Roll No.

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem 2019-20

Course Code: CIV 201

Course Name: STRENGTH OF MATERIALS

Program & Sem: B.Tech (Civil) & III

Date: 27.09.2019

Time: 2:30 PM to 3:30 PM

Max Marks: 40

Weightage: 20%

Instructions:

(i) Read the question properly and answer accordingly

(ii) Scientific and Non-programmable calculators are permitted

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Part A (Memory Recall Questions)

Answer all the Questions. Each Question carries four marks. (3Qx4M=12M)

1. Hooke's law states that stress is proportional to strain within elastic limit. Represent this on a stress-strain plot of Mild Steel. (C.O.NO.1)[Knowledge]

2. If E = 2G(1 + 1/m) and E = 3K(1 – 2/m), then give a relationship connecting E, G and K. Explain the notations. (C.O.NO.1)[Knowledge]

3. A member is loaded axially in tension resulting in elongation of the member. Give the expression to compute this deformation (or extension) and explain the terms.

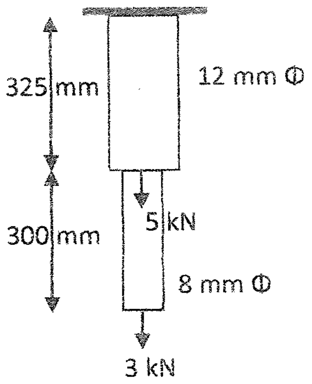
   (C.O.NO.1)[Knowledge]

Part B (Thought Provoking Questions)

Answer all the Questions. Each Question carries six marks. (3Qx6M=18M)

4. A stepped bar shown in the figure is subjected to axial tensile load. Compute the change in length of the section. Take E = $2.1\text{x}10^5$ N/mm^2.

   (C.O.NO.1)[Knowledge]



5. Drop in temperature can have detrimental effect on a material, resulting in thermal stresses and contraction of the material. A steel rod of 20 mm diameter and 6000 mm in length is connected to two grips, one at each end, at a temperature of 120°C. Find the force exerted when the temperature falls to 40°C: (a) if the ends do not yield (b) if the ends yield by 0.12 cm. Take E = $2x10^5$ N/mm^2 and $\alpha = 12x10^{-6}$ per °C.
(C.O.NO.1)[Comprehension]

6. Mohr's circle is a graphical method of finding stresses on any plane in the stressed element devised German Scientist Otto Mohr. However, for the following data: σ_x =50 N/mm^2 and σ_y = 80 N/mm^2, both tensile, you are required to calculate the normal stress, tangential or shear stress, and the resultant stress on a plane inclined at 30° to the major principal plane.
(C.O.NO.1)[Comprehension]

Part C (Problem Solving Questions)

Answer both the Questions. Each Question carries five marks. (2Qx5M=10M)

7. If a load is suddenly applied on a member then the resultant stress on the member will be twice the intensity of the same load applied gradually. Now, if a bar is 3m long, 60 mm in diameter & subjected to a tensile load of 195 kN, find the stress and deformation when the load is gradually applied. What will be the maximum stress and deformation if this load is suddenly applied? Take E = $2x10^5$ N/mm^2.
(C.O.NO 1)[Comprehension]

8. A composite material is made up of atleast two different materials. In this case, an 18 mm diameter steel rod passes centrally through a copper tube of 26 mm internal diameter and 38 mm external diameter. The composite rod is 750 mm long, closed at each end by a rigid plate and subjected to an axial force of 35 kN. Find stresses induced in the steel rod and copper tube. Take E_s = $2x10^5$ N/mm^2 and E_c = $1x10^5$ N/mm^2.
(C.O.NO 1)[Comprehension]

SCHOOL OF ENGINEERING

TEST – 1 SOLUTION

Semester: III

Course Code: CIV 201

Course Name: Strength of Materials

Branch & Sem: B.Tech Civil, III Sem, II Year

Date: 27-09-2019

Time: 2:30 PM to 3:30 PM

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO	C.O.NO	Unit/Module Number / Unit/Module Title	Memory recall type [12 M] [Knowledge]			Thought provoking type [18 M] [Comprehension]			Problem solving type [10 M] [Comprehension]			Total Marks
			K			C			C			
1	1	1 – Stresses and Strains	4									4
2	1			4								4
3	1				4							4
4	1					6						6
5	1						6					6
6	1							6				6
7	1								5			5
8	1									5		5
	Total Marks		12			18			10			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60% of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

[I hereby certify that All the questions are set as per the above guide lines. Dr. Nakul Ramanna]

Reviewers' Comments

SCHOOL OF ENGINEERING

TEST - 1 SOLUTION

Semester. III

Course Code: CIV 201

Course Name: Strength of Materials

Branch & Sem: B.Tech Civil. III Sem. II Year

Date: 27-09-2019

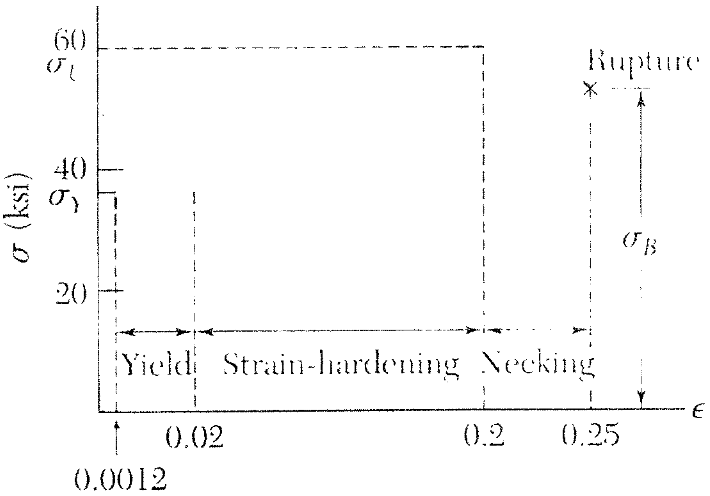
Time: 2:30 PM to 3:30 PM

Max Marks: 40

Weightage: 20%

Part A

(3Q x 4M = 12 Marks)

Q No	**Solution**	**Scheme of Marking**	**Max. Time for each Question**
1	 Note: Students are not expected to label all the salient points on the plot. If the line is linear upto elastic limit and the slope of this line is represented as E. within that limit. then full marks are to be given.	4M	4 mins
2	E= 9KG / (3K+G) E = Youngs modulus or modulus of elasticity K = Bulk modulus G (or C) = Shear modulus or modulus of rigidity	4M (3M for Equation and 1M for notation)	3 mins

3	$\Delta L = PL/AE$ ΔL = Deformation or Extension P = Axial Load L = Length of Member A = Area of member E = Youngs modulus or modulus of elasticity	4M (2M for Equation and 2M for notation)	3 mins

Part B (3Q x 6M = 18 Marks)

Q No	Solution	Scheme of Marking	Max. Time for each Question
4	Area: Section 1 = $\pi*12^2 / 4 = 113.1\ mm^2$ Section 2 = $\pi*8^2 / 4 = 50.27\ mm^2$ $\Delta L = \Delta L_1 + \Delta L_2 = (PL/AE)_1 + (PL/AE)_2$ $\Delta L = [(8*1000*325) / (113.1*2.1x10^5) + (3*1000*300) / (50.27*2.1x10^5)$ $\Delta L = [\ 0.1095 + 0.08525\ ]$ $\Delta L = 0.1947$ mm	6M	8 mins
5	$A = \pi*20^2 / 4 = 314.16\ mm^2$ (a) If the ends do not yield $P = \sigma A = \alpha T E A$ $P = 12x10^{-6}*80*2x10^5 * 314.16$ P = 60318.72 N = 60.32 kN (b) If the ends yield by 0.12 cm $P = \sigma A = [(\alpha T L - \delta) / L]*E*A$ $P = [(12x10^{-6}*80*6000 - 1.2) / 6000] * 2x10^5 * 314.16$ P = 47752.32 N or 47.75 kN	6M	8 mins
6	Normal Stress, $\sigma = (\sigma_x + \sigma_y)/2 + (\sigma_x - \sigma_y)/2 * \cos 2\theta$ $\sigma = (50+80)/2 + (50-80)/2 * \cos(2*30)$ $\sigma = 65 + (-7.5) = 57.5\ N/mm^2$ Shear stress, $\tau = (\sigma_x - \sigma_y)/2 * \sin 2\theta$ $\tau = (50-80)/2 * \sin(2*30) = -12.99\ N/mm^2$	6M	9 mins

	Resultant stress, $\sigma_r = sqrt(\sigma^2 + \tau^2)$ $\sigma_r = sqrt(57.5^2+12.99^2) = 58.95\ N/mm^2$		

Part C (2Q x 5M = 10 Marks)

Q No	**Solution**	**Scheme of Marking**	**Max. Time for each Question**
7	$As = \pi*60^2/4 = 2827.43\ mm^2$ <u>Gradual Loading</u> $\sigma = P/A = 195*1000 / 2827.43 = 68.97\ N/mm^2$ $\Delta L = PL/AE = 195*1000*3000 / (2827.43*2x10^5) = 1.0345\ mm$ <u>Gradual Loading</u> $\sigma = 2*68.97 = 137.94\ N/mm^2$ $\Delta L = 2*1.0345 = 2.069\ mm$	5M	9 mins
8	$As = \pi*18^2/4 = 254.5\ mm^2$ $Ac = \pi*(38^2 - 26^2)/4 = 603.18\ mm^2$ P = 35 kN P = Ps + Pc 35*1000 = Ps + Pc → (1) Now, Ps = (AsEs/AcEc)*Pc [From Deformation Condition] $Ps = \frac{254.5 * 2 * 10^5}{603.18 * 1 * 10^5} Pc$ Ps = 0.844 Pc Substituting in (1), 35000 = 0.844 Pc + Pc Hence **Pc = 18980.5 N (or 18.98 kN)** Substituting back in (1), **Ps = 16019.52 N (or 16.02 kN)** Again, P = Ps + Pc	5M	12 mins

	$35*1000 = \sigma_s A_s + \sigma_c A_c \rightarrow (2)$ Also. $\sigma_s = (E_s / E_c) \sigma_c$ $\sigma_s = (2*10^5/1*10^5) \sigma_c = 2* \sigma_c$ Substituting above in (2) $35*1000 = 2* \sigma_c * 254.5 + \sigma_c * 603.18$ So **σ_c = 35000 / 1112.18 = 31.5 Mpa** Substituting back in (2) $35000 = \sigma_s *254.5 + 31.5*603.18$ Hence **σ_s = 15999.83 / 254.5 = 62.87 Mpa**		

Roll No.												

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem. 2019-20
Course Code: CIV 201
Course Name: STRENGTH OF MATERIALS
Program & Sem: B.Tech (CIV) & III

Date: 16.11.2019
Time: 2:30 PM to 3:30 PM
Max Marks: 40
Weightage: 20%

Instructions:

I. Read the question properly and answer accordingly.
II. Scientific and Non-programmable calculators are permitted.

Part A (Memory Recall Questions)

Answer all the Questions. Each Question carries four marks. (3Qx4M=12M)

1. Write the statement for parallel axis and perpendicular axis theorem for calculating the moment of inertia. (C.O.NO.2) [Knowledge]
2. List the different types of structure support with number of support reactions. (C.O.NO.3) [Knowledge]
3. Write the relationship between shear force, bending moment and rate of loading. (C.O.NO.3) [Knowledge]

Part B (Thought Provoking Questions)

Answer both the Questions. Each Question carries eight marks. (2Qx8M=16M)

4. A cantilever beam is subjected to three-point loads as shown in figure 1. Draw SFD and BMD. Also, locate the POC if any. (C.O.NO.1) [Application]

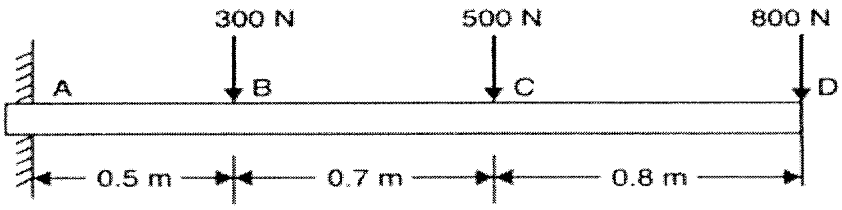


Figure 1

5. A simply supported beam is shown in figure 2. Calculate support reactions and draw SFD and BMD. Also, locate the POC if any. (C.O.NO.3) [Application]

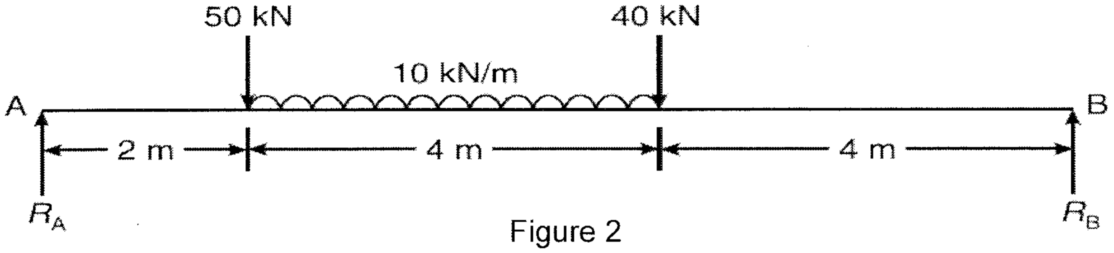


Figure 2

Part C (Problem Solving Questions)

Answer the Question. The Question carry twelve marks. **(1Qx12M=12M)**

6. Determine Centroid ($\bar{x}$ and $\bar{y}$), and Moment of Inertia (I_x and I_y) for the figure 3: (C.O.NO 2)[Comprehension]

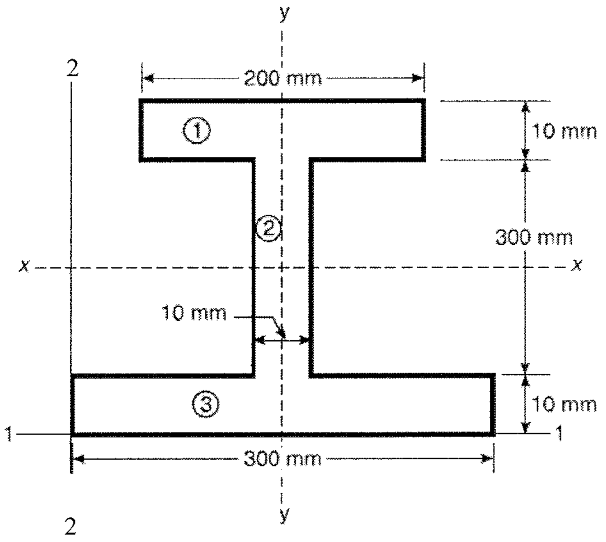


Figure 3

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Sem and AY: Odd & 2019-20
Course Code: CIV201
Course Name: Strength of Materials
Branch & Sem: B.Tech (Civil) & III

Date: 16/11/2019
Time: 1 hour
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	2	2	4									4
2	3	3	4									4
3	3	3	4									4
4	3	3								8		8
5	3	3								8		8
6	2	2					12					12
	Total Marks		12				12			16		40

K =Knowledge Level   C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below-average students must be able to attempt, About 20% of the questions must be such that only above average students must

be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Sem and AY: Odd & 2019-20

Course Code: CIV201

Course Name: Strength of Material

Branch & Sem: B.Tech (Civil) & III

Date: 16/11/2019

Time: 1 hour

Max Marks: 40

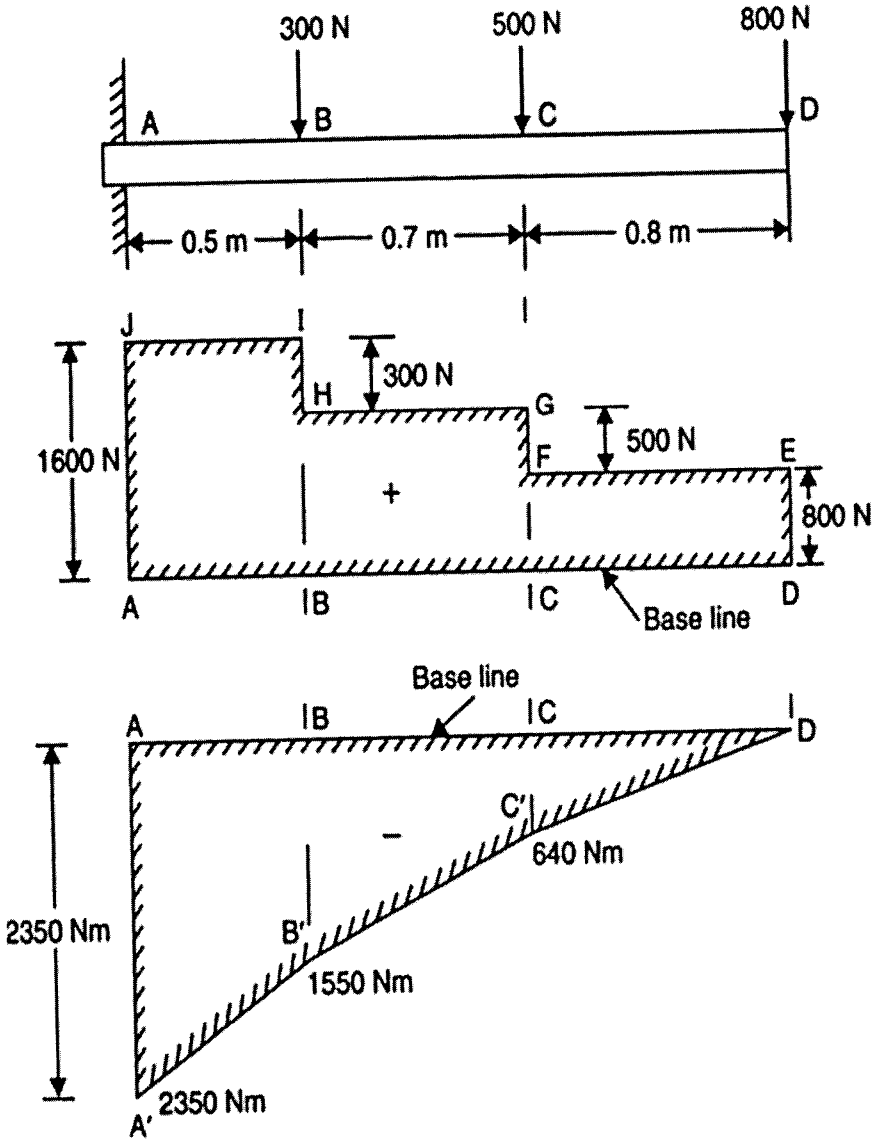
Weightage: 20%

Part A

(3Q x 4M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. The time required for each Question
1		2 mark for each statement	5 mins
2	Simple support (1) Hinge support (2) Roller support (1) Fixed support (3)	1 mark for each support	3 mins
3	$\frac{dM}{dx}$ = V (Slope of BM= Shear force) $\frac{dV}{dx}$ = w (Slope of SF= rate of loading)	2 mark for each relationship	3 mins

Part B (2Q x8M =16Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
4		2 mark for support reactions, 3+3 for SFD and BMD	12 mins

5

S.F. Diagram

The S.F. at A, $F_A = R_A = +80$ kN

The S.F. will remain constant between A and C and equal to + 80 kN

The S.F. just on R.H.S. of C $= R_A - 50 = 80 - 50 = 30$ kN

The S.F. just on L.H.S. of D $= R_A - 50 - 10 \times 4 = 80 - 50 - 40 = -10$ kN

The S.F. between C and D varies according to straight line law.

The S.F. just on R.H.S. of D $= R_A - 50 - 10 \times 4 - 40 = 80 - 50 - 40 - 40 = -50$ kN

The S.F. at $B = -50$ kN

The S.F. remains constant between D and B and equal to − 50 kN

The shear force diagram is drawn as shown in Fig. 6.31 (*b*).

The shear force is zero at point E between C and D.

Let the distance of E from point A is x.

Now shear force at $E = R_A - 50 - 10 \times (x - 2)$

$= 80 - 50 - 10x + 20 = 50 - 10x$

But shear force at $E = 0$

$\therefore$ $50 - 10x = 0$ or $x = \frac{50}{10} = 5$ m

B.M. at C, $M_C = R_A \times 2 = 80 \times 2 = 160$ kNm

B.M. at D, $M_D = R_A \times 6 - 50 \times 4 - 10 \times 4 \times \frac{4}{2}$

$= 80 \times 6 - 200 - 80 = 480 - 200 - 80 = 200$ kNm

At E, $x = 5$ m and hence B.M. at E,

$$M_E = F_A \times 5 - 50(5-2) - 10 \times (5-2) \times \left(\frac{5-2}{2}\right)$$

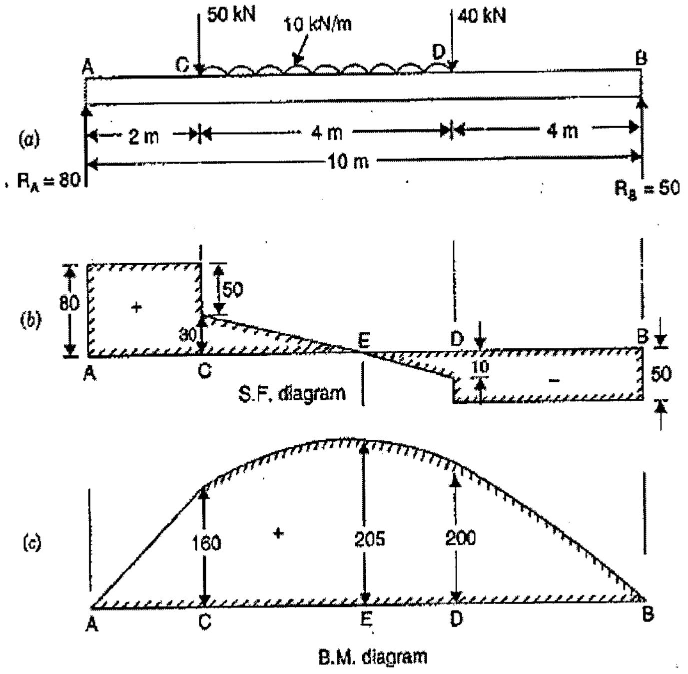
$$= 80 \times 5 - 50 \times 3 - 10 \times 3 \times \tfrac{3}{2} = 400 - 150 - 45 = 205 \text{ kNm}$$

The B.M. between C and D varies according to parabolic law reaching a maximum value at E. The B.M. between A and C and also between B and D varies according to linear law.

Maximum B.M.

The maximum B.M. is at E, where S.F. becomes zero after changing its sign.

$\therefore$ Max. B.M. $= M_E =$ **205 kNm. Ans.**



2 mark for support reaction and 3+3 SFD and BMD

15 min

Part C (1Q x 8M =12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
6			15 mins

Roll No

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 20

Course Code: CIV 201

Course Name: STRENGTH OF MATERIALS

Program & Sem: B.Tech.(CIV) & III

Date: 23 December 2019

Time: 1:00 PM to 4:00 PM

Max Marks: 80

Weightage: 40%

Instructions:

(i) Read the all questions carefully and answer accordingly.
(ii) Use of non-programmable scientific calculator is permitted

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Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 4 marks. (5Qx4M=20M)

1. Define: (i) Young's Modulus (ii) Poisson's ratio (iii) Modulus of Rigidity (iv) Bulk Modulus (C.O.No.1) [Knowledge]

2. Write the moment of Inertia about horizontal and vertical centroidal axis for:
   (i) Triangular section with base b and height h
   (ii) Hollow circular section with internal dia. D_i and external dia. D_O
   (C.O.No.2) [Knowledge]

3. Using standard notations, write the bending equation and explain the terms (C.O.No.3) [Knowledge]

4. Define torsional stiffness and strength (C.O.No.4) [Knowledge]

5. Differentiate between short and long columns (C.O.No.4) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 10 marks. (3Qx10M=30M)

6. a) Draw the Shear Force Diagram and Bending Moment Diagram for the simply supported beam shown in Figure 6a. [5 M] (C.O.No.3) [Application]

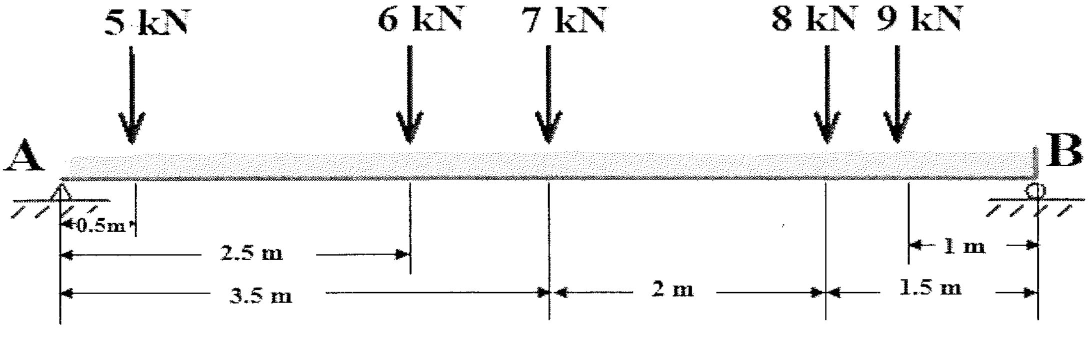


Fig. 6 a

b) Draw the Shear Force Diagram and Bending Moment Diagram for the cantilever beam shown in Figure 6b.

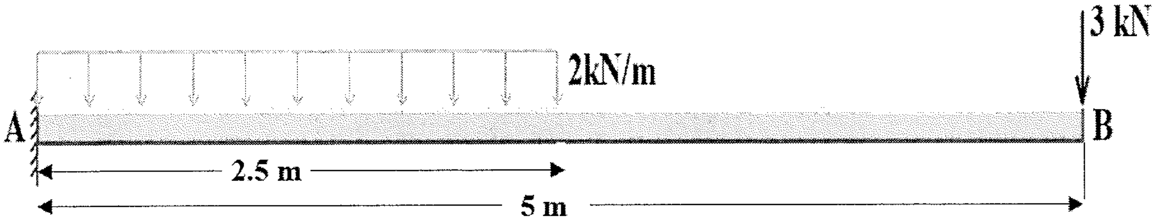


Fig. 6 b [5 M] (C.O.No.3) [Application]

7. Determine the principal stresses, principal planes and maximum shearing stresses for an element subjected to state of stress as shown in Fig. 7

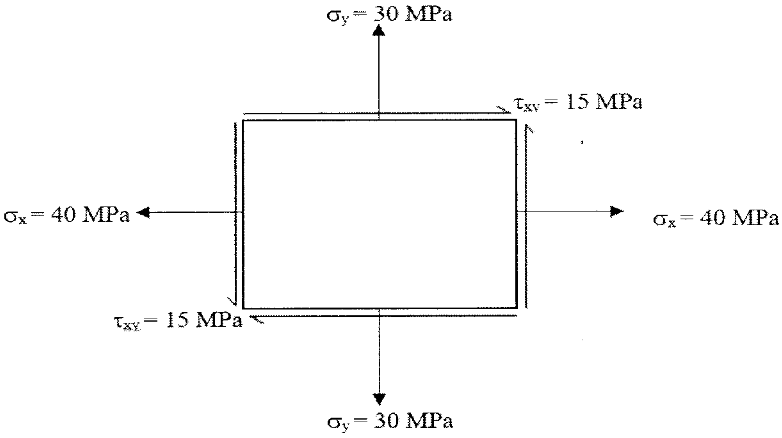


Fig. 7 (C.O.No.1) [Comprehension]

8. Determine the internal and external diameter required for a hollow circular shaft to transmit 10kW power at 150 rpm if the:
   (i) maximum shear stress is not to exceed 100N/mm^2
   (ii) maximum twist is not to exceed 1.5° in a span of 4m
   The internal diameter is 0.6 times the external diameter (C.O.No.4) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries 15 marks. (2Qx15M=30M)

9. A simply supported beam 20 cm wide, 60 cm deep and 5m long is subjected to a UDL of 50 kN/m.
   (i) Derive the bending equation used to compute the bending stresses. [10 M]
   (ii) Calculate the maximum bending stress in extreme fiber. [5 M]
   (C.O.No.3) [Application]

10. A 6m long steel column fixed at both ends is made up of a solid circular section of diameter 100mm.
    i) Derive the formula to be used for computing the Euler's crippling load for the given column [7 M] (C.O.No.4) [Comprehension]
    ii) Compute the slenderness ratio of the column [3 M] (C.O.No.4) [Comprehension]
    iii) Determine the safe compressive load that the column can carry, given E = 2x10^5 N/mm^2 and Factor of safety = 3 [5 M] (C.O.No.4) [Comprehension]

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Level	Thought provoking type [Marks allotted] Bloom's Level	Problem Solving type [Marks allotted] Bloom's Level	Total Marks
			K	C	A	
1	CO1	Module 1	04			04
2	CO2	Module 2	04			04
3	CO3	Module 3	04			04
4	CO4	Module 4	04			04
5	CO4	Module 4	04			04
6	CO3	Module 3		10		10
7	CO1	Module 1		10		10
8	CO4	Module 4		10		10
9	CO3	Module 3			15	15
10	CO4	Module 4			15	15
	Total Marks		20	30	30	80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Comment:

SCHOOL OF ENGINEERING

SOLUTION

Semester: Odd Sem. 2019-20
Course Code: CIV 201
Course Name: Strength of Materials
Program & Sem: B.Tech (Civil), & III

Date: 23 Dec 2019
Time: 1:00 to 4:00 PM
Max Marks: 80
Weightage: 40%

Part A

(5Q x 4M = 20Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>1</td><td>(i) Young's Modulus is defined as the ratio of Stress to strain within the elastic limit.
(ii) Poisson's ratio is the ratio of lateral strain to longitudinal strain.
(iii) Modulus of Rigidity is defined as the ratio of shear stress to shear strain
(iv) Bulk Modulus is the ratio of direct stress to volumetric strain when identical pressure is applied along three mutually perpendicular directions.</td><td>01 Mark for each definition</td><td>05 Minutes</td></tr>
<tr><td>2.</td><td>(i) Moment of Inertia of a triangle
About horizontal centroidal axis, Ixx = $bh^3/36$
About vertical centroidal axis, I_{YY} = $hb^3/36$
(i) Moment of Inertia of hollow circular section
About horizontal centroidal axis, Ixx = $\pi (D_o{}^4 - Di^4)/ 64$
About vertical centroidal axis, I_{YY} = $\pi (D_o{}^4 - Di^4)/ 64$</td><td>1M
1M

1M
1M</td><td>05 Minutes</td></tr>
<tr><td>3.</td><td>M/I = f/y = E/R

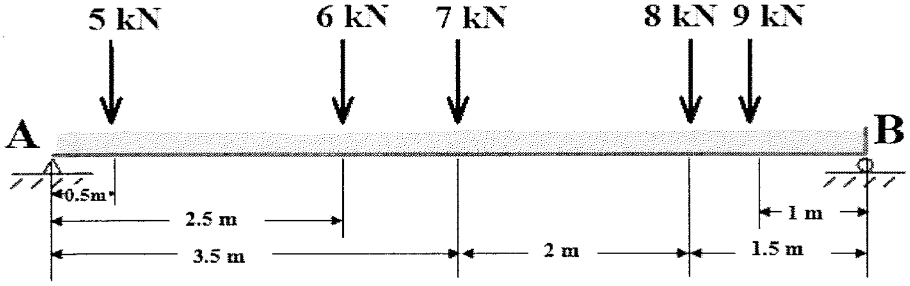
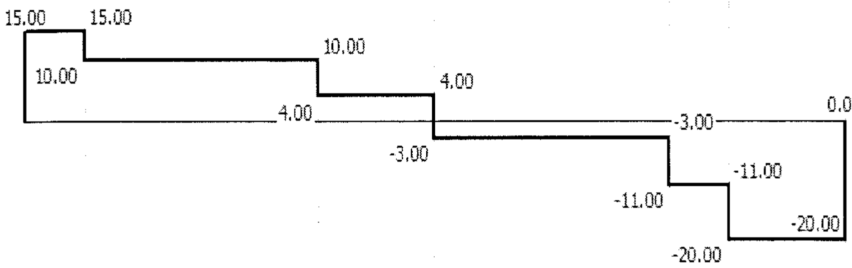
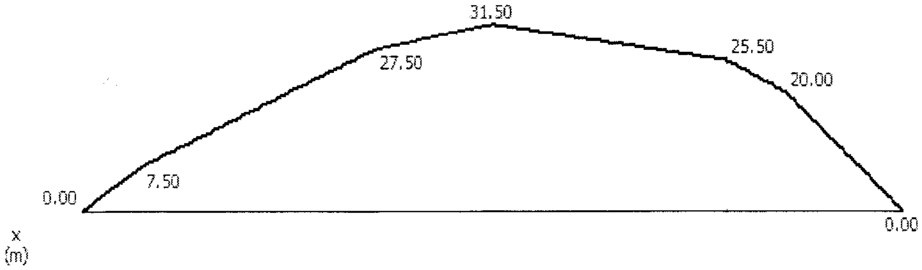
where M = Bending Moment
I = Moment of Inertia
f = Bending stress
y = Distance from neutral axis
E = Young's modulus
R = Radius of curvature</td><td>Bending Equation/ expression – 1 M

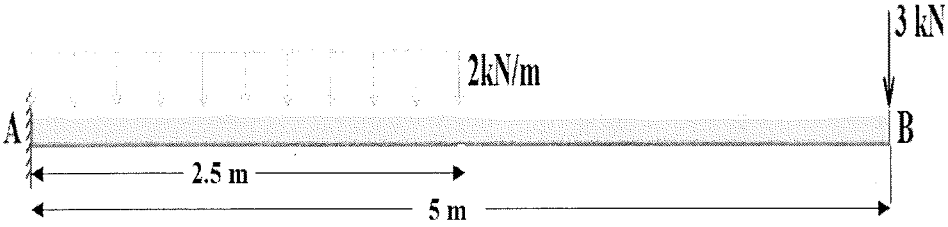
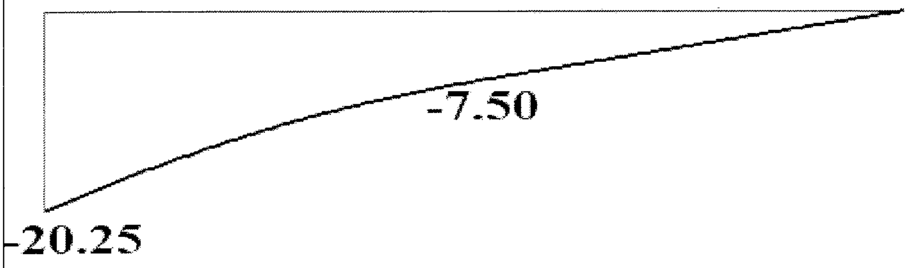
Explanation of notations – 3M</td><td>05 Minutes</td></tr>
<tr><td>4.</td><td>Torsional strength is defined as the torque required to produce unit shear stress. Torsional strength = (T/τ) = (J/R) = z
Torsional strength = Polar Section Modulus

Torsional stiffness or Torsional rigidity is defined as the torque required to produce unit angle of twist in unit length.
Torsional stiffness = GJ</td><td></td><td>05 Minutes</td></tr>
<tr><td>5.</td><td><table><tr><th>Short Columns</th><th>Long Columns</th></tr></table></td><td></td><td>05 Minutes</td></tr>
</table>

	Column having length less than 12 times its width is called short column. L/d < 12	Column having length less than 12 times its width is called short column. L/d > 12	2 Marks for each difference (02 x 02 M)
	Columns having slenderness ratio < 50	Columns having slenderness ratio > 50	
	Short columns are governed by compression failure.	Long columns are governed by buckling failure.	
	Rankine's formula is used to compute critical load of short columns.	Euler's formula is used to compute buckling load of long columns	
	(Note: Student is expected to write at least two differences)		

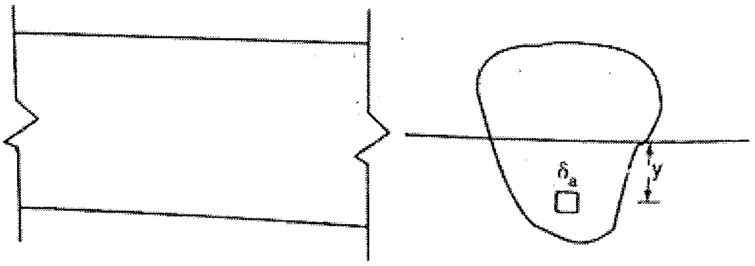
Part B (3Q x 10M = 30 Marks)

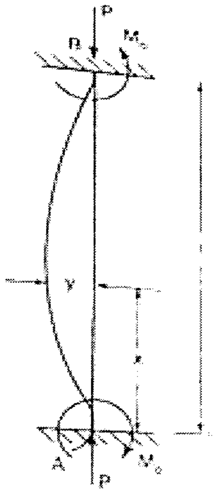
Q No	Solution	Scheme of Marking	Max. Time required for each Question
6	**a)** Support Reactions – R_A = 15 kN, R_B = 20 kN-m   **Shear Force Diagram (SFD)**  **Bending Moment Diagram (BMD)** **b)** Support Reactions – V_A = 8 kN, M_A = 21.25 kN-m	1M for Reactions 2M SFD 2M BMD	15 min

	  **Shear Force Diagram (SFD)**  **Bending Moment Diagram (BMD)**	1M for Reactions 2M SFD 2M BMD	15 Min
7	$\sigma_x = +40$ N/mm^2, $\sigma_y = +30$ N/mm^2, $\tau_{xy} = 15$ N/mm^2 Principal Stresses, $\sigma_{1,2} = \frac{1}{2}\left[(\sigma_x + \sigma_y) \pm \sqrt{\left(\sigma_x - \sigma_y\right)^2 + 4\tau_{xy}^2}\right]$ $\sigma_{1,2} = \frac{1}{2}\left[(40+30) \pm \sqrt{(40-30)^2 + 4 * (15)^2}\right]$ $\sigma_{1,2} = \frac{1}{2}\left[(40+30) \pm \sqrt{(40-30)^2 + 4 * 225}\right]$ **Major Principal Stress, σ_1 = 50.81 N/mm^2 (Tensile)** **Minor Principal Stress, σ_2 = 19.19 N/mm^2 (Tensile)** Principal planes, $\tan 2\theta = \frac{2\tau_{xy}}{(\sigma_x - \sigma_y)}$ $\tan 2\theta = \frac{2 \times 15}{(40-30)}$; $\tan 2\theta = 3$ So $\theta_1 = \tan^{-1}(3)/2 = 35.\ 78^\circ$; $\theta_2 = 35.\ 78^\circ + 90^\circ = 125.78^\circ$ **$\theta_1 = 35.\ 78^\circ$; $\theta_2 = 125.78^\circ$** Maximum shearing stress, $\tau_{max} = \pm (\sigma_1 - \sigma_2)/2 = (50.81 - 19.19)/2$ **Maximum shearing stress, $\tau_{max} = \pm$ 15.81 N/mm^2**	Principal stresses – 4M Principal planes – 4M Max. shear stress – 2M	15 min

8	$D_i = 0.6\ D_O$ Power, $P = 10kW = 10 \times 10^3$ W N = 150 rpm $P = \frac{2 \pi N T}{60000}$ Torque, $T = \frac{60000\ P}{2 \pi N}$ $T = \frac{60000 \times 10 \times 10^3}{2 \times \pi \times 150}$ T = 636619.77 N-mm	2M for computing Torque	25 Min
	i) Allowable shear stress, $\tau = 100$ N/mm^2 $\frac{T}{J} = \frac{\tau}{R_O}$ $J = \pi (D_O^4 - D_i^4)/64 = \pi (D_O^4 - 0.6^4 D_O^4)/64$ $J = 0.0427\ D_O^4$ $\frac{J}{R_O} = \frac{T}{\tau}$ $\frac{0.0427\ D_O^4}{D_O/2} = \frac{636619.77}{100}$; $\frac{0.0853\ D_O^4}{D_O} = 6366.97$ $0.0853\ D_O^3 = 6366.197$; $D_O^3 = 6366.197/0.0853$ $D_O^3 = 74642.09$ External Diameter, $D_O = 42.1mm \approx$ **43mm** Internal Diameter, $D_i = 0.6 * 43 =$ **25.8mm**	4M for external and internal diameter from shear stress condition	
	ii) Allowable twist, $\theta = 1.5° = 1.5 \times (\pi/180) = 0.02618$ radians L = 4m = 4000mm $\frac{T}{J} = \frac{G\ \theta}{L}$ $J = \pi (D_O^4 - D_i^4)/64 = \pi (D_O^4 - 0.6^4 D_O^4)/64$ $J = 0.0427\ D_O^4$ $J = \frac{T\ L}{G\ \theta}$ $J = \frac{636619.77 \times 4000}{80 \times 10^3 \times 0.02618} = 1215851.36$; $0.0427\ D_O^4 = 1215851.36$ $D_O^4 = 1215851.36/0.0427$; $D_O^4 = 28474270.63$; $D_O = (28474270.63)^{1/4}$ External Diameter, $D_O = 73.05mm \approx$ **74mm** Internal Diameter, $D_i = 0.6 * 74 =$ **44.4mm** **Hence, provide larger of the two diameters from shear stress and twist condition. $D_o = 74mm$, $D_i = 44.4mm$**	4M for external and internal diameter from stiffness condition or from allowable twist	

Part C (3Q x 10M = 30Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
9	i) Bending equation Consider an elemental area δa at distance y from neutral axis in the beam, the cross-section of which is shown in Fig. 4.6.  Fig. 4.6 Now stress 'f' on this element is given by $f = \frac{E}{R} y$ (from eqn.4.2) $\therefore$ Force on this element $= f\delta a$ $= \frac{E}{R} y\delta a$ Moment of this resisting force about neutral axis $= \frac{E}{R} y\delta a y = \frac{E}{R} y^2 \delta a$ $\therefore$ Total moment of resistance (M') of the cross-sectional area $M' = \Sigma \frac{E}{R} y^2 \delta a$ $M' = \frac{E}{R} \Sigma y^2 \delta a$ From the definition of moment of inertia, which is second moment of area about centroid, we can write $I = \Sigma y^2 \delta a$ where I is centroidal moment of inertia. $\therefore$ $M' = \frac{E}{R} I$ For equilibrium moment of resistance (M') should be equal to applied moment M *i.e.* $M' = M$ Hence, we get $M = \frac{E}{R} I$ or $\frac{M}{I} = \frac{E}{R}$ (3) From equation 1 and 3 we can write the *bending equation* as $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$ (4) where M — Bending moment I — Moment of inertia about centroidal axis f — Bending stress y — Distance of the fibre from neutral axis E — Young's modulus and R — Radius of curvature	Fig. – 2 M 4M 4M	20 min

	ii) Maximum bending stress in extreme fiber Width of beam, B = 200mm Depth of beam, D = 600mm Length of beam, L = 5m = 5000mm UDI, w = 50kN/m Maximum B.M., $M_{max} = wL^2/8 = 50*5^2/8$ M_{max} = 156.25 kN-m Depth of N.A. from extreme fiber, y_{max} = D/2 = 600/2 = 300mm Moment of Inertia, $I = B*D^3/12 = (200*600^3)/12 = 3.6 \times 10^9$ mm^4 The bending equation is given by, $\frac{f}{y} = \frac{M}{I} = \frac{E}{R}$ Bending stresses, $f_{max} = M_{max}.y/I$ Bending stresses, $f_{max} = (156.25 * 10^6 * 300)/ (3.6 \times 10^9)$ Bending stresses, f_{max} = 13.02 N/mm^2	2M 3M	15 Min
10	i) Euler's Crippling Load for column with both ends fixed Consider column *AB* of length *l* with fixed ends as shown in Fig. . Let end moment developed be M_0. Now the bending moment at any point is given by $EI\frac{d^2y}{dx^2} = M_0 - Py$ *i.e.* $\frac{d^2y}{dx^2} + \frac{Py}{EI} = \frac{M_0}{EI}$ The solution of the above differential equation is $y = C_1\cos\left(x\sqrt{P/EI}\right) + C_2\sin\left(x\sqrt{P/EI}\right) + \frac{M_0}{P}$ $\therefore \frac{dy}{dx} = -C_1\sqrt{P/EI}\sin\left(x\sqrt{P/EI}\right) + C_2\sqrt{P/EI}\cos\left(x\sqrt{P/EI}\right)$  From condition $\frac{dy}{dx} = 0$ at $x = 0$, we get $0 = C_2\sqrt{P/EI}$ Since *P* cannot be zero, $C_2 = 0$ At $x = 0$ $y = 0$ $0 = C_1 + \frac{M_0}{P}$ $C_1 = -\frac{M_0}{P}$ $\therefore y = -\frac{M_0}{P}\cos\left(x\sqrt{P/EI}\right) + \frac{M_0}{P}$ From the boundary condition $y = 0$ at $x = l$, we get $0 = -\frac{M_0}{P}\cos\left(l\sqrt{P/EI}\right) + \frac{M_0}{P}$ or $\cos\left(l\sqrt{P/EI}\right) = 1$ $\therefore l\sqrt{P/EI} = 0, 2\pi, 4\pi \ldots$ Taking the least significant value we get $l\sqrt{P/EI} = 2\pi$ or $P = \frac{4\pi^2 EI}{l^2}$	Fig. – 2M Diff. Eq. and Soln. – 2M Boundary Cond. – 2M Final expression - 1M	20 min

	ii) Slenderness ratio Length of Column, L = 6m = 6000mm Diameter of Column, D = 100mm Area of Column, $A = \pi * D^2/4 = \pi * 100^2/4 = 7.85 \text{ x } 10^3 \text{ mm}^2$ Moment of Inertia, $I = \pi * D^4/64 = \pi * 100^4/64 = 4.91 \text{ x } 10^6 \text{ mm}^4$ Slenderness ratio = L_e/k Effective length, $L_e = (L/2) = (6000/2) = 3000$mm (Both ends fixed) $k = \sqrt{\frac{I}{A}} = \sqrt{\frac{4.91 \text{ x } 10^6}{7.85 \text{ x } 10^3}}$ k = 25mm Slenderness ratio = L_e/k Slenderness ratio = (3000/25) Slenderness ratio = 120 iii) Safe Compressive Load that the column can carry $E = 2 \text{ x } 10^5 \text{ N/mm}^2$, Factor of Safety, FOS = 3 $L_e = L/2$ (Both ends fixed) = 6000 / 2 = 3000 mm $P_{cr} = \pi^2 EI/L_e^2 = \pi^2 * 2 \text{ x } 10^5 * 4.91 \text{ x } 10^6 / 3000^2 = 1076.88 \text{ x } 10^3 \text{ N}$ $P_{cr} = 1076.88 \text{ x } 10^3$ N or 1076.9 kN $P_{safe} = P_{cr}$ / FOS = 1076.9/3 **P_{safe} = 358.97 kN**	Det. of Effective Length, L_e – 1 M Det. of k – 1M Det. of slenderness ratio, k – 1M Euler's Crippling Load – 3M Safe Load - 2M	15 Min 15 Min