UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2022

Module Number: ME3206 **Module Name: Strength of Materials**

[Three Hours]

[Answer **all questions,** each question carries 12 marks]

Q1. a) Explain followings

i Stress at a point

ii Normal Stress and Shear Stresses

iii Principal stress and principal planes

[3.0 Marks]

b) Consider a mechanical component under direct load F_1 and F_2 giving rise to stresses σ_y and σ_x vertically and horizontally as shown in Figure Q1.

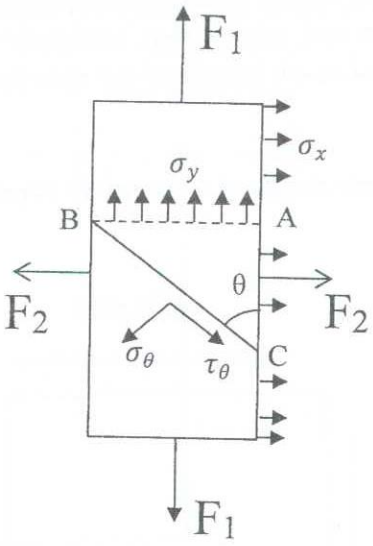

Figure Q1

Derive equations to find τ_θ (shear stress along BC plane) and σ_θ (normal stress to BC plane).

[3.0 Marks]

c) By examining the equations, conclude the followings;

i Maximum normal stress

ii Maximum shear stress

[2.0 Marks]

d) A cast iron block of 10 cm^2 cross-section carries an axial tensile load of 50 kN. Calculate;

i Magnitude of the normal stress and shear stress on a plane inclined at 30^0 to the axis of the block

ii Maximum shear stress in the block

[4.0 Marks]

Q2. a) Derive an expression for the theoretical fracture strength of a material.

[4.0 Marks]

b) Modulus of elasticity of steel is 25×10^{10} Pa. Calculate the theoretical fracture strength of steel.

[2.0 Marks]

c) In actual fracture strength of steel is 22.7×10^9 Pa. Is there any difference between actual and theoretical fracture strength values of steel?. If it is so, what are the reasons for that?

[2.0 Marks]

d) What do you understand by Stress Intensity Factor and Critical Stress Intensity Factor (Fracture toughness)?

(Clue- $K_I = \sigma\sqrt{\pi a} f(\alpha, a)$)

[2.0 Marks]

e) Suppose that a wind component on an aircraft is fabricated from an aluminum alloy. During an experiment, it has been determined that a fracture occurs at a stress of 450 MPa when the maximum internal crack length is 2.6 mm. For this same component and same alloy, compute the stress level at which fracture will occur for a critical crack length of 4.8 mm (internal).

[2.0 Marks]

Q3. a) The state of plane stress at a point is represented by the stress element below (Figure Q3).

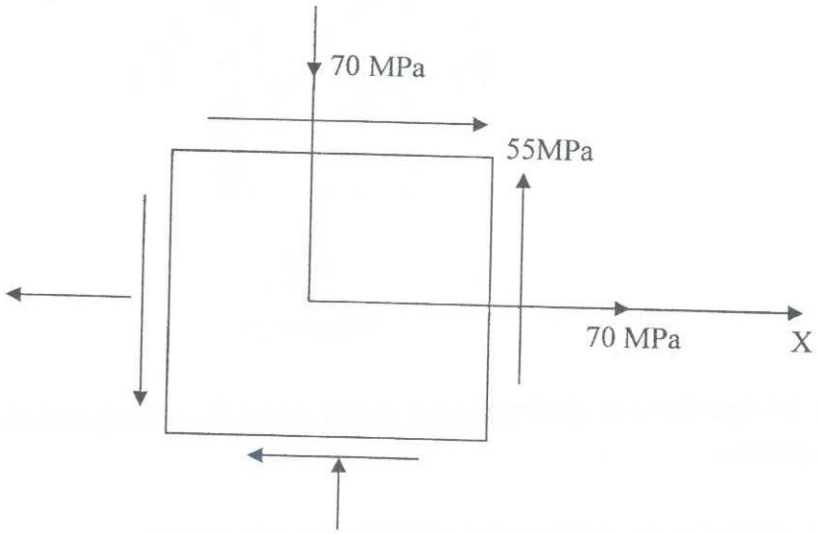

Figure Q3

Draw the corresponding Mohr's stress circle for the above stress system.

[3.0 Marks]

b) Find the stresses on an element inclined at 230° clockwise and draw the corresponding stress elements.

[3.0 Marks]

c) Calculate (or find using corresponding Mohr's stress circle) the principal stresses and the planes on which they act.

[3.0 Marks]

d) What would be the effect on above results if owing to a change of tensile loading to compressive while shear stresses remain unchanged?

[3.0 Marks]

Q4. a) What do you understand by 'fatigue' failure of materials?

[2.0 Marks]

b) What are the stages of fatigue failure and explain them briefly with suitable sketches.

[3.0 Marks]

c) What are the roles of the following kinds of stress in fatigue failure?
   i Compressive stress
   ii Tensile stress

[2.0 Marks]

d) State the Miner's law of cumulative fatigue.

[2.0 Marks]

e) **Figure Q4** shows a part of *S-N* curve of a metallic material. Rotating shaft of a machine was fabricated by above mentioned metal. When it was used following rotations had been done.

Stress (MPa)	Number of cycles operated (Under particular stress)
400	4×10^3
160	1×10^2

Due to a new requirement, operating stress is changed to 240 MPa. Then how many further rotations can it be operated before failure?

[3.0 Marks]

Q5. a) What is the Griffith's criterion for fracture of brittle materials?

[2.0 Marks]

b) Using the above mentioned (Q5. a)) criterion show the fracture strength of a material,

$$\sigma_f = \sqrt{\frac{8E\gamma_s}{\pi a(1+\upsilon)(1+k)}}$$

Where,

σ_f - Fracture strength of a material
E - Modulus of elasticity and
γ_s - Specific surface energy of a fractured surface.
υ - Poisson's ratio
a - Half-length of a crack

If

$$k = \frac{3-\upsilon}{1+\upsilon}$$

derive an expression for fracture strength for plane stress conditions.

[2.0 Marks]

c) Explain briefly <u>three</u> (03) reasons for occurrence of fracture in materials.

[3.0 Marks]

d) Explain how the following factors cause a material lead towards one type of fracture (Ductile or Brittle fracture).

- Temperature
- Dislocation density
- Grain size

[3.0 Marks]

e) Describe all the steps involve with ductile fracture initiation and propagation.

[2.0 Marks]

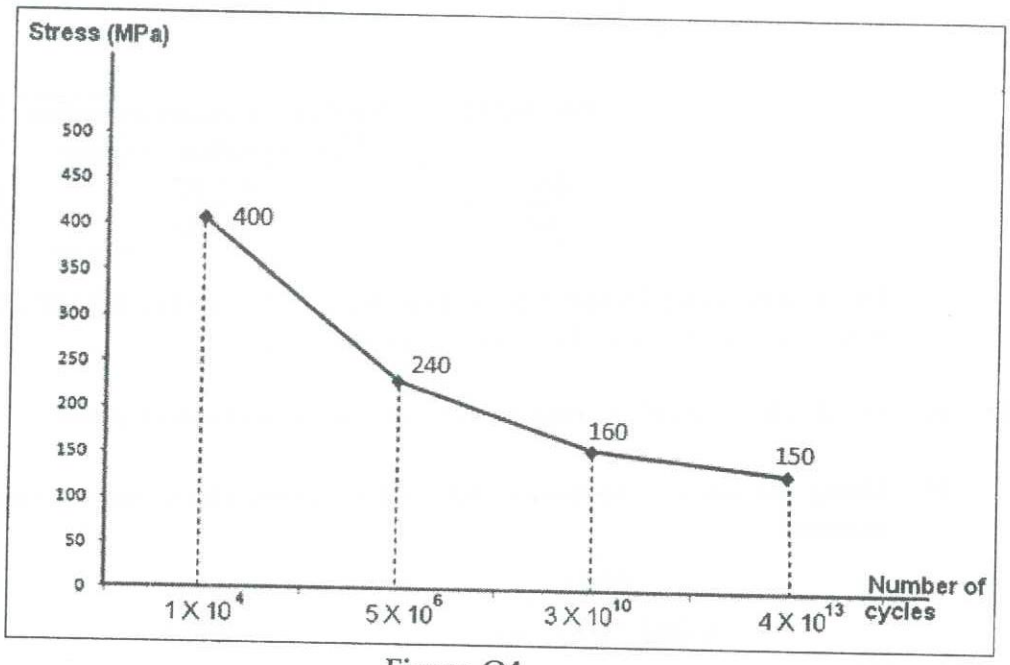

Figure Q4