Experiment 15: Electric Circuits

Electric Motors, Efficiency & Electric Bills (2/27/24)

EQUIPMENT
1 PASCO Energy Transfer Generator w/mass & string
1 drop tube
1 BeeSpi Photogate
2 Right angle Clamps
2 Three finger Adjustable Clamps
1 Analog Ammeter
1 Magnet & Solenoid setup w/ alligator clips
1 Exercise machine with Wattmeter

Introduction

In **Experiment 14A: Introduction to Electric Currents**, the concepts of work, energy, power, energy loss, alternating currents, the cost of electricity and what quantity the power company charges you for were examined. In this experiment we will examine these concepts further by looking at the concepts of efficiency in general, the efficiency of electric motors and how to interpret an electric bill.

In part B of Experiment 14A the concept of the coefficient of restitution was examined where it should have been noted that **none of the balls used, bounced higher than the height from which they were dropped**. This makes sense when one considers that "**coefficient of restitution (COR)** can be thought of as a measure of the extent to which mechanical energy is conserved when an object bounces off a surface." Furthermore, Hewitt defines efficiency of a machine as

$$Efficiency = \frac{useful\ energy\ output}{useful\ energy\ input}$$

Your observations were a verification that no mechanical process is 100% efficient. The heat, sound and others losses that you observed dictated that the balls would not return to their original height (i.e., energy is conserved). We will examine the efficiency of an electric motor/generator and verify that (in general) they are much more efficient that internal combustion engines and are (seemingly) the future of transportation.

Part A of the experiment is a demonstration to emphasize the difference between energy and power as well as to show just how much energy we use in our daily life and just how large a horsepower is. This will be done by using an exercise machine and student volunteers.

Part B of this lab is also designed to give a quick introduction to how an alternating current (i.e., an AC current) is produced. This is done by observing the behavior of an ammeter connected to a solenoid (which is a coil of wire) while a magnet is moved into and out of the solenoid. The current behavior is analogous to what you observed when you 'rocked' ends of the current model (i.e., the container with the marbles and push pins) up & down and observed the motion of the marbles.

Part C of the lab is designed to measure the efficiency of an electric generator. **It should be noted that an electric generator and an electric motor are essentially the same thing.** This can be easily demonstrated by connecting a generator and a motor together and turning the crank on one & observing what happens and then turning the other crank.

Since efficiency is simply the ratio of useful energy output divided by useful energy input, it can be obtained as follows: 1) Drop a mass a known distance and measure the velocity at the end of the fall- This gives us the **total energy into the system (E_{total}).** 2) Attach the mass to a generator with a string and then measure both the **energy output of the generator (E_{gen})** as well as the **remaining kinetic energy (KE_{remain})** of the mass (since it still has some speed at the end of the fall).

Since we are interested in the useful energy input into the system we see it is equal to **E_{total} - KE_{remain}**

The useful energy output is simply the measured energy output of the generator **(E_{gen}).** Efficiency is the ratio of these two values., i.e.,

$$Efficiency = \frac{E_{generator}}{E_{Total} - KE_{remaining}}$$

Part D of the lab will show you how to read & interpret an electric bill

Procedure

A. Exercise Machine & Power

Power is defined as energy divided by time and is a measure of rate of work (or effort). We will explore the concept of power in this part of the experiment by seeing how much power some of you can generate for a short period of time. It is hoped that this exercise will give you an idea how much effort a horsepower is and a new respect for a horse.

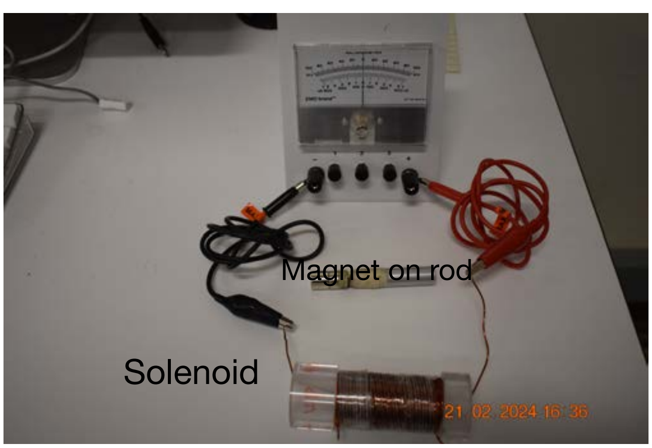
Professional (male) bike riders in the Tour de France (TDF) average between 230 to 250 watts on a flat stage which is usually over 100 miles with an average speed of ~25 mph. The power output for the uphill section of a mountainous stages is much higher- over 400 watts (for 20 plus minutes) with some riders exceeding 500 watts on climbs. In last part of what are called *sprint stages* the power output can exceed 1500 Watts for a very short burst.

https://ciclofilia.org/tour-de-france-average-watts/#google_vignette

We will see how much power some of you can generate for a short period of time. **If you have health issues that might be aggravated by intense exercise please do not volunteer!**

B. Introduction to AC Current

1. Your table should have setup similar to the setup in the figure below.

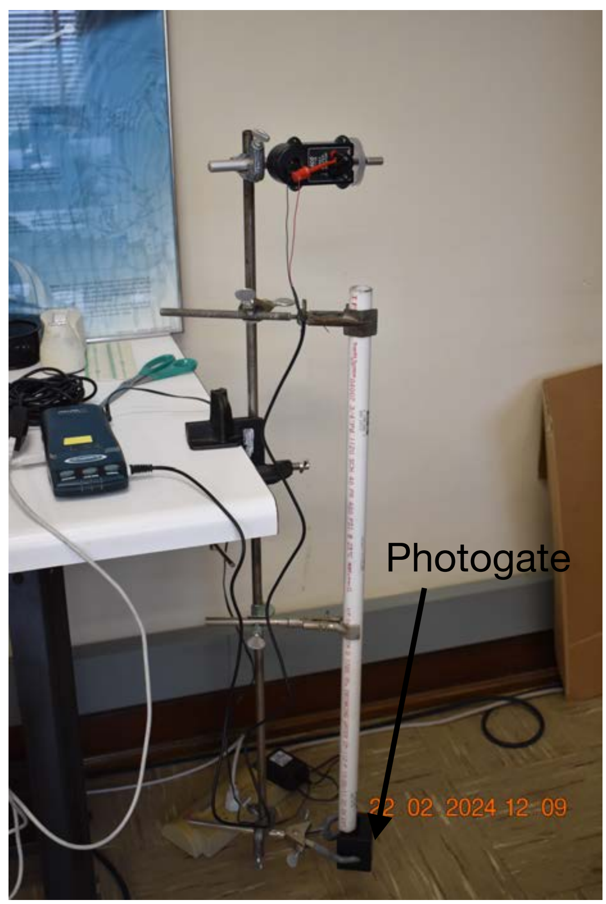


2. Take the magnet and see what happens when you insert it and remove it from the solenoid. What happens to the needle and what does this imply about the direction of current?
3. What happens to the current when you insert the magnet and leave it there without moving?
4. It might be too small to notice, but what do you think you would feel (or not feel) if you disconnected one of the alligator from the solenoid and moved the magnet in and out of the solenoid?

C. Efficiency of an Electric Motor

There are only six setups for the next part, so you should form a group of 4.

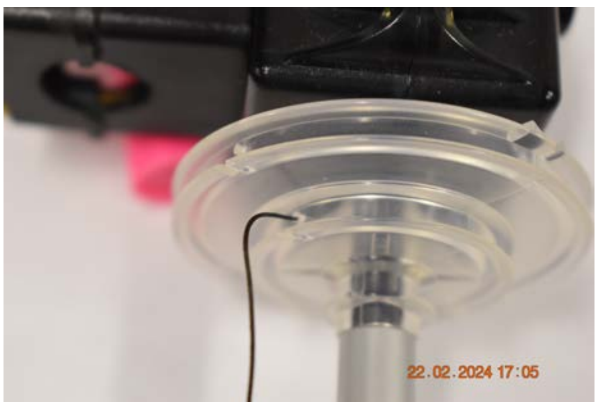
You should have setup similar to the figure below.



1. Measure the mass of the weight that will be used in this part. It should have a mass a little under 50g.

2. With the top of the weight even with the top of the tube, press start on the photo gate, release the weight and record the speed of the weight as it passes through the photo gate. It should be slightly under 4 m/s. Record this velocity on the data page below. Repeat once.

3. Attach the looped end of the string to the weight and the plain end of the string through small hole in the middle pulley and wind the string on the pulley until the **mass is even with the top of the tube.**



4. Your computer should have a program called Logger Pro open and a page that looks like the figure on the data page below. The plots may or may not be included. They will be generated by the program when you tell it to record.

5. Press the start button on the photo gate and the green start button on the software. Drop the mass. Stop the program by hitting the green run button again. Record the velocity from the photo gate on data page below.

6. You should have a run that looks like the one on the page below. The plot on the top is a plot of voltage vs. time. Note that it oscillates just like the needle of the ammeter when you moved the magnet back and forth. **The 2nd plot is a plot of power vs. time.** *This is very similar to what your power usage would look like it you plotted the power you use vs. time.*

7. Go to the plot of **Power vs. time plot** and highlight the area of interest. It is the blue region on the plot below. Press the integral icon on the tool bar. See figure below.

8. This button calculates the area under the curve and is the total power that the generator generates.**This is E_{gen} used in the efficiency equation.** Record ion the date page below.

9. Repeat steps 3-8.

D. How to Read An Electric Bill

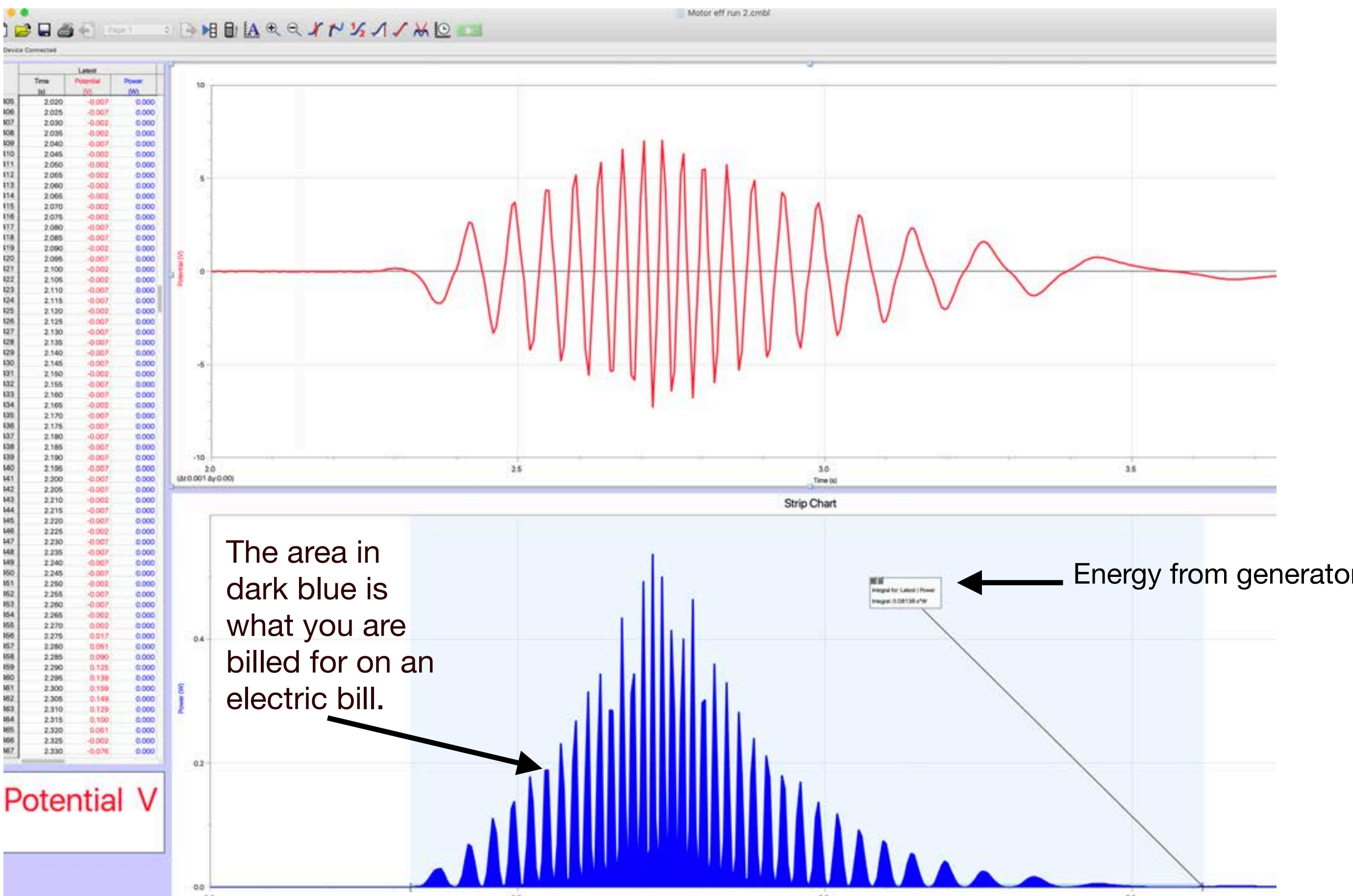
See figure on page 5 & the go to Post Lab Question 5 to complete this part.

Exp 15: Electric Motor Data

Name: ______________________

Section: _____________________

Part C Data



Velocity 1 from step 2= ______ Velocity 2 from step 2= ______ V average initial = ______

Velocity 1 from step 5 = _____ Velocity 2 from step 5 = ______ V average remaining =_____

Energy total = 1/2 mass of weight x (V average initial)^2 = ____________Joules

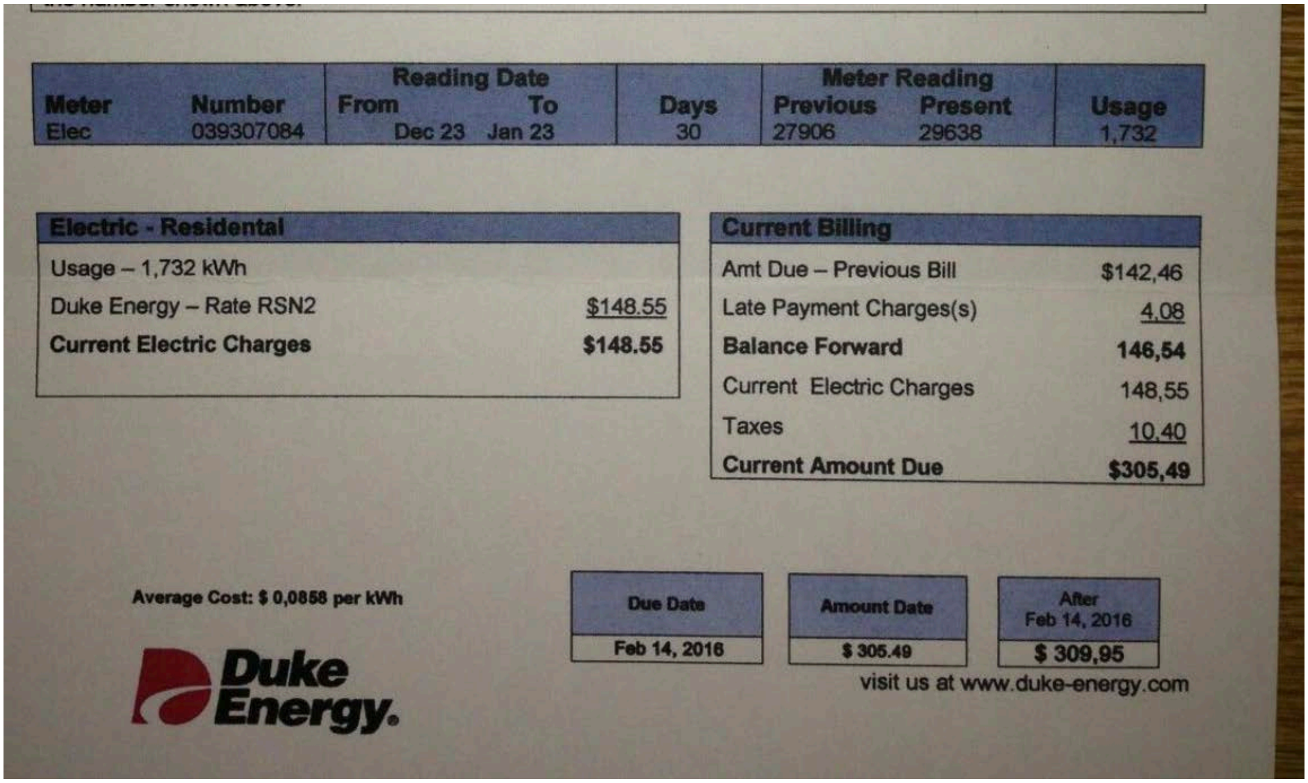
Energy remaining = 1/2 mass of weight x (V average remaining)^2 = ____________Joules

Useful energy input = Energy total - Energy remaining = ____________Joules

Useful Energy output from generator (from integral value of plot) = ___________

Efficiency of motor/generator = Energy from generator/Useful Energy Input =__________%

Part D Data



Meter	Number	Reading Date From	Reading Date To	Days	Meter Reading Previous	Meter Reading Present	Usage
Elec	039307084	Dec 23	Jan 23	30	27906	29638	1,732

Electric - Residental

Usage – 1,732 kWh	
Duke Energy – Rate RSN2	$148.55
Current Electric Charges	**$148.55**

Current Billing

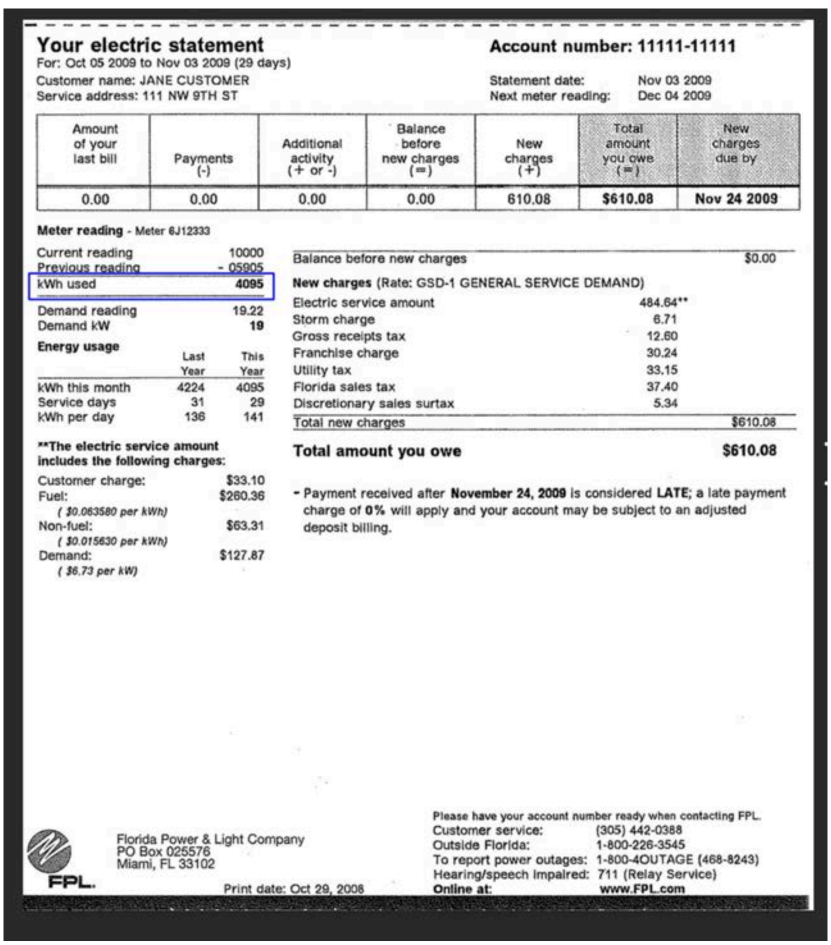
Amt Due – Previous Bill	$142,46
Late Payment Charges(s)	4,08
Balance Forward	**146,54**
Current Electric Charges	148,55
Taxes	10,40
Current Amount Due	**$305,49**

Average Cost: $ 0,0858 per kWh

Due Date	Amount Date	After Feb 14, 2016
Feb 14, 2016	$ 305.49	$ 309,95

Duke Energy.

visit us at www.duke-energy.com



Your electric statement

For: Oct 05 2009 to Nov 03 2009 (29 days)

Customer name: JANE CUSTOMER

Service address: 111 NW 9TH ST

Account number: 11111-11111

Statement date: Nov 03 2009

Next meter reading: Dec 04 2009

Amount of your last bill	Payments (-)	Additional activity (+ or -)	Balance before new charges (=)	New charges (+)	Total amount you owe (=)	New charges due by
0.00	0.00	0.00	0.00	610.08	**$610.08**	**Nov 24 2009**

Meter reading - Meter 6J12333

Current reading	10000
Previous reading	- 05905
kWh used	**4095**
Demand reading	19.22
Demand kW	**19**

Energy usage

	Last Year	This Year
kWh this month	4224	4095
Service days	31	29
kWh per day	136	141

****The electric service amount includes the following charges:**

Customer charge:	$33.10
Fuel: *($0.063580 per kWh)*	$260.36
Non-fuel: *($0.015630 per kWh)*	$63.31
Demand: *($6.73 per kW)*	$127.87

Balance before new charges		$0.00
New charges (Rate: GSD-1 GENERAL SERVICE DEMAND)		
Electric service amount	484.64**	
Storm charge	6.71	
Gross receipts tax	12.60	
Franchise charge	30.24	
Utility tax	33.15	
Florida sales tax	37.40	
Discretionary sales surtax	5.34	
Total new charges		$610.08

Total amount you owe **$610.08**

- Payment received after **November 24, 2009** is considered **LATE**; a late payment charge of **0%** will apply and your account may be subject to an adjusted deposit billing.

FPL.

Florida Power & Light Company
PO Box 025576
Miami, FL 33102

Print date: Oct 29, 2008

Please have your account number ready when contacting FPL.

Customer service:	(305) 442-0388
Outside Florida:	1-800-226-3545
To report power outages:	1-800-4OUTAGE (468-8243)
Hearing/speech impaired:	711 (Relay Service)
Online at:	**www.FPL.com**

Postlab Questions

1. In part A of the the lab stated that a TDF rider can ride a long flat stage in four hours at an average power output of 250 watts. Calculate: a) the total energy expended in *joules*, b) the total energy expended in *kw*hr* where 1 kw*hr = 1000 watts *3600 seconds = 1000*3600 J, c) the total number of food calories burned*. **Show all work.**

Useful conversion factors: 1000 cal = 1kcal = 1 food Calorie
1 cal = 4.19 J
1 Cal = 4190 J (Please note Calorie with a capital C is a food Calorie)

*Because of the efficiency of the digestion process (~20% to 25%) you will have to consume **4 to 5 times the amount** of food calories that are calculated above.

2. The top plot on page 4 is a plot of voltage (on the y axis) and time (on x axis). Compare the up & down motion of the red line on the plot to the back & forth motion of the ammeter when you moved the magnet into & out of the solenoid. How are the motions similar and why? It might be helpful to look at the generator/motor apparatus.

3. In this question you are asked to show the calculation of the efficiency of the electric generator used in Part C of the lab using the equation below. See page 4.

$$Efficiency = \frac{E_{generator}}{E_{Total} - KE_{remaining}}$$

4. The average efficiency of an internal combustion engine ranges from 20% to 40% (from wikipedia). The efficiency of an electric motor can range from 75% to 96%.

Compare the efficiency of your generator/motor to that of an internal combustion engine. Show work.

5. One lab partner should calculate the cost (in kilowatt*hours) of one of the bills in Part D and the one lab partner should calculate the cost of the other bill. Show work.

6. You (CEO) and your lab partner (CTO) want to co-fund a start-up company that builds exercise machines which can also charge electric devices. Use the power output measurements you observed today in Part A and Post Lab Question-1b to **assess the viability** (*as defined by the expected physical abilities of your customers*) of **each of the following devices**:

"ipeloton": A device that let you **charge your iPhone** while working out.

"NetFlicycle": An online streaming service that you can watch a movie while using the exercise bicycle to **charge your TV**. (no refund if customer can't work out for the length of the movie)

"Tesla Manual": A device that let you pedal bicycle to **charge your electric car**.

(Please list the source(s) of any online data that you need and justify briefly why it's a reliable source).

7. You (CEO) and your lab partner (CFO) owns an international manufacturing company that uses electricity heavily. You are now considering opening more branches around the world. Please discuss the cost of electricity in other countries and figure out which major economies you should and should not consider.

(Please list the source(s) of any online data that you need and justify briefly why it's a reliable source).

8. Your business empire is so successful that you are tired of living under spotlight & you have decided to live "off-grid". Despite being a billionaire, you want to save some money on electricity bill and power the house by yourself with the exercise machines your company invented.

Use the power measurements from Part A of lab calculate the amount of energy you can generate each hour and compare that to the cost of electricity to see how much money you can save.