Minds•On Physics Activity

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Recognizing and Comparing Kinetic Energy

Purpose and Expected Outcome

This activity will familiarize you with the definition of *kinetic energy*. After completing this activity, you should be able to recognize kinetic energy in complex situations, and you will know when it changes and when it does not change during a process. You will see that in some cases the velocity changes but the kinetic energy does not. You should appreciate the similarities and differences between kinetic energy and momentum.

Prior Experience / Knowledge Needed

You should be familiar with the definition of work, and be able to compute the work done by a constant force.

KINETIC ENERGY

As we saw in an earlier activity, the *total work* done on a rigid, non-rotating body is equal to one-half the change in the quantity Mv^2. If we think of the total work as an amount of energy given to the object, then $\Delta(\frac{1}{2}Mv^2)$ is the change in the energy of the object. Because this form of energy depends on the speed of the object, we call it the *kinetic* energy. We define the kinetic energy in a very particular way, because this quantity comes into play in a wide variety of situations.

For a point object (zero volume) having mass m and speed v, its kinetic energy is defined to be:

$$E_K \equiv \frac{1}{2}mv^2$$

definition of kinetic energy for a point object having mass m and speed v

For a collection of point objects, the total kinetic energy is the sum of the kinetic energies of all of its parts:

$$E_{K,\text{total}} \equiv \frac{1}{2}m_a v_a{}^2 + \frac{1}{2}m_b v_b{}^2 + \ldots$$

definition of total kinetic energy for a collection of point objects, a, b, …

For a non-deformable (rigid), non-rotating object, every part is moving with exactly the same speed, so we can add up all the kinetic energies of all the parts to get:

$$E_{K,\text{total}} = \frac{1}{2}Mv^2$$

(for a rigid, non-rotating object having mass M and speed v)

This is exactly the quantity that changed in the earlier activity. For any particular situation, you must decide how to apply the definition to determine the total kinetic energy. Note that kinetic energy is a scalar quantity, and therefore has no direction associated with it.

Explanation of Activity

For each situation below, you will compare the kinetic energy and the momentum.

A1. Two identical minivans (1600kg each) are traveling in opposite directions with the same speed of 90km/h (25m/s).

(a) What is the total momentum of the two minivans?

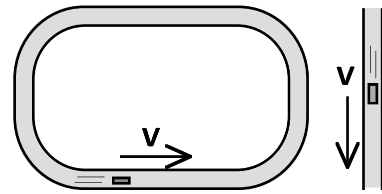
(b) What is the total kinetic energy of the two minivans?

continued

A2. Two identical race cars travel at the same constant speed v. One is going around an oval track as shown, and the other is traveling on a long, straight highway.

(a) When, if ever, do the two cars have the same momentum?

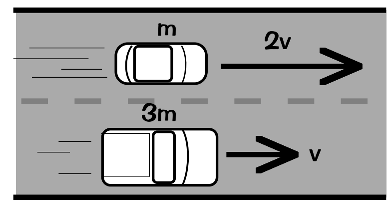
(b) When, if ever, do the two cars have the same kinetic energy?



A3. A certain truck has three times the mass, but only half the speed, of a small car.

(a) Which vehicle has the larger momentum? Explain.

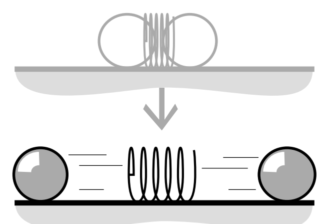
(b) Which vehicle has the larger kinetic energy? Explain.



A4. Two marbles are used to compress a spring and released from rest.

(a) Does the total momentum of the two marbles remain constant? Explain.

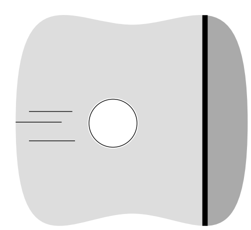
(b) Does the total kinetic energy of the two marbles remain constant? Explain.



A5. A 150g superball hits a wall traveling at 80cm/s and rebounds with exactly the same speed.

(a) What is the superball's change in momentum as a result of hitting the wall?

(b) What is the superball's change in kinetic energy as a result of hitting the wall?



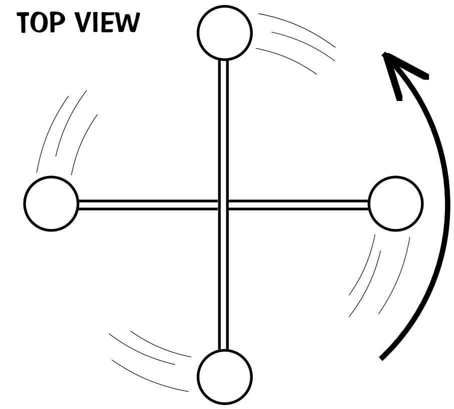
A6. Consider the gas molecules inside your classroom.

(a) Do the gas molecules have a zero or non-zero total momentum? Explain.

(b) Do the gas molecules have a zero or non-zero total kinetic energy? Explain.

continued

A7. A simple mobile is made by attaching four small balls (0.1kg each) to the ends of two very light rods as shown. The mobile spins counterclockwise with each ball moving at 0.15m/s.



(a) What is the kinetic energy of each ball? What is the total kinetic energy of the four balls? Does the kinetic energy stay the same as the mobile is spinning? Explain.

(b) What is the total momentum of the four balls? Does the total momentum stay the same? Explain.

(c) Is there a net force exerted on any one of the balls? Is it constant? Is there total work being done on any of the balls as they move through $1/4$ revolution?

A8. A bicycle wheel is spinning around a fixed axle.

(a) Does the wheel have a zero or non-zero total momentum? Explain.

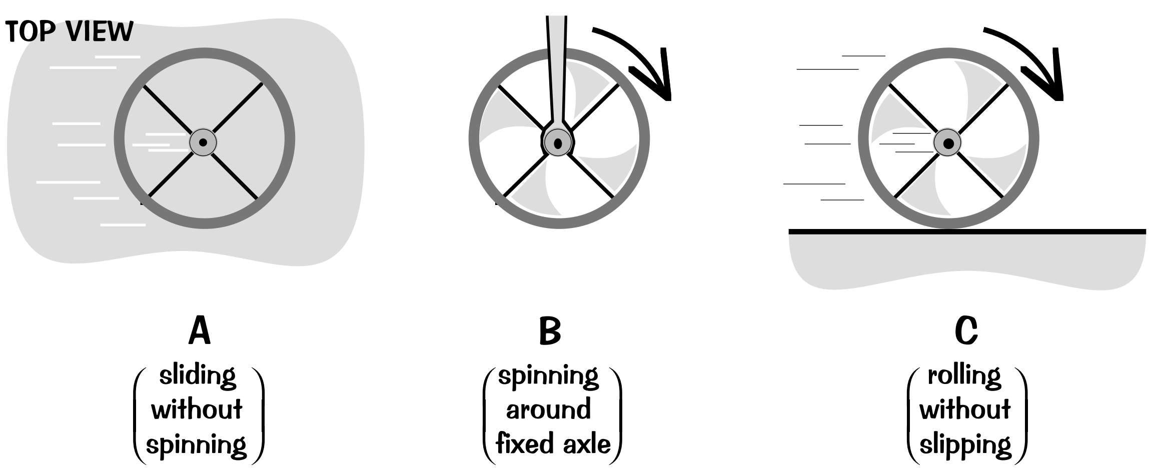
(b) Does the wheel have a zero or non-zero total kinetic energy? Explain.

A9. Three identical wheels move in different ways, as shown and described below:

Wheel *A* slides along a smooth surface at constant speed v. (The top view is shown.)

Wheel *B* rotates around a fixed axle with every point on its rim moving at speed v.

Wheel *C* rolls without slipping across the floor. Its center moves with speed v.



(a) Which wheel has the largest momentum? Which wheel has the smallest momentum? Explain.

(b) Which wheel has the largest kinetic energy? Which wheel has the smallest kinetic energy? Explain.

Integration of Ideas

Fill in the blanks in the following table listing the similarities and differences between kinetic energy and momentum.

	SIMILARITIES	DIFFERENCES
I1.	(a) Both momentum and kinetic energy depend upon the _________ and the _________ of the object.	(b) Only the momentum depends on the _________ . The kinetic energy does not depend upon it.
I2.	(a) When both change, we know there must be a _________ exerted on the object.	(b) _________ is a vector quantity, but _________ is a scalar quantity.
I3.	(a) For a collection of objects, both the <u>total</u> momentum and the <u>total</u> kinetic energy are found by _____________________________ .	(b) Whenever there is a net force on an object, its _________ <u>must</u> change, whereas in some cases its _________ does <u>not</u> change.

Reflection

R1. In general, which is more difficult to determine, the total momentum or the total kinetic energy? Explain.

R2. If you know the momentum of an object, can you determine its kinetic energy? If your answer is yes, explain how. If your answer is no, what additional information is needed?

R3. If you know the kinetic energy of an object, can you determine its momentum? If your answer is yes, explain how. If your answer is no, what additional information is needed?

R4. Is it possible to have a non-zero total momentum, but zero total kinetic energy? Explain. If your answer is yes, give an example.

R5. Is it possible to have a non-zero total kinetic energy, but zero total momentum? Explain. If your answer is yes, give an example.

R6. Give an example of a situation in which the momentum of an object changes, but the kinetic energy does not. Give an example of a situation in which the total kinetic energy changes but the total momentum does not.

R7. Consider situation A3, in which a car and a truck are traveling side-by-side along the highway. If the same constant force were applied to stop each vehicle, which would travel the longer displacement? Explain. Which would require more time to stop? Explain. (**Hint:** Draw sketches of velocity vs. time for the two vehicles. What do the slopes of these graphs represent? Which graph has the larger slope? Why? What do the areas below these graphs represent? Which graph has the larger area?)