UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE & ENGINEERING

END OF FIRST SEMESTER EXAMINATIONS: 2013/2014

MTEN 403: COMPOSITE DESIGN AND FABRICATION (3 Credits)

TIME ALLOWED: 2 Hrs 30 Mins

ANSWER ALL QUESTIONS

(Graph sheets are provided upon request)

1. (a) What are "composites"?

   (b) Identify the basic features of a composite material that influence and determine its properties.

   (c) Which of the three (3) primary composite geometries is most likely to possess isotropic properties?

   (d) What is the attractive aspect of the strength that is induced by the particles in a dispersion-strengthened particulate composite material?

   (e) Give two examples of commercial products which are laminar composite structures.

   (g) Name the three primary geometries of composite materials.

   10 Marks

2. (a) What are the common forms of reinforcing phase in composite materials?

   (b) What is the distinction between cement and concrete?

   (c) Cite three important limitations that restrict the use of concrete as a structural material.

   (d) Briefly explain three techniques that are used to strengthen concrete by

reinforcement.

(e) What is the most significant energy absorbing mechanism during composite failure?

(f) Why is concrete not attractive for lightweight structures.

(g) Cemented carbides are what class of composites?

15 Marks

3. (a) The mechanical properties of aluminum may be improved by incorporating fine particles of aluminum oxide (Al_2O_3). Given that the moduli of elasticity of these materials are, respectively, 69 GPa and 393 GPa, plot modulus of elasticity versus the volume percent of Al_2O_3 in Al from 0 to 100 vol%, using both upper- and lower-bound expressions.

(b) What is the rule of mixtures?

(c) Derive the rule of mixtures for the modulus of elasticity of a fiber-reinforced composite when a stress σ, is applied along the axis of the fibers.

(d) Derive the equation for the modulus of elasticity of a fiber-reinforced composite when a stress is applied perpendicular to the axis of the fiber.

(e) Cermets are examples of what types of composites?

(f) What is a Whisker?

(g) Ply-wood is an example of which type of composite?

20 Marks

4. (a) One method to improve the fracture toughness of a ceramic material is to reinforce the ceramic matrix with ceramic fibers. A materials designer has suggested that Al_2O_3 could be reinforced with 25% Cr_2O_3 fibers, which would interfere with the propagation of any cracks in the alumina. The resulting composite is expected to operate under load at 2000°C for several months.
Using the phase diagram (**figure 1**) for Al_2O_3-Cr_2O_3, criticize the appropriateness of this design.

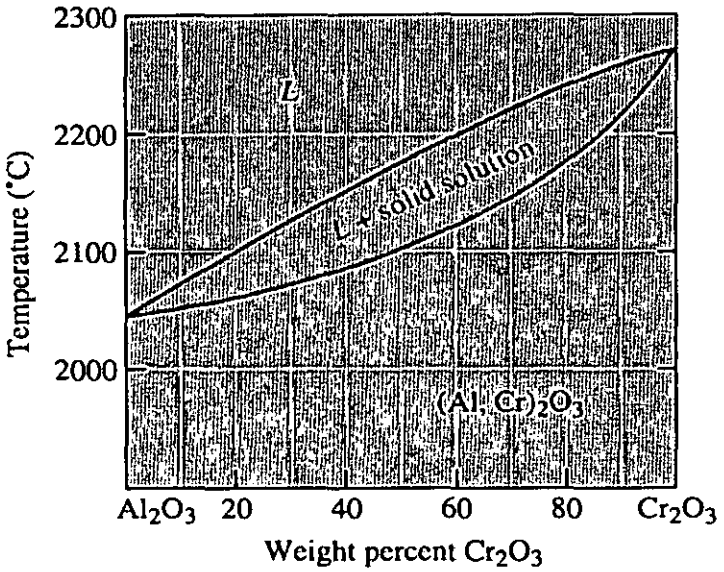

Figure 1. Phase diagram for Al_2O_3-Cr_2O_3.

(b) Glass fibers in nylon provide reinforcement. If the nylon contains 30 vol% E-glass, what fraction of the applied force is carried by the glass fibers? The modulus of elasticity for each component of the composites;

$E_{glass} = 10.5 \times 10^6$ psi $\quad E_{nylon} = 0.4 \times 10^6$ psi.

(c) A continuous and aligned fiber–reinforced composite is to be produced consisting of 30 vol% silicon-carbide and 70 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are given in table 1 as:

Table 1.

	Modulus of Elasticity [GPa]	Tensile Strength [MPa]
Silicon Carbide	400	3900
Polycarbonate	2.4	65

Also, the stress on the polycarbonate matrix when the Silicon carbide fails is 45 MPa (6500 psi). For this composite, compute

(i) The longitudinal tensile strength, and

(ii) The longitudinal modulus of elasticity

(d) Calculate the maximum and minimum thermal conductivity values for a cermet that contains 90 vol% titanium carbide (TiC) particles in a cobalt matrix. Assume thermal conductivities of 27 and 69 W/m·K for TiC and Co, respectively.

(e) A large-particle composite consisting of tungsten particles within a copper matrix is to be prepared. If the volume fractions of tungsten and copper are 0.60 and 0.40, respectively, estimate the upper limit for the specific stiffness of this composite given the data in table 2 as follows;

Table 2

	Specific Gravity	Modulus of Elasticity [GPa]
Copper	8.9	110
Tungsten	19.3	407

25 Marks