UNIVERSITY OF GHANA

BSc (Eng.) MATERIALS SCIENCE AND ENGINEERING

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

FIRST SEMESTER EXAMINATIONS 2016/2017

MTEN 401 COMPOSITE MATERIALS DESIGN AND FABRICATION (3 CREDITS)

FIRST SEMESTER **TIME: 2 ½ HOURS**

ANSWER ALL QUESTIONS

1.

a. Describe briefly what hybrid composites are? ***[5 Marks]***

b. List and explain two important advantages of hybrid composites over normal fiber composites. ***[2 Marks]***

c. Derive an expression for the modulus of elasticity for a hybrid composite in which all fibers of both types are oriented in the same direction. ***[8 Marks]***

d. Using this expression, compute the longitudinal modulus of elasticity of a hybrid composite consisting of aramid and glass fibers in volume fractions of 0.25 and 0.35, respectively, within a polyester resin matrix. (Modulus of Matrix, E_m = 4.0 GPa) ***[5 Marks]***

2.

a. Derive expressions for the upper and lower bound composite Young's moduli and Strengths. ***[5 marks]***

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. ***[6 Marks]***

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. ***[6 Marks]***

d. Estimate the percentage of the total load that is carried by the carbon fibers in the composite described in 2(b) above. ***[3 Marks]***

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

a. List and explain three functions of the matrix phase. ***[3 Marks]***

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

c. Briefly explain two reasons why there must be a strong bond between fiber and matrix at their interface. ***[2 Marks]***

d. Is it possible to produce a continuous and oriented aramid fiber–epoxy matrix composite having longitudinal and transverse moduli of elasticity of 35 GPa and 5.17 GPa, respectively? Why or why not? Assume that the elastic modulus of the epoxy is 3.4 GPa and the aramid fiber Modulus, E, is 131.0 GPa). ***[12 Marks]***

4.

a. Consider a fiber population for which the function $g(\sigma)$ is constant between the lower stress σ_1 and the upper stress, σ_2, and zero at all other stress levels.

i. Determine $G(\sigma_f)$ ***[3 Marks]***

ii. Determine the fiber stress, $\sigma_{f\max}$, at which the function $\sigma_f[1-G(\sigma_f)]$ is a maximum. ***[3 Marks]***

iii. Derive an expression for the expected bundle stress. ***[4 Marks]***

b. Estimate V_c and V_{min} for the SiC fibers, SiC whiskers, Al_2O_3 whiskers using fiber properties in Table 1

i. the aluminum has a yield strength of 69 MPa and a tensile strength of 124 MPa

ii. the polymer matrix has a yield strength equal to the tensile strength of 21 MPa

Material class	Material	E (GN/m²)	T.S. (GN/m²)	ρ (Mg/m³)	E/ρ (MNm/kg)	T.S./ρ (MNm/kg)
Metals	Be	315	1.3	1.8	175	0.72
	Pearlitic steel	210	4.2	7.9	27	0.53
	Stainless steel	203	2.1	7.9	26	0.27
	Mo	343	2.1	10.3	33	0.20
	β-Ti	119	2.3	4.6	26	0.50
	W	350	3.9	19.3	18	0.20
Inorganics	Al_2O_3	470	2.0	3.96	119	0.51
	Al_2O_3 whiskers	470	2.0–20.0	3.96	119	—
	B	385	7.0	2.6	148	2.69
	BN	90	1.4	1.9	47	0.74
	Graphite	490	3.2	1.9	258	1.68
	Graphite (Kevlar)	133	2.8	1.5	89	1.87
	E Glass	84	4.6	2.55	33	1.80
	S Glass	72	6.0	2.5	29	2.40
	Mica	231	3.2	2.7	86	1.19
	SiC	380	2.8	2.7	141	1.04
	SiC whiskers	470	2.0–20.0	3.17	148	—
	Si_3N_4	380	1.0–10.0	3.8	100	—
Polymers	Nylon 66	4.9	1.05	1.1	4	0.95

Data from: (1) *Modern Composite Materials*, ed. L. J. Broutman, and R. H. Krock, Addison-Wesley, Reading, Mass., 1967, articles of P. T. B. Shaeffer (p. 197), J. A. Roberts (p. 228), F. E. Wawner, Jr., (p. 244). (2) J. D. Embury, in *Strengthening Methods in Crystals*, ed. A. Kelly and R. B. Nicholson, J. Wiley, New York, 1971, p. 331.

Table 1 – Properties of Selected Fibers

[10 Marks]