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# PTQ

## Prelims Through Questions

for

## ESE 2021

# Mechanical Engineering

## Day 1 of 11

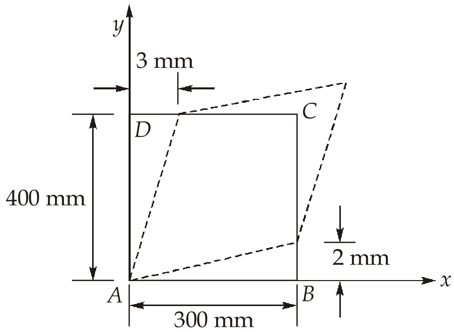
**Q.1 - Q.50**

(Out of 500 Questions)

Strength of Materials + Engg. Mechanics + IC Engines

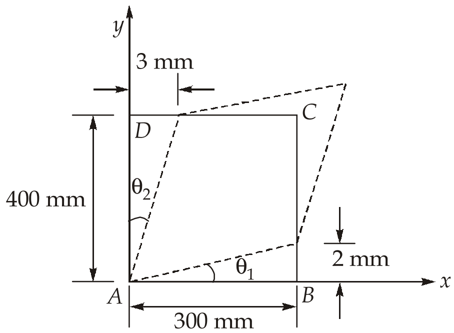
# Strength of Materials + Engg. Mechanics + IC Engines

**Q.1** A piece of rubber as shown in figure is subjected to the displacements of 2 mm and 3 mm at corner B and D respectively. The average shear strain $\gamma_{xy}$ at corner A is




(a) 0.000833 rad
(b) 0.015 rad
(c) 0.0142 rad
(d) 0.005 rad

**1. (c)**




$$\tan\theta_1 = \frac{2}{300}$$

$$\theta_1 = \frac{2}{300}\text{ rad} \quad [\text{Since } \theta \text{ is very small, } \tan\theta = \theta \text{ rad}]$$

$$\tan\theta_2 = \frac{3}{400}$$

$$\theta_2 = \frac{3}{400}\text{ rad}$$

Average shear strain at A,

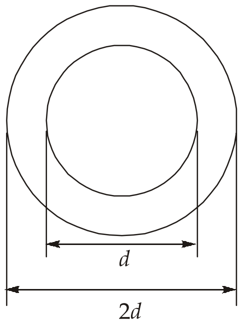
$$(\gamma_{xy})_A = \theta_1 + \theta_2$$
$$= (2/300 + 3/400)$$
$$= 0.0142\text{ rad}$$

**Q.2** What is the maximum torque transmitted by a hollow shaft of outer diameter and inner diameter of $2d$ and $d$ respectively?

(a) $\frac{15}{16}\pi d^3\tau$  (b) $\frac{15}{32}\pi d^3\tau$

(c) $\frac{15}{256}\pi d^3\tau$  (d) $\frac{15}{2}\pi d^3\tau$

**2. (b)**



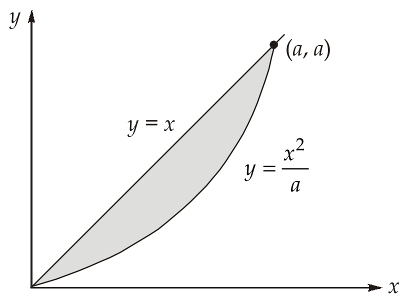

$$\frac{T}{J} = \frac{\tau}{r}$$

$$\frac{T}{\frac{\pi}{32}\left[(2d)^4 - d^4\right]} = \frac{\tau}{\frac{2d}{2}}$$

$$\frac{32T}{\pi\left[15(d)^4\right]} = \frac{\tau}{d}$$

$$T = \frac{15}{32}\pi d^3\tau$$

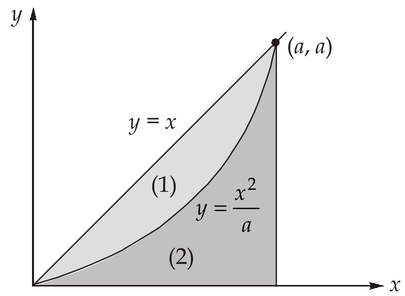
**Q.3** What will be the centroid $x_c$ of the area between the parabola, $y = \frac{x^2}{a}$ and the straight line $y = x$?




(a) $x_c = \frac{a}{2}$  (b) $x_c = \frac{2a}{5}$

(c) $x_c = \frac{3a}{8}$  (d) $x_c = \frac{5a}{8}$

**3. (a)**




where 1 is used for triangle and 2 is used for parabola,

$$\bar{x} = \frac{A_1\bar{x}_1 - A_2\bar{x}_2}{A_1 - A_2} = \frac{\frac{a^2}{2}\times\frac{2a}{3} - \frac{a^2}{3}\times\frac{3a}{4}}{\frac{a^2}{2} - \frac{a^2}{3}}$$

$$= \frac{\frac{a^3}{3} - \frac{a^3}{4}}{\frac{a^2}{6}} = \left(\frac{a}{2}\right)$$

**Q.4** Two simply supported beams 'I' and 'II' are of same length $L$ and are subjected to point load '$W$' and uniformly distributed load of intensity '$W/L$' respectively. What will be the ratio of deflection of mid point in beam 'I' to that in beam 'II'?

(a) $\frac{5}{8}$ (b) $\frac{8}{5}$

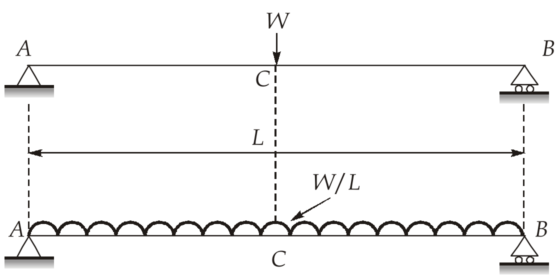
(c) 8 (d) Data insufficient

**4. (d)**

If load is taken at mid point:

Deflection of point C in beam 'I',

$$\Delta_{C,I} = \frac{WL^3}{48EI}$$




Deflection of point C in beam II,

$$\Delta_{C,II} = \frac{5wL^4}{384EI} = \frac{5}{384}\frac{(W/L)L^4}{EI}$$

$$\Delta_{C,II} = \frac{5}{384}\frac{WL^3}{EI}$$

So, $$\frac{\Delta_{C,I}}{\Delta_{C,II}} = \frac{\frac{WL^3}{48EI}}{\frac{5}{384}\frac{WL^3}{EI}} = \frac{8}{5}$$

**Q.5** A trolley of mass 5000 kg is descending a slope with uniform velocity of 2 m/s at the end of a steel cable which is wound round a drum. When the length of cable laid out is 200 m, emergency brakes are suddenly applied and the wagon is brought to halt. If the cross-section area of the cable is 500 mm$^2$ and $E$ = 200 GPa, the stress developed in the cable is

(a) 166.67 MPa
(b) 200 MPa
(c) 400 MPa
(d) 83.33 MPa

**5. (b)**

Kinetic energy of trolley = Strain energy in the cable

$$\frac{mV^2}{2} = \frac{\sigma^2}{2E} \times A \times L$$

$$\sigma^2 = \frac{5000 \times 2^2}{2} \times \frac{2 \times 200 \times 10^9}{500 \times 200 \times 10^{-6}}$$

$$\sigma^2 = 4 \times 10^{16}$$
$$\sigma = 2 \times 10^8 \text{ Pa}$$
$$\sigma = 200 \text{ MPa}$$

**Q.6** A 20 m long steel rod is at a temperature of 20°C. The rod is heated so that temperature rises by 50°C. If rod is allowed to expand by 14 mm, what will be the stress induced in rod? Take $E$ = 200 GPa and $\alpha = 12 \times 10^{-6}$/°C.

(a) 20 MPa
(b) 35 MPa
(c) 68 MPa
(d) None of these

**6. (d)**

Free expansion due to temperature rise,

$$\Delta L = L\alpha\Delta T$$
$$= 20 \times 1000 \times 12 \times 10^{-6} \times 50$$
$$= 12 \text{ mm}$$

Expansion permitted, $\lambda$ = 14 mm

Since, free expansion of rod is less than expansion permitted therefore, no stress will be induced in the rod.

**Q.7** A cylindrical shell 4 m in diameter, is made of 20 mm thick steel plates. The efficiency of longitudinal joint and circumferential joint are 0.88 and 0.7 respectively. If the maximum permissible tensile stress in the plate is 120 MPa, the safe pressure for the shell is

(a) 2.12 MPa
(b) 0.84 MPa
(c) 1.05 MPa
(d) 1.68 MPa

**7. (c)**

For safe design, $\sigma_{hoop} \leq \sigma_{per}$

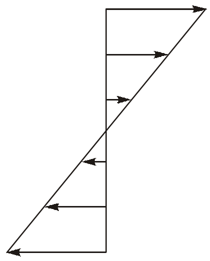
$$\frac{pD}{2t\eta_{LJ}} \leq \sigma_{per}$$

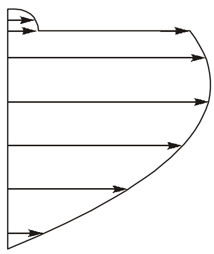
$$\frac{p \times 4000}{2 \times 20 \times 0.88} \leq 120$$

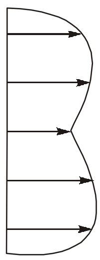
$$p \leq \frac{2 \times 20 \times 0.88 \times 120}{4000}$$

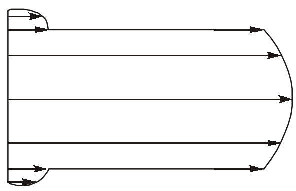
$$p \leq 1.056 \text{ MPa}$$

**Q.8** Which one of the following is the correct representation of shear stress distribution over 'T' section?

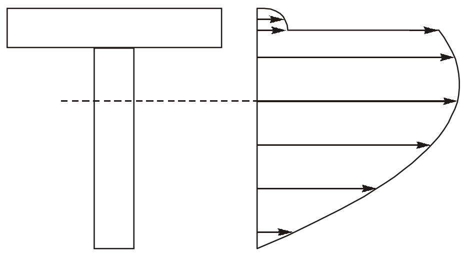
(a)


(b)


(c)


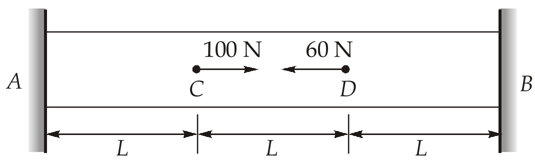
(d)


**8. (b)**



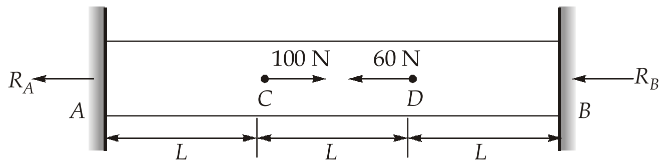
Shear stress distribution

**Q.9** A prismatic bar is fixed at edges $A$ and $B$ as shown in figure. What is the axial force in $CD$ portion?



(a) $\frac{160}{3}$ N (tensile)
(b) $\frac{40}{3}$ N (tensile)
(c) $\frac{40}{3}$ N (compressive)
(d) $\frac{160}{3}$ N (compressive)

**9. (d)**




Writing compatibility equation for this case:

$$\Delta_{BA} = 0$$

$$\Delta_{AC} + \Delta_{CD} + \Delta_{DB} = 0$$

$$\frac{R_A L}{AE} + \frac{(R_A - 100)L}{AE} + \frac{(R_A - 100 + 60)L}{AE} = 0$$

$$R_A + R_A - 100 + R_A - 40 = 0$$

$$3R_A = 140$$

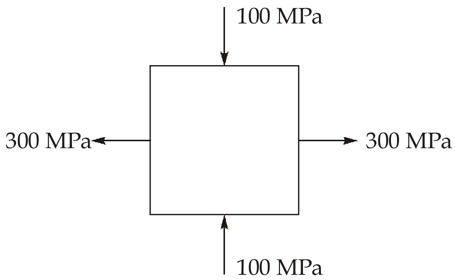
$$\Rightarrow \qquad R_A = \frac{140}{3}\text{N}$$

Force in portion 'CD',

$$F_{CD} = (R_A - 100) = \frac{140}{3} - 100 = \frac{-160}{3}\text{N}$$

So, force in CD portion is $\frac{160}{3}$ N compressive.

**Q.10** For the biaxial state of stress at a point as shown in figure, the shear stress on the plane of pure shear is



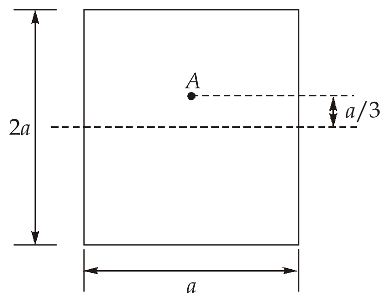

(a) 141.4 MPa
(b) 200 MPa
(c) 100 MPa
(d) 173.2 MPa

**10. (d)**

$$\tau = \sqrt{-\sigma_1 \times \sigma_2} = \sqrt{300 \times 100}$$

$$= 173.2 \text{ MPa}$$

**Q.11** For the section as shown in figure, average shear stress due to bending is 50 MPa. What will be the shear stress at point 'A'?




(a) 11.11 MPa
(b) 75 MPa
(c) 66.67 MPa
(d) 14.81 MPa

**11. (c)**

Average shear stress, $\tau_{avg} = 50$ MPa

As we know,

Maximum shear stress, $\tau_{max} = \frac{3}{2}\tau_{avg} = \tau_{NA} = \frac{3}{2} \times 50 = 75$ MPa

Now, $\tau = \frac{PA\bar{y}}{Ib}$

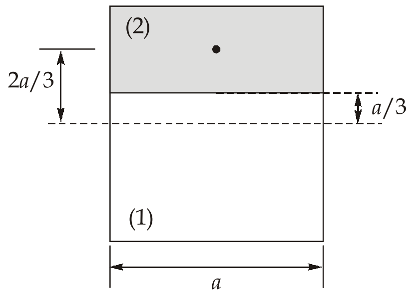
$$\frac{\tau_A}{\tau_{NA}} = \frac{\frac{PA_2\bar{y}_2}{Ib}}{\frac{PA_1\bar{y}_1}{Ib}} \quad \ldots (i)$$

$$A_2 = a \times \frac{2a}{3} = \frac{2a^2}{3}, \quad \bar{y}_2 = \frac{a}{3} + \frac{1}{2}\left(\frac{2a}{3}\right) = \frac{2a}{3}$$

$$A_1 = a \times a = a^2, \quad \bar{y}_1 = \frac{a}{2}$$

From (i):

$$\frac{\tau_A}{\tau_{NA}} = \frac{\frac{2a^2}{3} \times \frac{2a}{3}}{a^2 \times \frac{a}{2}}$$




$$\frac{\tau_A}{75} = \frac{8}{9}$$

$$\tau_A = \frac{8}{9} \times 75 = 66.67 \text{ MPa}$$

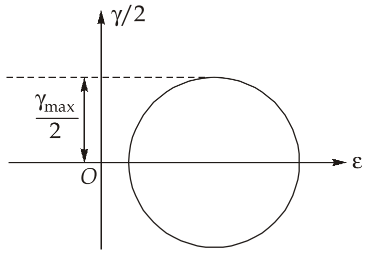
**Q.12** Radius of Mohr's circle for strain is 40 mm. If 1 mm = 15 μ, the maximum in-plane shear strain is

(a) 600 μ
(b) 1200 μ
(c) 300 μ
(d) 400 μ

**12. (b)**

As we know,

In-plane $\frac{\gamma_{max}}{2}$ = Radius of Mohr circle

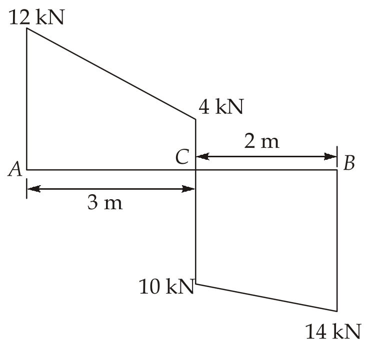



In-plane $\frac{\gamma_{max}}{2} = 40 \times 15\mu$

In-plane $\gamma_{max} = 600 \times 2\mu$

In-plane $\gamma_{max} = 1200\ \mu$

**Q.13** For a simply supported beam AB, the shear force diagram is shown in figure:




What will be the bending moment at point C?

(a) 16 kN-m
(b) 12 kN-m
(c) 24 kN-m
(d) None of these

**13. (c)**

Since AB beam is simply supported, bending moments at ends A and B will be zero.

i.e. $M_A = 0$ and $M_B = 0$

As we know, $M_C - M_A$ = Area of SFD between A and C

$$M_C - 0 = \frac{1}{2} \times 3 \times (12 + 4)$$

$$M_C = 24 \text{ kN-m}$$

**Q.14** Which of the following techniques are used for strengthening of thick pressure vessels?

1. Wire winding
2. Autofrettage
3. Compound cylinder

Select the correct answer using the codes given below:

(a) 1 and 2
(b) 2 and 3
(c) 1 and 3
(d) 1, 2 and 3

**14. (b)**

Wire winding is used to strengthen thin pressure vessels.

**Q.15** Consider the following statements:

1. Toughness is total area under stress-strain curve.
2. Poisson's ratio remains constant in linearly elastic range.
3. More flexible materials have a lower modulus of elasticity.

Which of the above statements are correct?

(a) 1 and 2
(b) 2 and 3
(c) 1 and 3
(d) 1, 2 and 3

**15. (b)**

Modulus of toughness is the total area under the stress-strain curve whereas toughness is the area under the load-deflection curve.

Poisson's ratio remains constant in linearly elastic range.

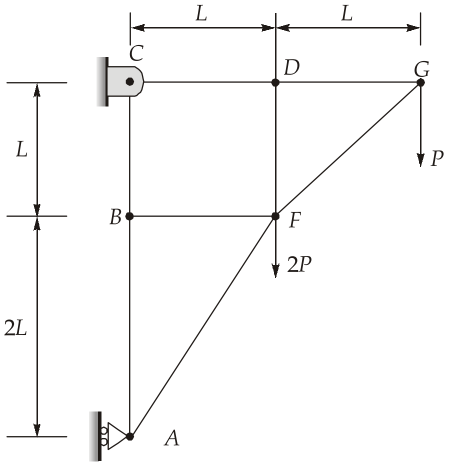
Lower modulus of elasticity means lower stiffness which in turn means more flexible material.

**Q.16** For orthotropic materials, total number of independent elastic constants are

(a) 2
(b) 12
(c) 21
(d) 9

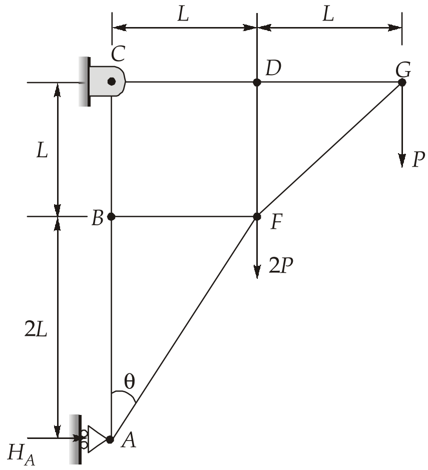
**16. (d)**

**Q.17** Pinned members as shown in figure carry the loads $P$ and $2P$. The force in member $AF$ is




(a) $\frac{8}{3}P$, tensile
(b) $\frac{4\sqrt{5}}{3}P$, compressive
(c) $\frac{4\sqrt{5}}{3}P$, tensile
(d) $\frac{8}{3}P$, compressive

**17. (b)**




Taking moment about point $C$,

$$\Sigma M_C = 0$$

$$H_A \times 3L - 2P \times L - P \times 2L = 0$$

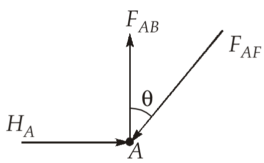
$$H_A = \frac{4P}{3}$$

$$AF = \sqrt{AB^2 + BF^2} = \sqrt{(2L)^2 + (L)^2}$$

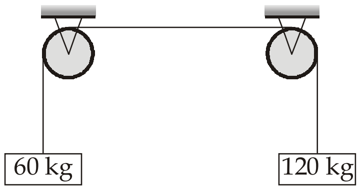
$$AF = \sqrt{5}L$$

$$\frac{F_{AF}}{H_A} = \frac{\sqrt{5}L}{L}$$

$$F_{AB} = \sqrt{5} \times \frac{4P}{3} = \frac{4\sqrt{5}P}{3}$$




**Q.18** A system of masses and pulleys is arranged in vertical plane as shown in figure.




Neglecting friction and the inertia of the pulleys, the acceleration of 120 kg mass is

(a) $\frac{g}{5}$ (b) $\frac{g}{3}$

(c) $\frac{2g}{3}$ (d) $\frac{g}{2}$

(Where $g$ is acceleration due to gravity)

**18. (b)**

Let acceleration be '$a$'

From Newton's second law of motion:

For 120 kg mass, $120g - T = 120a$ ... (i)

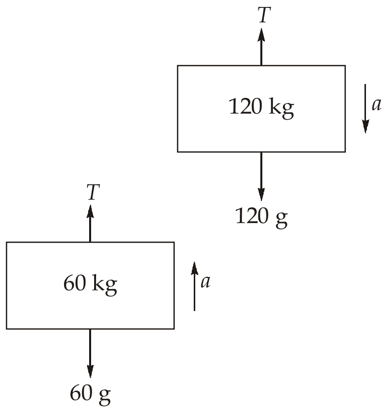
For 60 kg mass, $T - 60g = 60a$ ... (ii)

Adding equation (i) and (ii)

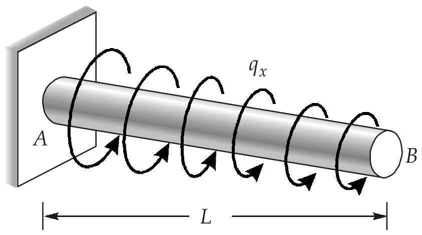
$$120g - 60g = (120 + 60)a$$

$$60g = 180a$$

$$a = \frac{g}{3}$$



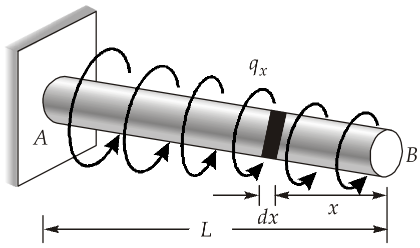

**Q.19** A prismatic bar $AB$ of solid circular cross section (torsional rigidity = $GI_p$) is fixed at the left-hand end and is subjected to a distributed torque of varying intensity $q$ which varies linearly from a maximum value $q_0$ at end $A$ to zero at end $B$. What is the angle of rotation at the free end of the bar?

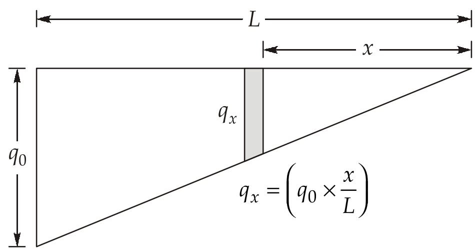



(a) $\frac{q_0 L^2}{2GI_P}$ (b) $\frac{q_0 L^2}{3GI_P}$

(c) $\frac{q_0 L^2}{6GI_P}$ (d) $\frac{q_0 L^2}{4GI_P}$

**19. (c)**



We know that,

$$\theta = \frac{TL}{GI_P}$$

$$\theta_{strip} = \int_0^L \frac{T_x \cdot dx}{G \cdot I_P} = \int_0^L \frac{\frac{1}{2} \times q_0 \times \left(\frac{x}{L}\right) \times x}{G \cdot I_P} dx$$

$$= \frac{1}{GI_P} \times q_0 \times \left[\frac{x^3}{6L}\right]_0^L$$

$$\theta_{strip} = \frac{q_0 L^3}{6GI_P \times L} = \frac{q_0 L^2}{6GI_P}$$

**Q.20** A solid circular bar initially has radius $r$. Then a hole of radius $\frac{2r}{3}$ is bored longitudinally through the shaft. What is the % reduction in the magnitude of the torque that may be applied to the bar?

(a) 29.63% (b) 44.44%

(c) 19.75% (d) 24.63%

**20. (c)**

Given,

Initial radius of solid bar $= r$

Outer radius of hollow bar, $r_0 = r$

Inner radius of hollow bar, $r_i = \frac{2r}{3}$

Since,

Maximum shear stress will be same as hole is being drilled in the same solid circular bar.

$$(\tau_{max})_{solid} = (\tau_{max})_{hollow} = \tau_{max}$$

$$(\tau_{max})_{solid} = \frac{16T_{solid}}{\pi d^3} = \tau_{max}$$

$$(\tau_{max})_{hollow} = \frac{16T_{hollow}}{\pi d^3(1-K^4)} = \tau_{max} \qquad \left\{\text{where, } K = \frac{d_i}{d_0}\right\}$$

$$\% \text{ Reduction in torque} = \left(\frac{T_{solid} - T_{hollow}}{T_{solid}}\right) \times 100\%$$

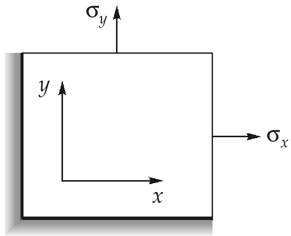
$$= \left[\frac{\frac{\pi}{16}d^3 \times (\tau_{max}) - \frac{\pi}{16}d^3(1-K^4) \times \tau_{max}}{\frac{\pi}{16}d^3 \times \tau_{max}}\right] \times 100\%$$

$$= \frac{\left[d^3 - d^3\left(1 - \left(\frac{2}{3}\right)^4\right)\right] \times 100\%}{d^3}$$

$$\% \text{ Reduction in torque} = \left[1 - 1 + \left(\frac{2}{3}\right)^4\right] \times 100\%$$

$$= \frac{1600}{81}\% = 19.75\%$$

**Q.21** A thin stainless steel ($E$ = 190 GPa and $G$ = 86 GPa) plate is subjected to biaxial state of stress. The strains measured in the plate are $\varepsilon_x = 625\mu$ and $\varepsilon_y = 475\mu$, then the ratio of stresses $\sigma_x$ to $\sigma_y$ will be:




(a) greater than one
(b) less than one
(c) insufficient data
(d) none of these

**21. (a)**

As per given data,

$$E = 190 \text{ GPa}$$
$$\varepsilon_x = 625\ \mu$$
$$G = 86 \text{ GPa}$$
$$\varepsilon_y = 475\ \mu$$
$$E = 2G(1 + \nu)$$
$$190 = 2 \times 86\ (1 + \nu)$$
$$(1 + \nu) = 1.104$$
$$\nu = 0.104 < 1$$

As we know that,

$$\sigma_x = \frac{E}{1-\nu^2}(\varepsilon_x + \nu\varepsilon_y)$$

$$\sigma_y = \frac{E}{1-\nu^2}(\varepsilon_y + \nu\varepsilon_x)$$

$$\frac{\sigma_x}{\sigma_y} = \frac{(\varepsilon_x + \nu\varepsilon_y)}{(\varepsilon_y + \nu\varepsilon_x)} = \frac{(625\mu + \nu \times 475\mu)}{(475\mu + \nu \times 625\mu)}$$

$$= \frac{625 + 475 \times 0.104}{475 + 625 \times 0.104} > 1$$

So, option (a) is correct.

**Q.22** A spherical ball having volume $10^6$ mm$^3$, and bulk modulus, $K$ of 150 kN/mm$^2$. If the ball goes down to a depth of 1000 meter in sea water, then the change in volume of the ball will be (Take specific weight of sea water as $10^{-5}$ N/mm$^3$)

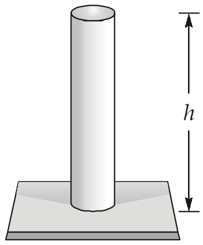
(a) 33.33 mm$^3$
(b) 66.66 mm$^3$
(c) 99.99 mm$^3$
(d) 121.33 mm$^3$

**22. (b)**

Given,

$$\text{Volume of spherical ball, } V = 10^6 \text{ mm}^3$$
$$\text{Bulk modulus, } K = 150 \text{ kN/mm}^2$$
$$\text{Depth of sea water above ball, } h = 10^3 \text{ m}$$
$$h = 10^6 \text{ mm}$$
$$\text{Specific weight of sea water, } w = 10^{-5} \text{ N/mm}^3$$
$$\text{Hydrostatic pressure, } P = wh$$
$$= 10^{-5} \times 10^6$$
$$P = 10 \text{ N/mm}^2$$
$$\text{Volumetric strain, } \varepsilon_v = \frac{P}{K} = \frac{10}{150 \times 10^3}$$
$$\varepsilon_v = \frac{1}{15} \times 10^{-3}$$
$$\text{Change in volume, } \delta V = \varepsilon_v \times V$$
$$= \frac{1}{15} \times 10^{-3} \times 10^6$$
$$\delta V = 66.66 \text{ mm}^3$$

**Q.23** A tall open-top stand pipe has an inside diameter of 1600 mm and a wall thickness of 8 mm. The stand pipe contains water, which has a mass density of 1000 kg/m$^3$. What height, $h$ of water will produce a maximum circumferential stress of 16 MPa in the wall of the stand pipe? [Take $g$ = 10 m/s$^2$]




(a) 4 m
(b) 8 m
(c) 12 m
(d) 16 m

**23. (d)**

Given data,

$$\text{Inner diameter, } d = 1600 \text{ mm}$$
$$\text{Thickness, } t = 8 \text{ mm}$$
$$\text{Density, } \rho = 1000 \text{ kg/m}^3$$
$$\text{Maximum circumferential stress, } \sigma_h = 16 \text{ MPa}$$

We know that,

$$\sigma_h = \frac{Pd}{2t}$$
$$P = \frac{\sigma_h \times (2t)}{d} = \frac{16 \times 2 \times 8}{1600}$$

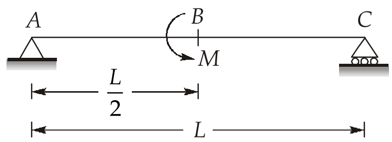
$$\text{Maximum pressure, } P = 16 \times 10^{-2} \text{ MPa}$$
$$P = 160 \text{ kPa}$$
$$\text{Height of water, } h = \frac{P}{\rho g} = \frac{160 \times 10^3}{10^3 \times 10} = 16 \text{ m}$$

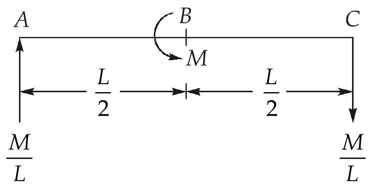
**Q.24** A simply supported beam is subjected to constant moment '$M$' at its midspan. If the span of beam is having length '$L$'. What will be the value of slope at its midspan?

(a) $\left(\frac{ML}{3EI}\right)$ (b) $\left(\frac{ML}{24EI}\right)$

(c) $\left(\frac{ML}{12EI}\right)$ (d) $\left(\frac{ML}{6EI}\right)$

**24. (c)**




Total strain energy,

$$U = U_{AB} + U_{BC}$$

By symmetry,

$$U_{AB} = U_{BC}$$
$$U_{Total} = 2U_{AB}$$
$$U = 2\int_0^{L/2} \frac{M_x^2 dx}{2EI} = 2\int_0^{L/2} \frac{\left(\frac{M}{L} \times x\right)^2 dx}{2EI}$$
$$= \frac{M^2}{(EI)L^2}\int_0^{L/2} x^2 dx = \frac{M^2}{(EI)L^2} \times \left[\frac{x^3}{3}\right]_0^{L/2}$$
$$U = \frac{M^2 L}{(3 \times 8)EI} = \frac{M^2 L}{(24EI)}$$

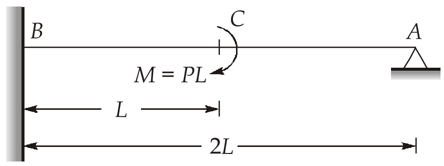
Slope at point $B$,

$$\theta_B = \frac{\partial U}{\partial M} = \frac{2ML}{(24EI)} = \left(\frac{ML}{12EI}\right)$$

Slope at point $B$,

$$\theta_B = \left(\frac{ML}{12EI}\right)$$

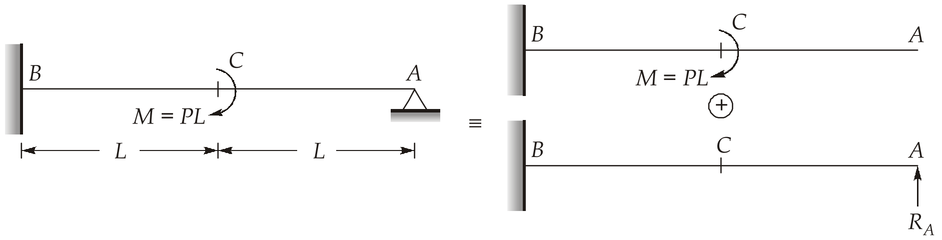
**Q.25** A propped cantilever beam is loaded as shown in figure. What will be the reaction at $A$ such that there is no deflection at $A$?




(a) $\frac{3P}{8}$ (b) $\frac{3P}{16}$

(c) $\frac{9P}{8}$ (d) $\frac{9P}{16}$

**25. (d)**




Deflection at $A$,

$$y_A = 0$$

$$y_1 + y_2 = 0$$

Where, $y_1$ is deflection at $A$ due to moment only

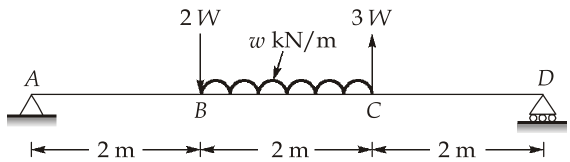
$y_2$ is deflection at $A$ due to reaction at point $A$ only.

$$-\left[\frac{(PL)L^2}{2EI} + \frac{(PL)L \times L}{EI}\right] + \frac{R_A(2L)^3}{3EI} = 0$$

$$\frac{R_A \times 8L^3}{3EI} = \frac{3PL^3}{2EI}$$

$$R_A = \frac{9}{16}P(\uparrow)$$

**Q.26** A simply supported beam is loaded as shown in figure.



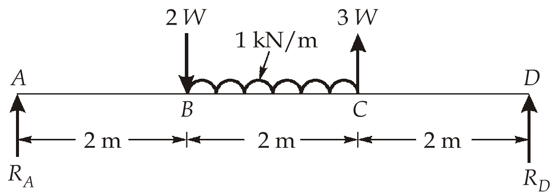

If $W$ = 1 kN and $w$ = 1 kN/m, then the value of maximum shear force will be:

(a) $\frac{-8}{3}$kN (b) $\frac{-5}{3}$kN

(c) $\frac{-22}{3}$kN (d) $\frac{-11}{3}$kN

**26. (a)**

**Loading Diagram:**



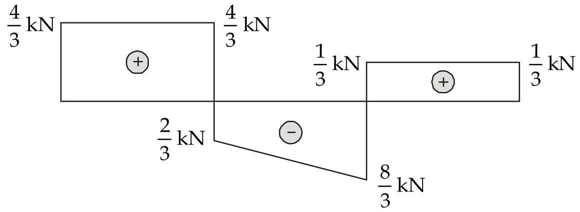

We know that,

$$R_A + R_B = 2 + (2 \times 1) - 3$$
$$R_A + R_B = 1 \text{ kN}$$

Taking moment about A,

$$2 \times 2 + (2 \times 3) - 3 \times 4 = 6 \times R_D$$
$$\frac{-2}{6} = R_D$$
$$\Rightarrow \quad R_D = \frac{-1}{3} \text{kN}$$
$$R_A = 1 - \left(\frac{-1}{3}\right) = \frac{4}{3} \text{ kN}$$

**SFD:**




So, the value of maximum shear force $= -\frac{8}{3}$ kN

**Q.27** An aluminium wire of diameter 10 mm is subjected to a tensile force of 16.5 kN in its longitudinal direction. Taking Young's modulus, $E$ for Al = 70 GPa and Poisson's ratio, $\mu$ = 0.33, the final diameter of the wire will be:

(a) 9.999 mm
(b) 9.99 mm
(c) 9.89 mm
(d) 10.01 mm

**27. (b)**

$$\text{Tensile force, } P = 16.5 \text{ kN} = 16.5 \times 10^3 \text{ N}$$
$$\text{Young's modulus, } E = 70 \text{ GPa} = 70 \times 10^3 \text{ N/mm}^2$$
$$\text{Poisson's ratio, } \mu = 0.33 \simeq \frac{1}{3}$$
$$\text{Initial diameter, } d_i = 10 \text{ mm}$$
$$\text{Longitudinal strain, } \varepsilon_x = \frac{P}{AE} = \frac{16.5 \times 10^3}{\frac{\pi}{4} \times 10^2 \times 70 \times 10^3}$$
$$= \frac{16.5 \times 4 \times 10^3}{\frac{22}{7} \times 10^2 \times 70 \times 10^3} = \frac{66}{22 \times 10^3} = 3 \times 10^{-3}$$

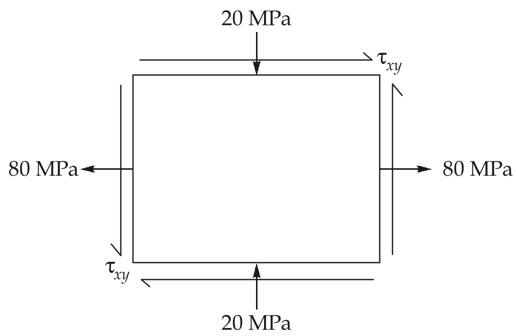
$$\varepsilon_y = -\mu\varepsilon_x = -\frac{1}{3}\times 3\times 10^{-3} = -10^{-3}$$

$$\varepsilon_y = \frac{\delta d}{d} = -10^{-3}$$

Change in diameter, $\delta d = -10^{-3} \times d_i = -10^{-3} \times 10 = -0.01$ mm

So, final diameter, $d_f = d_i + \delta d = 10 - 0.01 = 9.99$ mm

**Q.28** The stress in $x$ and $y$ direction on an element is 80 MPa (tensile) and 20 MPa (compressive) and diameter of Mohr's circle is 10 cm where, 1 cm represents 12 MPa stress on $x$-axis of Mohr's circle. What will be the value of shear stress $\tau_{xy}$ on this element as shown in figure below?




(a) 33.166 MPa
(b) 66.332 MPa
(c) 44.34 MPa
(d) 49.90 MPa

**28. (a)**

Given, $\sigma_x = 80$ MPa

$\sigma_y = -20$ MPa

Diameter of Mohr's circle = 10 cm

= 10 × 12 = 120 MPa

We know that,

Diameter of Mohr's circle, $\sigma_1 - \sigma_2 = \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}$

$$\Rightarrow (120) = \sqrt{(80-(-20))^2 + 4\tau_{xy}^2}$$

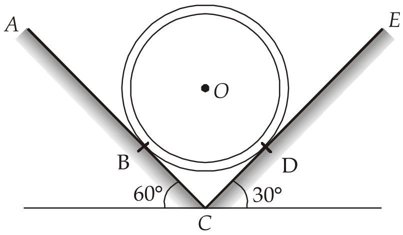
$$\Rightarrow (120)^2 = (100)^2 + 4\tau_{xy}^2$$

$$\Rightarrow \frac{4400}{4} = \tau_{xy}^2$$

$$\Rightarrow \tau_{xy}^2 = 1100$$

$$\Rightarrow \tau_{xy} = 33.166 \text{ MPa}$$

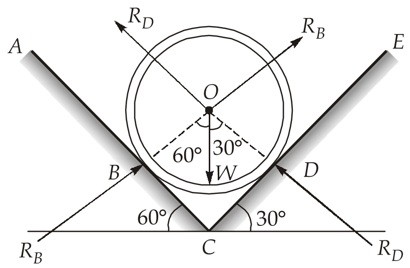
**Q.29** A smooth circular cylinder of radius 1 meter is lying in a triangular groove, one side of which makes 60° angle and the other 30° angle with the horizontal. What will be the reaction at point $B$, if there is no friction and the cylinder weighs 5 kN? [O is the centre of cylinder in figure shown below]




(a) 5.77 kN
(b) 4.33 kN
(c) 10 kN
(d) 2.5 kN

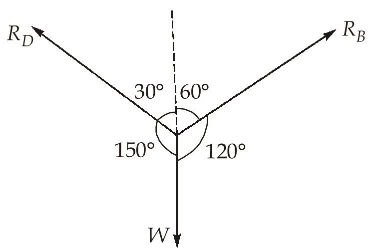
**29. (d)**

Given,Weight of cylinder, $W$ = 5 kN




Assume $R_B$ and $R_D$ are the reaction at point $B$ and $D$.

By Lami's theorem,

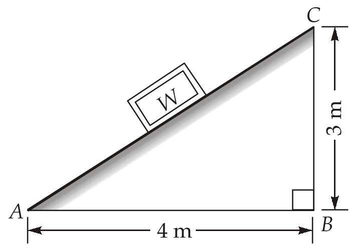



$$\frac{W}{\sin 90°} = \frac{R_B}{\sin 150°} = \frac{R_D}{\sin 120°}$$

$$\Rightarrow \quad R_B = \frac{5 \times \sin 150°}{\sin 90°} = \frac{5 \times 0.5}{1}$$

$$\Rightarrow \quad R_B = 2.5 \text{ kN}$$

**Q.30** An inclined plane as shown in figure is used to unload slowly a heavy safe weighing 5000 N from a truck 3 m high into the grounds. The coefficient of friction between the safe and the plane is 0.3. What force is required parallel to the plane to hold it back from sliding down?



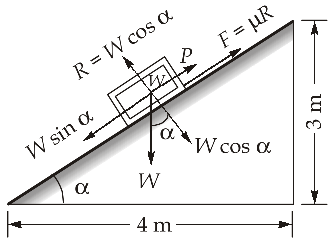

(a) 1800 N
(b) 3100 N
(c) 2200 N
(d) 1200 N

**30.** **(a)**

Given,

Weight of safe, $W$ = 5000 N

Coefficient of friction, $\mu$ = 0.3




Assume normal reaction is $R$ and force of friction is $F$.

$$\text{Now, } \tan\alpha = \frac{3}{4} = 0.75$$

$$\text{Normal reaction, } R = W\cos\alpha = (5000)\times\left(\frac{4}{5}\right) = 4000 \text{ N}$$

$$\text{Force of friction, } F = \mu R = 0.3 \times 4000 = 1200 \text{ N}$$

Now, resolving the 5000 N force along the plane

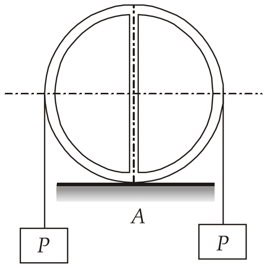
$$= 5000 \sin\alpha$$

$$= 5000\times\frac{3}{5} = 3000 \text{ N}$$

Force required parallel to the plane to hold the safe back,

$$P = 3000 - 1200 = 1800 \text{ N}$$

**Q.31** Two halves of a round homogenous cylinder are held together by a thread wrapped round the cylinder with two weights each equal to P attached to its ends as shown in figure. If the weight of complete cylinder is W and the plane of contact, of both of its halves, is vertical, what will be the minimum value of $P$, for which both halves of the cylinder will be in equilibrium on a horizontal plane?

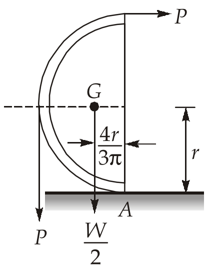



(a) $\frac{W}{2}$ (b) $\frac{2W}{3\pi}$

(c) $\frac{W}{2\pi}$ (d) $\frac{3W}{2\pi}$

**31. (b)**

Taking one halve of cylinder. Centre of gravity of a semicircle is at a distance of $\frac{4r}{3\pi}$ from centre.




Taking moment about $A$,

$$P \times 2r = P \times r + \left(\frac{W}{2}\right) \times \left(\frac{4r}{3\pi}\right)$$

$$\Rightarrow \quad P \times r = W\left(\frac{2r}{3\pi}\right)$$

$$\Rightarrow \quad P = \frac{2W}{3\pi}$$

**Q.32** A car is moving at 25 m/s and the wheels are 50 cm in diameter. If the car comes to rest in a distance of 25 m, under a uniform retardation, what will be the angular retardation of the wheels?

(a) 50 rad/$s^2$ (b) 3.125 rad/$s^2$

(c) 12.5 rad/$s^2$ (d) 25 rad/$s^2$

**32. (a)**

Given:Speed, $u$ = 25 m/s; diameter, $d$ = 50 cm = 0.5 m; Radius, $r$ = 0.25 m

We know that, $v^2 = u^2 + 2as$

$$\Rightarrow \quad 0 = (25)^2 + 2 \times a \times (25)$$

$$\Rightarrow \quad a = \frac{-625}{50} = -12.5 \text{ m/s}^2$$

[Here minus sign represents retardation]

Angular retardation of the wheel,

$$\alpha = \frac{a}{r} = \frac{-12.5}{0.25} = -50 \text{ rad/s}^2$$

[Minus sign indicates retardation]

$$\Rightarrow \quad \alpha = 50 \text{ rad/s}^2 \text{ (Retardation)}$$

**Q.33** A cyclist, riding at 2.5 m/s has to turn at a corner. What is least radius of the curve, in which the rider will be able to turn safely, if the coefficient of friction between the tyres and the road is 0.2?

(a) 1.5625 m  (b) 0.15625 m
(c) 0.3125 m  (d) 3.125 m

**33. (d)**

Given, Velocity, $v$ = 2.5 m/s

Coefficient of friction, $\mu$ = 0.2

Let, least radius of the curve = $r$

We know that,

Centrifugal force ≤ Frictional force

$$\frac{mv^2}{r} \leq \mu mg$$

$$v^2 \leq \mu gr$$

$$v_{max} = \sqrt{\mu gr}$$

$$2.5 = \sqrt{0.2 \times 10 \times r}$$

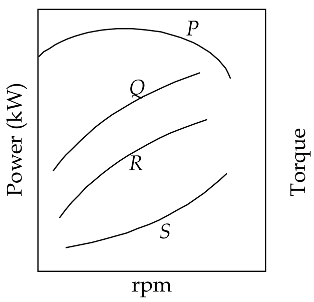
$$(2.5)^2 = (2r)$$

$$r = \frac{6.25}{2} = 3.125 \text{ m}$$

Least radius of curve, $r$ = 3.125 m

**Q.34** Match the column with respect to S.I. engine and answer using the codes given below:

**List-I**




**List-II**

1. Indicated Power
2. Brake Power
3. Friction Power
4. Torque

**Codes:**
(a) 1–Q, 2–R, 3–S, 4–P
(b) 1–R, 2–Q, 3–P, 4–S
(c) 1–P, 2–Q, 3–R, 4–S
(d) 1–S, 2–P, 3–Q, 4–R

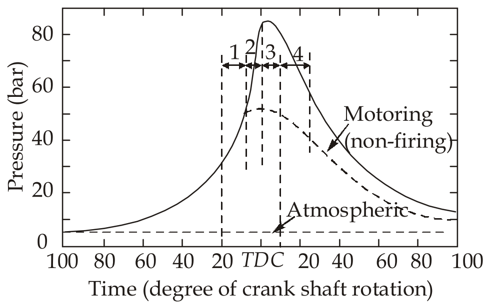
**34. (a)**

Indicated Power = Brake Power + Friction Power

- As the rpm increases indicated power also increases as a result of this brake power and friction power also increases.
- At very high rpm the increment in friction power is non-linear.

**Q.35** Consider the following curve showing various stages of combustion in C.I. engine and answer using the codes given below:

**List-I**




**List-II**

A. Ignition delay period/preflame combustion
B. After burning
C. Controlled combustion
D. Rapid combustion/uncontrolled combustion

**Codes:**

| | A | B | C | D |
|---|---|---|---|---|
| (a) | 1 | 4 | 3 | 2 |
| (b) | 1 | 2 | 4 | 3 |
| (c) | 2 | 3 | 4 | 1 |
| (d) | 4 | 3 | 2 | 1 |

**35. (a)**

- The growth and development of a semi propagating nucleus of flame is called Ignition Lag or preparation phase.
- Spreading of flame is throughout the combustion chamber.

**Q.36** Consider the following statements with respect to SI engine :

1. The maximum speed occurs when the fuel mixture is about 10% richer than the stoichiometric value.
2. An increase in intake temperature increases the flame speed.
3. An increase in compression ratio decreases the flame speed.

Which of the statements given above are correct?

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

**36. (a)**

An increase in intake temperature and pressure increases the flame speed. And also increase in compression ratio increases the flame speed.

**Q.37** A SI engine having compression ratio 9 and total volume of cylinder is 0.9 $m^3$. What is the mean effective pressure if the work output is 1600 kJ?

(a) 20 bar (b) 200 Pa
(c) 2 bar (d) 2000 Pa

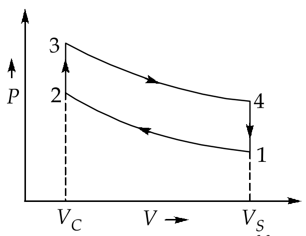
**37. (a)**

Given:

$$V_s + V_c = 0.9 \text{ m}^3 \qquad \ldots(1)$$

divide the eq. (1) $V_c$

$$r = \frac{0.9}{V_c}$$




$$V_c = \frac{0.9}{9}$$

$$V_c = 0.1 \text{ m}^3$$

$$V_s = 0.8 \text{ m}^3$$

$$\text{mean effective pressure} = \frac{\text{Work output}}{\text{Swept volume}}$$

$$\text{mep} = \frac{1600 \times 10^3}{0.8} = 2000 \times 10^3 = 20 \text{ bar}$$

**Q.38** Consider the following statements regarding knocking in CI engine:

1. The rate of pressure rise in diesel knock is lower than the detonation in spark ignition engine.
2. Long ignition delay period increases the tendency of knocking in SI engine.
3. The diesel knock occurs near the end of combustion.

The correct statements is/are

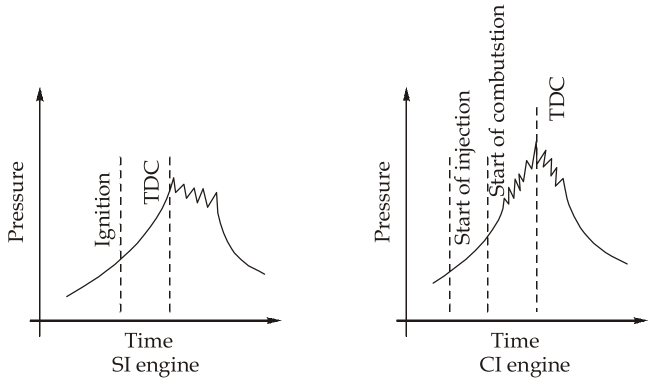
(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

**38. (a)**

As in the start of combustion in CI engines the quantity of diesel present inside the cylinder is less so the rate of pressure rise during knock is also less.

While in the case of combustion in SI engine all the air-fuel mixture is already present so rate of pressure rise is more.




**Q.39** A four-stroke single cylinder SI engine of 8 cm diameter and 10 cm stroke, running at 3000 rpm develops power at a mean effective pressure of 14 bar. The power developed by the engine is

(a) 15.6 kW (b) 17.6 kW
(c) 14.6 kW (d) 12.6 kW

**39. (b)**

Number of stroke = 4
Bore diameter = 8 cm
Length of stroke = 10 cm
rpm = 3000 rpm
Mean effective pressure = 14 bar
Power = ?

$$\text{Power} = B_{mep} \times \text{Swept volume}$$

$$= 14 \times 10^5 \times \frac{\pi}{4} \times \frac{8^2 \times 10}{10^6} \times \frac{3000}{60 \times 2}$$

$$P = 17.6 \text{ kW}$$

**Q.40** In a 2 litre four-stroke indirect injection diesel engine, the indicated thermal efficiency is 60%, the mechanical efficiency is 85% and the volumetric efficiency is 80%. The air-fuel ratio (by mass) is 13 : 1 and the calorific value of fuel is 40 MJ/kg. What is the brake specific fuel consumption?

(a) 0.05 kg/kW-hr (b) 0.062 kg/kW-hr
(c) 0.18 kg/kW-hr (d) 0.225 kg/kW-hr

**40. (c)**

We know that,

$$\eta_m = \frac{\eta_{bth}}{\eta_{ith}} = \frac{\text{Brake thermal efficiency}}{\text{Indicated thermal efficiency}}$$

$$\eta_{bth} = 0.85 \times 0.6 = 0.51$$

and
$$\eta_{bth} = \frac{BP}{\dot{m}_f \times C.V.} \text{ or } \eta_{bth} = \frac{1}{SFC \times C.V.}$$

$$SFC = \frac{1}{\eta_{bth} \times C.V.} = \frac{1}{0.51 \times 40} = 0.049 \approx 0.05$$

$$= 0.05 \text{ kg/MJ}$$

$$= \frac{0.05 \text{ kg/s}}{10^3 \text{ kJ/s}} = \frac{0.05 \times 3600 \text{ kg/hr}}{10^3 \text{ kW}}$$

$$= 0.18 \text{ kg/kW-hr}$$

**Q.41** An oil engine works on the dual cycle. The heat added at constant pressure being twice that added at constant volume. The cut-off ratio is 1.5. The temperature at the end of compression is 650 K.

What is the maximum temperature in the cycle? [Assume $\gamma = 1.4$]

(a) 1000 K
(b) 1500 K
(c) 1300 K
(d) None of these

**41. (b)**

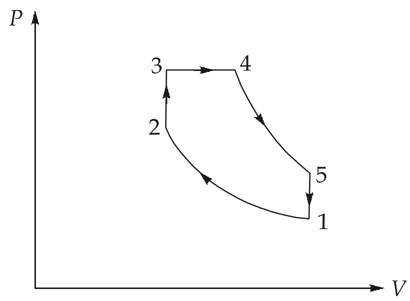
Heat added during constant pressure combustion

= 2 × Heat added during constant volume combustion

$$c_p(T_4 - T_3) = 2 \times c_v(T_3 - T_2)$$

$$\frac{c_p}{c_v}\left(\frac{T_4}{T_3} - 1\right) = 2 \times \left(1 - \frac{T_2}{T_3}\right)$$

$\because$ For constant pressure process, $\frac{V_4}{V_3} = \rho = \frac{T_4}{T_3}$ (Where $\rho$ is cut-off ratio)




$$1.4 \times (1.5 - 1) = 2 \times \left(1 - \frac{T_2}{T_3}\right)$$

$$\frac{1.4 \times 0.5}{2} = 1 - \frac{T_2}{T_3}$$

$$\frac{T_2}{T_3} = 1 - 0.35 = 0.65$$

$$T_3 = \frac{T_2}{0.65} = \frac{650}{0.65} = 1000 \text{ K}$$

$$\frac{T_4}{T_3} = 1.5$$

$\Rightarrow$ $$T_4 = 1.5 \times 1000 = 1500 \text{ K}$$

**Q.42** In which of the following combustion period, knocking occurs in CI engine?

(a) Ignition delay period
(b) Period of rapid combustion
(c) Period of controlled combustion
(d) Period of after burning

**42. (b)**

The period of rapid combustion is also called the uncontrolled combustion period. In this period knocking phenomenon occurs.

**Q.43** Palladium in catalytic converters especially promote the oxidation of:

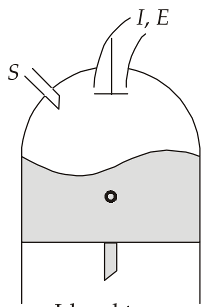
(a) CO
(b) CO, HC and $NO_x$
(c) HC
(d) $NO_x$

**43. (a)**

**Q.44** Which of the following is not correct for I-head type combustion chambers for SI engine?

(a) High surface to volume ratio and so high heat loss.
(b) Less flame travel length and hence greater freedom from knock.
(c) Higher volumetric efficiency because of larger valves or valve lifts.
(d) None of these

**44. (a)**




I-head type

**I-head combustion chamber or overhead valve:**

- Lower pumping losses and higher volumetric efficiency from better breathing of the engine from larger valves or valve lifts and more direct passage ways.
- Less distance for the flame to travel and therefore greater freedom from knock, or in other words, lower octane requirements.
- Less force on the head bolts and therefore less possibility of leakage.
- Lower surface to volume ratio and therefore, less heat loss and less air pollution.

**Direction (Q.45 to Q.50) :** The following questions consists of two statements, one labelled as **Statement (I)** and the other labelled as **Statement (II)**. You have to examine these two statements carefully and select your answers to these items using the codes given below:

**Q.45** **Statement (I):** A beam is said to be a beam of uniform strength if the bending stress developed at every cross-section of the beam is same.

**Statement (II):** In case of cantilever beam subjected to transverse shear load, if we keep the depth constant and vary the width of the beam then variation in width of the beam is parabolic and cross-section at every point is rectangular.

**45. (c)**

A beam is said to be a beam of uniform strength when bending stress developed at every cross-section of the beam remains same.

There are two methods of making a rectangular cross-section beam as a beam of uniform strength:

I. Varying width and keeping depth as constant.

II. Varying depth and keeping width as constant.

In case of cantilever beam subjected to transverse shear load:

If we keep the depth as constant and vary the width, then variation in width will be linear.

$$b_x = b\left[\frac{x}{L}\right]$$

where, $b$ is maximum width at fixed end and $x$ is distance from free end.

If we keep the width as constant and vary the depth, then variation in depth will be

$$d_x = d\sqrt{\frac{x}{L}}$$

where, $d$ is depth at fixed end of cantilever beam and $x$ is distance from free end.

**Q.46 Statement (I):** Elongation of a prismatic bar under its self weight is independent of area but dependent on length of bar.

**Statement (II):** Maximum axial stress in case of prismatic bar under its self weight is dependent on area as well as on length.

**46. (c)**

In case of prismatic bar under its self weight, load at a distance x from free end is given as,

$$P_{x-x} = \gamma A x = \frac{Wx}{L} \qquad \{\gamma = \text{Weight density}\}$$

$$\sigma_{x-x} = \frac{\gamma A x}{A} = \gamma x$$

Maximum axial stress,

$$(\sigma_{max})_{axial} = \gamma L$$

Change in length,

$$(\delta L)_{P.B.} = \frac{\gamma L^2}{2E}$$

Change in length is independent of area but dependent on length of bar. Maximum axial stress is also independent of cross-sectional area but depends on length.

**Q.47 Statement (I):** Continuous beam is statically determinate beam.

**Statement (II):** If the static equilibrium equations are sufficient to determine the reactions, then the beam is statically determinate beam

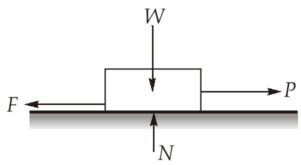
**47. (d)**

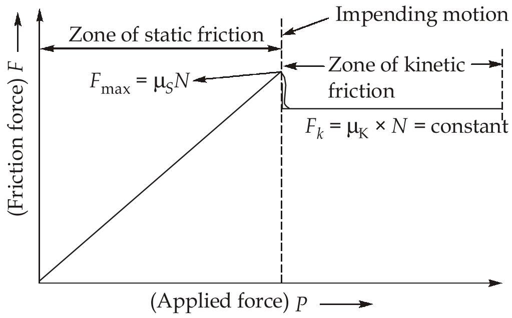
Continuous beam is statically indeterminate beam because number of reaction in the beam is more than the number of static equilibrium equations.

**Q.48** **Statement (I):** After reaching the optimum or threshold value beyond which the block start moving, friction force now drops almost instantaneously and remains fairly constant irrespective of the increase in pulling force.

**Statement (II):** When the block starts moving, the bonding becomes weak and it is prevalent only along the humps that reduce frictional resistance.

**48. (a)**




Where, $W$ = weight of body, $N$ = normal reaction, $F$ = Frictional force, $P$ = Pulling force or applied force

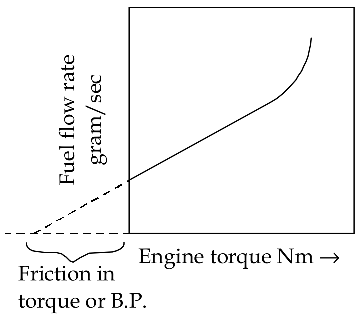
The temporary bonding that took place between the asperities of mating surface that cause friction is self adjusting. The value of friction force increases linearly from zero to $F_{max}$ with the increase in value of $P$. The maximum value of friction force, which comes into play when the motion is impending, is known as limiting friction.

**Q.49** **Statement (I):** In Willian's line method gross fuel consumption versus brake power at constant speed is plotted and graph is extrapolated back to zero fuel consumption.

**Statement (II):** The negative work in the graph represents the combined loss due to mechanical friction, pumping and blowby.

**49. (b)**

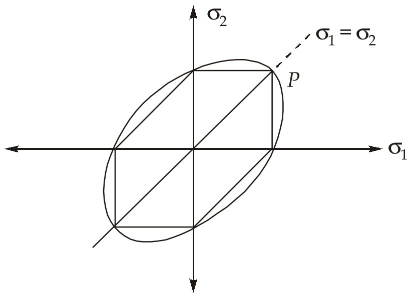
- Willan's Line Method channel rate extrapolation is used to measure friction power
- The test is applicable only to compression ignition engines.




**Willan's Line Method**

**Q.50** **Statement (I):** For bi-axial state of stress with both principal stresses equal and like in nature, maximum shear stress theory gives safe and economic design.
**Statement (II):** For bi-axial state of stress with both principal stresses unlike in nature, maximum shear stress theory is more conservative than maximum distortion energy theory.

**50.** **(b)**
At point P, i.e., when principle stresses equal and like in nature, both MSST and MDET gives same results.




For bi-axial state of stress condition with both principal stress unlike in nature, safe region of MSST lies under the safe region of MDET. So, MSST is more conservative than MDET.

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