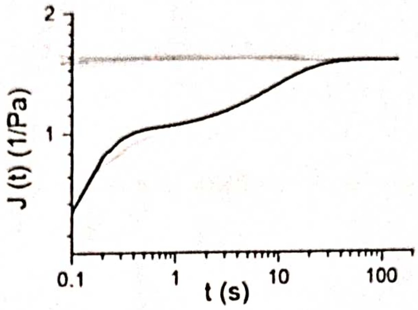
Indian Institute of Technology Kharagpur
Mid-Autumn Semester 2023 – 2024

Date of Examination: Session: Duration 2 hrs **Full Marks 60**
Subject Number: CH61017 Subject: Rheology of Complex Fluids
Department: Chemical Engg.

Specific Instructions: Assume and write any assumption and data that you feel are missing.

1. A polymer-nanocomposite when subjected to a step stress, the creep-compliance shows two step exponential increase followed by creep-compliance plateau (as shown in fig. below), Answer the following:



a) Suggest a mechanical model (consist of spring and dashpot elements), which can capture the above mentioned experimental behavior (5)

b) Derive the constitutive equation for the above proposed mechanical model. (assume your own model parameters) (5)

c) Solve your proposed mechanical model for step stress test and show that creep-compliance indeed show shows two step exponential increase with an ultimate plateau. (5)

2. Using Boltzmann superposition principle, show that zero shear viscosity ($\dot{\gamma} \rightarrow 0$) for any material can be expressed as: $\eta_0 = \int_0^\infty G(s)ds$. ($\dot{\gamma} \rightarrow 0$, *ensures linear regime deformation*)

Using Boltzmann's Superposition principle, obtain the expression for G' and G'' as a function of angular frequency (ω) in terms of relaxation modulus $(G(t))$.

Hence, prove that, zero shear viscosity $((\dot{\gamma} \rightarrow 0))$ is given by, $\eta_0 = \underset{\omega \rightarrow 0}{Lt} \dfrac{G''}{\omega}$ (ω is the angular frequency). (5+5+5)

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

3. Under what criterion the dynamic moduli (storage and loss modulus), show power law dependence on frequency with exponent 2 and 1 respectively, within linear regime stress/strain amplitude)? Provide mathematical support to your answer. (5)

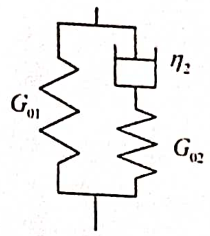
4. Answer the following:

$\mapsto$ Linear Viscoelastic regime.

a. How LVR regime depends on frequency of imposed strain/stress field, kindly show four curves on a single plot in proper order for different frequencies ($\omega_1 < \omega_2 < \omega_3 < \omega_4$)? (3)

b. How you can get a rough estimate of relaxation time scale using frequency sweep test in linear regime? (2)

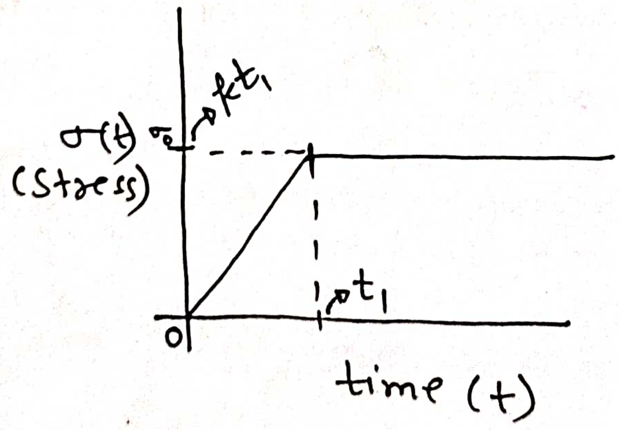
5. Consider a mechanistic rheological model shown in the figure below.



$\gamma_{t=0} = \dfrac{\sigma_0}{G_{01}+G_{02}}$

a) Obtain the expression of creep compliance ($J(t)$) and relaxation modulus ($G(t)$) for this model. (7+5)

b) Hence, obtain the strain at time $t > t_1$ for the stress profile shown below using Boltzmann's superposition principle. (8)



($\sigma_0 = k t_1$)

k is a constant.