Name: ______________________________________ Date: ________________________

Student Exploration: Inclined Plane – Sliding Objects

Vocabulary: acceleration, coefficient of friction, conservation of energy, friction, gravitational potential energy, inclined plane, kinetic energy, potential energy, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Two skiers are at the top of a mountain. Amanda decides to go down a steep trail that leads directly to the bottom. Brandon decides to take a longer, more gradual trail.

1. Assuming neither skier tries to slow down, who will reach the bottom first? ______________

2. Who will be going faster at the bottom? Explain. ___________________________________

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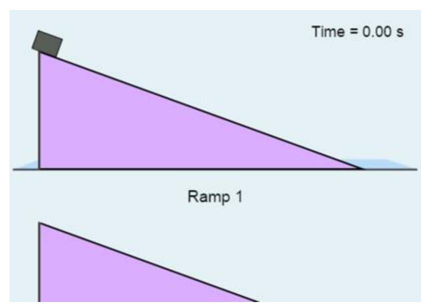
Gizmo Warm-up
The two ski trails are examples of **inclined planes**. As objects move from the top of an inclined plane to the bottom, their **potential energy**, or energy of position, is converted into **kinetic energy**, or energy of motion. This process is explored in the *Inclined Plane – Sliding Objects* Gizmo.



To begin, check that **Ramp 1** has a **Steel block** on a **Frictionless ramp** with an **Angle** of 20°.

1. Click **Play** (▶). How does the block's speed change as it slides? ____________________

2. Select the TABLE tab and scroll to the bottom of the table.

   A. What is the final **velocity** (*v*) of the block? ____________________

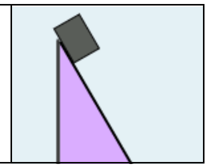
   B. What is the **acceleration** (*a*) of the block? ____________________

   The acceleration of the block is equal to how much its velocity increases each second.

3. Click **Reset** (↺). On the CONTROLS tab, change the **Angle** of **Ramp 1** to 60°. Select the TABLE tab and click **Play**. What is the final velocity and acceleration of the block this time?

   Final velocity: ____________________ Acceleration: ____________________

   Did the steepness of the plane affect the final velocity of the block? __________________

Activity A: Potential and kinetic energy	Get the Gizmo ready: • Click **Reset**. • Check that **Ramp 1** is a **Frictionless ramp**. • Check that the **Angle** of **Ramp 1** is 60°.	

Introduction: Potential energy is energy of position or shape. In this Gizmo, the block at the top of the ramp has **gravitational potential energy**, which is equal to the product of the block's weight and height: *GPE* = *wh*. The weight of an object is equal to the product of its mass and gravitational acceleration, which is 9.8 m/s^2 on Earth's surface. So, $GPE = 9.8\ m/s^2 \cdot m \cdot h$.

Question: How is potential energy converted into kinetic energy?

1. Predict: As the block slides down the ramp, how do you expect the gravitational potential energy and kinetic energy of the block to change?

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2. Observe: Select the ENERGY tab, and turn on **Show values**. Click **Play**.

   A. What happens to the potential energy (*PE*) over time? _______________________

   B. What happens to the kinetic energy (*KE*) over time? ________________________

   C. Click **Reset**. Click **Play**, and then click **Pause** (⏸) when the block is about halfway down the plane. What is the sum of the potential and kinetic energy percentages?

   PE %: __________ *KE* %: __________ *PE* % + *KE* %: __________

3. Observe: Click **Reset**. Select the GRAPH tab, and check that the graph shows **Energy vs. Time**. Click **Play**. What do you notice? ____

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4. Confirm: Repeat the experiment with ramps of varying steepness. Does the same pattern hold true? Explain.

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This demonstrates the law of **conservation of energy**, which states that in a closed system, energy is neither created nor destroyed.

(Activity A continued on next page)

Activity A (continued from previous page)

5. Manipulate: The kinetic energy (*KE*) of an object is equal to half of its mass (*m*) multiplied by the square of its velocity (*v*):

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

Rearrange the terms in this equation to solve for velocity:

v =

6. Demonstrate: If you know an object's mass and height, you can determine its gravitational potential energy. You can then use conservation of energy to determine the object's kinetic energy when it slides to the bottom of a frictionless ramp. Finally, you can determine the object's final velocity because you know its kinetic energy and mass.

Click **Reset**. In the Gizmo, the object has a mass of 1 kg and an initial height of 1 m.

   A. What is the initial gravitational potential energy of the block? ___________________

   B. Based on conservation of energy, what will be the kinetic energy of the block when it gets to the bottom? ___________________

   C. What will be the final velocity of the block? __________

   Show your work:

   D. Click **Play** and select the TABLE tab. What is the block's final velocity? __________

   E. How does this experiment demonstrate conservation of energy? ________________

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7. Think and discuss: Why doesn't the steepness of a frictionless ramp affect the velocity of the block at the bottom of the ramp? (Hint: Discuss conservation of energy in your answer.)

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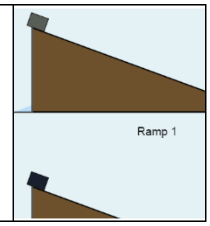
Activity B: **Friction**	Get the Gizmo ready: • Click **Reset**. On the CONTROLS pane, select a **Steel block** on a **Wood ramp** for **Ramp 1**. Select a **Rubber block** on a **Wood ramp** for **Ramp 2**. • Set the **Angle** of both ramps to 45°.	

Introduction: Friction is a force that opposes motion. The **coefficient of friction** (*μ*) is a value that represents how much friction exists between an object and a surface.

Question: How does friction affect a block sliding down an inclined plane?

1. Predict: Which block do you think will slide down the ramp most quickly? _______________

2. Observe: Select the ENERGY tab. Click **Play**.

   A. Which block reached the bottom first? _______________

   B. For the steel block, what percentage of its potential energy was converted into kinetic energy? __________ What percentage was lost due to friction? __________

   C. For the rubber block, what percentage of its potential energy was converted into kinetic energy? __________ What percentage was lost due to friction? __________

   D. Which block was more affected by friction? Explain. __________________________

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3. Observe: Click **Reset**. Change the **Angle** of both ramps to 20°. Click **Play**. What happens?

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   In some cases, the friction is so great that the object doesn't move at all!

4. Gather data: On the CONTROLS pane, turn on **Show coefficient of friction** for each ramp. Use the Gizmo to find the smallest ramp angle that still allows each block to slide. Use a calculator to find the sine (sin), cosine (cos), and tangent (tan) of that angle.

Block	Ramp	Angle	Sine	Cosine	Tangent	*μ*
Steel	Wood					
Rubber	Wood					

(Activity B continued on next page)

Activity B (continued from previous page)

5. Analyze: What pattern do you notice? ____

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You can use this relationship to calculate an unknown coefficient of friction.

6. Apply: Click **Reset**. Turn off **Show coefficient of friction** for each ramp. For each combination of materials, use the Gizmo to find the smallest ramp angle that still allows each block to slide. Use a calculator to find each coefficient of friction. Then, turn on **Show coefficient of friction** and record the actual values.

Block	Ramp	Angle	μ (calculated)	μ (actual)
Ice	Rubber			
Rubber	Steel			
Wood	Ice			
Steel	Steel			
Wood	Wood			
Rubber	Rubber			

7. Interpret: Which combination resulted in the greatest friction? ________________________

   Which combination had the least friction? _______________________________________

8. Analyze: Based on your results, which factors do you think are most important in determining the amount of friction between two surfaces?

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9. Think and discuss: When an object slides down a ramp with friction, the kinetic energy at the bottom of the ramp is not equal to the potential energy at the top. Why doesn't this situation violate the law of conservation of energy?

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