UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: August 2015

Module Number: ME 3304 **Module Name: Strength of Materials**

[Three Hours]

[Answer **all questions**, each question carries **12** marks]
(State your assumptions clearly)

Q1. a) Explain stage I, stage II, and stage III of fatigue crack growth.

[2.0 Marks]

b) What are the roles of the following kinds of stress in fatigue failure?

I. Compressive stress
II. Tensile stress
III. Shear stress

[2.0 Marks]

c) Describe all the steps involved in brittle fracture and its different forms.

[2.0 Marks]

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

[4.0 Marks]

e) Modulus of elasticity of steel is 2×10^{11} Pa. Calculate the theoretical fracture strength of steel.

[1.0 Mark]

f) Actual fracture strength of steel is 2.27×10^{8} Pa. Is there any difference between actual and theoretical fracture strength values of steel? If so, what are the reasons for that?

[1.0 Mark]

Q2. a) State clearly the Griffith's criterion for fracture of brittle materials?

[2.0 Marks]

b) i) Using the above criterion, show the fracture strength of a material is given by, $\sigma_f = \sqrt{\dfrac{8E\gamma_s}{\pi a(1+\upsilon)(1+k)}}$.

Where,

σ_f - Fracture strength of a material,
A - Crack size,
υ - Poisson's ratio,
E - Modulus of elasticity,
k - Stress intensity factor, and
γ_s - Specific surface energy of a fractured surface.

[4.0 Marks]

ii) If $k = \frac{3-\upsilon}{1+\upsilon}$, derive an expression for fracture strength for plane stress conditions.

[1.0 Mark]

c) Theoretical value and actual values of γ_s have a difference. What are the reasons for such a difference and how do you overcome it by correcting the equation?

[2.0 Marks]

d) A relatively large glass plate is subjected to a tensile stress (a plane stress) of 40 MPa. The specific surface energy and modulus of elasticity for this glass are 0.3 Jm^{-2} and 69 GPa, respectively. Determine the maximum length of a surface flaw that is possible without fracture.

[3.0 Marks]

Q3. a) Differentiate Primary creep, Secondary creep, and Tertiary creep of materials.

[3.0 Marks]

b) What are the places which we can see creep failures?

[2.0 Marks]

c) What are the necessities of performing creep tests?

[3.0 Marks]

d) Suggest and explain a method to perform a creep test for a particular material (Metallic).

[4.0 Marks]

Q4. Figure Q4 shows a metallic plate (Young's modulus is 200 GPa) in a machine component which has been subjected to various loading conditions. The 0.5 cm thick rectangular plate is pulled in tension by two loads in the *X* and *Y* directions as shown. The total deflection in the *X* and *Y* directions has been noted as 0.021 cm and 0.009 cm, respectively. By clearly stating all the assumptions you may make, determine;

a) Stress components along loading directions.

[4.0 Marks]

b) Hence, the strain components along loading directions.

[4.0 Marks]

c) The Poisson's ratio of the material in which the plate has been made.

[4.0 Marks]

Q5. a) Consider a Mechanical component under direct load *F* giving rise to a stress σ_y vertically as shown in Figure Q5.

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

[2.5 Marks]

ii) By examining the equations, conclude the followings.

- Maximum normal stress.
- Maximum shear stress.

[1.5 Marks]

b) For a given loading conditions, the state of stress in the wall of a cylinder is expressed as follows;

- 85 MN/m^2 tensile stresses vertically upwards.
- 25 MN/m^2 tensile at right angles vertical stress.
- Shear stresses of 60 MN/m^2 on the planes on which the two direct stresses act.
- The sheer couple acting on planes carrying the 25 MN/m^2 stress is clockwise in effect.

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

[3.0 Marks]

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

[3.0 Marks]

iii) What would be the effect on these results, if owing to a change of both tensile loadings to compressive while shear stresses remain unchanged?

[2.0 Marks]

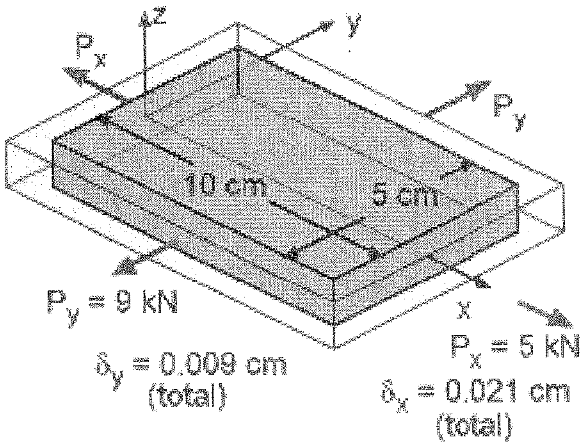

Figure Q4.

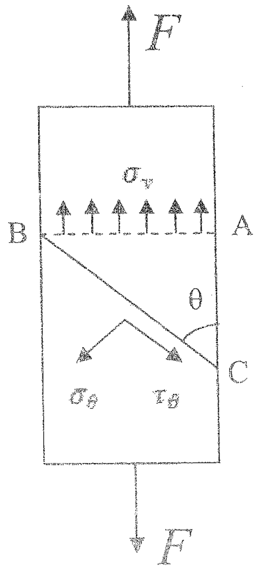

Figure Q5.

Q2 a) State Biot-sarvart's low [3 Marks]

b) i A circular loop located on $x^2+y^2=\rho^2$, $z=0$. Show that the magnetic flux intensity at **H**(0, 0, h) is

$$\bar{H}\frac{I\rho^2}{2[\rho^2+h^2)^{3/2}}\bar{a}_z$$

[3 Marks]

ii. A solenoid of length l and radious a consists of N turns of wire carrying current I. Show that at point P along its axis,

$\bar{H}=\frac{nI}{2}(\overset{\text{cos}}{\cancel{\sin}}\,\theta_2-\cos\theta_1)\,\bar{a}_z$ where, $n=\frac{N}{l}$, θ_1 *and* $\theta_2$are the angles subtended at P by the end turns as illustrated in Figure Q2.

Also show that if $l \gg a$, at the center of the solenoid, $\boldsymbol{H}=nI\bar{a}_z$ [4 Marks]

Q3 a) What do you meant by boundary condition analyze in electrostatic and magneto-static fields [4 Marks]

b) The magnetic field component of a plane wave in a lossless dielectric is

$$\bar{H}=30\sin(2\pi\times10^8\,t-5x)\,\bar{a}_z\;mA/m.$$

Assume that relative permeability of the medium μ_r is 1.

i. Find ε_r

ii. Calculate the wave length and wave velocity.
iii. Determine the wave impedance.
iv. Find the corresponding electric field component.
v Find the displacement current.

[6 Marks]

Q4 a) State the Poynting's theorem for power flow in a time varying electromagnetic field. [2 Marks]

b) In free space, magnetic field component of a plane wave is

$$\bar{H}=0.2\cos(\omega t-\beta x)\,\bar{a}_z\ \ A/m.$$

Find the total power passing through

i) a square plane of side 10 cm on plane $x+z=1$, and [2 Marks]

ii) a circular disc of radius 5 cm on plane $x=1$. [1 Mark]

c) A U-shaped electromagnet shown in figure Q4 is designed to lift a 400 kg mass (which includes the mass of the keeper). The Iron yoke ($\mu_r=3000$) has cross section of 40 cm² and mean length of 50 cm, and the air gap are each 0.1 mm long.

Neglecting the reluctance of the keeper, calculate the number of turns (*N*) in the coil for an excitation current of 1 A.

Hint: The tractive force across the two air gaps must balance the weight. Tractive force across a single gap is given by $F = B^2S/2\mu_0$, where, S is the area of the cross section and B is the magnetic flux intensity.

[5 Marks]

Q5 a) What is electromagnetic compatibility? [2 Marks]

b) Define electromagnetic interference(EI) [2 Marks]

c) How do you improve immunity of the electronic based system against EI?

[2 Marks]

d) How do you assure electromagnetic compatibility of the system? [2 Marks]

e) Selecting appropriate examples, describe how do you find solution to improve electromagnetic compatibility by using given chart in figure Q5

[2 Marks]

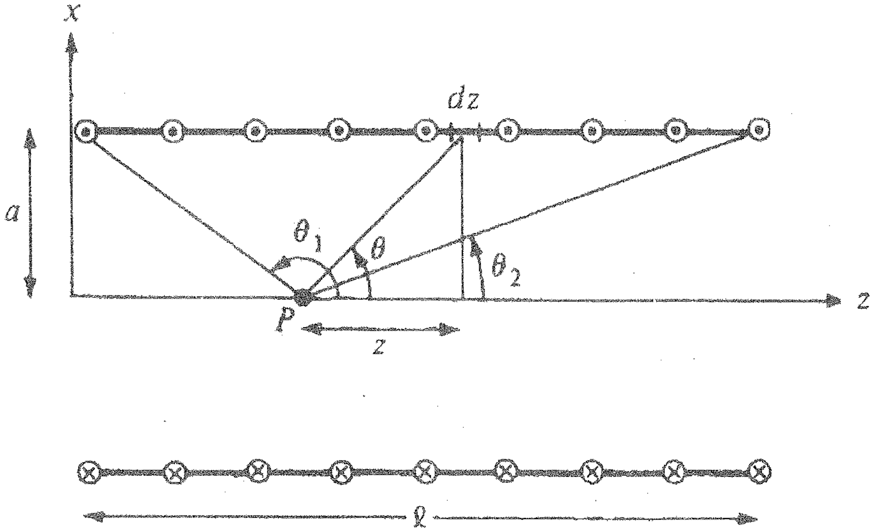

Figure Q2: Cross section of the solenoid

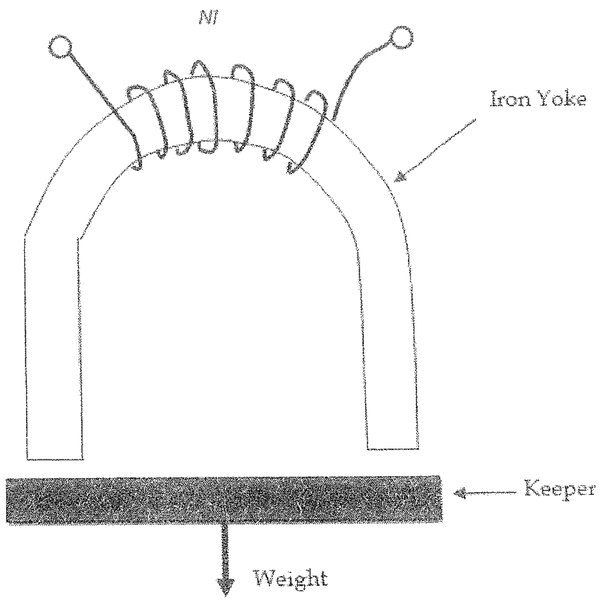

Figure Q4

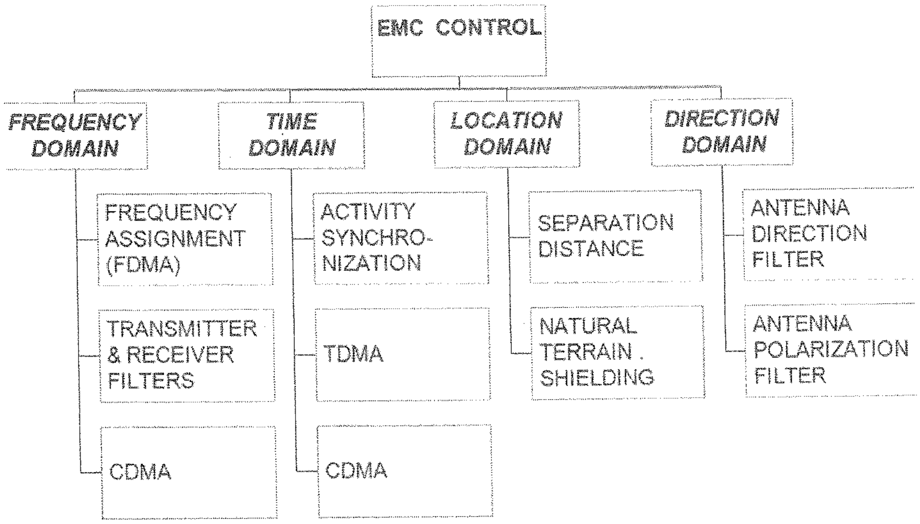

Figure Q5