INTRODUCTION TO FORCE

Investigation 1: Examining our initial ideas about force

To explore **Our ideas about the connection between forces and various states of motion or of rest.**

Introduction **We have made a thorough study of motion, but we have avoided, so far, considering any explanation of motion in terms of cause. Generally we consider force as the cause of motion. Thus, we explain motion by invoking the idea of force. In our study of motion we have looked at velocity, change in velocity and even no motion, standing still, rest. We begin our consideration of force by thinking about what we mean by the term, force.**

ACTIVITY F1.1: ***WHAT DO WE MEAN BY THE TERM, FORCE, IN THIS CONTEXT?***

Space for class notes.

WHAT DO YOU THINK?

The word, force, is used in many settings. In military settings we talk of Air Force or overwhelming force. In psychology we talk of forceful personalities. In politics we talk of a force for good. In these instances the word, force, means slightly different things, but maybe related. In our study of force as it relates to motion we are probably using yet another meaning for the term. In the space below try to express in your own words what you the word, force, means to you in our context of the motion or non-motion of objects. Accompany these words with a diagram if you think it will help clearly express your ideas.

This is an activity best done in class as a start to the unit.

It will become clear that not every student is thinking the same thing when you speak of force. This activity serves the purpose of getting these different ideas out on the table in terms of the various words that the students associate with the term, force.

What common, ordinary, everyday words do you associate with what you think of as a force? List them in the space below.

They will come up with words such as energy, effort, momentum, push, pull, exertion, etc.

WHAT DOES YOUR GROUP THINK?

When you have written your ideas about the nature of force and made your list of words, share them with your neighbors and make notes about any alternative you hear in the space below.

Space for class notes.

Ideas about the meaning of the word, force, in this context of motion or non-motion.

Some students will find it somewhat surprising that their peers have the associations that they do, but this is all good in that makes the purpose of this activity all the more clear, that we are trying to all start out more or less at the same place.

What common, ordinary, everyday words does your group associate with what they think of as a force? List them in the space below.

You can have each group prepare a presentation which consists of their list of words, any simple picture they might sketch, and ideas which describe force. This can be done on a section of the board, on transparencies, etc.

At this point, <u>stop and wait patiently</u> for the other groups to finish their discussion of what they are thinking about the meaning of the word, force. DO NOT GO ON PAST THIS POINT UNTIL THE CLASS HAS GATHERED FOR DISCUSSION.

WHAT DOES THE CLASS THINK?
Be prepared to contribute ideas from the discussion of your group. Listen to the ideas presented by the other groups. Make notes in the spaces provided below about any new ideas you hear and new words they associate with the idea of force.
Ideas about the meaning of the term, force.

Here is where the class gets to see the range of words and ideas that come up relating to force. Almost all will agree that the simplest and probably most widely agreed upon meanings for force would be the words, push and pull. You should ask if they can agree on that. Allow some discussion. Ask if they think they are all thinking the same thing about these two words and allow discussion on this. Point out that the notion of a force as a push or a pull is to be used as a starting point for thinking about force.

Additional words associated with the term, force, in this context of motion or non-motion.

The lists of words and the particular words brought up should serve to give you and the class an idea of the range of ideas associated with the term, force.

Space for class notes.

Can the class come to some consensus as to some very plain and simple words which express the basic idea of force in this context? **If so, write them in the space below.**

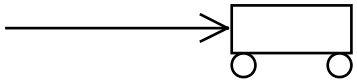
The plainest and simplest words are "push" and "pull." While in some classes there will be those who want to advocate possibly other terms, usually it is not a big stretch to settle on these two words. If you have to suggest using these two words as a place for everyone to start. If possible give them a chance to decide if they all mean the same thing by these two terms. Sometimes students will be shy about questioning things. One way to bring out some of the questions is to ask them to write a short note (possibly a journal entry if you are having them keep journals) about how they feel about these two words as a starting point and any questions they might have about the use of these two words. In the large class settings such short writings at the end of a class period helps you know more about what people are thinking and can be used as indications of who is in attendance.

ACTIVITY F1.3: *WHAT SHOULD THE FORCES BE LIKE ON AN OBJECT SO THAT THE OBJECT MAINTAINS A CONSTANT VELOCITY?*

WHAT DO YOU THINK?

In order to examine your own ideas on this subject, consider a cart which is pushed along a horizontal table at a CONSTANT VELOCITY. In the diagram at the top of page F1.3-4 is a series of images of a cart at equal time intervals as it moves along a flat, horizontal table under constant velocity.

1. **On each image sketch the forces acting on the cart at the time represented by that image. Use arrows to represent the forces as in the figure just below.**



   If a force is bigger (stronger) than another make its arrow longer. If a force gets larger as time goes on make its arrow longer in successive images. If a force gets smaller as time goes on make its arrow shorter in successive images.

2. **Once you have sketched the forces. Label them with a descriptive word such as: "push force", "friction force", etc. You can do this by using a letter to label each force and then make a key below the diagram to indicate what each letter represents.**

3. **When you have finished, look at your diagram and check to make sure that your drawing represents the forces and how you think they must behave to result in a constant velocity.**

4. **Under your drawing, write in words the conditions that you think the forces on the cart must satisfy in order that the cart move at a constant velocity.**

5. **Make sure you fill in the identifying information at the top of this sheet (page F1.3-4).**

6. **Next consider what the graphs of the motion of a cart with constant velocity moving away from the detector would look like. Do not include the "start up". Just imagine that the cart has already achieved the constant velocity before the graphs start. Sketch what you think they should look like on the Position-time, Velocity-time, and Acceleration-time axes on page F1.3-5. For now it is the shape of the graphs we are worried about. Do not worry about the numbers on the vertical axes.**

7. **Now imagine a new kind of graph, a Force-time graph. In this graph at the bottom of page F1.3-5 plot how you think the size of the force that is primarily responsible for the constant velocity must change in order to maintain the constant velocity. Do not include the "start up". Just imagine that the cart has already achieved the constant velocity before the graphs start. For now assume that positive (+) represents a force exerted in the direction away from the motion detector and negative (–) represents a force exerted in the direction toward the motion detector.**

8. **Finally make sure you fill in the identifying information at the top of this sheet of graphs (page F1.3-5).**

We put a header on both F1.3-4 and F1.3-5 which has blanks for name, lab section, date, partners, etc. so that we can collect them. Usually these are duplicated by us after the students hand them in so that what they say can be studied at some length, but the originals can be returned to them so that their own record of their ideas can be complete.

It would be best to demonstrate the motion. It suffices to move a cart along a table at a more or less constant velocity with your hand. Self-propelled objects might introduce unnecessary complications at this point.

They will ask some about the force-time graph. Suggest that they imagine a graph that looks like the motion graphs. They represent the value and direction of something which "goes on" in time. The positive is to represent force acting away from the detector.

Generally most of the students focus on "the force that causes the motion," the pull or push force away from the detector. This is indicative of how they are thinking of the forces. The only one that counts is the one that "overcomes" all others. If someone is worried about representing other forces in the graph, tell them that at this point we'd like their ideas represented how they see fit.

WHAT DOES YOUR GROUP THINK?

Share your work with your group. Listen as they share with you. Make careful notes below about any differences between your original ideas and theirs. If you decide to change your mind about any of the issues involved, DO NOT ERASE your original notations and drawings. Make careful notes about what you have changed your mind to and what made you change your mind. Use the back of the previous page if you need more space.

There will be class discussion on this activity. Make sure you record the consensus ideas about the forces required to maintain a constant velocity which will be decided as a result of that discussion.

Again, it is very important for you to collect and study what the students are saying. It is extremely important for you to understand what they are apparently thinking about force in relationship to motion. This can help you with the task of generating questions and experiences for the students to consider as they wrestle with their ideas and the fit of their ideas to the phenomena.

Together with the results of Activity F1.4, you should also, again, categorize the responses of this activity and give an accounting of how many said what so that the class can see what the "majority" view is here. As we have indicated in previous sections of this manual. It is frequent that 70 - 80% will be "saying" essentially the same thing.

Remember this activity and the next are part of an extended elicitation of ideas which is followed in the next investigation with "Making observations" and "Making sense" steps. The point in Activities F1.3 & F 1.4 is to elicit the pre-instruction ideas, not to guess the "right" answers or argue our way to some "right" answers.

(Motion detector is to the left. The cart is moving away from the detector.)

Constant Velocity →

You can put a header at the top of this page to provide space for the student filling out the sheet to identify him or herself.

The pictures of the cart are intended to be a kind of strobe (multiple exposure) photograph of the cart at equal time intervals.

You want the students to focus not on starting up but maintaining constant velocity. Tell them that in the first picture to the left the cart is already at that constant velocity.

As they are drawing the diagrams, remind them that the length of the arrows indicates how strong the force is and the direction indicates the direction the force is acting. If two forces are the same strength then their arrows should be the same lengths. If not, then the arrows should have different lengths according to which is stronger and which is weaker. This will be important in all three of these activities.

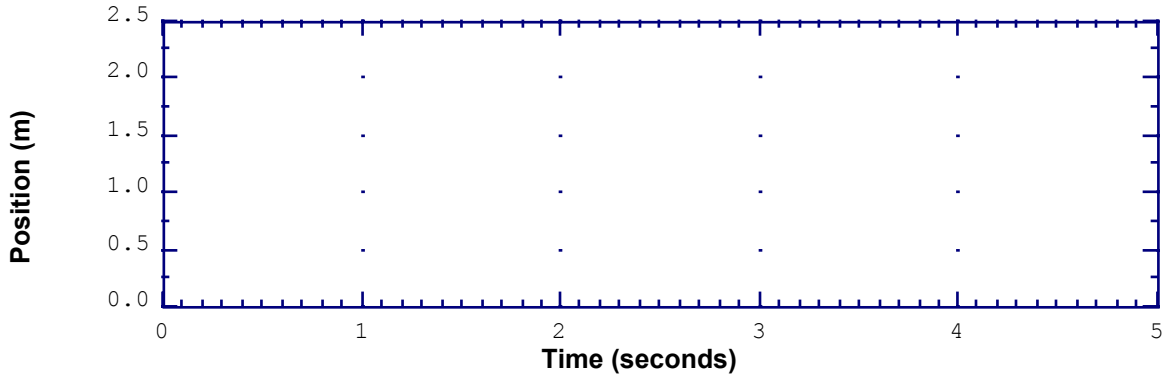
Make a list of the forces involved in the space below.

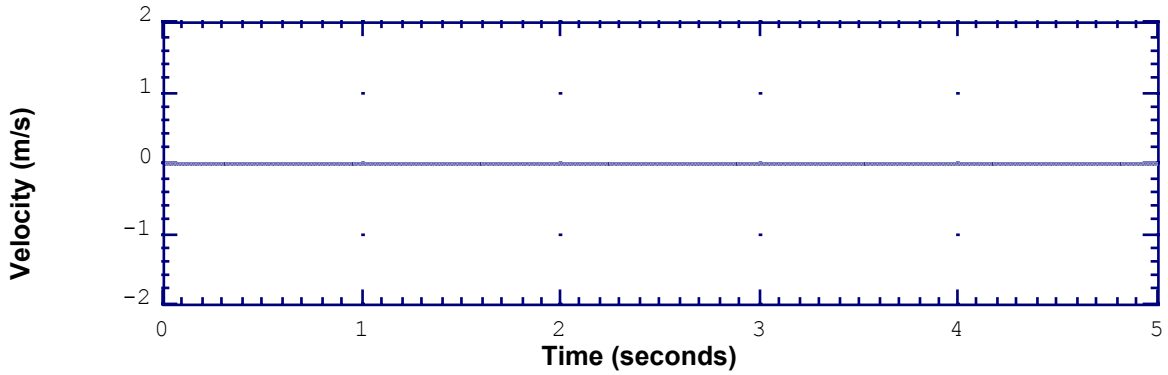
Again it is important to get them to clearly identify the forces they are representing in the diagram as arrows.

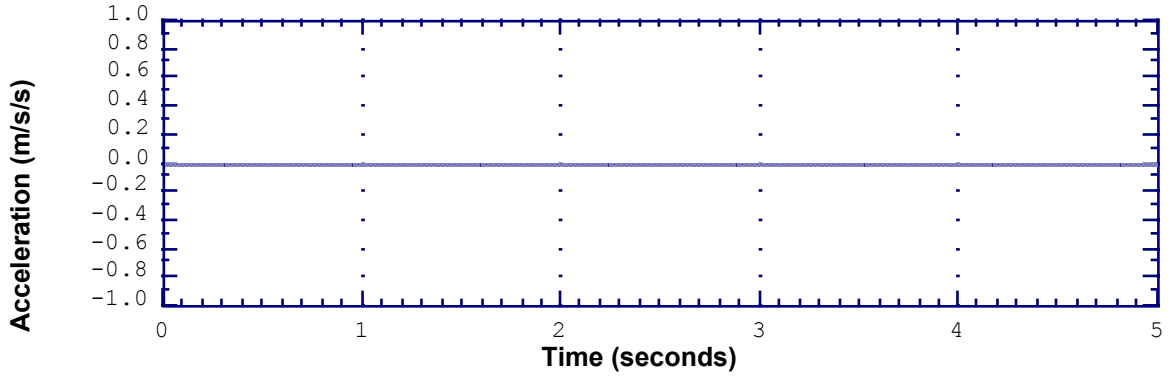
Summarize in words what you are trying to show in the diagram about what the forces must be like in order to maintain a constant velocity. Remember we are not worried in this activity about how we get to that constant velocity only how it is maintained once the velocity is achieved.

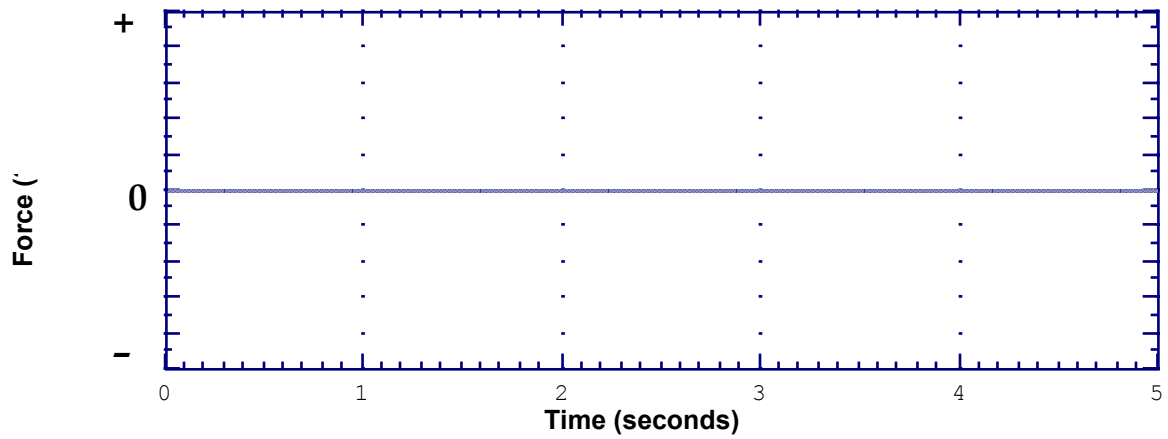
When you have the appearance of a match between what is depicted in the diagrams above and what is said in this space, you have some confidence that you know something about what the student is thinking. It is important to get them to pay careful attention to both of these parts on this sheet.

CONSTANT VELOCITY (assume the cart is moving away from the detector)







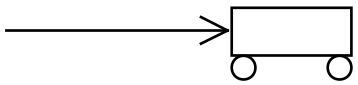


ACTIVITY F1.4: *WHAT SHOULD THE FORCES BE LIKE ON A OBJECT SO THAT THE OBJECT MAINTAINS A CONSTANT ACCELERATION?*

WHAT DO YOU THINK?

In order to examine your own ideas on this subject, consider a cart which is pushed along a horizontal table at a CONSTANT ACCELERATION (in this case constant speeding up moving to the right.) In the diagram at the top of page F1.4-4 is a series of images of a cart at equal time intervals as it moves along a flat, horizontal table under constant acceleration.

1. **On each image sketch the forces acting on the cart at the time represented by that image. Use arrows to represent the forces as in the figure just below.**



   In these diagrams please imagine that the constant speeding up is already underway in the first picture. In other words, for the first image of the cart on the left, the cart is already moving with a small velocity.

   If a force is bigger (stronger) than another make its arrow longer. If a force gets larger as time goes on make its arrow longer in successive images. If a force gets smaller as time goes on make its arrow shorter in successive images.

2. **Once you have sketched the forces. Label them with a descriptive word such as: "push force", "friction force", etc. You can do this by using a letter to label each force and then make a key below the diagram to indicate what each letter represents.**
3. **When you have finished, look at your diagram and check to make sure that that your drawing represents the forces and how you think they must behave to result in a constant acceleration.**
4. **Under your drawing, write in words the conditions that you think the forces on the cart must satisfy in order that the cart move with a constant acceleration.**
5. **Make sure you fill in the identifying information at the top of this sheet (page F1.4-4).**
6. **Next consider what the graphs of the motion of a cart constantly speeding up, say from rest, moving away from the detector would look like. Sketch what you think this motion should look like on the Position-time, Velocity-time, and Acceleration-time axes on page F1.4-5. For now it is the shape of the graphs we are worried about. Do not worry about the numbers on the vertical axes.**
7. **Now imagine a new kind of graph, a Force-time graph. In this graph at the bottom of page F1.4-5 plot how you think the size of the force that is primarily responsible for the constant acceleration must change in order to maintain the constant acceleration. For now assume that positive (+) represents a force exerted in the direction away from the motion detector and negative (–) represents a force exerted in the direction toward the motion detector.**

8. **Finally make sure you fill in the identifying information at the top of this sheet of graphs (page F1.4-5).**

Essentially the same comments apply here as did in the previous activity. Headers on the last two pages which have spaces for their names, date, etc. can be of great assistance for keeping track of changes they might make during the semester.

It would be good to demonstrate the motion that they are thinking about. It would be best to merely push a cart along a horizontal surface such that the speed increases continually. Having fancy apparatus to produce this motion might be distracting, although the thought of a fan cart is appealing here.

WHAT DOES YOUR GROUP THINK?

Share your work with your group. Listen as they share with you. Make careful notes below about any differences between your original ideas and theirs. If you decide to change your mind about any of the issues involved, DO NOT ERASE your original notations and drawings. Make careful notes about what you have changed your mind to and what made you change your mind. Use the back of the previous page if you need more space.

There will be class discussion on this activity. Make sure you record the consensus ideas about the forces required to maintain a constant acceleration which will be decided as a result of that discussion.

Again, it is very important for you to collect and study what the students are saying. It is extremely important for you to understand what they are apparently thinking about force in relationship to motion. This can help you with the task of generating questions and experiences for the students to consider as they wrestle with their ideas and the fit of their ideas to the phenomena.

The features of this view in the diagrams, statements and graphs from Activities F1.3 & F1.4 can be the depiction of this initial class view. This view is described in these materials in Section II.A. The Students' Prior Beliefs as Described in the Research on Student Conceptions. Point out that this is the view we will be testing in particular when we begin to make observations.

Again, now is not the time to get people to argue their way to the "right" answer, but encouraging some discussion of the summary of the results can help clarify the majority view for some. Some evidence of people holding a view similar to the view the rest of the class will develop is often there, but only a very small percentage of the students appear to hold the view.

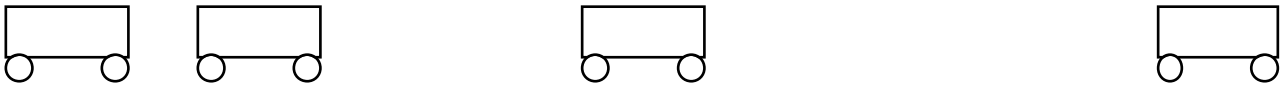
Handing out a summary of the graphs, diagrams and statements which represent the majority view clearly labeled as the initial class view can be quite useful at this point.

There is a question or issue that you could engage the students in at this point:

Ask them: "If one were to try to maintain a constant speed twice as great as the one they were thinking of in Activity F1.3, what, if anything, would have to change about the forces?" You would expect the majority not to have too much trouble coming up with the notion that the force "that causes the motion" would have to double. This force would be the one in that direction if no other forces are considered. On the other hand, it might be the difference between forces would have to be doubled for some students. Either way the underlying idea is the same. For a bigger velocity you need a bigger force. Ask them if this is consistent with the majority view.

Motion detector is to the left. The cart is moving away from the detector.

Constant Acceleration



Here the strobe photo representation illustrates a car speeding up to the right. You should ask them what they think the increasing spaces represent. This can aid some of the students in gathering their thoughts about what and how to draw their ideas here.

Make a list of the forces involved in the space below.

As usual this step is very important for interpreting what they have drawn.

Summarize in words what you are trying to show in the diagram about what the forces must be like in order to maintain a constant acceleration. Remember we are not worried in this activity about how we get to that constant acceleration only how it is maintained once the constant acceleration has begun.

Again, it is important to get them to write this thoughtfully and then to look back at the diagram to check to see whether they are "saying" the same thing.

CONSTANT ACCELERATION (assume the cart is moving away from the detector)