UNIVERSITY OF GHANA

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BSC. (ENG) MATERIALS SCIENCE & ENGINEERING

END OF FIRST SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING

MTEN 401: COMPOSITE DESIGN AND FABRICATION (3 CREDITS)

INSTRUCTIONS:

ANSWER ALL QUESTIONS IN (SECTION A) AND (SECTION B)

(Graph sheets are provided upon request)

TIME ALLOWED: TWO AND A HALF $(2\frac{1}{2})$ HOURS

SECTION A: OBJECTIVES

1. Composite materials are classified based on:

(a) Type of matrix

(b) Size-and-shape of reinforcement

(c) Both

(d) None

2. Major load carrier in dispersion-strengthened composites

(a) Matrix

(b) Fiber

(c) Both

(d) Can't define

3. Usually softer constituent of a composite is

(a) Matrix

(b) Reinforcement

(c) Both are of equal strength

(d) Can't define

4. Usually stronger constituent of a composite is

(a) Matrix

(b) Reinforcement

(c) Both are of equal strength

(d) Can't define

5. Last constituent to fail in fiber reinforced composites

(a) Matrix

(b) Fiber

(c) Both fails at same time

(d) Can't define

6. Size range of dispersoids used in dispersion strengthened composites

(a) 0.01-0.1 μm

(b) 0.01-0.1 nm

(c) 0.01-0.1 mm

(d) None

7. Rule-of-mixture provides _____ bounds for mechanical properties of particulate composites.

(a) Lower

(b) Upper

(c) Both

(d) None

8. Al-alloys for engine/automobile parts are reinforced to increase their

(a) Strength

(b) Wear resistance

(c) Elastic modulus

(d) Density

9. Mechanical properties of fiber-reinforced composites depend on

(a) Properties of constituents

(b) Interface strength

(c) Fiber length, orientation, and volume fraction

(d) All the above

10. Longitudinal strength of fiber reinforced composite is mainly influenced by

(a) Fiber strength

(b) Fiber orientation

(c) Fiber volume fraction

(d) Fiber length

11. The following material can be used for filling in sandwich structures

(a) Polymers

(b) Cement

(c) Wood

(d) All

12. Not an example for laminar composite

(a) Wood

(b) Bimetallic

(c) Coatings/Paints

(d) Claddings

13. The reinforcing material with the highest strength available for composites is

(a) Whiskers

(b) Graphite fibers

(c) SiC fibers

(d) OUHMWPE

14. Which of the following fibers has the highest specific tensile strength?

(a) Kevlar

(b) OUHMWPE

(c) SiC

(d) Boron

15. Which of the following fiber degree layering sequences produces a balanced symmetric composite material?

(a) 0/60/120/0/60/120

(b) 0/90/90/0

(c) 0/60/120/120/60/0

(d) 0/45/135/0/45/135

16. The lowest-strength direction and loading for a uniaxial-fiber reinforced composite materials is

(a) In the fiber plane shear

(b) Axial compression

(c) Transverse tension

(d) Transverse compression

17. In a composite material with a brittle matrix and brittle fibers, if the strain to fracture of the fibers is greater than the strain to fracture of the matrix, which of the following is not true?

(a) The slope of the composite stress-strain curve has a discontinuity at the fracture strain of the matrix.

(b) The stress in the composite increases after the matrix is fractured and is given by $\varepsilon E f v f$.

(c) The composite fractures at the fracture strain of the fibers.

(d) The composite fractures at the fracture strain of the matrix.

18. Which of the following processes would be the most likely process for making low-cost continuous-fiber composite fenders for a truck?

(a) Resin transfer molding

(b) Vacuum bagging

(c) Pultrusion

(d) Filament winding

19. Which of the following processes would be the most likely process for making continuous-fiber composite material for a Formula 1 race car chassis?

(a) Resin transfer molding

(b) Vacuum bagging

(c) Pultrusion

(d) Filament winding

20. Which of the following processes would be the most likely process for making composite materials for the shafts of golf clubs?

(a) Resin transfer molding

(b) Vacuum bagging

(c) Pultrusion

(d) Filament winding

SECTION B (Attempt All questions)

1.

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

b. Cite three important limitations that restrict the use of concrete as a structural material.

c. In one polymer-matrix composite, as produced, discontinuous glass fibers are introduced directly into the matrix; in a second case, the fibers are first "sized." Discuss the effect this difference might have on the critical fiber length and the strength of the composite.

d. Explain why bonding between carbon fibers and an epoxy matrix should be excellent, whereas bonding between silicon nitride fibers and a silicon carbide matrix should be poor.

e. Carbon nanotubes (CNTs) with low weight (density = 1.3 g/cm^3), high tensile strength (50 GPa), and modulus of elasticity (1 TPa) in the axial direction have been touted as the strongest material yet discovered;

i. Calculate the specific strength for CNTs.

ii. If a composite was made using an alumina (Al_2O_3) matrix with modulus of elasticity (386 GPa) and 1% volume CNT fibers, what fraction of the load would the CNT fibers carry?

iii. In practice, ceramic matrix CNT composites do not exhibit the expected improvement in mechanical properties. What could be some possible reasons for this?

[20 Marks]

2.

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;

i. perpendicular to the axis of the fiber

ii. along the axis of the fiber

e. Cermets are examples of what types of composites?

[20 Marks]

3.

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.

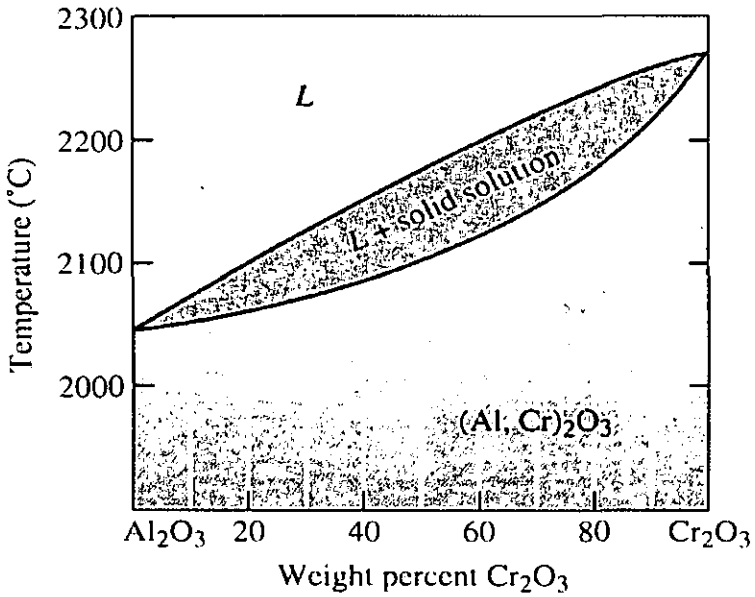

Figure 1. Phase diagram for Al_2O_3-Cr_2O_3.

[10 Marks]

b. 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. For this composite, compute;

i. The longitudinal tensile strength, and

ii. The longitudinal modulus of elasticity.

[10 Marks]

c. 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.

[10 Marks]

d. 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

10 Marks