DETAILED SOLUTIONS

MADE EASY
India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Pune, Kolkata

ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 12

Section A : Theory of Machines
Section B : Strength of Materials & Engineering Mechanics-1
Section C : Heat Transfer-2 + IC Engine-2

Answer Key

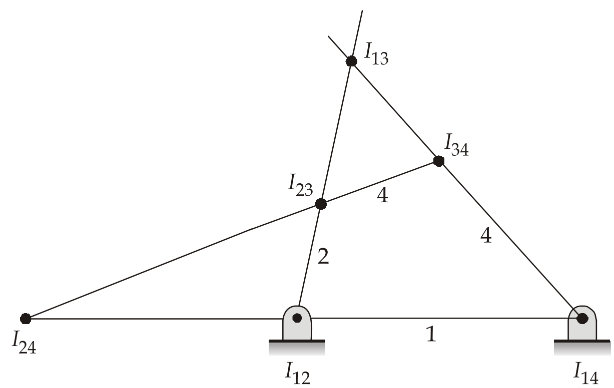
1.	(b)	**16.**	(d)	**31.**	(b)	**46.**	(d)	**61.**	(c)
2.	(c)	**17.**	(b)	**32.**	(a)	**47.**	(c)	**62.**	(a)
3.	(a)	**18.**	(a)	**33.**	(d)	**48.**	(a)	**63.**	(c)
4.	(d)	**19.**	(b)	**34.**	(b)	**49.**	(d)	**64.**	(a)
5.	(b)	**20.**	(a)	**35.**	(c)	**50.**	(a)	**65.**	(c)
6.	(b)	**21.**	(b)	**36.**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

Section A : Theory of Machines

1. (b)

$$\begin{aligned} DOF &= 3(l-1) - 2j \\ &= 3(10-1) - 2 \times 13 \\ &= 1 \end{aligned}$$

2. (c)



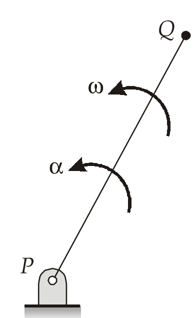
- Fixed I-center $\rightarrow I_{12}$ and I_{14}.
- Permanent I-center $\rightarrow I_{34}$ and I_{23}.
- Neither fixed nor permanent I-center $\rightarrow I_{24}$ and I_{13}.

The first two types are called primary IC and the last one as secondary IC.

3. (a)

DOF of a kinematic pair is determined by the number of independent coordinates needed to fully describe its relative motion.

4. (d)

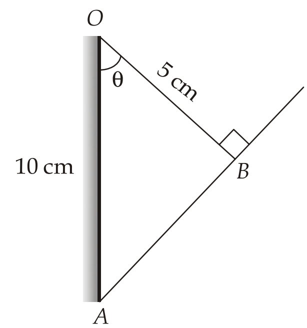


$$\begin{aligned} a_Q^t &= \alpha(PQ) \\ &= \frac{5}{3} \times 3 = 5 \text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} a_Q^r &= \omega^2(PQ) \\ &= 2^2 \times 3 = 12 \text{ m/s}^2 \end{aligned}$$

$$\begin{aligned} a_Q &= \sqrt{\left(a_Q^t\right)^2 + \left(a_Q^r\right)^2} \\ &= \sqrt{5^2 + 12^2} = 13 \text{ m/s}^2 \end{aligned}$$

5. (b)



$$\cos\theta = \frac{5}{10}$$

$$\theta = 60°$$

$$\frac{\text{Return time}}{\text{Forward time}} = \frac{60}{180-60} = \frac{1}{2}$$

6. (b)

$$\text{Natural frequency, } f_n = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta_{st}}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{10\times10^3}{1}} = \frac{100}{2\pi} = \frac{50}{\pi}\text{Hz}$$

7. (c)

$$T_{min} = \frac{2A_G}{\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2 30} - 1}$$

$$= \frac{2\times1}{\sqrt{1+\frac{1}{5}\left(\frac{1}{5}+2\right)\sin^2 30} - 1} = \frac{2}{\sqrt{\frac{111}{100}}-1} = 37.73 \simeq 38$$

8. (c)

- A flywheel does not regulate the mean speed of an engine. It reduces speed fluctuations within a cycle by storing and releasing kinetic energy.
- A governor regulates the mean speed by adjusting the fuel supply based on load changes.
- The coefficient of fluctuation is the ratio of maximum speed fluctuation and mean speed.

9. (c)

$$\mu = \tan\theta = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \quad \theta = 30°$$

$$\eta_{max} = \frac{1-\sin\theta}{1+\sin\theta}$$

$$= \frac{1-\frac{1}{2}}{1+\frac{1}{2}} = \frac{\frac{1}{2}}{\frac{3}{2}} = \frac{1}{3}$$

10. (d)

Gyroscopic couple, $c = I\omega\omega_p$

$$= 2000 \times (0.5)^2 \times 325 \times \frac{36 \times \frac{5}{18}}{100} \times 10^{-3}$$

$$= 16.25 \text{ kN-m}$$

11. (a)

Natural frequency, $\omega_n = \sqrt{\frac{k_1 + k_2}{m}}$

$$= \sqrt{\frac{(7.5+2.5)\times 10^3}{25}} = 20 \text{ rad/s}$$

12. (c)

Equation of correct steering,

$$\cot\phi - \cot\theta = \frac{b}{L}$$

$$\cot\phi - \cot 45° = \frac{160}{320}$$

$$\phi = \cot^{-1}(1.5)$$

13. (d)

- For machine, frequency of vibration is equal to forcing frequency, i.e. engine speed and it is independent of damping.
- Critical damping ensures that the system returns to equilibrium as quickly as possible without oscillations.
- Resonance occurs when the forcing frequency matches the natural frequency not damped frequency.

14. (b)

$$N_{max} = \frac{N}{\cos\alpha}$$

$$= \frac{1000}{\cos 30} = \frac{1000 \times 2}{\sqrt{3}} = 1154.7 \text{ rpm}$$

15. (b)

$$\text{Maximum velocity, } V_{max} = \frac{2h\omega}{\phi}$$

$$= \frac{2 \times 0.15 \times 9.42}{\frac{60}{180} \times \pi} \simeq 2.7 \text{ m/s}$$

16. (d)

$$\frac{c}{m} = 2\xi\sqrt{\frac{k}{m}}$$

$$\xi = \frac{c}{2\sqrt{km}} = \frac{3}{2\sqrt{112.5 \times 2}} = 0.1$$

17. (b)

$$\Delta KE = \frac{I}{2}\left(\omega_1^2 - \omega_2^2\right)$$

$$100 = \frac{I}{2}\left(45^2 - 25^2\right) = \frac{I}{2}(45+25)(45-25)$$

$$100 = I(35) \times 20$$

$$\Rightarrow \quad I(35) = \frac{100}{20} = 5$$

At 35 rad/s,

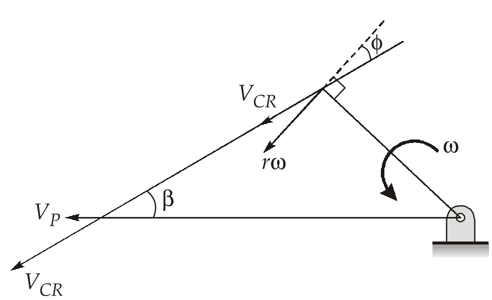
$$\therefore \quad \frac{35}{2} \times I(35) = 5 \times \frac{35}{2}$$

$$\Rightarrow \quad \frac{I}{2} \times 35^2 = 87.5 \text{ kJ}$$

18. (a)

A redundant chain has more constraints than required for relative motion between links. When one of its links is fixed, the entire system losses mobility and behaves like a rigid structure with no independent motion.

19. (b)



$$V_{CR} = r\omega\cos\phi$$

$$V_P = \frac{V_{CR}}{\cos\beta} = \frac{r\omega\cos\phi}{\cos\beta}$$

When crank and CR are perpendicular, i.e. $\phi = 0$ and V_P takes its maximum value.

20. (a)

21. (b)

$$a^c = 2v\omega$$
$$= 2\times 10\times\frac{\pi\times 120}{30}$$
$$= 251.3 \text{ m/s}^2$$

22. (b)

Disturbing force along line of stroke = $(1 - c)\, mr\omega^2 \cos\theta$

$$= (1 - 0.4) \times 6 \times 0.1 \times 10^2 \times \cos 60°$$
$$= 18 \text{ N}$$

23. (b)

$$\xi = \frac{c}{2\sqrt{km}} = \frac{50}{2\sqrt{10^3\times 10}} = 0.25$$
$$\omega_d = \sqrt{\left(1-\xi^2\right)\times\frac{k}{m}} = \sqrt{\left(1-0.25^2\right)\times\frac{10^3}{10}}$$
$$\simeq 9.7 \text{ rad/s}$$

24. (c)

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{490}{10}} = 7 \text{ rad/s}$$
$$\omega = 5 \text{ rad/s}, F_0 = 100 \text{ N}$$
$$A = \frac{\frac{F_0}{k}}{1-\left(\frac{\omega}{\omega_n}\right)^2} = \frac{\frac{F_0}{m}}{\omega_n^2-\omega^2}$$
$$= \frac{\left(\frac{100}{10}\right)}{7^2-5^2} \simeq 0.42 \text{ m}$$

25. (d)

$$\text{Output torque} = \frac{\eta P_{input}}{\frac{t}{T}\cdot\frac{\pi N}{30}} = \frac{0.9\times 5000}{\frac{24}{48}\times\frac{\pi\times 1200}{30}}$$
$$= 71.6 \text{ N-m}$$

26. (a)

$$\text{Velocity of slider, } V = r\omega\left(\sin\theta+\frac{\sin 2\theta}{2n}\right)$$

$$= 0.1 \times \frac{2 \times \pi \times 1000}{60}\left(\sin 60 + \frac{\sin 120}{2 \times 4}\right) \qquad \left[\because n = \frac{l}{r} = \frac{400}{100} = 4\right]$$

$$= 10.2 \text{ m/s}$$

27. **(c)**

$$h = \sqrt{200^2 - 120^2} = 160 \text{ mm}$$

$$N^2 = \frac{895}{h}\left(\frac{m+M}{m}\right) = \frac{895}{0.16}\left(\frac{3+24}{3}\right) = 50343.75$$

$$N = 224.4 \text{ rpm}$$

28. **(c)**

Given : $a = b$, $\Delta x = 8$ mm, $r_2 = 100 + 8 = 108$ mm, $r_1 = 100 - 8 = 92$ mm

$$S = 2\left(\frac{a}{b}\right)^2\left(\frac{F_2 - F_1}{r_2 - r_1}\right)$$

$$= 2 \times \frac{m\left(r_2\omega_2^2 - r_1\omega_1^2\right)}{r_2 - r_1} \qquad [\because \ a = b]$$

$$= 2 \times \frac{2 \times \left(\frac{\pi}{30}\right)^2 \left(0.108 \times 440^2 - 0.092 \times 400^2\right)}{0.008}$$

$$= 8483.47 \text{ N/m} \simeq 8.5 \text{ kN/m}$$

29. **(c)**

$$\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{\pi}{30}\left(\frac{610 - 400}{10}\right) = 2.2 \text{ rad/s}$$

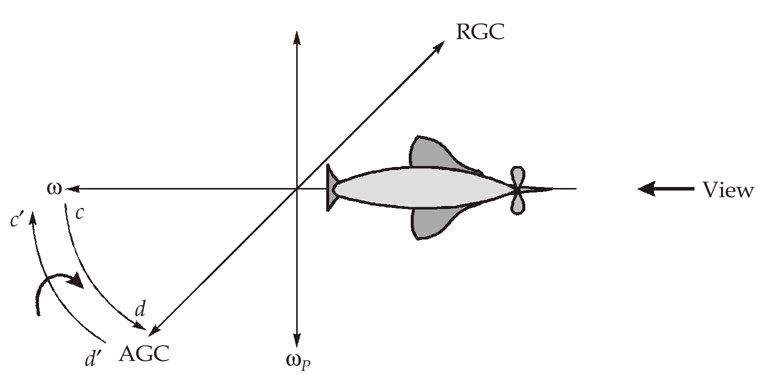
$$|\text{Torque}| = I\alpha$$

$$= 10 \times 2.2 = 22 \text{ N-m}$$

30. **(d)**

A single mass can always be balanced using another appropriate mass.

31. **(b)**



The reactive couple is given by '*dc*'. The couple acts in the vertical plane and is clockwise when viewed from the right hand side of the plane. Thus, it tends to dip the nose and raise the tail of the aircraft.

32. (a)

Static force analysis is performed when the machine is either at rest or moving at very low acceleration meaning inertia forces can be ignored. This simplifies force calculations, making the analysis static instead of dynamic.

33. (d)

$$\text{Center distance} = \frac{m}{2}\left[\frac{T_1}{\cos\psi_1}+\frac{T_2}{\cos\psi_2}\right]$$

$$= \frac{10}{2}\left[\frac{45}{\cos 60^\circ}+\frac{50}{\cos 45^\circ}\right]\text{mm}$$

$$= 5\left(90+50\sqrt{2}\right)$$

$$= 803.55 \text{ mm} = 80.36 \text{ cm}$$

34. (b)

Action	Sun	Planet
$N_{arm}=0$ $N_s=x$	x	$-\frac{150x}{30}=-5x$
$N_{arm}=y$	$x+y$	$y-5x$

Given $x + y = 2$

$y = -4$

∴ $x = 6$

$y - 5x = -4 - 5(6)$

$= -34$

35. (c)

$$\text{Coefficient of detention} = \frac{\text{Friction force at sleeve}}{\text{Weight of the ball}}$$

$$= \frac{5}{80}=\frac{1}{16}=0.0625$$

36. (d)

$$V_{\max} = \sqrt{\frac{\sigma}{\rho}}=\sqrt{\frac{39.2\times10^6}{8\times10^3}}$$

$$V_{\max} = 70 \text{ m/s}$$

37. (d)

$$V_{\text{rubbing}} = \frac{20}{2}(10-5) = 50 \text{ mm/s}$$

Section B : SOM & Engg Mechanics-1

38. (d)

For the cantilever, $$y_c = \frac{(W-P)L^3}{3EI}$$

For the beam, $$y_c = \frac{PL^3}{48EI}$$

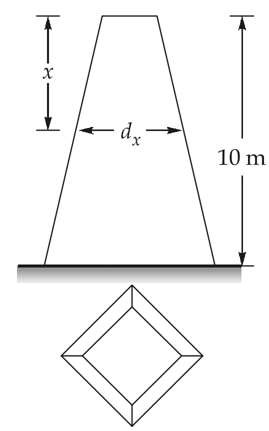
$$\frac{W-P}{3} = \frac{P}{48}$$

$$16W - 16P = P$$

$$P = \frac{16W}{17}$$

$$R_A = R_B = \frac{8W}{17} = 16 \text{ kN}$$

39. (c)



$$d_x = 50 + \frac{x}{10}(100-50)$$

$$d_x = (50 + 5x) \text{ mm}$$

$$I_x = \frac{d_x^4}{12}$$

$$y_{\max} = \frac{d_x}{\sqrt{2}} \text{ mm}$$

$$Z_x = \frac{I_x}{y_{\max}} = \frac{d^3}{6\sqrt{2}} = \frac{(50+5x)^3}{6\sqrt{2}}$$

$$M_x = 1000x \text{ N-m} = 10^6\, x \text{ N-mm}$$

$$\sigma_x = \frac{M_x}{Z_x} = \frac{10^6 x \times 6\sqrt{2}}{(50+5x)^3} = \frac{6\sqrt{2}\times 10^6 x}{(50+5x)^3}$$

$$\sigma_{x,max} = \frac{d\sigma_x}{dx} = 0$$

$$= 6\sqrt{2}\times 10^6 \left[\frac{(50+5x)^3 - x\times 3\times(50+5x)^2\times 5}{(50+5x)^6}\right]$$

$$(50+5x)^2\left[\frac{(50+5x)-15x}{(50+5x)^6}\right] = 0$$

$$50 - 10x = 0 \Rightarrow x = 5 \text{ m}$$

40. (a)

Consider a length dx, at distance x,

$$t_x = t\cdot\frac{x^2}{L^2}$$

Increase in length of dx due to temperature rise

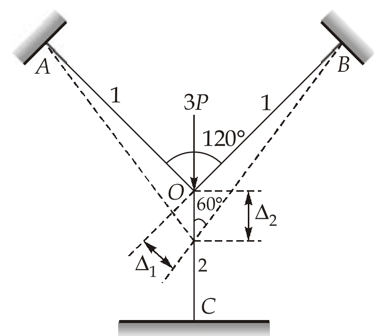
$$\Delta l_x = dx\cdot \alpha t_x = \alpha t\frac{x^2}{L^2}\cdot dx$$

or $$\Delta l = \int_o^L \alpha t\frac{x^2}{L^2}dx = \frac{\alpha t}{L^2}\cdot\frac{L^3}{3} = \frac{\alpha t L}{3}$$

Compressive stress will be, $$\sigma_c = \Delta l\cdot\frac{E}{L} = \frac{\alpha t L}{3}\left(\frac{E}{L}\right) = \frac{\alpha t E}{3}$$

41. (b)

Let use suffix 1 for bar AO and BO and suffix 2 for CO.



$$2(P_1\cos 60°) + P_2 = 3P \quad \text{... (i)}$$

$$P_1 + P_2 = 3P$$

$$\frac{\Delta_1}{\Delta_2} = \cos 60°$$

$$\Delta_1 = \Delta_2\cos 60° = \frac{1}{2}\Delta_2$$

$$\frac{P_1L}{AE} = \frac{1}{2}\frac{P_2L}{AE}$$

$$P_2 = 2P_1 \quad \text{... (ii)}$$

$$P_1 + 2P_1 = 3P$$

$$P_1 = P$$

$$P_2 = 2P$$

$$\Delta_2 = \frac{P_2L}{AE} = \frac{2PL}{AE}$$

42. (c)

Inclination with the vertical plane,

$$\theta = 90° - 30° = 60°$$

$\therefore$ $$\sigma_{60°} = \sigma_x\cos^2\theta + \sigma_y\sin^2\theta$$
$$= 10\cos^2 60 + (-20)\sin^2 60$$
$$= -12.5 \text{ MPa}$$

43. (a)

- The material has the same properties of every point, it is homogeneous.
- The material's properties vary with direction, so it is anisotropic.
- All homogeneous materials are not isotropic (eg: Wood, fiber-reinforced composites etc.)

44. (c)

$$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z = \frac{\delta}{L} - \mu\frac{\delta}{L} - \mu\frac{\delta}{L} = \frac{\delta}{L}(1-2\mu)$$

$$= \frac{0.03}{150}(1-2\times0.3) = \frac{0.03\times0.4}{150} = 8\times10^{-5}$$

45. (a)

$$I_P = \frac{\pi}{32}d_o^4\left[1-\left(\frac{d_i}{d_o}\right)^4\right] = \frac{\pi}{32}d_o^4\left[1-\left(\frac{1}{2}\right)^4\right]$$

$$= \frac{\pi}{32}\times\frac{15}{16}d_o^4 = 0.09199d_o^4$$

$$P = \frac{2\pi NT}{60\times10^3}$$

$$\frac{T}{I_p} = \frac{2\tau}{d_o}$$

$$T = \frac{100\times60\times10^3}{2\pi\times50} = 19098.593 \text{ Nm}$$

$$\frac{T}{I_p} = \frac{2\tau}{d_o}$$

$$\frac{19098.593\times10^3}{0.09199d_o^4} = \frac{2\times40}{d_o}$$

$\therefore$ $d_o = 137.422$ mm

46. (d)

$$M_e = \frac{1}{2}\left[M+\sqrt{M^2+T^2}\right] = \frac{1}{2}\left[4+\sqrt{16+9}\right]$$

$$= \frac{1}{2}[4+5] = \frac{1}{2}[9]$$

Maximum bending stress, $\sigma = \dfrac{M_e}{Z} = \dfrac{32M_e}{\pi d^3}$

$$T_e = \sqrt{M^2+T^2} = \sqrt{16+9} = 5$$

$$\tau = \frac{16T_e}{\pi d^3}$$

$$\frac{\sigma}{\tau} = \frac{2M_e}{T_e} = \frac{2\times\frac{9}{2}}{5} = \frac{9}{5}$$

47. (c)

48. (a)

Area of triangle, $A_1 = \dfrac{1}{2}\times3\times2 = 3 \text{ m}^2$

Area of rectangle, $A_2 = 6\times2 = 12 \text{ m}^2$

$$\text{Area of semicircle, } A_3 = \frac{1}{2}\times\pi\times(1)^2 = \frac{\pi}{2}$$

$$x_1 = 6+\frac{1}{3}\times 3 = 7\text{ m}$$

$$x_2 = 3$$

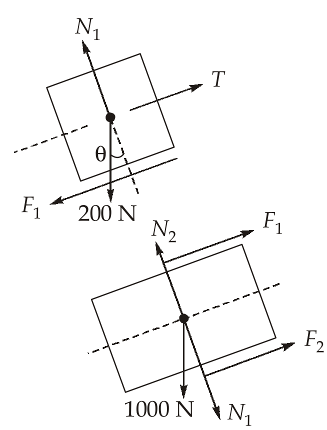
$$x_3 = -\frac{4R}{3\pi} = -\frac{4}{3\pi}$$

$$\bar{x} = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3}$$

$$= \frac{3\times 7 + 12\times 3 + \frac{\pi}{2}\times\left(-\frac{4}{3\pi}\right)}{3+12+\frac{\pi}{2}} = \frac{21+36-\frac{2}{3}}{15+\frac{\pi}{2}} = 3.4\text{ m}$$

49. (d)

Refer the F.B.D. of both blocks



Consider the equilibrium of 200 N block

$$\Sigma F \text{ normal to plane} = 0$$

$$N_1 - 200\cos\theta = 0$$

$$N_1 = 200\cos\theta \quad \text{...(i)}$$

From law of friction, $F_1 = \mu N_1 = \frac{1}{2}\times 200\cos\theta = 100\cos\theta$

For 1000 N block:

$$\Sigma\text{Forces normal to plane} = 0$$

$$N_2 - N_1 - 1000\cos\theta = 0$$

$$N_2 = N_1 + 1000\cos\theta = 200\cos\theta + 1000\cos\theta$$

$$F_2 = \mu N_2 = \frac{1}{2}\times 1200\cos\theta = 600\cos\theta$$

$\Sigma F_x = 0 \quad\Rightarrow\quad F_1 + F_2 - 1000\sin\theta = 0$

$$100\cos\theta + 600\cos\theta = 1000\sin\theta$$

$$\frac{700}{1000} = \tan\theta$$

$$\Rightarrow \quad \tan\theta = \frac{7}{10}$$

50. (a)

1000 N force is shifted to point *B* along the line of action.

$$F_x = 1000\cos\theta = 1000 \times \frac{4}{5} = 800\text{ N}$$

By Varignon's theorem, moment of 1000 N force about *A* is,

$$6000 = 800 \times y$$

$$y = \frac{6000}{800} = 7.5\text{ m}$$

51. (c)

$$\text{Resultant velocity, } V_R = \sqrt{V_x^2 + V_y^2} = \sqrt{3^2 + 4^2} = 5\text{ m/s}$$

52. (c)

$$\frac{\text{Flexural rigidity}}{\text{Torsional rigidity}} = \frac{\text{EI}}{\text{GJ}} = \frac{E \times \frac{\pi}{64}D^4}{G \times \frac{\pi}{32}D^4} = \frac{E}{2G}$$

We know that, $E = 2G(1 + \mu)$

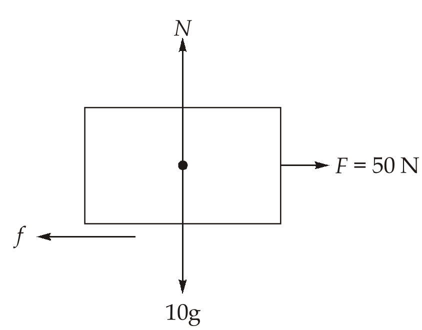
$$\Rightarrow \quad \frac{E}{2G} = (1 + \mu)$$

53. (d)

- The yield point is where plastic deformation starts before this, deformation is reversible beyond this point, permanent deformation occurs.
- During necking, the true stress increases because the cross-sectional area reduces faster then applied load decreases. However, the engineering stress decreases.

54. (c)

FBD of block



$$f_{max} = \mu_s N = 0.4 \times 10 \times 9.81 = 39.24\text{ N}$$

$$F > f_{max} \Rightarrow a \neq 0$$

$$F - f_k = ma$$

$$a = \frac{F - f_k}{m} = \frac{50 - 0.3 \times 10 \times 9.81}{10}$$
$$= 2.057 \text{ m/s}^2 \simeq 2 \text{ m/s}^2$$

55. (c)

$$\frac{\delta V}{V} = \frac{Pd}{4tE}(5 - 4\mu)$$
$$\frac{20 \times 10^{-6}}{\frac{\pi}{4} \times (0.2)^2 \times 1} = \frac{5 \times 10^6 \times 0.2}{4 \times 5 \times 10^{-3} \times 210 \times 10^9}(5 - 4\mu)$$
$$\mu = 0.58$$

56. (a)

Section C : Heat Transfer-2 + IC Engine-2

57. (c)

Given : $h = h_c + h_r = 18 \text{ W/m}^2\text{K}$, $T_1 = 127 + 273 = 400$ K, $T_2 = 27 + 273 = 300$ K

By radiation,
$$\frac{Q}{A} = \sigma\varepsilon\left(T_1^4 - T_2^4\right)$$
$$= 5.67 \times 10^{-8} \times 0.8 \times (400^4 - 300^4)$$
$$= 793.8 \text{ W/m}^2$$
$$h_r = \frac{Q}{A(T_1 - T_2)} = \frac{793.8}{100} = 7.938 \text{ W/m}^2\text{K}$$
$$h_c = h - h_r$$
$$h_c = 18 - 7.938 = 10.06 \text{ W/m}^2\text{K}$$

58. (d)

Because of potential performance gain, dropwise condensation is provoked artificially by surface coating called promoters, that inhibit wetting.

59. (c)

Electrical input to wire, $Q = V \cdot I = 14.5 \times 42.5 = 616.25$ W

Wire surface area, $A = \pi dl = \frac{22}{7} \times 0.001 \times 0.14 = 4.39 \times 10^{-4} \text{ m}^2$

Boiling energy flux $= \frac{616.25}{4.39 \times 10^{-4}} = 1.4 \times 10^6 \text{ W/m}^2$

60. (a)

Neglecting tube thickness, $A_i = A_o$

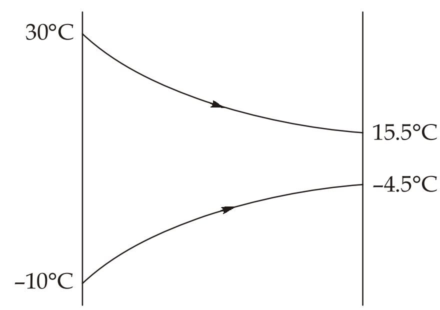
then the overall coefficient of heat transfer is given by

$$U_i = U_0 = U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}}$$

$$= \frac{h_i \times h_o}{h_i + h_o} = \frac{12000 \times 20000}{12000 + 20000}$$

$$= 7500 \text{ kJ/m}^2\text{-hr-K}$$

61. (c)



$$\text{LMTD} = \frac{\theta_1 - \theta_2}{\ln \frac{\theta_1}{\theta_2}}$$

$$\theta_1 = t_{h_1} - t_{c_1} = 30 - (-10) = 40°\text{C}$$

$$\theta_2 = t_{h_2} - t_{c_2} = 15.5 - (-4.5) = 20°\text{C}$$

$$\text{LMTD} = \frac{40 - 20}{\ln \frac{40}{20}} = \frac{20}{\ln 2} = 28.85°\text{C}$$

62. (a)

$$\text{Heat transfer from water, } Q = m_{cp} \Delta t$$

$$= \frac{9}{60} \times 4.2 \times (30 - 15.5)$$

$$= 9.135 \text{ kJ}$$

$$\text{Heating surface area} = \frac{Q}{U \times LMTD}$$

$$= \frac{9.135 \times 10^3}{860 \times 28.55} = 0.368 \text{ m}^2$$

63. (c)

Since the black and gray body are emitting the same amount of radiation,

$$\therefore \quad \sigma_b \times A \times T_f^4 = \sigma_b \times \varepsilon \times A \times T_g^4$$

$$\varepsilon = \left(\frac{T_f}{T_g}\right)^4$$

$$\varepsilon = \left(\frac{1000}{1250}\right)^4 = 0.4096$$

64. (a)

A body that reflects all the incident thermal radiation is called a specular body (if the reflection is regular) or an absolutely white body (if the reflection is diffused).

65. (c)

We know that, $F_{12} = 1$ and $F_{11} = 0$

From reciprocating theorem,

$$A_1F_{12} = A_2F_{21}$$

$$4\pi \times (0.05)^2 \times 1 = 4\pi \times (r_2)^2 \times 0.6$$

$$r_2 = \left[\frac{(0.05)^2}{0.6}\right]^{1/2} \simeq 0.0645 \text{ m}$$

or, $r_2 = 6.45$ cm

66. (a)

The rate of heat interchange between the two surface is

$$Q_{12} = (F_g)_{12} A_1\sigma_b (T_1^4 - T_2^4) \quad \text{...(i)}$$

where,

$$(F_g)_{12} = \frac{1}{\frac{1-\varepsilon_1}{\varepsilon_1} + \frac{1}{F_{12}} + \frac{1-\varepsilon_2}{\varepsilon_2} \times \frac{A_1}{A_2}}$$

For infinite long parallel planes which see each other and nothing else $F_{12} = 1$ and $A_1 = A_2$

$$\therefore \quad (F_g)_{12} = \frac{1}{\frac{1-\varepsilon_1}{\varepsilon_1} + 1 + \frac{1-\varepsilon_2}{\varepsilon_2}}$$

$$= \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = \frac{1}{\frac{1}{0.025} + \frac{1}{0.025} - 1}$$

$$= \frac{1}{40 + 40 - 1} = \frac{1}{79} = 0.01266$$

$$Q_{12} = 0.01266 \times 1 \times 5.67 \times 10^{-8} \times (400^4 - 300^4) \quad \text{from eq ...(i)}$$

$$= 12.56 \text{ W}$$

67. (b)

$$\text{Swept volume/Cylinder, } V_S = \frac{2000}{4} = 500 \text{ CC}$$

$$\text{Volume of air taken in/Cycle} = \eta_V \times V_S = 0.7 \times 500 = 350 \text{ CC}$$

$$\text{Volume of fuel taken in/Cycle} = \frac{350}{9} = 38.88 \text{ CC}$$

$$\text{Energy supplied/Cylinder, } E = 38.88 \times 10^{-6} \times 34 \times 10^3$$

$$E = 1.32 \text{ kJ}$$

68. (c)

Blending : It is a process of obtaining a product of desired quality by mixing certain products in same suitable proportions.

Polymerization : It is the process of converting olefins the unsaturated products of cracking into heavier and stable compounds.

Cyclization : It joins together the ends of a straight chain molecule to form a ring compound of the naphene family.

69. (b)

We know that,

$$P = \frac{2\pi NT}{60000} = \frac{p_{bm}LAn}{60000}$$

$$p_{bm} = \frac{2\pi NT}{LAn} = \frac{2\times\pi\times NT}{L\times\frac{\pi}{4}\times D^2\times\frac{N}{2}} = \frac{16T}{D^2L}$$

$$p_{bm} = \frac{16\times 25}{(0.08)^2\times 0.11} = 5.68\times 10^5\,\text{Pa} = 5.68\text{ bar}$$

70. (b)

Morse Test : In this test the engine is first run at the required speed by adjusting the throttle in SI engine or the pump rack in CI engine and the output is measured. The throttle rack is locked in this position. Then, one cylinder is cut out by short circuiting the spark plug in the SI engine or by disconnecting the injector in the CI engine. Under this condition all the other cylinders will motor the cut out cylinder and the speed and output drop. The engine speed is brought to its original value by reducing the load. This will ensure that the frictional power is the same while the brake power of the engine will be with one cylinder less.

71. (a)

Brake thermal efficiency, $\eta_{bth} = \eta_{ith} \times \eta_m$
$= 0.32 \times 0.75$
$= 0.24$

Rate of energy input from fuel $= \dfrac{20\times 42000}{3600} = 233.34$ kW

Brake power $= \eta_{bth} \times 233.34$
$= 0.24 \times 233.34$
$= 56$ kW

72. (b)

The concentration of NO_x from the exhaust of an SI engine can be reduced by the following methods:

1. **By decreasing the combustion temperature :** Temperature of combustion products can be decreased by
- Retarding spark
- Avoiding knock
- Decrease inlet temperature of the charge

- Decreasing the compression ratio
- Increasing the humidity of air, or water rejection

2. By decreasing the availability of oxygen : This can be reduced by

- Using rich mixtures
- Decreasing the homogeneity of mixture
- Using a stratified charge

73. (a)

Heat lost by exhaust gases in exhaust calorimeter

$$= 12 \times 4.18 \times (55 - 15)$$
$$= 2006.4 \text{ kJ/min}$$

74. (d)

Hartridge smoke-meter and Bosch smoke-meter are used to measure the intensity of exhaust-smoke. Gas chromatography is used for the detailed analysis of exhaust gas mixtures. Dilution tunnel is used to measure the amount of particulate present in the exhaust gas from the diesel engine.

75. (a)

Diesel fuels are less volatile and more viscous than gasoline because of these properties the formation of a combustible mixture during cold starting becomes difficult. In order that the fuel should start the cold engine easily, a high cetane rating of the fuel is required. It reduce the self ignition temperature.

❍❍❍❍