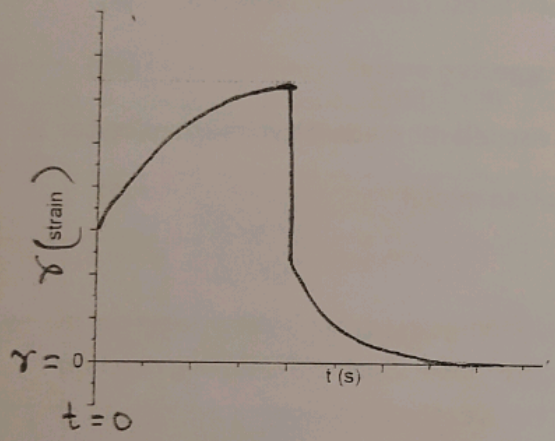
Indian Institute of Technology Kharagpur
Mid-Autumn Semester 2024 – 2025

Date of Examination: Session: Duration 2 hrs Full Marks **100**
Subject Number: CH61017 Subject: Rheology of Complex Fluids
Department: Chemical Engineering
Specific Instructions: Assume and write any assumption and data that you feel are missing.

Q1. Figure below shows strain evolution during a creep-recovery test for a viscoelastic material.



a) In the above plot, at first the strain increases exponentially towards a plateau value, followed by sudden drop and eventually decays exponentially. Suggest a model to capture the above shown strain evolution during creep-recovery test. **(6)**

b) Obtain the strain as a function of time during creep (over time 0 to t_1) and during recovery ($t>t_1$) in terms of your model parameters. **(9)**

2) Derive viscosity in terms multimode Maxwell model parameters. Explain physical meaning of the expression. **(7)**

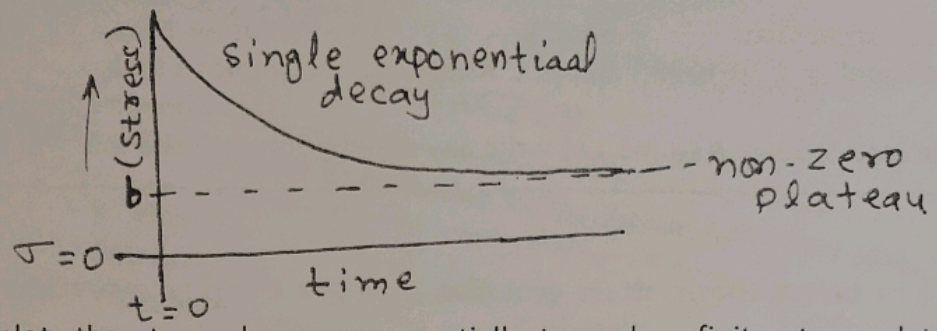
3) Explain the dependence of Linear regime on frequency of imposed strain/stress field, you can use plots for better explanation? **(5)**

4) Prove that, zero shear viscosity ($\dot{\gamma} \to 0$, which implies linear regime) is given by $\eta_0 = \underset{\omega \to 0}{Lt} \frac{G''}{\omega}$ (ω is the angular frequency and G'' is the loss modulus). **(8)**

(Hint: Use the expansion of cosine term, $\cos(\omega s) = 1 - \frac{(\omega s)^2}{2!} + \frac{(\omega s)^4}{4!} - \ldots\ldots\ldots\ldots)$

5) What do you understand from relaxation phenomenon (fundamentally what does it mean). Which oscillatory test can provide an estimate of relaxation time scale? Justify your choice of test and explain how it can provide the rough value of relaxation time scale. **(5+3+7)**

6) The stress relaxation behavior for a viscoelastic material is shown below.



a) In the above plot, the stress decays exponentially towards a finite stress plateau. Suggest a mechanistic model which can capture the such stress relaxation behavior. **(8)**

b) Find out the constitutive equation for the above suggested model. **(10)**

c) Find out the relaxation modulus expression for the viscoelastic material whose rheological behavior has been captured using the above-mentioned model. **(7)**

7) A polymer melt (Poly-dimethyl-siloxane liquid) is undergoing cross-linking reaction in continuous manner for 12 hours in the presence of a cross-linker. Such cross-linking reaction leads to permanent chemical links between polymers. Answer the following:

a) How you will measure the relaxation time scale at the regular interval of 2hr? **(5)**

b) Plot relaxation time scale (measured at regular interval of 2hr) as a function of time (t=2, 4, 6, 8, 10^{th} hour). Provide the physical picture explaining the nature of your curve. **(7)**

c) You have applied step strain for 2 min at regular interval of two hours. Plot qualitatively the stress relaxation curves (at t=2, 4, 6, 8, 10^{th} hour) in a single plot. Explain the trend of your curve by providing physical explanation. **(7)**

d) You have been asked to perform an oscillatory experiment at small strain amplitude (within linear regime) at a fixed frequency to probe the structural evolution (build-up) in terms of storage modulus as function of time in continuous manner. Plot storage modulus vs time curve qualitatively, and explain the associated physics. **(6)**