ENERGY (PART I) and WORK (PART II)

Purpose:

- To understand work, potential energy, & kinetic energy.
- To understand conservation of energy and how energy is converted from one form to the other.

Apparatus: Pasco track, Pasco cart, LabPro interface and cables, motion sensor, pulley, mass bucket & long thin string, assorted mass hanger weights

Background: Reread your textbook to refresh your memory on the concepts of energy, work, kinetic energy, and potential energy. In this lab we will be using four equations, which we summarize here:

$$W = F\,\Delta x\ \cos\theta, \qquad \text{(work)} \qquad (1)$$

where θ is the angle between the force F doing the work and the displacement Δx of the object during the time work is being done. The kinetic energy of a mass M moving with speed v is:

$$KE = \tfrac{1}{2} M v^2 \qquad \text{(kinetic energy)} \qquad (2)$$

The gravitational potential energy of a mass m raised a distance Δy above the zero-level of potential energy is:

$$PE = m\,g\,\Delta y \qquad \text{(gravitational potential energy)} \qquad (3)$$

The point where the potential energy is zero can be arbitrarily chosen (since only changes in potential energy can be measured). It is conventional to make the lowest point in height the zero of PE. Conservation of energy states that:

$$KE_i + PE_i + W_{nc} = KE_f + PE_f\,, \qquad \text{(energy conservation)} \qquad (4)$$

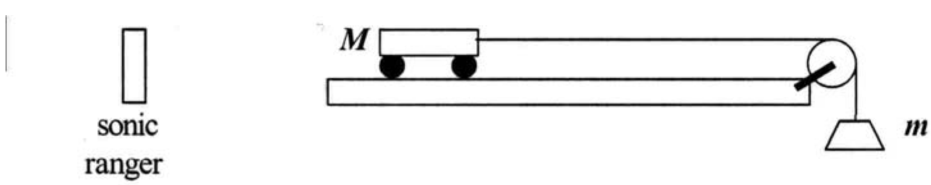
where W_{nc} is the work done on the system by non-conservative forces such as friction. Work done by conservative forces like gravity is taken care of by defining the potential energy due to the force. Note in the case of friction that the force of friction always opposes the motion ($\theta = 180^o$) so that W_{nc} is always negative. Friction always removes energy from the system. Also remember that **work is a process** that transfers energy into or out of a system. Although a system can contain energy, it cannot contain work.

For the ActivPhysics exercises you will also need the potential energy of a spring when compressed a distance Δx,

$$PE = \tfrac{1}{2}\,k\,\Delta x^2, \qquad \text{(potential energy of a spring)} \qquad (5)$$

where k is the force constant of the spring ($F = -\,k\,\Delta x$). Note that the potential energy is zero when the spring in not compressed.

Experimental Set-up: You will study a wheeled cart of mass M (~ 0.2 - 0.5 kg) on a horizontal low friction track. M is attached to a smaller mass m (~ 0.005 - 0.080 kg) by means of a string passing over a pulley. The mass m is allowed to fall vertically to the floor through a distance Δy. The initial speed of both m and M is $v_i = 0$; they are both released from rest. You will measure v_f, the final speed of M, after the small mass m travels a distance Δy to the floor. The speeds of m and M are the same as long as the connecting string stays taut.



You will use the same sonic motion sensor as you did in the first two labs. Open the file WorkEnergy.xmbl. The velocity at any time or position can be obtained from the Logger Pro program.

The speed v_f will depend on three variables -- M, m, and Δy -- that you can vary to test conservation of energy [eq.(4) above] and examine whether any discrepancy can reasonably be attributed to friction.

Important checks:

- Check that the low-friction track is level.
- Be sure to add the mass of the bucket (written on the bucket) to the small masses you put inside to get to the total falling mass m.
- Because of friction, there is a minimum value for m that is needed to produce any acceleration. Determine this value and be sure that you use considerably larger values of m for your experiment. Otherwise the friction will dominate and give poor agreement.

PART I

Activity 1 (60 min): Dependence of the final speed v_f on m, Δy and their product m Δy. Use the set-up described above to determine the final speed of the cart for several different values for m while keeping M constant. In each case choose the height Δy above the floor at which m is released so that the product m Δy is a constant (meaning that PE always changes by the same amount). Then make additional measurements for the case where only Δy varies. Answer the questions on the lab hand-in sheet.

Activity 2 (40 min): Relationship between kinetic energy and total potential energy. Using the data from Activity 1 (second case) for which m is a constant, make a plot of total potential energy versus v_f and fit the data to curves that vary as v_f , v_f^2, and v_f^3 to see which gives the best fit. Answer the questions on the lab hand-in sheet.

Activity 3 (20 min): Conservation of energy. Use your data from Activity 1 to determine whether conservation of energy holds. Discuss any discrepancies as indicated on the lab hand-in sheet.

PART II

Activity 4 (60 min): Work. Draw free-body diagrams for m and M for the experimental set-up used above. Calculate the work each of these forces does during the time m falls to the floor. Include friction. Use symbols rather than numbers and be careful about the signs.

ENERGY and WORK (preliminary questions)

Name: ____ Section: ________

PART I

1. A 130 g arrow is shot straight up with an initial velocity of 20 meters/second.

a) What is its initial kinetic energy? To what height does it go?

b) At what height does the arrow have maximum potential energy? What is its maximum potential energy?

c) At what height does the kinetic energy equal the potential energy?

Report -- ENERGY and WORK (PART I)

Name: ____ Section: _____________
Partner: _______________________________________ Date: ______________

PART I (try to be very accurate and record 3 significant figures if possible)

Activity 1: Dependence of final speed v_f on m and Δy and their product m Δy. Determine the final speed at the floor for several different values for m (20, 30, 40, 50, 60 gram) while keeping M constant. In each case calculate the height Δy above the floor at which m can be released so that the product m Δy is a constant. Calculate the corresponding change in potential energy PE. To improve your accuracy repeat each measurement (for given M, m, Δy) THREE times and record the average final speed v_f with 3 significant figures.Use values of Δy between 0.2 and 0.8 m.

Table 1 (constant M, vary m, vary y, change in PE is constant)

M(kg)	m(kg)	Δy(m)	m Δy(kg.m)	PE_m	v_i	3 runs v_f	average v_f

[PE_m is the initial gravitational potential energy of m given by Eq. (3).]
Comment on the values of the final speed in Table1. Should they really all have the same value?

Now repeat the experiment with **the same fixed values for M and m as in the first line of data in Table 1** but with 4 new values of Δy (now PE_m does not remain constant).

Table 2 (both M and m constant, vary y)

M(kg)	M(kg)	Δy(m)	m Δy(kg m)	PE_m	v_i	3 runs v_f	average v_f

What can you conclude from your data in Tables 1 and 2 about the general relationship between v_f and PE_m? (Later you will specify this relationship more precisely!)

Activity 2: Relationship between kinetic energy and total potential energy.

In Tables 1 and 2 you calculated PE_m. Where did you choose the zero of potential energy to be?

You now want to calculate the sum of potential energies of m and M, $PE_{M+m} = PE_m + PE_M$. Do you have to choose the zero for PE_m and PE_M to be at the same height? Realize that PE_m changes but PE_M does not.

Fill in the following table using all your data, which have the same value for m (Table 2 and the first line of data in Table 1).

Should you include $\Delta y = 0$ as a data point?

Table 3 (for fixed m = , and fixed M =)

Δy(m)	PE_m	PE_M	PE_{M+m}	v_f	v_f^2	v_f^3

Using Graphical Analysis, make a plot of PE_{m+M} versus v_f for the data given in Table 3. Make a linear fit to the data (which would mean that $PE_{m+M} \propto v_f$). Also plot PE_{m+M} versus v_f^2, then try a linear fit. Similarly plot PE_{m+M} versus v_f^3, followed by a linear fit. For each fit record the value of the correlation coefficient R^2. Make a copy of your graphs showing all three fits and attach it to your report. [Pay attention to the appearance and quality of the graph.]

Which power of v_f provides a better fit to you data? What is the value of the correlation coefficient in each plot?

In view of the definition of kinetic energy given in Eq.(2), explain why these data strongly suggest that the change in potential energy is related to the change in kinetic energy.

We have considered only the initial potential energy and the final kinetic energy. Reason is that and the initial kinetic energy is zero since the masses start from rest, and the final potential energy is zero by our convention,

Activity 3: Check of conservation of energy expressed in Joules.

Use your data from first line of Table 1 to determine whether conservation of energy holds. Use that data to fill in the following table:

Table 4 (kinetic and potential energies)

Initial K.E. of M (in Joule)	
Initial K.E. of m	
Initial P.E. of M	
Initial P.E. of m	
Total initial energy of m + M	
Final K.E. of M	
Final K.E. of m	
Final P.E. of M	
Final P.E. of m	
Total final energy of m + M	
Difference between initial and final total energies	

From this table what can you conclude about energy before and after the fall?

You did this experiment to verify that energy is conserved, but your data show a discrepancy between the initial and final total energies. To what do you attribute this discrepancy?

Report -- ENERGY and WORK (PART II)

Name: ____ Section: ______________
Partner: ____ Date: _______________
Partner: ____

PART II

Activity 4: Work.

Draw separate free-body diagrams for m and M for the experimental set-up used above. Calculate the work each of these forces does during the time m falls to the floor. Include friction. Use symbols rather than numbers and be careful about the signs.

What is the total work done on M during the fall?

What is the total work done on m during the fall?

What is the total work done on M+ m during the fall?

What is wrong with this statement?

During the time that m falls through a distance Δy the force of friction F_f removes an amount of work $W_f = -\Delta y\, F_f$ from the system of (M + m).