Reaching For Results

Teacher-to-Teacher
Video Series
for Secondary Educators

TITLE: Introduction to Motion

PRIMARY SUBJECT AREAS: Physics

GRADE LEVEL: 9-12

OVERVIEW: This introductory lesson on motion serves to find out what students already know about the topic of motion, and reinforces and extends motion concepts that should have been introduced in the middle school grades. Because the lesson only involves studying objects traveling in a straight line in a single direction, scalar quantities of distance and speed are used in this lesson. The lesson provides the foundation for later introducing students to vector quantities of displacement, velocity and acceleration, and for studying two-dimensional motion.

The lesson introduces students to kinematics, the description of motion. It develops the idea that the motion of an object can be described in multiple ways—through words, pictures, mathematical formulae, or graphs. The lesson begins by giving students a battery-operated or pull-back toy car and challenging them to find a way to determine quantitatively “how fast” the car goes. This leads to a discussion of speed and the difference between the terms constant speed, average speed, and instantaneous speed. Students next consider the motion of a boy riding a bike to his friend’s house along a hilly path and discuss how they think his motion would be represented graphically. Finally, the students collect data and graph the motion of four different runners along a straight 30-meter track. By analyzing these distance-time graphs, which are all plotted on the same coordinate system, students discover that:) the graph of an object traveling at a constant speed is linear;) the graph of an object moving with a uniformly changing speed is curved;) the direction in which a graph curves indicates whether the object is speeding up or slowing down; and) the slope of a distance-time graph indicates the speed of a moving object.

APPROXIMATE DURATION: Three 50-minute class periods

LOUISIANA CONTENT STANDARDS:
http://www/DOE/assessment/standards/SCIENCE/pdf

Science as Inquiry
Benchmarks:

SI-H-A4 formulating and revising scientific explanations and models using logic and evidence;

SI-H-A6 Communicating and defending a scientific argument.

SI GLEs:

7. Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships,

plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
9. Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)

Physical Science
Benchmarks:

PS-H-A1 Manipulating and analyzing quantitative data using the SI system

PS-H-E2 Understanding the relationship of displacement, time, rate of motion, and rate of change of motion; representing rate and change of motion mathematically and graphically

PS GLEs:

2. Gather and organize data in charts, tables, and graphs (PS-H-A1)
31. Differentiate between speed and velocity.
32. Plot and compare line graphs for acceleration and velocity.

Physics GLEs:

1. Measure and determine the physical quantities of an object or unknown sample using correct prefixes and metric system units (e.g., mass, charge, pressure, volume, temperature, density) (PS-H-A1)
9. Describe and measure motion in terms of position, displacement time, and the derived quantities of velocity and acceleration (PS-H-E2)
10. Determine constant velocity and uniform acceleration mathematically and graphically (PS-H-E2)
11. Plot and interpret displacement-time and velocity-time graphs and explain how these two types of graphs are interrelated (PS-H-E2)

EDUCATIONAL TECHNOLOGY GUIDELINES:

N/A

INTERDISCIPLINARY CONNECTIONS:

Mathematics

This lesson has a strong integration of mathematics as students prepare and analyze motion graphs, use the slope formula and slope-tangent method to determine velocity from displacement-time graphs, and compare graphical representations of motion to mathematical formulae.

OBJECTIVES:

1. The student will calculate the average speed of a moving object.
2. The student will differentiate between average speed and instantaneous speed.
3. The student will collect and graph displacement-time data for objects traveling in a straight line in a constant direction.
4. The student will analyze a displacement-time graph to determine the velocity of an object traveling at a constant speed in a straight line.
5. The student will analyze a displacement-time graph to determine and compare the velocities at different times for an object traveling in a straight line with changing speed.

6. The student will draw conclusions about rate of motion and rate of change of motion from the shape and slope of displacement-time graphs.

LESSON MATERIALS AND RESOURCES:

Battery-operated or pull-back toy cars (one per small group of students)
stop watches
meter sticks
chart paper
markers
graph paper
student handouts (Attachments 1 and 2)
Attachment 3 is a teacher's transparency master

TECHNOLOGY TOOLS AND MATERIALS:

Calculators and graphing software may be used.

BACKGROUND INFORMATION:

Students should know how to prepare line graphs. Students should have learned in algebra how to determine the slope of a straight graph line, and to use the slope-tangent method to find the slope at a particular point along a curved graph line graph. (It may be necessary for the teacher to review slope and slope-tangent at the appropriate point in this lesson.)

LESSON PROCEDURES:

1. For this introductory activity, students are divided into small groups of 3-4 students.

   Each group is provided with a toy car (battery-operated or pull-back), a meter stick and a stopwatch. Groups are challenged to find a way to use the materials provided to determine "how fast" their toy car travels. The teacher intentionally avoids using the term "speed" in giving students instructions because the purpose of the activity is to elicit students' notions about speed and how it is measured.

   Student groups are assigned a flat space (floor or long table) on which to work and are given time (about 5-10 minutes) to accomplish the task. When finished, each group is given markers and a sheet of chart paper on which to represent what they did and what they found out for sharing with the whole class. Have the groups present their findings. While most groups will represent "how fast" their car moved in terms of distance/time, the teacher should anticipate that one or more groups will represent "how fast" in terms of time/distance.

   Following group presentations, the teacher explains the scientific convention of expressing speed in terms of distance/time. The teacher then asks the students whether their toy car traveled at a "constant speed" and to supply evidence to support their answer. If necessary, groups can be provided time to return to their flat workspace to collect additional data to determine whether their car's speed was constant. Then, students are asked what the speed of their car was after it had traveled 0.5 meters. This leads to a discussion of the difference between "average speed" and "instantaneous speed". The idea is developed that whenever one divides distance traveled by time of travel, one is expressing the average speed over that interval, or: average speed = Δdistance/Δtime. The teacher discusses how one can find the "instantaneous speed" of a moving object at a certain point by determining the average speed of an infinitesimally small interval about that point. As an example, the teacher might discuss how an automobile's speedometer indicates instantaneous speed by measuring the time it takes for one rotation of the tires. (An interesting extension is to ask the class to consider the effect of putting larger tires on the car.)

The teacher culminates the activity with a brief oral assessment to check that students have grasped the difference between the terms "average speed" and "instantaneous speed." The teacher reminds the students of the classic Aesop's fable about the hare and the tortoise and asks the students, in their small groups, to discuss which had the greatest speed. The students should conclude that while the tortoise had the greatest average speed because he won the race, the hare had the greatest instantaneous speed.

2. The next activity, Tom's Bike Ride" (Attachment 1) is designed to elicit the students' current ideas about motion graphs. A copy of "Tom's Bike Ride" is projected on an overhead and/or copies are distributed to students.

   A "think-pair-share" strategy is used to have students thoughtfully consider and respond to the scenario. Using this strategy, students are first given time to individually think about the scenario and to come up with an answer, are then paired with another student to compare answers and the reasons for them in order to reach a consensus answer, and finally, the pairs of students share and defend their responses with the whole class.

   At this point, the teacher does not give feedback as to the correctness of the students' ideas. The scenario will be revisited after the main activity of the lesson.

3. The main activity of the lesson involves having students collect data for four different "runners" along a 30-meter track. The activity is done as a whole class outside in a field or parking lot where the teacher has marked off a 30-meter track.

   a. Six students are selected to be "timers" and are positioned with stopwatches at 5-meter intervals along the track.
   b. Four students are selected to be "runners," and each is assigned a particular kind of motion with which to run the 30-meters: walking at a regular constant speed; running at a constant speed; starting from rest and uniformly increasing speed along the entire 30 meters; starting with a high speed and uniformly decreasing speed along the entire 30 meters. (The last runner will have to actually begin running behind the starting line in order to have a high speed at the starting line when the timers start their watches.)

c. Four students are selected to be "data recorders" and each is assigned a runner for whom to collect data from the timers at the end of the run.

Once the four runs are completed and data collected, students return to the classroom where the data recorders each post the data for their respective runners in a T-chart on the board. The teacher distributes activity sheets (Attachment 2) on which the students can copy this data. The students are then assigned to graph the data for each of the four runners on the same distance-time graph. Students may use Graphmaster® or other graphing software to produce their graphs electronically; however, it is essential that the motion of each of the four runners be graphed on the same coordinate system.

Students may be assigned to complete their graph for homework and bring it to class the next day. Before class the next day, the teacher prepares a graph of the data on an overhead transparency. (A sample showing what this graph should look like appears on Attachment 3). The teacher displays the graph showing the four runners' motions, and the students compare their graphs to that of the teacher.

The teacher calls on students to share their responses to questions on the activity sheet, and uses these to develop the following important ideas:

- Constant speed is represented by a straight line on a distance-time graph; the slope of the graph line indicates the value of the constant speed (slope = $\Delta y/\Delta x$ = Δdistance/Δtime);
- Accelerated motion is represented by a curved line on a distance-time graph; the direction in which the graph line curves provides a visual indication of whether the speed is increasing or decreasing;
- The slope-tangent method can be used to determine the value of the instantaneous speed at any point on the curved graph line. (In this method, one draws a tangent to the graph line at the point on the graph for which one wants to determine the instantaneous speed, and then determines the slope of the tangent line.)

As an optional extension to this activity, the teacher may have the students use the distance-time graphs of the runners to prepare corresponding speed-time and acceleration-time graphs. These graphs may be prepared by hand or by using an electronic graphing program designed for the creation of motion graphs (such as DataPro®).

4. As a culminating activity and assessment for the lesson, students revisit the scenario about Tom's bike ride, changing their initial responses, if they desire, based on what they have learned through the main activity. They also write a justification for their answer.

   Students turn in their activity sheets to be graded by the teacher. The correct graph choice is (b) because: •the slopes of the various sections of this graph are consistent with the different constant speeds Tom would ride (medium speed on the flat sections, slow speed on the uphill sections, and high speed on the downhill section); •this graph represents equal distances being traveled in each section (the "rise" of each section is 4 units on the distance axis) and the scenario stated that each section of the road was of equal length.

ASSESSMENT PROCEDURES:

The lesson includes several embedded assessments which include having students determine the speed of a toy car, asking students to compare the speeds of the hare and the tortoise in Aesop's fable, having students graph and analyze the motions of four runners, and, as a final assessment, having students respond to the scenario about Tom's Bike Ride by choosing the correct graph and giving a clear and complete written justification for their answer. (The correct answer and justification are described in the teacher procedure section.)

ACCOMMODATIONS/MODIFICATIONS:

N/A

REPRODICIBLE MATERIALS:

Attachment 1: Tom's Bike Ride
Attachment 2: Four Runners
Attachment 3: Sample graph for Four Runners, transparency master

EXPLORATION AND EXTENSION:

If motion sensors which interface with a PC, or CBL motion probes, are available, students can use them to create and analyze motion graphs of objects such as pull back toy cars, bouncing balls, etc. Students can also be given a certain type and shape of graph and asked to walk toward the motion sensor in a way that will reproduce the graph on the electronic screen.

LESSON DEVELOPMENT RESOURCES:

http://www.connectedteacher.com/newsletter/citeintres.asp

REFLECTIONS:

The strong feature of this lesson is that it uses a constructivist approach to introduce students to motion concepts. Before each concept is introduced, students' notions about the concept are elicited. For example, students use their prior experience and knowledge to determine the speed of their toy cars, and initially consider and respond to the scenario about Tom's Bike Ride based on prior knowledge of graphing motion. New concepts emerge from students experiences, and concept vocabulary terms are introduced only after the concepts they represent have been developed.

CONTACT INFORMATION:

Gail Kirwan kirwans@cox.net