UNIVERSITY OF GHANA

BSc (Eng.) MATERIALS SCIENCE AND ENGINEERING

FIRST SEMESTER EXAMINATIONS 2018/2019

SCHOOL OF ENGINEERING SCIENCES

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 305: MECHANICAL BEHAVIOUR OF MATERIALS

TIME: TWO (2) HOURS

ANSWER ALL QUESTIONS

1.

a. Show that the strain hardening exponent of a material that exhibits Hollomon's dependence of stress on strain is equal to the true strain corresponding to the ultimate tensile strength. The Hollomon's equation relates the flow stress, σ, to the true strain, ε, via the expression $\sigma = K\varepsilon^n$, where K is a material constant, and *n* is the strain hardening exponent.

b. The state of stress of an aeroplane wing is given by $\sigma_x = 25p$, $\sigma_y = 5p$ and shear stress, τ_{xy}. On a plane 45° counterclockwise to the plane on which σ_x acts, the state of stress is 50 MPa in tension and 5 MPa in shear. Determine the values of:

   i. σ_x,
   ii. σ_y,
   iii. τ_{xy}.

The following equations may be helpful:

$$\tau_{x'y'} = \frac{\sigma_y - \sigma_x}{2}\sin 2\theta + \tau_{xy}\cos 2\theta \text{ ----------------------------------(i)}$$

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2}\sin 2\theta + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta \text{ ------------------(ii)}$$

$$\sigma_x + \sigma_y = \sigma_{x'} + \sigma_{y'} \text{ --(iii)}$$

c. A tensile specimen with a 12 mm initial diameter and 50 mm gauge length reaches maximum load at 90 kN and fractures at 70 kN. The maximum diameter at fracture is 10 mm. Determine:

   i. Engineering stress at maximum load (the ultimate tensile strength),
   ii. True fracture stress,
   iii. True strain at fracture and
   iv. Engineering strain at fracture.

d.

   i. Stress analysis of a Kantanka automobile structural member gives the state of stress shown in **Figure 1**. If the part is made from 7075-T6 aluminium alloy with $\sigma_o = 500$ MPa, will it exhibit yielding? If not, what is the safety factor?

   ii. Use the maximum-shear-stress criterion to establish whether yielding will occur for the stress state shown in the d (i) above.

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B. AGYEI-TUFFOUR

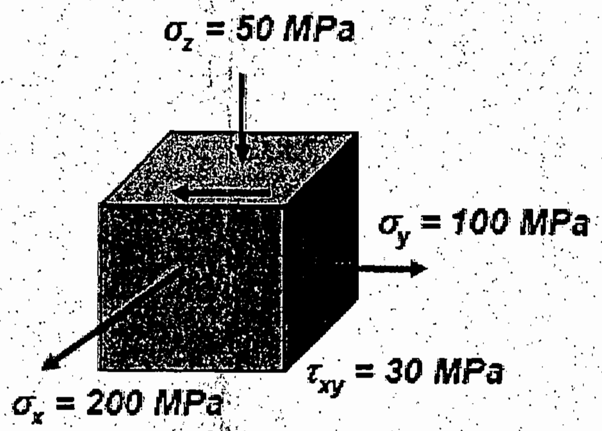
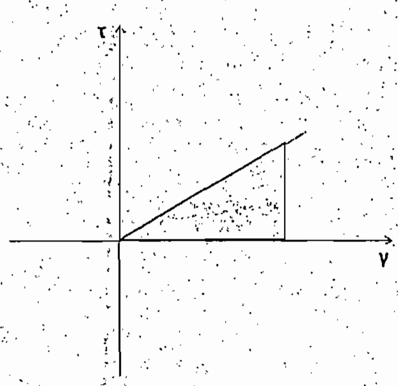


Figure 1. *The state of stress of a structural member of a Kantanka Automobile*

(40 Marks)

2.

a. For a typical force-strain energy (U) around an edge dislocation as shown below,



Prove that the strain energy per unit length is related by the expression below, where U is the strain energy, L is the length, G is shear modulus and *b* is the Burgers vector.

$$\frac{U}{L} = Gb^2$$

b. Describe in your own words, four strengthening mechanisms and be sure to explain how dislocations are involved in each of the strengthening techniques.

   i. grain size reduction,
   ii. solid-solution strengthening,
   iii. strain hardening and
   iv. precipitation strengthening.

c. During strain hardening of an FCC single crystal; there are three stages in the deformation path as shown in **Figure 2**,

   i. Explain what happens at each stage of the deformation.
   ii. Explain the deformation stage that is usually adopted for materials strengthening purposes

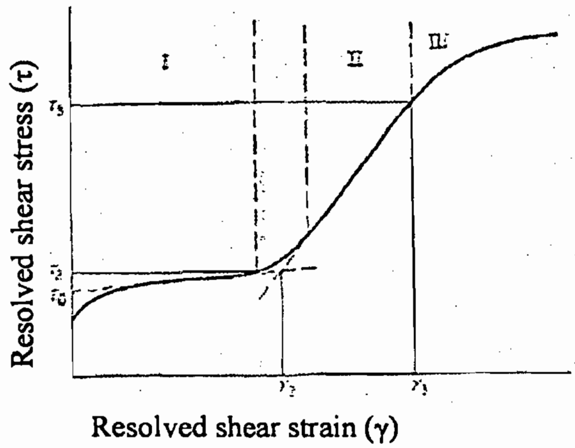


Figure 2. *A flow curve for an FCC single crystal*

(30 Marks)

3.

a. Derive an expression for the evolution of strain in a solid that is loaded by a stress, σ and well characterized by the Maxwell's model. Sketch the time dependence of strain on a plot of strain versus time. You may assume that the material has a Young's modulus, E, and a viscosity, η.

b. A thin plate of Al is subjected to a state of stress represented by the tensor below. Determine the principal stresses associated with this state. Describe the resulting stress state using Mohr's circle approach. Indicate the maximum shear stress on your plot.

$$\left[\sigma_{ij}\right] = \begin{bmatrix} 0 & 0 & 300 \\ 0 & -400 & 0 \\ 300 & 0 & -800 \end{bmatrix} MPa$$

c. If the uniaxial yield strength of the plate material is 150 MPa, use Tresca and Von Mises criteria to determine whether yielding will occur. Comment on the relative accuracies of the two methods.

(30 Marks)