UNIVERSITY OF GHANA

BSc (Eng.) MATERIALS SCIENCE AND ENGINEERING

FIRST SEMESTER EXAMINATIONS 2017/2018

SCHOOL OF ENGINEERING SCIENCES

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 401 COMPOSITE MATERIALS DESIGN AND FABRICATION (3 CREDITS)

FIRST SEMESTER **TIME: 2 HOURS 30 MINUTES**

ANSWER ALL QUESTIONS

1.

a. Briefly describe pultrusion, filament winding, and prepreg production fabrication processes and cite the major advantages and disadvantages of each method.

b. Briefly describe sandwich panels and indicate the primary reason for fabricating structural composites.

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

d. Determine 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. (E_m = 4.0 GPa, E_g = 72.5 GPa and E_{aramid} = 131 GPa).

[25 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~~ MPa. 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.

[25 Marks]

3. From the plate constitutive equations,
   a. Indicate all the components of the ABD Matrix and explain the source of A, B, and D matrices. Explain briefly the implications of any two of the ABD matrix components.

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

   c. If for a fighter jet, it is desired that an appropriate laminate lay-up should be such that, the wings can twist as they bend upwards under an aerodynamic condition, explain which of the ABD matrix and how you will manipulate it to achieve this effect.

   d. A plate is subjected to stresses shown in Figure 1 below.
      i. Determine the associated strains if the material is isotropic with E=70 GPa and υ = 0.3
      ii. For most materials, it is assumed that they exhibit isotropic behavior, i.e 2 independent elastic constants E, G and υ are required for their deformation. Prove that these elastic constants are related by the expression

$$E = 2G(1+\nu)$$

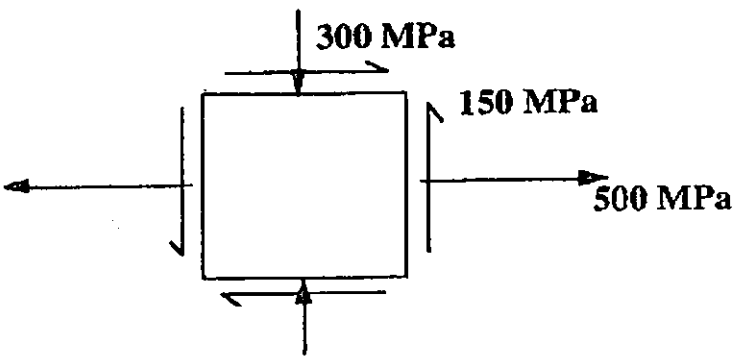

Figure 1 A plate subjected to different stress states

[25 Marks]

4.

   a. The probability density function (Weibull Random Variable) is given by the expression:

$$f(x:\lambda:k) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k}, x \geq 0 \\ 0, x < 0, \end{cases}$$

where k>0 is the *shape parameter* and k<0 is the *scale parameter*. When k = 1; the function is an exponential distribution and when k = 2 and $\lambda = \sqrt{2\sigma}$; the function is a Rayleigh Distribution function. The quantity x is the "time-to-failure". In Weibull distributions, the rate of failure of the fiber is proportional to the power of time. k is that power of time and can be interpreted appropriately given different conditions.

Therefore, with the following conditions stated below, determine the fiber failure rates and the potential causes of the failure when

i. $k<1$,

ii. $k=1$ and

iii. $k>1$

iv. Sketch the cumulative density profile and the probability density function for the following conditions: $\lambda=1, k=0.5$, $\lambda=1, k=1$, $\lambda=1, k=1.5$, $\lambda=1, k=5$

b. Verify that Equation F_f/F_c, the expression for the fiber load–matrix load ratio is valid.

i. What is the ratio in terms of E_f, E_m and V_f?

ii. 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.

iii. Using the data provided in table 1,

a. determine the volume fraction of fibers that will be required.

b. 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 fibers

	Modulus of Elasticity [GPa]	*Tensile Strength [MPa]*
Carbon fiber	260	4000
Nylon 6.6	2.8	76

[25 Marks]