OR iii. A column of timber section 15cm X 20cm is 6m long, is both ends being fixed. If young's modulus for timber 17.50 KN/m^2, determine: **6**

(a) Crippling load

(b) Safe load for the column if factor of safety = 3.

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Enrollment No......................................

Faculty of Engineering

End Sem (Odd) Examination Dec-2018

CE3ES10 Strength of Material

Programme: B.Tech. Branch/Specialisation: CE

Duration: 3 Hrs. Maximum Marks: 60

Note: All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d.

Q.1 i. Unit of Strain is **1**

(a) mm (b) cm (c) m^2 (d) Unit less

ii. Poisson ratio is **1**

(a) Lateral Stress / Longitudinal Strain

(b) Lateral Strain / Longitudinal Strain

(c) Longitudinal Stress / Longitudinal Strain

(d) Stress / Strain

iii. At point of contraflexure **1**

(a) Shear force is Zero

(b) Bending moment is Zero and changes sign

(c) Bending moment is maximum

(d) Torsion is Zero

iv. For a simply supported beam with a central load, the bending moment is **1**

(a) Least at the centre (b) Least at the supports

(c) Maximum at the supports (d) Maximum at the centre

v. In a simple bending theory, one of the assumptions is that the material of the beam is isotropic. This assumption means that the **1**

(a) Normal stress remains constant in all directions

(b) Normal stress varies linearly in the material

(c) Elastic constants are same in all the directions

(d) Elastic constants varies linearly in the material

vi. Unit of Section modulus is **1**

(a) mm^2 (b) cm^3 (c) m^2 (d) m

vii. If diameter of a shaft is doubled the power transmitted capacity will be **1**
(a) Either twice or half (b) Four times
(c) Eight times (d) Same

viii. A thin cylinder under internal fluid pressure 'p_i' will have maximum stress at the **1**
(a) Outer radius (b) Inner radius
(c) Means radius (d) None of these

ix. The load at which a vertical compression member just buckles is known as **1**
(a) Critical load (b) Crippling load
(c) Buckling load (d) Any one of these

x. The slenderness ratio is the ratio of **1**
(a) Length of column to least radius of gyration
(b) Moment of inertia to area of cross-section
(c) Area of cross-section to moment of inertia
(d) Least radius of gyration to length of the column

Q.2 i. Explain Hook's law and Draw stress strain curve of mild steel and explain it? **3**

ii. At a point within a body is subjected to a body subjected two mutually perpendicular direction the stresses are 80N/mm2 (tensile) and 40 N/mm2 (tensile). Each of above stress are accompanied by a shear stress of 60N/mm2. Determine the normal stress, tangential stress and resultant stress at an oblique plane at an angle 45° with the axis of minor stress. **7**

OR iii. A steel tube of 30mm external diameter and 20 mm of internal diameter. Enclosed a copper rod of 15 mm diameter to which it is rigidly joined at each end. If at a temperature of 10°C there is no longitudinal stress. Calculate the stress in the rod and tube when the temperature is raised to 200°C. Take Es=2.1x10^5 N/mm^2, E_c=1x10^5N/mm^2. αs = 11x10^{-6}/°C, αc=18x10^{-6}/°C. **7**

Q.3 i. Explain shear force, bending moment and point of contraflexure with suitable example. **3**

ii. A symmetrical simply supported overhang beam of length 12m is over hanged on both the ends on 2m length and loaded with an UDL of 12 KN/m on entire span, draw SFD and BMD and find point of contra flexure. **7**

OR iii. A simply supported beam of 3m span carries point loads of 120 KN and 80KN at a distance of 0.6 and 2m from left support. If moment of inertia for the beam is 16x10^8 mm^4 and E=210 GN/m^2, find the deflection under the loads. **7**

Q.4 i. Define the concept of pure bending? What are the assumptions made in theory of pure bending? **4**

ii. A rectangular beam 200 mm deep and 300 mm wide is simply supported over a span of 8 meter. What uniformly distributed load per meter the beam may carry, if the bending stress is not to exceed 120N/mm^2. **6**

OR iii. An I section beam 350mm x 150mm has a web thickness of 10mm and a flange thickness of 20mm. If the shear force acting on the section is 40 KN, find the maximum shear stress developed in the I section. **6**

Q.5 Attempt any two:

i. Derive torsional equation. **5**

ii. A solid circular shaft is to transmit 375kw at 150 rpm find the diameter of shaft if the shear stress is not exceed 65 N/mm^2. **5**

iii. Write assumptions used in torsion of shafts. Derive torsion equation for solid shaft. **5**

Q.6 i. Explain Slenderness ratio and give Euler's formula and effective length for a cylindrical column for four end conditions. **4**

ii. A hollow cast iron column 200mm outside diameter and 150mm inside diameter, 8m long has both ends fixed. It is subjected to an axial compressive load. Taking a factor of safety as 3, σ_c= 560N/mm^2. α= 1/1600, determine the safe Rankine load. **6**

Marking scheme.

CE3ES10 Strength of Materials Dec. 2018

01 mark each

Q.1 (i) (d) unit less

(ii) (b) lateral strain/ longitudinal strain

(iii) (b) Bending moment is zero and changes sign

(iv) (d) maximum at the centre

(v) (c) Elastic constants are same in all the direction.

(vi) (b) cm^3

(vii) (c) Eight times

(viii) (a). OUTER RADIUS

(ix) (d) any one of these.

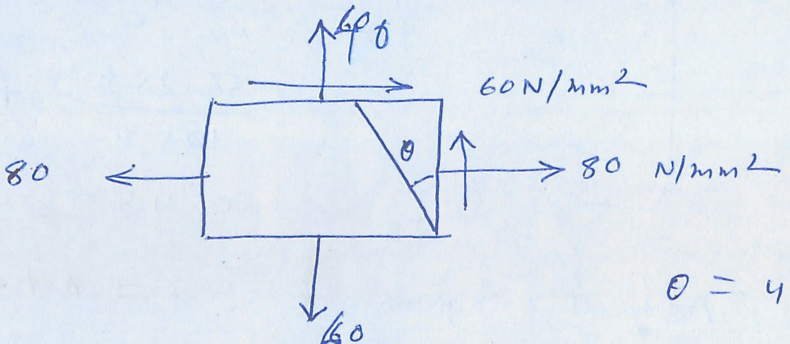
(X) (a) length of column to least radius of gyration.

Q.2 i. Explain hook's law — (01)

Draw stress-strain curve — (01)

explain curve — (01)

ii.



$\theta = 45$

$$p_n = \frac{p_1+p_2}{2} + \frac{p_1-p_2}{2}\cos 2\theta + q\sin 2\theta$$

$$= \frac{80+40}{2} + \frac{80-40}{2}\cos 90 + 60\sin 90$$

$$= 60 + 0 + 60 = 120 \text{ N/mm}^2$$

$$p_t = \frac{p_1 - p_2}{2}\sin 2\theta - q\cos 2\theta$$

$$= \frac{80 - 40}{2}\sin 90 - 60\cos 90$$

$$= 20 - 0$$

$$= 20$$

$$p_r = \sqrt{120^2 + 20^2} = 121.65 \ N/mm^2$$

p_n — (03) marks | correct formula (02)
correct Ans. (3)

p_t — (03) —"—

p_r — (01) —"— correct formula 1/2
correct Ans. 1/2

(iii) $A_s = \frac{\pi}{4}(30^2 - 20^2) = 125\pi$

$$A_c = \frac{\pi}{4}(15^2) = 56.25\pi$$

$$\delta_s = \delta_c = \delta$$

Correct expression 02 marks.

Total tension in steel = Total compression in copper.

$$f_s A_s = f_c A_c$$

$$f_s = \frac{A_c}{A_s} \cdot f_c$$

$$= \frac{56.25\pi}{125\pi} \cdot f_c$$

$$f_s = 0.45 f_c \quad - (1)$$

correct expression 03 Marks.

Actual expansion of steel = actual expansion of copper

$$\alpha_s T l + \frac{f_s}{E_s} l = \alpha_c T l - \frac{f_c l}{E_c}$$

$$\alpha_s T + \frac{f_s}{E_s} = \alpha_c T - \frac{f_c}{E_c}$$

$T = 200 - 10$
$= 190^\circ$

$$11 \times 10^{-6} \times 190 + \frac{0.45 f_c}{2.1 \times 10^5} = 18 \times 10^{-6} \times 190 - \frac{f_c}{1 \times 10^5}$$

$$11 \times 190 + \frac{4.5}{2.1} \cdot f_c = 18 \times 190 - 10 f_c$$

$$f_c = 109.56 \ N/mm^2 \ (com)$$

$$f_s = 0.45 f_c = 49.3 \ N/mm^2 \ (Ten).$$

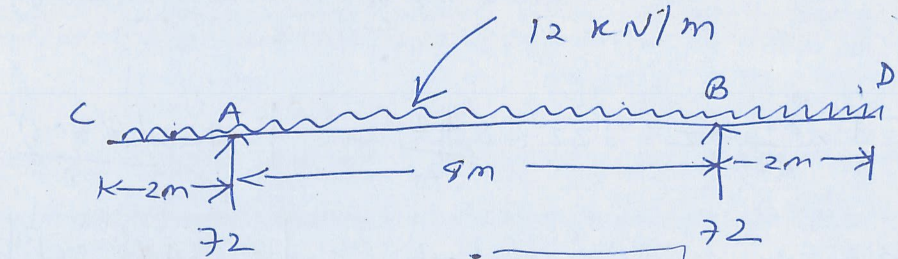
correct answer 02 marks.

3. i Explain S.F. – (01)

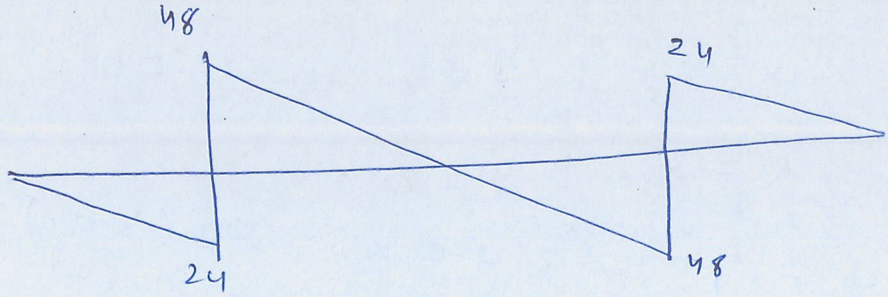
BM – (01)

POC – (01)

ii

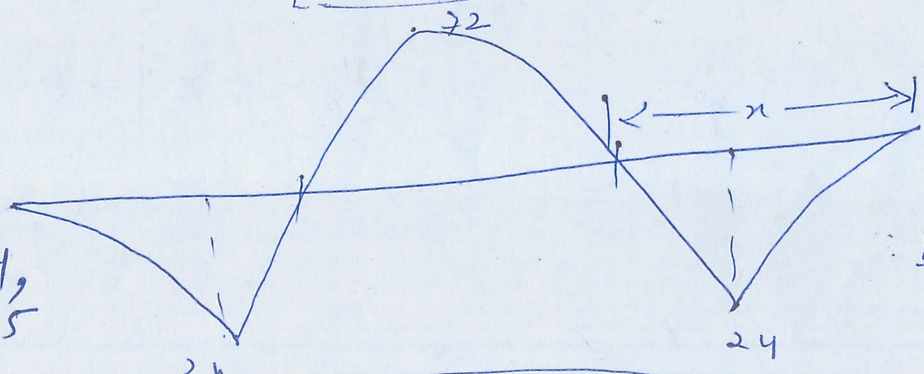


reaction calculation – $\boxed{\text{1 marks}}$



SFD

SFD – $\boxed{\text{2 marks}}$



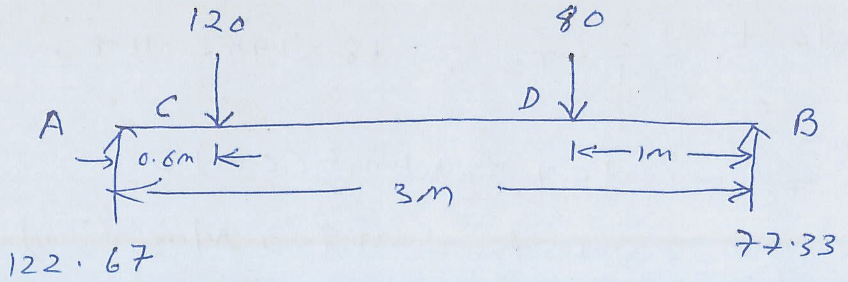
$X = 9.464,$
2.535

$$\frac{12x^2}{2} = 72(x-2)$$

$$x = 2.535, \ 9.464$$

$\boxed{\text{BMD – 3 marks}}$ $\boxed{\text{POC – 1 marks}}$

3 (iii)



$$V_B \times 3 = 120 \times 0.6 + 80 \times 2$$

$$V_B = 77.33$$

Reactions 01 mark

$$V_A = 122.67$$

03 marks.

$$EI \frac{d^2y}{dx^2} = 122.67x \,\Big|\, - 120(x-0.6) \,\Big|\, - 80[x-2]$$

$$EI \frac{dy}{dx} = 122.67 \frac{x^2}{2} + C_1 \,\Big|\, - 120 \frac{(x-0.6)^2}{2} \,\Big|\, - \frac{80(x-2)^2}{2}$$

$$EI \frac{dy}{dx} = 61.34x^2 + C_1 \,\Big|\, - 60(x-0.6)^2 \,\Big|\, - 40[x-2]^2$$

$$EI\,y = 20.45x^3 + C_1x + C_2 \,\Big|\, - 20(x-0.6)^3 \,\Big|\, - \frac{40}{3}(x-2)^3$$

$x = 0, \quad y = 0 \quad \therefore C_2 = 0$

$x = 3, \quad y = 0$

$$0 = 20.45 \; 3^3 + C_1 \times 3 - 20(3-0.6)^3 - \frac{40}{3}(1)^3$$

$$0 = 552.15 + 3C_1 - 276.48 - 13.33$$

$$C_1 = -87.45$$

02 marks. Hence $EI\,y = 20.45x^3 - 87.45x \,\Big|\, - 20(x-0.6)^3 \,\Big|\, - \frac{40}{3}(x-2)^3$

Put $x = 0.6$

$$EI\,y_c = 20.45(0.6)^3 - 87.45 \times 0.6$$

$$= 4.417 - 52.47$$

$$= 48.053$$

$$y_c = \frac{48.053}{210 \times 10^3 \times 16 \times 10^8} \times (1000)^3$$

$$= -0.000143 \text{ mm.}$$

Put $x = 2$

$$EI\,y_D = 20.45 \times 2^3 - 87.45 \times 2 - 20(1.4)^3 - \frac{40}{3} \times 0$$

$$= 163.6 - 174.9 - 2.744$$

$$\therefore y_D = \frac{14.044 \times (1000)^3}{210 \times 10^3 \times 16 \times 10^8}$$

$$\therefore y_D = 0.000042 \text{ mm.}$$

Correct ~~equation~~ answer

y_c = 01 mark

y_D = 01 mark

Q.4 (i)

(1) CONCEPT OF PURE BENDING (1 MARK)

(2) ASSUMPTION OF PURE BENDING (3 MARK)

1/2 mark for each assumption.

Q: 4

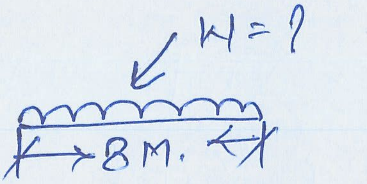
(ii) Given that $\Rightarrow$ $D = 200\,MM$

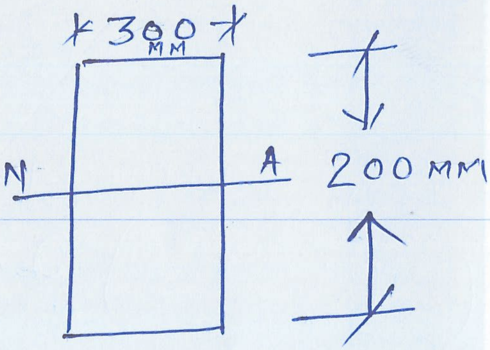
$B = 300\,MM$

$l = 8\,M. = 8000\,MM$

$W = ?$

$\sigma = 120 \frac{N}{MM^2}$





BY BENDING EQ^n

01 mark $\left[\dfrac{\sigma}{Y} = \dfrac{M}{I} \right.$

$Y = D/2 = \dfrac{200}{2} = 100\,MM$

01 mark $\left[M = \dfrac{Wl^2}{8} \right.$

0·1 marks. $\left[I = \dfrac{BD^3}{12} = \dfrac{300 \times 200^3}{12} = \cancel{450000000\,MM^4} \right.$

$= \cancel{45 \times 10^7\,MM^4}$

$\Rightarrow 2 \times 10^8\,MM4$

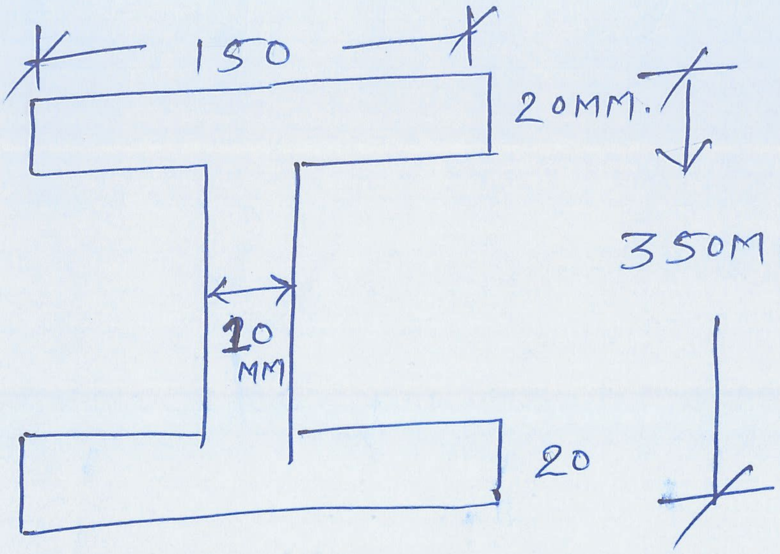
$\Rightarrow \dfrac{120}{100} = \dfrac{\frac{W(8000)^2}{8}}{20 \times 10^7}$ 02 marks.

$\Rightarrow W = 30\,N/MM$ ANS

$= 30\,KN/M$

correct answer 01 mark

Q: 4
III



Given ⇒ Shear force = 40KN

overall width ⇒ 150MM

Depth ⇒ 350 MM

$t_w = 10MM$

$t_f = 20MM$

$B_w = 150MM$

$d = D_w = 350 - 40 = 310MM.$

Moment of inertia Developed = τ_{max}

2 marks. $I = \left[\frac{BD^3}{12} - \frac{2 \times bd^3}{12}\right]$

$= \left[\frac{150 \times (350)^3}{12} - \frac{2 \times 70 \times 310^3}{12}\right]$

$= 535937500 - 173780833$

$I = 362156667 \ MM^4$

Correct I - 01 mark

(2)

02 marks. $\left[\tau_{MAX} \Rightarrow \frac{S}{8Ib}\left[B(D^2-d^2)+bd^2\right]\right.$

$$\Rightarrow \frac{40 \times 10^3}{8 \times 36215666.7 \times 10}\left[150(350^2-310^2)+10 \times 310^2\right]$$

$$= 3960001.33 \frac{N}{mm^2}$$

$$= 3.96 \; M\frac{N}{m^2} \quad \underline{An}$$

Correct answer 01 marks.

Q:5 (I)

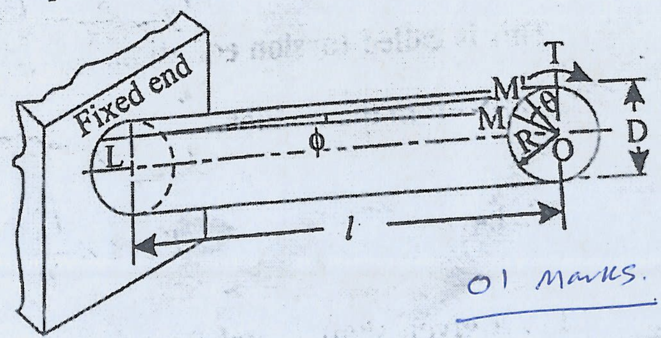
TORSION EQUATION

The *torsion equation* is based on the following **assumptions:**

1. The material of the shaft is uniform throughout.
2. The shaft circular in section remains circular after loading.
3. A plane section of shaft normal to its axis before loading remains plane after the torques have been applied.
4. The twist along the length of shaft is uniform throughout.
5. The distance between any two normal cross-sections remains the same after the application of torque.
6. Maximum shear stress induced in the shaft due to application of torque does not exceed its elastic limit value.

Let, T = Maximum twisting torque,
D = Diameter of the shaft,
I_p = Polar moment of inertia,
τ = Shear stress,
C = Modulus of rigidity
θ = The angle of twist (radians), and
l = Length of the shaft.

In Fig. 13·1 is shown a shaft fixed at one end and torque being applied at the other end. If a line LM ...wn on the shaft, it will be distorted to LM' on the ...cation of the torque ; thus cross-section will be ...d through angle θ and surface by angle ϕ.



01 Marks.

Fig. 13.1

Here, shear strain, $\phi = \dfrac{MM'}{l}$

Also, $\phi = \dfrac{\tau}{C}$

$\therefore \quad \dfrac{MM'}{l} = \dfrac{\tau}{C}$ $\quad \left[\because MM' = R \times \theta, \; R \text{ being radius of the shaft}\right]$

or, $\quad \dfrac{R\theta}{l} = \dfrac{\tau}{C}$ ...(13·1)

$\therefore \quad \dfrac{\tau}{R} = \dfrac{C\theta}{l}$ 02 marks

Refer to Fig. 13·2. Consider an elementary ring of thickness dx at a radius x and let the shear stress at this radius be τ_x.

The turning force on the elementary ring

$$= \tau_x \cdot 2\pi x \cdot dx$$

Turning moment due to this turning force,

$$dT = \tau_x \cdot 2\pi x \cdot dx \times x$$

To get total turning moment integrating both sides, we get

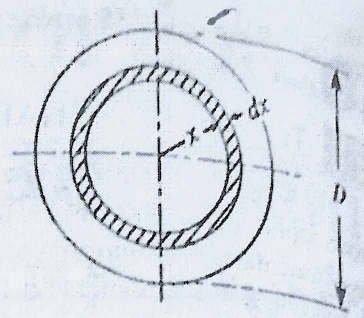


Fig. 13.2

$$\int dT = \int_0^R \tau_x \cdot 2\pi x \, dx \times x$$

or,
$$\int dT = 2\pi \int_0^R \tau_x \cdot x^2 \cdot dx = 2\pi \int_0^R \frac{\tau \cdot x}{R} \cdot x^2 \cdot dx \qquad \left[\because \frac{\tau}{R} = \frac{\tau_x}{x} \text{ or } \tau_x = \frac{\tau x}{R}\right]$$

$$= 2\pi \frac{\tau}{R} \int_0^R x^3 \, dx$$

or,
$$T = 2\pi \frac{\tau}{R} \left|\frac{x^4}{4}\right|_0^R = 2\pi \frac{\tau}{R} \cdot \frac{R^4}{4}$$

$$T = \tau \cdot \frac{\pi R^3}{2} = \tau \cdot \frac{\pi}{16} D^3 \qquad \text{...(Strength of solid shaft)}$$

or,
$$T = \frac{\tau}{R} \cdot \frac{\pi R^4}{2} = \frac{\tau}{R} I_p \qquad \left[\because I_p = \frac{\pi}{32} D^4 = \frac{\pi}{2} R^4\right]$$

∴
$$\frac{T}{I_p} = \frac{\tau}{R} \qquad \text{...(13·2)}$$

6 2 Marks

From eqns. (13·1) and (13·2), we have

$$\frac{T}{I_p} = \frac{\tau}{R} = \frac{C\theta}{l} \qquad \text{...(13·3)}$$

This is called **torsion equation.**

Note. From the relation, $\frac{T}{I_p} = \frac{\tau}{R}$,

We have
$$T = \tau \times \frac{I_p}{R}$$

For a given shaft I_p and R are constants and $\frac{I_p}{R}$ is thus a constant and is known as polar modulus of the shaft section.

Thus
$$T = \tau \times Z_p \qquad \text{... (13·4)}$$

For a shaft of given material τ, the maximum permissible shear stress is fixed and thus the greatest twisting moment that the shaft can withstand is proportional to the polar modulus of the shaft. *Polar modulus of the section is thus measure of strength of shaft in torsion.*

Q. 5 III

assumption 02 Marks

derivation 03 Marks.

Q. 6

(i) SLENDERNESS RATIO DEFINITION (1MARK)

EULER FORMULA (1MARK)

Effective Length for FOUR END condn (2 MARK)

1/2 mark for each condition.

Q. 5. (II)

Given that ⇒ $P = 375 KW$

$\tau \Rightarrow 65 \frac{N}{MM^2}$

$N \Rightarrow 150 RPM$

POWER TRANSMITTED BY SHAFT.

01 Mark $\left[P = \frac{2\pi N T}{60000} \; KW \right.$ Formula 01 Marks.

$$375 = \frac{2\pi 150 T}{60000} \; KW$$

$$\frac{22500\,000}{2\pi \times 150} = T$$

right T 1½ Marks

01½ Mark $\left[\; 23873 \; NM = T \right.$

$$T = \frac{\pi}{16} \tau D^3$$

Formula 01 Marks.

$$2\cancel{3}873 \; N \; M = \frac{\pi}{16} \; 65 \frac{N}{MM^2} \; D^3$$

$$2\cancel{3}873 \; N \times 10^3_{MM} = \frac{\pi}{16} \; 65 \; D^3$$

$$D^3 = 2183938.82 \; MM$$

$$D = 12\cancel{3}.7 \; MM$$

right D 1½ Marks

ANS = Dia of shaft

120 to 130 MM

Q. 6.
II Given that

$D_o = 200 MM$
$D_i = 150 MM$
$l = 8 M.$
$FOS = 3$
$\sigma_C = 560 \frac{N}{MM^2}$
$\alpha = \frac{1}{1600}$

Safe Ranking Load = ?

Formula :=

02 Marks $\left[P_R = \frac{\sigma_C A}{1+\alpha\left(\frac{l_e}{K}\right)^2} \right.$

$K = \sqrt{\frac{I}{A}} = \sqrt{\frac{53689327}{13744}} = 62.50$ MM

1/2 mark $\left[I = \frac{\pi}{64}\left(D_o^4 - D_i^4\right) \Rightarrow 53689327 \text{ MM}^4 \right.$

1/2 mark $\left[A = \frac{\pi}{4}\left(D_o^2 - D_i^2\right) = 13744 \text{ MM}^2 \right.$

Here Both End fixed

1/2 mark $\left[l_e = l/2 = 8/2 = 4M. = 4000 MM \right.$

Q.6 (3)

Given $\Rightarrow$ $l = 6 M.$

$E = 17.50 \frac{KN}{M^2}$

$B = 15 CM. = 0.15 M$

$D = 20 CM = 0.2 M$

01 mark

Both End fixed = $l_{eff} = l/2$

$= 6/2 = 3 M.$

02 marks.

$$P = \frac{\pi^2 E I}{(l_{eff})^2}$$

01 mark

$$I = \frac{B D^3}{12} = \frac{0.15 \times (0.2)^3}{12}$$

$$\Rightarrow 0.0001 M^4$$

$$P = \frac{\pi^2 \times 17.50 \times 0.0001}{(3)^2}$$

(a)
1 mark

$P = 1.91 \times 10^{-03}$ KN

$= 1.91$ N

(b)
1 mark

Safe Load $= \frac{P}{3} = 0.636$ N