



# TOBB EKONOMİ VE TEKNOLOJİ ÜNİVERSİTESİ

**Department of Mechanical Engineering**

## **MAK 206 STRENGTH OF MATERIALS**

*2016-2017 Spring*  
Midterm

Dr. Mehmet Ali Güler

Name \_\_\_\_\_

05 March 2017, Sunday

Student # \_\_\_\_\_

Duration of Examination: **2 hours (16:00-18:00)**

QUESTION	Maximum Point	Points
1	20	
2	35	
3	35	
4	35	
<b>Total</b>	<b>125</b>	

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### **ÖNEMLİ UYARI !!!**

Yükseköğretim Kurumları Öğrenci Disiplin Yönetmeliği Madde 9-m'ye göre "sınavlarda kopya yapmak veya yaptırmak veya bunlara teşebbüs etmek" fiilinin suçu YÜKSEKOĞRETİM KURUMUNDAN BİR VEYA İKİ YARIYIL İÇİN UZAKLAŞTIRMA cezasıdır.

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#### **Özel Sınav Kuralları:**

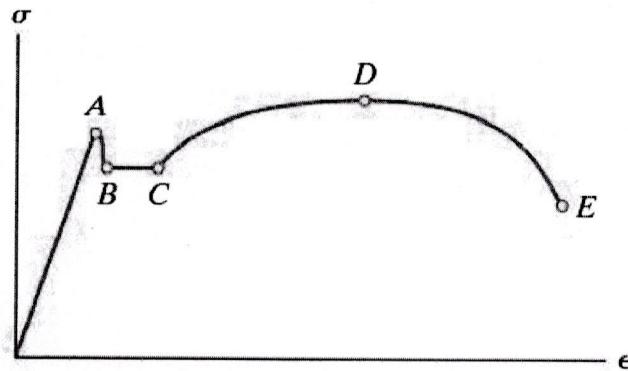
Sınav süresince cep telefonları kapalı konumda olmak suretiyle sıra üzerine konulmalıdır.

**UYARI VE KURALLARI OKUDUM.**

**Öğrencinin İmzası:**

**Adı Soyadı :.....**

Ön sayfa dahil, bu sınav kağıdında toplam (9) sayfa vardır.



(a) Define the points on the stress-strain diagram

- A point : Proportional limit
- B-C points : Yield stress
- D point : Ultimate stress
- E point : Fracture (Failure) stress

(b) Define the modulus of elasticity E.

The slope of stress-strain curve in the elastic deformation region

(c) Define the shear modulus of elasticity G.

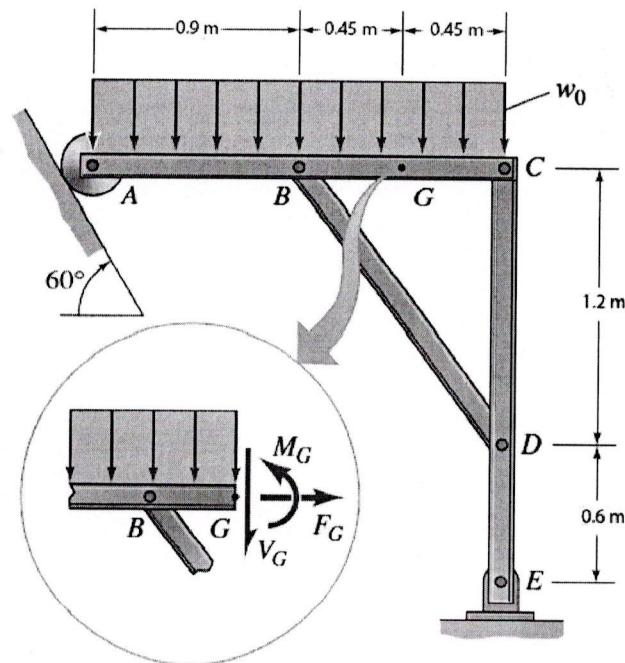
The slope of shear stress - shear strain curve in the elastic deformation region

(c) Define the relationship between E and G.

$$G = \frac{E}{2(1+\nu)}$$

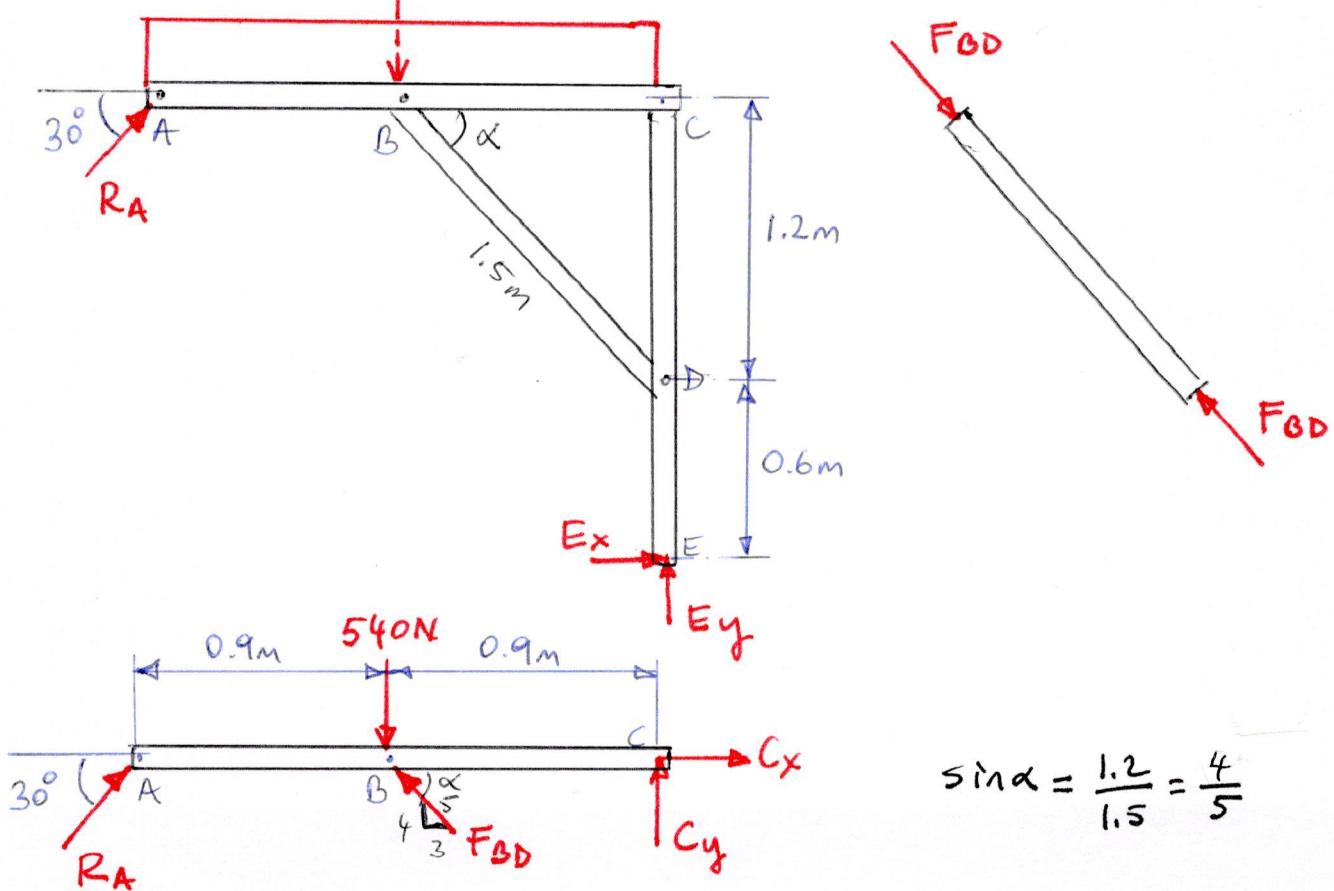
$\nu$ : Poisson's ratio

## Question 2: (35 points)



The pins at B and D apply an axial load to diagonal bracing member BD. If BD has a rectangular cross section measuring  $12.5 \text{ mm} \times 50 \text{ mm}$ , what is the axial stress in member BD when the load is  $w_0 = 300 \text{ N/m}$ ?

$$(300)(1.8) = 540 \text{ N}$$



$$\rightarrow \sum M_E = 0 : R_A \cos 30 (1.8) + R_A \sin 30 (1.8) - 540 (0.9) = 0$$

$$R_A = 197.65 \text{ N}$$

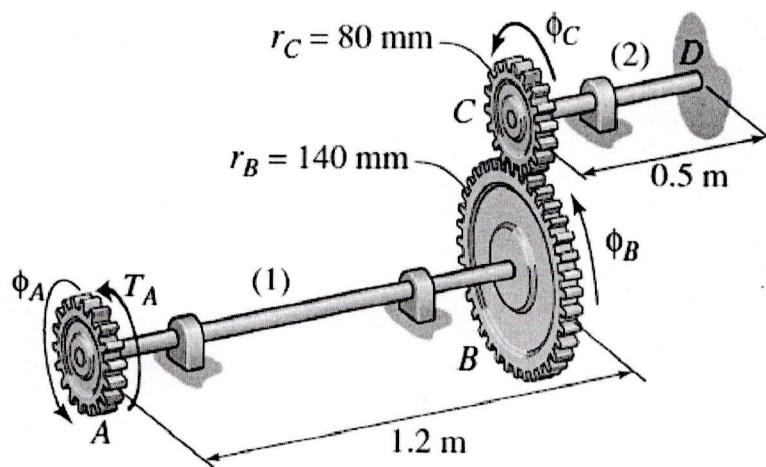
$$\rightarrow \sum M_C = 0 : R_A \sin 30 (1.8) - 540 (0.9) + F_{BD} \sin \alpha (0.9) = 0$$

$$F_{BD} = \frac{-R_A \sin 30 (1.8) + 540 (0.9)}{\left(\frac{4}{5}\right)(0.9)}$$

$$F_{BD} = 428.125 \text{ N}$$

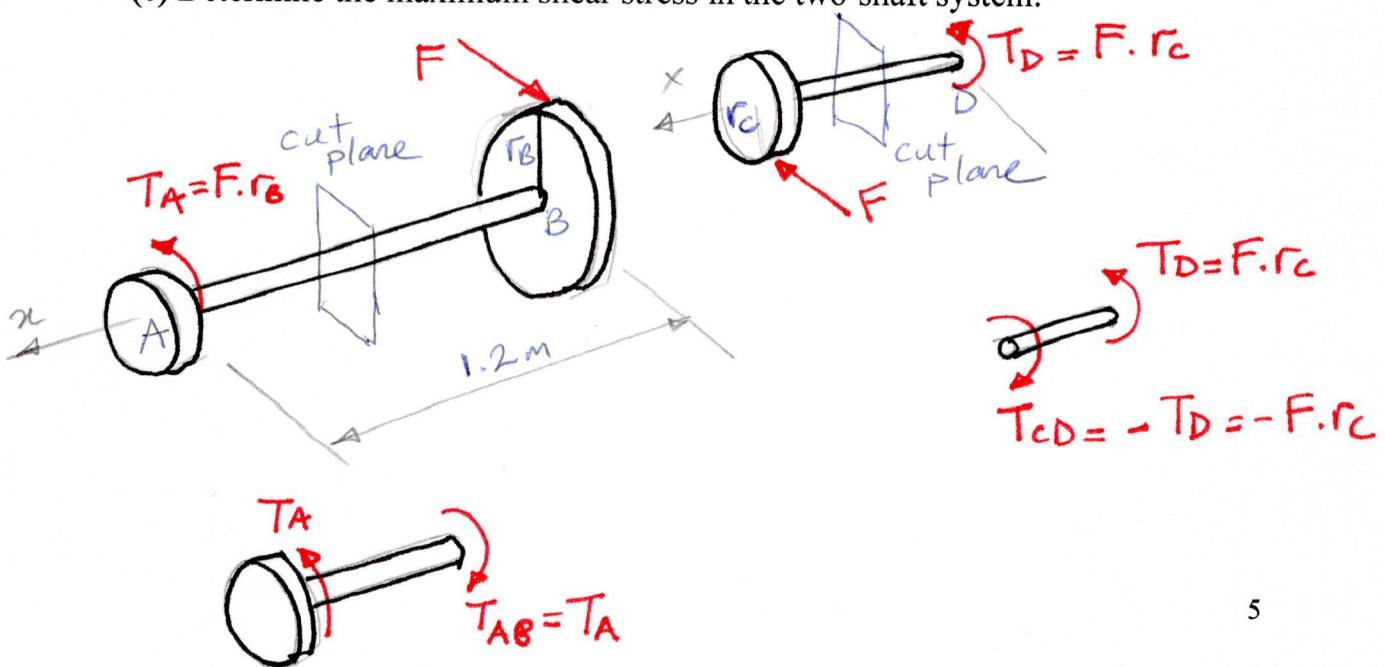
$$\sigma_{BD} = \frac{F_{BD}}{A_{BD}} = \frac{428.125}{(12.5)(50)} = 0.685 \text{ MPa} = 685 \text{ kPa}$$

## Question 3: (35 points)



A torque  $T_A$  is applied to gear A of the two shaft system in Figure, producing a rotation  $\varphi_A = 0.05 \text{ rad}$ . The shafts are made of steel ( $G = 80 \text{ GPa}$ ), and each has a diameter of  $d = 32 \text{ mm}$ . The shafts are supported by frictionless bearings, and end D of shaft CD is restrained.

- (a) Using the Displacement Method, determine the angle of rotation of gear C and the angle of rotation at gear B.
- (b) Determine the internal torques in shafts (1) and (2).
- (c) Determine the maximum shear stress in the two-shaft system.



$$\sum M_x=0 : T_A - F \cdot r_B = 0$$

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$$T_A = F \cdot r_B$$

$$\sum M_x=0 : F \cdot r_C - T_D = 0$$

$$T_D = F \cdot r_C$$

$$T_{AB} = T_A = F \cdot r_B$$

$$T_{CD} = -T_D = -F \cdot r_C$$

$$\phi_{A/B} = \frac{T_{AB} \cdot L_{AB}}{JG} = \frac{F \cdot r_B \cdot (1200)}{\frac{\pi}{32} (32)^4 \cdot 80 \times 10^3} = 2.04 \times 10^{-5} F$$

$$\phi_{C/D} = \frac{T_{CD} \cdot L_{CD}}{JG} = \frac{-F \cdot r_C \cdot (500)}{\frac{\pi}{32} (32)^4 \cdot 80 \times 10^3} = -4.857 \times 10^{-6} F$$

Also

$$\phi_A = \phi_B + \phi_{A/B}$$

$$\phi_C = \cancel{\phi_D}^0 + \phi_{C/D} = \phi_{C/D}$$

Also

$$r_B \phi_B = -r_C \phi_C \Rightarrow \phi_B = -\frac{r_C}{r_B} \phi_C = -\frac{r_C}{r_B} \phi_{C/D}$$

$$\rightarrow \phi_A = -\frac{r_C}{r_B} \phi_{C/D} + \phi_{A/B}$$

$$= -\frac{80}{140} (-4.857 \times 10^{-6} F) + 2.04 \times 10^{-5} F$$

$$= 2.3175 \times 10^{-5} F$$

$\phi_A$  is given as 0.05 rad

Therefore

$$0.05 = 2.3175 \times 10^{-5} F \Rightarrow$$

$$F = 2157.46 N$$

$$T_{AB} = F \cdot r_B = 302044.4 \text{ N mm}$$

$$T_{CD} = -F \cdot r_C = -172596.8 \text{ N mm}$$

$$a) \phi_C = \phi_{C/D} = -4.857 \times 10^{-6} F \Rightarrow \boxed{\phi_C = -10.48 \times 10^{-3} \text{ rad}}$$

$$\phi_B = -\frac{r_C}{r_B} \phi_C = -\frac{80}{140} (-10.48 \times 10^{-3}) \Rightarrow \boxed{\phi_B = 5.99 \times 10^{-3} \text{ rad}}$$

b) Internal Torques are

$$T_{AB} = 302044.4 \text{ N mm} = 302.04 \text{ N.m}$$

$$T_{CD} = -172596.8 \text{ N.mm} = -172.6 \text{ N.m}$$

c) Maximum shear stress

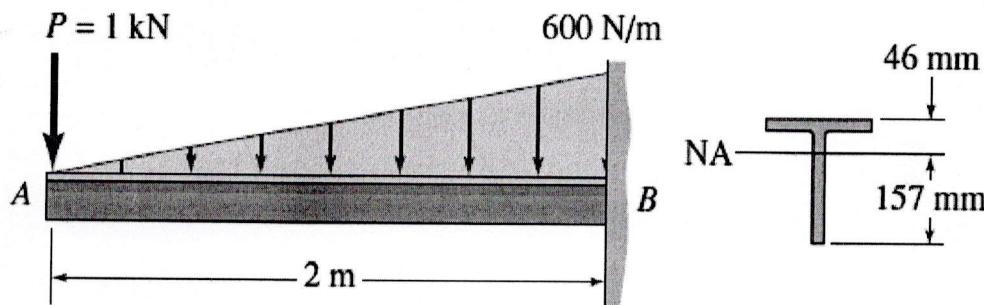
$$(\tau_{\max})^{AB} = \frac{T_{AB} \cdot (d/2)}{\frac{\pi d^4}{32}} = \frac{16 T_{AB}}{\pi d^3} = \frac{16 (302044.4)}{\pi (32)^3}$$

$$(\tau_{\max})^{AB} = 46.9 \text{ MPa}$$

$$(\tau_{\max})^{CD} = \frac{T_{CD} (d/2)}{\frac{\pi d^4}{32}} = \frac{16 T_{CD}}{\pi d^3} = \frac{16 (172596.8)}{\pi (32)^3}$$

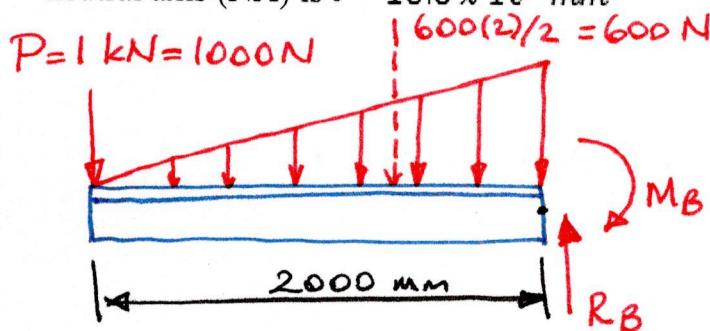
$$(\tau_{\max})^{CD} = 26.8 \text{ MPa}$$

## Question 5: (30 points)



A structural tee section is used as a cantilever beam to support a triangular distributed load of maximum intensity  $w = 600 \text{ N/m}$  and a concentrated load  $P = 1 \text{ kN}$ , as shown in Figure.

- (a) Draw the shear and moment diagrams for the beam.
- (b) Determine the maximum tensile flexural stress and the maximum compressive flexural stress at end B. The relevant dimensions of the cross section are shown in the figure, and the moment of inertia about the neutral axis (NA) is  $I = 13.8 \times 10^6 \text{ mm}^4$



$$(+\uparrow \sum F_y = 0)$$

$$R_B - 1000 - 600 = 0$$

$$R_B = 1600 \text{ N}$$

$$+\odot \sum M_B = 0$$

$$M_B - (1000)(2000)$$

$$-(600)\left(\frac{2000}{3}\right) = 0$$

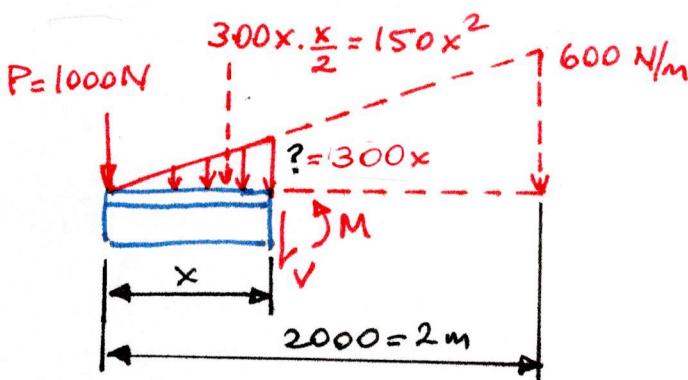
$$M_B = 2400000 \text{ N.mm} = 2400 \text{ N.m}$$

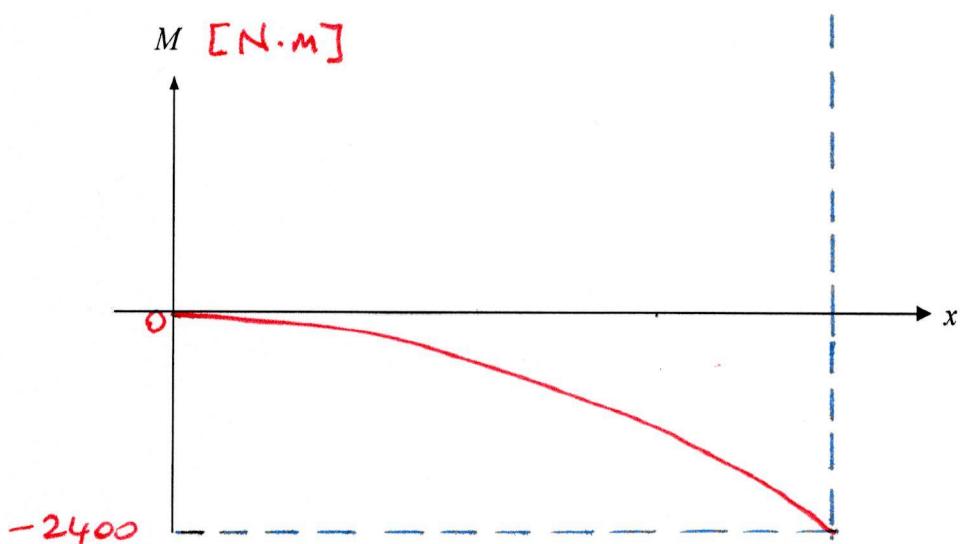
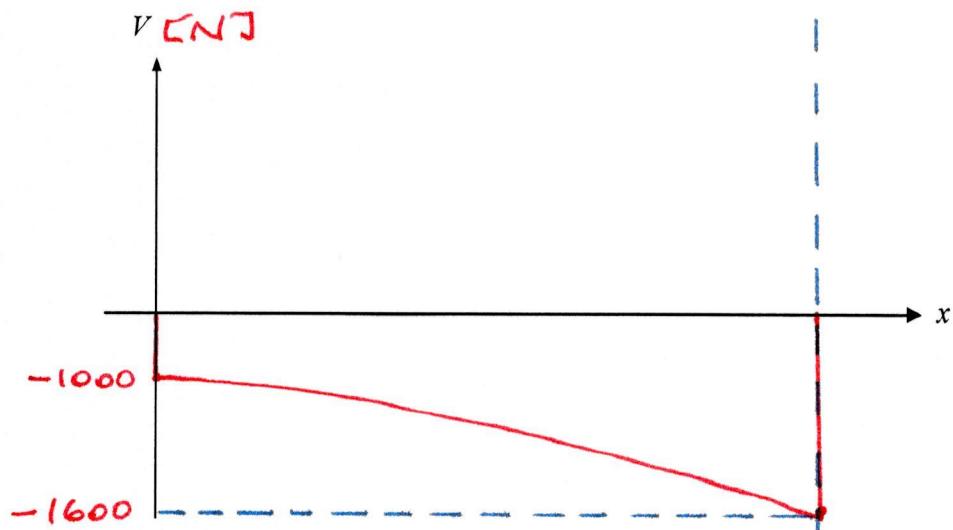
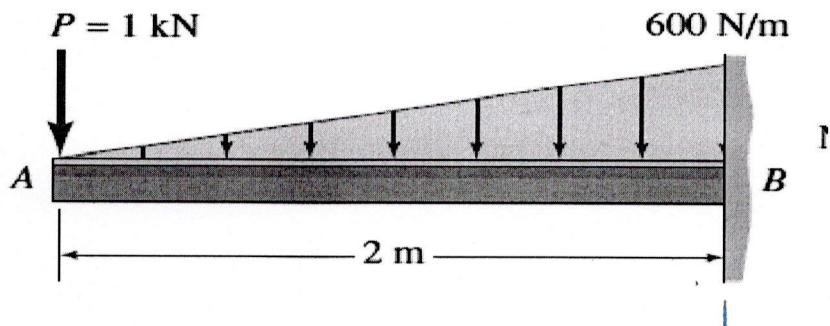
$$= 2.4 \times 10^6 \text{ N.mm}$$

$$\frac{?}{600} = \frac{x}{2}$$

10

$$? = 300x$$





$$\uparrow \sum F_y = 0 \quad -1000 - V - 150x^2 = 0 \Rightarrow V = -1000 - 150x^2$$

$$x=0 \Rightarrow V = -1000 \text{ N}$$

$$x=2 \Rightarrow V = -1600 \text{ N}$$

$$\sum M = 0 \quad 1000x + 150x^2 \cdot \frac{x}{3} + M = 0$$

$$M = -1000x - 50x^3$$

$$x=0 \Rightarrow M=0$$

$$x=2 \Rightarrow M = -2400 \text{ N.m}$$

b) Maximum tensile flexural stress is at  
 $y = 46 \text{ mm}$

$$\sigma_B^{\text{tensile}} = -\frac{M \cdot y}{I} = -\frac{-2.4 \times 10^6 \cdot (46)}{13.8 \times 10^6 \text{ mm}^4} = 8 \text{ MPa (tension)}$$

$$\sigma_B^{\text{comp}} = -\frac{M \cdot y}{I} = -\frac{-2.4 \times 10^6 (-157)}{13.8 \times 10^6 \text{ mm}^4} = -27.3 \text{ MPa (comp)}$$