1. A group of students arrange two level tracks side-by-side so they can have a race between two carts. They mount identical fan units (each with two real batteries) on two identical carts. When the two carts, with fans turned on, are released simultaneously from the end of the tracks they speed up at the same rate, traveling side-by-side, and so the race ends in a tie (Experiment 1).

The students then add extra mass to one of the carts and repeat the experiment (using the same fan units), and record speed-time data for both carts (Experiment 2).

a) The next week, when they look at the speed-time data they graphed (shown below), there are two lines (labeled A and B), and they are not sure which is which. Can you help by identifying which line represents the motion of the cart with the added mass? Justify your choice.
Line B represents the motion of the cart with added mass. Since the fan units were identical they would have provided the same strength force on each cart. However, the cart with the added mass would have sped-up more slowly than the one without the extra mass. The line that represents a lower rate of speeding up is B.

b) However, one of the students remembers that they also attempted to break the tie in Experiment 1 by adding a additional battery to one of the fan units without adding extra mass to either cart (Experiment 3). Could the speed-time data shown in the graph on the previous page be from Experiment 3? Yes or No. Justify your answer.

Yes, the data could be from Experiment 3. In this experiment two different strength forces were applied to identical carts. This would mean that the cart with the stronger fan force acting on it would speed up at a higher rate than the other cart - this would correspond to line A, with line B being the cart with the weaker fan force acting on it.
2. In one of your experiments you used a friction cart with a fan mounted on it. You carefully adjusted the friction pad so that, with the fan running, the cart still did not move. However, you then made it move by giving it a push with your hand and found that the cart moved at a constant speed after the push. Using ideas about forces, write your own explanation for why the speed of the cart was constant after the push.

**Explanation: Why does the cart move at a constant speed after it is given a quick push?**

*Draw the Force Diagram*

- Force exerted on cart by fan unit
- Frictional force exerted on cart by track

*Write the explanation:*

When a balanced combination of forces acts on an object at rest it will remain at rest. With the fan running the cart did not move. This tells us the force that the fan unit exerted on the cart and the frictional force opposing motion were balanced. After being given a quick shove to get it started the force of the push was gone and so the only remaining forces acting on the cart were that of the fan unit and the frictional force opposing its motion, and we know from before we know that these two forces are balanced. When balanced forces act on a moving object it will continue to move at a constant speed, so with these balanced forces acting on it the cart moves at a constant speed.

3. A child playing with a toy car gives it a quick shove on a smooth level floor. (The car does not have any type of motor inside it.) After his push, the car very gradually slows down and stops.

Four students are discussing why the car very gradually slows down and stops, after the shove.

- The car slows down because the force pushing it forward is getting weaker and weaker.
- It slows because, after the shove, there is no more force to keep it moving.
Kristen: "It slows down because the forces acting on it are balanced, and balanced forces make a moving object come to rest."

Daryl: "The car slows down because there is a force acting on it in the opposite direction to its motion."

Samantha: 

Victor: 

Which student do you agree with (if any)? Please explain your reasoning.
I agree with Victor. He has an idea that is consistent with those we developed in class; that objects slow and stop because a force (or unbalanced combination of forces) on them in a direction opposite to their motion.

Kristen’s idea is not consistent with our class ideas. She seems to be saying that there is still a force pushing the car forward after the initial shove, but our idea was that the force of the shove is gone as soon as the hand loses contact. Her idea that the car slows down because the forward force gets weaker is also inconsistent with our class ideas. We said objects slow down because stop because a force (or unbalanced combination of forces) on them in a direction opposite to their motion.

Daryl’s idea might be OK, but without more information it is impossible to tell. He implies that for the car to keep moving a force is needed in the direction of motion. If he is accounting for the effects of the friction force that slows the car down, he is correct, but he doesn’t say that. On the other hand his thinking could be something like Kristen’s, in that he thinks that for any motion to continue a continuous forward force is needed, even in the absence of friction, and without such a forward force it is just natural for the car to stop. This is not consistent with our class ideas.

Samantha thinks that if balanced forces act on a moving object, then it will slow and stop. However, in class we found out that when balanced forces act on an object its speed will remain constant. So if balanced forces acted on the car after the initial shove then it would not slow down, but continue at a constant speed.

Energy Description of Gravitational Interactions

4. An archer uses a bow to shoot an arrow straight up into the air on a still, calm day. The arrow rises to a certain height and then falls straight back down, sticking in the ground. The speed time graph for the arrow shown below is for the period starting just after it leaves the bow to just before it sticks in the ground.
a) At what time does the arrow reach its highest point? Briefly justify how you know.

The arrow reaches its highest point at 5 seconds. We can tell this from the graph because it is at this time that it stops slowing down as it rises, stops for an instant at its highest point, and then begins to speed up again as it falls.

b) Indicate on the graph the entire region during which the arrow was an energy receiver. Briefly justify how you know.

The arrow was an energy receiver from 5 seconds to 10 seconds. You can tell this because it was during this period that it was speeding up, hence its kinetic energy was increasing, indicating it must be receiving mechanical energy in an interaction.

c) During the entire time that the arrow was an energy receiver, what was the energy source?

During this time the energy source was the gravitational field of the Earth and the arrow.

5. 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 an 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 only an imperceptible effect on the Earth because its mass is very much larger than the ball.

d) Draw an energy diagram for the interaction that makes the ball fall.
6. A small child attempts to push a box full of toys across the floor in his playroom. However, despite pushing as hard as he can, the box does not move. Which one of the following statements best describes the reason the box does not move while he is pushing it.

h) The force resisting moving the box is greater in strength than the child’s push.

i) The child weighs less than the box does.

j) The force resisting moving the box is equal in strength to the child’s push.

k) The strength of the child’s push is greater than the strength of the force resisting moving the box, but not great enough to move it.

Please explain your reasoning

If an object is at rest and remains at rest, then the forces acting on it must be balanced. This means the force of the boy and the force resisting him must be equal.

7. The child in the previous question 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.

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

n) The combined push of the mother and child is greater in strength than the force resisting the movement of the box.

o) 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. Three identical balls are thrown from the top of a building, all with the same initial speed. The first ball is thrown horizontally, the second at some angle above the horizontal, and the third at some angle below the horizontal, as in Active Figure 5.15. Neglecting air resistance, rank the speeds of the balls as they reach the ground, from fastest to slowest.

(a) 1, 2, 3
(b) 2, 1, 3
(c) 3, 1, 2
(d) all three balls strike the ground at the same speed.

Figure. Three identical balls are thrown with the same initial speed from the top of a building.

Answer: (d)

2. A constant net torque is applied to an object. Which one of the following will not be constant?

(a) angular acceleration
(b) angular velocity  
(c) moment of inertia  
(d) center of gravity  

**Answer:** (b)

4. Two spheres, one hollow and one solid, are rotating with the same angular speed around an axis through their centers. Both spheres have the same mass and radius. Which sphere, if either, has the higher rotational kinetic energy?  
(a) The hollow sphere  
(b) The solid sphere  
(c) They have the same kinetic energy

**Answer:** (a)

5. Assume that following objects with the same mass are released from rest at the top of incline. Which object arrives at the bottom first,  
(a) a ball  
(b) a solid cylinder  
(c) a box

**Answer:** (c)

5. A small sports car collides head-on with a massive truck. The greater impact force (in magnitude) acts on  
(a) the car,  
(b) the truck,  
(c) neither, the force is the same on both.  
**Answer:** (c);  

7. small sports car collides head-on with a massive truck. Which vehicle undergoes the greater magnitude acceleration?  
(a) the car,  
(b) the truck,  
(c) the accelerations are the same.

**Answer:** (a)

7. An object moves in a circular path with constant speed \( v \). Which of the following statements is true concerning the object?  
(a) Its velocity is constant, but its acceleration is changing.  
(b) Its acceleration is constant, but its velocity is changing.  
(c) Both its velocity and acceleration are changing.  
(d) Its velocity and acceleration remain constant.  

**Answer:** (c)
8. A ball falls to the ground. Which of the following statements are false?
(a) The force that the ball exerts on Earth is equal in magnitude to the force that Earth exerts on the ball.
(b) The ball undergoes the same acceleration as Earth.
(c) Earth pulls much harder on the ball than the ball pulls on Earth, so the ball falls while Earth remains stationary.

**Answer:** (b), (c)

4. A horizontal force of 100 N is applied to move a 45-kg cart across a 9.0-m level surface. What work is done by the 100-N force?
a. 405 J
b. 500 J
c. 900 J
d. 4500 J

**Answer:** (c)