Minor 1
MCL730 Designing with Advanced Materials
Dept. of Mechanical Engineering, IIT Delhi

Date: 16th Mar. 2021
Time: 9:30-10:30 AM
Points: 60

Note: Answer all questions. Calculator is permitted. Open book/notes.

1. [12 points: 3 each] Answer in one or two sentences.
   a. How does degree of polymerization affect the rubbery behavior?

   b. The Young's modulus of natural rubber decreases from 3 GN/m^2 at -200°C to 3 MN/m^2 at room temperature, whereas the Youngs's modulus of epoxy resin is approximately 10 GN/m^2 at both temperatures. Explain the difference in behavior.

   c. What are secondary transitions in the context of polymers? Why do they occur?

   d. Explain why fibers drawn from thermoplastics have very high moduli and tensile strength.

2. [10 pts] Derive the differential equation relating stress and strain for the model shown in Figure 1.

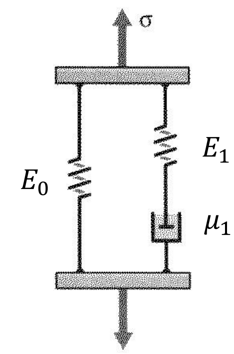

Figure 1

3. [10 pts] Determine the material specifications for a design of a shock absorber for a design that requires 63% of the elastic strain to be delayed (retarded) in 2.0 s. Assume a Kelvin model for material behavior and assume maximum strain is limited to 0.01 when a constant stress of 7 MPa is applied. Take *e* = 2.718.

4. [14 pts] Figure 2 shows a realistic relaxation test for a material. Consider Maxwell fluid with $E(t) = Ee^{-t/\tau}$.
   a. Determine the stress response for times greater than t_0 using the Boltzman superposition principle.
   b. Show with clear steps that the effect of the initial ramp loading is negligible if the time of ramp load t_0 is small compared to the relaxation time τ.

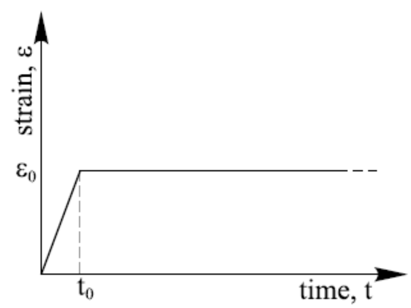

Figure 2

5. [14 pts] Consider a beam with uniformly varying distributed load with a time dependency as given in figure below. The beam is made of viscoelastic material following the Kelvin model with $D = \frac{1}{E}\left[1 - e^{-t/\tau}\right]$.
   Determine the expression for the deflection of beam for time $t_1 < t < 2t_1$.
   Elastic solution of the beam is given as $\delta(x,t) = \frac{p_0}{24\,EI}\left[x^4 - 2Lx^3 + L^3x\right]f(t)$.