

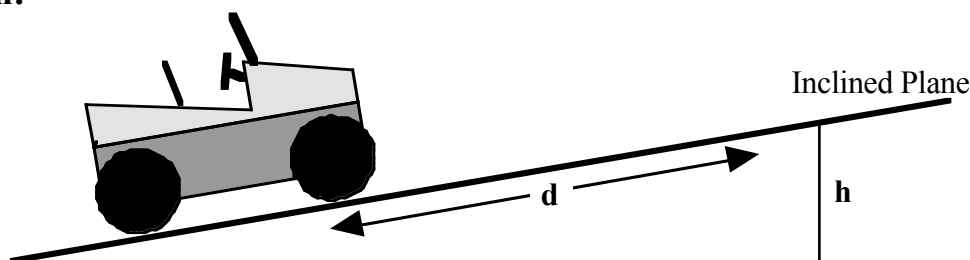
Efficiency of an Electric Car

Purpose:

Electricity from the batteries in an electric car is converted into mechanical energy by the motor. If we monitor the flow of electricity into the motor, specifically the voltage and current, we can determine the rate at which energy is used to drive the car. We can use this rate, the power, to determine how much energy is needed to go a distance across the floor or table. If the car is moving at a constant speed, all of that energy essentially goes into overcoming the resistive effects of friction and motor losses.

If the car climbs a gradual incline, we can monitor the power again. For the same distance, a larger amount of energy will be required as the car will be gaining gravitational potential energy. If we compare the gain in potential energy to the total energy, we can determine the efficiency of the motor.

Diagram:



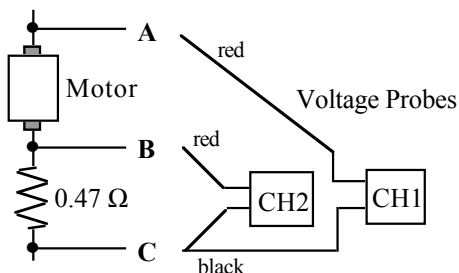
See diagram on last page for connecting the two Voltage Probes.

Materials:

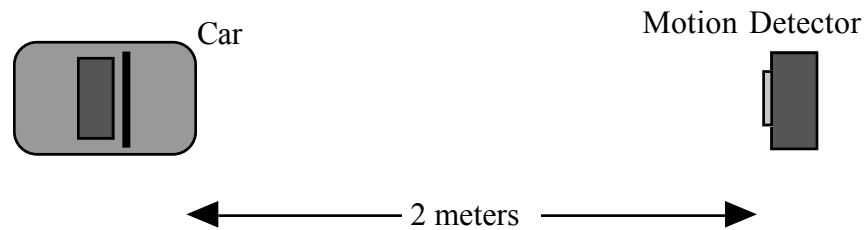
Modified* Constant Velocity Car**, Voltage Probes (2), Motion Detector, LabPro, Logger Pro software, Macintosh or PC computer, Board for inclined plane, Meter stick, “dummy” battery

Procedure:

1. Obtain the materials you will need. Make sure the Constant Speed Car operates successfully before connecting it to the sensors. The car should move across the room smoothly and climb the incline you are going to be using later.
2. Measure the mass of your car in kilograms and enter this data into the Data Table.
3. Connect the two Voltage Probes to the terminal lugs on the Constant Speed Car. Use the next diagram as a guide:



4. Plug the Voltage Probe leads into the LabPro, and connect the Motion Detector to SONIC/DIG1. These are the places the file expects the probes to be connected. Make sure the LabPro is connected to your computer, then launch the *Logger Pro*. Open up the file titled electriccar.cmbl.
5. Set up a straight, level, clear space about 2 meters long. Put the Motion Detector near one end, aligned with the path the car will be taking. You will need to move the LabPro and the Voltage Probes along with the car when taking data. While doing so, avoid getting in the path between the Motion Detector and the car.



6. Hold the car slightly above the floor, approximately 2 meters from the Motion Detector. Start the motor and when the computer operator begins data collection, set the car down so it can move towards the detector. Pick up the car before it crashes into the detector, which will be the end of your data run.
7. Go to the **Analysis** section, step (1). You will return here for a second run in a while.
1. Store the data from your first run using the menu item under **Experiment**. Set up the inclined plane with the Motion Detector near the top and the car near the bottom. The angle should be less than 5° . Measure 1 meter along the incline (100 cm). Measure the height of the inclined plane from the floor or table at each end of this section. Enter the difference between these two values, the amount the car would rise during a meter of travel, in the right side of the data table (**1-m Δh**).
9. Repeat Procedure step (6), with the car climbing the inclined plane, then return to the Analysis section, step (7).
10. Make sure all equipment is returned to the place indicated by your instructor. Complete your analysis according to the instructor's directions.

Analysis:

1. Several quantities have been calculated for you. In the file provided, the resistor that's mounted on the Constant Velocity Car is assumed to be 0.47 ohm. If your resistor has a different value, go to the menu bar item **Data** and select **Column Options**. Choose the **Power** column. In the space for Calculation, change the resistor value (the denominator that was formerly 0.47) to your value. Note that you are calculating $P = V_M \times V_2/R$.
2. Examine the position vs. time graph. Part of this graph should be a non-horizontal straight line. During this part of the data collection, the car was going at a constant speed. Click and drag over this straight-line section, then use the Regression button to determine the slope, the velocity. Record this value.

3. Based on this velocity, determine how long it would take the car to go one meter. $t = d/v$
4. Examine the Power vs. time graph. Click and drag across the section of this graph that corresponds to the time the car was going its constant velocity. Use the Statistics button to determine the average power during this interval.
5. If the car was expending its average power for the time you calculated in (3), how much energy went into the motor? $E = P \times t$ Where did this energy go?
6. Go back to Procedure step (8). This time you will run the car up an inclined plane.
7. Calculate the gain in gravitational potential energy for your car if it had gone one meter along the inclined plane. $mg\Delta h$
8. Repeat Analysis steps (2) to (5). Record your results in the Data Table.
9. How much more energy would the car have expended to go one meter up the incline as compared to going 1 meter across the floor?
10. Calculate the efficiency of this extra energy by comparing the gain in potential energy to the extra energy expended. $100\% \times PE \text{ Gain} / \text{Extra Energy}$

Data Tables:

Level Run Full Voltage		Incline Run Full Voltage	
Car Mass		Car Mass	
		Δx	
		Δy	
		1-m Δh	
		PE Gain	
Velocity		Velocity	
1-m Time		1-m Time	
Power avg.		Power avg.	
Energy In		Energy In	
		Extra Energy	
		Efficiency	

Extensions:

1. Make up a dummy battery. Cut a dowel to match the measurements of the C-cell (1" diameter, 2" long). Wrap it tightly in heavy-duty aluminum foil. When placed in the car in place of one of the cells, it will reduce the voltage to half. Using the dummy, you can

compare the efficiency of the motor when it has its normal power to when it has less than full power. Note: Don't use a depleted battery as the dummy. This will reduce the power even more due to its large internal resistance.

2. Study the efficiency of the car at various angles. Is there a pattern? If so, is it trigonometric as one might expect?
3. Study the efficiency when the car runs downhill. Is the energy input reduced like we would expect?

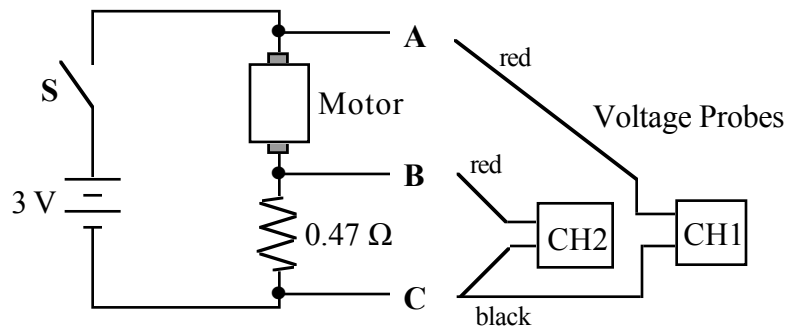
*** Modification:**

Open the body of the Constant Speed Car by removing two Phillips-head screws on the bottom, one inside the battery compartment. By tracing the wires, you can determine the pathway of the electricity, which goes through a mechanical switch and then to the motor and the lights.

Drill two holes in the back seat, one to mount a three-lug terminal strip and the second to move wires from inside to outside. The final installation can be as esthetically pleasing as the car was originally.



Construct the circuit below, bringing the three wires up to the terminal strip and connecting them to the points labeled A, B and C. The resistor can be soldered to the terminal strip. Its value should be 1-Ω or less. We found a 0.47- Ω, 5-watt resistor at Radio Shack. Note that the wire leading from the negative terminal of the batteries to the motor will have to be removed. The resistor takes the place of this wire. Disconnect one lead to the lights as they pull power from the battery that doesn't go into moving the car. A switch could be wired into this portion of the circuit so the car could be operated with and without the lights.



** Constant Velocity Car: product number 44-1090 from Arbor Scientific.
www.arborsci.com

Program Note:

The experiment file does several things. First, it calculates the voltage across the motor by subtracting the voltage across the resistor from the total voltage, $V_M = V_1 - V_2$.

Current is calculated using Ohm's Law, the voltage across the resistor, V_2 , divided by that resistor value. I used a $0.47\text{-}\Omega$, 5-W resistor at Radio Shack for this experiment. If you use a different value, the calculation needs to be changed using the **Column Options** choice under **Data**. Current flow may be calculated at the same time Power is calculated.

Then it calculates the power using this voltage and the current flow.

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