BE/APh 161: Physical Biology of the Cell, Winter 2016
Homework #8
Due at the start of lecture, 1PM, March 9, 2016.

Problem 8.1 (Tensile strength of the ϕ29 capsid, 10 pts)**.**
In lecture and in the last homework, we discussed the packaging of the ϕ29 viral capsid. Specifically, we used Fig. 1 to estimate packaging forces. Here, we will estimate a lower bound for the tensile strength of the capsid. Tensile strength, measured in units of force per area, is the maximum stretching stress a material can bear before rupturing. Based on that curve and our discussion in lecture, estimate the minimum that the tensile strength of the ϕ29 virus must be to contain the genome? How does this compare to the tensile strength of bone? *Hint*: It might be useful to read about the Young-Laplace Law, described in section 11.3.1 of *PBoC2*.

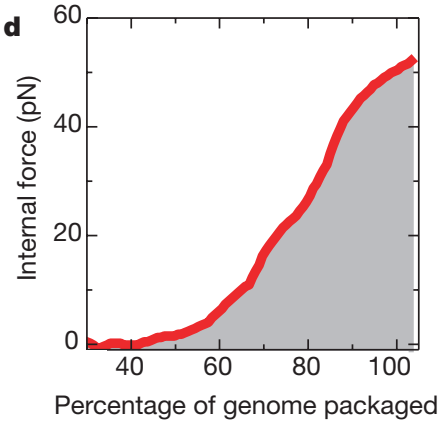

Figure 1: Force/fractional packaging curve for a ϕ29 virus. Figure taken from Smith, et al., *Nature*, **413**, 748, 2001.

Problem 8.2 (Antenna model for microtubule length control, 30 pts)**.**
Do problem 15.7 of *PBoC2*.

Problem 8.3 (Kinesin as an ATP-hydrolyzing enzyme, 15 pts)**.**
Do problem 16.3 of *PBoC2*. You will need to perform a nonlinear regression. If you do not know how to do this, you may find this tutorial from my Intro to Programming Bootcamp from this past summer. When you do your nonlinear regression, fit the approximate Michaelis-Menten expression to obtain the parameters $v_{\max}$ and K_m. The data from the Schnitzer and Block paper are given below.

ATP concentration (μM)	motor speed (nm/s)
0.75	9
1	13
2	19
4	50
10	95
40	260
100	410
400	650
1000	650

Problem 8.4 (Optical cell stretching, 45 pts)**.**
We briefly discussed optical cell stretchers in lecture. Optical cell stretchers work by taking advantage of the difference in index of refraction between a cell and the surrounding solution to trap a free cell in two counter-propagating laser beams. The power of the laser is then increased to exert stress and elongate the trapped cell. The induced stress is proportional to the laser power. The constant of proportionality, F_G is dependent on geometry and cannot be ascertained. The deformation (strain) is measured by taking images with a light microscope. The process is illustrated in Figure 2. In this way, the mechanical properties of an entire cell can be measured.

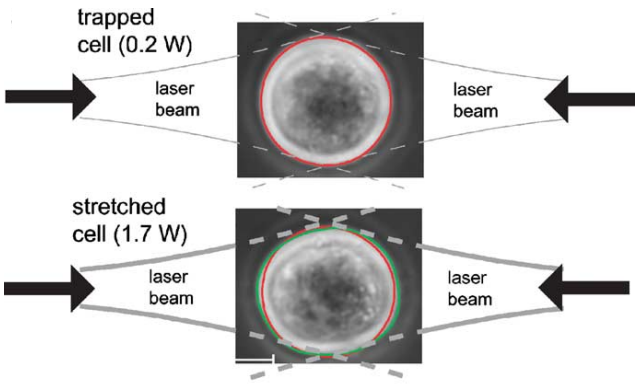

Figure 2: Schematic of an optical stretcher. The cell stretches along the axis parallel to the laser beams. The strain is given by the fractional change of the diameter of the cell along the stretching axis. Figure take from Wottawah, et al., *Acta Biomaterialia*, **1**, 263–271, 2005.

This technique was used to assess the mechanical properties of two mammalian cell types, 3T3 and SVT2 (which have reduced actin), in Wottawah, et al., *PRL*, **94**, 098103, 2005. In this work, the authors performed a stress step experiment in which a constant stress σ_0 was applied at $t = 0$, as in lecture. The stress was set back to zero at time $t = t_1$. The authors can obtain the creep compliance from this measurement.

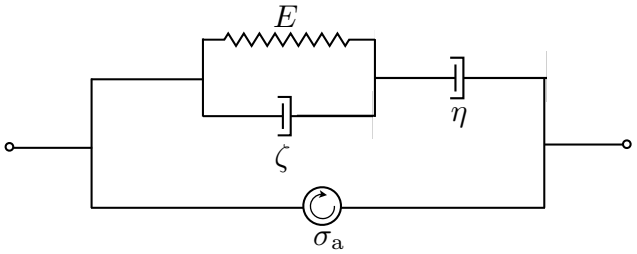

Figure 3: Schematic of an active Jeffreys fluid.

a) Derive an expression for the strain in the stress step experiment if we model the cell as an active Jeffreys fluid as in Figure 3. The stress step can be described mathematically as

$$\sigma(t) = F_G \, \sigma_0 \, \theta(t) \, \theta(t_1 - t), \tag{8.1}$$

where $\theta(t)$ is the Heaviside step function. Assume the active stress is constant, given by σ_a.

b) The authors perform curve fits of the expression you derived in part (a) to get values for the parameters of the cell. Explain why they cannot independently measure E, η, and ζ, but only products thereof. Can a constant active stress be detected in this experiment?

c) The authors then use the curve fit parameters to compute the storage and loss moduli (E' and E'') of the cell. Derive expressions for the storage and loss moduli from the fit parameters. (*Note*: These reported storage and loss moduli are dependent on choosing a model for the viscoelastic behavior of the cell. This is not ideal, but is apparently a necessity due to experimental constraints.)