

# ELECTRICAL ENERGY WITH HANDHELD

## LAB HAND 30

**RELATED TOPICS** Energy Conversion/Efficiency  
Gravitational Potential Energy

## STANDARDS ADDRESSED

### Science and Technology

3.1.10, 3.1.12

3.2.10, 3.2.12

3.4.10, 3.4.12

3.7.10, 3.7.12

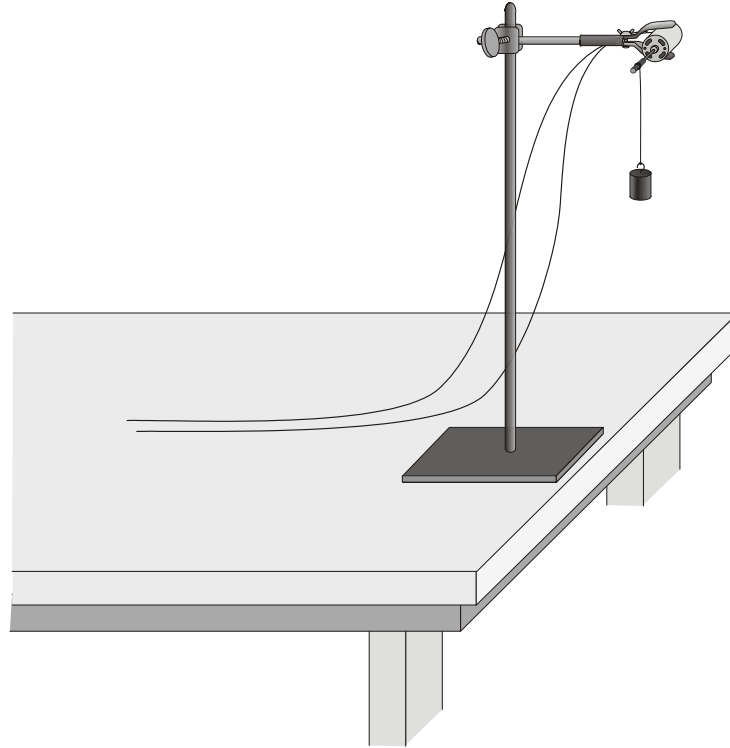
## CONSIDERATIONS

In this experiment, you will study a small, inexpensive electric motor used as a crude elevator. You will measure the current through, and voltage across, a motor as it lifts a small mass. If you know the current and voltage, you can calculate another electrical quantity – *power*. The power used by an electrical device can be calculated from

$$power = current \times voltage$$

The unit of power is the watt (W). An electrical device that has a power of 1 W converts one joule of energy to another form every second (1 J/s). If the power provided to a device is constant over time, you can multiply the power by the time and get the energy. If the power provided to a device changes during the experiment, the electrical energy can be determined by finding the area under a power vs. time graph.

You will use this approach to determine the electrical energy used by the motor and compare it to the change in gravitational potential energy of the mass. The gravitational potential energy gained by an object can be calculated if you know the mass and the distance it is lifted. By comparing the electrical energy supplied to the motor with the gain in potential energy of the mass you can calculate the efficiency of the motor as a machine used for lifting.



*Figure 1*

## **OBJECTIVES**

- Measure the power and electrical energy used by an electric motor.
- Measure the gain in potential energy of a mass lifted by the motor.
- Calculate the efficiency of the motor.
- Study the efficiency of the electric motor under different conditions.

## **MATERIALS**

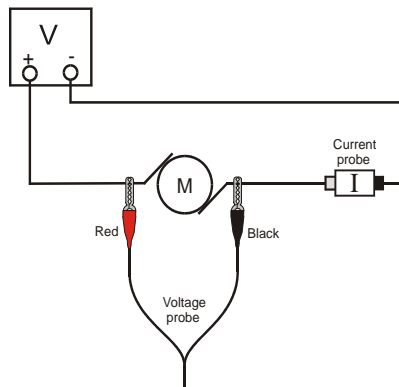
LabPro interface  
Palm handheld  
Data Pro program  
one Vernier Current Probe and  
one Vernier Differential Voltage Probe  
or, one Current & Voltage Probe System  
adjustable-voltage DC power supply  
ring stand

small wooden dowel rod  
wires  
clips to hold wires  
electric motor  
mass set  
string  
utility clamp

## SETUP AND PRELIMINARY QUESTIONS

1. Set up the motor apparatus as shown in Figure 1. There should be an axle on your motor where the string can be wound as the mass is lifted. Allow room for the mass to be lifted at least 0.5 m; a longer distance would be better. Make a loop at the end of the string for connecting the mass.

2. Connect the circuit as shown in Figure 2. Take care that the positive (red) lead of the Voltage Probe and the red terminal from the Current Probe are oriented toward the + terminal of the power supply.



3. Connect the sensors to the LabPro interface:

- If you are using the newer Current Probe and Differential Voltage Probe, connect the Current Probe to Channel 1 and the Differential Voltage Probe to Channel 2.
- If you are using a Current & Voltage Probe

System, connect DIN 1 on the Dual Channel Amplifier to Channel 1 of the LabPro interface. Connect DIN 2 to Channel 2. Then connect a Current Probe to PROBE 1 on the Dual Channel Amplifier and a Voltage Probe to PROBE 2.

4. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.
5. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap **New** to reset the program.
6. Set up the handheld and interface for the correct Current and Voltage probes.
  - a. On the Main screen, tap **Setup**.
  - b. If the handheld displays CURRENT(A) in CH 1 and VOLTAGE(V) in CH 2, proceed directly to Step 7. If it does not, continue with this step to set up your sensors manually.
  - c. On the Setup screen, tap **CH1:**, then choose CV CURRENT(A) from the list of sensors.
  - d. Tap **CH2:**. Choose CV VOLTAGE(V) from the list of sensors.
7. Zero both probes with no current flowing and with no voltage applied (power supply off).
  - a. Tap **Zero**.
  - b. Ensure that the boxes in front of CH1: CURRENT(A) and CH2: VOLTAGE(V) are checked. If they are not, tap CH1: CURRENT(A) and CH2: VOLTAGE(V) to check the boxes.

- c. Wait for the readings on the screen to stabilize, and then tap . When the  button changes back to , the process is complete, and readings for both sensors should be close to zero.
  - d. Tap  twice to return to the Main screen.
8. Set the voltage control on your power supply to 0 V. Turn on the power supply and gradually increase the voltage setting. Watch the motor to see when it starts to turn slowly. The current and voltage readings are displayed on your calculator screen. Control the voltage so that the motor turns and lifts the mass slowly. Set the control to 0 V when the mass reaches the top.
  9. Explain the energy changes that take place as the mass is lifted.
  10. Without making any measurements, make a guess of what you would expect for the efficiency of this electric motor; that is, guess the percentage of the electrical energy consumed by the motor that goes into lifting the mass.

## PROCEDURE

1. Check the voltage rating of your motor. This is the maximum voltage you should use. If you are not sure of the rating, ask your instructor. Record the voltage rating in the data table.
2. Place a 10 g mass at the end of the string as the load to be lifted. Note the starting position, as the mass must be lifted the same distance each trial. Measure the distance the mass will rise, and record the value in your data table.
3. Now you will gather data of the current through the motor and the voltage across the motor as it lifts the mass.
  - a. Set the voltage control on your power supply to 0 V and turn it on.
  - b. Tap  to begin data collection.
  - c. Gradually increase the voltage setting on the power supply. Watch the motor to see when it starts to turn slowly. Control the voltage so that the motor turns and lifts the mass slowly. You have about 18 s to make the lift.
  - d. Set the control to 0 V when the mass reaches the top, which must be before data collection ends.
  - e. When data collection is complete, a graph of current and voltage *vs.* time will be displayed.

Your goal is to get a graph of voltage and current readings for the complete process of lifting the mass from the starting position all the way to the top. If necessary, repeat this step until you get a good run.

4. The voltage and current data can be used to calculate the electrical power consumed by the motor as it lifted the mass. To do this, first the moment-by-moment power can be calculated from the product of the current data and the voltage data. Then the total energy consumed can be found from the time integral of the power data.

Using your handheld, calculate the electrical power using  $P = I \times V$ , and store the data in a new column.

On the Graph screen, tap . Then tap .

- a. Enter the column name (Power) and unit (J).
  - b. Tap  and choose the formula,  $X1 * X2$ .
  - c. Choose  $X1 = \text{CURRENT(A)}$  as the Column for  $X1$ .
  - d. Choose  $X2 = \text{VOLTAGE(V)}$  as the Column for  $X2$ .
  - e. Tap  to display the graph of power vs. time.
5. The energy used is the product of the rate at which it was used and the time over which it was used. To account for the variations in the rate, the energy is calculated from the integral of the power vs. time data. For data taken in discrete time steps, this is equivalent to the sum of the power at each moment times the length of each time step. Fortunately this sum can be calculated easily.
- a. On the Graph screen, tap .
  - b. On the Analyze screen, tap . The integral values for the current, voltage, and power data will be displayed on the screen. The area, or integral, of the power data value has units of W's, or J.
  - c. Record the value of the power integral in the data table.
  - d. Tap  twice to return to the Graph screen.
6. Increase the load by 10 g and repeat Steps 3 – 5. Again, make sure you get voltage and current data for the entire lift. Note the mass used in each run in the data table below.
7. Repeat Step 6 five more times, or until the motor will not lift the load without exceeding its voltage rating. Be sure that the mass is lifted the same distance each time.

**DATA TABLE**

Distance mass was lifted (m)	
Voltage rating of motor (V)	

Run	Load lifted (g)	Electrical energy used (J)	Mechanical energy output (J)	Efficiency (%)
1				
2				
3				
4				
5				
6				
7				

### **ANALYSIS**

1. For each experimental run, calculate the increase in gravitational potential energy of the mass. Note that you must use mass in kg for the calculation. The increase in gravitational potential energy is equal to the mechanical energy output of the motor. Record the values in the data table.
2. For each run, calculate the efficiency of the motor; that is, what percentage of the electrical energy in the motor was converted to mechanical energy? Record your answer in the data table.
3. For which load was the motor most efficient?
4. What happened to the remainder of the electrical energy that went to the motor?

### **EXTENSIONS**

1. Plot a graph of the efficiency of the motor as a function of the load. Print or sketch a copy of the graph.
2. Investigate the efficiency of the motor at different speeds using the same load.
3. Try other motors and see if you can find more efficient ones.
4. Use a temperature probe to monitor the temperature change of the motor.
5. Show that the following units are equivalent:  $1V \times 1A = 1 J/s$ .
6. Can you use your motor as a generator? Raise the mass using the motor and hold it at the top by hand. Turn off and remove the power supply. Connect a  $10 \Omega$  resistor between the leads on the power supply. Take current and voltage data of the power *generated* by the falling mass as it turns the motor. You may need to add more mass. Compare the power measured by the interface to the change in gravitational potential energy of the falling mass.