LAB 8
Energy and Power

What to learn and explore

Things that move all have **energy**—so how do we get them moving? We convert stored energy to energy of motion. This is done by making a **force** act through a **distance**—we call it **work**. Simply put, e**nergy is the capacity to do work.**

In this lab, we will learn the difference between **energy** and **power**. We will meet various forms of energy, and observe them as they convert from one form to another. We will follow some of our energy from its source to its final destination. We will observe how much of it truly gets used to do our work, and how much is "wasted" along the way. We will meet the concept of **efficiency.**

There are various ways to store energy. We refer to stored energy as Potential Energy, so you might hear of gravitational potential energy (when something is lifted up high), chemical potential energy (like in a battery), etc. Other kinds of energy that you'll use today are thermal energy, light energy, kinetic energy (energy of motion), and electrical energy.

Mandatory Comments

When you finish the lab, please write a few comments here. This is a new lab, and we hope to improve it each time we do it. Please tell us which parts were the most/least interesting and educational. Any ideas for how we can improve this lab?
What are the main things you got out of this lab?

1) Energy Units

When we talk about energy, we use many different kinds of units, depending on the situation. Common units of energy we use are Joules and Calories. In this section, you'll get a sense for how large these are and how they compare to each other.

a) Joules. A Joule is defined as the amount of energy it takes to pull (or push) on something with a force of 1 Newton for a distance of 1 meter. The aluminum cylinder weighs about one Newton. Try lifting it up from the floor to the counter and you'll see what a Joule of energy feels like.

Is that more or less than you would have guessed?

b) Food Calories. When you read a food label from the USA, the energy stored in the food is given in Calories. A Calorie is a surprisingly large amount of energy—it's about 4000 Joules! To store a Calorie of energy, you would have to lift **forty** 10 kg masses from the floor to the counter. The briefcase is 10kg – try it out! A lot, isn't it? (If you take chemistry, you'll hear about another type of calorie, spelled with a small 'c'. This is 1/1000 of a food calorie. Because of this, the food calorie is also called a kilocalorie.)

Now you might ask yourself whether you would have burned off a Calorie of food by doing that work. You actually burned off more than that, because our bodies, like any machine, are inefficient and we have to burn three or four Calories to get out one Calorie of useful work.

c) Labels on Food. In many other countries, the energy in food is given in kiloJoules. We have some food labels from New Zealand for you to look at.

Which do you think contains more energy, a small packet of almonds or a stick of dynamite? ___________

Check out the labels and see if you are right.

Energy in entire package of almonds = _____________ Energy in stick of dynamite = _____________

Why are we more afraid of a stick of dynamite than we are of a package of almonds?

2) Power Units:

Power is a measurement of how fast energy is being stored up or used (so it's a **rate**). If we use money as an analogy, I could say "I saved $1000". That would be like an amount of energy. If I said "I saved $100 per month, that would be a **rate.**

Watts. The most common unit of power is the Watt. A Watt is a rate of energy consumption of 1 Joule per second. A fluorescent light bulb might use about 10 Watts. The power plant at Moss Landing generates about 2000 Megawatts, or 2000 million Watts. A typical array of solar panels on someone's house might generate 2400 Watts on a sunny afternoon.

Horsepower. 1 horsepower = 746 Watts. A car with a lot of horsepower gets up to speed *fast.* In Part 3 you will measure your own power in Watts and in Horsepower.

a) Power used by appliances.
Some of these appliances use energy quickly (many Joules per second), and others use energy not so quickly. Try to guess how many Joules per second (or Watts) each appliance uses – don't worry about being wrong. Then look at the label to see what it is supposed to use, and also measure its actual power with the kill-a-watt. When you are measuring, try different speeds/settings if the appliance has them.

Appliance	**Guessed Watts (Joules/sec)**	**Watts from Label**	**Measured Watts**
Pencil sharpener	________________	_____________	_____________
Fan	________________	_____________	_____________
Hair Dryer (hot)	________________	_____________	_____________
Hair Dryer (cool)	________________	_____________	_____________
__________________	________________	_____________	_____________
__________________	________________	_____________	_____________
__________________	________________	_____________	_____________
__________________	________________	_____________	_____________

-Which ones do you think you'd be able to run with your own human power?

-Did any of them surprise you?

b) Different Kinds of Light bulbs. We have 3 different light bulbs set up that use very different technologies to create light. They all put out roughly the same amount of visible light.

How do they compare with respect to how much heat (also known as infrared light) they put out? - *Be careful not to burn your fingers.*

Try to judge the bulbs' heat output, and rank them according to how much power you think they use, from lowest to highest.

coolest _________ , __________ , ___________ hottest

Now use the **kill-a-Watt** device to measure the power each bulb uses.

Fluorescent bulb uses _______Joules/sec Incandescent Bulb uses _______Joules/sec

LED bulb uses ________ Joules/sec

Was your ranking correct?

3) Your Power: stairs!

An old fashioned light bulb may convert electrical power into light and heat at a rate of 100 Watts (remember , that's a rate of 100 Joules every sec)—and your body converts food energy into movement and heat at about 100 Watts when you are being a couch potato. Another way of measuring it is that you use about 2000 Calories per day just to keep yourself warm. When you exercise, you can increase this rate by over 10 times! Today, you will do some work and see how powerful you are.

a) Use the Newton-o-Meter bathroom scale to measure the force that gravity pulls on you, in Newtons Record this force (your weight in Newtons**)** here:

Weight = ______________ **Newtons**

b) Go outside with a measuring device, a stopwatch, and pen and paper. Find a nice long flight of stairs. Measure the height of each stair and count them**.**

Height of each stair: __________cm x Number of stairs ______ = Total height ________cm

Divide your **cm** number by 100 to get meters . **Height** = ____________________ **meters**

c) Take turns **r**unning up the stairs and time each other. My personal **Time** ____________ **seconds**

Partners times (just for fun) ________________, __________________, _______________

d) Work is **Force times Distance,** so multiply your weight by the height of the stairs.

My work (energy spent) = __________ **Newtons x** __________ **meters =** __________**Joules**

Since 4000 Joules = 1 food Calorie, divide your work in Joules by 4000 to get the number of Calories of work you did in climbing the stairs. *Actually, you probably burned off about 4 times this much food to climb the stairs, because your body (or anyone else's) is about 25% efficient.*

Calories of work you did climbing the stairs: _____________

e) Your Power is your work in Joules (part d above) divided by your time in seconds: Write it out with the units attached. (Joules per Second = Joules/sec = WATTS.)

My Power: ____**Watts!**
If you produced over 746 watts, that's a Horsepower (Hp)!!

f) How long do you think you could keep up that power output until you pooped out? ___________

What level of power do you think you could sustain for a full day's work? ________________ Watts

4) Your Power: Bicycle

a) Fluorescents and LEDs. On the light box, set the switch on the side to Compact Fluorescent. Use the bottom switches to turn on either the fluorescent or the LED bulbs. Feel how much power it takes to run these bulbs.

b) Incandescents. While still pedaling, have your partner flip the side switch to "incandescent". What do you notice?

c) Sustainable Power level – what power level could you sustain for an hour? Try different numbers of incandescent bulbs until you find a level you think you could keep up a whole hour. (They use 50W each if you keep the needle in the green region). Try doing it for 1 minute on the clock and see if you still agree with your first guess. How many Watts (or Joules per second) can you keep up for an hour? ________

5) Cost of Energy. (please do the bike station before this one.)

When PGE charges you for electricity, they charge in units called **Kilowatt-hours**. (abbreviated kWh) This is the energy you would use by pedaling at a rate of 1000W (= 1kiloWatt) for 1hour. It is 3,600,000 Joules!

Let's estimate how much one kilowatt-hour would cost if you had to create it with bikes.

About how many people would have to pedal together to produce 1000 Watts? (hint: remember how much power you produced in part 4). _______________

If you paid them minimum wage, about how much would this kilowatt-hour cost? $_____________

Now guess how much PG&E charges for this 1 kilowatt-hour? My guess: $____________

Now look at the sample PG&E bill and write down the actual cost of 1 kWh: $__________

How do you think it's possible for PG&E to sell this much energy for that amount of money?

The average household in the US consumes about 30 kWh of electrical energy every day! If you had people instead of fossil fuels doing this 30 kWh of work for you every day, how many people would you need? Here's how you can figure it out:

If each of your helpers worked steadily at the rate of 100 watts for 10 hours in a day, you'd get 100 x 10 = 1000 Watt-hours, or 1 kilo-Watt hour of energy from them. How many of these people would it take to equal 30 kWh? ________

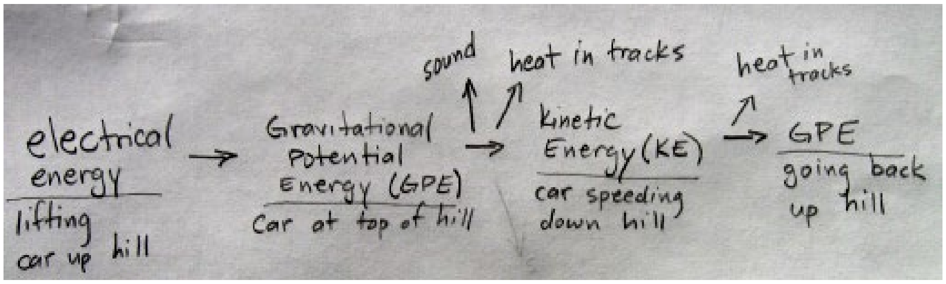
Optional - Do the same calculation for horse helpers (about 750 watts) instead of people. Horses (and wood) were our main energy sources for a long time.

6) Converting Energy from one form to another

Energy is constantly being converted from one form to another, but in any conversion, we find that the total amount of energy stays the same. We're so confident that this is always the case that we call it a "law": the Law of Conservation of Energy. Another "law" says that in every kind of energy conversion, some amount of the energy gets converted into "not useful" heat energy.

Look at each of these situations and name the initial form of the energy (gravitational potential energy, chemical potential energy, light energy, electrical energy, kinetic energy, etc.) Then see if you can identify each form the energy takes as it is converted into its final form. Also identify places where energy is converted into heat energy.

Here's an example, using the roller coaster at the Boardwalk:



a) Hydrogen Fuel Cell - Turn on the switch and watch the propeller turn. Look at the apparatus to see all the different energy conversions.

b) Falling weight lights a light bulb – wind up the string around the generator wheel and then let it fall. The light bulb should light up.

c) Lifting a mass – connect the wires to the motor and watch it lift the mass. (reverse the wires to lower it back down when you're done.)

7) Kinetic Energy and Speed

We know that gravitational potential energy depends on an object's height: something twice as high up has twice the Gravitational Potential Energy (GPE). Kinetic Energy depends on how fast something is moving. But how does something's kinetic energy relate to its speed? If it moves twice as fast, does it have twice as much KE? Here's a fun experiment you can do to help find out.

The spring-loaded launcher shoots a ball up into the air. Since we know that GPE goes up simply with height, we'll use the ball's maximum height as a measurement of how much energy it has. With this method, you can shoot the ball with different speeds and see how the speed changes the total energy.

There are three marks on the tube, labeled A, B, and C. The marks are carefully placed, so releasing the spring from B shoots the ball up with twice the speed as from A, and shooting from C releases it with three times the speed as from A.

Shoot the ball from mark A and make a mark at its high point. Now predict how high the ball will rise - that is, how much energy it will have - if we shoot it with twice the speed and three times the speed. After you have made your predictions, do the experiment and report on your results.

8) Efficiency of Energy Conversions

Here is a little story for this activity:

Your Aunt Mabel lives in Colorado and is in need of some energy to help her lift her piano to the 2nd floor of her house. You decide to help her out by producing some energy and sending it to her over the power lines. To produce the energy, you lift some heavy weights up from the floor. As they fall down, they generate electricity that you send to your Aunt Mabel. You think that some energy might get lost along the way, so you lift a weight that is 10 times heavier than her piano, just to be safe.

Try this out and see what happens.

Did it seem that all your original energy went into lifting the weight on the other side?

Did it seem that even half your energy went into lifting the weight on the other side?

To calculate the efficiency, we measure how much energy you put in and how much you got out. The energy is simply the weight of the object times the height it was lifted.

Lifted weight = 10 Newtons Height lifted = __________ meters

Energy put in = (weight x height) ____________________ Joules

"Piano": weight = 1 Newtons Height raised = ___________ meters

Energy gotten out = (weight x height) ____________________ Joules

To find out what fraction of your original energy did go into the final outcome – which we call the efficiency – divide the energy gotten out by the energy put in:

Efficiency = (Useful Energy gotten out) / (Energy put in)

The efficiency of this conversion was about ___________________.

(you can multiply the answer by 100 to make it a percent if you want)

What percent of your original energy 'got lost'?

Did it just disappear, or did it get converted into something else? What might it have gotten converted into?