Recitation Questions – April 1 Draft

1. Consider an electric automobile (such as a Tesla Model 3) of mass m whose fully-charged battery has electric potential energy U when it is fully charged. The car's electric motor can convert this energy to kinetic energy with a maximum power P_e.

   Recall that if a force $\vec{F}$ acts on an object moving with velocity $\vec{v}$, that force does work on the object with a power $P = \vec{F} \cdot \vec{v}$.

   (a) First, let's determine the maximum speed this car can sustain on flat ground.
   At high speeds, the most significant force slowing the car down is air drag. This has the form $F_{\text{drag}} = \gamma v^2$.
   If the driver of this car wants to drive at a speed v, find the rate that air drag does work (that is, the power) on the car. Is this power positive or negative?

   (b) In order to sustain this speed, the car's motor must do positive work on the car at the same rate. If the engine's maximum power is P_e, find the top speed of this car in terms of γ and P_e.

(c) For a Tesla Model 3, the values are approximately:

- $P_e = 200$ kW
- $U = 270$ MJ (2.7×10^8 J)
- $\gamma = 0.8$ kg/m

Based on these values, estimate the top speed of a Model 3. (At this high speed, air drag is the dominant force slowing the car down.) Convert your value into km/hr or miles per hour; is it reasonable?

(d) How far could a Model 3 drive at this speed before its battery is depleted?

(e) Suppose that the driver only went half as fast. How many times further could the driver travel on a charge? (*Hint: Look back at your result for (a). You should be able to figure this out without much math.)*

2. Suppose that a block of mass m is resting against a spring of spring constant k right before the base of a ramp elevated at an angle θ above the horizontal. The coefficient of kinetic friction between the block and the ramp is μ. The spring is compressed by an amount d.

   When the spring is released, it propels the block up the ramp. (There is no friction until the block reaches the ramp; this will simplify your algebra.) It slides up the ramp a distance L, then slides back down and compresses the spring again by a maximum amount b. (You know m, k, μ, θ, and d; you don't know L or b, but will find them later.)

   (a) Will b (the distance it compresses the spring when it comes back down) be larger than, the same as, or smaller than d (the distance the spring was compressed in the beginning)? You should be able to make a logical argument here without doing any mathematics.

(b) Determine L, the distance the block travels up the ramp, in terms of k, m, d, μ, g, and θ.

(c) Determine b, the distance the block compresses the spring when it comes back down. Since you have found a formula for L previously, you may use L in your answer here. (This is to save you writing, since substituting in for it is not all that enlightening.)