Gizmos

Name: ______________________________________ Date: ________________________

Student Exploration: Inclined Plane – Rolling Objects

[Note to teachers and students: This Gizmo was designed as a follow-up to the Inclined Plane – Sliding Objects *Gizmo. We recommend doing that activity before trying this one.]*

Vocabulary: moment of inertia, rotational kinetic energy, translational kinetic energy

Prior Knowledge Question (Do this BEFORE using the Gizmo.)
A boy rolls an old car tire down a hill. It goes pretty fast, but he wants the tire to go even faster. So, the boy climbs inside and rolls down the hill inside the tire.

Assuming there are no crashes, how do you think the speed of the tire with the boy inside will compare to the speed of the empty tire? Explain your answer.

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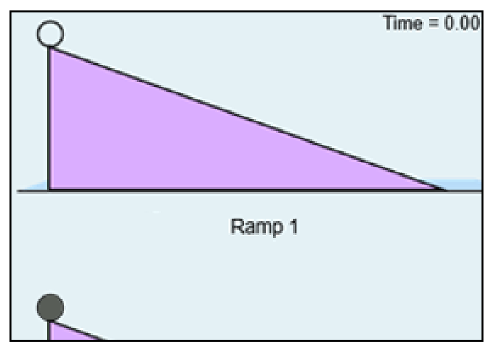
Gizmo Warm-up
Do all round objects roll at the same rate, or does their distribution of mass make a difference? You can explore this question with the *Inclined Plane – Rolling Objects* Gizmo.



On **Ramp 1**, select a **Ring** of **Steel** on a **Frictionless** ramp. On **Ramp 2**, select a **Disk** of **Steel** on a **Frictionless** ramp. Check that each ramp has an **Angle** of 20°.

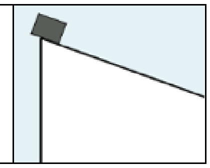
1. Click **Play** ( ).What was the result of the race to the bottom? ______________________

2. On a frictionless ramp, neither object will roll. Instead, they will slide. Click **Reset** ( ), and change the material of each ramp to **Wood**. Click **Play**.

   Which object wins the race this time? _________________

3. Which object is similar to an empty tire? _________________

   Which is similar to a tire with a person inside of it? _________________

Activity A: **Ring vs. block**	Get the Gizmo ready: • Click **Reset**. • For **Ramp 1**, choose a **Block** of **Steel** on an **Ice** ramp. • For **Ramp 2**, choose a **Ring** of **Steel** on an **Ice** ramp.	

Introduction: A sliding object has a type of kinetic energy, called **translational kinetic energy**, which is equal to half the object's mass multiplied by the square of its velocity. A rotating object, such as a spinning top, has a different type of kinetic energy, called **rotational kinetic energy**. A rolling object has both translational and rotational kinetic energy.

Question: How is potential energy converted to kinetic energy for a rolling object?

1. Predict: Which object do you think will reach the bottom of the ramp first? _______________

   Explain your choice: ____

2. Observe: Click **Play**. Which object reached the bottom first? __________________________

   How did the motion of the ring differ from that of the block? ___________________________

3. Record: Select the ENERGY tab and turn on **Show values**. Complete the table below.

Object	*KE* (translational)	*KE* (rotational)	Energy lost
Block			
Ring			

4. Analyze: Compare the energy distribution of each object at the bottom of the ramp.

   A. Which object lost more energy to friction? ________________

   B. Which object had more translational kinetic energy at the bottom? ________________

   C. If the ring lost so much less energy to friction than the block, why did it lose the race?

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5. Investigate: Does the angle of the ramp affect the results of a race between the block and the ring? Use the Gizmo to find out. Describe the results of your investigation below.

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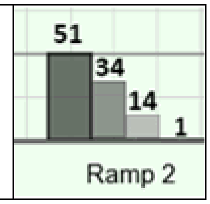
Activity B: **The fastest rollers**	Get the Gizmo ready: • Click **Reset**. • For **Ramp 1**, choose a **Disk** of **Steel** on an **Ice** ramp. • For **Ramp 2**, choose a **Ball** of **Steel** on an **Ice** ramp. • Set the **Angle** of both ramps to 20°.	

Introduction: In activity A, you discovered that a ring can lose a race with a block because much of its potential energy is converted to rotational kinetic energy rather than translational kinetic energy. In this activity, you will compare the translational and rotational kinetic energies for a variety of rolling objects.

Question: What are the fastest rolling objects?

1. Predict: The Gizmo allows you to experiment with a disk, a ring, a solid ball, and a hollow sphere. Predict which will be the slowest and fastest objects by ranking them below.

   Slowest __________ __________ __________ __________ Fastest

2. Experiment: Use the Gizmo to find the actual order:

   Slowest __________ __________ __________ __________ Fastest

3. Gather data: For each object, list the percentage of potential energy that was converted to translational kinetic energy, converted to rotational kinetic energy, and lost to friction.

Object	*KE* (translational)	*KE* (rotational)	Energy lost
Disk			
Ring			
Solid ball			
Hollow sphere			

4. Analyze: Look at the results in the data table and from your racing experiment.

   A. How does the final percentage of translational kinetic energy relate to the speed of the object? ____

   B. In general, which rolls faster, hollow objects like the ring and sphere or solid objects like the disk and ball? ____________________________________

   C. Why do you think this is the case? ______________________________

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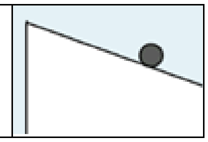
Activity C: **Moment of inertia**	Get the Gizmo ready: • For **Ramp 1**, choose a **Disk** of **Steel** on an **Ice** ramp. • For **Ramp 2**, choose **None**.	

Introduction: The **moment of inertia** (*I*) of an object is a value that represents the object's resistance to rotating. The moment of inertia for many objects is given by the formula:

$$I = kmr^2$$

In this formula, *m* is the mass, *r* is the radius, and *k* is a constant that represents how far the mass is distributed away from the axis of rotation.

Question: How does an object's distribution of mass relate to how fast it rolls?

1. Calculate: The value of *k* for a rolling object can be found by determining the ratio of its rotational kinetic energy (*RKE*) to its translational kinetic energy (*TKE*):

$$k = \frac{RKE}{TKE}$$

   Calculate the value of *k* for each rolling object in the Gizmo. (Note: You can use the data you collected for each object in activity B, or collect new data.)

   Disk: ___________ Ring: ___________ Ball: ___________ Sphere: ___________

2. Analyze: Look at the moment of inertia equation, the values of *k* listed above, and the results of the races between objects in activity B.

   A. How do you think the value of *k* relates to the moment of inertia for each object?

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   B. How does the value of *k* affect how fast each object rolls? ______________________

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3. Find a pattern: Suppose a ring and a disk have the same mass and radius.

   A. Which object has its mass distributed as far as possible from the axis of rotation?

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   B. Which object has a greater moment of inertia? ______________________________

   C. Which object will roll down a ramp most quickly? ____________________________

(Activity C continued on next page)

Activity C (continued from previous page)

4. Make a rule: In general, how does the distribution of mass affect the moment of inertia, the translational kinetic energy, and the speed of a rolling object? Explain your rule in detail.

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5. Explain: Why does a solid ball roll faster than a hollow sphere? _______________________

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6. Challenge: Suppose two rings are at the top of a ramp. The rings have the same mass, but one ring has a much larger radius than the other. Which ring will win the race to the bottom, and why? (Hint: Consider the potential energy, translational kinetic energy, and rotational kinetic energy of each ring.)

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