Analysis or Action … or Both?

Research in a Quantum Optics Lab
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Mathematicians and scientists generally focus their attention on analysis. More than anything else, the basic goal of their work is to understand general relationships and the regular patterns of the universe. Engineers and technicians, on the other hand, tend to focus on action. They take on specific problems or tasks and achieve specific, physical results.

Construction of Hoover Dam Bridge Bypass
(Photo taken June 9, 2009)
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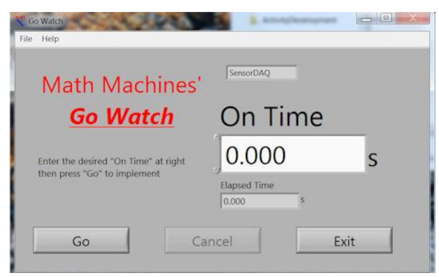
Scientists Serge Harocheand and David J. Wineland won the 2012 Nobel Prize in Physics, for example, by achieving a new understanding about the motion of tiny particles and how these can deviate from both Newton's Laws and the usual patterns of quantum mechanics. Meanwhile, the 2012 Outstanding Civil Engineering Achievement Award was given to the engineers and technicians who built the Hoover Dam Bypass/Mike O'Callaghan-Pat Tillman Memorial Bridge in Nevada, greatly improving traffic flow and reducing a significant security threat to the water and electrical supplies of the region.

While different STEM professionals may have very different jobs and goals, science, technology, engineering and mathematics are still deeply intertwined. Quantum research would be impossible without the equipment, materials and techniques provided by engineers and technicians, and projects like the Hoover Dam Bypass would be impossible without the understanding of forces and materials and mathematical relationships developed by people like Isaac Newton. It is impossible to know what practical benefits may flow from the work of Harocheand and Wineland, but possibilities include a new generation of faster and more powerful computers—computers that could help to design projects to exceed even the Hoover Dam Bypass. The better we understand what we are doing, the more effective our actions can be.

Task: In this activity you will analyze the motion of a motorized cart and use this information to predict and control future motions.



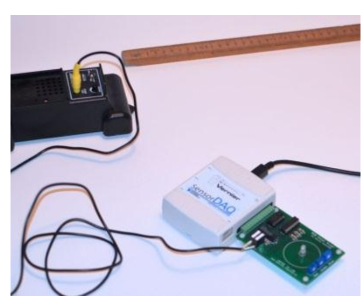
Materials:

One set for the class:

- Motorized cart with leads (such as Pasco's ME-9781)
- 2-meter stick,
- RGB Color Mixer or other computer-controlled electrical relay
- Motion detector (Optional)

For each group:

- Graphs of displacement vs. time and velocity vs. time
- Wooden block or masking tape



Math Machines Program:

GoWatch

Activity Files: None

Join with the class to investigate the motion of a motorized cart as it moves along a linear (one-dimensional) path.

1. Power the cart's motor for one second and measure how far it travels. Record the result below.

2. Predict how far the cart will move if the motor is powered for two seconds. Record below both your prediction and ***your brief justification for that prediction***. Place a marker (labeled with the names of your team members) where you believe the front of the cart will stop.

Continue working within your group as you examine graphs of the cart's motion and answer the questions below. When you are ready to test your predictions, let your instructor know. She or he will want you to explain the ***basis*** for your predictions before you test them.

3. Why doesn't the car go exactly twice as far when the motor is turned on for twice as long?

4. How much time is required for the cart to reach essentially a constant speed?

5. How far does the cart travel while its speed is increasing?

6. Calculate the cart's average acceleration as the rate of change in velocity ($a = \Delta v/\Delta t$) while the speed is increasing.

7. How much time is required for the cart to stop after power to the motor has stopped?

8. How far does the cart travel after power to the motor has stopped?

9. Calculate the cart's negative acceleration as the rate of change in velocity ($a = \Delta v/\Delta t$) while the speed is decreasing.

10. On your group's copy of the velocity vs. time graph, draw 3 line segments which show the general trend of the velocity, and label the segments as indicated below:
    a. Positive acceleration
    b. Constant speed
    c. Negative acceleration

11. Do the 3 line segments describe the actual motion reasonably well? If not, what is the smallest number of segments that would match the data closely?

12. On your group's copy of the displacement vs. time graph, mark the segments, which correspond to each of the same 3 intervals (positive acceleration, constant speed, negative acceleration).

13. Describe the shape of the displacement vs. time graph in each of these 3 segments.
    a. Positive acceleration:

    b. Constant speed:

    c. Negative acceleration:

14. Based on the graphs and measurements, predict how far the cart will travel if the motor is turned on for three times as long as before. Justify your answer clearly.

    How well does your prediction agree with the measured result?

15. Based on the graphs and measurements, predict how far the cart will travel if the motor is turned on for half a second. Justify your answer clearly.

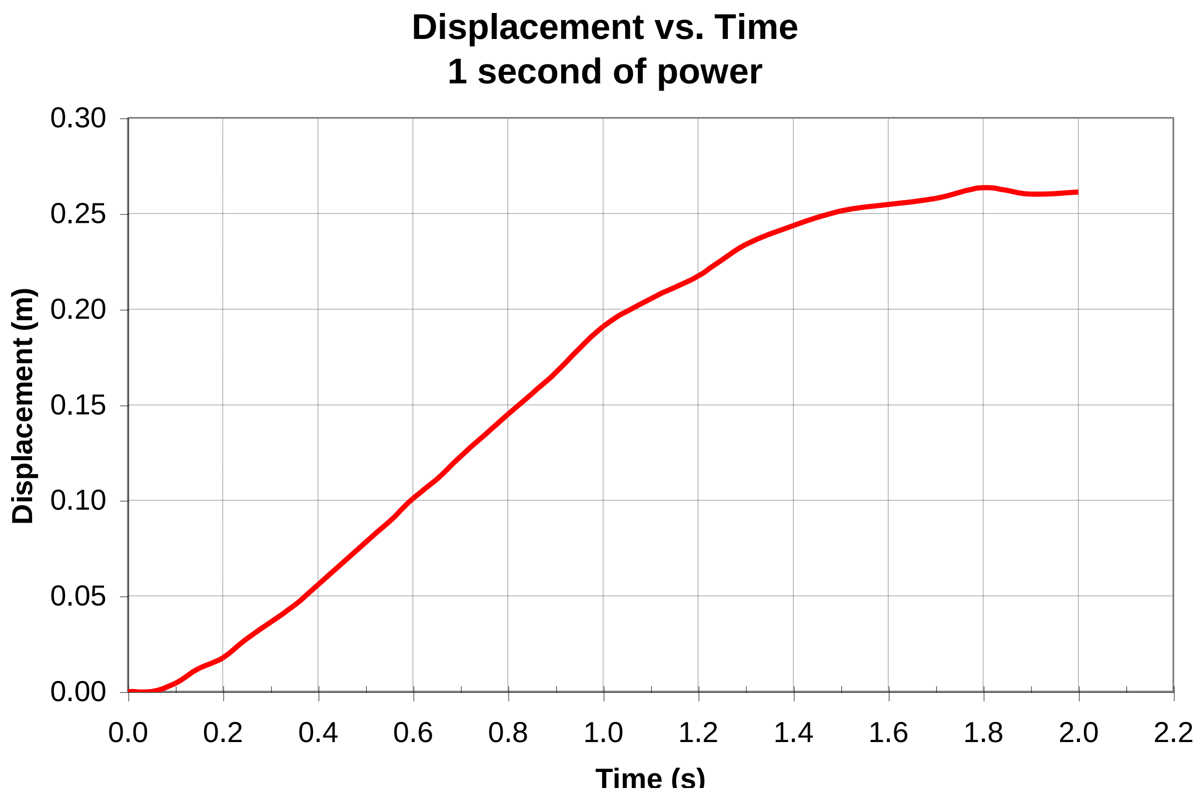
    How well does your prediction agree with the measured result?

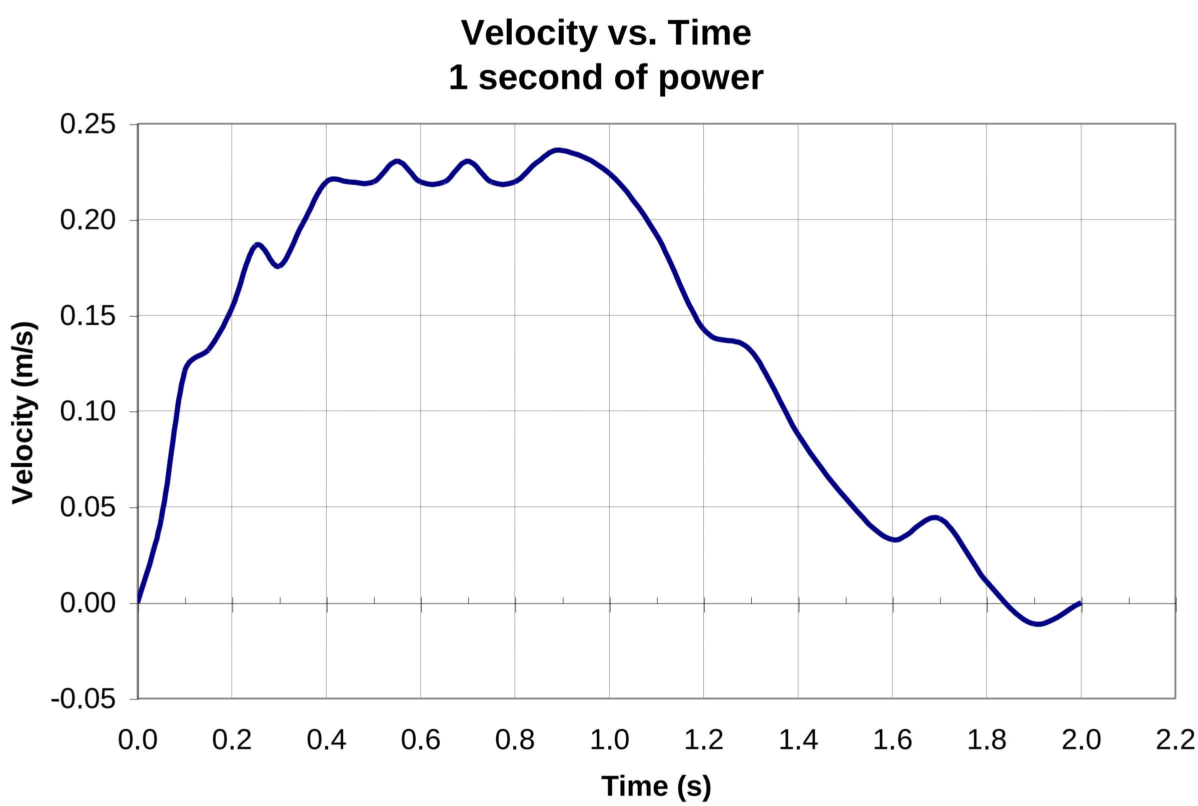
16. Based on the graphs and measurements, determine how many seconds the motor should be run to make the vehicle travel 0.60 meter? Justify your answer clearly.

How well does your prediction agree with the measured result?

CHALLENGE ACTIVITY -- Determine a formula that will calculate the time the motor should run in order to move the cart any required distance, D.

Test your formula for a variety of distances. Does the cart always stop where it should?


Displacement vs. Time
1 second of power
Displacement (m)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Time (s)


Velocity vs. Time
1 second of power
Velocity (m/s)
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Time (s)