1. Shown below is a speed-time graph for a cart moving in front of the motion sensor. For convenience it has been divided into four sections (A,B,C,D).

During each of the four separate periods shown on the graph (A, B, C, D), was an unbalanced force acting on the cart? YES or NO. If not, how can you tell from the graph? If yes, did the unbalanced force act in the same direction as the cart’s motion, or against it? Briefly explain how you can tell this from the graph.

A  The speed of the cart is increasing. For this to happen the forces must be unbalanced, with the strongest force in the same direction as the motion.

B  The speed of the cart is decreasing. For this to happen the forces must be unbalanced, with the strongest force in the opposite direction to the motion.

C  The speed of the cart is constant. For this to happen the forces acting on it must be balanced.

D  The speed of the cart is decreasing again. For this to happen the forces must be unbalanced, with the strongest force in the opposite direction to the motion.

2. Two students were discussing if they could tell whether a force (or an unbalanced combination of forces) was acting on an object just from observing its motion.
Which student do you agree with (if either), and why?

I agree with Luisa. She has an idea consistent with those we developed in class. The effect of a force (or an unbalanced combination of forces) acting on a moving object is to change its motion in some way, either making it speed up, slow down, or change direction. If the motion of an object is not changing in any way this means that no force (or a balanced combination of forces) is acting on it. So, just because an object is moving does not necessarily mean a force is acting on it.

Daryl's idea is not consistent with those we developed in class. He says that if no force acts an object will stop, but we saw that objects stop because a force does act on them (in a direction opposite to their motion).

3. Five identical crates are initially at rest, side-by-side. One is acted on by a single force of 45 N, as shown.

Which of the other crates, shown below, would move side-by-side with the crate described above? (Choose as many as you think appropriate.)
Briefly explain your choice(s).

Since they are identical, in order for the other crates to move side-by-side with the first one they will need to have a net force acting on them that has the same strength and direction as the single force acting on the first crate; namely 45 N to the right.

Both of crates b) and c) have this.
Crate b) has a total of 90 N to the right and 45 N to the left. Subtracting 45 N from 90 N gives a net force of 45 N to the right. 
Crate c) has 75 N to the right and 30 N to the left. Subtracting 30 N from 75 N gives a net force of 45 N to the right.

(The net force on crate a) is only 25 N to the right. The net force on crate d) is 45 N to the left.)

Connecting Unbalanced Forces and Acceleration

4. Block A, shown below, is moving to the right. At the moment shown, three different forces are acting on the block. The strengths and directions of the three forces are shown in the force diagram.

a) Will block A speed up, slow down, or move at constant speed? Briefly explain how you know.

Block A will slow down as it moves. This is because the forces acting on it are unbalanced, with the net force acting opposite the motion of the block.

b) Suppose there was another block (B) that was identical in size and mass to block A. At the same moment shown above, block B is alongside block A and is
moving at the same speed as block A. What single force should be applied to block B, so it continues to move side-by-side with block A? Draw this force (strength and direction) on the block below, and briefly explain how you know.

Since the blocks are identical, Block B will need the same net force acting on it in order to move side-by-side with Block A. The net force acting on Block A is 3 N to the left (12 N to the left minus a total of 9 N to the right) so that is the single force that should act on Block B.

5. A hockey player uses his stick to maintain a **continuous constant strength push** on the puck as he moves it across the smooth ice. Assuming that the effects of friction are negligible, which of the following choices best describes the motion of the puck while this constant strength push is acting on it?

   a) The speed of the puck will continuously decrease.
   b) The puck will move at a constant speed.  
   c) The speed of the puck will continuously increase.
   d) Something else – you describe it.

   Briefly explain the reasoning behind your choice (remember to include a description of the motion if you chose option d).

   We learned in class that when a constant strength force acts on an object, it speeds up. As long as the force continues to act the puck’s speed will continuously increase.

6. A large block is on rollers so that it can move across a level surface as if there was no friction affecting it. After they have started the block moving to the right, two men want it to continue moving in the same direction, at a **constant speed**.

   Below are force diagrams representing four possible arrangements of forces the men could apply to the block. The situations are also described briefly in words.

| A. Pull to the right is stronger than the pull to the left. | B. No-one pulls, either to the right or the left. |
Indicate all the situations shown above (if any) that you think would result in the block moving to the right at a constant speed after it has already started moving. Briefly explain the reasoning behind your choices.

The diagrams all show the block moving to the right. Since it is already in motion any unbalanced combination of forces would result in a change in speed. Only a balanced combination of forces would result in motion at a constant speed. So C would work. B would also work since having no forces act is the same as having a balanced combination of forces.

c) For those situations that you did not select in part a), what do you think the motion of the cart would be like? Again, explain your reasoning.

In both A and D a stronger force acts in the direction of motion than acts against it. In this case both situations would result in a steadily increasing speed.

7. A small child attempts to push a box full of toys across the floor in his playroom. The child calls for help and his mother comes and helps him push the box, in the same direction. Which one of the following statements best describes why the box now begins to move.

The combined push of the mother and child is equal in strength to the force resisting the movement of the box.
The mother weighs more than the box does.

The combined push of the mother and child is greater in strength than the force resisting the movement of the box.
The strength of the mother’s push alone is greater in strength than the force resisting the movement of the box.

Please explain your reasoning

For an object at rest to start moving, the forces acting on it must be unbalanced. This means the combined forces of the boy and the mother must be greater than the force resisting them.

8. Now the small child is pushing the box of toys across the room at a constant speed. Create an explanation for why the box moves at a constant speed as the child pushes it.

Draw the Force Diagram:

Write the explanation:

For an object in motion to move at a constant speed the forces acting on it must be balanced. If the box in question does move at a constant speed this must mean that the strength of the force acting in the direction of motion must be exactly equal to that of the force opposing its motion. Therefore the box moves at a constant speed because the strength of the child’s push is equal to that of the frictional force exerted on it by the floor.

9. The famous chef, Antonio, is making pizza. He shapes the dough for the base into a large round, flat shape, and then tosses it into the air. It rises about three feet before falling back down, where he catches it.

Which of the following diagrams best represents the forces acting on the pizza after he has tossed it up, and it is still rising. Circle your choice.
Diagram C is correct. The gravitational force of the Earth pulls downward on the pizza and all the diagrams show that. However, after the pizza has left Antonio’s hands the force of his hands no longer acts, so both A and B can be eliminated. Like friction, the force of air resistance always opposes the motion of objects and since the pizza is still moving upward, this force must be pushing down on the pizza. Thus both gravity and air resistance oppose the upward motion, so the correct diagram is C.

10. Imagine holding a small ball at arms length and then releasing it, so that it falls to the ground. (Assume air resistance is negligible.)

a) Is the ball involved in an interaction as it falls? What evidence supports your answer?
Yes, the ball is involved in an interaction as it falls, because it speeds up as it does so.

b) Is the falling ball an energy source or an energy receiver? How do you know?

The falling ball is an energy receiver. Since its kinetic energy is increasing as it falls it must be receiving mechanical energy in some type of interaction.

c) What other object does the ball interact with while it is falling? Why does the interaction have only an imperceptible effect on this other object?

The ball is interacting with the Earth as it falls. This interaction has an imperceptible effect on the Earth because its mass is very much larger than that of the ball.

d) Draw an I/O energy diagram for the system of the falling ball and the object it is interacting with.

11. After being given a quick push, a small ball moves at a constant speed inside a flat circular track. (A top view is shown to the right.) A section of the track is missing, as shown, and the ball leaves the track and rolls across the table top.

Which line in the diagram best represents the path the car will follow when it leaves the track? Briefly explain the reasoning behind your choice.
12. Now the student removes the fans from the two carts, and in the second experiment holds them both high above the floor (with a soft cushion to break the fall) and drops them at the same time. You can ignore the effects of air resistance. To the right is a force diagram (with motion arrow) for cart B one-half second after the carts begin falling:

Consider cart A (the more massive one). Suppose you wanted to draw a force diagram for cart A at the same time (one-half second after starting), including both a force arrow and a motion arrow:

a) Which of the following arrows could best represent the length of the force arrow on cart A. Circle your choice and briefly justify why you made that choice.

b) Which of the following arrows could best represent the length of the motion arrow for cart A. Circle your choice and briefly justify why you made that choice.
13. A soccer goalie is practicing by punting a ball straight up into the air and then catching it again when it falls back down. Consider a moment just after the ball has been kicked, but is still moving upward (as shown in the picture). Which of the following forces do you think are acting on the soccer ball at this moment? (Choose all those that you think are present.)

c) A force pushing upward due to the motion of the ball.
d) A force of gravity pulling downward.
e) A force from the kick pushing upward.
f) A force of gravity pushing upward.
g) Some other force (describe what you think it is below)

Briefly explain the reasoning behind your choice(s).