Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

GX 817

Semester II Examinations, 2002/2003
Front Page Template

Exam Code(s)	4BM121, 4BG121
Exam(s)	4th Year Engineering Mechanical, Biomedical
Module Code(s)	ME413
Module(s)	Polymers, Ceramics and Composites
Paper No.	1
Repeat Paper	- Special Paper -
External Examiner(s)	Prof. P.J. Mallon
Internal Examiner(s)	Prof. J.F. McNamara Dr. C.M. Ó Brádaigh
Instructions:	Answer 5 questions All questions marked equally Attached are the following information -
Duration	3hrs.
No. of Answer books	-
Requirements:	
Handout	Yes Supplementary equations (2 pages)
MCQ	-
Statistical Tables	-
Graph Paper	Yes
Log Graph Paper	Yes
Other Material	-
No. of Pages	9 incl. this cover page
Department(s)	Mechanical Engineering

(4 marks) Q.1. (a) (i) For the standard linear solid model shown in Figure 1(a), write expressions for the unrelaxed modulus, G_U and the relaxed modulus, G_R, in terms of the spring and dashpot constants.

(8 marks) (ii) Derive the shearing stress relaxation modulus for the standard linear solid:

$$G(t) = G_R + (G_U - G_R) \exp(-t/\tau)$$

where τ $(=\eta_3 / \xi_1)$ is a time constant

Note: standard solutions for ordinary differential equations are attached at the back of the paper

(8 marks) (b) A 300 mm long hollow polymer tube, of diameter 75mm and wall thickness 2mm is subject to a torsional twist of one (1°) degree [Figure 1(b)]. If the polymer is represented by a standard linear solid with the following material properties:

$G_U = 45$ GPa, $G_R = 15$ GPa, $\tau = 300$ seconds

Calculate the torque response at:

(i) 0 seconds
(ii) 200 seconds
(iii) 500 seconds

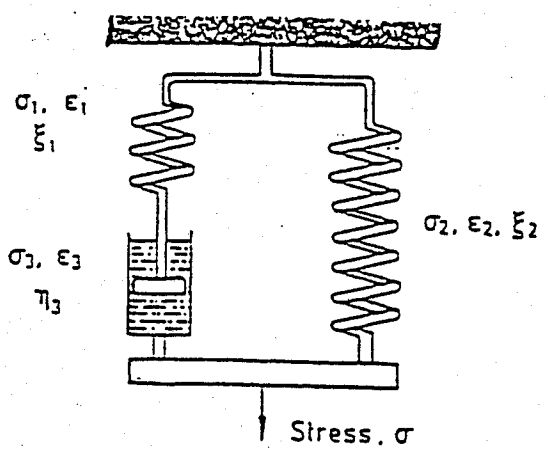

Figure 1(a)

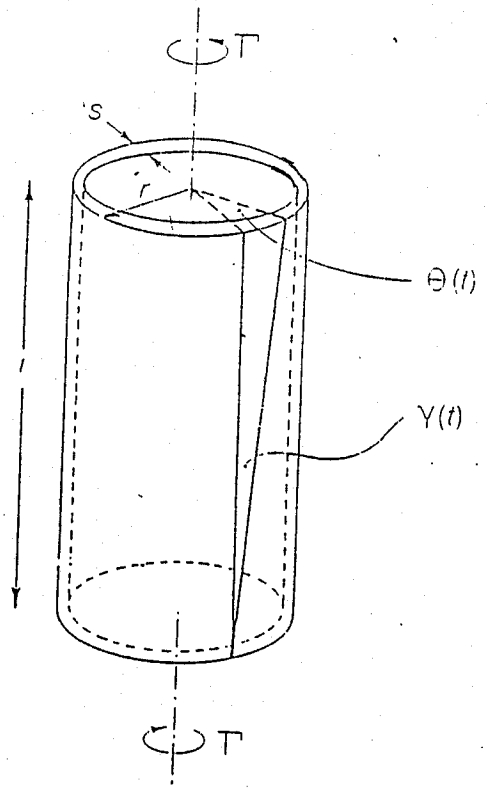

Figure 1(b)

(10 marks) Q.2 (a) Derive the creep compliance of the 4-element viscoelastic model, shown in Figure 2(a):

$$D(t) = \frac{1}{\xi_1} + \frac{t}{\eta_1} + \frac{1}{\xi_2}\left[1 - \exp\left(\frac{-\xi_2 t}{\eta_2}\right)\right]$$

(10 marks) (b) A set of polymer creep curves are shown in Figure 2(b). Using any one of the creep curves, find the values of the 4 spring and dashpot constants that would fit the curve best, if the polymer is to be represented by the 4-element viscoelastic model (3 of the 4 constants will suffice).

Hint: Plot strain against time in hours and curve-fit

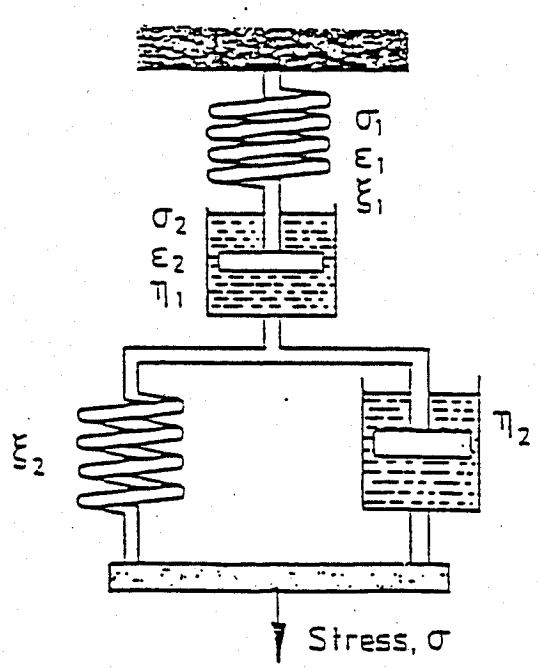

Figure 2(a)

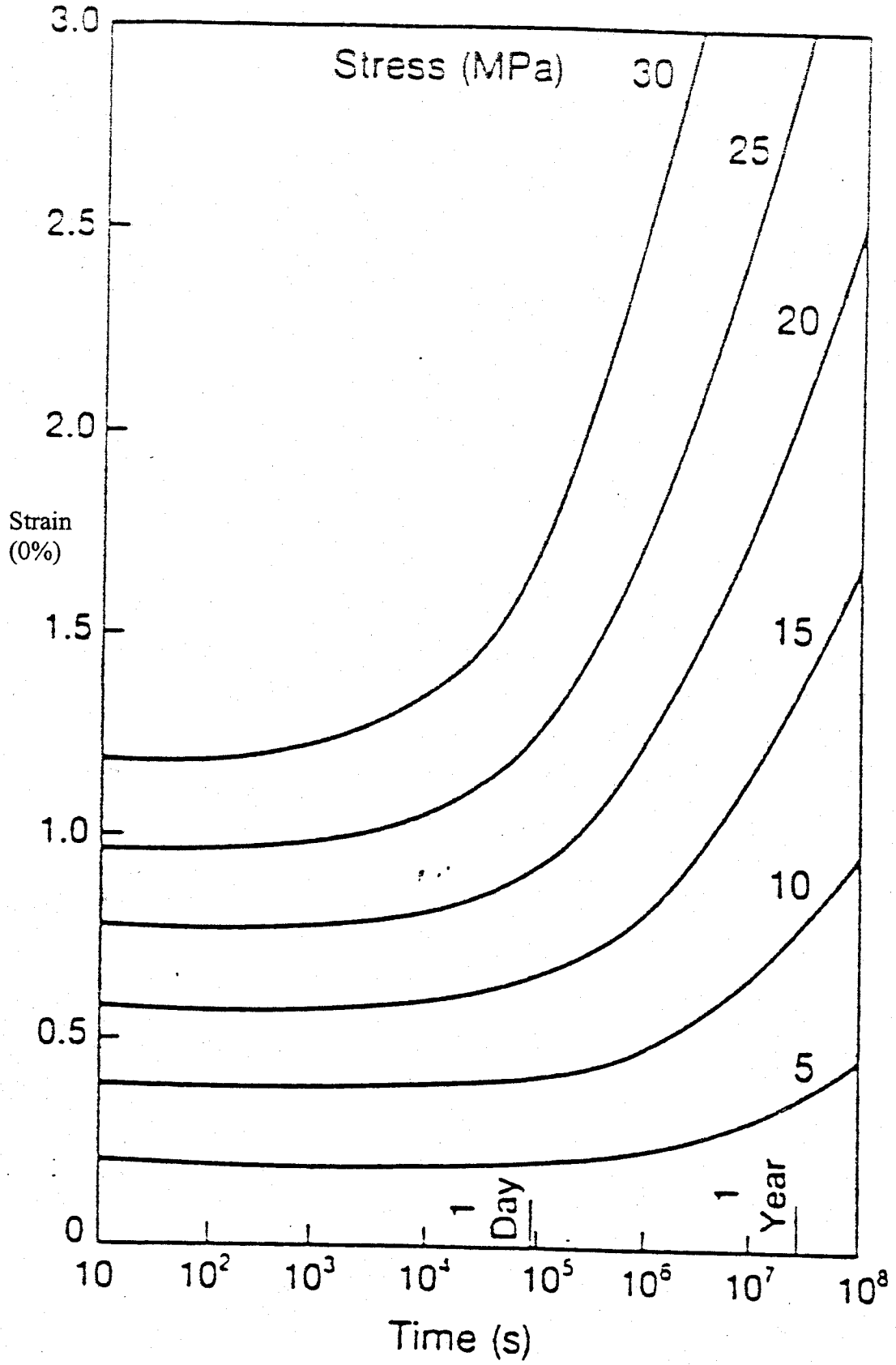
Stress (MPa)
30
25
20
15
10
5
3.0
2.5
2.0
1.5
1.0
0.5
0
Strain (0%)
1 Day
1 Year
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Time (s)

Figure 2(b)

(6 marks) Q.3. (a) Describe the phenomenon of creep rupture in plastics and compare it to fatigue failure mechanisms in plastics. Why is creep rupture sometimes called "static fatigue"?

(7 marks) (b) Creep rupture tests on a grade of uPVC gave the following results:

Stress (MPa)	60	55	52	48	45	43
Time (secs)	800	7×10^3	3.25×10^4	2.15×10^5	8.9×10^6	2.4×10^7

Calculate the time for creep rupture at an applied stress of 50 MPa.

(7 marks) (c) Cracks are found to grow in uPVC following the law:

$$\frac{da}{dt} = 2.5 \times 10^{-11} K^{3.2}$$

where a is the half-crack length and K is the stress intensity factor. If the critical stress intensity factor for the uPVC is $K_C = 5.0$ MPa$\sqrt{m}$ calculate the creep rupture life for a specimen under 50 MPa stress, with an initial flaw size of $2a_i = 5$ mm.

You may assume an elliptical crack, $Y = \sqrt{\pi}$

Compare your result to that of part (b)

(4 marks) Q.4. (a) (i) Describe in detail the operation of a rotational stress rheometer.

(5 marks) (ii) Derive an expression for polymer shear viscosity for the rheometer.

(3 marks) (iii) Sketch the viscosity – shear rate behaviour of both a shear-thinning and a shear-thickening fluid. Plot viscosity versus shear rate for polymers which have power-law exponents of n = 0.3 and n =1.3 respectively.

(8 marks) (b) Show that, for an incompressible material, Poisson's Ratio, $\nu = 0.5$

(7 marks) Q.5. (a) Describe the operation of a single-screw extruder. Sketch the extruder, label and discuss all important components.

(13 marks) (b) A polymer with a shear viscosity of 600 Pa.secs is to be extruded through a flat, rectangular die to produce sheet of up to 10mm thickness and 1000mm width. The extruder characteristics are as follows:

Barrel diameter = 150mm ; screw depth = 7mm ; screw helix angle = 16.5°
. Screw rotational speed = 30 rpm

Specify a wall thickness for the extruder barrel if the extruder is to operate safely under all circumstances (i.e. at limiting cases). Use the Von Mises combined failure criterion, a factor of safety of 2.5, and a barrel steel with yield stress of 600 MPa.

Given:

$$Q_{EXTRUDER} = \frac{1}{2}\pi^2 D^2 N H \sin\varphi \cos\varphi \; - \; \frac{\pi D H^3 \sin^2\varphi}{12\eta} \cdot \frac{dP}{dL}$$

Von Mises Failure Criterion:

$$\sigma_{YS}^2 = \sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2$$

(10 marks) Q.6 (a) Discuss and compare the relative toughness and impact properties of both metals and polymers. What factors in particular affect the impact strength of polymers? Define the following terms: *nil-ductility temperature, notch-sensitivity, fracture-transition plastic temperature.*

(10 marks) (b) Discuss the main classes of reinforcements and matrices used in advanced polymeric composite materials and their relative advantages and disadvantages. List three application fields in which the usage of composites is growing and give the reasons for this growth.

(8 marks)

Q.7 (a) Using micromechanics, derive the Rule of Mixtures expression for the transverse modulus of a unidirectionally fibre-reinforced composite material:

$$E_T = \frac{E_F E_M}{E_F(1-V_F)+E_M V_F}$$

Where E_F, E_M are the fibre and matrix modulii respectively and V_F is the fibre volume fraction (0 – 1.0)

(12 marks)

(b) A $[\,0^\circ_2 / 90^\circ\,]_S$ carbon-fibre reinforced epoxy laminate is loaded in uniaxial tension in the X-direction (0° direction). Given the ply properties below, calculate the values of strain in the x and y directions that will be experienced in the laminate at an applied stress of 400 MPa.

Given: $E_L = 120$ GPa ; $E_T = 8.5$ GPa ; $G_{LT} = 5.2$ GPa ; $\nu_{LT} = 5.2$ GPa

Note: Composite mechanics and transformation equations are given on attached sheets.