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 401 COMPOSITE MATERIALS DESIGN AND FABRICATION (3 CREDITS)

TIME: 2 HOURS 30 MINUTES

ANSWER ALL QUESTIONS

1.

a. Briefly distinguish between cements and concretes.

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

c. Briefly explain three techniques that are utilized to strengthen concretes by reinforcement.

d. Briefly explain the phenomenon of transformation toughening as used in the strengthening of most ceramic matrix composites.

e. A continuous and aligned glass fiber-reinforced composite consists of 40 vol% of glass fibers having a modulus of elasticity of 69 GPa and 60 vol% of a polyester resin that, when hardened, displays a modulus of 3.4 GPa.

   i. Compute the modulus of elasticity of this composite in the longitudinal direction.

   ii. If the cross-sectional area is 250 mm^2 and a stress of 50 MPa is applied in this longitudinal direction, compute the magnitude of the load carried by each of the fiber and matrix phases.

   iii. Determine the strain that is sustained by each phase when the stress in part (ii) is applied.

[30 Marks]

2.

a. Derive expressions for the upper and lower bound composite Young's moduli and Strengths.

b. A fiber–reinforced composite of 60% volume fraction of carbon fibers with Young's modulus of 200 GPa and an epoxy matrix with Young's modulus of 100 GPa. Estimate the upper and lower bound Young's moduli of the composite.

c. If the same composite in 2(b) of this question has carbon fibers with a fracture strain of 1% and epoxy with yield stress of 60 MPa, estimate the upper and lower bound tensile strengths of the composite. You may assume that epoxy is a brittle matrix.

d. Estimate the percentage of the total load that is carried by the carbon fibers in the composite described in 2(b) above.

[30 Marks]

3. For a polymer-matrix fiber-reinforced composite,

   a. List and explain three functions of the matrix phase.

   b. Compare and explain three (3) desired mechanical characteristics of matrix and fiber phases.

   c. Briefly explain two reasons why there must be a strong bond between fiber and matrix at their interface.

   d.

      i. Verify that this equation, $\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m}$, the expression for the fiber load–matrix load ratio in the longitudinal direction is valid.

      ii. What is the ratio of $\frac{F_f}{F_c}$ in terms of E_f, E_m and V_f?

      iii. In an aligned and continuous carbon fiber reinforced nylon 6,6 composite, the fibers are to carry 97% of a load applied in the longitudinal direction. Using the data provided in **Table 1**, determine the volume fraction of fibers that will be required.

      iv. What will be the tensile strength of this composite? Assume that the matrix stress at fiber failure is 50 MPa.

Table 1 Mechanical Properties of Carbon and Nylon Fibers

	Modulus of Elasticity [GPa	*Tensile Strength [MPa*
Carbon fiber	260	4000
Nylon 6,6	2.8	76

[30 Marks]

4.

   a. From the first principles:
      i. Derive the plate constitutive equations.
      ii. Indicate all the components of the ABD Matrix.
      iii. Explain the sources of A, B, and D matrices.

   b. What are the implications of the following matrices:
      i. A13 and A23
      ii. B13 and B23
      iii. D13 and D23
      iv. B33

   c. Briefly explain the coupling modes that may be deemed undesirable during laminate composites lay-up and suggest three (3) ways of eliminating undesirable coupling.

   d. If for example the engineer desires that an appropriate laminate lay-up should be such that, the wings can twist (nose down) as they bend upwards under an aerodynamic condition, explain which of the ABD matrix and how you will manipulate it to achieve this effect.

[30 Marks]