NAME___________________________________ DATE________________

Lab 3: Work, Energy & Power
Essentials of Physics: PHYS 101

Most of us love the dear old Earth, in fact we're quite attracted to it. That attraction arises from the Earth's large mass, not the fact that it is spinning. When we lift a book away from the center of dear old Earth, we *do work* on that book. We do work because we must counteract its attraction to the Earth in the process. We *do work* by applying a force over a distance. What does that do for us? Well, it tires us. The book, however, gets *energy* out of the deal.

Doing work on something, or having it do work, results in a change of its energy. Sometimes doing the work results in changing an object's "motion energy" (called Kinetic Energy, or KE)… I push on my broken-down car and it begins to move. Other times doing work results in a change in Potential Energy (PE)— something the object can later turn into Kinetic Energy. Hold the book you just lifted. It has Gravitational Potential Energy. Let go, it converts the GPE into KE.

In fact, *mechanical energy* (PE or KE) can be defined as the capacity to *do work*. In dropping our book, it converts GPE into KE and, if it hits something when falling, it can exert a force on that something, over a distance. So we have a very strict definition of energy couched in terms of *doing work*. Why is this important? Well, now we can compare the amount of energy in a liter of gasoline to that in a 1000kg car moving down the road at 30 m/s. We can compare energy in peanut butter to energy needed to heat bath water. We have a portable and universal definition. That's handy.

Experiment One: *Houston, we have liftoff*

Introduction:

We use falling water, after it is impounded behind dams, to do work on turbines and make electricity (electrical energy) for us. Although nature does the work of lifting this water into the air over the oceans, we can similarly do work on an object by lifting it above the ground. As long as we don't let go, we have increased that object's gravitational potential energy, or GPE.

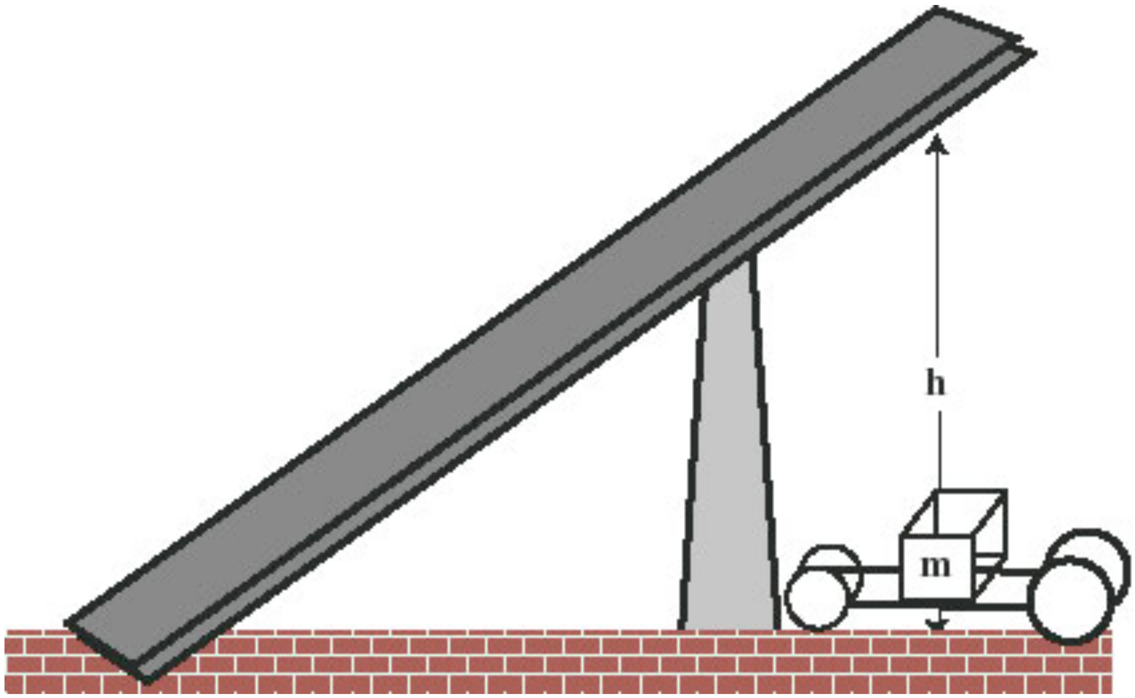
Question: If I lift a 1kg book 1m above the floor, how much GPE has it gained? Show your calculation below. How could I confirm the change in the book's GPE. Explain. Now, if I take my lifted book and move it sideways, do I change its GPE. How can you confirm your answer?

Checkpoint: Have a laboratory instructor check your answers before proceeding .

During this part of the experiment you will be lifting a cart to a height where it can be placed on a ramp (used during the next part of the experiment).

Procedures:

1. "Mass" the vehicle without and with additional masses. Massing something is similar to weighing it, but if you took it to the moon it would still have the same mass. Enter the vehicle's different masses in the table on the next page.



2. Measure the distance *(h)* to the top of the ramp. Record it below.
3. Attach the spring scale to the vehicle. (you may want to use a harness of string for this.)
4. Slowly lift the vehicle to the top of the ramp. Watch the spring scale while doing this. Record the average reading on the spring scale below.
5. If you have trouble, do a few trials while watching the spring scale. Estimate the <u>average reading</u> from all the trials.
6. Follow this procedure for the vehicle with one, none, and two double washers attached to it.

Observations:

Data Table: Experiment One

	mass of vehicle (kg)	ramp height (m)	Force when lifting vehicle (N) (from spring scale)	Work in lifting vehicle (N•m)	Change in vehicle's GPE (J)
no double washers					
1 added mass					
2 added masses					

Calculations/Questions:

1. Our definition for work is force applied over a distance. How do you calculate work in lifting the vehicle for the table above? (note: N•m means Newtons x meters, which is a Joule (J), the unit of energy, by the way)

2. Use your formula for 1 (or ask an instructor if you're not certain) to complete the Work Column, above.

3. Approximately how much more work was done on the two added-mass vehicle compared to the one added-mass vehicle? Half as much? The same? Twice as much? More? Explain

4. Calculate the vehicle's change in Gravitational Potential Energy (GPE) for the lift (see last page for formula). Use your answer to complete the final column, above.

Experiment 2: *After the fall…*

Introduction:

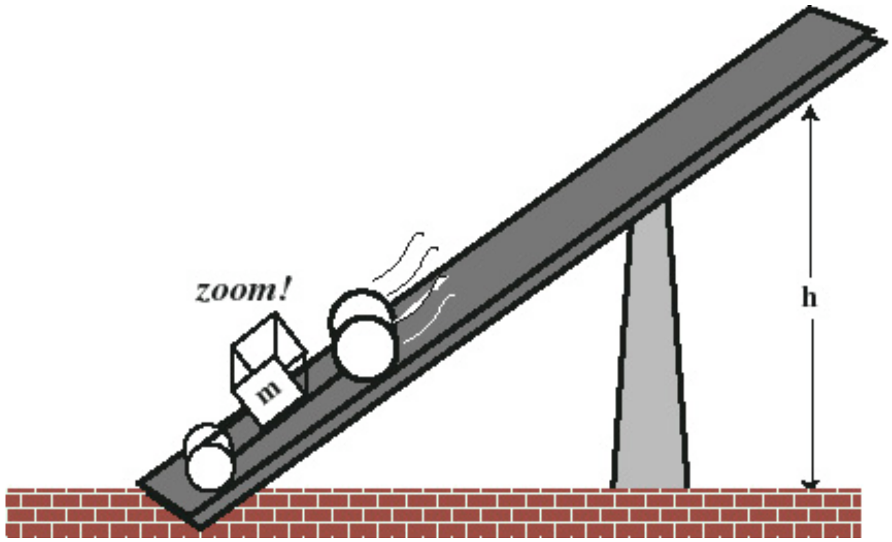
Now that you have *done work* *on* your vehicle and added masses, how can you calculate how much energy it gained in the process? Why, let it fall down a ramp, of course. Besides giving the car the opportunity to convert GPE to KE, it gives us a chance to make *really cool sound effects* along the way.

Important! There are three different ways to assess the amount of kinetic energy the vehicles have at the bottom of the ramp. **Your group is responsible for using just one of these methods ("Setups")**. The lab setups will be clearly labeled as to which method it supports. The procedures, below, will include entries for the setup/method you use.

Question: But, wait. Didn't the instructor say that all things fall at the same rate in class?! Even when falling down a ramp? If that's true, will the heavier vehicle be moving faster at the bottom of the ramp? If not, how can it have greater KE? Oh, I'm so confused! **Choose one of the two hypotheses, below**, that you agree with (circle it). Explain your reasoning below it.

Hypothesis One: Each vehicle (+ added masses) will have a different velocity at the bottom of the ramp. The vehicle with more added masses will be moving faster. Thus it will have more kinetic energy, as kinetic energy is proportional to velocity squared (v ● v)

Hypothesis Two: Each K'vehicle (+ added massess) will have the same velocity at the bottom of the ramp. The vehicle with more added masses will be moving the same velocity as the others. It will, however, have more kinetic energy as kinetic energy is proportional to mass.



Procedures (remember, your group is doing ONE of these setups):

Setup 1: Measuring how far the car goes on the ground.

1. For each vehicle+added mass combination (+none, +one, or +two), let the vehicle & load drop down the ramp.
2. Measure how far the vehicle/combo went after it reached the bottom of the ramp and record in the table, below.
3. Get data from a group doing Setup 3 for the two appropriate columns in the table, below.

Data Table: Experiment Two, Setup 1

	mass of vehicle + added masses (kg)	GPE at top of ramp (N•m)	**Setup 1:** distance traveled (m)	Ranking **(based on Setup 1)**	**(From setup 3):** velocity of car (m/s)	**(From setup 3**): Kinetic Energy (J)	Efficiency (complete when you reach page 6)
Vehicle							
vehicle +1 added mass							
vehicle + 2 added mass							

NOW GO TO PAGE 7 and complete Calculations/Questions section.

Setup 2: Measuring how quickly the car covers a fixed distance at the bottom of the ramp.

1. Put a piece of tape across the vehicles path 1.0 m from the end of the ramp.
2. For each vehicle + added masses combination (+none, one, two), let the vehicle combo drop down the ramp.
3. Time how long it takes the car to go from the bottom of the ramp to the tape using a stopwatch. Record the time in the table, below.
4. You may (should!) want to run three trials for each vehicle/added mass combination and average the three times.
5. Use the measured distance and time to calculate the car's average velocity, and enter below.
6. Get data from a group who used Setup 3 to fill in the appropriate table column, below.

Data Table: Experiment Two, Setup 2

	mass of vehicle + added masses (kg)	GPE at top of ramp (N•m)	**Setup 2:** time to travel 1.0m (s)	**Setup 2** Avg. velocity (m/s)	**(From Setup 3):** velocity of car (m/s)	Kinetic Energy (J) (from Setup 2)	Efficiency (from Setup 2, see page 6)
Vehicle							
vehicle+ 1 added mass							
vehicle + 2 added mass							

NOW GO TO PAGE 7 and complete Calculations/Questions section.

Setup 3: Measuring the cars speed at the bottom of the ramp directly.

1. The motion detector should be connected to the computer via a Vernier LabPro
2. The motion detector should already be oriented properly. If you accidently bump it, ask an instructor for help.
3. Software running on the computer will allow you to plot the vehicle's position as a function of time.
4. Have one person release the vehicle while another clicks on the Start button on the computer screen. The third group member should be positioned to catch the car at the end of its trip.
5. The plot of the cars position will be straight and will then change as the motion detector picks up the car at the bottom of the ramp. Under the Analyze menu item, select Tangent. Now move the mouse until the crosshair is over the part of the graph where the position first begins to change. (Ask a TA for help if you have problems.) Record the speed in the graph, below, under Setup 3.

Data Table: Experiment Two, Setup 3

	mass of vehicle + double washers (kg)	GPE at top of ramp (N•m)	**Setup 3:** speed of car (m/s)	Kinetic Energy (J)	Efficiency
vehicle					
vehicle+ 1 double washers					
vehicle + 2 double washers					

Calculations/Questions (to be answered by all, regardless of setup):

1. Fill in the first two columns in the table you used (pages 5, 6 or 7) using information from the table for Experiment One (page 3).

2. Looking at the speed of the car from Setup 3, did the speed at the bottom of the ramp vary significantly for the vehicle by itself vs. the vehicle with added masses? Did the speed at the bottom of the ramp vary significantly for the vehicle with one added mass vs. the vehicle with two? Explain.

3. Use your information entered in the appropriate Setup column to either rank (if you did Setup 1) or calculate the kinetic energy of the vehicle/double washers combinations at the bottom of the ramp (if you did Setups 2 or 3) (see "**Definitions**," below, for a formula for kinetic energy.)
4. When the cars were lifted to the top of the ramp, they gained a certain amount of gravitational potential energy, as we saw in Experiment One. When they rolled down the ramp, some of the energy was converted to kinetic energy. The ratio of the kinetic energy gained to the work put in to lifting the cars is the *efficiency* (KE/GPE) of the system. Using the estimates of kinetic energy from problem 3, calculate the efficiency (energy in vs. usable energy out) of the 3 different car/added masses setups and record them above. Is the efficiency the same for all three combinations? Why or why not?

5. The principle of conservation of energy says that energy is neither created nor destroyed, but converted from one form to another. In calculating the efficiency, above, you saw that not all of the work necessary to lift the cars was converted back into usable kinetic energy after the car rolled down the ramp. Where do you think the energy went? Explain.

Experiment Three: Your Personal Power Rating

Introduction:

When you measured the work involved in lifting your loaded K'nex vehicle in experiment one, you may have wondered if it matters whether you lifted slowly or quickly. From the energy point of view, the answer is <u>no</u>. If it did matter, and lifting the vehicle quickly somehow gave it more energy, then you would expect it to have more kinetic energy after falling down the ramp.

Quickly lifting the vehicle to a fixed height does require more *power*, however. Power is defined as work done per unit time. By lifting the vehicle quickly you have done the same amount of work, but in a shorter time.

Question: Say that you lift the vehicle with one added mass to a height of 1m. It takes you 1 second to do this. After lowering the vehicle, you then lift it 2m in 2 seconds. Have you generated more power in doing the second task? Explain.

For this experiment, you will measure your "personal power" rating. Typically people have different power ratings for different tasks. Your instructor's power rating for simple telekinesis, for example, is quite low. Here you will measure your power rating for climbing stairs.

Procedures:

1. Find a flight of stairs near the lab room.
2. Measure the total height of the stairs. Enter below.
3. While another member of your group times you, run up the stairs as fast as you can. (hint: have the person with the stopwatch stand at the top of the stairs.) Enter the stair climber's weight below.

Note: To convert your weight in lbs to Newtons, multiply by 4.45

4. Have all group members (who are capable) do this activity. Ensure that the manner in which the timing is done is the same for each group member. Fill out the table, below.

Observations:

Height of stairs = __________m (multiply # of steps x height of one step).

Data Table: Experiment Three

group member	weight (N)	time (s)	work done (J)	power rating (J/s)

Questions:

1. Calculate the work each group member did in climbing the stairs. Enter this in the "work done" column above. (hint: see the glossary of terms for ideas.)

2. Calculate the power rating of each group member and enter it above. Who has the highest power rating?

3. A typical human's power rating for an entire day is 100watts (W = J/s). How did your power rating when climbing stairs compare to that value?

4. A typical human consumes 2500 Kcal of energy during a day. This is the equivalent to 10,450,000 J! Say you decided to run stairs all day. Given that there are:

   24 ~~hours~~ / day • 60 ~~minutes~~ / ~~hour~~ • 60 seconds / ~~minute~~ = 86,400 seconds / day

   How much energy, in Joules, would you burn in climbing stairs all day?

5. How many Kcal of food energy would you need to consume to do so? (remember that there are 4180 J / Kcal.)

Definitions:

Name	Symbol	Definition	Formula
"Do Work"	W	force applied over a distance.	F x d
Energy	E	in general, the capability to do work.	
Mechanical Energy	ME	energy due to position or movement of mass.	
Potential Energy	PE	stored energy.	
Gravitational Potential Energy	GPE	an object's potential for gravity to do work on it.	m x g x h
Kinetic Energy	KE	energy in motion.	1/2 x m x v x v

Units:

Work and Energy have units of Joules (J). A Joule is a N•m (Newton • meter). A Newton, of course, is a unit of force.

Power has units of Watts (W), which is a Joule per second (J/s).