2022 SECOND SEMESTER FINAL EXAMINATION

Faculty: **Engineering and the Environment**

Department: **Metallurgical Engineering**

Paper Code/Title: **EMR 2202 Solid Mechanics**

Duration: **3 Hours**

Examiner: **Eng S. Hobwana**

Additional Requirement

Graph paper

Calculators

Data Tables

INSTRUCTIONS TO CANDIDATES

1. Answer **ANY FOUR** questions
2. Start the answer to each question on a fresh page.
3. Show all your working.
4. Each question carries **25 marks**.
5. This question paper comprises 5 printed pages including cover page.

Question 1

a) Rigid bar AB shown in **Figure 1** is pinned at A and is initially horizontal, supported by two vertical circular rods CD and EB. The brass rod CD has a diameter of 25mm while the diameter of the steel rod, EB, is 20mm.

Determine the stress in each rod when the force of 150kN is applied as shown. The weights of AB, CD and EB may be neglected. **[10 marks]**

Elastic modulus of brass = 70 x 10^3 N/mm^2
Elastic modulus of steel = 200 x 10^3 N/mm^2

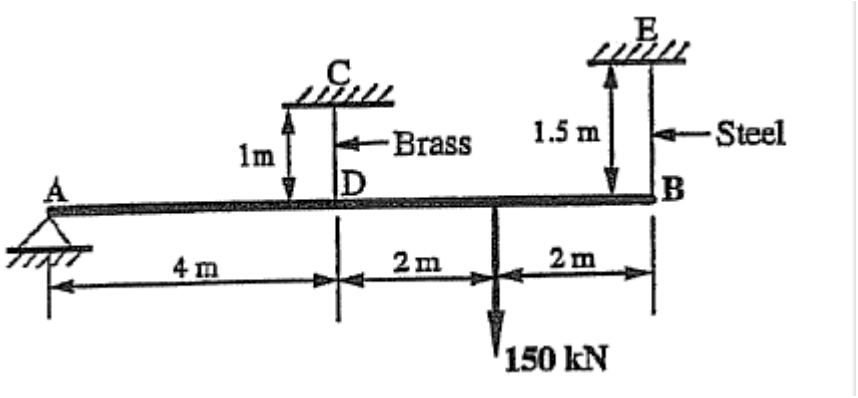


Figure 1

b) An I-beam is made of three wooden planks glued together as shown in **Figure 2**. The beam is to carry a concentrated load of 100kN at its mid-span as shown in **Figure 3**. **[15 marks]**

Determine:

1. Draw a shear force diagram and Calculate I_{xx} **[5 marks]**
2. The shear stress in the glued joint. **[5 marks]**
3. The maximum shear stress in the wood **[5 marks]**

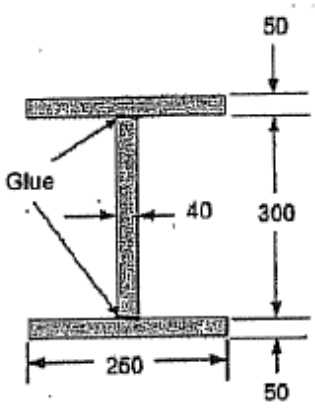


Figure 2

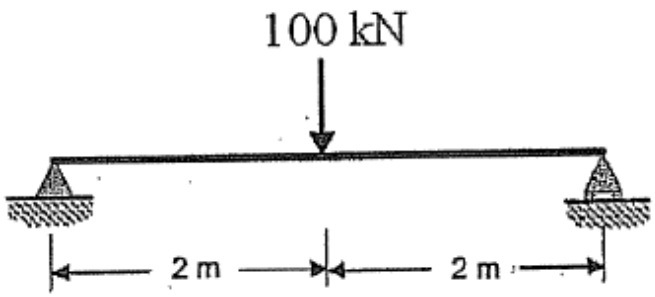


Figure 3

Question 2

a) An axially loaded composite bar consists of steel and aluminum (two materials are bonded together) as shown in **Figure 4**. The bar is fixed at end A. The force F=120 kN is to be positioned so that the bar is to elongate uniformly. The elastic moduli of steel and aluminum are $E_s=210\times10^3$ MPa and $E_a=70\times10^3$ MPa, respectively. Determine

1. the normal stress σ_x in each material; **[10 marks]**
2. the normal strain of the member ε_x; **[2 marks]**
3. the value of *e* such that the force F causes uniform strain. **[3 marks]**

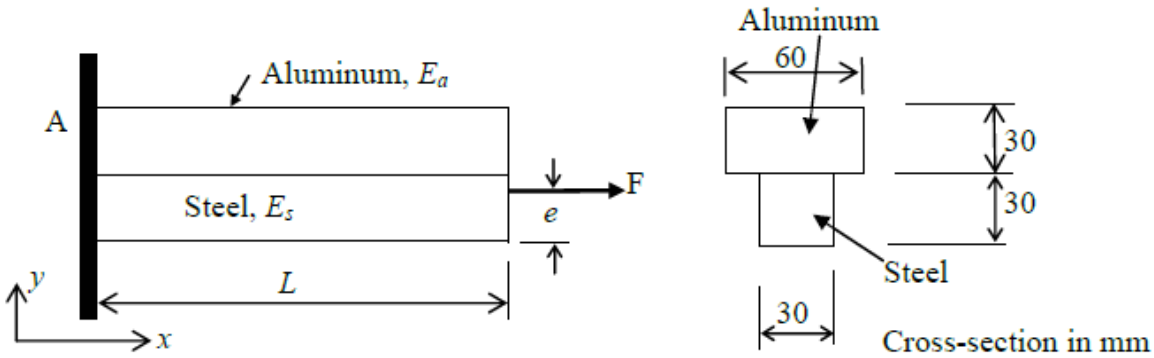


Figure 4

b) The composite shaft shown in **Figure 5** consists of a 5 mm thick brass jacket (Gb = 39 GPa) bonded to a 40 mm diameter steel core (Gst = 77 GPa). The shaft is subjected to a 600 N.m torque, determine

1. the maximum shearing stress in the brass jacket, **[6 marks]**
2. the maximum shearing stress in steel core, **[2 marks]**
3. the angle of twist of B relative to A. **[2 marks]**

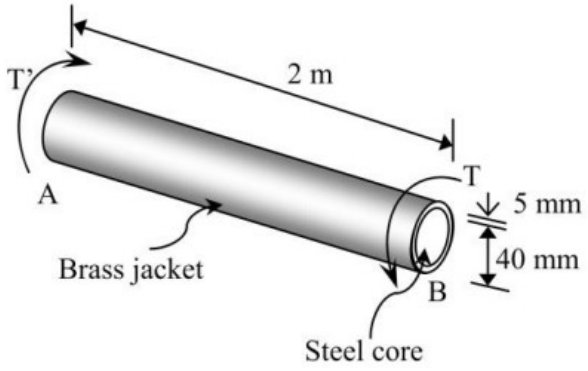


Figure 5

Question 3

Figure 6 shows a curved beam of C-section. The beam is subjected to a bending moment M = 1 kNm which tends to "straighten" it as shown.

a) Determine the radius of the neutral surface of the section **[9 marks]**

b) Determine the radius of the centroid of the section and the difference between this and the radius of the neutral surface **[4 marks]**

c) Determine the maximum tensile bending stress in the beam **[6 marks]**

d) Determine the maximum compressive bending stress in the beam **[6 marks]**

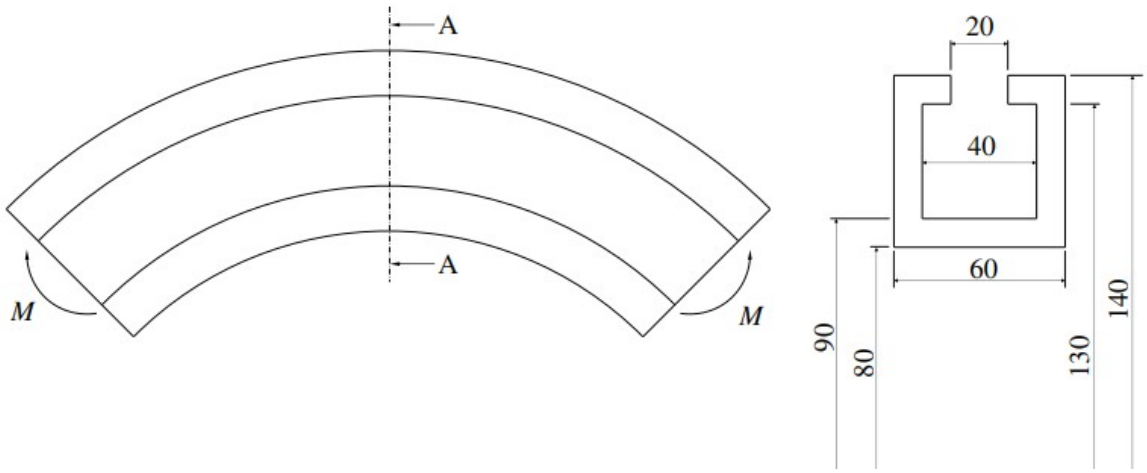


Figure 6 (dimensions in mm)

Question 4

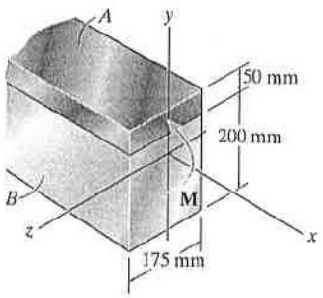
A solid steel shaft of external diameter 50 mm is pressed into a steel cylinder of external diameter 70 mm. The diametral interference of the fit is 10 μm, and the length of the contact area is 50 mm. Assume E = 210 GPa, ν = 0.3 for both components.

a) Calculate the contact pressure between shaft and cylinder. **[12 marks]**

b) What is the maximum hoop stress induced in the cylinder due to the shrink fit? **[4 marks]** c) If the coefficient of friction between the shaft and the cylinder is μ = 0.2, what is the maximum torque that can be transferred by the assembly without slippage? **[9 marks]**

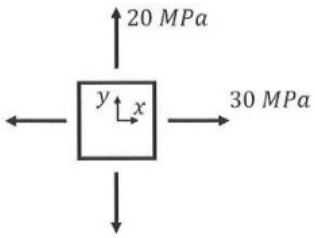
Question 5

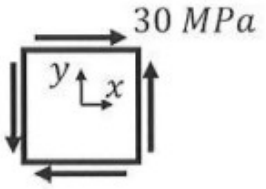
a) The composite beam is made of steel (A) bonded to brass (B) and has the cross section shown. If the allowable bending stress for the steel is $(\sigma_{allow})_{st}$ = 180MPa, and for the brass $(\sigma_{allow})_{br}$ = 60MPa, determine the maximum oment M that cn be applied to the beam.
Ebr = 100GPa,Est = 200GPa **[10 marks]**



b) Draw Mohr's circle for the following Stress elements **[8 marks]**

1. 2.



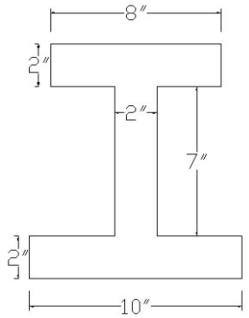


c) When the material is stressed beyond the yield point, permanent deformation will occur. In particular, steel has a region of yielding, whereby the material will exhibit an increase in strain with no increase in stress. The region of strain hardening causes further yielding of the material with a corresponding increase in stress. Finally, at the ultimate stress, a localized region on the specimen will begin to constrict, forming a neck. It is after this that the fracture occurs. Illustrate this in a stress strain diagram showing the elastic region, plastic region, yielding, strain hardening and necking regions. **[7 marks]**

Question 6

a) A machine component with given critical stresses is ductile, with yield strengths in tension and compression of 60 ksi (kilopound per square inch). Determine the safety factor according to**:**
   1. The maximum-normal-stress theory **[3 marks]**
   2. The maximum-shear-stress theory **[3 marks]**
   3. The maximum-distortion-energy theory **[3 marks]**
   4. Which of the above mentioned theories is best applicable in their order **[1 mark]**

b) Find the centroid of I-section given below. **[12 marks]**



c) Define the following terms?
   1. Moment of inertia **[2 marks]**
   2. Center of gravity **[1 mark]**

END OF QUESTION PAPER!!!