NB1140: Physics 1A - Classical mechanics and Thermodynamics
Quiz 2
7 December 2016
You have 10 minutes to finish this quiz

Optical tweezers - Forces, work done, and energy

We can model the optical trap setup as a block of mass m attached to two opposing Hookian springs (Fig. 1B). One spring, representing the DNA, has a spring constant k_{DNA}. The other spring, representing the laser beam, has a spring constant k_{trap}. Let $x = 0$ be the trap center (where the optical tweezer does not exert any force). The trap center $x = 0$ is so far away from the glass slide that the DNA is actually stretched by distance L when the bead is at $x = 0$.

(**a**) The equilibrium position is the position of the bead at which the bead has zero net (total) force acting on it. When the bead is at the equilibrium position, by how much is the DNA stretched? [*Answer*: $L(1 - \frac{k_{DNA}}{k_{DNA}+k_{trap}})$]

(**b**) What is the total energy (kinetic energy + potential energy) of the system when the block is at equilibrium position and not moving? Here, you can leave your answer in terms of k_{DNA}, L, k_{trap}, and k, where we define $k = k_{DNA}/(k_{trap} + k_{DNA})$. [*Answer*: $\frac{L^2}{2}(k_{DNA}(1-k)^2 + k_{trap}k^2)$]

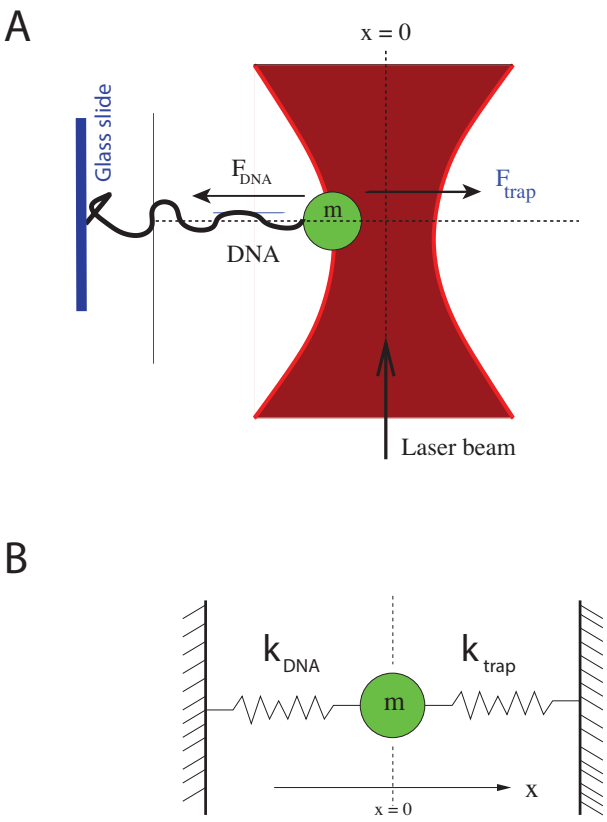

Figure 1: (**A**) Optical trap set up. One end of DNA is attached to a glass slide and the other end is attached to a polystyrene bead (green circle) of mass m. It is trapped by a beam of laser light (red) whose shape and intensity is precisely sculpted by lenses. (**B**) We can model the optical trap set up as a block (representing the bead) of mass m that is attached to two opposing springs, one with a spring constant k_{DNA} (representing spring-like DNA) and another one with a spring constant k_{trap} (representing spring-like optical trap).