Physics 174 - Spring 2021: Homework 2

Due: Monday, April 5, 2:30pm (Students giving presentations on April 5 and 7 may turn this assignment in one week later, by Monday, April 12, 2:30pm)

Question 1: Viscous forces are the fluid analog of friction, indeed they can be seen a frictional force between layers of fluid. But we know that that frictional forces are dissipative. In a few sentences explain how we can resolve the fact that frictional forces increase the entropy of the system and yet in the most highly viscous regime we see beautifully laminar motion, such as the video shown in class in which an ink blob "reassembled" itself. (Hint: consider the entire system).

Question 2: Atherosclerosis leads to constriction of arteries. This can be detected due to an audible murmuring sound from the onset of turbulence. Using what you know about the Reynolds' number, why does the flow become turbulent?

Question 3: In this problem we will look at the stretching and bending properties of three different biopolymers (DNA, actin, microtubules). We will treat each of these as a circular rod with the following properties:
DNA: solid rod (circular cross section), 2 nm diameter, Young's modulus = 1.0 GPa Actin: solid rod (circular cross section), 8 nm diameter, Young's modulus = 2.3 GPa Microtubule (tubulin) (annular/hollow circular cross section), outer diameter: 25 nm, inner diameter: 21 nm, Young's modulus: 1.9 GPa

Part a: For each of these structures, what is the force required to generate a strain of 1%?

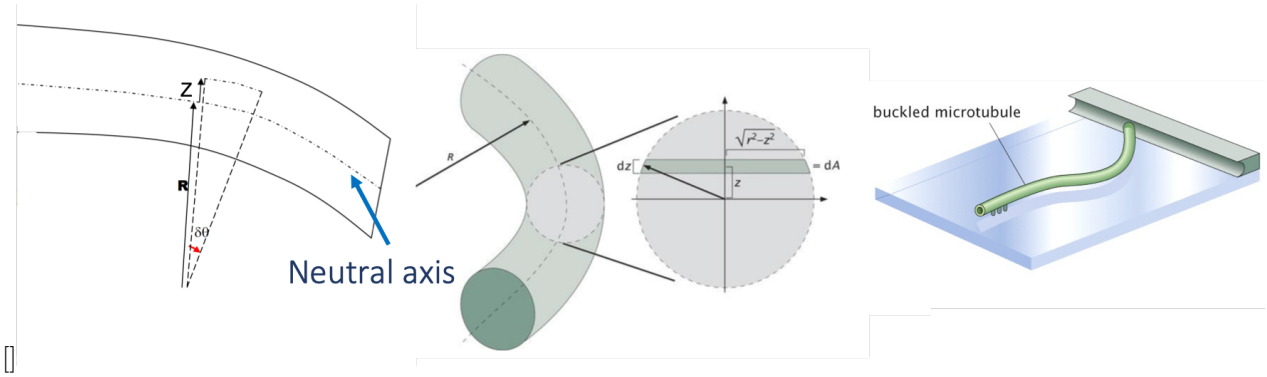

Figure 1: The biopolymers are represented as a cylindrical rod, which bends about a neutral axis through the length of the beam

Part b: Calculate the area moment of inertia about the neutral axis for each of the three biopolymers. Please note that the area moment of intertia is often referred to in beam theory and particularly in engineering in this context as the moment of intertia and uses the letter, I. This is directly related to the moment of intertia you have learned in your physics classes but does not include the mass. For uniform mass density the two moments of inertia are proportional.
The area moment of interia is given by:

$$I = \int z^2 dA$$

where z is the distance of the area element, A, from the neutral axis.
Hint 1: The above sketch is intended to help with setting up the integral
Hint 2: To evaluate the integral you will find helpful to make a change of variables using $z = r\sin\theta$
Hint 3: You may directly make use of the following integral: $\int_0^{\pi/2} \sin^2\theta\cos^2\theta d\theta = \frac{\pi}{16}$
Hint 4: Don't forget that while the DNA and actin are treated as solid rods, the microtubules are hollow

Part c: Using the formulas from class calculate the persistence length for each of these biopolymers and the moment of inertia calculated above, estimate the persistence length for each of the three biopolymers. For comparison, the measured persistence length of DNA is $\approx 50nm$.