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# ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

# MECHANICAL ENGINEERING

**Test 10**

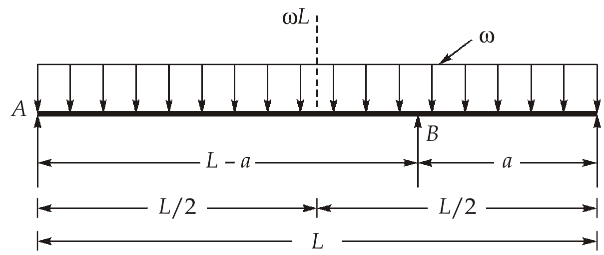
**Section A :** Strength of Materials & Engineering Mechanics
**Section B :** Heat Transfer-1 + IC Engines-1
**Section C :** Fluid Mechanics and Turbo Machinery-2

## Answer Key

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

## Section A: Strength of Materials & Engg. Mechanics

**1. (c)**




$$R_A + R_B = \omega L \quad \text{...(i)}$$

$\Sigma M_A = 0 \quad \Rightarrow$
$$R_B = \frac{1}{L-a}\left(\frac{\omega L^2}{2}\right) = \frac{\omega L^2}{2(L-a)}$$

From equation (i),
$$R_A = \omega L - \frac{\omega L^2}{2(L-a)} = \frac{\omega L}{2}\left(\frac{L-2a}{L-a}\right)$$

Maximum, B.M. occurs in *AB* at a section where S.F. is zero. Hence, at a distance $x$ from $A$.

$$F_x = \frac{\omega L(L-2a)}{2(L-a)} - \omega x = 0$$

$$x = \frac{L(L-2a)}{2(L-a)} \quad [\text{As } F_x = 0 \text{ for } M_{max}]$$

$\therefore$
$$M_{max} = \frac{\omega L}{2}\left(\frac{L-2a}{L-a}\right) \times \frac{L}{2}\left(\frac{L-2a}{L-a}\right) - \frac{\omega}{2}\left[\frac{L(L-2a)}{2(L-a)}\right]^2$$

$$= \frac{\omega L^2}{8}\left(\frac{L-2a}{L-a}\right)^2$$

**2. (a)**

Diameter of wire = 10 mm, $y_{max} = \frac{10}{2} = 5\text{ mm}$, Radius of curvature , $R$ = 20 m = 20 × $10^3$ mm, $E$ = 2 × $10^5$ N/mm$^2$.

$$\frac{\sigma}{y} = \frac{E}{R+t}$$

$$\sigma_{max} = \frac{E}{R+t} y_{max} = \frac{2 \times 10^5}{20000+5} \times 5 \simeq 50 \text{ N/mm}^2$$

**3. (c)**

Every layer of material is free to expand or contract longitudinally and laterally under stress, and do not exert pressure upon each other. Thus the poisson's effect and the interference of the adjoining differently stressed fibres are ignored.

**4. (d)**

For a simply supported beam with central point load $W$,

We have,
$$\theta = \frac{WL^2}{16EI} \text{ and } y = \frac{WL^3}{48EI}$$

$$\theta = 1° = \frac{1\times\pi}{180} = 0.01745 \text{ radian}$$

$$y = \frac{WL^3}{48EI} = \frac{WL^2}{16EI}\times\frac{L}{3} = \theta\times\frac{L}{3} = 0.01745\times\left(\frac{3000}{3}\right)$$

$$y = 17.45 \text{ mm}$$

**5. (a)**

A composite beam is the one which is made up of two or more materials. For such a section the deflection of each component/material, at a given location will be the same.

**6. (b)**

Given: $d$ = 80 mm, $M$ = 5 kN-m, $T$ = $4\sqrt{2}$ kN-m

According to maximum shear strain energy theory,

$$\tau = \frac{16}{\pi d^3}\sqrt{4M^2+3T^2} = \frac{16}{\pi(80)^3}\sqrt{4(5)^2+3\times\left(4\sqrt{2}\right)^2}\times 10^6$$

$$= \frac{16}{\pi\times(80)^3}\times 14\times 10^6 = 139.26 \text{ MPa}$$

**7. (a)**

Given: $d$ = 3 m, $t$ = 25 mm, $\eta_L$ = 0.88, $\sigma$ = 120 N/mm$^2$

$$\sigma_c = \frac{pd}{2t\eta_L}$$

$$p = \frac{\sigma_c\times 2\times t\times\eta_L}{d} = \frac{120\times 2\times 25\times 0.88}{3000} = 1.76 \text{ N/mm}^2$$

**8. (a)**

Distance of the centroid of the net section from the bottom edge,

$$y = \frac{120\times 180\times 90 - 60\times 90\times(60+45)}{120\times 180 - 60\times 90} = 85 \text{ mm}$$

$$I = \left[\frac{120\times 180^3}{12} + 120\times 180\times(5)^2\right] - \left[\frac{60\times 90^3}{12} + 60\times 90\times(20)^2\right]$$

$$I = 58.86\times 10^6 - 5.805\times 10^6$$
$$= 53.05\times 10^6 \text{ mm}^4$$

**9. (a)**

Stresses in $x$ and $y$ directions is given by

$$\sigma_1 = \frac{E(\varepsilon_1 + \mu\varepsilon_2)}{1-\mu^2} = \frac{80 \times 10^3 (0.00108 + 0.3 \times 0.00024)}{1-(0.3)^2}$$

$$= 101.27 \text{ N/mm}^2 \text{ or MPa}$$

**10. (a)**

When $\sigma_2$ is applied along two lateral directions

$$\varepsilon_2 = \varepsilon_3 = \frac{\sigma_2}{E} - \frac{\mu\sigma_2}{E} - \frac{\mu\sigma_1}{E}$$

However, if $\sigma_2$ is not applied

$$\varepsilon_2 = -\frac{\mu\sigma_1}{E}$$

According to question, $\frac{\sigma_2}{E} - \frac{\mu\sigma_2}{E} - \frac{\mu\sigma_1}{E} = \frac{1}{3}\left(-\frac{\mu\sigma_1}{E}\right)$

$$\sigma_2 = \frac{2}{3}\left(\frac{\mu}{1-\mu}\right)\sigma_1$$

**11. (c)**

Principal stresses, $$(\sigma_{1,2}) = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$(\sigma_{1,2}) = \left(\frac{60+40}{2}\right) \pm \sqrt{\left(\frac{60-40}{2}\right)^2 + (20)^2}$$

$$\sigma_{1,2} = 50 \pm 22.36$$

$$\sigma_1 = 72.36 \text{ N/mm}^2, \sigma_2 = 27.64 \text{ N/mm}^2$$

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{72.36 - 27.64}{2}$$

$$= 22.36 \text{ N/mm}^2 \text{ or MPa}$$

**12. (b)**

Let uniformly distributed load be $\omega$ N/mm.

We know that, $$M_{max} = \frac{\omega L^2}{8} = \frac{\omega \times 6000 \times 6000}{8} = 4.5\omega \times 10^6 \text{ N-mm}$$

Also, $$\frac{M_{max}}{I} = \frac{\sigma_{per}}{y}$$

$$\frac{4.5 \times \omega \times 10^6}{I} = \frac{120}{200}$$

$$\frac{\omega}{I} = \frac{3\times10^{-6}}{5\times4.5}$$

$$y_{max} = \frac{5}{384}\times\frac{\omega L^4}{EI} = \frac{5}{384}\times\left(\frac{\omega}{I}\right)\times\frac{(6000)^4}{2\times10^5}$$

$$y_{max} = \frac{5}{384}\times\frac{3\times10^{-6}}{5\times4.5}\times\frac{36\times36\times10^{12}}{2\times10^5} = 11.25 \text{ mm}$$

**13. (a)**

$$\sigma_{1,2} = \frac{\sigma_x+\sigma_y}{2}\pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}$$

$$= \frac{40-30}{2}\pm\sqrt{\left(\frac{40+30}{2}\right)^2+(20)^2} = 5\pm40.31$$

$\sigma_1$ = 45.31 N/mm$^2$ (tension), $\sigma_2$ = 35.35 N/mm$^2$ (compression)

According to question:

Maximum principal stress (or direct stress) becomes 45.31 k, which is not to exceed 100 N/mm$^2$.

$$45.31\,k = 100$$

$$k = \frac{100}{45.31} = 2.207 \simeq 2.21$$

**14. (b)**

**15. (c)**

Change in temperature ($\Delta T$) = 400 – 300 = 100 K

$$\frac{\sigma_t L}{E} = (L\,\alpha\,\Delta T - a)$$

$$\sigma_t = \frac{E}{L}(L\alpha\Delta T-5) = E\alpha(\Delta T)-\frac{5E}{L}$$

$$= 2\times10^5\times12\times10^{-6}\times100 - \frac{5\times2\times10^5}{8000}$$

$$= 240 - 125 = 115 \text{ N/mm}^2$$

**16. (a)**

We have,

$$E = 3K(1-2\mu)$$

$$K = \frac{E}{3(1-2\mu)}$$

As

$$\mu = \frac{1}{m}$$

$$K = \frac{E}{3\left(1-\frac{2}{m}\right)} = \frac{mE}{3(m-2)}$$

**17. (d)**

Isotropic materials have the same properties in all directions. The number of independent elastic constants for such a material is 2, out of E, G, K and μ if any two constants are known for any linear elastic and isotropic material then rest two can be derived.

**18. (c)**

Given: $d_i$ = 12 mm, $d_f$ = 11.98 m, $L_i$ = 200 mm, $L_f$ = 201 mm.

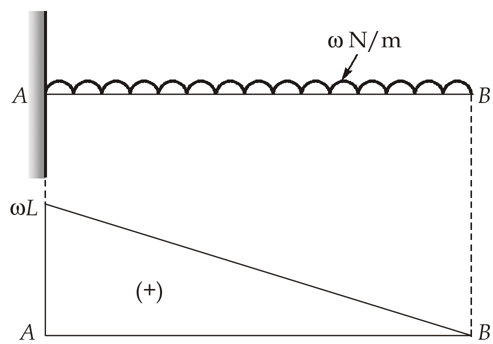
$$\text{Poisson's ratio } (\mu) = -\frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

$$\mu = \frac{-\left(\dfrac{d_f - d_i}{d_i}\right)}{\left(\dfrac{L_f - L_i}{L_i}\right)} = \frac{-\left(\dfrac{11.98 - 12}{12}\right)}{\left(\dfrac{201 - 200}{200}\right)} = -\frac{\left(-1.67 \times 10^{-3}\right)}{5 \times 10^{-3}}$$

$$\mu = \frac{1.67}{5} = 0.33$$

**19. (b)**

For a cantilever beam having uniform distributed load (UDL) over its whole length the shear force (SF) diagram is a right angled triangle having its base representing the length of the beam.




**SFD (Right angled triangle)**

**20. (d)**

Given: $d_i = d$, $d_o = 3d$, $P$ = Internal pressure

In thick cylinder, maximum hoop stress,

$$\sigma_{hoop} = P \times \frac{r_2^2 + r_1^2}{r_2^2 - r_1^2} = P \times \left[\frac{\left(\dfrac{3d}{2}\right)^2 + \left(\dfrac{d}{2}\right)^2}{\left(\dfrac{3d}{2}\right)^2 - \left(\dfrac{d}{2}\right)^2}\right]$$

$$= P \times \left[\frac{\dfrac{9d^2}{4} + \dfrac{d^2}{4}}{\dfrac{9d^2}{4} - \dfrac{d^2}{4}}\right] = P \times \frac{10d^2}{8d^2} = \frac{5P}{4}$$

**21. (a)**

Equation of deflected shape of beam,

$$y = \frac{1}{EI}\left(2x^3 - \frac{x^4}{6} - 36x\right)$$

$$\text{Intensity of loading } (w) = -\left(EI\frac{d^4y}{dx^4}\right) \quad \text{...(i)}$$

$$y = \frac{1}{EI}\left(2x^3 - \frac{x^4}{6} - 36x\right)$$

$$\frac{dy}{dx} = \frac{1}{EI}\left(6x^3 - \frac{4x^3}{6} - 36\right)$$

$$\frac{d^2y}{dx^2} = \frac{1}{EI}\left(12x - \frac{12x^3}{6} - 0\right)$$

$$\frac{d^3y}{dx^3} = \frac{1}{EI}\left(12 - \frac{24x}{6}\right)$$

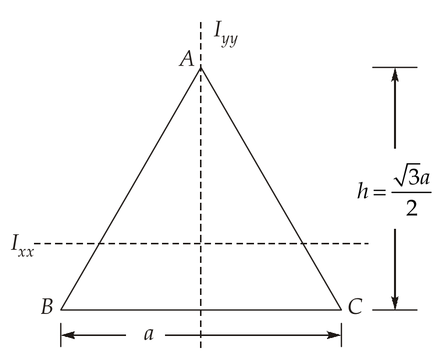
$$\frac{d^4y}{dx^4} = \frac{1}{EI}\left(-\frac{24}{6}\right)$$

$$\left(EI\frac{d^4y}{dx^4}\right) = -\frac{24}{6} \quad \text{...(ii)}$$

On company equation (i) and (ii).

$$w = \frac{24}{6} = 4 \text{ kN/m}$$

**22. (b)**



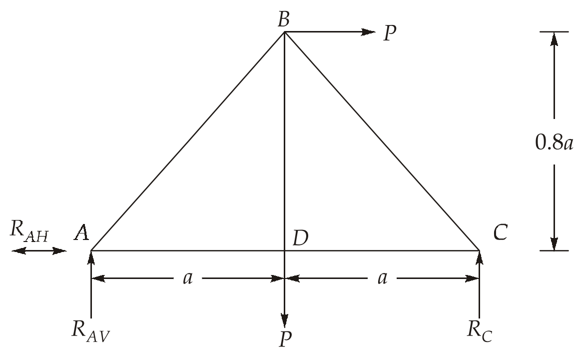

[For equilateral triangle $h = \frac{\sqrt{3}a}{2}$ ]

$$I_{xx} = \frac{ah^3}{36}, \quad I_{yy} = \frac{ha^3}{48}$$

$$I_{zz} = I_{xx} + I_{yy} = \frac{ah^3}{36} + \frac{ha^3}{48} = \frac{ah}{144}\left(4h^2 + 3a^2\right)$$

$$= \frac{a}{144}\frac{\sqrt{3}a}{2}\left(4 \times \frac{3a^2}{4} + 3a^2\right) = \frac{\sqrt{3}}{48}a^4 = \frac{1}{16\sqrt{3}}a^4 = \frac{a^4}{16\sqrt{3}}$$

**23. (b)**




Taking moment of forces about point A.

$$R_C \times 2a = P \times 0.8a + P \times a$$

$$R_C = \frac{1.8P}{2} = 0.9P$$

Also, $R_{AV} + R_C = P$ $[\Sigma F_V = 0]$

$$R_{AV} = P - R_C = P - 0.9P$$

$$R_{AV} = 0.1P$$

and $R_{AH} = P$ $[\Sigma F_H = 0]$

∴ Resultant reaction at $A = \sqrt{(R_{AH})^2 + (R_{AV})^2} = \sqrt{(P)^2 + (0.1P)^2}$

$$= 1.005P$$

**24. (b)**

Acceleration, $a = -kv^2 = \frac{dv}{dt}$

$$\int_u^{v'} \frac{dv}{v^2} = -\int_o^t kdt$$

$$\left[\frac{-1}{v}\right]_u^{v'} = -kt$$

$$\frac{1}{u} - \frac{1}{v'} = -kt \qquad \text{...(i)}$$

But, $u = 6$ m/s, $v' = 3$ m/s when $t = 200$ sec

∴ $\frac{1}{6} - \frac{1}{3} = -k \times 200$

$$-\frac{1}{6} = -k \times 200$$

$$k = \frac{1}{1200}$$

At any instant, $\frac{1}{u} - \frac{1}{v'} = -\frac{t}{1200}$ [from equation (i)]

Hence, at $t$ = 100 sec,

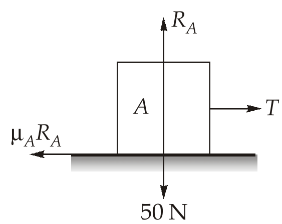
$$\frac{1}{3} - \frac{1}{v''} = -\frac{100}{1200} \Rightarrow \frac{1}{v''} = \frac{1}{3} + \frac{100}{1200} \Rightarrow \frac{1}{v''} = \frac{5}{12}$$

$\Rightarrow$ $v'' = 2.4$ m/s

**25. (c)**

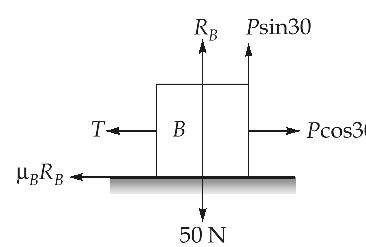
F.B.D. of block $A$ and block $B$, $\Sigma F_x = 0$, $\Sigma F_y = 0$

**For '*A*'**




$$R_A = 50 \text{ N};$$
$$T = \mu_A R_A = 0.3 \times 50;$$
$$T = 15 \text{ N}$$

**For '*B*'**




$$R_B + P\sin 30° = 50$$
$$R_B = 50 - P\sin 30$$
$$P\cos 30° = T + \mu_B R_B$$
$$= 15 + 0.3\,(50 - P\sin 30°)$$
$$0.866P = 15 + 15 - 0.15P$$
$$1.016P = 30$$
$$P = \frac{30}{1.016} = 29.527 \approx 29.53 \text{ N}$$

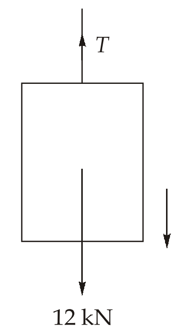
**26. (d)**

Following points must be remembered in an engine powered vehicle:

- On a smooth surface driving wheels will rotate about axis of axle but vehicle will not move.
- Frictional torque on driving wheels is overcome by engine torque.
- Friction on driven wheels provides motion to driven wheels.
- Friction on driving wheels provides driving force or tractive force to the vehicle.

**27. (b)**

Given: $s$ = 30 m, $t$ = 15 sec




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

$$30 = \frac{1}{2} \times a \times 15^2$$

$$a = 0.267 \text{ m/s}^2$$

$$12000 - T = ma$$

$$T = 12000 - ma = 12000 - \frac{12000}{9.81} \times 0.267$$

$$T = 11.674 \text{ kN}$$

**28. (a)**

Maximum load ($W$).

Let $R$ = Normal reaction of the pulley on the beam at $C$. Consider the equilibrium of the beam $AB$. Taking moments about the hinge A and equating the same,

$$R \times 1 = 5 \times 1.5$$

$$R = 7.5 \text{ kN}$$

Now consider the equilibrium of the pulley. The load W tends to rotate it. A little consideration will show that the rotation of the pulley is prevented by the frictional force between the pulley and beam at C.

We know that,

$$\text{Maximum force of friction at C} = \mu R = 0.2 \times 7.5 = 1.5 \text{ kN}$$

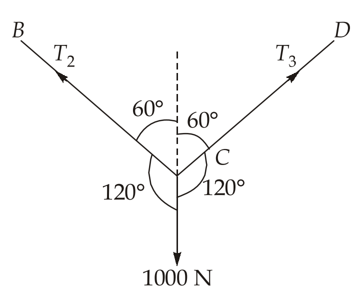
Taking moments about the centre of the pulley and equating the same.

$$W \times 50 = 1.5 \times 75$$

$$W = \frac{112.5}{50} = 2.25 \text{ kN}$$

**29. (b)**

Applying Lami's theorem at joint C.




$$\frac{T_2}{\sin 120°} = \frac{T_3}{\sin 120°} = \frac{1000}{\sin 120°}$$

$$T_3 = \frac{1000 \times \sin 120°}{\sin 120°} = 1000 \text{ N}$$

**30. (d)**

Man moving in an accelerated train on horizontal tracks feels that his weight will be same. Man weight (apparent) changes when motion is in vertical direction means toward earth or away from earth or motion against or in direction of gravity.

**31. (a)**

Let $\hat{i}$ and $\hat{j}$ be in the x and y direction, respectively.

$$\vec{F_1} = 3\hat{i} - 5\hat{j}, \quad \vec{F_2} = x\hat{i} + y\hat{j}, \quad \vec{F_R} = -4\hat{i}$$

$$\therefore \quad \vec{F_1} + \vec{F_2} = \vec{F_R}$$

$$3\hat{i} - 5\hat{j} + x\hat{i} + y\hat{j} = -4\hat{i}$$

$$(3+x)\hat{i} + (y-5)\hat{j} = -4\hat{i}$$

On comparing. $3 + x = -4, \quad y - 5 = 0$

$$x = -7, \quad y = 5$$

The $x$ and $y$ components of second force is (–7, 5).

**32. (a)**

$$A = \frac{\pi}{4} \times (30)^2 = 225\pi \text{ mm}^2$$

$$\sigma = \frac{50 \times 10^3}{225\pi} = 70.73 \text{ MPa}$$

We know, $$\mu = \frac{\frac{\delta d}{d}}{\frac{\delta L}{L}} = \frac{\frac{0.004}{30}}{\frac{0.15}{500}} = \frac{0.004 \times 500}{30 \times 0.15} = 0.44$$

$$\therefore \quad E = \frac{\sigma}{\frac{\delta L}{L}} = \frac{70.73 \times 500}{0.15} = 235766.67 \text{ MPa}$$

Also we know,

$$k = \frac{E}{3(1-2\mu)} = \frac{235766.67}{3(1-2\times 0.44)}$$

$$k = 654907.4 \text{ MPa or } 654.90 \text{ GPa}$$

**33. (b)**

Given, $\sigma_x = \sigma_y = \sigma$

For maximum obliquity of the resultant with the normal to the plane

$$\tan\theta = \sqrt{\frac{\sigma_x}{\sigma_y}} = \sqrt{1} = 1$$

or $\theta = 45°$

**34.** **(b)**

**35.** **(c)**

$$m_1 = m_2$$
$$(A_1 \times t_1)\rho_1 = (A_2 \times t_2)\rho_2$$
$$A_1\rho_1 = A_2\rho_2$$
$$\rho_1 \neq \rho_2$$
$$\Rightarrow \quad A_1 \neq A_2$$
$$(R_1 \neq R_2)$$

Therefore, $I_1 \neq I_2$

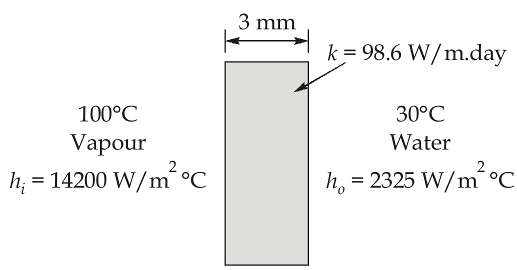
**36.** **(b)**

**37.** **(b)**

## Section B : Heat Transfer-1 + IC Engines-1

**38.** **(c)**

Thermal resistance of composite system is given by:




$$R_{th} = \frac{1}{A}\left[\frac{1}{h_i} + \frac{L}{k} + \frac{1}{h_o}\right]$$

The wall area A is constant for all the layers. Considering unit area and inserting appropriate values.

$$R_{th} = \frac{1}{1}\left[\frac{1}{14200} + \frac{0.003}{98.6} + \frac{1}{2325}\right]$$
$$= 7.04 \times 10^{-5} + 3.04 \times 10^{-5} + 43.01 \times 10^{-5}$$
$$= 53.09 \times 10^{-5} \text{ °C m}^2/\text{W}$$

Rate of heat transfer from the vapour to water side

$$Q = \frac{\Delta T}{R_{th}} = \frac{100 - 30}{53.09 \times 10^{-5}} = 131.8 \text{ kW/m}^2$$

**39.** **(a)**

According to Wiedemann and Franz law, the ratio of the thermal and electrical conductivities is same for all metals at the same temperature and that the ratio is directly proportional to the absolute temperature of the metal.

**40. (d)**

For one dimensional steady state, the heat flow through the test specimen is

$$Q = \frac{kA(t_1 - t_2)}{L}$$

$$15 = \frac{k \times 0.065 \times 0.065 \times (325 - 300)}{0.01} = 1.42 \text{ W/mK}$$

**41. (c)**

The temperature distribution is given as:

$$t = 80 - 60x + 12x^2 + 25x^3 - 20x^4$$

$$\frac{dt}{dx} = -60 + 24x + 75x^2 - 80x^3$$

$$\frac{d^2t}{dx^2} = 24 + 150x - 240x^2$$

Rate of temperature change is given by

$$\frac{dt}{d\tau} = \alpha \frac{d^2t}{dx^2}$$

$$\therefore \quad \left(\frac{dt}{d\tau}\right)_{x=0.2} = \alpha\left(\frac{d^2t}{dx^2}\right)_{x=0.2} = 0.02\left[24 + 150 \times 0.2 - 240 \times (0.2)^2\right]$$

$$= 0.88°\text{C/hr.}$$

**42. (a)**

$$\frac{d^3t}{dx^3} = 150 - 480x$$

The rate of heating would be maximum at a location,

where, $$\frac{d}{dx}\left(\frac{dt}{d\tau}\right) = 0$$

$$\frac{d}{dx}\left(\alpha \frac{d^2t}{dx^2}\right) = 0$$

$$\alpha \frac{d^3t}{dx^3} = 0$$

$$\frac{d^3t}{dx^3} = 0$$

$$150 - 480x = 0$$

$$x = 0.3125 \text{ m}$$

**43. (b)**

For circular shaft of diameter, $d$

$$\frac{P}{A_C} = \frac{\pi d}{\frac{\pi}{4}d^2} = \frac{4}{d} = \frac{4}{0.02}$$

$$m = \sqrt{\frac{hP}{kA_C}} = \sqrt{\frac{8 \times 4}{400 \times 0.02}} = 2\ \text{m}^{-1}$$

Heat loss from the rod is given by:

$$Q_{loss} = kA_C\, m\, (t_o - t_a)$$

$$= 400 \times \frac{\pi}{4} \times (0.02)^2 \times 2 \times (100 - 20) = 20.106 \approx 20.11\ \text{W}$$

**44. (d)**

The convective heat transfer coefficient is prescribed by the relation

$$h = \frac{-k}{(t_s - t_\infty)}\left(\frac{dt}{dy}\right)_{y=0} \quad \text{...(i)}$$

We have,

$$t = t_s - (t_s - t_\infty)\sin\left(\frac{\pi y}{0.015}\right)$$

$$\frac{dt}{dy} = -(t_s - t_\infty)\cos\left(\frac{\pi y}{0.015}\right) \times \frac{\pi}{0.015}$$

$$\left(\frac{dt}{dy}\right)_{y=0} = -(t_s - t_\infty)\cos(0) \times \frac{\pi}{0.015}$$

$$\left(\frac{dt}{dy}\right)_{y=0} = -(t_s - t_\infty) \times \frac{\pi}{0.015}$$

From equation (i)

$$h = -\frac{k}{(t_s - t_\infty)} \times (t_s - t_\infty) \times \frac{\pi}{0.015}$$

$$= k\left(\frac{\pi}{0.015}\right) = \frac{0.03 \times \pi}{0.015} = 6.28\ \text{W/m}^2\text{K}$$

**45. (b)**

The convective heat flow from a solid surface to the surrounding fluid is given by Newton's law of cooling,

$$Q = hA\,(t_s - t_f)$$

$$8.8 = 1.2 \times A \times (65 - 20)$$

$$A = \frac{8.8}{1.2 \times 45} \simeq 0.163\ \text{m}^2$$

**46. (c)**

The local film coefficient for laminar flow past a flat plate may by obtained from the correlation:

$$Nu_x = 0.332(\text{Re}_x)^{0.5}\ (\text{Pr})^{0.33} \quad \text{...(i)}$$

where,

(i) Fluid properties are evaluated at the mean film temperature, i.e., arithmetic average of the temperature of the fluid and the temperature of the surface of the plate.

(ii) Reynolds number must not be less than 40000.

(iii) Pr must be more than 0.6.

**47. (b)**

$$\beta = \frac{1}{160+273} = 2.31\times10^{-3} \text{ per K}$$

$$\text{Grashof Number, Gr} = \frac{D^3\rho^2(\beta g\Delta T)}{\mu^2} = \frac{D^3(\beta g\Delta T)}{v^2}$$

$$= \frac{0.05^3\times2.31\times10^{-3}\times9.81\times(295-25)}{(30.09\times10^{-6})^2} = 0.8447\times10^6$$

$$\text{Rayleigh Number (Ra)} = \text{Gr.Pr.} = (0.8447\times10^6)\times0.68$$

$$R = 0.574\times10^6$$

**48. (b)**

**Nusselt number:** It is a convenient measure of the convective heat transfer coefficient.

**Fourier number:** It signifies the degree of penetration of heating or cooling effect through a solid.

**Biot number:** It gives an indication of the ratio of internal resistance (conduction) to the surface resistance (convection).

**Prandtl number:** It is indicative of the relative ability of fluid to diffuse momentum and internal energy by molecular mechanism.

**49. (c)**

$$\text{For four stroke engine, I.P.} = \frac{P_{mi}LANn}{120}$$

$$\text{For two stroke engine, I.P.} = \frac{P_{mi}LANn}{60}$$

$$\text{Average piston speed, } V_p = 2\text{ LN}$$

$$\text{LN} = \frac{V_p}{2}$$

$$(\text{I.P.})_1 = P_{mi}\times A_1\times\frac{V_{p1}}{2}\times\frac{6}{120} \quad \text{...(i)}$$

$$(\text{I.P.})_2 = P_{mi}\times A_2\times\frac{V_{p2}}{2}\times\frac{2}{60} \quad \text{...(ii)}$$

From equation (i) and (ii):

$$\frac{(I.P.)_1}{(I.P.)_2} = \frac{A_1}{A_2}\times\frac{V_{p1}}{V_{p2}}\times\frac{6}{120}\times\frac{60}{2}$$

$$V_{p_2} = \left(\frac{A_1}{A_2}\right)\times V_{p1}\times\frac{6}{120}\times\frac{60}{2}\times\frac{(I.P.)_2}{(I.P.)_1}$$

$$V_{p_2} = \left(\frac{2}{1}\right)^2\times 12\times\frac{6}{120}\times\frac{60}{2}\times\frac{12}{60}$$

$$V_{p_2} = 14.4 \text{ m/s}$$

**50. (a)**

The boost venturi is positioned upstream of the throat of the larger main venturi.

**51. (c)**

Let, B.P. at full load = $x$ kW

B.P. at 75% of load = $0.75x$ kW

I.P. at 75% of load = $(0.75x + FP)$ kW

At 75% load, $$\eta_m = \frac{0.75x}{0.75x + F.P.} = 0.7$$

$$0.75x = 0.525x + 0.7 \text{ F.P.}$$

$$\therefore \quad \text{F.P.} = \frac{0.225x}{0.7} = 0.3214x$$

It remains constant at all loads.

At full load, $$\text{I.P.} = \text{B.P.} + \text{F. P.} = 50$$

$$x + 0.3214x = 50$$

$$x = \frac{50}{1.3214} = 37.84 \text{ kW}$$

$$\text{B.P.} = 37.84 \text{ kW}$$

**52. (b)**

Since the engine is square, $L = d$

Swept volume per cylinder, $$V_s = \frac{3}{6} = 0.5l = 0.0005 \text{ m}^3$$

Compression ratio, $$r = \frac{V_s + V_c}{V_c}$$

$$V_c = \frac{V_s}{r-1} = \frac{0.0005}{9-1} = 62.5\times 10^{-6}\text{ m}^3$$

$$V_c = 62.5 \text{ cm}^3$$

**53. (d)**

Specific power is the power per unit piston area. It measures the effectiveness with which the piston area is used, regardless of the cylinder size.

$$\text{Specific power, SP} = \frac{Bp}{A_p}$$

**54. (c)**

**Multi-Point Fuel Injection :** It is also called multi-point port fuel injection or indirect multi-point injection (IMPI) or simply multiport injection (MPI). The injectors are positioned in the intake ports just upstream of each cylinder's intake valve. It requires one injector per cylinder and in some systems, one or more injectors are used to supplement the fuel flow during starting and warm-up periods. The advantages of port fuel injection are increased power and torque through improved volumetric efficiency and more uniform fuel distribution to each cylinder, more rapid engine response to changes in throttle position and more precise control of the equivalence ratio during cold start and engine warm-up.

**55. (c)**

**56. (c)**

Varying the ignition timing is more difficult. Since the breaker points must be opened when the rotating magnets are in the most favourable position.

## Section C : Fluid Mechanics & Turbo Machinery-2

**57. (b)**

For above condition,

$$u(r) = \frac{1}{4\mu}\left(\frac{\partial P}{\partial x} - \rho g\right)\left(R^2 - r^2\right)$$

If $\frac{\partial P}{\partial x} - \rho g = 0$, then velocity profile simplifies to

$$u(r) = \frac{1}{4\mu}(0)\left(r^2 - R^2\right) = 0$$

This means no flow occurs instead of plug flow.

If $\frac{dp}{dx} = 0$, then velocity profile becomes

$$u(r) = \frac{1}{4\mu}(\rho g)\left(R^2 - r^2\right)$$

Which is still parabolic. This is similar to Hagen-Poiseuille flow but driven solely by gravity.

**58. (b)**

The Darcy-Weisbach equation is not limited to horizontal pipes. It is applies to any fully developed, steady, incompressible flow in a closed conduit, regardless of pipe orientation.

**59. (b)**

$$\text{Propulsive power} = \frac{\dot{m}}{2}\left(V_j^2 - V_a^2\right) = \frac{25}{2}\left(1800^2 - 1200^2\right) \times 10^{-6}$$

$$= 22.5 \text{ MW}$$

**60. (b)**

As diameter of parallel pipes are same so they will convey same flow rate for equivalent pipe,

$$\frac{fLQ^2}{12D^5} = \frac{fL\left(\frac{Q}{2}\right)^2}{12d^5} \Rightarrow \frac{D}{d} = 4^{1/5}$$

**61. (c)**

At supersonic speeds, the formation of shock waves in the engine intake reduces pressure recovery and mass flow rate, there by limiting the maximum achievable speed of a turbojet - powered aircraft.

**62. (d)**

$$\text{Power} = \dot{m}\left(\phi u^2\right) = \frac{p\dot{V}}{RT}\left(\phi u^2\right)$$

$$= \frac{28.7 \times 10^2 \times \frac{600}{60}}{0.287 \times (273 + 127)} \times 0.9 \times 400^2 \times 10^{-6}$$

$$= 36 \text{ MW}$$

**63. (c)**

- Flow coefficient = $\dfrac{\text{Axial flow velocity}}{\text{Blade peripheral velocity}}$
- Reasons of higher isentropic efficiency of axial compressors:
  (a) Compresses air gradually over multiple stages, reducing shock and turbulence losses. In contrast, centrifugal compressors achieve compression in a single stage (or few stages), leading to higher energy losses due to sudden pressure jump.
  (b) In axial compressor, air moves mostly in axial direction, maintaining smooth and uniform flow, but in a centrifugal compressor, the air moves radially outward, causing flow separation and higher frictional losses.

**64. (b)**

Propulsive efficiency of rocket engine,

$$\eta = \frac{2V_jV_a}{V_j^2 + V_a^2} = \frac{2 \times 200 \times 100}{200^2 + 100^2} = 0.8 \text{ or } 80\%$$

**65. (d)**

- In turbulent flow, the velocity profile is much flatter in the central region due to intense mixing and energy dissipation.
- In turbulent flow, shear stress is dominated by eddy viscosity, which is much greater than the molecular viscosity.
- The Darcy friction factor in turbulent flow depends on both the Reynolds number and relative roughness ($\in/D$).

**66. (b)**

Power developed in $n^{th}$ row in velocity compound turbine = $\dfrac{P}{2^n}$

$$\text{For } 8^{th} \text{ row} = \frac{128}{2^8} = \frac{1}{2}\,\text{MW}$$

**67. (a)**

$$\text{Energy loss} = \frac{\dot{m}}{2}\left(V_{r1}^2 - V_{r2}^2\right) = \frac{\dot{m}V_{r1}^2}{2}\left(1-k^2\right)$$

$$= \frac{20\times 250^2}{2}\left(1-0.9^2\right)\times 10^{-3} = 118.750\,\text{kW}$$

**68. (b)**

$$\text{DOR, } R = 1-\frac{V_{w2}}{2u_2} = 1-\frac{200}{2\times 250} = 0.6$$

**69. (c)**

Since, the compression of air is obtained by virtue of its speed relative to the engine, the take-off thrust is zero and it is not possible to start a ramjet without an external launching device.

**70. (d)**

Flow always takes place from high energy to low energy.

$$Q_1 = Q_2 + Q_3$$

**71. (c)**

A sudden expansion causes a more significant increase in turbulence then contraction due to flow separation and recirculation in the expanded section.

**72. (a)**

In a multi-cylinder reciprocating compressor, keeping the stroke length equal minimizes torque fluctuations, simplifies balancing and reduces construction costs. Due to standardization of components.

**73. (c)**

**74. (a)**

$$\frac{\partial p}{\partial x} = \frac{8\mu V}{R^2}$$

$$h_L = \frac{\Delta p}{\rho g} = \frac{8\mu VL}{R^2 \rho g}$$

$$h_L \; \alpha \; V$$

**75. (b)**

$$\tau_W = \frac{R}{r}\tau = \frac{40}{10}\times 30 = 120 \text{ Pa}$$

$$= \frac{f}{8}\rho V^2$$

$$f = \frac{8\tau_W}{\rho V^2} = \frac{8\times 120}{10^3 \times 4^2} = 0.06$$

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