Scope, Sequence & Coordination

A National Curriculum Development and Evaluation Project for High School Science Education

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National Science Education Standard—Physical Science
Motions and Forces
Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force. Whenever one object exerts a force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Teacher Materials

Learning Sequence Item:

916

Laws of Motion

March 1996
Adapted by: Carlee Boethger

Dynamics: Newton's Laws of Motion. Students should first consider the qualitative aspects of forces and changes in motion, gaining experience with force as push and pull. They should then consider simple interactions and observe equal and opposite forces by pulling on pairs of connected spring scales. Observing motion under nearly frictionless conditions, they will see evidence of Newton's first law.. (*Physics, A Framework for High School Science Education, p. 11.)*

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This micro-unit was adapted by **Carlee Boethger** (Georgetown Day School, Washington, D.C.)

916
Learning Sequence

Dynamics: Newton's Laws of Motion. Students should first consider the qualitative aspects of forces and changes in motion, gaining experience with force as push and pull. They should then consider simple interactions and observe equal and opposite forces by pulling on pairs of connected spring scales. Observing motion under nearly frictionless conditions, they will see evidence of Newton's first law.. (*Physics, A Framework for High School Science Education, p. 11.)*

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Suggested Sequence of Events

Event #1

Lab Activity

1. It's Not Fair!

Alternative or Additional Activities

2. Soda Pop Bottle Wobble
3. Spheres of Influence
4. Reaching the Breaking Point

Event #2

Lab Activity

5. He's Not My Brother, But He's Heavy

Event #3

Readings from Inquiry, Science and Technology, Personal and Social Perspectives, and History of Science. Students select two or three from list (not including SI-6 and SI-7 which are read in conjunction with SI-1). The readings are selected on Internet:

Reading 1: Biography: Sir Isaac Newton
http://www.maths.tcd.ie/pub/HistMath/People/Newton/RouseBall/RB_Newton.html
Reading 2: Quotes by Newton
http://wwwsp2.cern.cn/~mcnab/n/T/NewQuote.html
Reading 3:
Reading 4:

The above readings can be found in the student version of this publication.

Assessment items can be found 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

It’s Not Fair!

Demonstrate Newton’s First Law

Materials:

two pool balls
pool stick (meter stick)
strip of green felt, 30 cm × 90 cm
silver dollar (or other heavier coin)
chalk

Procedure:

Using the chalk, students should draw a 20 cm diameter circle at the far end of the felt. One pool ball should be placed at the center of this circle. On top of this pool ball balance the coin. Students should shoot the cue ball from the far end of the felt. Their goal is to knock the ball hard enough so that the coin is flung outside the circle. If the coin lands outside the circle, the student is awarded that coin as a prize.

Background:

This is an old carnival trick. The “carnies” applied the principle of inertia in order to glean money from science-illiterate customers. Newton’s Law of Inertia states that an object at rest will remain at rest. The coin on top of the pool ball will have inertia. Regardless as to how the ball is hit, the coin will tend to remain in that place. In the event the ball is knocked away, the coin will fall to the felt close to the center of the circle.

Further Variations:

1. Encourage the students to use any combination of back, top or side spin, and to vary the amount of strength used to hit the ball. Other types of coins could be used. There may be an observable difference between the performance of a penny and that of a silver dollar.

alternative activity for Event 1

Teacher Sheet

Science as Inquiry

Soda Pop Bottle Wobble

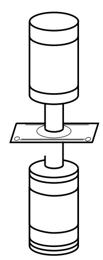
Identify the Role of Inertia in Structures

Materials:

Per lab group:
2 soda pop bottles
1 (very crisp) dollar bill

Procedure:

Set up the lab as shown in the figure. With a rapid motion, have students remove the dollar bill from between the two bottles.



Background:

With a rapid, smooth pull, it is possible to remove the bill from between the bottles with out toppling them. Newton's First Law explains that the bottles at rest will remain at rest. For best results, care must be taken to align the bottles exactly. Using a new dollar bill will decrease the amount of friction and make the removal of the bill easier. If students are having trouble with this lab, the bill may be moved off center, thus decreasing the distance pulled.

Further Variations:

Different bills may be used, new and old, thus varying the friction in the experiment. Or, vary the mass or type of the bottles used. This will provide further chance for concept development. Add mass, (i.e., sand, etc.) to the bottom of the bottle, significantly increasing the inertia.

Adapted from:
SS&C Physics Planning Group, July 1995.

alternative activity for Event 1

Teacher Sheet

Science as Inquiry

Spheres of Influence

Identify Methods of Measuring Inertia Without Using a Balance

Materials:

Per lab group:

3 spheres (same size but different masses)
variety of materials (string, tape, clay, metersticks, etc.)

Procedure:

Ask students to determine the relative order of inertia of three spheres without using a balance. Then ask groups to generate their own ideas of measurement techniques, and organize these into a graph. Have students make inertia comparisons between various objects, ordering the masses from least to the greatest inertia. Discuss results, having students explain test ideas, procedures and conclusions.

Background:

One way to determine inertia is to measure the degree of difficulty in moving an object from rest. This can be done by taping objects to the end of a meterstick. Using a C-clamp, fix the meterstick to the table and pluck it. More massive objects, (having more inertia) will slowly wiggle at the end of the meterstick. Less massive objects will wiggle relatively quickly at the end of the meterstick. Example: If using clay and the spheres, it is possible to drop the spheres into the clay from the same height. The more massive sphere will embed itself into the clay further than the less massive sphere. Objects with more inertia are harder to get moving than objects with less inertia.

Adapted from:
SS&C Physics Group, July 1995.

alternative activity for Event 1

Teacher Sheet

Science as Inquiry

Reaching the Breaking Point

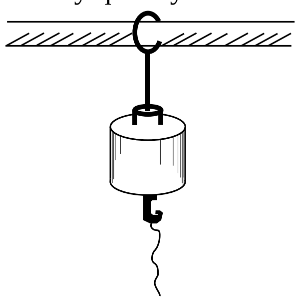
Identify the Role of Inertia in a Tense Situation

Materials:

Per lab group:
1 ring stand,
1 ring clamp
thread
2 masses

Procedure:

Set up the experiment as shown in the figure. A door knob could be used if stable support is needed beyond the capabilities of a ring stand and clamp structure. Have students pull on the bottom thread very slowly. Next, have them pull on the thread very quickly.



Background:

The thread to be used for this lab should have a breaking point 2 to 4 times the mass used in the experiment. When pulling on the bottom thread slowly, the top thread will break. This is because the mass and your pull are both pulling down and the only resistance is the upper thread. The upper thread will break. However, when pulling on the bottom thread quickly the bottom thread will break. A fast pull will have more force than that of the mass and top thread. The inertia of the mass will retard the increase in tension on the top thread.

Further Variations:

Add additional masses and threads to the system. Have students predict where the thread will break. Instead of a chain system (like the figure), try a parallel (side-by- side) system of masses and thread. Have students predict where the thread will break. Have students determine if the same effect can be identified.

Adapted from:
World Inside Out, Lab C.7. (As of July 20, 1995, this citation was not available.)

Science as Inquiry

He's Not My Brother, But He's Heavy

Investigate the Relationship between Mass, Inertia and Force

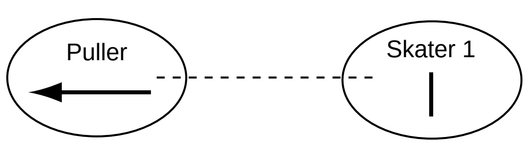
Materials:

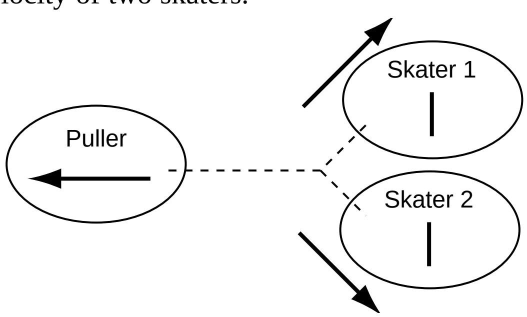
Per lab group
2 sets roller blades
2 spring balances
1 stopwatch
1 meterstick
tape

Procedure:

It is important for the participants to maintain constant force. This will simplify the variables used within this experiment. To begin, have one student, *(Skater 1),* start at rest while holding the curved end of the spring balance. Have the second student, (*Puller*), hold the hook end. Then have the third group member (*Observer*), watch the needle on the spring balance as the *Puller* begins to pull. *Skater 1* should be pulled at a constant force. Have students record data to include: a description of the motion of the needle as the skater begins to move; the velocity of the skater as the force remains constant; the student mass and; the average force used as read on the spring balance.

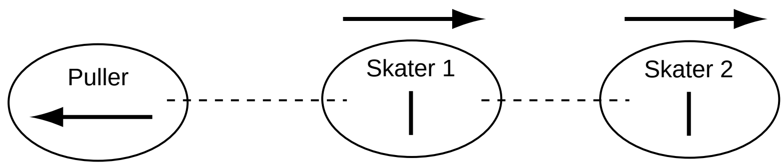
Add a second skater *(Skater 2),* to this experiment—holding the spring balance as described above. Again, force should remain constant. Record the data obtained. Repeat the experiments above to show a contrast between the velocity of only one skater and the velocity of two skaters.





Background:

This activity will build foundation information in order to explore Newton's First Law and carry into another activity with Newton's Second Law. Students should identify a significant amount of force used to initially start the skater's motion. This is called *starting friction*. Once moving, the skater experiences rolling or *moving* friction. The needle of the spring balance should jump as the experiment begins. Once the skater is moving smoothly, it will not take as much effort to maintain the motion—and the spring balance needle will indicate less force. Force should increase significantly when a second skater is added. Concluding discussion may include topics of friction, the difficulty of keeping both the force and the motion constant, and ideas on how to measure acceleration.



Further Variations:

Add a second skater as a chain to the first skater. Or, a chain of skaters could be created with your class. Contrast data with a group comprised of only one or two skaters. Additionally, vary the surface you skate over with one or two skaters.

Adapted from:
Hewitt, Paul, *Conceptual Physics Laboratory Manual*, Addison-Wesley Company.

Science as Inquiry

Magic Act

Item:

A piece of notebook paper rests on a smooth table. On the paper rests a set of keys and a pen. When you pull the paper rapidly off the table, the keys and pen remain on the table. Which property of the keys and pen best explains this? Explain your choice.

A. weight
B. volume
C. mass
D. none of the above.

Explanation:

Answer:

C. mass

Science as Inquiry

The Big Squeeze

Item:

When you compress a sponge, which quantity changes?
A. mass
B. inertia
C. volume
D. weight

Explanation:

Item:

C. volume

Science as Inquiry

Hangin' Around

Item:

Part 1. A mass is suspended by a string from above and is pulled slowly from below.
A. Is the string tension greater in the upper or the lower string?
B. Which string is more likely to break?

Part 2. A mass is suspended by a string from above and is pulled in a snapping motion.
A. Which string is more likely to break? Explain your answer.
B. Which property (mass or weight) is important here?

Answer:

Part 1. A. The string tension is greater in the upper string if you pull the string slowly. The upper string is more likely to break.

Part 2.

Science as Inquiry

Movin' On

Item:

Explain why it is more difficult to accelerate a loaded pickup truck than an empty one.

Answer:

The loaded pickup truck has greater inertia. An object with greater inertia is more difficult to get moving from a position of rest. However, it should be noted that once moving, the loaded pickup truck would be more difficult to stop than the empty one.

Science as Inquiry

Putting on the Brakes

Item:

Big, heavy, large, loaded trucks (18-wheelers) run routes in the steep Rocky Mountains. It is not uncommon for the brakes to go out when driving down the long passes. How would you design a road system to help truck drivers when their brakes go out?

Answer:

Truck stopping turnoffs are available periodically on downslopes. These are turnoffs of gravel or soft earth, of a long distance, and go right up the slope of a mountain. The combination of slope, soft material and long distance will stop even the heaviest truck.