Name: ______________________________________ Date: ________________________

Student Exploration: Energy Conversion in a System

Vocabulary: energy, gravitational potential energy, heat energy, kinetic energy, law of conservation of energy, specific heat capacity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A battery contains stored **energy** in the form of chemical energy.

1. What are some examples of devices that are powered by batteries? ____________________

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2. What different forms of energy are dmonstrated by these devices? ____________________

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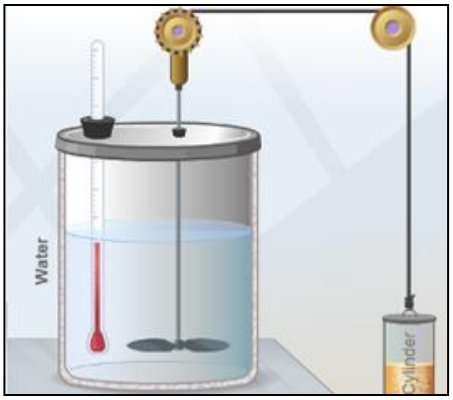
Gizmo Warm-up
Energy constantly changes from one form to another, but in a closed system, the total amount of energy always remains the same. This concept is known formally as the **law of conservation of energy**.



The *Energy Conversion in a System* Gizmo™ allows you to observe the law of conservation of energy in action. In the Gizmo, a suspended cylinder has **gravitational potential energy**. When the cylinder is released, the gravitational potential energy is converted into **kinetic energy**, which causes the stirrer in the water to spin.

1. What is the initial temperature (***T***) of the water? ___________________________________

2. Click **Play** (▶). What happens as the cylinder drops? _______________________________

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3. What is the final temperature of the water? ______________________________________

4. Why do you think the temperature of the water increased? ___________________________

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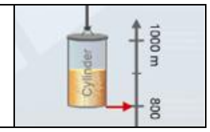
Activity A: Potential energy and height	Get the Gizmo ready: • Click **Reset** ( ).	

Introduction: The raised cylinder in the Gizmo has gravitational potential energy (*GPE*) because gravity can cause the cylinder to drop. When the cylinder drops, its kinetic energy is converted into **heat energy**, which raises the temperature of the water.

Question: How does the cylinder's initial height affect its gravitational potential energy?

1. Predict: How do you think increasing the cylinder's height will affect the final temperature of the water? ____

2. Gather data: Make sure the water's **Mass** is 1.0 kg, its **Temp** is 25 °C, and the cylinder's **Mass** is 5 kg. Set the cylinder's **Height** to 100 m. (Note: The large height scale used by the Gizmo, while not practical in a real-world experiment, makes it easier to produce observable temperature changes in the water.)

   Click **Play**, and record the water's final temperature in the table below. Repeat the experiment at each cylinder height to complete the second column in the table.

Cylinder height (m)	Final temp. (°C)	Change in temp. (°C)	Cylinder *GPE* (J)
100 m			
200 m			
500 m			
1,000 m			

3. Calculate: Subtract the water's initial temperature from its final temperature to complete the third column of the table.

   An object's *GPE* can be calculated by multiplying its height (h) by its mass (m) and acceleration due to gravity (g): $GPE = mgh$. On Earth, g = 9.8 m/s^2. Calculate the cylinder's *GPE* for each of the trials you completed and fill in the last column of the table.

4. Analyze: Study the data you collected.

   A. How does doubling the height of the cylinder affect its *GPE*? ____________________

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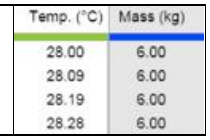
   B. How does doubling the cylinder's *GPE* affect the change in temperature experienced by the water? ____

Activity B: Potential energy and mass	Get the Gizmo ready: • Click **Reset**.	

Temp. (°C)	Mass (kg)
28.00	6.00
28.09	6.00
28.19	6.00
28.28	6.00

Question: How does the cylinder's mass affect its gravitational potential energy?

1. Predict: How do you think increasing the cylinder's mass will affect the final temperature of the water? Explain your prediction. ____

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2. Gather data: Make sure the water's **Mass** is still set to 1.0 kg and its **Temp** is 25 °C. Set the cylinder's **Height** to 500 m.

   Use the Gizmo to complete the second column of the table below, and then calculate the change in temperature and the cylinder's *GPE* for each trial.

Cylinder mass (kg)	Final temp. (°C)	Change in temp. (°C)	Cylinder *GPE* (J)
1 kg			
2 kg			
5 kg			
10 kg			

3. Compare: Describe any patterns you see and compare your results with the results you got when experimenting with the cylinder's height in activity A: _________________________

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4. Apply: Suppose the cylinder had a mass of 20 kg and started at a height of 2,000 m. If the initial temperature of the water was 25 °C, what would be the final temperature? Explain.

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Activity C: Heat energy and temperature	Get the Gizmo ready: • Click **Reset**. • Select the GRAPH tab and choose the **Generated heat** option.	

Question: What factors affect how much the water's temperature changes when a given amount of heat energy is added to the water?

1. Form hypotheses: In activity A, you discovered how changing the cylinder's *GPE* affects the water's final temperature. Now consider the following questions:

   A. How will changing the water's initial temperature affect how much the water's temperature increases when the cylinder is dropped?

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   B. How will changing the water's mass affect how much the water's temperature increases when the cylinder is dropped?

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2. Gather data: Set the cylinder's **Mass** to 5 kg and its **Height** to 500 m. Use the Gizmo to test each of the scenarios listed in the table and record your results in the last three columns. Use the graph to estimate the generated heat.

Water's mass (kg)	Water's initial temp. (°C)	Water's final temp. (°C)	Change in temp. (°C)	Generated heat (kJ)
1 kg	0 °C			
1 kg	20 °C			
1 kg	40 °C			
0.5 kg	25 °C			
1 kg	25 °C			
1.5 kg	25 °C			

3. Explain: Why was the amount of heat generated the same each time? ___________________

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(Activity C continued on next page)

Activity C (continued from previous page)

4. Analyze: Use the data you collected to answer the following questions.

   A. What was the effect of the initial temperature on the temperature change of the water, and why do you think this happened?

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   B. What was the effect of doubling the water mass on the temperature change, and why do you think this happened?

   ____

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5. Challenge: Not all substances heat up and cool down at the same rate. A substance's resistance to temperature change is described by its **specific heat capacity**, or specific heat for short. For example, the specific heat of iron is 0.46 J/g °C. That means it takes 0.46 joules of heat energy to increase the temperature of a gram of iron by one degree Celsius.

   Specific heat capacity can be calculated using the following equation: $q = mc\Delta T$.

   In the equation, q represents the amount of heat energy gained or lost (in joules), m is the mass of the substance (in grams), c is the specific heat capacity of the substance (in J/g °C), and ΔT is the temperature change of the substance (in °C).

   Click **Reset**. Set the water **Mass** to 1.0 kg (1,000 g). The cylinder should have a **Mass** of 5.0 kg and a **Height** of 500 m.

   A. What is the gravitational potential energy of the cylinder? ________________

   B. If no energy is lost, how much heat energy is added to the water? ________________

   C. What is the mass of the water? ________________

   D. What is the temperature change of the water? ________________

   E. What is the specific heat of the water? (Show your work below.) ________________

   F. How does the specific heat of water compare to the specific heat of iron? __________

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