Name: _____ Date: _____

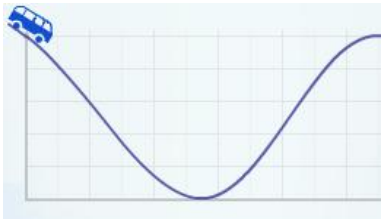
Student Exploration: Energy of a Pendulum

Vocabulary: conservation of energy, gravitational potential energy, kinetic energy, pendulum, potential energy, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

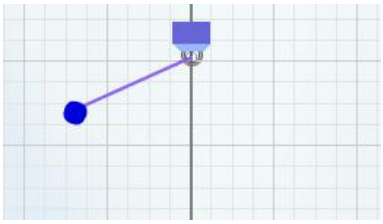
1. A toy car is about to roll down a track, as shown below. At what point do you think the car will reach its greatest speed?

   Mark this point on the image.



2. A **pendulum** consists of a weight that is suspended from a pivot. At what point will the pendulum below move fastest?

   Mark this point on the image.



3. What do these two situations have in common? _____

   _____

Gizmo Warm-up

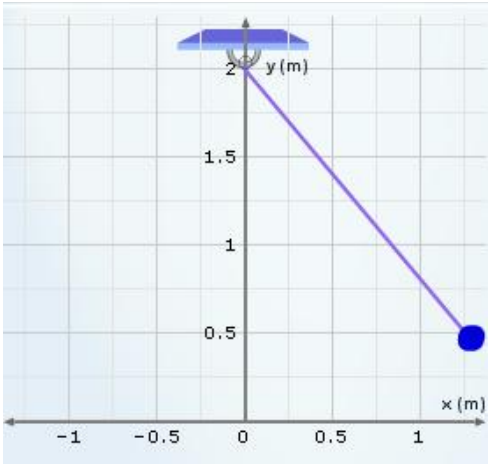
Objects have several types of energy. **Potential energy** depends on an object's position or shape. **Kinetic energy** is the energy of movement. The *Energy of a Pendulum* Gizmo™ allows you to explore how the amounts of these types of energy change for a pendulum in motion.

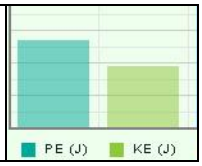
1. On the DESCRIPTION pane, change the initial angle (***θ***) to 40 degrees. Click **Play** ( ). How does the **velocity** (speed and direction) of the pendulum change as it swings from right to left?

   _____

   _____

2. On the image at right, mark the point where the pendulum swings fastest with an *X*. Then, circle the two points where the velocity is zero.



Activity A: **Potential and kinetic energy**	Get the Gizmo ready: • Click **Reset** ( ). • Check that ***m*** is 0.5 kg, ***L*** is 2.0 m, ***g*** is 9.8 m/s^2, and ***θ*** is 40 degrees.	

Introduction: An object that is a certain height (*h*) above the ground has the potential to do work, and therefore has potential energy. This type of potential energy is called **gravitational potential energy** (*GPE*, or *PE* for short). The unit of energy is the joule (J).

Question: How are potential and kinetic energy related?

1. Observe: Select the BAR CHART tab. Click **Play** and observe. What do you notice about the gravitational potential energy (***PE***), kinetic energy (***KE***), and total energy (***TE***)?

   _____

   _____

   _____

2. Measure: Click **Reset**. Turn on **Show numerical values**.

   A. What is the gravitational potential energy? _____

   B. What is the kinetic energy? _____

   C. What is the total energy? _____

3. Measure: Click **Play**, and then try to click **Pause** ( ) when the pendulum is in the middle of its swing. (This might require several tries.)

   A. What is the gravitational potential energy now? _____

   B. What is the kinetic energy now? _____

   C. What is the total energy? _____

4. Analyze: At any given time, what can you say about the total energy of the pendulum?

   _____

   _____

   This illustrates the principle of **conservation of energy**. In a closed system, energy can be converted from one form to another, but the total amount of energy remains the same.

(Activity A continued on next page)

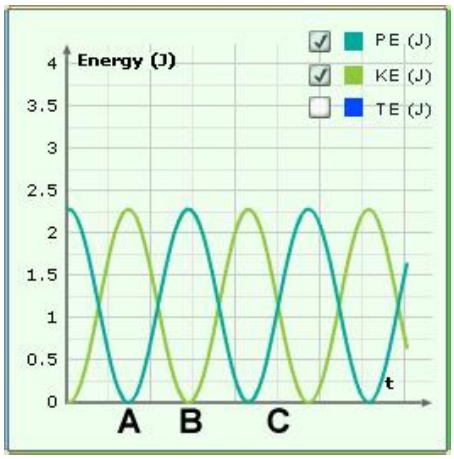
Activity A (continued from previous page)

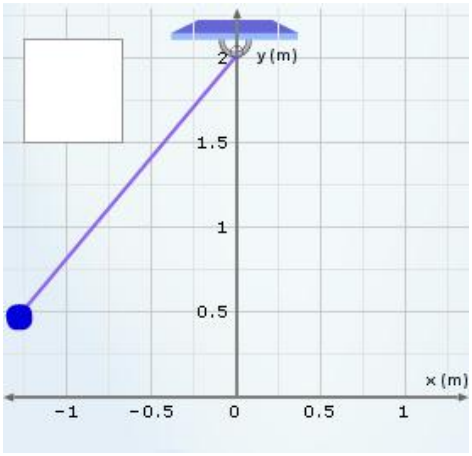
5. Interpret: Click **Reset**. Select the GRAPH tab and turn on the ***PE*** and ***KE*** checkboxes. Click **Play**, wait about 4 seconds, and then click **Pause**.

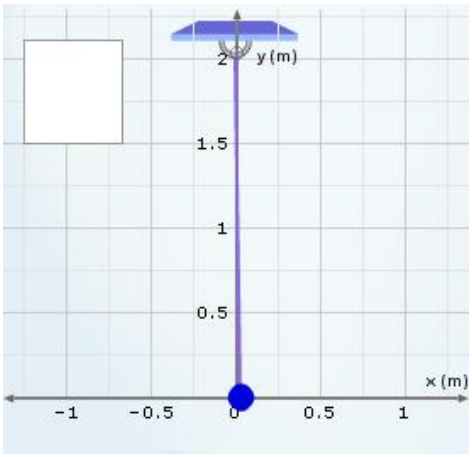
   What is the relationship between potential and kinetic energy? _____

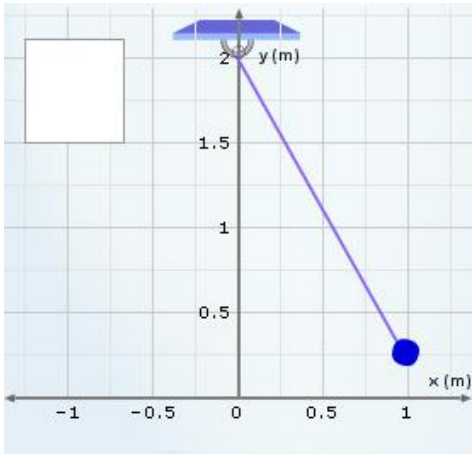
   _____

6. Match: The graph below shows the potential and kinetic energy curves for a pendulum. Label each pendulum image with the corresponding letter on the graph (*A, B,* or *C*).







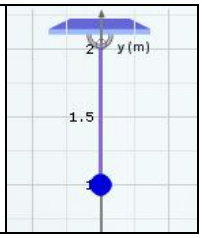


7. Apply: Suppose a pendulum starts with a potential energy of 100 J. Assuming the pendulum has a height of 0 m at the bottom of its swing, what is its maximum kinetic energy? Explain.

   _____

   _____

   _____

Activity B: **Calculating potential energy**	Get the Gizmo ready: • Click **Reset**. • Set ***m*** to 1.0 kg, ***L*** to 1.0 m, and ***g*** to 1.0 m/s^2. (Note: You can set the slider values directly by entering values into the text boxes.) • Set ***θ*** to 0 degrees.	

Question: How is gravitational potential energy calculated?

1. Observe: Select the BAR CHART tab, and check that **Show numerical values** is on.

   What is the potential energy of the pendulum? _____

2. Gather data: Record the potential energy of the pendulum for each of the following sets of values for ***m***, ***L***, and ***g***. Record the height (*h*) of the pendulum as well. (Because the pendulum's pivot is 2 m above the ground, the height is equal to 2 meters – *L* meters.)

m **(kg)**	***L*** **(m)**	***h*** **(m)**	***g*** **(m/s^2)**	***PE*** **(J)**
0.5 kg	1.0 m		6.0 m/s^2	
1.0 kg	1.2 m		2.0 m/s^2	
0.3 kg	1.1 m		1.0 m/s^2	
0.2 kg	1.5 m		3.0 m/s^2	

3. Find a pattern: What is the relationship between the potential energy of a pendulum and the values for mass (*m*), height (*h*), and gravitational acceleration (*g*)?

   _____

   _____

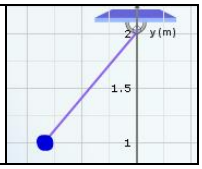
4. Make a rule: Write an expression for potential energy based on *m*, *h*, and *g*. Test your expression using the Gizmo.

   PE =

5. Apply: What is the potential energy of a pendulum with a mass of 0.7 kg, a height of 0.3 m, and a value of *g* equal to 9.8 m/s^2?

   _____

   Check your answer using the Gizmo. (Hint: Set the length of the pendulum to 1.7 m.)

Activity C: **Kinetic energy and velocity**	Get the Gizmo ready: • Select the DESCRIPTION tab. • Set ***m*** to 1.0 kg, ***L*** to 1.3 m, ***g*** to 1.0 m/s^2, and ***θ*** to ⁻40 degrees.	

Question: How is potential energy converted to kinetic energy?

1. Observe: Select the BAR CHART tab, and check that **Show numerical values** is on.

   A. What is the height of the pendulum? _____

   B. What is the potential energy of the pendulum? _____

   C. What is the kinetic energy of the pendulum? _____

2. Observe: Click **Play**, and then click **Pause** when the pendulum is at the bottom of its swing.

   A. What is the approximate height of the pendulum now? _____

   B. What is the potential energy of the pendulum? _____

   C. What is the kinetic energy of the pendulum? _____

3. Calculate: The formula for kinetic energy is as follows:

$$KE = \frac{1}{2}mv^2$$

   Based on this formula, what is the velocity (v) of the pendulum at the bottom of its swing? Show your work.

   Velocity = _____

4. Apply: Click **Reset**. Set ***m*** to 1.0 kg, ***L*** to 2.0 m, ***g*** to 9.8 m/s^2, and ***θ*** to ⁻40 degrees. What is the maximum velocity of this pendulum? Show your work. (Hint: The exact height of the pendulum is now 0.468 m.)

   Velocity = _____