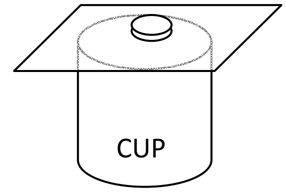
Name_____________________________________
Period________

AP Phys 1 Discovery Lesson – Causes of Motion

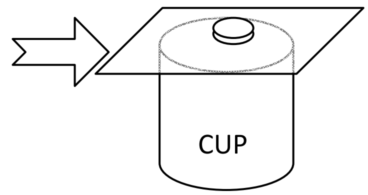
1.0 Experiment: Objects at Rest

(a) Set a card atop a cup as shown. Place a coin on top of the card:



PREDICT: What will happen to the coin when the card is flicked aside? Explain.

(b) Now test your prediction by giving the card a quick flick to the side, knocking the card completely off the cup. (You may have to hold the cup to make sure it doesn't move away with the card.) Describe your observations:

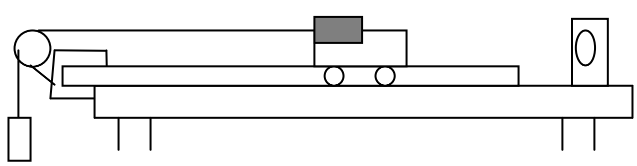


*The natural tendency for objects that are at rest (such as coins) to stay at rest is called *inertia*. Masses always resist changes to their motion.

1.1 Experiment: Slowing Down While Moving Away and Speeding Up While Moving Toward The Origin

(a) How do you think a constant push or pull will move an object? **Predict** graphs that would represent this motion with a *dashed line* in the graphs in Part (c) below.

(b) Set up the cart, meter stick, pulley, hanging mass, force probe, and motion detector as described/shown in class (below). You will examine the acceleration and applied force. Give your cart a push away from the pulley and make the measurements of motion and force.



(c) Use your data to create velocity and acceleration graphs of the motion. Sketch them below:

PREDICTION:	– – – – – – – – –
ACTUAL:	———————

(d) What (attached to the cart) pulls the cart after you let the system go?

Which direction does it pull?

The pulley, in this case, only changes the direction of the force, so it changes a downward force of gravity into a sideways force of tension.

(e) Use this formula to calculate the force of gravity exerted on the hanging mass (its *weight*) and write it here:

Weight of hanging mass = F_{grav} = (mass in kg)x(9.8 m/s/s) = _______________

(f) How does the force applied by the hanging masses change as time goes on? Does it change at all?

(g) Re-sketch your velocity, acceleration, and force graphs of the motion below. On your graphs label the regions corresponding to: (A) motion away from the origin, (B) stopped at the end of the motion, and (C) motion toward the origin.

(h) During the cart's motion <u>away from the origin</u>, did the signs of the velocity, force, and acceleration agree with your predictions? If not, try to explain the signs.

(i) Did the velocity and acceleration during this part of the motion both have the same sign?

(j) Did the force and acceleration have the same sign?

What does that tell you about the direction of the force in relation to the direction of the acceleration? Explain.

(k) After you released the cart, was the force applied by the hanging mass constant, increasing, or decreasing?

Explain why this kind of force is necessary to cause the observed motion of the cart.

(l) Write down a simple rule in words which describes the relationship between the direction of the applied force and the direction of the acceleration for any motion of the cart.

(m) Is the direction of the velocity always the same as the direction of the force?

Is the direction of the acceleration always the same as the direction of the force?

In terms of its magnitude and direction, what is the effect of a force on the motion of an object?

(n) Describe the force and acceleration at the moment when the cart reverses direction.

(o) Based on your knowledge of acceleration and force, explain why the force and acceleration have the sign they have at this moment.

1.2 Demonstration: Opposing Forces

(a) Fans mounted on carts can be used to exert forces in different directions. Two carts will be linked together, each having fans acting in opposite directions. Demonstrations will be performed showing the motion of the carts when one fan is on by itself, and when the other fan is on by itself. What do you observe about the motion of the cart system when each fan is on separately?

(b) Suppose that each fan pushed on the carts with the same magnitude (size) force. What do you predict would be the combined force acting on the carts when both fans are on?

(c) What do you predict would be the acceleration of the cart?

(d) Given your prediction for the acceleration, describe the motion of the carts:
(a) if they are initially at rest when the fans are turned on:

(b) if they are given a slight push after the fans are turned on.

(e) A demonstration will now be performed showing the motion of the carts when the two fans are on at the same time. Describe the motion of the carts. Were your predictions correct?

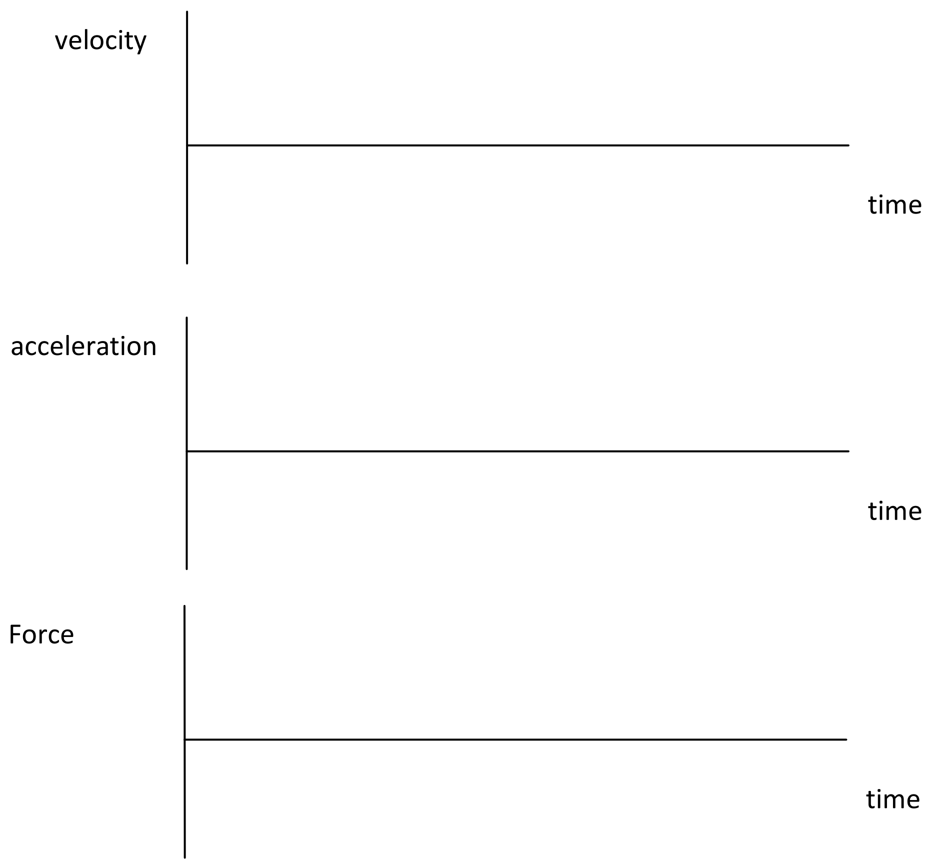
*Forces acting in opposite directions tend to cancel. The net (combined) force is equal to the difference in the strengths (magnitudes) of the pulls and acts in the direction of the larger of the two forces. The acceleration of any object is always the result of the net force acting on that object. The demonstration you just observed shows that the velocity of a cart does not change when the net force is zero.

1.3 Experiment: Once a Pull, Always a Pull?

You have seen that to make the carts move with a constant velocity you need to apply a force to get them moving, but no applied force (or a very small force to balance the frictional force) was needed to keep them moving at a constant velocity.

(a) Suppose that you give the cart a little pull with a force probe to start it moving and then release it. Sketch your prediction of the velocity vs. time and acceleration vs. time graphs for the motion of the cart and the force vs. time graph of the applied force. Indicate on your sketches the moment when your pulling force acting on the cart is discontinued.

PREDICTION: _ _ _ _ _ _ _ _



(b) Test your predictions. The cart's friction should be as small as possible. Give the cart a short pull in the direction away from your zero position and then let go.

(c) Use the motion detector and force probe to obtain graphs of velocity, acceleration, and force vs. time. Sketch the graphs for the actual motion. <u>Indicate with an arrow the time when the pull stopped</u>.

ACTUAL: ————————

(d) Do the velocity and acceleration graphs agree with your predictions? If not, how do they differ?

(e) What happened to the force of the pull after you released the cart? Explain.

(f) Do your results agree with what you observed in a previous experiment about the applied force needed to keep an object moving at a constant velocity? Explain.

1.4 Experiment: Acceleration and Mass

You can easily change the mass of the cart by placing masses on it, and you can apply forces to the cart using a spring scale or hanging masses as before. By measuring the acceleration of different mass-cart systems you can find a mathematical relationship between the acceleration for the cart and its mass. Remember that all but two variables (the Independent Variable and the Dependent Variable) must be kept constant in order to determine how the two variables are related. That is what we will be doing here:

(a) To compare mass and acceleration, what must be held constant?

(b) For this test, **the _________________________ is the independent variable (IV),** because we make changes to it in order to determine **the _______________________________, which is the dependent variable (DV)** since it depends on what we do with the IV.

(c) Try some informal tests to determine how acceleration and mass are related.
Describe your informal procedure here (What did you try?):

(d) How do you think acceleration and mass are related mathematically? (make an approximate prediction)

(e) What evidence supports the prediction you made?

1.5 Experiment: Acceleration and Force

This time we will keep something else constant but change the force and measure the accelerations. You can easily change the force exerted on the cart by moving masses from the cart to the hanging mass. This keeps the total mass constant while changing the applied force. By measuring the acceleration of different mass-cart systems you can find a mathematical relationship between the force exerted on a cart and its acceleration, with the mass kept constant. That is what we intend to do here:

(a) To compare acceleration and force, what must be held constant?

(b) For this test, **the _________________________ is the independent variable (IV),** because we make changes to it in order to determine **the _______________________________, which is the dependent variable (DV)** since it depends on what we do with the IV.

(c) Try some informal tests to determine how acceleration and force are related.
Describe your informal procedure here (What did you try?):

(d) How do you think acceleration and force are related mathematically? (make an approximate prediction)

(e) What evidence supports the prediction you made?

1.6 Experiment: Interacting Pairs of Forces

(a) Team up with a partner to hook two spring scales together to perform the next experiment:
Use your spring scale or force probe to pull gently on your partner's spring scale or force probe.
What force did your spring scale exert on your partner's? Write your answer in the blank below:

Force of my spring scale on my partner's = _______________ Newtons

What force did your partner's exert on yours? Write your answer in the blank below:

Force of my partner's spring scale on mine = _______________ Newtons

(b) This time, **have your partner gently pull on *your* spring scale or force probe** and observe the force this time. What force did your spring scale exert on your partner's? Write your answer in the blank below:

Force of my spring scale on my partner's = _______________ Newtons

What force did your partner's exert on yours? Write your answer in the blank below:

Force of my partner's spring scale on mine = _______________ Newtons

(c) Now **both pull gently on each other's spring scales or force probes**. What were both forces this time? Fill in the blanks below:
Force of my spring scale on my partner's = _______________ Newtons

Force of my partner's spring scale on mine = _______________ Newtons

(d) How are the two forces related in each case? Describe the resulting forces you exert on each other in terms of size and direction. (Who pulls harder? Are they the same or opposite directions?)

(e) Try stretching a rubber band between your thumb and forefinger.
Can you stretch it out without using your thumb to pull back on it? Explain.

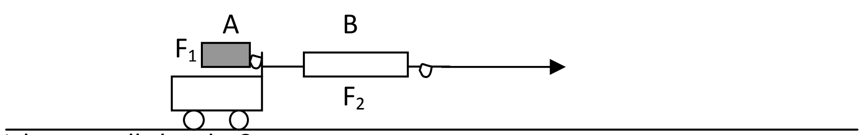
(f) Suppose object A pushes (or pulls) on object B. Must object B push (or pull) back on object A?

What can you conclude about the forces each object exerts on the other? Which one, if any, is larger?

(g) Is it possible to push without being pushed? Try to describe a situation where a force is exerted all by itself without another force pushing or pulling back in response, if you can. (Can a force exist in isolation?)

1.7 Experiment: Dynamic Pull

(a) Attach a force probe to a lab cart with a kilogram of mass loaded onto it. Use the spring scale to pull on the force probe attached to the cart and get the cart moving. Observe both forces (from force probe A and spring scale B) as you do this.



Which one pulls harder?

(b) How hard did the spring scale pull on the cart in this case?

(c) What does this pull do to the motion of the cart?

(d) What direction does the cart pull (as measured by the force probe attached to it)?

(e) How hard did the cart pull back on the spring scale (as measured by the force probe attached)?

(f) What effect does that pull (the cart's pull on the spring scale) have on the motion of the cart itself?

What's motion might it influence? (What does this force have an effect on?)

(g) There are forces from both cart and spring scale, acting in both directions. Explain, then, how the cart gets moving when you give it a pull. (Note: it's not because one force pulls harder!)

*Newton's Third Law can be stated as follows: "If one object exerts a force on a second object, then the second object exerts a force back on the first object which is equal in magnitude and opposite in direction to that exerted on it by the first object."

1.8 Demonstrations:

Newton's First Law is also called the Law of Inertia, and there is a slightly different way to express it than to say that the acceleration of an object is zero (velocity is constant) when the net force acting on the object is zero. For instance, there are two ways in which the velocity can be constant: the object is not moving (e.g., its velocity is constant at zero) or it is moving (e.g., its velocity is constant and not zero). The Law of Inertia can be stated as follows: An object at rest will remain at rest if no net force acts on it. An object in motion will remain in motion with constant velocity if no net force acts on it. For the velocity vector to be constant both its magnitude and its direction must be constant.

For each of the demonstrations briefly explain how the Law of Inertia applies.

1. Air track beneath the glider demo

2. Glider moving on frictionless air track demo

3. Cloth under dishes demo

4. Inertia Ball Demo

5. Pan and eggs demo