TESTING COULOMB'S FRICTION MODEL

The Coulomb model of kinetic friction assumes the force of kinetic friction on an object sliding over a uniform surface at constant speed is not dependent on the magnitude of that speed. Is this assumption of Coulomb's model for friction valid? If so, is it valid for any speed or just a limited range of speeds?

Objectives

- Accurately measure the force of friction over a range of speeds.
- Use the data to evaluate the claim that the kinetic friction force is independent of speed.
- Create a model using the data to predict the kinetic friction force at a speed outside the range that was tested.

Materials and Equipment

- Data collection system
- Smart Cart
- Smart Cart Motor
- Aluminum track
- Track end stop
- Friction block
- 250 g mass
- String

Safety

Follow regular laboratory safety precautions.

Procedure

1. Attach the Smart Cart Motor to the Smart Cart using the 2 supplied screws and cable.

2. Attach the supplied hook to the other end of the Smart Cart.

3. Place the cart on the track so that the end with the motor is at least 0.5 meters from the end of the track. The cart will move with the motor in front. Attach the end stop at the end of the track facing the motor.

4. Place the friction block on the track and place a 250 g mass on the center of the block. Connect the block with a short (< 10 cm) loop of string to the hook. See Figure 1. Indicate below whether you are placing the wood or felt side down. It doesn't matter which you choose as long as you don't change it.

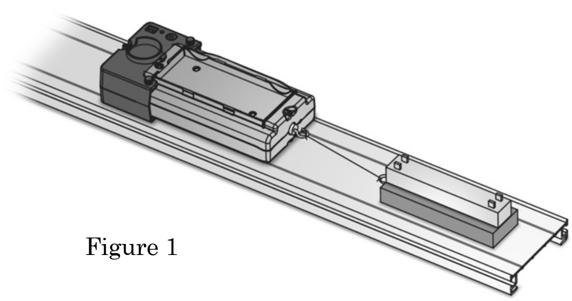

Figure 1

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5. Turn the Smart Cart on and connect it to your data collection system. Create two graph displays, force vs. position and velocity vs. position. Change the data collection rate to 50 Hz.

6. After making sure the string is not pulling on the hook, zero the cart's force sensor.

7. Use the Smart Motor Control Panel to set the power to -100 and check the Auto box. This will cause the Smart Cart Motor to start moving automatically when data is recorded. It is negative because the cart needs to move in the -x direction so the force sensor can pull the friction block.

8. Note at which centimeter mark the front end of the friction block is starting. You will want to start it in this position for every trial. For example, in Figure 1 the block is at the 20 cm mark.

9. Start recording data, then click stop after the cart has gone more than 0.4 m but before it reaches the end of the track.

10. Use the tools of the data collection system to select only the portion of the velocity graph between -0.4 m and -0.2 m. Find the mean value of the velocity in this region and record its magnitude (speed) in Table 1.

11. The force sensor measures the force of tension in the string pulling the block. When the block is moving at a constant speed, how will the magnitude of the force of kinetic friction on the block compare to the force sensor measurement? Explain.

12. Use the tools of the data collection system to select only the portion of the force graph between -0.40 m and -0.2 m. Find the mean value of the force in this region and record it in Table 1. Measuring the mean values over this region ensures that the force value is measured for the same part of the track and that the cart has reached its top velocity for each trial.

13. A power setting of -100 is the maximum setting of the Smart Cart Motor in reverse. At a setting of -50 it will move at about half of the speed at the -100 power setting. Using the first data point, predict the value of the force of friction on the block. Show your prediction and your reasoning below. It is OK to predict incorrectly.

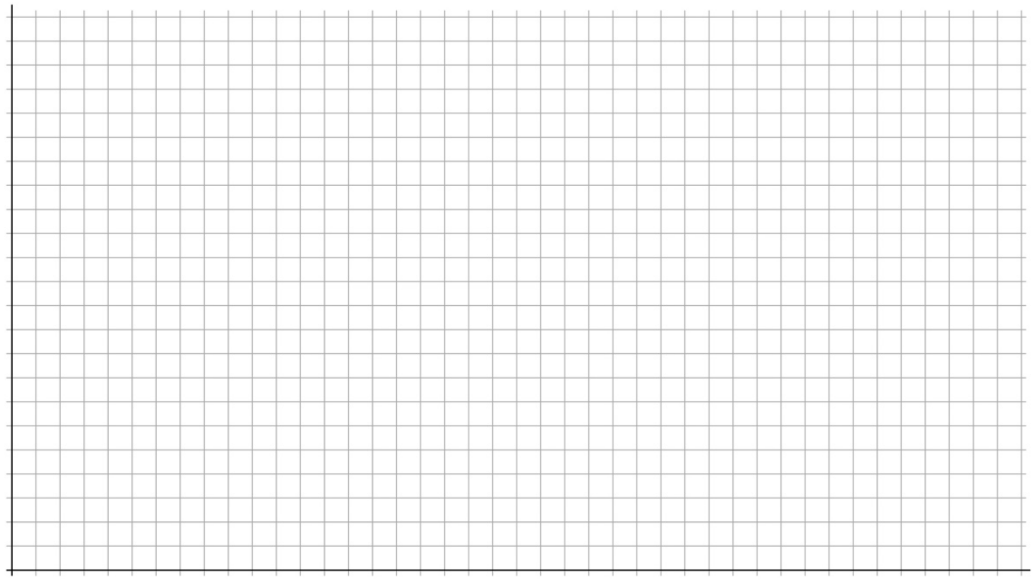
14. Reduce the motor power setting by 10 and repeat steps 8-12 until you have measured 5 trials.

Table 1: Speed and friction force for 5 power settings

Power	Speed (m/s)	Friction Force (N)
-100		
-90		
-80		
-70		
-60		

15. Plot a graph of *friction force* on the y-axis versus *speed* on the x-axis in the blank axes below. Label both axes, include units, and use the correct number scale.

Graph 1: *Average force* versus *average speed*



Questions and Analysis

1. Draw a line of best fit through your data with a straight edge. Pick 2 points on the line and calculate the slope. Show all of your work below and include the units.

2. Measure the y intercept of your graph by extending the line through the y-axis and reading the graph carefully or use your slope and one of the points on the line to calculate the y-intercept. Show your result and include the units below.

3. Write an equation for the line using y = mx + b. Substitute F for y and v for x. Substitute your numerical values for the slope and y-intercept. Show your result below.

4. Coulomb's friction model states that the force of friction does not depend on the speed of the object sliding over a uniform surface at a constant velocity. Does your data and graph support Coulomb's model? Explain using your data and graph below.

5. Assuming that the speed of the cart at a power of -50 will be half the speed of the cart at a power of -100, use the equation of the line to predict the force of friction for a power setting of -50. Show all of your work below.

6. Calculate the average of the 5 values for the friction force from Table 1 and record it below. According to Coulomb's model, the friction force should be the same for any speed or power setting. Coulomb's model would predict this average to be the force of friction at a power setting of -50, or any other non-zero setting. How does it compare to the value you predicted for -50 using the equation of your line?

7. Change the power setting to -50 in the motor control panel and collect one more trial. Obtain the mean value of the force between -0.40 m and -0.2 m as you did for the other trials and record it below. Compare this experimental value with the 3 predicted values, your prediction in the procedure, your prediction using the equation of the line, and the prediction from Coulomb's friction model. Based on these comparisons, how valid is Coulomb's model?

8. Give an example of a practical application where might it be important to collect data for several different speeds to predict the force of friction. (hint: think about situations where something is pulling something else across a surface). Is it OK to ignore any effect of speed on the force of friction in a physics class? What about a homework or test problem?

9. The force of friction is a very complex interaction between two surfaces. Many of the assumptions made in simple models like Coulomb's do not apply in all situations. One of these is that the temperature of the sliding object and surface is not changing. Another is that the roughness of the object and surface is not changing as the object slides. Explain how these assumptions might not be valid in all situations. Give an example where each assumption might break down.