

Work and Energy

PES 1150 Prelab Questions

Lab Station: 005

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1. Lift a book from the floor to the table. Did you do work? To answer this question, consider whether you applied a force parallel to the displacement of the book.

Work is defined by applying a force parallel to the displacement of an object **or** applying a displacement parallel to an acting force.

$$W = F \cdot \Delta l \cos(\theta)$$

If we draw a free body diagram of the book:

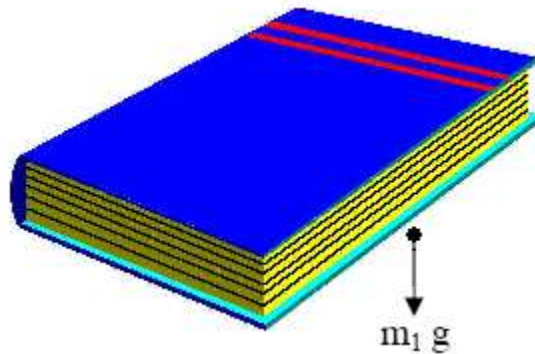


Figure 1: Free body diagram of a book under the influence of gravity.

There is always force acting on the book, due to the acceleration due to gravity. This is in the “down” direction. Hence, according to the definition for work, the only way to do work is by moving the book in a direction parallel to the acting force of gravity. This means directly “up” or directly “down”. Any displacement (movement) of the book perpendicular to the acting force does not do any work. This means “side-to-side”.

Now, let's consider the movement of a book from the floor to a table (see the figure below).

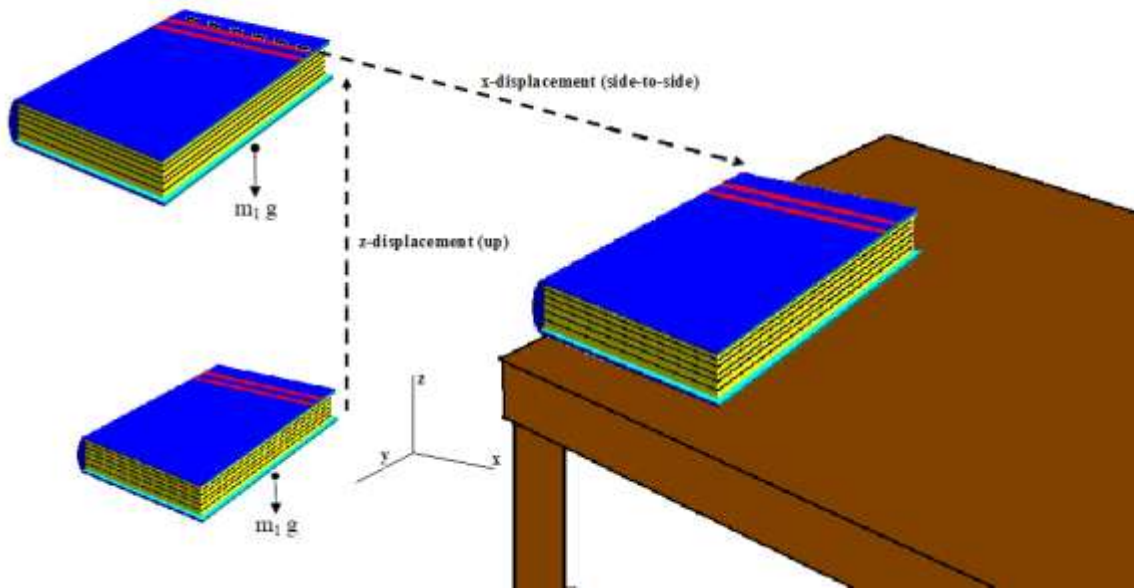
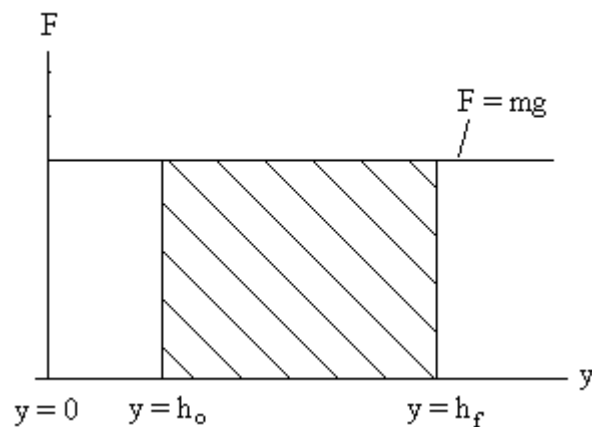


Figure 2: Displacement of a book from the Floor to a Table.

By lifting the book, you are applying a displacement directly up. This is precisely the definition of work. So by lifting the book up, you **are** doing work.

By moving the book (at the same height), over to the table, you are applying a displacement side-to-side. This motion is perpendicular to the acting force; hence, there is no work being done. So by moving the book to the side, you **are not** doing work.

2. The following graph shows how a constant force, in this case gravity, acts over distance: Lifting a mass (m) up against gravity.



Show that the indicated area under the force curve is just the potential energy stored in the object by the force, $\Delta U = mg\Delta h$. What units does the “length” of the rectangle have? What units does the “height” of the rectangle have? What units does the area under the curve have?

The area under the force line (the shaded area) is simply a rectangle. The area of a rectangle is given by:

$$\underline{Area = (height) \times (width)}$$

The height and width of the rectangle can be found from the difference of the final value and initial values (sides of the box).

Height:

$$\underline{\Delta F = F_{final} - F_{initial} = mg - 0 = mg}$$

Width:

$$\underline{\Delta h = h_{final} - h_{initial} = h_f - h_o}$$

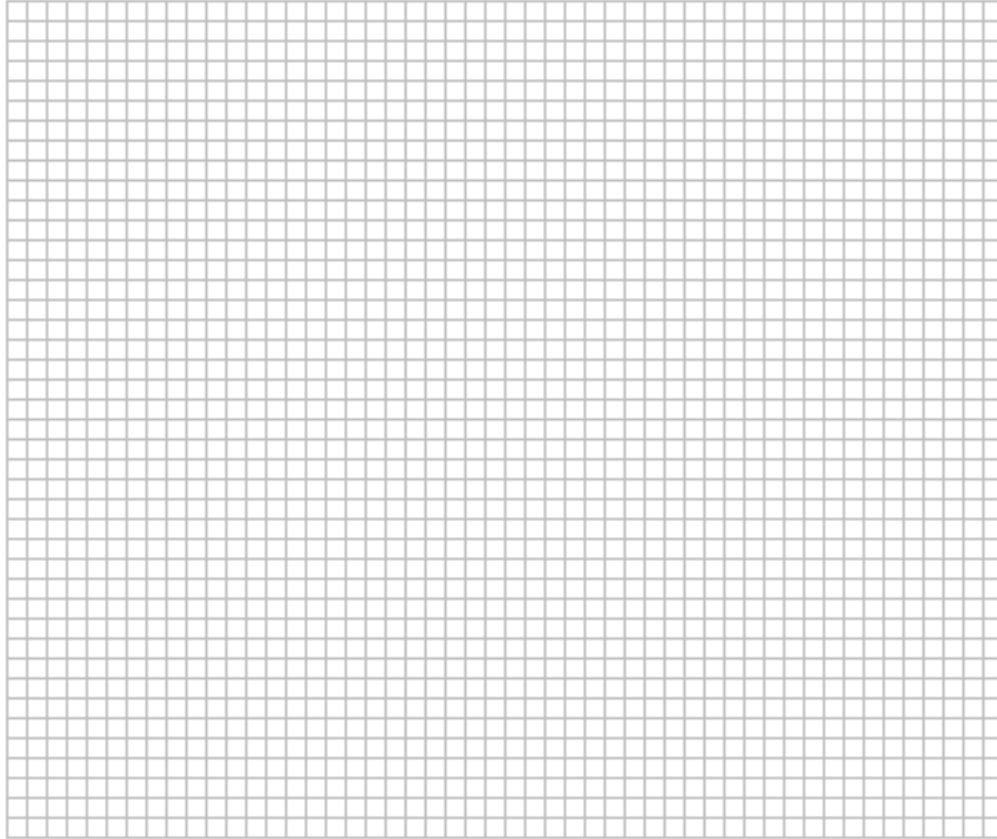
Hence the Area of the shaded box in the figure above is:

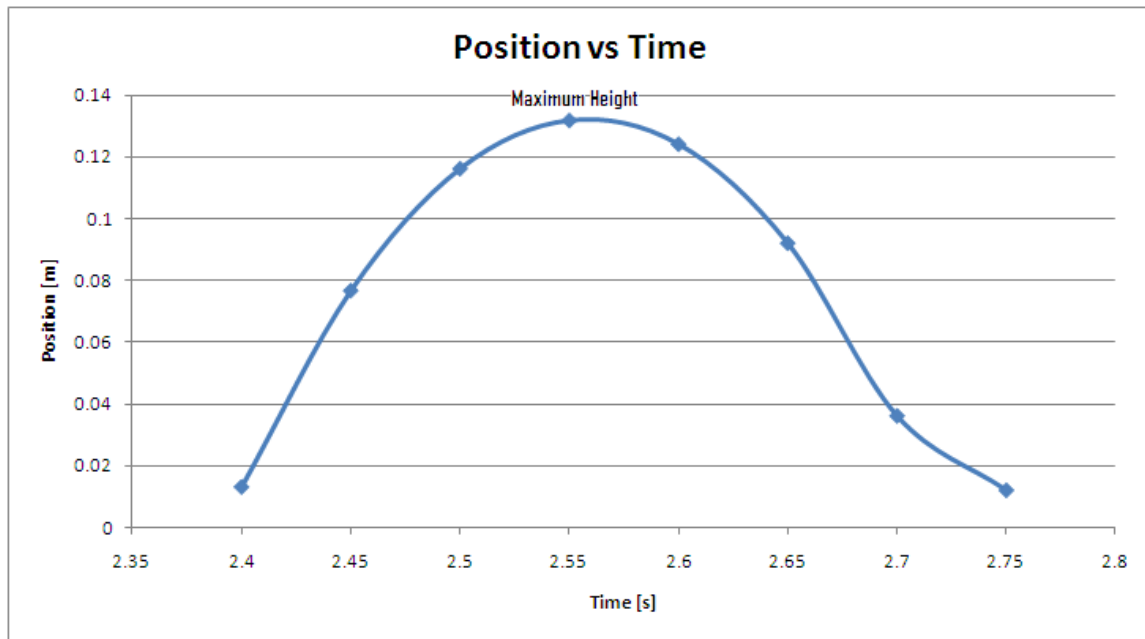
$$\underline{Area = \Delta h(\Delta F) = \Delta h(mg)}$$

$$\boxed{Area = mg\Delta h = \Delta U}$$

The units of the Height of the rectangle are Newtons (which is a kilogram-meter-per-second-squared). The units of the Width of the rectangle are meters. Hence, the Area of the rectangle (potential energy) has units of Newton-meters (which is a Joule or a kilogram-meter-squared-per-second-squared).

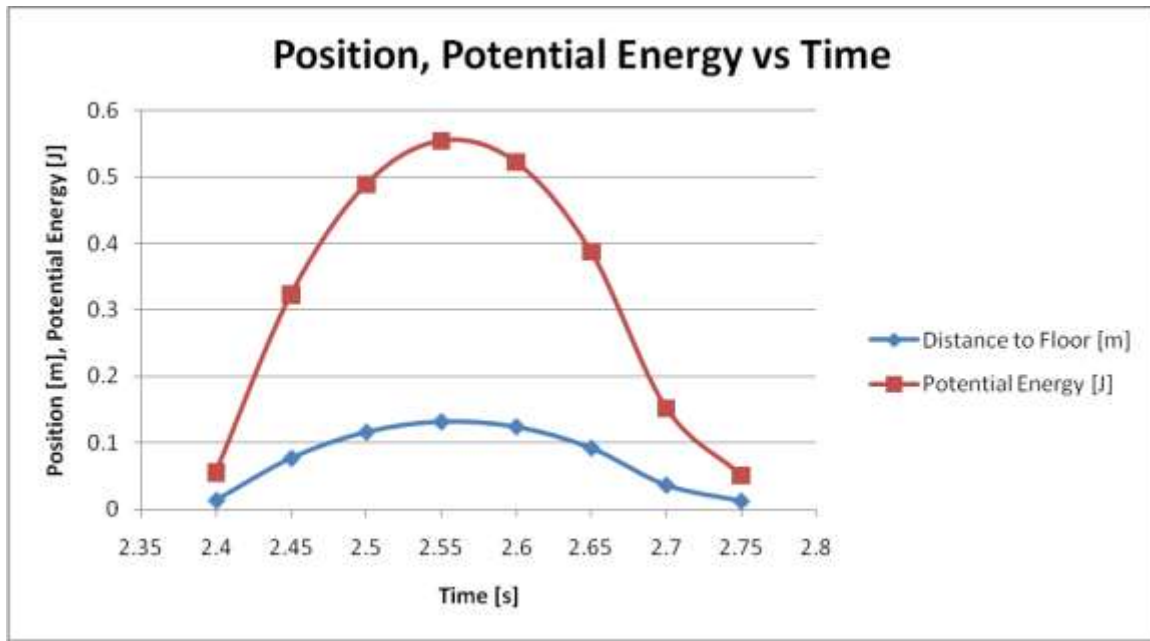
3. Think about the physics behind tossing a ball into the air and catching it. Sketch out a plot of the ball's position vs. time and indicate the maximum height.





Throwing a ball into the air will follow the kinematic ballistic motion (we can refer to labs 3 and 4 to see this action). That means that the shape of height versus time should be parabolic (since it has a quadratic dependence on time). In a drag-less (frictionless) environment, the maximum height will be exactly halfway over the duration of the flight.

4. Now let's see if you know what a graph of the potential energy should look like.
Plot the potential energy vs. time. Sketch the potential energy curve on the same graph as the position vs. time sketch.
 - When will the potential energy be the greatest?



The potential energy will be the greatest when the ball will be at its maximum height. [Please note that the mass and the acceleration due to gravity will not change over time, so they are simply a constant scaling factor.]

- When will the potential energy be the least?

The potential energy will be the least every time it hits the ground and the potential energy goes to zero. (Note that this is when the kinetic energy will be at its local maximum.)

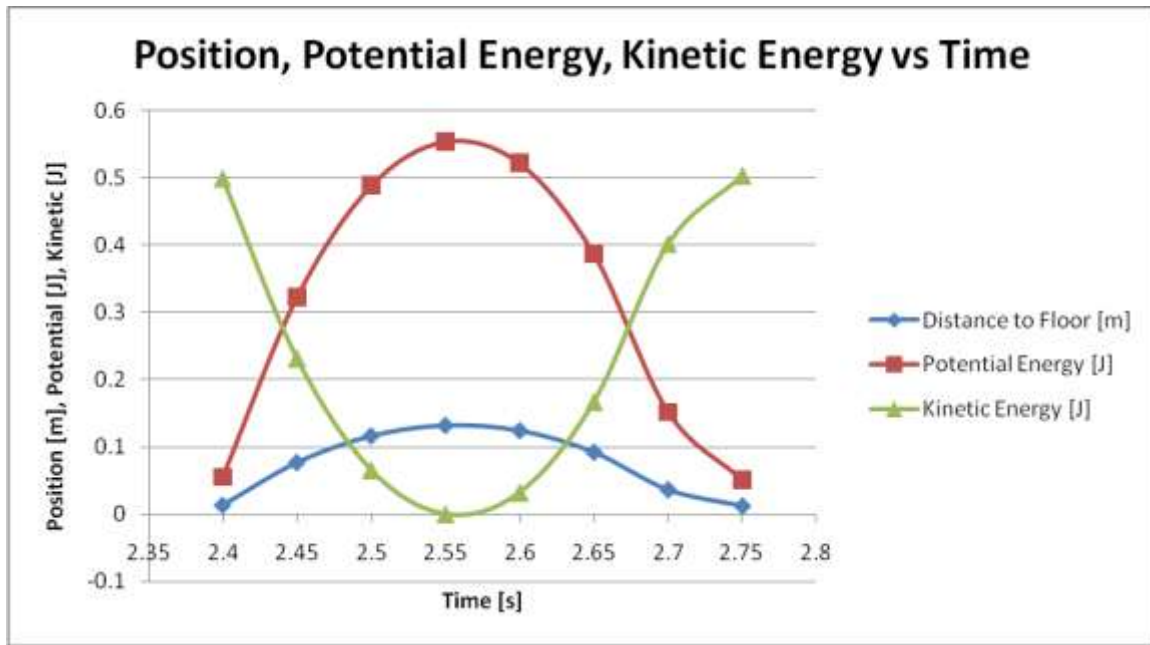
The mathematical equation for potential energy is given as:

$$\underline{U = mgh}$$

Also note that the potential energy is a function of mass of the object, the acceleration due to gravity, and the relative height of the object (off the ground or from the reference point). Since the mass of the ball and gravity are remaining constant, then the graph of potential energy versus time should look almost identical to the graph of height versus time.

5. Now for the tricky one. Sketch the kinetic energy vs. time. Use the same graph as the one above.

- When will the kinetic energy be a maximum (velocity be the greatest)?



The kinetic energy will be the greatest right before and right after the ball hits the ground on the initial drop.

(The previous sentence is worded carefully – because unlike the graph above, the kinetic energy is not a continuous function. This type of “smooth kinetic energy” would only occur if the collision between the floor and the ball was perfectly elastic for the ball, and perfectly inelastic for the floor.) This is when the ball will be at its minimum relative heights; and since kinetic energy is a function of mass, and velocity, the only point where each of these is at their respective maximums is at the impact points.

- When will the kinetic energy be zero?

The kinetic energy will be zero when the ball will be at each of its local maximum height. The kinetic energy will return to zero every time the velocity of the ball goes to zero. The mathematical equation for potential energy is given as:

$$K = \frac{1}{2}mv^2$$

Note that the mass cannot go to zero so for the kinetic energy to be zero, the acceleration must be zero.)

Have your instructor check your sketches before starting the experiment.