Energy and Work

1. Suppose I stand on the top of a ladder and drop an egg of mass $m$. I want to find out how fast it is going after it has fallen through a distance $\Delta h$. Assume that the acceleration due to gravity is $g$.

   (a) Draw a free-body diagram for the egg.
   (b) Identify two different possible systems. (Remember that a system is a list of objects that you want to group together.)
   (c) For each system, do the following:
      i. Identify the initial and final states.
      ii. List external forces on the system. Do they do any work?
      iii. Decide which types of energy to consider.
      iv. Describe the system’s transformation process using energy bars.
      v. Describe the system’s transformation process using an equation.
      vi. Solve the equation for the egg’s final velocity.
   (d) Compare your final velocities for the two different systems. Are they the same? Is this what you expect?
   (e) Was one system easier to use than the other?
   (f) If the egg was sliding down an inclined plane instead of freely falling, would one system be easier to use than the other?

2. Riddle: What’s the easiest way to drop an egg 1 m without breaking it? (This really has nothing to do with physics.)

3. Now we’re going to think about a rollercoaster car that starts from rest at the top of a hill and then falls down a track into a loop, as shown below. If the car is not going fast enough, it will fall off the track at the top and the riders will die. If the car is going very fast, the riders will feel “squished” at the top of the loop. We are going to find the magical height $h$ that will ensure that the ride is safe and that the riders feel weightless at the top, assuming that the radius of the loop is $R = 20$ m.

   (a) Carefully choose a system.
   (b) Identify the initial and final states.
   (c) List external forces on the system. Do they do any work?
(d) Decide which types of energy to consider.
(e) Describe the system’s transformation process using energy bars.
(f) Describe the system’s transformation process using an equation.
(g) You should now have two unknowns \((v_f, h)\) but only one equation. To get another equation:
   i. Draw a free body diagram for the car at the top of the loop.
   ii. Remember that we want the riders to feel weightless at the top of the loop.
   iii. Think about what you learned last week about circular motion.
   iv. Write another equation.
(h) You now have two equations and two unknowns. Solve for \(h\!\)
(i) If we build a taller rollercoaster, will it still be safe?

4. Explain in your own words why potential energy is a useful concept. (Think about what you would have needed to do to solve the previous problem if you didn’t have potential energy.)