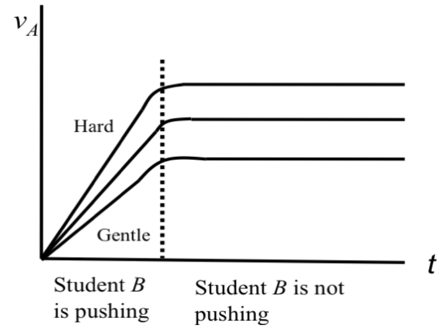
Newton's Second Law: Qualitative

5.1 Observe and Find a Pattern

Student *A* is on rollerblades and stands in front of a motion detector. The motion detector produces the velocity-versus-time graphs shown. Student *B* (not on rollerblades) stands behind Student *A* and pushes her forward. Student *A* starts moving. The surface is very smooth (linoleum floor).



a) Describe any patterns you see on the graph.

b) Draw a motion diagram and a force diagram for student *A* (1) when student *B* is pushing and (2) when she is not pushing. Are the diagrams consistent with each other for each time interval?

c) What is the meaning of the slope of the graph? Write a mathematical function that describes each part of one line on the graph. Write a second mathematical function that describes each part of a second line on the graph. What is the difference in the functions?

d) What can you say about the relationship between an **unbalanced force** exerted on an object and its **acceleration**?

5.2 Reason

Refer to the previous activity and graphs.

a) Why do you think student *A* does not stop moving when student *B* stops pushing?

b) Break each motion down into two parts: when student *B* is pushing and when student *B* is not pushing. What is different about the motion of student *A* for the three cases? What is the same?

c) Imagine that while student *A* is moving at a constant speed, student *B* starts pulling her in the direction opposite to her motion, exerting a constant force. Draw a motion diagram and a force diagram for student *A* and extend the existing velocity versus time graphs to represent the experiment.

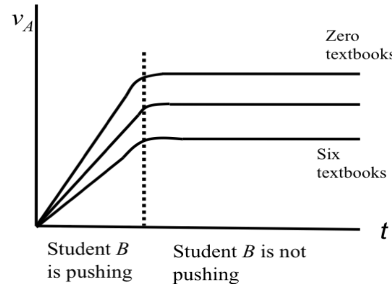
d) Repeat c but imagine that student *B* pulls even harder in the direction opposite to student *A*'s motion.

5.3 Test the Pattern

Download to your computer PhET simulation "Forces in one dimension." Turn off "Friction." Click on "graph Applied Force" and "Graph velocity." Use the file cabinet as your object. Predict the shapes of the graphs (sketch them) if you first exert a force of 200N on the cabinet for 6 seconds and then turn the force off but continue playing the simulation. After you sketched the predicted graphs, play the simulation and reconcile your predictions with the simulation graph. Repeat the same procedure for the force of 400N.

5.4 Observe and Find a Pattern

Student *A* is still on rollerblades, but this time she is wearing a backpack filled with textbooks. Student *B* pushes Student *A* several times; each time, student *A* adds three more books to the backpack. Student *B* pushes **exerting the same force each time**.



a) Use the graph to find a qualitative pattern between the **change** in Student *A*'s velocity and the **amount of stuff** in her backpack.

b) What can you say about the velocity of Student *A* after Student *B* stops pushing her?

c) Does the mass of an object affect the **velocity** of an object or the **change of velocity** when there is a force exerted on it?

d) How does changing the mass of the object affect the **acceleration** of an object if the *force exerted on it is the same*?

5.5 Test the Pattern (PhET simulations) Use the same situation as before. This time, predict the shapes of the applied force and velocity graphs you use the same magnitude force first exerted on the file cabinet (200 kg) and then on the refrigerator (400 kg). After you made the predictions, run the simulation. Did your prediction match the graphs on the simulation? If not, how can you reconcile?

5.6 Find a Relationship

Summarize how the change in the velocity of the object depends on the unbalanced force exerted on it by other objects. Then summarize how the change in the velocity of the object depends on the mass. Use the words: more, less, and constant. Now combine these two relationships into one.

5.7 Test the Relationship

a) Use the relationship you formulated in activity 6.4 to predict the shape of the velocity versus time graph for an object that is dropped

b) Use the relationship you formulated in activity 6.4 to predict the shape of the velocity versus time graph for an object that is thrown downward.

c) Explain the shape of the graphs in terms of the relationship you are testing.

d) Conduct the experiment using *a motion detector*. If there is no motion detector in your classroom, use the graphs provided by your teacher to compare the prediction with the actual outcome.

e) Revise the relationship if the prediction does not match the outcome.

Did You Know?

Two new words are used in physics to describe the processes and objects in activity 6.3. The first is "**inertia**". It describes the **motion of an object** that *does not interact with any other objects* – AND – inertia also describes the motion of an object *whose interactions with other objects are balanced*. Only observers in "inertial reference frames" observe inertia.

The second word is "**inertness**". **Inertness** is a property of objects that **describes how hard it is to change their velocity** by exerting forces on them.

Mass: Mass *m* characterizes the *amount of matter* in an object and the ability of the object to change velocity in response to interactions with other objects. The unit of **mass** is called a kilogram (kg). Mass is a scalar quantity, and masses add as scalars (mass is always positive)

5.8 Reason

Examine the graphs in activity 5.3. Discuss which parts of the graph relate to the word "inertia" and which parts relate to the word "inertness". What is a familiar physical quantity that is a quantitative measure of inertness?