Motion Module for Middle School

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I. Major Concepts - graphically representing position, speed, velocity and acceleration

II. Desired Outcomes – Missouri Standards
- Properties and principles of force and motion
- SC21.8 - Graphically represent and explain an object’s motion in terms of distance over time (speed).
- SC23.1 – Compare the speed of two object in terms of distance and time.
- SC23.1 – Interpret the motion of an object from a distance vs. time graph.
- SC23.1 – Distinguish between speed and velocity.
- SC23.1 – Describe and represent and objects motion graphically in terms of distance over time (speed)

III. Student Objectives: It is expected that the learner will be able to:
- Collect distance-time data
- Construct distance-time graphs to represent constant speed, increasing speed and decreasing speed.
- Analyze distance time graphs qualitatively to determine when an object is speeding up, slowing down or traveling at a constant speed.
- Collect speed-time data
- Construct speed-time graphs to represent constant speed, increasing speed and decreasing speed.
- Analyze speed-time graphs qualitatively to determine when an object is speeding up, slowing down or traveling at a constant speed.
- Collect acceleration of time data
- Construct the acceleration time graph to represent constant speed, increasing speed and decreasing speed.
- Analyze acceleration time graphs qualitatively to determine when an object is speeding up, slowing down or traveling at a constant speed.
- Construct strobe diagrams to represent the motion of objects that are speeding up, slowing down and traveling at a constant speed.
- Analyze strobe diagrams qualitatively to determine if objects are speeding up, slowing down or traveling at a constant speed.
- Analyze strobe diagrams qualitatively to compare two objects speed or compare the speed of the same object at different times.
IV. Background – See Target Ideas for Cycle I in CPU Curriculum

V. Overview
This unit is geared toward middle school students. It focuses on qualitatively understanding of motion (speed, velocity and acceleration). The unit could be taught at any time of the year. It is independent of student’s math abilities. Ideally graphing should be introduced beforehand. Afterward, teachers may want to consider leading directly into how motion relates to force i.e. Newton’s Laws of Motion. Lessons will be taught with a constructivist approach. Students will work in small groups of 3 to 5, depending on materials available, to carry out short motion investigations that they will graph and analyze.

VI. Time Required – This module includes one elicitation activity design pull out prior knowledge and start students thinking. There are four developmental activities to increase student understanding of motion. There are two fun challenge activities to demonstrate their understanding of the concepts that have been developed. Depending on the class make-up a minimum of two weeks is required to teach the entire module. This is based on a class meeting everyday for 45 minutes.

VII. Assessment Tools – A traditional paper and pencil assessment could be used or if a teacher preferred the motion and speed challenges would provide and excellent performance assessment.

VIII. Materials – per station
Activity 1-E – 2 tracks, 2 carts, 1 fan unit,
Activity 1-D1 – meter stick, 1 lab pro, 1 motion detector
Activity 1-D2 – CPU software
Activity 1-D2a – 1 Lab Pro, 1 Motion Detector, 2 battery powered toy cars (that move at a constant speed), meter stick
Activity 1-D3 – 1 meter stick, 1 fan unit, 1 cart, 1 track, 1 lab pro, 1 motion detector
Activity 1-A1 – 1 meter stick, 1 stopwatch, 1 motion detector, 1 lab pro, CPU software
Activity 1-A2 – CPU Software
IX. Activities

F&M Activity I-E
How do You Represent Motion?

Name: _____________________________
Class Period: _____________________________

F&M Activity I-D1
Can You Represent Motion With Graphs?

Name: _____________________________
Group: _____________________________
Class Period: _____________________________

F&M Activity I-D1
Can You Represent Motion With Graphs?

Name: _____________________________
Class Period: _____________________________

Answer Sheet

1. Now you are ready to collect data that we want you to analyze. Try walking slowly and at a constant speed away from the detector for about three seconds, and then stop and stand still until the graphing stops. Your speed-time graph probably has some bumps or wiggles in it. What do you think these bumps or wiggles represent?

2. If you graph has a lot of bumps try it again. When you get a graph you like “print Screen” and paste a copy of your graph here. (If the widths of the graphs are too large to fit in the space below, make them smaller by using the mouse to drag the bottom right corner of the MBL graph window. Then take a snapshot and paste it below.)
1. Imagine walking away from the detector at a constant speed that is faster than before for the three seconds, then stopping. Draw a distance-time and speed-time graphs to show how you predict the graphs would change (if at all) for this faster motion. Draw your graphs below.

2. Test your predictions. Collect data while moving away at a faster constant speed for three seconds, and then stand still until the data collection stops. Repeat, if necessary, until you are satisfied with your graphs. Hit “print screen” and paste your graph below.

3. How does your data for the faster motion compare with your predictions? (Consider separately the distance-time and the speed-time graphs.)

4. It is very important to be able to interpret a graph and tell what kind of motion it is representing. Based on your experience in this activity, answer the following questions:

   a. How can you tell from a distance-time graph whether or not an object is moving at a constant speed? (assuming you ignore the bumps or wiggles)
b. How can you tell from a speed-time graph whether or not an object is moving at a constant speed? (assuming you ignore the bumps or wiggles)

c. Suppose you were shown distance-time graphs representing the motion of several objects moving at different constant speeds. How could you tell which graph represented the object moving the slowest? The fastest?

1. How might you tell from the strobe diagram that the object is moving at a constant speed (neither speeding up nor slowing down)?

Questions to go along with computer program:

2. Imagine that the launcher gave a stronger push so the ball moved twice as fast as the ball
shown above. **Predict** how you would expect the strobe diagram (pattern of dots) to change, if at all. **Explain** how you decided.

1. How did the strobe diagrams provided by the simulator compare with your predictions?

2. How can strobe diagrams be used to compare the speeds of moving objects?

3. How did the lengths of the three speed arrows compare to each other? (You might need to return to the simulator and take a closer look.)
4. Predict what the green graph will look like and draw it on top of the graph below.

5. **Compare** your predicted graphs for the Green object with those provided by the simulator. If there are differences, discuss what those differences might mean.
6. Both the distance-time and speed-time graphs seem to provide information about the motion of the object. We want you to consider how these two graphs are related to each other. 

**Imagine** seeing just the distance-time graph for an object moving at a constant speed. How could you determine the speed-time graph for the same motion? Try out your idea by using the two sets of graphs that you have pictures of above. Describe your method below. (Hint: Look carefully at the numbers on the scales of the graphs. Your idea should allow you to correctly predict the exact values on the speed-time graph.)

7. You can further test your idea for how to predict the speed-time graph from the distance-time graph by returning to the simulator and changing the speed of either object by changing the strength of the launcher. If you choose a stronger push for the green object, you might have to select the corresponding graph and make it taller in order to see larger values for speed or distance. What did you find out?

8. Now back to motion. Because you were able to infer the speed-time graph from the distance-time graph, it is clear that the three quantities—speed, change in distance, and change in time—are all related to each other. Below, write down a mathematical equation with speed on the left and the other two quantities on the right. Then test your equation using actual numbers (including units) from the graphs. Record the values that you used in the space below, along with your calculations.
How Can You Describe Motion With Strobe Diagrams, Motion Graphs and Simple Equations?

Representing faster and slower motions!

Materials: Logger Pro, Motion Detector, toy car, and meter stick

Get one of the toy cars. Set up your detector to take data on its motion. Again, you might have to arrange things and keep trying out data collection until you can get graphs that show only the motion of the car and not other objects nearby.

1. Collect data on the car moving away from the detector for two or three seconds, then pick up the car and set it down so that it returns back towards the detector (while the detector and the car are still running.) Your goal is to get graphs that show the car moving both away from the detector and towards the detector in a single 10 second period. Some parts of the graphs might look messy but if the “moving towards” and “moving away” parts of the graphs look good, that is OK. Print your graph and attach it to your paper. (file – print screen)

2. The toy cars come in two speeds. Red cars go faster and blue cars go slower. Predict what the “moving towards” and “moving away” parts of the graph would look like if you got a car of the other color and repeated the motion that you just graphed. Sketch graph lines on your graph that you just printed and label the lines red and green.

3. Test your prediction. Now try the other car. You will probably have to trade with another group. (Collect data on the car moving away, and then pick it up and turn it around and set it down moving the other way.) When you get a good graph print it (file-print screen), compare it to your group’s prediction on the previous page.

Summarize what you have learned:
   a. Did you predict the velocity-time graph correctly? Did you predict the position-time graph correctly? If not, what needed changing?
   b. How does a velocity-time graph indicate different speeds?
c. How does a position-time graph indicate different speeds?

d. Sketch below graphs that represent an object moving at different constant speeds away from, or towards, the detector. Show both the away and towards on the same graph. You will need 4 graphs – position vs time for both cars and velocity vs time for both cars.

Moving slowly
away & towards

Moving faster
away and
towards
In the Elicitation activity, you saw two types of motion: constant speed and increasing speed. You have seen what position-time graphs and speed-time graphs look like for constant speed. What do you think graphs would look like of a car that leaves a stoplight at an ever-increasing speed, then slows down at the next stoplight?

**Materials:** meter stick, fan, cart, track, tape, safety gloves, MBL equipment

1. Do **NOT** move the motion detector. Open **Act I-D3 MBL1**. You should see the distance-time and speed-time graphs. Do **NOT** turn on the fan for this part of the experiment. Start with the fan cart about 50 cm away from the motion detector, start collecting MBL data and give the cart a gentle push so it travels to the other end of the track in a little more than three seconds with constant speed. Repeat until you have good data over the 3-second range showing the cart moving with essentially a constant speed. Print these graphs and staple to your assignment.

2. How can you tell from the speed-time graph that the cart moved with essentially a constant speed?

3. You will use the battery driven fan unit for this experiment. **Be very careful when using the fan carts.**
   
   a. You should only run the motor for a **BRIEF** time (a few seconds) while you are making a measurement, or practicing a measurement.
   
   b. Because we have made them simple, they can be broken easily, particularly by dropping them.
Please don't drop them!

c. No safety features protect you from the fan blades. Don't stick your finger in the blades.

4. Practice working with the fan cart. (Do not collect MBL data yet.) Push the red button to turn on the fan, then let go. Stop the cart carefully when it reaches the other end of the track by placing your finger on the cart away from the rotating fan blades. Then turn off the fan.

5. Imagine collecting MBL data while the fan cart is moving away from the detector. Sketch what you predict the new distance-time and speed-time graphs might look like.

How did you decide?

6. Open Act 1-D3 MBL2. There should be three graphs: distance-time, speed-time and acceleration-time. Set the cart about 50 cm from the motion detector. Hold the cart still, turn on the fan, start collecting MBL data, and then let the cart go. Carefully stop the cart and fan at the end of the track. It is not uncommon that the acceleration-time graph has lots of bumps. If they seem unusually large, ask your teacher to help check your apparatus to see if the data collection can be improved.

Print the 3 graphs to be stapled and turned in with your assignment.
7. Compare the MBL distance-time and speed-time graphs for the speeding up fan cart with the ones you predicted. Were the MBL graphs reasonably close to the ones you predicted? If they were quite different, describe how they were different.

8. How can you tell from the speed-time graph that the fan cart is increasing its speed as it moves along the track?

9. What does the acceleration-time graph tell you about the motion of the fan cart?

10. Place the cart about 50 cm from the motion detector, but this time turn it around so the fan blades are facing away from the motion detector. Do not collect MBL data yet! You'll need to practice the following procedure, and please be careful! Turn on the fan and push the cart so it moves away from the motion detector, slows down, and comes to a momentary stop about 3/4 of the way along the track. Stop the cart before it speeds up again and moves back towards the motion detector.

   Draw your predictions for how you think the three graphs might change for the slowing down fan cart (assuming it starts at some initial speed).
How did you decide?

11. Use the MBL to test your predictions. Click on the MBL graph window, go up to the Data Menu, and choose Store Latest Run.

After you have practiced sufficiently, repeat the motion described above and collect the MBL data for the fan cart slowing down as it moves away from the detector and comes to a stop. If your acceleration-time graph looks too bumpy, ask to get help.

Print the graphs to be stapled to your assignment.

12. Do the distance-time and speed-time graphs make sense? How do they compare to your own "slowing-down" predictions?

13. What is different about the acceleration for this slowing-down case, as compared to the acceleration for the speeding-up case?
In Activity 1-D1, you walked away from the motion detector to explore constant speed motion. Here is a challenge for you. Think carefully about it, and do your best.

**Materials:** meter sticks, watches, motion detector, MBL equipment

**Part I:**
1. Open Act 1-A1 MBL1. The graph is an idealized distance-time graph. Predict how you should move across the floor to come as close as possible to reproducing the idealized motion represented in this graph. **Write down your prediction** for how you should move in the space below.

2. Practice the motion using meter sticks and watches until you think you can perform the motion well. (Do not use the motion detector for this)

3. Collect data and try to duplicate the motion represented on the graph. Repeat a few times. Print your best effort and attach it to the answer sheet. Include your name on the paper.
4. Critique your results. Try to determine what differences are due to mistakes and what differences are due to the difference between real motion and idealized motion. Then close Act.1-A1_MBL-1.

Part II: The Speed Match Challenge

1. Open Act. 1-A1_MBL2. The graph is an idealized speed-time graph. Use the graph to predict how you should move across the floor to come as close as possible to reproducing this idealized graph. Write your prediction for how you should move in the space below.

2. Practice the motion using meter sticks and watches until you think you can perform the motion well. (Do not use the motion detector for this)

3. Collect data and try to duplicate the motion on the graph. Repeat a few times. Print your best effort and attach it to your answer sheet. Include your name on the paper.
4. Critique your results. Try to determine what differences are due to mistakes and what differences are due to the difference between real motion and idealized motion. Close Act1-A1 MBL2.

More Challenging Graph

Open Act1-A1 MBL3. The graph is a speed-time graph. Write your prediction for how you should move in the space below.

1. Practice the motion using meter sticks and watches until you think you can perform the motion well. (Do not use the motion detector for this)

2. Collect data and try to duplicate the motion represented on the graph. Repeat a few times. Make a copy of your best effort and attach it to your answer sheet. Be sure to include your name.

3. Critique your results. Try to determine what differences are due to mistakes and what differences are due to the differences between real motion and idealized motion. Close Act1-A1 MBL3.
How can you tell by looking at two objects that are moving in the same direction whether they have the same speed? In this short activity you will see if you can figure it out.

Materials: CPU software

1. Open Act I-A2 Sim 1 and run the simulator, showing the motion of two objects, one red and one blue. Do the two objects ever have the same speed during the first eight seconds? If so, at approximately what time, and how do you know? If not, how do you know they do not?

2. To get feedback, delete the black rectangle. Underneath there are speed-time graphs for each object. If necessary, rewind and repeat the motion. How close were you in your estimate?
Bibliography

1. CPU Curriculum, http://cpucips.sdsu.edu
2. DESE; www.dese.state.mo.us