S.Y. Diploma : Sem. III
[ME/MH/MI/PG/PT/AE/FE/PS]

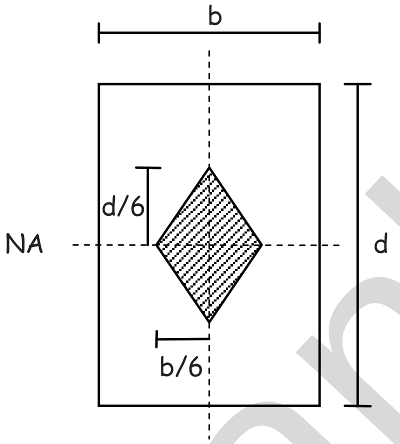
Strength of Materials

Time: 3 Hrs.] Prelim Question Paper Solution [Marks : 100

Q.1(a) Attempt any SIX of the following : [12]

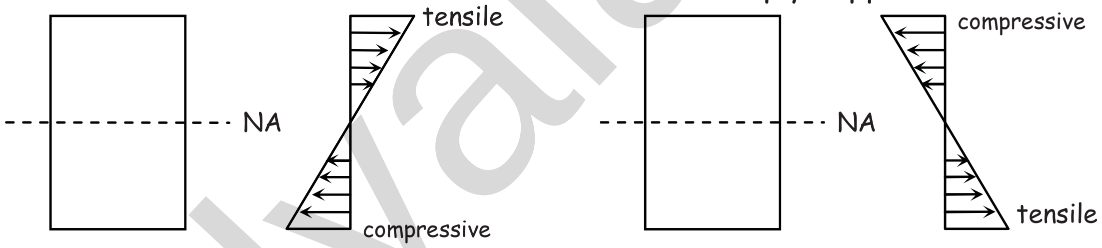
Q.1(a) (i) Draw Core section for rectangular column. [2]

(A) Core of rectangular section,.



Q.1(a) (ii) Draw stress distribution on Rectangular section subjected to bending. [2]

(A) For cantilever beam For simply supported



Q.1(a) (iii) Define Poisons Ratio & modular of elasticity. [2]

(A) Poisson's Ratio (μ/v)

It is the ratio of lateral strain to longitudinal stress.

$$\mu = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

Modulus of Elasticity

It is a ratio of stress induced in body to the strain.

$$E = \frac{\text{Stress}}{\text{Strain}}$$

Q.1(a) (iv) Define creep. Give one example [2]

(A) **Creep :** Many structural members and machine parts sustain steady loads for long periods of time. For example, beams in a R.C.C. building, plastic mountings for the parts of electronic devices, blades of turbine rotor, etc. Under such conditions, the material may continue to deform and will ultimately break. Creep continues as long as the load is applied. Therefore, it is a time dependent phenomenon. The greater the time, the more will be the creep. The continuous deformation with time which the material undergoes due to application of external steady loads is called creep or time yield or plastic flow.

Q.1(a) (v) State any four assumptions in the theory of simple bending. [2]

(A) The following assumptions are made in the theory of simple bending while deriving the flexural formula.

1) The material of the beam is homogeneous and isotropic. i.e. the beam is made up of the same material throughout and it has the same elastic properties in all the directions.
2) The beam is straight before loading and is of uniform cross-section throughout.
3) The beam material is stressed within its elastic limit and thus obeys Hooke's law.
4) The transverse sections which were plane before bending remain plane after bending.
5) The beam is subjected to pure bending i.e. the effect of shear stresses is totally neglected.
6) Each layer of the beam is free to expand or contract independently of the layer above or below it.
7) Young's modulus E for the beam material has the same value in tension and compression.

Q.1(a) (vi) Give the relationship between E, G and K. [2]

(A) $E = 3k(1 - 2\mu)$ where as

$E = 2G(1 + \mu)$

E = Young's modulus

K = Bulk modulus

G = Shear modulus

μ = Poisson's ratio

Q.1(b) Attempt any TWO of the following : [8]

Q.1(b) (i) A load of 5 KN is to be raised with the help of a steel wire. Find the minimum diameter of the steel wire, if the stress is not to exceed 100 MPa. [4]

(A) $P = 5 \times 10^3$ N, $\sigma = 100$ N/mm^2

$$\sigma = \frac{P}{A}$$

$$100 = \frac{5\times10^3}{(\pi/4)d^2}$$

$$\therefore \quad d = 7.97 \text{ mm}$$

$$\approx 8 \text{ mm}$$

Q.1(b) (ii) Calculate polar M.I. of a square section having 200 m as side. [4]

(A) Data: A square of side 200 mm.

To find: I_P

Concept: (i) $I_P = I_{XX} + I_{YY}$

(ii) For a square section

$$I_{XX} = I_{YY} = \frac{a^4}{12}$$

(i) For a square of side a,

$$I_{XX} = \frac{a \cdot a^3}{12} = \frac{a^4}{12} = \frac{(200)^4}{12} = 1.33 \times 10^8 \text{ mm}^4$$

(ii) For a square section

$$I_{YY} = I_{XX} = 1.33 \times 10^8 \text{ mm}^4$$

$$\therefore I_P = I_{XX} + I_{YY} = 1.33 \times 10^8 + 1.33 \times 10^8$$

$$= 2.66 \times 10^8 \text{ mm}^4$$

$$I_P = 2.66 \times 10^8 \text{ mm}^4$$

Q.1(b) (iii) A mild steel flat 150 mm wide by 20 mm thick, 6 m long, carries an axial pull of 300 kN, if the modulus of elasticity of steel is 200 kN/mm² and Poisson's ratio = 0.25. Calculate the change in length, width, thickness volume of the flat. [4]

(A) To Find Change in length (δL)

$$6 = \frac{P}{A} = \frac{P}{P \times D} = \frac{300}{150 \times 20} = 0.1 \text{ kN/mm}^2$$

$$e = \frac{6}{E} = \frac{0.1}{200} = 5 \times 10^{-4}$$

But $e = \frac{\delta L}{L}$ $\quad \therefore \delta L = e \times L$ $\quad \therefore \delta L = 5 \times 10^{-4} \times 6000$

$\delta L = 3\text{mm}$ (increase)

To find change in width (δb) and thickness (δt)

Lateral Strain (eL) = i.e. $= 0.25 \times 5 \times 10^{-4} - 1.25 \times 10^{-4}$

But Lateral Strain $= \frac{\delta b}{b} = \frac{\delta t}{t} = 1.25 \times 10^{-4}$

$\therefore \delta b = 1.25 \times 10^{-4} \times 150 = 0.01875$ (decrease)

$\delta t = 1.25 \times 10^{-4} \times 20 - 2.5 \times 10^{-3}$ (decrease)

To Find change in Volume (dv)

We know $\frac{\delta v}{v} = e(1 - 2u)$

$\therefore \delta v = e(1 - 2u)v$

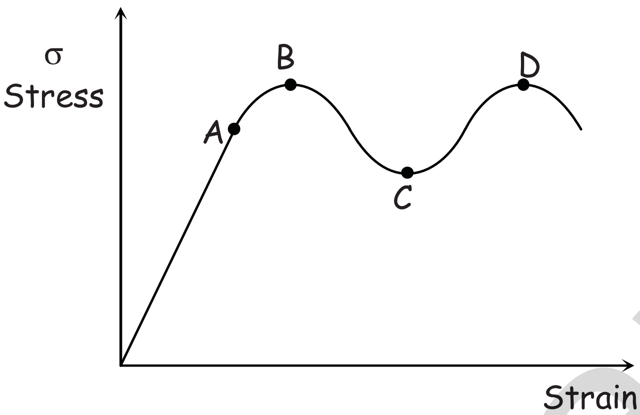
$= s \times 10^{-4} (1 - 2 \times 0.25)(6000 \times 150 \times 20)$

$\therefore \delta v = 4500 mm^2$

Q.2 Attempt any FOUR of the following : [16]

Q.2(a) Draw the stress strain curve for ductile material and explain the term ultimate stress. [4]

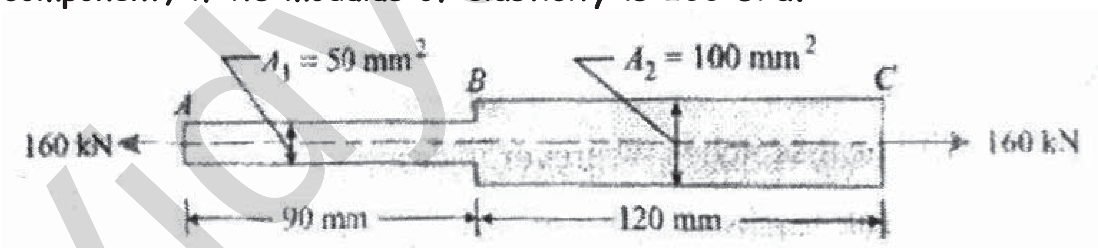
(A)



A : Elastic limit
B : Upper Yield stress
C : Lower Yield stress
D : Ultimate stress

Ultimate Stress : It is maximum value of stress the material can withstand before breaking or failure.

Q.2(b) An automobile component shown in fig no. 1. is subjected to a tensile load of 160 KN. Determine the total elongation of the component, if its modulus of elasticity is 200 GPa. [4]



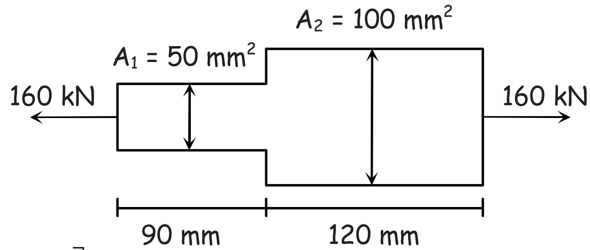
(A) Total elongation, $\delta L = \delta L_1 + \delta L_2$

$$= \frac{P_1 L_1}{A_1 E_1} + \frac{P_2 L_2}{A_2 E_2}$$

$$= \frac{P}{E}\left[\frac{L_1}{A_1} + \frac{L_2}{A_2}\right]$$

$$= \frac{160 \times 10^3}{2 \times 10^5}\left[\frac{90}{50} + \frac{120}{100}\right]$$

$\delta L = 2.4$ mm



Q.2(c) A steel rod 4 m long and 20 mm diameter is subjected to an axial tensile load of 45 kN. Find the change in length and diameter of the rod. $E_S = 2 \times 10^5$ N/mm². Poisson's Ratio = $\frac{1}{4}$. **[4]**

(A) Data : Steel rod, L = 4 m = 4000 mm

d = 20 mm

P = 45 kN = 45 × 103 N

E = 2 × 105 N/mm2

$\mu = \frac{1}{4} = 0.25$

To find : (i) δL

(ii) δd

Concept : (i) $\delta L = \frac{PL}{AE}$

(ii) Lateral strain = $\mu e = \frac{\delta d}{d}$

Solution :

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4} \times (20)^2 = 314.16 \text{ mm}^2$$

$$\delta L = \frac{PL}{AE} = \frac{(45 \times 10^3) \times 4000}{314.16 \times (2 \times 10^5)}$$

= 2.86 mm (increase)

Note : Since the rod is subjected to an axial tensile load, there will be increase in the length of the bar and decrease in the diameter.

$$\text{Linear strain, } e = \frac{\delta L}{L} = \frac{2.86}{4000} = 0.000715$$

Lateral strain $= \mu \times e = 0.25 \times 0.000715$
$= 0.00017875$

$$\therefore \quad \frac{\delta d}{d} = 0.00017875 \qquad \left(\because \text{ lateral strain} = \frac{\delta d}{d}\right)$$

$$\therefore \quad \frac{\delta d}{20} = 0.00017875$$

$$\therefore \quad \delta d = 20 \times 0.00017875$$

= 0.003575 mm (decrease)

(i) δL = 2.86 mm (increase),
(ii) δd = 0.003575 mm (decrease)

Q.2(d) A rod 300 mm long and 20 mm in diameter is heated through 100° C and at the same time pulled by a force 'P'. If the total extension is 0.4 mm. What is the magnitude of 'P'? Take E = 2× 10^5 N/mm² and ∝ = 12 × 10^{-6}/ °C. **[4]**

(A) ***Given data***

L = 300

d = 20 mm

t = 100°

Total extension = 0.4 mm

E = 2 10^5 N/mm² and $\propto = 12 \times 10^{-6}/°C$

Total extension of the rod

= free expansion + extension δL due to force 'P'

0.4 = (L ∝ t) + δL due to force 'P'

$0.4 = (300 \times 12 \times 10^{-6} \times 100) + \delta L$

0.4 = 0.36 + δL

∴ δL = 0.04 mm

But

$$\delta L = \frac{PL}{AE}$$

$$0.04 = \frac{P \times 300}{\left(\frac{\pi \times 20^2}{4}\right) \times 2 \times 10^5}$$

$$\therefore \quad P = \frac{0.04 \times \left(\frac{\pi}{4} \times 20^2\right) \times 2 \times 10^5}{300}$$

∴ $P = 8.377 \times 10^3$ N or P = 8.377 KN

Q.2(e) A cylindrical shell is 8 m long, 1 m internal diameter and 15 mm metal thickness. Calculate circumferential strain and longitudinal strain, if cylindrical shell is subjected to internal pressure of 1.5 N/mm². Take E = 2 × 10^5 N/mm² and μ = 0.25. **[4]**

(A) ***Given data :*** L= 3m=3000mm d = 1m=100mm t = 15mm, p = 1.5 N/mm²

$E = 2 \times 10^5$ N/mm² μ =0.25.

i) To find circumferential strain (e_c)

$$e_c = \frac{Pd}{4tE}(2-\mu) \qquad = \frac{1.5 \times 1000}{4 \times 15 \times 2 \times 10^5}(2-0.25)$$

$e_c = 2.1875 \times 10^{-4}$

ii) To find longitudinal strain (e_L)

$$e_L = \frac{Pd}{4tE}(1-2\mu)$$

$$= \frac{1.5 \times 1000}{4 \times 15 \times 2 \times 10^5}(1 - 2 \times 0.25)$$

$$e_L = 6.25 \times 10^{-5}$$

Q.2(f) A steel bar of 30 mm diameter is heated to 70°C and then clamped at ends. It is then allowed to cool down to 20°C. Calculate temperature stresses developed and reactions at the clamps, length of bar = 10 m, α=12 × 10^{-6}/°C; E = 2 × 10^5 N/mm². [4]

(A) Diameter d = 30 mm

Fall in temperature t = 7 - 20

= 50°C

Length of bar L = 10 m

= 10000 mm

$\alpha = 12 \times 10^{-6}/°C$, E -= 2×10^5 N/mm²

∴ Temperature Stress

$\sigma = \alpha\, t\, E$

$= 12 \times 10^{-6} \times 50 \times 2 \times 10^5$

= 120 N/mm² (Tensile)

Reactions at the clamps

B = 6A

$$= \alpha t E \times \left(\frac{\pi d^2}{4}\right) \quad = 120 \times \frac{\pi(30)^2}{4}$$

= 84823 = 84.823 kN

Q.3 Attempt any FOUR of the following : [16]

Q.3(a) A beam AB 10 m long has supports at its ends A and B. It carries a point load of 5 KN at 3 meters from A and a point load of 5KN at 7 meters from A and a udl of 1KN per meter between the point loads. Draw S.F. Diagram and B.M. diagram for the beam.

(A) $\Sigma F_y = 0$

$R_A + R_D = 5 + 5 + (1 \times 4) = 14$

$M_A = 0$

$R_D \times 10 = (5 \times 1) + (1 \times 4 \times (3 + 2))$

$+ (5 \times 7)$

$R_D = 7 = R_A$

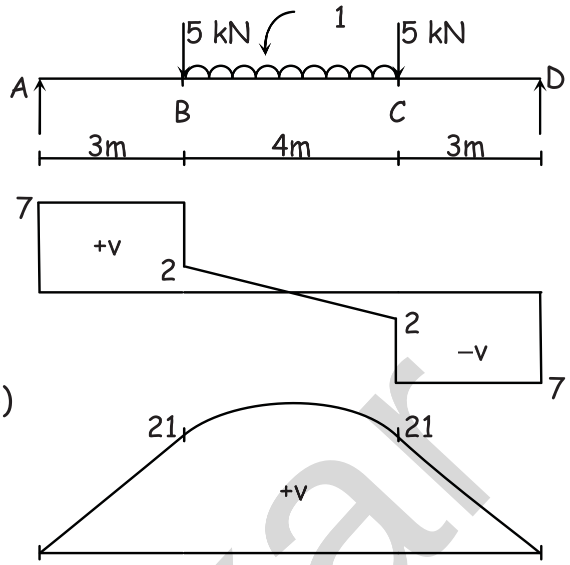
For SFD

$SF_{AL} = 0$, $SF_{AR} = 7$

$SF_{BL} = 7$, $SF_{BR} = 7 - 5 = 2$

$SF_{CL} = 2 - (1 \times 4) = -2$, $SF_{DL} = -7$

$SF_{CR} = -2 - 5 = -7$, $SF_{DR} = 0$



For BMD

$BM_B = (-1 \times 4 \times 2) + (7 \times 7) - (5 \times 4)$

$= 21$

$BM_L = 7 \times 3 = 21$

Q.3(b) A simply supported right side overhanging beam supported at 4 meter and right side 1 meter overhang. A Loaded by udl 10 KN/m over entire span. Draw S.F. diagram and B.M. diagram. [4]

(A) $\Sigma F_y = 0$

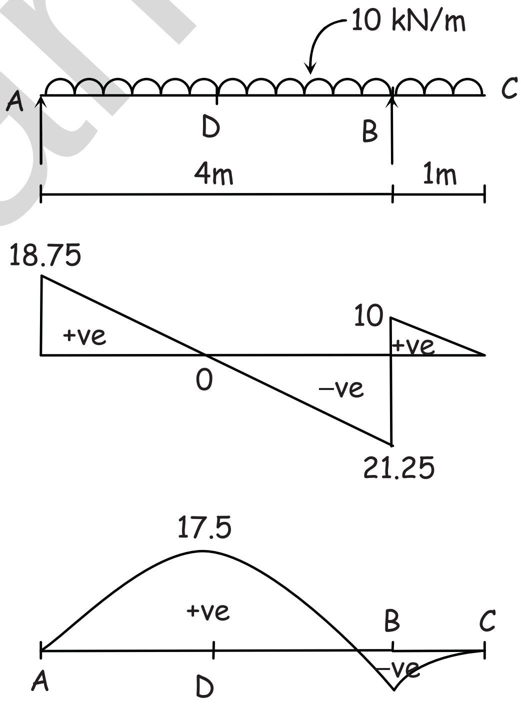
$R_A + R_B = 10 \times 5 = 50$

$M_A = 0$

$4R_B = 10 \times 5 \times 2.5$

$R_B = 31.25$

$R_A = 18.75$



For SFD

$SF_{AL} = 0$ $\quad SF_{BL} = 18.75 - 10 \times 4$

$SF_{AR} = 18.75$ $\quad = -21.25$

$SF_{CL} = 10 - 10$ $\quad SF_{BR} = -21.25 + 31.25$

$SF_{CR} = 0$ $\quad = 10$

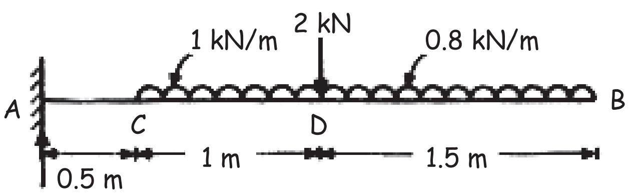
For BMD

$BM_A = 0$

$BM_D = -10 \times 3 \times 1.5 + 31.25 \times 2 = 17.5$

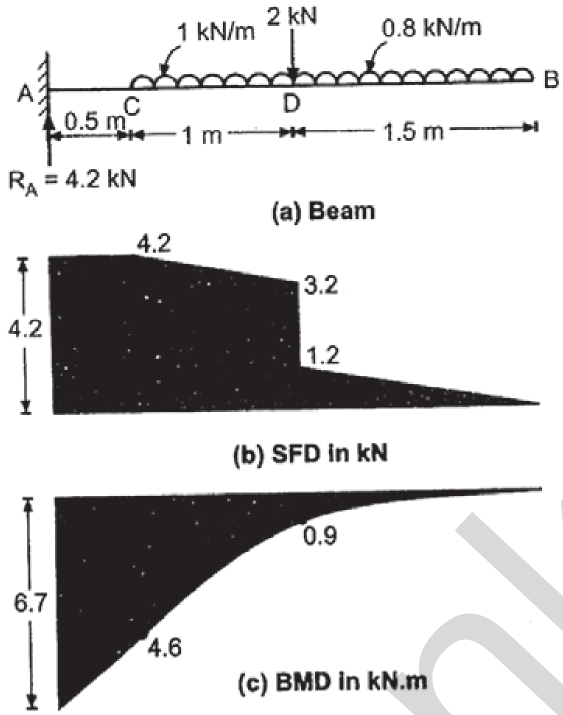
$BM_B = -10 \times 1 \times 0.5 = -5$

Q.3(c) Draw S.F. and B.M. diagram for the beam as shown in Figure. [4]



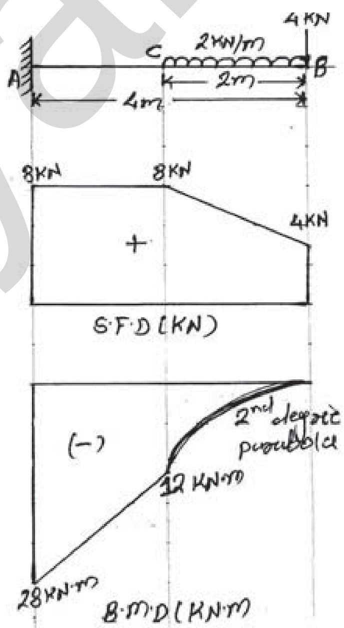
$R_A = 4.2$ kN

(A)



Q.3(d) A cantilever beam 4 m long carries a udl of 2kN/m over 2 m from free end and a point load of 4kN at free end. Draw S.F. and B.M. diagrams. **[4]**

(A)



i) support reactions

a) $\Sigma Fy = 0$; $R_A = 4 + (2 \times 2) = 8KN$ [1 mark]

ii) S.F calculation

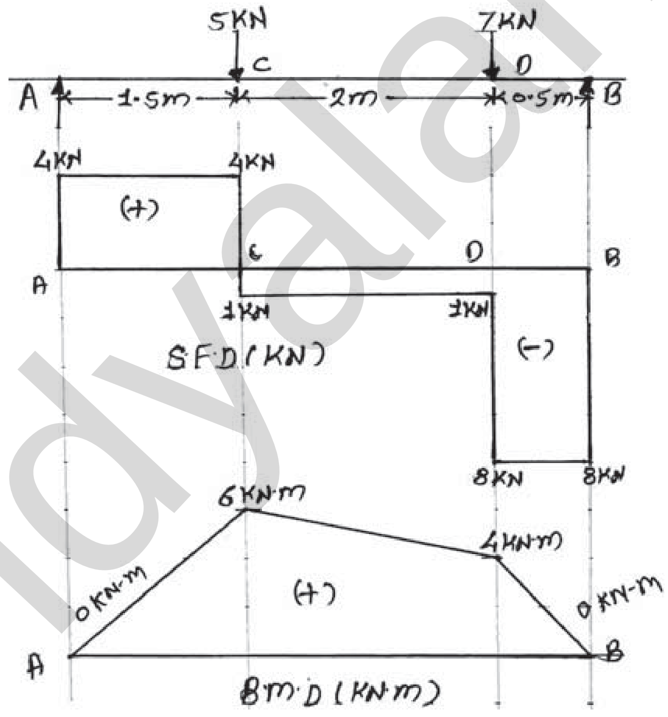
S.F at just left of A = 0 KN

S·F at just right of A = R_A = 8KN
S·F just C = 8KN
S·F just left of B = 8 – (2 × 2) = 4KN
S·F just right of B = 4 – 4 = 0 KN.

iii) B·M calculation
B·Mat B = 0….free end
B·Mat c = – 4 × 2 – 2 × 2 × 1
= – 12 KN·M
B·Mat A= – 4 × 4 – 2 × 2 × 3
= – 12 KN·m
B·Mat A= – 4 × 4 – 2 × 2 × 3
= – 28 KNM

Q.3(e) A simply supported beam of span 4 m carries two point loads of 5kN and 7kN at 1.5 m and 3.5 m from the left hand support respectively. Draw SFD and BMD showing important values. [4]

(A)



i) Support reactions
a) $\Sigma Fy = 0$
$R_A + R_B = 5 + 7 = 12$KN
b) $\Sigma m@A = 0$
$(5\times1.5) + (7\times3.5) - 4R_B = 0$
$32 = 4R_B$
$\therefore R_B = 8$ KN
$\therefore R_A = 12-8 = 4$KN

ii) S·F calculation

S·F at just left of A = 0

S·F at just right of A = R_A = 4KN

S·F at just left of C = 4KN

S·F at just right of C = 4–5 = –1KN

S.F at just left of D = –1 KN·M

S·F at just right of D = –1–7 = –8KN

S.F at just left of B = –8KN

S.F at just right of B = –8 + R_B = 0 KN.

iii) B·M calculation

B·M at A = B·M at B = 0 ……. simple support

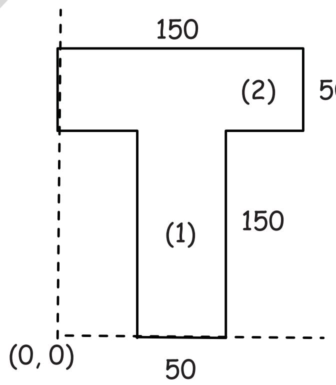
B·M at C = $R_A \times 1.5 = 4 \times 1.5$ = 6KN·M

B·M at D = $R_A \times 3.5 - (5 \times 2) = 4 \times 3.5 - 10$ = 4 KN·M

Q.4 Attempt any FOUR of the following : [16]

Q.4(a) Find M.I. about x-x axis of T-section having flange 150 mm × 50 mm and web 150 mm × 50 mm, overall depth 200 mm. [4]

(A) Find out I_{xx}



$A_1 = A_2 = 150 \times 50 = 7500$

$y_1 = 75,\ y_2 = 175$

$$\bar{y} = \frac{A_1y_1 + A_2y_2}{A_1 + A_2} = \frac{7500\times75+7500\times175}{7500\times2}$$

$$= \frac{250}{2}$$

$\therefore \bar{y} = 125$

$I_{xx} = I_{xx1} + I_{xx2}$

$$I_{xx1} = \frac{bd^3}{12} + A(\bar{y} - y_1)^2$$

$$= \frac{50\times150^3}{2} + 7500(125-75)^2$$

$= 32.812 \times 10^6\ mm^4$

$$I_{xx2} = \frac{bd^3}{12} + A(\bar{y} - y_2)^2$$

$$= \frac{150\times50^3}{12} + 7500(12.5-175)^2$$

$= 20.312 \times 10^6\ mm^4$

$I_{xx} = 53.214 \times 10^6\ mm^4$

Q.4(b) An I-section have the following dimensions Top flange 60 mm × 20 mm. bottom flange 100 mm × 20 mm, web 100 mm × 20 mm, overall depth 140 mm. Find the M.I. about y-y axis. [4]

(A) To find I_{yy}

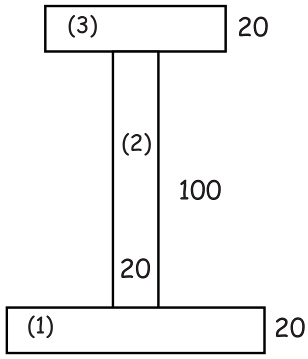
$\therefore x_1 = x_2 = x_3 = \bar{x} = 50$

$\therefore \quad I_{yy} = I_{yy1} + I_{yy2} + I_{yy3}$

$$= \left[\frac{db^3}{12}\right]_1 + \left[\frac{db^3}{12}\right]_2 + \left[\frac{db^3}{12}\right]_3$$

$$= \frac{20\times100^3}{12} + \frac{100\times20^3}{12} + \frac{20\times60^3}{12}$$

$$I_{yy} = 2.093 \times 10^6 \text{ mm}^4$$



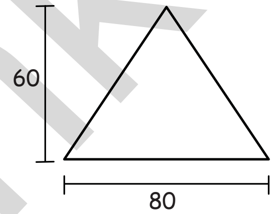
Q.4(c) An isosceles triangular section ABC has a base width 80 mm and height 60 mm. Determine the M.I. of the section about c.g. of the section and the base BC. [4]

(A) (i) MI about CG

$$I_{xx} = \frac{bd^3}{36}$$

$$= \frac{80\times60^3}{36}$$

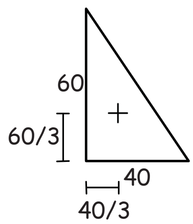
$$I_{xx} = 0.48 \times 10^6$$



$$I_{yy} = 2\left[\frac{db^3}{36} + A\left(\frac{40}{6}\right)^2\right]$$

$$= 2\left[\frac{60\times40^3}{36} + \frac{1}{2}\times60\times40\times\left(\frac{40}{3}\right)^2\right]$$

$$I_{yy} = 0.64 \times 10^6 \text{ mm}^4$$



(ii) MI about BASE

$$= \frac{bd^3}{36} + A\left(\frac{60}{3}\right)^2 = \frac{80\times60^3}{36} + \frac{1}{2}\times60\times80\times\left(\frac{60}{3}\right)^2$$

$$= 19.68 \times 10^6 \text{ mm}^4$$

Q.4(d) Calculate moment of inertia of a hollow rectangle about an axis passing through base 200 mm size, it has the following details. [4]

(i) internal dimension = 160 mm × 260 mm

(ii) external dimension = 200 mm × 300 mm

(A) Data : A hollow rectangle as shown in Fig.

b = 160 mm, d = 260 mm,

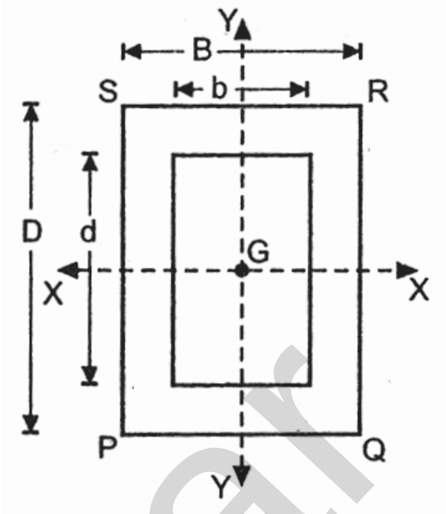
B = 200 mm, D = 300 mm

To find : I_{Base}.

Concept : (i) M.I. of hollow rectangle.

(ii) Use of parallel axis theorem.

We have to calculate the moment of inertia of a hollow rectangle about the base PQ. Base PQ is parallel to XX axis.



(i) $I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12} = \frac{1}{12}(BD^3 - bd^3)$

$= \frac{1}{12}[200 \times 300^3 - 160 \times 260^3]$

$= 215653333.3 \text{ mm}^4$

(ii) $A = BD - bd$

$= 200 \times 300 - 160 \times 260$

$= 18400 \text{ mm}^2$

(iii) Distance between base PQ and XX axis,

$h = \frac{D}{2} = \frac{300}{2} = 150 \text{ mm}$

(iv) Applying the theorem of parallel axis,

M.I. about parallel axis = M.I. about C.G. axis + $A \times h^2$

$I_{PQ} = I_{XX} + Ah^2$

$= 215653333.3 + 18400 \times 150^2$

$= 435563333.3 \text{ mm}^4$

$I_{PQ} = 435563333.3 \text{ mm}^4$

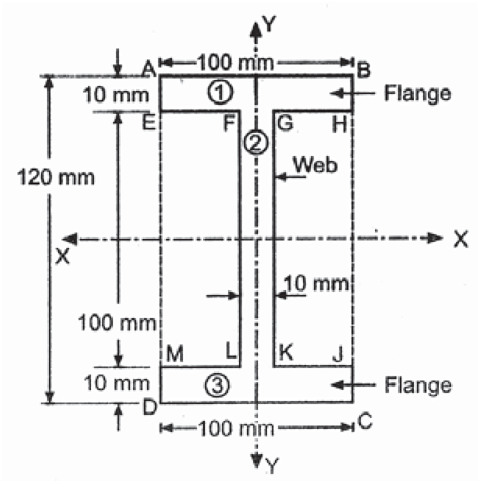
Q.4(d) A symmetrical I–section has the following dimensions. Calculate Polar M.I. of the section. Flanges = 100 mm × 10 mm, Web = 10 mm × 100 mm. **[4]**

(A) **Data :** A symmetrical I section as shown in Fig.

To find : I_p

Concept : Calculate I_{XX} and I_{YY}.

$I_p = I_{XX} + I_{YY}$.



(i) Since the section is symmetrical about XX axis, its M.I. can be determined by considering a hollow rectangular section.

B = 100 mm,

D = 10 + 100 + 10 = 120 mm,

b = (100 – 10) = 90 mm,

d = 100 mm

(ii) $I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12} = \frac{1}{12}(BD^3 - bd^3)$

$= \frac{1}{12}[100 \times 120^3 - 90 \times 100^3]$

$= 6.9 \times 10^6 \text{ mm}^4$

Note: M.I. about YY axis should not be calculated as $\frac{1}{12}(DB^3 - db^3)$ since the c.g. of rectangles EFLM and GHJK are not lying on YY axis.

(iii) I_{YY} = 2 × M.I. of flanges + M.I. of web

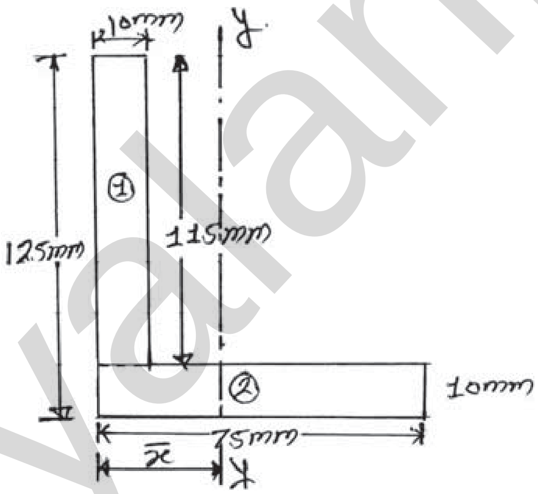
$$= 2\times\left(\frac{10\times100^3}{12}\right)+100\times\frac{10^3}{12} = 1.675\times10^6\ mm^4$$

(iv) Polar M.I. of section,

$$I_p = I_{zz} = I_{XX} + I_{YY} = 6.9\times10^6 + 1.675\times10^6$$
$$= 8.575\times10^6\ mm^4$$
$$I_p = 8.575\times10^6\ mm^4$$

Q.4(e) Find I_{yy} for an unequal angle section having vertical leg of 125 × 10 mm and horizontal leg of 75 × 10 mm. **[4]**

(A)



i) Position of y–y axis $(\bar{x})$

a_1 = 115 × 10 = 1150 mm^2 $\quad$ a_2 = 75×10 = 750 mm^2

$x_1 = \frac{10}{2} = 5mm$ $\quad$ $x_2 = \frac{75}{2} = 37.5\,mm$

$$(\bar{x}) = \frac{a_1x_1 + a_2x_2}{a_1 + a_2} = \frac{(1150\times5)+(750\times37.5)}{1150+750}$$

$(\bar{x})$ = 17.828 mm

ii) M.I. about y–y is given by parallel axis theorem

$$I_{yy} = Iyy_1 + Iyy_2$$

$$I_{yy1} = I_{G1} + A_1h_1^2 = \left[\frac{db^3}{12}+bd\left(\bar{x}-x_1\right)^2\right]_{(1)}$$

$$I_{yy1} = \frac{115 \times 10^3}{12} + 1150(17.828 - 5)^2 = 198.82 \times 10^3 mm^4$$

$$I_{yy2} = I_{G2} + A_2 h_2^2 = \frac{10 \times 75^3}{12} + 750(17.828 - 37.5)^2$$

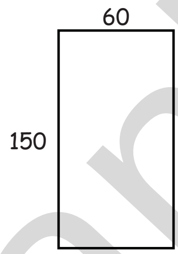
$$I_{yy2} = 641.80 \times 10^3 \ mm^4$$

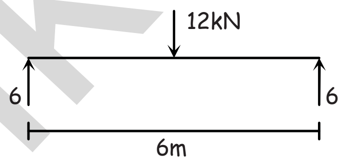
$$\therefore I_{yy} = 840.62 \times 10^3 \ mm^4$$

Q.5 Attempt any FOUR of the following : [16]

Q.5 (a) A rectangular beam 60 mm wide and 150 mm deep is simply supported over a span of 6 m. If the beam is subjected to central point load 12 KN, Find maximum bending stress induced in the beam section. [4]

(A) b = 60, d = 150





Max. BM = 6 × 3 = 18 kNm

$= 18 \times 10^6$ N-mm

$$I = \frac{60 \times 150^3}{12}$$

$$Y = \frac{150}{2} = 75$$

$$\frac{M}{I} = \frac{\sigma}{Y}$$

$$\sigma = \frac{MY}{I} = \frac{18 \times 10^6 \times 75}{\frac{60 \times 150^3}{12}} = 80 \ N/mm^2$$

$$\sigma_{max} = 80 \ N/mm^2$$

Q.5 (b) Calculate the limit of eccentricity for a circular section having diameter 50 mm. [4]

(A) For limit of eccentricity,

$$\sigma_{direct} = \sigma_{bend}$$

$$\frac{P}{A} = \frac{MY}{I}$$

$$\frac{P}{(\pi/4)d^2} = \frac{Pe \times (d/2)}{(\pi/64)d^4}$$

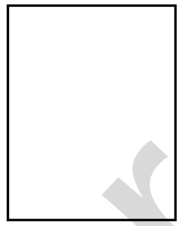
$$\therefore \quad e = \frac{d}{8}$$

$$= \frac{50}{8}$$

$$e = 6.25$$

Q.5 (c) A rectangular strut is 150 mm and 120 mm thick. It carries a load of 180 KN at an eccentricity of 10 mm in a plane bisecting the thickness. Find the maximum and minimum intensities of stress in the section. **[4]**

(A) $e = 10,\ P = 18 \times 10^4$ N



Total stress $= \sigma_{direct} \pm \sigma_{bend}$

$$\sigma_{direct} = \frac{P}{A} = \frac{18\times10^4}{120\times150}$$

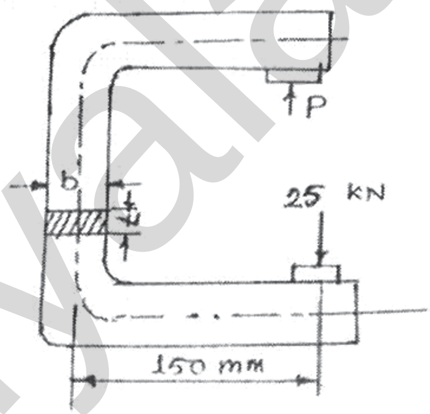
$= 10$ (comp)

$$\sigma_{bend} = \frac{MY}{I} = \frac{Pe\times Y}{I} = \frac{18\times10^4\times10\times75}{120\times\frac{150^3}{12}} = 4$$

$\therefore$ Max. stress $= -10-4 = -14$ i.e. 14 (comp)

Min. stress $= -10+4 = -6$ i.e. 6 (comp)

Q.5 (d) A c-clamp as shown in fig. no 2 carries a load P = 25 KN. The cross section of the clamp at x-x is rectangular, having width equal to twice the thickness. Assuming that the c-clamp is made of steel casing with allowable stress of 100N/mm². Find its dimensions. **[4]**



(A) $P = 25 \times 10^3,\ \sigma = 100$ N/mm², $b = 2t$

Total stress $= \sigma_{direct} + \sigma_{bend}$

$$\sigma_{direct} = \frac{P}{A} = \frac{25\times10^3}{b\times t} = \frac{25\times10^3}{2t^2}$$

$$\sigma_{bend} = \frac{MY}{I} = \frac{25\times10^3\times150\times b/2}{tb^3/12}$$

$$= \frac{25\times10^3\times150\times t\times12}{tb^3} = \frac{25\times10^3\times150\times12}{8t^3}$$

$$100 = \frac{25\times10^3\times150\times12}{8t^3} + \frac{25\times10^3}{2t^2}$$

$\therefore$ Solving for point t, t = 39.18 mm

$\therefore$ b = 78.36 mm

Q.5 (e) Determine the maximum bending stress developed in a beam of rectangular cross-section 50 mm × 150 mm when a bending moment of 600 N.m is applied about X–X axis. **[4]**

(A) **Data :** A rectangular section as shown in Figure 1,
$b = 50$ mm, $d = 150$ mm
$M = 600$ N.m $= 600 \times 10^3$ N.mm

To find : σ

Concept : Use of bending stress equation $\frac{M}{I} = \frac{\sigma}{y}$.

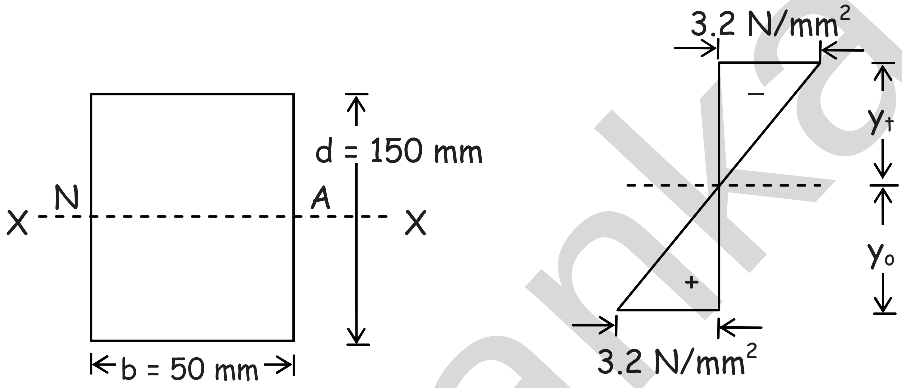


Fig. 1

Step (i) : $I_{XX} = \frac{bd^3}{12} = \frac{50 \times 150^3}{12} = 14062500 \text{ mm}^4$

Step (ii) : $y = \frac{d}{2} = \frac{150}{2} = 75$ mm

Step (iii) : Using the relation,

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\therefore \frac{600 \times 10^3}{14062500} = \frac{\sigma}{75}$$

$$\sigma = \frac{600 \times 10^3 \times 75}{14062500} = 3.2 \text{ N/mm}^2$$

$$\sigma = 3.2 \text{ N/mm}^2$$

Q.6 Attempt any FOUR of the following : **[16]**

Q.6(a) State the equation of torsion and write the notations used in it. **[4]**

(A) $$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$$

T = torque applied

J = polar MI
τ = shear stress at radius r
G = shear modulus
$\theta/2$ = angle of twist per unit length

Q.6(b) A solid circular shaft of 120 mm diameter is transmitting power of 120 KW at 150 rpm. Find the intensity of the shear stress induced in the shaft. Take Tmax = 1.4 Tavg. **[4]**

(A) d = 120 mm, P = 120 kW, N = 150 rpm, $T_{max} = 1.4\ T_{avg}$

$$P = \frac{2\pi NT}{60}$$

$$120 \times 10^3 = \frac{2\pi \times 150\,T}{60}$$

$$T = 7.639 \times 10^3\ \text{Nm}$$

$$T_{avg} = 7.639 \times 10^6\ \text{Nmm}$$

$$\therefore\quad T_{max} = 10.695 \times 10^6\ \text{Nmm}$$

$$\frac{T_{max}}{J} = \frac{\tau}{r}$$

$$\therefore\quad \tau = \frac{T_{max}\,r}{J} = \frac{10.695 \times 10^6 \times 60}{(\pi/32)\,120^4}$$

$$= 31.521\ \text{N/mm}^2$$

Q.6(c) Find power transmitted by a shaft having 60 mm diameter rotating at 120 rpm. If maximum permissible shear stress = 80 MPa. **[4]**

(A) d = 60 mm, N = 120 rpm, $\tau = 80$

$$T_{max} = \frac{\tau J}{r}$$

$$T_{max} = \frac{80 \times \pi \times 60^4}{30 \times 32}$$

$$= 3.392 \times 10^3\ \text{Nmm}$$

$$= 3.392 \times 10^3\ \text{Nm}$$

$$\text{Power} = \frac{2\pi NT}{60}$$

$$= \frac{2\pi \times 120 \times 3.392 \times 10^3}{60}$$

$$= 42.636 \times 10^3\ \text{W}$$

$$\text{Power} = 42.636\ \text{kW}$$

Q.6(d) A shaft of hallow circular cross section has outer diameter 120 mm, inner 90 mm. It is subjected to a torsional moment of 18 KN/m. For this shaft compute shear stress at the outer surface. **[4]**

(A) d_1 = 120 mm, d_2 = 90 mm, T = 18 kNm

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

$$\tau = \frac{Tr}{J} = \frac{18\times10^6\times60}{(\pi/32)(120^4-90^4)}$$

$$\tau_{max} = 77.606 \text{ N/mm}^2$$

Maximum shear stress occurs at outer surface.

Q.6(e) Find the torque that can be applied to a shaft of 100 mm in diameter, if the Permissible angle of twist is 2.75 in a length of 6m. Take G = 30 KN/mm² **[4]**

(A) **Data :** Solid shaft, D = 100 mm, $\theta = 2.75^\circ = \left(2.75\times\frac{\pi}{180}\right)$ rad,

L = 6m = 6 × 10^3 mm,

C = 80 kN/mm² = 80 × 10^3 N/mm²

To find : T

Concept : Use of torsional formula.

Using the relation,

$$\frac{T}{I_p} = \frac{C\theta}{L}$$

$$\therefore \quad \frac{T}{\frac{\pi}{32}D^4} = \frac{C\theta}{L}$$

$$\therefore \quad \frac{T}{\frac{\pi}{32}(100)^4} = \frac{(80\times10^3)\left(2.75\times\frac{\pi}{180}\right)}{6\times10^3}$$

T = 6282734.283 N.mm

= 6282.734 N.m = 6.282 kN.m

Q.6(f) A solid circular shaft of 120 mm diameter is transmitting power of 100 KW at 150 rpm. Find the intensity of the shear stress induced in the shaft. **[4]**

Take T_{max} = 1.4 T_{avg}

(A) **Data:** Solid shaft, D = 120 mm

Power P = 100 kW = 100 × 103 W,

Speed N = 150 rpm,
$T_{max} = 1.4\ T_{avg} = 1.4\ T_{mean.}$

To find : f_s
Concept : (i) Use equation of power first to find T_{mean}.
(ii) Find T_{max} by knowing T_{mean}.
(iii) Use equation of T_{max} to find f_s.

(i) $$\text{Power } P = \left(\frac{2\pi N T_{mean}}{60}\right) W$$

$$100 \times 10^3 = \frac{2\pi \times 150 \times T_{mean}}{60}$$

$$T_{mean} = 6366.197 \text{ N.m}$$

(ii) $$T_{max} = 1.4\ Tmean = 1.4 \times 6366.197$$
$$= 8912.68 \text{ N.m}$$
$$= 8912.68 \times 103 \text{ N.mm}$$

(iii) $$Tmax = \frac{\pi}{16} f_s D^3$$

$$8912.68 \times 103 = \frac{\pi}{16} \times f_s \times (120)^3$$

$$fs = 26.268 \text{ N/mm2}$$

Note: fs can also be calculated by using the relation,

$$\frac{T}{I_p} = \frac{f_s}{R}$$

$$\frac{8912.68 \times 10^3}{\frac{\pi}{32}(120)^4} = \frac{f_s}{\left(\frac{120}{2}\right)}$$

$\therefore$ $$fs = 26.268 \text{ N/mm2}$$

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