SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center
Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center
Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center
Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers
Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center
Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers
Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center
Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers
Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center
Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers
Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*
Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site
UPR Lab H.S.

* * * * * * * * * * * *

Pilot Sites
Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C., William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

*not part of the NSF-funded SS&C Project.

Project Associates

Bill G. Aldridge
SciEdSol, Henderson, Nev.

Dorothy L. Gabel
Indiana University

Stephen G. Druger
Northwestern University

George Miller
University of California-Irvine

National Science Education Standard—Physical Science

Motions and Forces

SS&C Inferred Generalization. Motions are described quantitatively in science using concepts given the names distance, displacement, speed, velocity, and acceleration. Relationships among these quantities are most easily interpreted and used to solve problems by means of graphical techniques involving slopes and areas under curves.

Teacher Materials

Learning Sequence Item:

915

Motion and Inertia

August 1996
Adapted by: Stephen Druger

Translational Kinematics. Students could compare accelerating a bowling ball along a straight-line path with the experience of trying to keep the ball moving in a circular path by pushing on it with a broom. Also, when accelerating in the forward direction in a car, students experience being "pushed backward" (the fictitious inertial force) against the car seat. They learn that this is their inertia: the car moves forward, and they tend to remain at rest until the cart seat pushes them forward (*Physics, A Framework for High School Science Education, p. 4*).

Contents

This micro-unit was adapted by **Stephen Druger** (Northwestern University, Evanston, Ill.)

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Learning Sequence

Translational Kinematics. Students could compare accelerating a bowling ball along a straight-line path with the experience of trying to keep the ball moving in a circular path by pushing on it with a broom. Also, when accelerating in the forward direction in a car, students experience being "pushed backward" (the fictitious inertial force) against the car seat. They learn that this is their inertia: the car moves forward, and they tend to remain at rest until the cart seat pushes them forward (*Physics, A Framework for High School Science Education, p. 4*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Pulling the Rug Out **Activity 1** Using a Line Level to Measure Motion **Activity 2** A Bus Ride **Activity 3** Going Around in Circles **Activity 4** Coin Trick **Assessment 1** More Coffee? **Assessment 2** Moving in Circles **Assessment 3** Train Ride **Assessment 4**			

Suggested Sequence of Events

Event #1

Lab Activity

1. Pulling the Rug Out (40 minutes)

Event #2

Lab Activity

2. Using a Line Level to Measure Motion (1 hour)

Event #3

Outside Activity

3. A Bus Ride

Event #4

Lab Activity

4. Going Around in Circles

Event #5

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Freiman, C., "Thrills Without Spills." *Science World*, Vol. 52, No. 8, 1995, pp. 8–10.
Gannon, R.. "Why Do We Throw Up?" *Popular Science*, March 1995, p. 100.
Shamos, M.H.. *Great Experiments in Physics*. New York: Dover, 1959.
Silbert, J., "On Track at the Indy 500." *Science World*, Oct. 8, 1993, p. 12.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Pulling the Rug Out

How do changes in motion affect speed of an object?

Overview:

Students examine the inertial properties of a column of blocks.

Materials:

Per lab group:

wooden blocks, cube shaped (of the kind sold in toy stores), 3–4
paper, 1 piece

Procedure:

Students stack three or more blocks in a vertical column on top of a piece of paper. They then try to pull the paper from beneath the blocks without disturbing them. They should first pull the paper slowly and smoothly along the table. Next they should try to remove the paper by abruptly yanking it along the table surface. They should then try the experiment for intermediate cases, observing the different effects of inertia in each case.

Background:

This activity is a version of the standard magician's trick of pulling a tablecloth out from beneath a table setting, leaving all the dishes and glasses in place. It is intended to help students appreciate the phenomenon of inertia and its relation to what they experience when riding in a moving vehicle. Students should conclude that when the paper is pulled abruptly along the table surface, the blocks remain almost stationary because of their tendency to resist being set into motion in such a short time, but that their resistance to changes in motion can be overcome by pulling the paper to reach the same speed over a longer period of time. Students might, for example, explain the toppling of the blocks in intermediate cases by observing that the lowest block is being pulled weakly enough to accelerate with the paper but that the rest of the column still resists the acceleration by tending to rotate. If the acceleration of the paper is slow enough for the bottom block to move with the paper, but rapid enough to rotate the column far enough, the column will topple.

A more detailed explanation than that appropriate for students at this point would involve the nature of the frictional forces and the conditions for stable mechanical equilibrium. The maximum frictional force between the paper and the bottom block depends on the weight of the column. When the paper is abruptly pulled along the table surface, the frictional force is insufficient to accelerate the blocks significantly in the short time available. At the other extreme, the force needed to accelerate the blocks slowly enough is less than that provided by static friction, so the lowest block will accelerate with the paper. In this case, if the column is to accelerate linearly and not lean over, the torque that the frictional force produces about the center of mass must be less than the restoring torque that gravity exerts about the center of mass. If the frictional torque is greater, then the column of blocks rotates instead of being merely accelerated linearly. If the column leans enough that its center of gravity is no longer above its base of support, it topples over. A taller column requires a smaller angle of rotation for the center of gravity to be no longer above the base of support and is less stable against toppling.

Adapted from:
Kearny, J.R., *The Physics Teacher*, September 1967, p. 292.

Science as Inquiry

Using a Line Level to Measure Motion

What can a line level tell us about linear and circular motion?

Overview:

Students observe that a bubble level can be used to test for acceleration in linear motion, and they apply it to circular motion.

Materials:

Per lab group:
mechanic's line level (i.e., bubble level)
string

Procedure:

Have students roughly calibrate the bubble line level by testing where the bubble lies when the level is resting on the top of the worktable. They then move the level in a straight line parallel to the length of the table, with the level pointed in the direction of motion, trying to do so at a roughly constant speed. They find little change in the location of the bubble compared with its location when the level is at rest.

Students again move the level in a straight line, this time so that its speed is increasing during most of its motion, and observe how the bubble location responds while accelerating.

Finally, have students tie one end of a string to the level and hold the other end pressed with one finger to the table. The string serves as a guide for moving the level in a circular arc at an approximately constant rate. The level should point radially along the direction of the string while it is being moved. Students thereby observe the effect of centripetal acceleration with the line level used to detect acceleration.

Background:

Accelerometers are often sophisticated electromechanical devices that find practical application in, for example, the triggering mechanism for automobile air bags. In that case they are often used in conjunction with other sensors to assure the air bag is likely to be inflated only in an actual collision. The motion of the liquid in a glass or plastic tube, however, provides a mechanism for constructing a simple and easily understood acceleration detector for classroom use.

Since it is natural to focus attention on the bubble rather than on the liquid in the tube, it usually seems strange at first sight that the bubble responds to an acceleration by being displaced within the level in the direction of acceleration rather than in the opposite direction. However, for present purposes, the bubble can be regarded approximately as a void (in comparison with the much more massive liquid), and the inertia responsible for the observed behavior is that of the liquid. When the level is accelerated forward, the inertia of the liquid leaves it pressed against the back of its container to a greater degree than otherwise, as the container in turn pushes to accelerate the liquid, so that the bubble is displaced toward the front of the tube. Similarly, when the level is decelerated, the liquid tends to keep moving with forces being exerted mainly by the front of the tube to slow it, so that the void appears displaced toward the back of the tube, again in the direction of the acceleration slowing the motion.

In examining the behavior of the accelerometer when moved in a circular path, students are expected merely to note that changes in motion can involve either a change in speed or a change in direction of the motion, both having effects on the bubble acceleration detector. The topic of circular motion and centripetal acceleration is dealt with in subsequent units.

Adapted from: none

Teacher Sheet

Science as Inquiry

A Bus Ride

What is a bus ride like from an accelerometer's perspective?

Overview:

In this activity students study the behavior of a bubble accelerometer in a moving vehicle as it accelerates and relate the behavior of the liquid in the accelerometer to the forces they feel acting on them under the same circumstances.

Materials:

Per student

bubble line level (or equivalent device) that can be borrowed for use on bus or while riding as passenger in car

Procedure:

Students rest the level in a horizontal position on some convenient surface when the vehicle happens to be at rest. They watch the response of the level when the vehicle speeds up, when it slows down, and when it is traveling in a straight-line path at an approximately constant speed.

Background:

The goal of this activity is to have students relate the behavior of the bubble acceleration detector to their own daily experience in riding in a train, bus, or car. By this point, they will have examined the mechanism by which the bubble acceleration detector works and should be able to relate the effect of the acceleration on the liquid (and bubble) in the tube to the effect of the acceleration on themselves when riding in an accelerating or decelerating vehicle.

Students who are unusually careful in their observations might recognize that they are able to sense their acceleration even apart from feeling changes in the forces acting between their bodies and the accelerating train. The role of the inner ear in detecting acceleration and in initiating reflexes to avoid falling is dealt with in Reading 3.

Adapted from: none

Science as Inquiry

Going Around in Circles

How do you keep an object on a circular path?

Overview:

Students compare the accelerations they must produce to cause an object to move approximately in a circle with that required to cause its motion in a straight line.

Materials:

Per lab group:

working surface, smooth and nonabsorbing
pencil
rubber ball, smooth
washable marker or chalk (depending on the surface used)
string

Procedure:

Have students tie the string to the marker, hold the other end of the string in place with one finger, and use it to guide the marker in a circular path to mark off a circle with a radius of 7–12 inches. (Alternatively, if damage to the available work surface by marking is of concern, students can use a bit of imagination about where a circular path would lie.) Holding the pencil near the end they tap the ball lightly, repeating as needed to try to keep the ball moving in a circular path. They then repeat the exercise, this time trying to keep the ball in a straight-line path, noting the differences in what must be done.

Background:

This exercise is intended to lead into study of circular motion. Students should note that it is necessary to keep striking the ball to change its motion in order to keep it approximately on a circular path, and that the accelerations they try to produce are in different directions as the ball moves approximately around the circle. They should note that the straight-line motion requires merely striking the ball to get it moving and then doing little more than allowing it to roll.

Adapted from: none

Science as Inquiry

Coin Trick

Item:

An old carnival trick is to place a ball with a coin balanced on top of it in the center of a circle and to convince spectators to bet that they can hit the ball so as to knock the coin out of the circle. It turns out to be a losing bet. Why might this be the case?

Answer:

If the ball is struck hard enough, the inertia of the coin will cause it to slip and remain in the same approximate location as the ball slips beneath it. If struck softly the coin will merely roll off.

Science as Inquiry

More Coffee?

Item:

Suppose you are on a train or an airplane that is exactly level and moves at a constant speed always in the same direction. If you pour coffee from a coffee pot into a cup on the rapidly moving vehicle, then in order for the coffee to pour into the cup and not onto the floor:

A. The cup should be closer to being directly beneath the coffee pot than it is when the train is not moving.

B. The cup must be further away from being directly beneath the coffee pot than it is when the train is at rest.

C. The cup should be in the same location as when the train is at rest.

D. Not enough information is given in the question to determine which choice is correct.

Answer:

C.

Justification:

Students are expected to explain in some way that the inertial effects on the moving train that might make the coffee miss the cup when held in the same location as in the stationary train all arise from acceleration, or changes in velocity, rather than merely from being in motion at a constant velocity.

Science as Inquiry

Moving in Circles

Item:

When an object rotates in a circle at a constant rate:

A. It is not accelerating because its rate of rotation stays the same.
B. It is not accelerating because its direction of motion stays the same.
C. It is accelerating always in the same direction.
D. It is accelerating in different directions as it continues to move.

Answer:

D.

Justification:

Velocity consists of both the speed and direction of motion, and a change in velocity either by changing its speed or its direction involves an acceleration. (Students should comment on the observation that in order to make the ball roll in a circle, they had to keep accelerating it in different directions depending on its location around the circle.)

Science as Inquiry

Moving in Circles

Item:

Imagine that you are standing in a train with your eyes closed. Describe how you would know when the train is speeding up and when it is slowing down.

Answer:

When the train slows down, the passenger would tend to keep moving and would feel forces between himself or herself and the train. The forces specifically would be that of feeling as if being pushed forward by inertia (relative to the train). When the train speeds up, the passenger tends to keep moving at the previous speed and would therefore feel pushed back within the train by inertia.

Alternate answer:

Unusually perceptive students might note that even apart from experiencing the forces between themselves and the part of the train they make contact with, they can sense when the train changes its motion. The inner ear, which provides information that the brain uses in keeping the body balanced while walking or standing, also detects accelerations by a mechanism resembling that of the acceleration detector of our experiments.

Consumables

Item	Quantity per lab group	Activity
paper	1 piece	1
pencil	1	4
string	—	2, 4
washable marker or chalk (depending on working surface)	1	4

Nonconsumables

Item	Quantity per lab group	Activity
mechanic's line level (bubble level)	1	2
mechanic's line level (bubble level)	1 per student	3
rubber ball, smooth	1	4
smooth, nonabsorbing, working surface	—	4
wooden blocks, cube shaped (as sold in toy stores)	3–4	1

Key to activities:
1. Pulling the Rug Out
2. Using a Line Level to Measure Motion
3. A Bus Ride
4. Going Around in Circles

Activity Sources

Kearny, J.R., *The Physics Teacher*, September 1967, p. 292.