Name: ______________________________

Balanced Force Model

A force is ______________________________

Common Types of Forces

Type of Force	Direction	When is it present?	Symbol	Equation

the $\left\{ \qquad \right\} \left\{ \qquad \qquad \right\}$ force the $\left\{ \qquad \right\}$ exerts on the $\left\{ \qquad \right\}$

Newton's 1st Law:

Newton's 3rd Law:

Notes from Force Discussion / FBDs & System Schemas

Worksheet 1: Forces and Motion

Take care in reading every word in these questions. Make sure you know exactly when we are taking our snapshots in each part of the problem. When making a whiteboard, arrange your work so that all parts of one question can fit on one board (neatly).

1. A cardboard box with a rubber bottom contains a cinder block at rest on a rough, concrete, horizontal floor.
   a. Draw a system schema for this situation.

   b. Since the shape of the [box + cinder block]—your "system"—is unimportant, shrink it to a point (this is where we are treating the box like a *particle*) and then show and clearly label each force on the system. **Make it obvious from your diagram which forces you intend to be equal and which you intend to be greater than others.**

   c. A person shoves the box horizontally so that it begins to move. Your answers to this part should concern the time *while the person is* ***still touching the box*** *and shoving.* (i) Draw a velocity-vs-time graph for the box, clearly marking the time when the box is at rest and the time when the person is still touching the box and shoving it. This should be qualitatively accurate (no numbers, but correct shape). (ii) Also draw a system schema for that same time period. (iii) Also draw a free body diagram for the box during that same time period. Label!

   d. The shove ends when *the box leaves contact with the person's hands.* (i) Draw a qualitatively correct velocity-vs-time graph for the box, clearly marking the time when the box is at rest, the time when the person is still touching the box and shoving it, and the time after the box loses contact with the person's hands. Make it obvious which lines are horizontal, which have greater slopes, smaller slopes, or negative slopes. (ii) Also draw a system schema for the box when it leaves contact with the person's hands. (iii) Also draw an FBD.

2. The rubber is now removed from the bottom of the box so that the cardboard surface rests directly on the same floor. It is then given a horizontal shove by a person. In the space below, modify your velocity vs. time graph as well as your system schemas and FBDs from problem 1 to accurately describe this new situation. Your diagrams do not have to be quantitatively accurate, but make it obvious which forces you intend to be equal and which you intend to be greater or less than others, so that comparisons can be made among forces in this problem as well as between forces in this problem and in problem 1. Make any differences in your graphs and diagrams *obvious*.

   a. Draw a velocity-vs-time graph for the box, clearly marking the three time periods.

   b. Draw a system schema and an FBD for this situation *while the box is at rest on the horizontal floor.*

   c. Draw a system schema and an FBD for this situation *while the person is still touching the box and shoving.*

   d. Draw a system schema and an FBD for this situation *during the time after the box loses contact with the person's hands.*

3. The box is now placed on a very smooth and polished floor. In the space below, modify your velocity vs. time graph as well as your system schemas and FBDs from problem 2 to accurately describe this new situation. Your diagrams do not have to be quantitatively accurate, but make it obvious which forces you intend to be equal and which you intend to be greater or less than others, so that comparisons can be made among forces in this problem as well as between forces in this problem and problems 1 and 2. Make any difference in your diagrams *obvious*.

   a. Draw a velocity-vs-time graph for the box, clearly marking the three time periods.

   b. Draw a system schema and an FBD for this situation *while the box is at rest on the horizontal floor.*

   c. Draw a system schema and an FBD for this situation *while the person is still touching the box and shoving.*

   d. Draw a system schema and an FBD for this situation *during the time after the box loses contact with the person's hands.*

4. Suppose that we could somehow succeed in making the floor <u>completely</u> frictionless. Again, make new diagrams/graphs to represent this new variation in the situation. Make any differences *obvious.*

   a. Draw a velocity-vs-time graph for the box, clearly marking the three time periods.

   b. Draw a system schema and an FBD for this situation *while the box is at rest on the horizontal floor.*

   c. Draw a system schema and an FBD for this situation *while the person is still touching the box and shoving.*

   d. Draw a system schema and an FBD for this situation *during the time after the box loses contact with the person's hands.*

5. Return to the case of the cardboard box resting on the concrete floor, with friction. A person pushes it hard enough to start it into motion and then continues pushing so that it maintains a constant velocity. In the space below, modify your velocity vs. time graph as well as your system schemas and FBDs from problem 2 to accurately describe this new situation.

   a. Draw a velocity-vs-time graph for the box, clearly marking the three time periods (at rest, velocity is changing, moving with a constant velocity).

   b. Draw a system schema and an FBD for this situation *while the box is at rest on the horizontal floor.*

   c. Draw a system schema and an FBD for this situation *while the box is changing velocity.*

   d. Draw a system schema and an FBD for this situation *while the box moves with a constant velocity.*

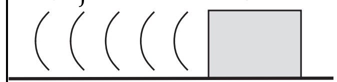
   e. After pushing the box with a constant velocity for a while, *you reduce your force to half the value needed to maintain a constant velocity.* Make a new (continued) velocity-vs-time graph to show what happens to the box while you continue to push with this force.

Worksheet 2: FBDs

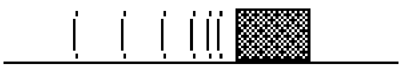
6. In each of the following situations, represent the object with a labelled free body diagram. Label each force with a meaningful symbol (ex: F_g) AND with the object exerting the force (ex: F_g(earth)).

1. Object lies motionless.

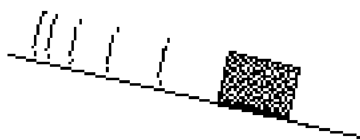
2. Object slides at constant speed without friction.



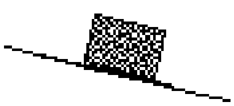
3. Object slows due to kinetic friction.



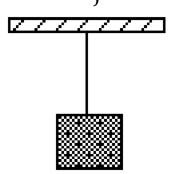
4. Object slides without friction.



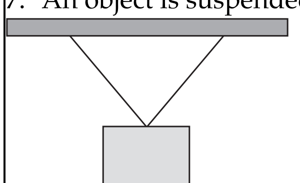
5. Static friction prevents sliding.



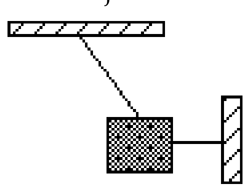
6. An object is suspended from the ceiling.



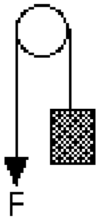
7. An object is suspended from the ceiling.



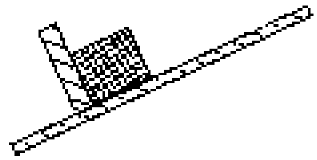
8. The object is motionless.



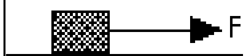
9. The object is pulled upward at constant speed.



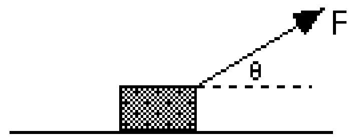
10. The object is motionless.



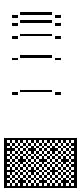
11. The object is pulled by a force parallel to the surface.



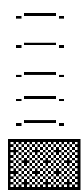
12. The object is pulled by a force at an angle to the surface.



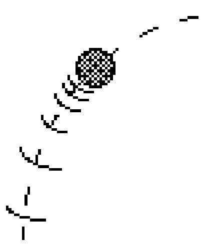
13. The object is falling (no air resistance).



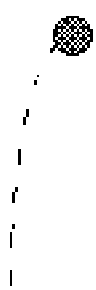
14. The object is falling at constant (terminal) velocity.



15. The ball is rising in a parabolic trajectory.



16. The ball is at the top of a parabolic trajectory.



Empirical Force Laws Experiments (F_g)

Sketch and label the experiment setup:

What could we measure? How could we measure it?

Objective:

Post-Lab Notes

Empirical Force Laws Experiments (F_s)

Sketch and label the experiment setup:

What could we measure? How could we measure it?

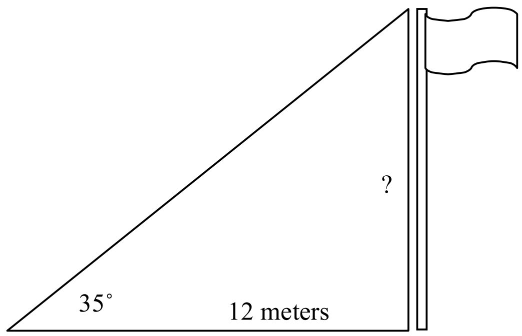
Objective:

Post-Lab Notes

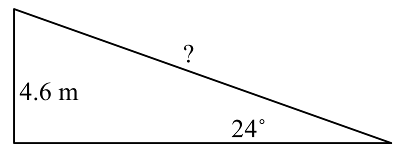
Worksheet 3: Vector Components

7. Find the magnitude of the side or the angle indicated with a “?” in each of the following triangles. Note: there are a LOT of practice problems here. Students who have already done similar problems in a math class might only need to do a few of these. You can stop when you feel comfortable dealing with components. The rest will always be here for more practice if you need it in the future.

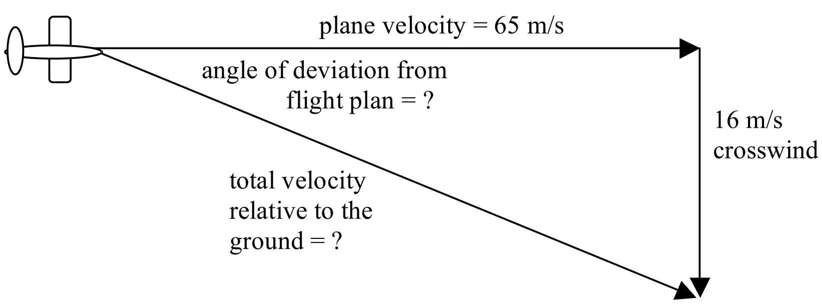
1.



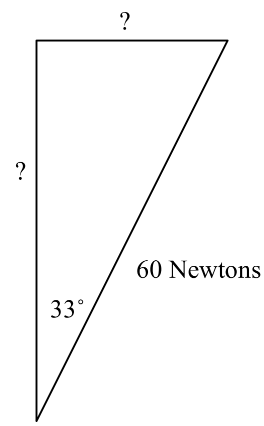
2.



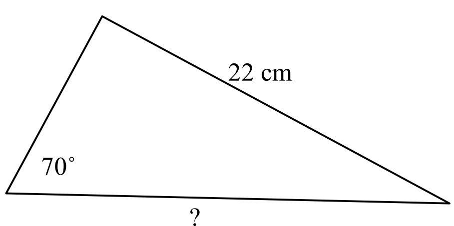
3.



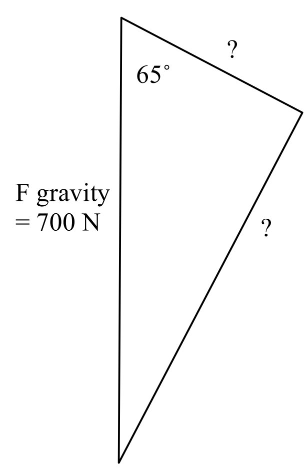
4.



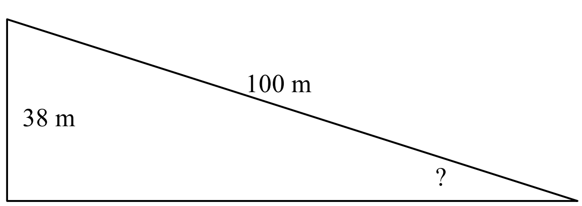
5.



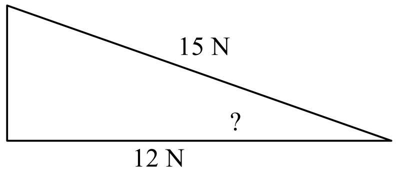
6.



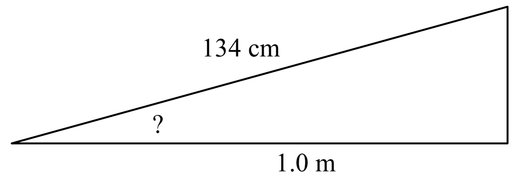
7.



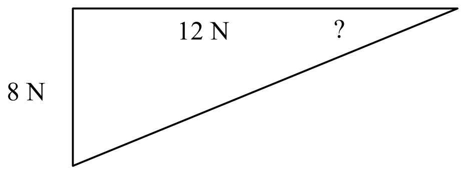
8.



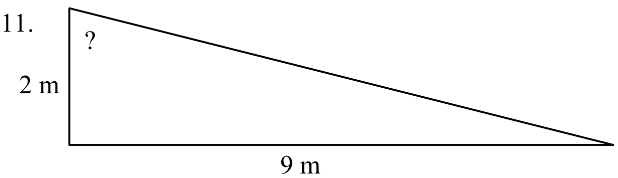
9.



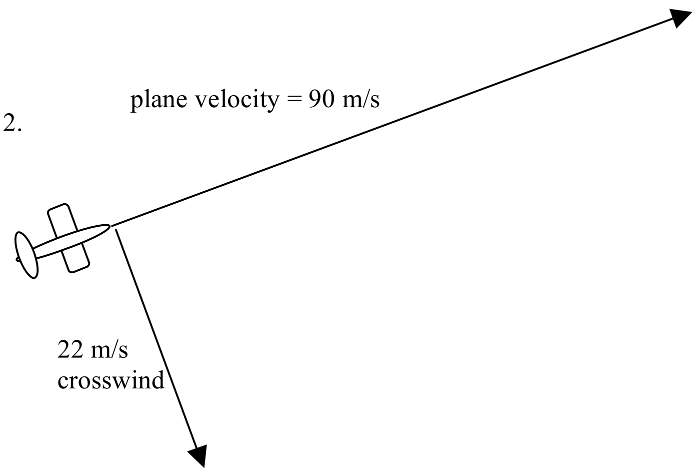
10.



11.



12.

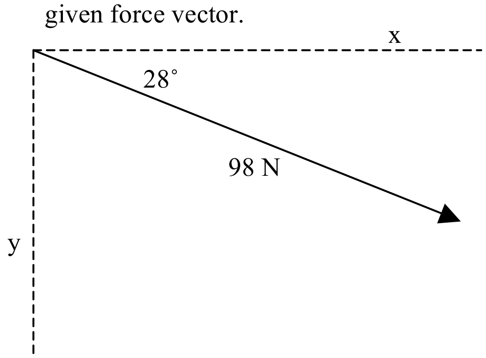


total velocity relative to the ground = ?

angle of deviation from flight plan = ?

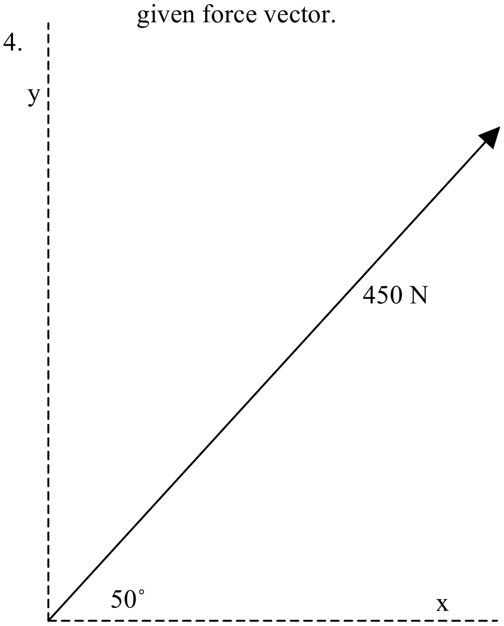
13.

Find the x and y components of the given force vector.



14.

Find the x and y components of the given force vector.



Worksheet 4: Interaction Problem Solving

8. The player in the photo exerts a 100 N horizontal force on a 25 kg blocking sled, pushing it across the grass with a constant speed of 2.0 m/s.
   a. Fill out the chart below, determining all of the forces on the blocking sled.

	System Schema
Motion Map	Qualitatively correct sketch of FBD

REMINDERS: ◈ *Does your system schema have a system boundary?* ◈ *In your FBD, did you represent the system with a particle?* ◈ *Is it obvious when you intend two forces to be equal or when you intend one force to be greater than another?* ◈ *Did you label your forces with the object exerting the force in parentheses?*

   b. On the graph below, draw an FBD to a precise scale. Make sure you write down your scale!

c. How would the situation change if the player pushed with more than 100 N, while the frictional force between the grass and the sled remained the same? Illustrate your answer with another FBD and motion map.

d. Describe, in terms of the amount of force he would have to apply, what the player would have to do to make the sled move with a constant velocity of 3.0 m/s. Assume that the frictional force between the grass and the sled remains the same under all circumstances. Illustrate your answer with diagrams and/or graphs as appropriate.

e. If he pushes the sled as originally described with a velocity of 2.0 m/s, how far will it slide in 7.5 seconds? Draw at least three diagrams/graphs to illustrate this situation, then solve this problem *using at least two different methods* (and getting the same answers).

f. With the sled moving at a constant velocity of 2.0 m/s, the person reduces his force to 75 N. Describe what happens to the sled. Illustrate your answer with another FBD and motion map.

9. A man pushes a 2.0 kg broom at a constant speed. The broom handle makes a 50° angle with the floor. He pushes the broom with a 5.0 N force directed parallel to the handle.
   a. Fill out the chart below, determining all of the forces on the broom.

	<u>(Qualitative) Sketch of FBD</u>
<u>System Schema</u>	<u>(Qualitative) Sketch of Vector Addition Diagram</u>

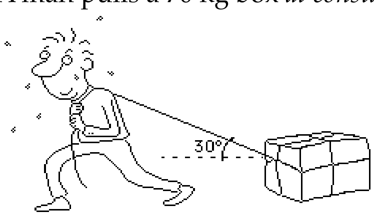
REMINDERS: ◈ *Does your system schema have a system boundary?* ◈ *In your FBD, did you represent the system with a particle?* ◈ *Is it obvious when you intend two forces to be equal or when you intend one force to be greater than another?* ◈ *Did you label your forces with the object exerting the force in parentheses?* ◈ *Did you add vectors tail to head?*

   b. On the graph below, draw the vector addition diagram to a precise scale. Be sure to write down your scale! Be sure to use a ruler and a protractor!

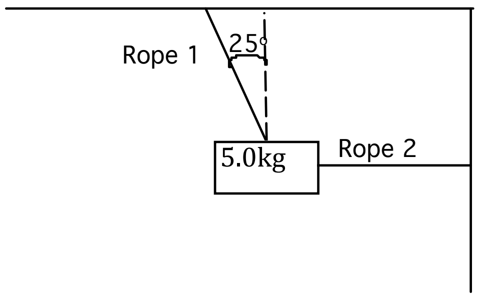
c. Is the contact normal force that the floor exerts on the broom (greater than, less than, or equal to) the gravitational force that the earth exerts on the broom? Explain!

d. How would your answers change if the person exerted the same force of 5.0 N along the handle, but the handle were closer to parallel to the floor? Illustrate your answer with another vector addition diagram.

10. A man pulls a 70 kg box *at constant speed* across the floor. He applies a 250 N force at an angle of 30°.



11. The 5.0 kg box hangs from two ropes.
    a. Fill out the chart below, determining all of the forces on the box.

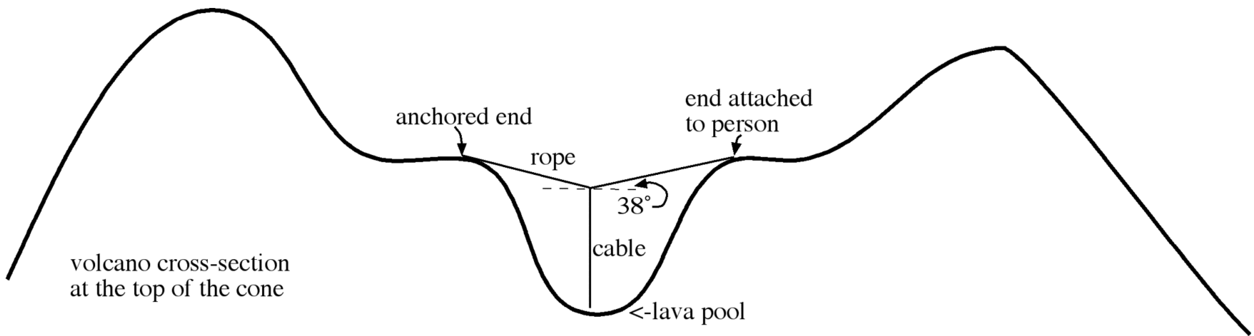
	<u>(Qualitative) Sketch of FBD</u>
<u>System Schema</u>	<u>(Qualitative) Sketch of Vector Addition Diagram</u>

REMINDERS: ◈ *Does your system schema have a system boundary?* ◈ *In your FBD, did you represent the system with a particle?* ◈ *Is it obvious when you intend two forces to be equal or when you intend one force to be greater than another?* ◈ *Did you label your forces with the object exerting the force in parentheses?* ◈ *Did you add vectors tail to head?*

b. On the graph below, draw the vector addition diagram to a precise scale. Be sure to write down your scale! Be sure to use a ruler and a protractor!

12. Volcanologists need a lava sample from an active lava pool below a plateau inside the volcano. After one end of a rope to is anchored to the rock, another scientist hikes around the plateau rim so that the rope, and an attached cable, hangs over the lava pool. The cable is dipped into the lava pool and then the lava that congeals on the cable is retrieved. (This was done at Nyiragongo in Africa.)

    When the cable with the lava sample has a weight of 125 N, how large is the tension in the rope? (Hint: make your force diagram for the junction between the cable and the rope, and don't worry about the fact that the rope has weight too.)



The actual apparatus has a pulley in the middle of the rope. The cable parallels one side of the rope, goes over the pulley and down to the lava pool. The reason for this is that simply tightening the rope can’t lift the lava sample out. Here's why: calculate how much tension would be needed in the rope to decrease the angle to 5°.

Activity: Broom Ball

For each of the situations, describe (using words, pictures, etc) how to accomplish each feat. Each situation refers to pushing a bowling ball on the floor with a broom.

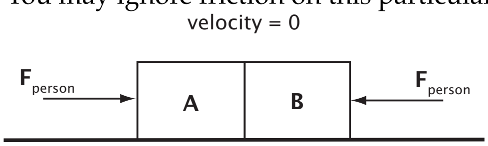
Speed up the bowling ball from rest.	Stop a moving bowling ball.
Keep a moving bowling ball moving at a constant velocity.	Move the ball from one line to the other and back as quickly as possible and without overshooting the lines. (WAIT for the whole class to do this together.)
With a moving bowling ball, make a sharp left turn. (Show your teacher how you do this before moving on.)	Travel at a constant speed along a curved line.
Move the ball around a circle as quickly as possible. (WAIT for the whole class to do this together.)	

Activity: Dueling Forces

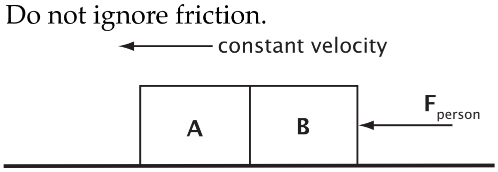
For each of the following situations:

1. Draw one system schema. In your system schema, draw the interaction between the two carts in colored pencil. (Keep everything else in regular pencil.)
2. Draw and label <u>two</u> FBDs (one for each cart). Draw the forces the carts exert on one another in colored pencil. (Again, keep everything else in regular pencil.) Be sure your FBDs look balanced or unbalanced as appropriate. Draw forces to approximate scale.
3. Finally, measure the colored pencil forces with the force sensors and correct your diagrams if necessary. Remember to zero your force sensors!
4. After completing the ones on this sheet, if you have time (or outside of class), you might be interested in trying additional variations and confirming your results.

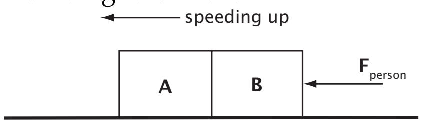
I. You may ignore friction on this particular situation.



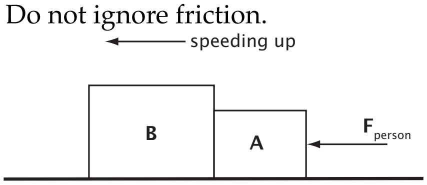
II. Do not ignore friction.



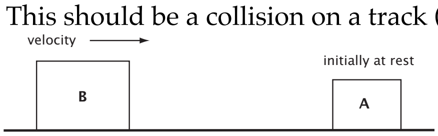
III. Do not ignore friction.



IV. Do not ignore friction.

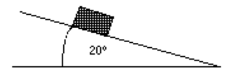


V. This should be a collision on a track (snapshot during the collision). You may ignore friction in this situation.



Worksheet 4: N3L in Action

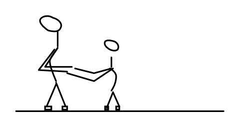
6. A block slides down a ramp at a constant speed. During that slide, the ramp sits at rest on a table. Draw one system schema for the situation, then draw an FBD for the block and an FBD for the ramp.



7. In frustration, Alec gets Henry to hold up his test and punches his fist completely through all of the sheets of paper. Which is greater: the force that Alec's fist exerted on the paper or the force that the paper exerted on Alec's fist? Explain.

8. Your friend's truck stalls out on a hill, so you get out to push. However, after a couple minutes you start to tire yourself out and the truck starts pushing you back down the hill. While the truck is pushing you back down the hill, which is greater: the force that you exert on the truck or the force that the truck exerts on you? Explain.

9. At the ice skating rink, Lydia (who has a mass of 50 kg) stands face to face with her brother, Marcus (who has a mass of 80 kg). They put their hands together and Lydia pushes Marcus backwards. Draw one system schema and two FBDs (one each for Lydia and Marcus) during the push. *You may assume that the ice is frictionless.*



BFPM Model Summary