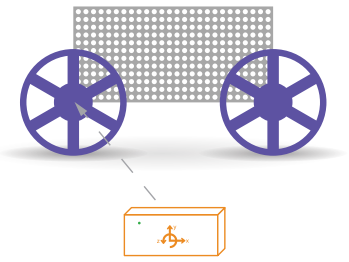
Linear Motion: Position, Velocity, and Acceleration

Exploration

What is velocity? Velocity is often defined as speed with direction and speed is often defined as how fast or slow an object is traveling. But what exactly does being fast or slow mean? How can we represent an object's velocity with an equation, graph, or other model? What is acceleration? How can we represent an object's acceleration with an equation, graph or other model? This experiment will use a cart with an attached PocketLab on the wheel. As the PocketLab rotates on the wheel, the VelocityLab app will measure the cart's position, velocity, and acceleration versus time. Analyzing how these three graphs relate will help you better understand the linear motion of an object

Materials

- PocketLab with VelocityLab app
- Meter stick
- Teacher Geek Electric Racer
- Ramp
- Walking wheel for match graph challenge



Objective

In this exploration students will:

1. Collect position, velocity, and acceleration data as a cart moves at a constant rate and at a changing rate.
2. Analyze the position, velocity, and acceleration versus time graphs.

3. Analyze how the position versus time graph is related to the velocity versus time graph and how the velocity versus time graph is related to the acceleration versus time graph.
4. Based on your analysis, define velocity and acceleration.

Pre-lab Questions

1. What is speed? What is velocity? Give a definition, in your own words, for both.
2. Before reading through the lab, how could somebody measure speed?

Part A

The motor on the Teacher Geek Electric Racer will turn the gear attached to the wheel at the same rate. The motor will not slow down, or speed up.

Position and Velocity

1. Attach the PocketLab to the wheel of the Teacher Geek Electric Racer.
2. Connect the PocketLab to the VelocityLab app. Follow the on-screen instructions.
3. Switch off the Velocity and Acceleration graphs so that only the Position graph is displayed.
4. Toggle the direction icon so the cart will be moving in a "positive" direction.
5. Zero the position.

- What do you think the Position graph will look like when the cart travels for a few meters? Draw a picture of your prediction.

6. Record the data as the cart runs for a few meters. (Note: Use the video feature, if available, to help in your analysis.)
7. Save your data and keep the VelocityLab app in review mode. Draw a picture of the Position graph.

- Looking at the data in review mode, what is the overall change in position of the cart every second? How did you find your answer?
- Find the slope of the Position graph during the run of the constant velocity cart.
- Before switching to the Velocity graph, predict what you think it will look like. Draw a picture of your prediction.

8. Switch to the Velocity graph.

- Was your prediction about the graph correct? Draw a picture of the Velocity graph.
- What do you notice about the value of the slope of the Position graph compared to the data collected in the Velocity graph? Explain.

Define Velocity

Thinking about the equation for slope and the position versus time graph, write a definition of velocity. Answer the questions below to help you come up with the equation:

- Equation for Slope: $\frac{y_2 - y_1}{x_2 - x_1}$
- What does the y-axis represent in the Position versus Time graph?
- What does the x-axis represent in the Position versus Time graph?

Definition for Velocity:

Velocity and Acceleration

1. Answer the questions below.

- Looking at the data in review mode, what is the overall change in velocity of the cart every second? How did you find your answer?
- Find the slope of the velocity versus time graph during the run of the electric racer. Before switching to the Acceleration graph, predict what you think it will look like. Draw a picture of your prediction.

2. Switch the graph to the acceleration versus time graph and answer the questions below.

- Was your prediction about the graph correct? Draw a picture of the Acceleration graph.
- What do you notice about the value of the slope of the Velocity graph compared to the data collected in the Acceleration graph? Explain.

Define Acceleration

Thinking about the equation for slope and the velocity versus time graph, write a definition of acceleration. Answer the questions below to help you come up with the equation:

- Equation for Slope: $\frac{y_2 - y_1}{x_2 - x_1}$
- What does the y-axis represent in the Velocity versus Time graph?
- What does the x-axis represent in the Velocity versus Time graph?

Definition for Acceleration:

Part B

When an object rolls down a hill, does it roll down at the same speed, or does it keep getting faster and faster as it rolls down the hill? In other words describe whether you think the object accelerates as it rolls down the hill.

Position

1. Attach the PocketLab to the wheel of the Teacher Geek Electric Racer. Remove the rubber band connecting the motor to the gears on the wheel (or use a different Teacher Geek cart that does not have a motor).
2. Connect the PocketLab to the VelocityLab app. Follow the on-screen instructions.
3. Switch off the Velocity and Acceleration graphs so that only the Position graph is displayed.
4. Toggle the direction icon so the cart will be moving in a "positive" direction.
5. Angle your ramp to 15 degrees. Place the cart at the top of the ramp. Zero the position on the graph.

- Thinking about your answers in Part A, what do you think the Position graph will look like when the cart rolls down the ramp? Draw a picture of your prediction.

6. Begin recording data (use the video function if available).
7. Release the cart so it rolls down the ramp. Observe the Position versus time graph as it rolls.

- Draw a picture of the position graph. Compare it to the position graph from Part A. What do you notice that's different?
- Was your prediction about the graph correct?
- Thinking about your Analysis in Part A, what do you think the Velocity graph will look like when the cart rolls down the ramp? Draw a picture of your prediction.

Velocity

Repeat the same steps from the "Position" run, except observe the Velocity graph instead of the Position graph.

- Draw a picture of the Velocity graph. Compare it to the Velocity graph from Part A. What do you notice that's different?
- Was your prediction about the graph correct?
- Thinking about your answers in Part A, what do you think the Acceleration graph will look like when the cart rolls down the ramp? Draw a picture of your prediction.

Acceleration

Repeat the same steps from the "Position" run, except observe the Velocity graph instead of the Position graph.

- Draw a picture of the Velocity graph. Compare it to the Velocoity graph from Part A. What do you notice that's different?
- Was your prediction about the graph correct?
- Thinking about your answers in Part A, what do you think all three graphs will look like together when the cart rolls down the ramp? Draw a picture of your prediction.

Position, Velocity, and Acceleration

Repeat the same steps from the "Position" run, except observe all three graphs at once.

- Draw a picture of all three graphs together. Compare it to the drawing of all three graphs from Part A. What do you notice that's different?
- Was your prediction about the graph correct?

Conclusion

- Write a conclusion paragraph that defines position, velocity, and acceleration and describes how they are related.
- What was the main difference between the motion of the cart in Part A compared to Part B. How do you know?
- Newton's Second Law tell us the force on an object is proportional to the acceleration of the object. In Part B, why did the cart accelerate as it rolled down the ramp?

Match Graph Challenge

1. Remove the cart from the ramp and place it on your table. Connect the PocketLab to the VelocityLab app like before. Display all three graphs.
2. Take turns in your group moving the cart back and forth in different ways and at different speeds to make unique graphs.
3. Have one person in the group draw a "Challenge" graph that the other group members must replicate in the VelocityLab app. Start with just Position. Then Position and Velocity. Finally try to match a Position, Velocity, and Acceleration graph. (NOTE: When drawing a "Challenge" graph you must draw a graph that can actually be made with the cart).
4. As a group draw a Position, Velocity, and Acceleration "Challenge" graph that another group must replicate.
5. Take turns as a class trying to replicate each other's "Challenge" graphs using the walking wheel.