The F₁-F₀ ATP synthase rotary motor
The F₁-F₀ ATP synthase rotary motor is a molecular motor that is driven by the flux of proteins down their electrochemical gradient. The rotational speed is 0.85 revolutions per second when a 2 µm long cylindrical actin filament is attached at its end (the rotational speed depends on the length of the attached actin filament). The viscosity of the liquid in which the actin filament is rotating is 0.89 mPa·sec. The average height of the filament is 100 nm above the surface and the diameter of the filament is 3 nm.

a) Calculate the torque that the motor must generate against the viscous drag. (To calculate this you need to consider the formulas of how to calculate torque for a rotating cylinder, these can e.g. be found in “Mechanics of Motor Proteins and the Cytoskeleton by J. Howard page 107, this page will be handed out in class)

b) How much work is done per revolution?

c) For one revolution the motor utilizes 3 ATP molecules, each providing an energy of approximately $1.0 \times 10^{-19}$ J. How efficient is this motor? How good is this compared, say, with a gas engine?