Homework 8

Due Sunday, 25 April, by the end of the day

1. We saw in class that in a pendulum the string does no work. We also saw that the normal force does no work on an object sliding down a ramp.

   (a) Explain why the tension in the string of a pendulum does no work.

   (b) Explain why the normal force does no work on an object sliding down a ramp.

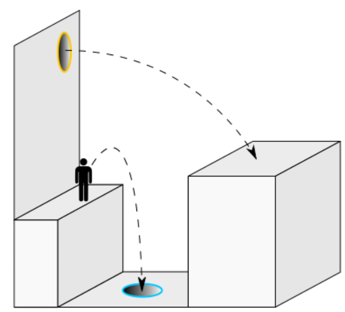
   (c) Give an example of a situation where tension *does* do work on an object.

   (d) Give an example of a situation where friction does positive work on something.

2. Consider again the portals from the game *Portal*.

   (a) When Chell jumps down the bottom portal and emerges from the top one moving sideways, does she conserve kinetic energy? Does she conserve *total* energy?

   We discussed in class that we can construct a potential energy term (like $U_g = mgh$ for gravity) for any force so long as the *work done by that force as an object goes from A to B* does not depend on the *path taken from A to B*. These forces are called *conservative forces.*

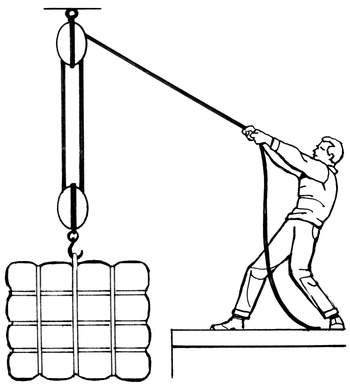
   (b) Is gravity a conservative force in a world with portals? Explain. If it is not a conservative force, give an example of two points A and B, and two paths between A and B for which the work done by gravity is different.

3. A lazy penguin slides down a snow-covered slope on its stomach. Suppose that the diagonal length of the slope is 12 m, and it is inclined at an angle of 10^o above the horizontal. If the penguin is traveling at 4 m/s when it reaches the bottom of the slope, what is the coefficient of friction between the penguin and the slope? Do this problem twice: once with Newton's second law and kinematics, and once with energy methods. Write a few sentences comparing the approaches.

4. Imagine that our same lazy penguin slides down another ice-covered slope. The coefficient of kinetic friction is μ_k. This slope is inclined at an angle θ above the horizontal and has a total length L. At the bottom of the slope, she keeps going, sliding past the end of the slope along the flat ground until friction brings her to a stop.

   How far will she travel past the end of the slope before friction brings her to rest?

5. A person uses a block-and-tackle system as shown below (from Wikimedia Commons) to lift a heavy load.



Suppose the load has a weight of 1250 N.

(a) Suppose our person lifts this load two meters slowly (at constant velocity). What force must he exert on the rope to do so?

(b) It seems like he's getting something for nothing – that he's able to lift a larger weight with a smaller force. But is he? Calculate the work done by the rope on the load, and calculate the work he does on the rope.

(c) If he lifts this load 2m and then holds it there, clearly its change in kinetic energy is zero: it started at rest and ended at rest. However, the rope did positive work on the load; the work-energy theorem thus says that its kinetic energy should increase unless some other force did an equal amount of negative work on it. What force was this?

(d) Explain why, using the definition of work $W = \int \vec{F} \cdot d\vec{s}$, that force does negative work.

6. Electric cars like the Tesla Model 3 or Chevrolet Bolt have battery capacities measured in "kilowatt-hours". The long-range model of the Model 3 has a battery rated at 75 kilowatt-hours.

(a) Using dimensional analysis, what sort of quantity (time, force, power, energy, distance, etc.) might be measured in kilowatt-hours? Convert one kilowatt-hour into more familiar units.

(b) The US Environmental Protection Agency estimates that a Model 3 can drive 523 km (325 miles) on a charge of its battery. If this is the case, estimate the size of the drag force applied to the car by the air it is driving through. How does this force compare with the weight of a person?

(c) If this car drives at 110 km/hr for a trip like this, estimate the power delivered to the wheels by the motor to sustain this speed. (Remember that power is the rate of doing work, and is equal to $\vec{F} \cdot \vec{v}$.)