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# THE INSTITUTION OF ENGINEERS, SRI LANKA

**PART I EXAMINATION – APRIL 2009**

## 103 PROPERTIES & STRENGTH OF MATERIALS

Time Allowed: 3 hours

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Answer **Five (5)** questions selecting at least two (02) from each of the two sections **A and B.**

**Use Separate answer books for each section.**

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### SECTION A

(1)

a. Sketch the Fe-$Fe_3C$ equilibrium phase diagram. [*10 marks*]

b. Sketch and name the microstructures expected at room temperature in the following cases:

I. Fe + 0.02%C alloy slowly cooled from $950^0C$
II. Fe + 0.4%C alloy slowly cooled from $950^0C$
III. Fe + 0.8%C alloy slowly cooled from $900^0C$
IV. Fe + 0.4%C alloy rapidly quenched from $950^0C$ [*08 marks*]

c. Calculate the relative proportions of the phases obtained in part **b(II)** above. [*02 marks*]

2)

a. For a radioactive isotope, show that the product of radioactive decay constant (λ) and the half-life (T) will be 0.69315. [*04 marks*]

b. Activity of a radioactive isotope falls to 25% of its original value in 50 days. How long would it take for the activity to fall to 5% of its original value? When will be the activity becomes zero? [*08 marks*]

c. Calculate the amount of energy released by 1kg of deuterium due to the fusion of deuterium nuclei to form He-3 nuclei. Relative atomic masses of deuterium, neutron and helium are 2.015, 1.009, and 3.017 respectively. Assume that destruction of 1g of mass produces $931 \times 6.023 \times 10^{23}$ MeV of energy.
Take $1eV = 1.6 \times 10^{-19}$ J [*06 marks*]

d. State the major difference between *fissile isotopes* and *fertile isotopes*. [*02 marks*]



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3)

a. Sketch the unit cells of BCC and FCC crystal structures. [*02 marks*]

b. Show the atomic arrangements of the planes having the closest packing in BCC and FCC lattices. [*04 marks*]

c. An X-ray diffractometer recorder chart for an element which has a cubic structure (simple cubic, bcc or fcc) shows diffraction peaks at the angles of deviation of $40^0$, $46.5^0$, $68^0$, $82^0$, $86^0$ and $104^0$. The wavelength of the X-ray is 0.15nm. Determine the crystal structure and lattice parameter of the element used. [14 *marks*]

4)

a. Describe the tensile test. [*06 marks*]

b. Sketch the tensile stress-strain diagram for pure copper and explain how you would determine the elastic modulus, yield strength, ductility and toughness of the material from the diagram. [*06 marks*]

c. Give a detailed description of the mechanism of fatigue using an example of your choice. [*08 marks*]



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## SECTION B

(5) Figure Q.5 shows a beam ABCD of length L, with supports at B and C, positioned at a distance $\alpha L$ from the ends of the beam. The beam is subjected to a uniformly distributed load of w per unit length.

a. Calculate the reactions at B and C due to this load. [2 marks]

b. Sketch a shear force and a bending moment diagram for the case $\alpha = 0.25$, indicating salient values. [6 marks]

c. Show by adding dashed lines to your plots from (b) the effects of decreasing $\alpha$ to 0.2, and the effect of increasing $\alpha$ to 0.3. (Salient values are not required). [5 marks]

d. Derive expressions for the bending moment in the beam as a function of x and $\alpha$:
   (i) for AB, $0 \le x \le \alpha L$ , $0 \le \alpha \le 0.5$;
   (ii) for BC $\alpha L \le x \le (1-\alpha)L$ , $0 \le \alpha \le 0.5$. [4 marks]

e. Show from your answers to (d) that the value of $\alpha$ that minimises the maximum magnitude of the bending moment carried by the beam is $\alpha = \left(\sqrt{2}-1\right)/2$. [3 marks]

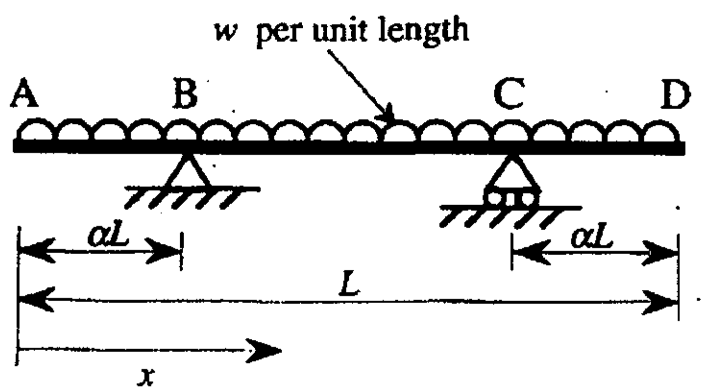


**Figure Q.5**

(6) Cross section of a steel I beam, which is simply supported over span of 5.0 m is shown in Figure Q.6. If the allowable stresses in tension and compression are limited to 150 N/mm$^2$, find the maximum weight of a point load that can be carried across the beam without exceeding the allowable stresses.





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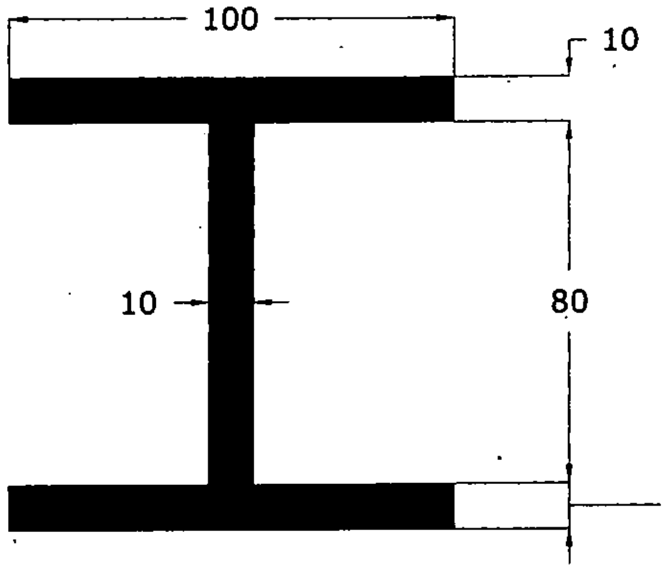


**Figure Q.6**
(All dimensions are in millimetres)

(7) A propped cantilever, of length L, is loaded by a uniformly distributed load of intensity q kN/m over its central third, as shown in Figure Q.7. Show that the maximum deflection occurs at 0.56L from the fixed end using Macaulay's method.

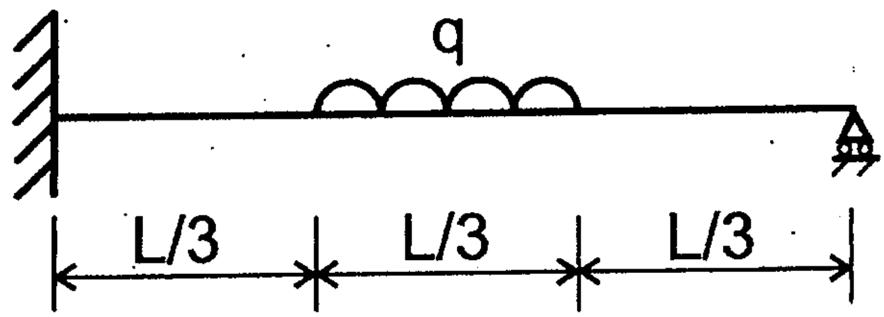


**Figure Q.7**



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(8) An initially straight pin-ended strut is loaded by a force **P** applied at an eccentric[ity] which represents a misalignment between the strut and the load it is designed to carry, a[s] shown in Figure Q.8.

a. Why a small error in the load position more important when dealing with struts and columns, and less important when dealing with beams loaded primarily in flexure? [4 marks]

b. By considering a deflection of the strut, **v**, measured from the undeformed position, derive the governing differential equation for the deflection. [5 marks]

c. Show that the solution of this differential equation takes the form

$$v = A\sin\alpha x + B\cos\alpha x + C$$

What are the coefficients A, B, C and α? [7 marks]

d. A strut has an eccentricity **e** that is 1% of its length. If it is loaded by an axial force that is 50% of the Euler buckling load of the strut, determine the lateral displacement of the strut at its centre and hence determine its maximum bending moment. [4 marks]

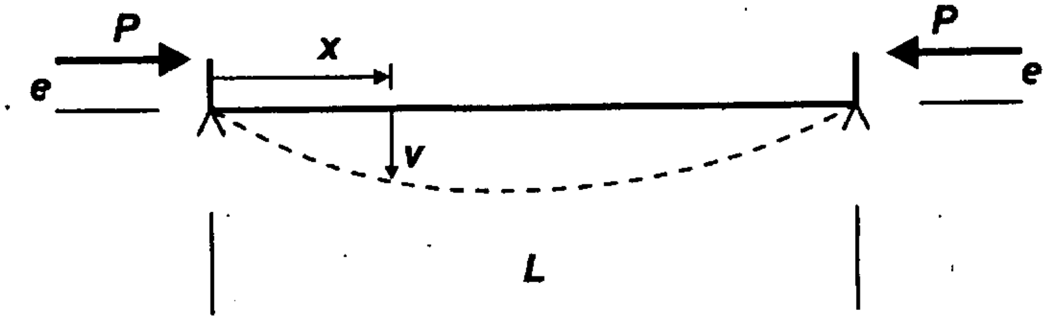


**Figure Q.8**



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