

## ELECTRICAL ENERGY

### LAB ELEC 1. CALC

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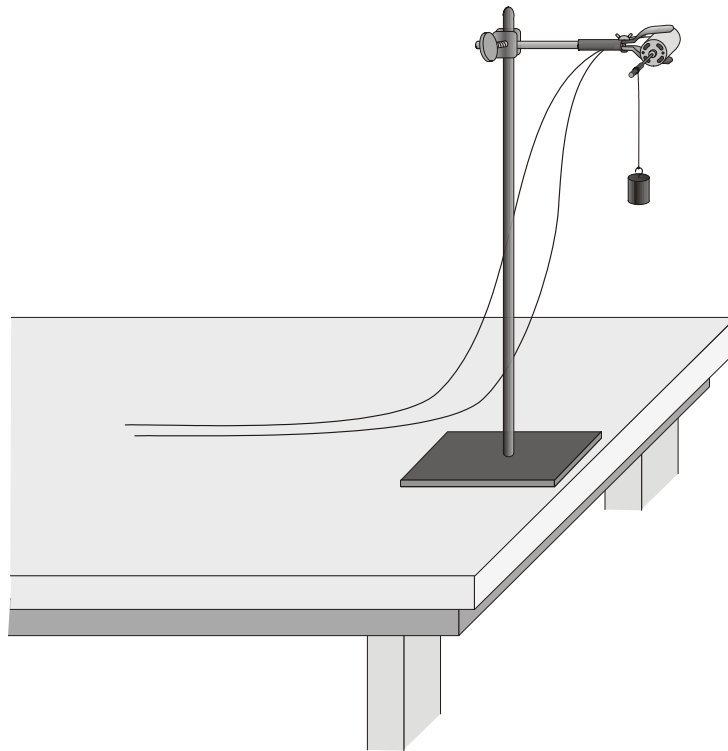
### INTRODUCTION

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

$$\text{power} = \text{current} \times \text{voltage}$$

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*

## PURPOSE

The purpose of this experiment is to measure the power and electrical energy used by an electric motor in lifting a mass, thereby increasing the gravitational potential energy of the mass. From these results, the efficiency of the motor is calculated and further studied by lifting different masses.

## MATERIALS

LabPro or CBL 2 interface	Wires with clips
TI Graphing Calculator	Ring stand
DataMate program	Clamp with arm
one Vernier Current Probe and	Mass hanger
one Vernier Differential Voltage Probe	Mass set
or, one Current & Voltage Probe System	String
Adjustable-voltage DC power supply	Angle clamp
Electric Motor	Small wooden dowel rod or metal rod

## SETUP AND PRELIMINARY QUESTIONS

- 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 (such as 1 meter, if possible). Make a loop at the end of the string for connecting the mass.

- 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.

- Connect the sensors to the LabPro or CBL 2 interface:

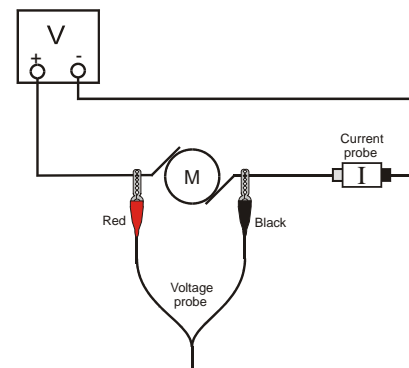
- If you are using the newer Current Probe and Differential Voltage Probe, connect the Current Probe to Channel 1 and the Differential Voltage Probe to Channel 2.
- If you are using a Current & Voltage Probe System, connect DIN 1 on the Dual Channel Amplifier to Channel 1 of the LabPro or CBL 2 interface. 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.

- Use the black link cable to connect the interface to the TI Graphing Calculator. Firmly press in the cable ends.

- Turn on the calculator and start the DATAMATE program. Press  to reset the program.

- If CH 1 displays the Current Sensor, proceed directly to Step 7. If it does not, set up your sensors manually.

- a. Select SETUP from the main screen.
- b. Press  to select CH 1.
- c. Select C V SYSTEM from SELECT SENSOR.
- d. Select CV CURRENT (A) from C V SYSTEM.



*Figure 2*

- e. Press  to select CH2 and press .
  - f. Select C V SYSTEM from SELECT SENSOR.
  - g. Select CV VOLTAGE (V) from C V SYSTEM.
  - h. Select OK once to return to the main screen.
7. Zero both probes with no current flowing and with no voltage applied (power supply off).
    - a. Select SETUP from the main screen.
    - b. Select ZERO from the setup screen.
    - c. Select ALL CHANNELS from SELECT CHANNEL.
    - d. Press  to zero the sensors.
  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. (With the Extech power supply, it seemed to ~ 15 V for 350g.) Record the voltage rating in the Data Table.
2. Place a 50-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. Select START 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. Press  to see the current vs. time graph. When you are done inspecting this graph, press , then press  and again  to see the graph of voltage vs. time.
  - f. Press  and select MAIN SCREEN.

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 (stored in a list L2 in your calculator) and the voltage data (stored in L3). Then the total energy consumed can be found from the time integral of the power data. This calculation requires working with data lists outside of the DATAMATE program, so select QUIT from the main screen. (On the TI-89, 92, and 92 Plus, after selecting QUIT press  $\boxed{\text{F5}}$  to return to the home screen.)

To calculate the electrical power using  $P = I \times V$ , store the data in L6:

TI-73, 83, 83 Plus, TI-84 Plus

- Press L2  $\boxed{\times}$  L3  $\boxed{\text{STO}} \blacktriangleright$  L6 and finish your entry with  $\boxed{\text{ENTER}}$ . (On the 73 press  $\boxed{2\text{nd}}$  [STAT] to access the list names.)
  - The product of the current and voltage readings will be stored in the list L6.
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.
- From the calculator home screen, press  $\boxed{2\text{nd}}$  [LIST].
  - Use the  $\blacktriangleright$  key to move to the menu.
  - Press “5” to select sum.
  - Press  $\boxed{2\text{nd}}$  L6  $\boxed{\times}$  0.25 and press  $\boxed{\text{ENTER}}$ .
  - The result is the energy consumed by the motor as it lifted the mass.

TI-83 and 83 Plus

- From the calculator home screen, press  $\boxed{2\text{nd}}$  [LIST].
  - Use the  $\blacktriangleright$  key to move to the MATH menu.
  - Press “5” to select sum. Note that the calculator has already entered the left parenthesis for you.
  - Press  $\boxed{2\text{nd}}$  [L6]  $\boxed{\times}$  “0.1” and press  $\boxed{\text{ENTER}}$ .
  - The result is the energy consumed by the motor as it lifted the mass.
6. This area, or integral, value has units of W·s, or J. Record the value of your integral in the Data Table.
7. Restart the DATAMATE program.
8. Increase the load by 50 g and repeat Steps 3 – 6. 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.
9. Repeat Step 8 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 (kg)	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:  $1\text{ V} \times 1\text{ A} = 1\text{ J/s}$ .
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  $10\text{-}\Omega$  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.