and C,

$$v_C^2 = v_B^2 + 2as$$

$$\Rightarrow \quad 0 = 4g - 2\mu g H$$

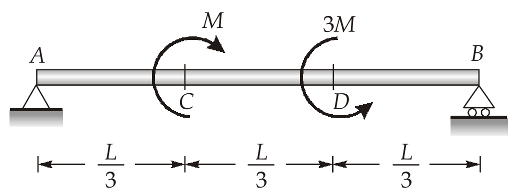
$$\Rightarrow \quad \mu = \frac{4g}{8g} = 0.5$$

8. (d)

The flexural rigidity can be increased by using a stiffer material (a material with a large modulus of elasticity E) or by distributing the material in such a way as to increase the moment of inertia of the cross-section, just as a beam can be made stiffer by increasing the moment of inertia.

The moment of inertia is also increased by distributing the material farther away from the centroid of the cross-section.

9. (a)

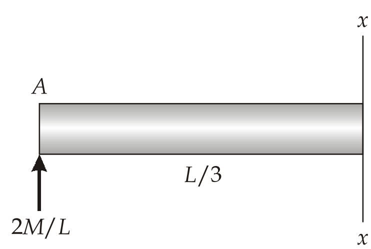


Calculating reactions at the supports,

$$\therefore \quad R_A \times L + M = 3M$$

$$\therefore \quad R_A = \frac{2M}{L}$$

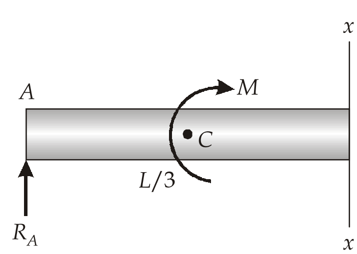
For portion AC $\left(0 \le x < \frac{L}{3}\right)$



$$BM = \frac{2M}{L}(x)$$

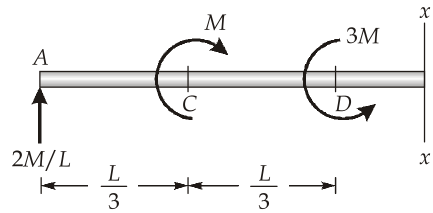
For portion CD $\left(\frac{L}{3} \le x < \frac{2L}{3}\right)$

$$BM = \frac{2M}{L}x + M$$



$$BM_C = \frac{2M}{L}\frac{L}{3} + M = \frac{5M}{3}$$

For portion $DB\left(\frac{2L}{3} \le x < L\right)$



$$BM = \frac{2M}{L}x + M - 3M$$

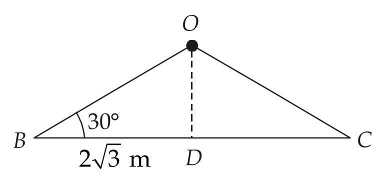
$$= \frac{2M}{L}x - 2M$$

$$BM_D = \frac{2M}{L} \times \frac{2L}{3} - 2M = \frac{4M}{3} - 2M = \frac{-2M}{3}$$

Therefore, option (a) is the right answer.

10. (a)

The triangle ABC is equilateral and the side is given from which radius of the circle can be calculated



$$\frac{BD}{OB} = \cos 30°$$

$$\Rightarrow \quad \frac{2\sqrt{3}}{OB} = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \quad OB = 4 \text{ m}$$

Moment of inertia of the circle about an axis perpendicular to the plane of the figure,

$$I_C = mr^2 \qquad \{m = \rho L = 0.5(2\pi R) = 4\pi \text{ kg}\}$$

$$I_C = (4\pi)(4)^2 = 64\,\pi \text{ kg-m}^2$$

Moment of inertia of a single side of the triangle about centre O,

$$I_{BC} = \frac{ml^2}{12} + m(OD)^2 \qquad \{m = \rho 4\sqrt{3} = 2\sqrt{3} \text{ kg}\}$$

$$= \frac{2\sqrt{3} \times 48}{12} + 2\sqrt{3}(2)^2$$

$$= 8\sqrt{3} + 8\sqrt{3} = 16\sqrt{3} \text{ kg-m}^2$$

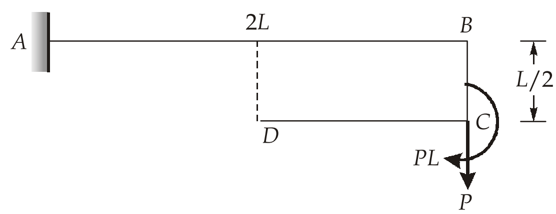
Moment of inertia of triangle $= 3 \times I_{BC}$

$$= 3 \times 16\sqrt{3} = 48\sqrt{3} \text{ kg-m}^2$$

$$I_{combined} = I_C + 3I_{BC}$$

$$= \left(64\pi + 48\sqrt{3}\right) \text{ kg-m}^2$$

11. (b)



The force can be transmitted at end C as shown.

Net moment at A will be, $M_A = 2PL - PL$

$= PL$

12. (a)

Since the given SFD is parabolic in nature, which means the slope of the shear force curve will give the variable loading. From the given loading diagrams, only the option (a) matches the equation,

$$\frac{\partial F}{\partial x} = -w$$

13. (d)

Taking moment about A,

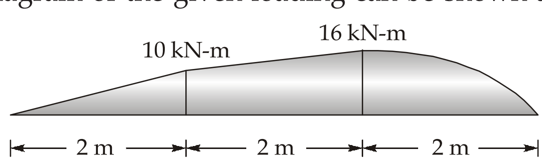
$\Sigma M_A = 0$

$$2 \times 2 + 6 \times 4 + 5 \times 2 \times 5 = R_B \times 6$$

$$R_B = \frac{78}{6} = 13 \text{ kN}$$

$\therefore$ $R_A = 6 + 2 + 10 - 13 = 5 \text{ kN}$

The bending moment diagram of the given loading can be shown as



14. (b)

In an I-section, the shear force carried by the flanges is small as compared to that carried by the web. This is true especially in case of widely thin sections.

Also, for a triangular section, the maximum value of the shear stress is 1.5 times the average shear stress.

15. (c)

Calculating the reactions at A and D.

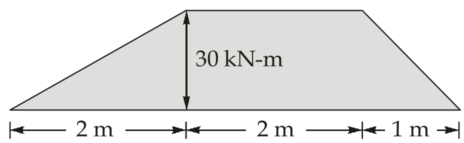
$\Sigma M_A = 0$

$$15 \times 2 + 30 \times 4 = R_D \times 5$$

$$\Rightarrow \quad R_D = 30 \text{ kN}$$

$$\Rightarrow \quad R_A = 15 + 30 - 30 = 15 \text{ kN}$$

Bending moment diagram for the beam can be made as



The magnitude of maximum bending stress is given by

$$\frac{\sigma_b}{y} = \frac{M_{\max}}{I}$$

$$\Rightarrow \quad \sigma_b = \frac{M_{\max}}{I} y$$

$$\sigma_b = \frac{30 \times 10^3 \times 0.2 \times 12}{(0.10) \times (0.4)^3}$$

$$\sigma_b = \frac{90}{8} = 11.25 \text{ MPa}$$

16. (b)

In the relation, $\frac{T}{J} = \frac{G\theta}{L}$, as T, L and θ are same for solid shaft and hollow aluminium shaft, therefore,

$$J_s G_s = J_{Al} G_{Al}$$

$$2G_{Al} \times \frac{\pi}{32} \frac{D^4 - d^4}{D} = G_{Al} \times \frac{\pi}{32} D^3$$

$$\Rightarrow \quad 2 \times (D^4 - d^4) = D^4$$

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

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

$$\Rightarrow \quad \frac{D}{d} = \sqrt{\sqrt{2}}$$

17. (b)

The torque in the shaft is

$$T = \frac{P}{\omega} = \frac{11000 \times 7}{2 \times 22 \times 25} = 70 \text{ N-m} = 70 \times 10^3 \text{ N.mm}$$

Maximum shear stress in the shaft is given by

$$\frac{\tau}{r} = \frac{T}{J}$$

$$\Rightarrow \qquad \tau = \frac{Tr}{J} = \frac{16T}{\pi D^3}$$

$$\Rightarrow \qquad \tau = \frac{16 \times 70 \times 10^3 \times 7}{22 \times (20)^3} = 44.5 \text{ MPa}$$

18. (d)

Axial compressive load in the bar is given by

$$P = EA\alpha\Delta T$$

Euler's crippling load is given by

$$P_{cr} = \frac{4\pi^2 EI}{L^2}$$

∴ Therefore, for the calculation of increase in temperature,

$$P = P_{cr}$$

$$\therefore \qquad EA\alpha\Delta T = \frac{4\pi^2 EI}{L^2}$$

$$\therefore \qquad \Delta T = \frac{4\pi^2 I}{\alpha A L^2}$$

19. (d)

$$\text{Initial Euler's crippling load, } P_1 = \frac{4\pi^2 EI}{L^2}$$

$$= \frac{4\pi^2 E}{L^2}\frac{\pi d^4}{64}$$

$$\text{Final Euler's crippling load, } P_2 = \frac{\pi^2 EI'}{L^2}$$

$$= \frac{\pi^2 E}{L^2} \times \frac{\pi(0.8d)^4}{64}$$

Percentage reduction in Euler's crippling load

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

$$= \frac{\frac{4\pi^2 E}{L^2} \times \frac{\pi d^4}{64} - \frac{\pi^2 E}{L^2} \times \frac{\pi}{64}(0.8d)^4}{\frac{4\pi^2 E}{L^2} \times \frac{\pi}{64} \times d^4}$$

$$= \frac{4 - (0.8)^4}{4} \times 100 = 89.76\%$$

20. (d)

Deflection at free end due to distributed load = Deflection at free end due to prop

$$\therefore \quad \frac{wl^4}{8EI} = \frac{Pl^3}{3EI}$$

$$\therefore \quad \frac{wl}{8} = \frac{P}{3}$$

$$\therefore \quad P = \frac{3wl}{8}$$

21. (a)

Internal diameter of the cylinder, $d = D - 2t$

$= 180 - 2 \times 7.5$

$= 165$ mm

$$\sigma_{long} = \frac{Pd}{4t} = \frac{20 \times 165}{4 \times 7.5} = 110 \text{ MPa}$$

$$\sigma_{hoop} = \frac{Pd}{2t} = \frac{20 \times 165}{2 \times 7.5} = 220 \text{ MPa}$$

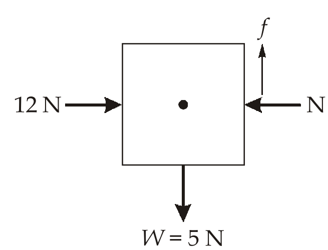
If the longitudinal axis of the cylinder is defined as the x-axis and circumferential direction as the y-axis, then the normal and shear stresses on longitudinal and circumferential faces of a stress element are

$$\sigma_x = \sigma_{p_1} = 220 \text{ MPa}, \sigma_y = \sigma_{p_2} = 110 \text{ MPa}$$

$$\tau_{max} = \frac{\sigma_{p_1} - \sigma_{p_2}}{2} = \frac{110}{2} = 55 \text{ MPa}$$

22. (c)

The free-body diagram of the block can be drawn as



For equilibrium of the block,

$N = 12$ N

$f = W = 5$ N

$\therefore$ Net force applied by the wall, $R = \sqrt{f^2 + N^2}$

$$\therefore \quad R = \sqrt{5^2 + 12^2} = 13 \text{ N}$$

23. (d)

Power of a body is given by,

$$P = Fv = (ma)(v)$$

$$\therefore \quad P = (ma)(at) \qquad (\because u = 0)$$

$$\therefore \quad a = \sqrt{\frac{P}{mt}}$$

Using 2nd equation of kinematics,

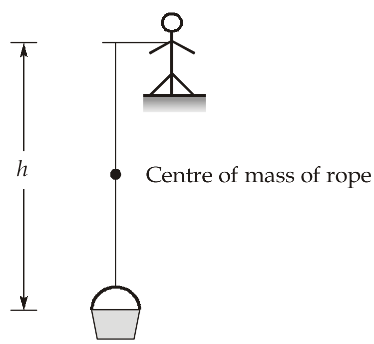
$$s = ut + \frac{1}{2}at^2 = \frac{1}{2}at^2$$

$$\therefore \quad s = \frac{1}{2}\sqrt{\frac{P}{mt}}\,t^2$$

$$\therefore \quad s = \frac{1}{2}\sqrt{\frac{P}{m}}\,t^{3/2}$$

$$\therefore \quad s \propto t^{3/2}$$

24. (b)



The centre of mass of the rope rises by $\frac{h}{2}$ and the centre of mass of the bucket rises by h.

$$W_{\text{man}} = \Delta PE \text{ (rope + bucket)}$$

$$= mg\frac{h}{2} + Mgh$$

$$= gh\left(\frac{m}{2} + M\right)$$

25. (a)

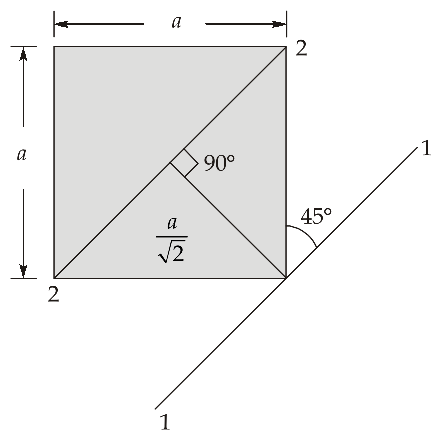
Centre of mass of the rod is given by,

$$x_{cm} = \frac{\int_0^L x\,dm}{\int_0^L dm} = \frac{\int_0^L x\,\rho dx}{\int_0^L \rho\,dx}$$

$$= \frac{\int_0^L x \frac{k}{L} x^2 dx}{\int_0^L \frac{k}{L} x^2 \, dx} = \frac{\frac{L^4}{4}}{\frac{L^3}{3}}$$

$$= \frac{3L^4}{4L^3} = \frac{3L}{4}$$

26. (a)



$$I_{22} = \frac{Ma^2}{12}$$

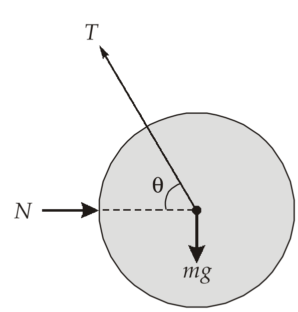
Using parallel-axis theorem,

$$I_{22} = I_{22} + M\left(\frac{a}{\sqrt{2}}\right)^2$$

$$= \frac{Ma^2}{12} + \frac{Ma^2}{2}$$

$$= \frac{Ma^2 + 6Ma^2}{12} = \frac{7Ma^2}{12}$$

27. (c)



The angle θ is given by

$$\cos\theta = \frac{R}{2R} = \frac{1}{2}$$

$$\theta = \cos^{-1}\left(\frac{1}{2}\right) = 60°$$

$$N = T\cos\theta \quad \text{...(i)}$$

$$mg = T\sin\theta \quad \text{...(ii)}$$

∴ Dividing equation (ii) by (i),

$$\frac{T\sin\theta}{T\cos\theta} = \frac{mg}{N}$$

$$\therefore \quad \tan\theta = \frac{mg}{N}$$

$$\therefore \quad \tan 60° = \frac{mg}{N}$$

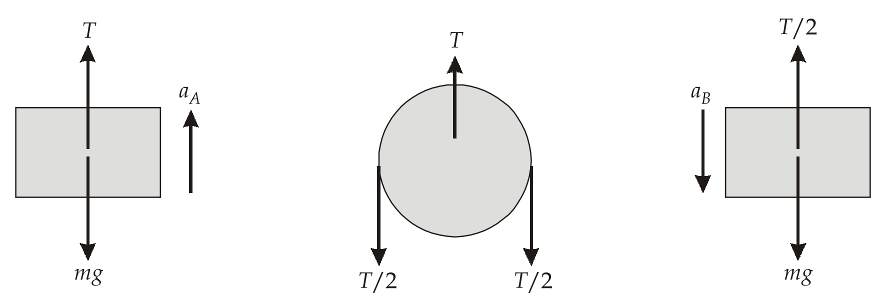
$$\therefore \quad N = \frac{mg}{\tan 60°} = \frac{mg}{\sqrt{3}}$$

28. (a)

The vertical reaction due to weight will be in upwards direction on both the hinges. The horizontal reactions will form an anticlockwise couple which will balance the moment due to weight.

29. (d)

Let the a_A and a_B be the acceleration of A and B respectively. Drawing free body diagrams and applying Newton's laws of motion.



Block A **Lower Pulley** **Block B**

$$T - mg = ma_A \quad \text{...(i)}$$

$$mg - \frac{T}{2} = ma_B \quad \text{...(ii)}$$

From constraint equations,

$$a_B = 2a_A \quad \text{...(iii)}$$

Eliminating T from equation (i) and (ii),

$$mg = m(a_A + 2a_B)$$

$$\therefore \quad mg = m\left(\frac{a_B}{2} + 2a_B\right)$$

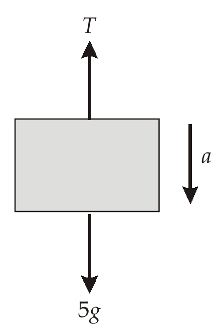
$$\Rightarrow \quad mg = m\left(\frac{5a_B}{2}\right)$$

$$\Rightarrow \quad a_B = \frac{2g}{5}$$

30. (d)

Acceleration the blocks is given by,

$$a = \frac{(5+3)g - 4g}{12} = \frac{4g}{12} = \frac{g}{3}\text{m/s}^2$$



Acceleration for A will be upwards and for B and C will be downwards. Applying Newton's law to the block C.

$$\therefore \quad 5g - T = 5a$$

$$T = 5g - 5a = 5g - \frac{5g}{3}$$

$$T = \frac{10g}{3}N$$

31. (b)

The area of the unslotted portion is

$$A_{\text{unslotted}} = (300)(10) = 3000 \text{ mm}^2$$

The slotted portion of the bar has an area of $A_{\text{slotted}} = (300 - 100)(10) = 2000 \text{ mm}^2$

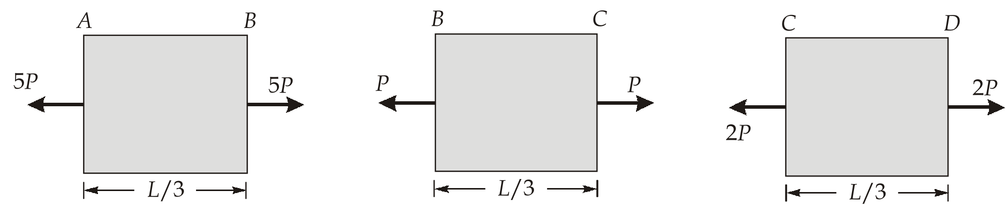
$\therefore$ The overall elongation of the bar is $\Delta = \frac{P}{E}\left[\frac{L_{unslotted}}{A_{unslotted}} + \frac{L_{slotted}}{A_{slotted}}\right]$

$$= \frac{18000}{100 \times 10^9}\left[\frac{1}{3000 \times 10^{-6}} + \frac{1}{2000 \times 10^{-6}}\right]$$

$$= \frac{18000}{10^8}\left[\frac{5}{6}\right] = 0.15 \text{ mm}$$

32. (d)

The forces on individual sections can be shown as



Total strain energy is given as

$$E = \Sigma \frac{P^2 L}{2AE} = \frac{(L/3)}{(2AE)}\left((5P)^2 + P^2 + (2P)^2\right)$$

$$= \left(\frac{L}{6AE}\right)\left(25P^2 + P^2 + 4P^2\right)$$

$$= \left(\frac{L}{6AE}\right)\left(30P^2\right) = \frac{5LP^2}{AE}$$

33. (b)

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4} \times \left(20 \times 10^{-3}\right)^2$$

$$= \frac{22}{7} \times 10^{-4}\,\text{m}^2$$

$$\Delta = \frac{PL}{AE}$$

$\Rightarrow$
$$P = \frac{\Delta AE}{L}$$

$$= \frac{0.5 \times 10^{-3} \times 22 \times 10^{-4} \times 56 \times 10^9}{2 \times 7}$$

$$= 4400 \text{ N}$$

35. (b)

Considering a short length dx, at a distance x from the end A,

$$\text{Temperature, } t_x = t\frac{x^3}{L^3}$$

$\therefore$ Increase in length of dx due to temperature rise

$$\Delta_{tx} = dx \cdot \alpha \cdot t_x$$

$$= \alpha t \frac{x^3}{L^3} dx$$

$$\text{Total increase in length, } \Delta_t = \int_0^L \alpha t \frac{x^3}{L^3} dx$$

$$= \frac{\alpha t}{L^3}\left[\frac{L^4}{4}\right] = \frac{\alpha t L}{4}$$

∴ Compressive stress setup in the bar

$$\sigma = \Delta_t \frac{E}{L} = \frac{\alpha t L}{4}\left(\frac{E}{L}\right)$$

$$= \frac{E\alpha t}{4}$$

36. (d)

If the centre of mass of a system is at the origin, then the product (mx) for the particles on the right side of the origin is equal to the product (mx) for the particles on the left side.

37. (d)

The point of contact between the ground and the man at which friction force acts, does not move, therefore work done by the friction is zero.

Second statement is true as the net work done by the all forces in a system is equal to the change in kinetic energy of the system. This is known as work-energy theorem.

38. (b)

For constant flux condition,

$$\text{Nu} = 4.36$$

$$\frac{hD}{k_f} = 4.36$$

$$h = \frac{4.36 \times 1.5}{0.12}$$

$$h = 54.5 \text{ W/m}^2\text{K}$$

39. (c)

$$\frac{\text{Nusselt number}}{\text{Biot number}} = \frac{hL_c / k_f}{hL_c / k_s} = \frac{k_s}{k_f}$$

40. (c)

The thermal conductivity of gases is inversely proportional to molecular weight of gas and directly proportional to its temperature.

43. (c)

Generalised conduction equation,

$$\nabla^2 T + \frac{\dot{q}_g}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

For steady state and no heat generation,

$$\nabla^2 T = 0$$

This is laplace equation

45. (c)

Ratio of temperature drop,

$$\Delta T_1 : \Delta T_2 : \Delta T_3 = \frac{q_1}{k_1} : \frac{q_2}{k_2} : \frac{q_3}{k_3}$$

[Since wall thickness and cross-section area are equal]

$$= \frac{1}{k_1} : \frac{1}{k_2} : \frac{1}{k_3} = \frac{1}{2k} : \frac{1}{3k} : \frac{1}{4k}$$

$$= \frac{12}{2} : \frac{12}{3} : \frac{12}{4} = 6 : 4 : 3$$

46. (c)

Critical radius of insulation, $r_c = \frac{k}{h} = \frac{0.15}{3}$

$r_c = 0.05 = 50 \text{ mm}$

Since the temperature given is of insulated surface.

$\therefore$ Heat lost by surface, $Q = hA_s\Delta T$

$= 3 \times 2\pi \times 0.05 \times 50$

$= 47.12 \text{ W}$

47. (b)

$$\dot{q}_g \times \frac{4}{3}\pi R^3 = q' 4\pi R^2$$

$$\Rightarrow \quad q' = \frac{\dot{q}_g R}{3}$$

49. (d)

The thermodynamic cycle is completed in two strokes of the piston or in one revolution of the crankshaft. Thus there is one power stroke for every revolution of the crankshaft. So, turning moment is more uniform and hence a lighter flywheel can be used.

50. (d)

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

$$\Rightarrow \quad 0.8 = \frac{B.P.}{I.P.}$$

$\Rightarrow \quad B.P. = 0.8 \times I.P.$

$\therefore \quad I.P. = B.P. + I.P.$

$\Rightarrow \quad I.P. = 0.8 I.P. + 25$

or $\quad 0.2 \times I.P. = 25$

$\therefore \quad I.P. = 125 \text{ kW}$

$\therefore \quad B.P. = 0.8 \times I.P. = 0.8 \times 125 = 100 \text{ kW}$

51. (d)

$$\text{I.P.} = \frac{P_m LANK}{60 \times 2}$$

Mean piston speed, $\bar{S}_P = 2\text{ LN}$

$$\therefore \quad 40 \times 10^3 = \frac{8 \times 10^5 \times 120 \times 10^{-4} \times 4 \times LN}{120}$$

$$\therefore \quad LN = \frac{40 \times 10^3 \times 120}{8 \times 120 \times 10^5 \times 10^{-4} \times 4}$$

$$LN = 125\text{ m/min}$$

or $$\bar{S}_P = \frac{2LN}{60} = \frac{2 \times 125}{60} = 4.16\text{ m/s} \simeq 4.2\text{ m/s}$$

53. (b)

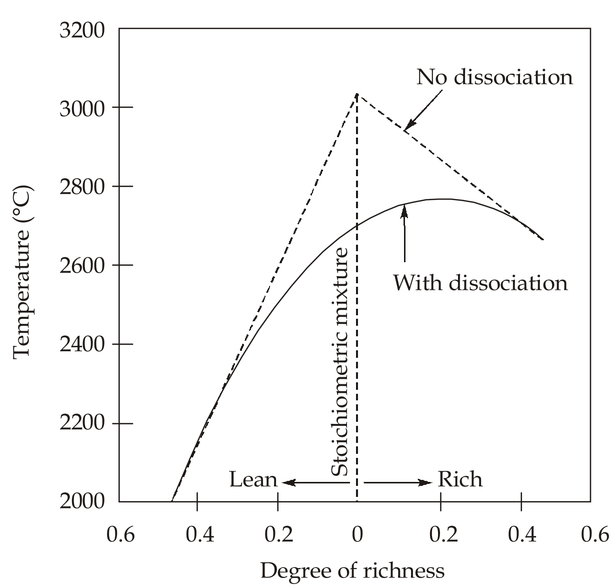
The mean effective pressure of the cycle is given by

$$P_m = \frac{P_1 r\left(r_p - 1\right)\left(r^{\gamma-1} - 1\right)}{(\gamma - 1)(r - 1)}$$

Thus, the mean effective pressure which is an indication of the internal work output increases with pressure ratio at a fixed value of compression ratio and ratio of specific heats.

54. (c)

With no dissociation maximum temperature is attained at chemically correct air-fuel ratio. With dissociation maximum temperature is obtained when mixture is slightly rich. Dissociation reduces the maximum temperature by 300°C even at the chemically correct air-fuel ratio.



Effect of dissociation on temperature

55. (a)

During idling, the final mixture of fuel and air in the combustion chamber is diluted more by exhaust gases. This results in poor combustion and loss in power output. It is therefore, necessary to provide more fuel particles by richening the air fuel mixture. This richening increases the probability of contact between fuel and air particles and thus improves combustion.

57. (b)

Equivalent length of pipe, $$\sqrt{\frac{18^5}{L_e}} = \sqrt{\frac{18^5}{100}} + \sqrt{\frac{18^5}{100}}$$

$$\frac{1}{L_e} = \frac{4}{100}$$

$$L_e = 25 \text{ m}$$

59. (a)

For Couette flow,

$$u = \frac{Vy}{t} - \frac{1}{2\mu}\left(\frac{\partial P}{\partial x}\right)\left(ty - y^2\right)$$

If $\frac{\partial P}{\partial x} = 0$ then it becomes simple Couette flow.

For simple Couetee flow,

$$u = \frac{Vy}{t}$$

$$\tau = \mu\frac{du}{dy} = \mu\frac{V}{t} = \text{constant}$$

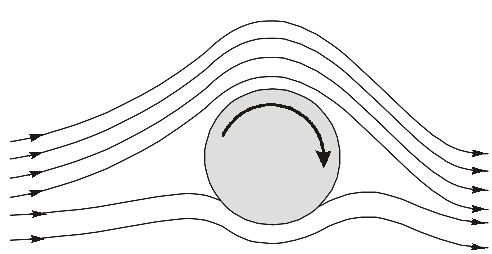
60. (d)

Given : $r = 10 - 6 = 4$ cm

For laminar flow, $$u_{\text{Local}} = u_{\max}\left(1 - \frac{r^2}{R^2}\right)$$

$$u_L = 1.5\left(1 - \frac{4^2}{10^2}\right) = 1.5 \times \frac{84}{100} = 1.26 \text{ m/s}$$

61. (d)



On upper side of cylinder fluid and boundary are moving in same direction so no formation of boundary layer will occur. This is one of the famous method to avoid boundary layer separation.

62. (a)

$$\delta^* = \int_0^{\delta}\left(1-\frac{u}{U}\right)dy = \int_0^{\delta}\left(1-\frac{(y)^{1/10}}{(\delta)^{1/10}}\right)dy$$

$$= \left(y - \frac{y^{11/10}}{\delta^{1/10}}\times\frac{10}{11}\right)_0^{\delta}$$

$$\frac{\delta^*}{\delta} = \left(1-\frac{10}{11}\right) = \frac{1}{11}$$

63. (c)

$$\text{Shear velocity, } u_* = \bar{u}\sqrt{\frac{f}{8}} = \bar{u}\sqrt{\frac{0.02}{8}} = 0.05\bar{u}$$

$$\frac{u_{max}-\bar{u}}{u_*} = 3.75$$

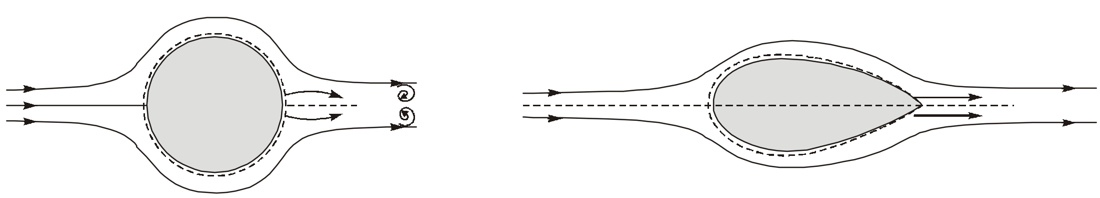
$$u_{max}-\bar{u} = 3.75 \times 0.05\bar{u}$$

$$u_{max}-\bar{u} = 0.1875\bar{u}$$

$$u_{max} = 1.1875\bar{u}$$

$$\frac{u_{max}}{u_*} = \frac{1.1875\bar{u}}{0.05\bar{u}} = 23.75$$

64. (a)



Flow past a sphere   Flow past a streamlined body

Wake over sphere will be more than that of streamlined body.

65. (c)

$$A_1V_1 = A_2V_2$$

$$\frac{\pi}{4} \times 36 \times 5 = \frac{\pi}{4} \times 144 \times V_2$$

$$V_2 = 1.25 \text{ m/s}$$

$$h_L = \frac{(V_1-V_2)^2}{2g} = \frac{(5-1.25)^2}{2\times 10} = 0.7 \text{ m}$$

66. (c)

$$\text{Diagram power, } P = F_t \times V_b$$
$$= 800 \times 400$$
$$= 320 \text{ kW}$$

$$\text{Now, diagram efficiency, } \eta_D = \frac{\dot{P}}{\frac{1}{2} \times \dot{m}_s \times V^2} = \frac{320 \times 10^3}{\frac{1}{2} \times 0.75 \times 1000^2}$$

$$\eta_D = 85.33\%$$

67. (d)

$$\text{Steam velocity, } V_1 = 44.72\sqrt{(\Delta h_{isen,T})}$$
$$= 44.72 \times \sqrt{1600}$$
$$= 1788.8 \text{ m/s}$$

For maximum blade efficiency,

$$\frac{V_b}{V_1} = \frac{\cos\alpha}{2} = \frac{\cos 30}{2}$$

$$\therefore \quad V_b = \frac{V_1 \cos 30}{2} = \frac{1788.8 \times \cos 30°}{2} = 774.57 \text{ m/s}$$

$$\text{or} \quad \frac{\pi D_m \times 3000}{60} = 774.57$$

$$\text{or} \quad D_m = \frac{774.57 \times 60}{\pi \times 3000}$$

$$D_m = 4.93 \text{ m}$$

69. (b)

$$\text{Thrust power, } P_T = \dot{m}_a C_j^2 \times \alpha(1 - \alpha)$$

where, $\alpha = \frac{C_i}{C_j}$; C_i = Air velocity at inlet and C_j = Jet velocity at exit

$$\text{For maximum thrust,} \quad \frac{dP_T}{d\alpha} = 0$$

$$\therefore \quad 1 - 2\alpha = 0$$

$$\Rightarrow \quad \alpha = \frac{1}{2}$$

$$\text{or} \quad \frac{C_i}{C_j} = \frac{1}{2}$$

$$\text{or} \quad C_j = 2C_i$$

70. (c)

$$\eta_{\text{Carnot}} = \eta_{\text{Brayton}}$$

$$1-\frac{T_{\min}}{T_{\max}} = 1-\frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

$\therefore$
$$1-\frac{278}{1112} = 1-\frac{1}{r_p^{0.5/1.5}}$$

or
$$0.75 = 1-\frac{1}{r_p^{1/3}}$$

or
$$\left(r_p\right)^{1/3} = 4$$

$$r_p = (4)^3 = 64$$

73. (a)

$$\text{Propulsive efficiency} = \frac{\text{Thrust power}}{\text{Propulsive power}}$$

$$\eta_{\text{prop}} = \frac{\dot{m}_a(C_j - C_i)C_i}{\frac{1}{2}\dot{m}_a\left(C_j^2 - C_i^2\right)}$$

$$\eta_{\text{prop}} = \frac{2C_i}{C_j + C_i}$$

74. (a)

If throttle governing is done at low loads, the turbine efficiency is considerably reduced. The nozzle control may then be a better method of governing. The nozzles are made up in sets, each set being controlled by a separate valve.

❍❍❍❍