UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

Unit 8
Rotational Motion

UEQ: How can rotational motion be described, measured, and quantified?

VOCABULARY

- **Radians**
- **Angular Displacement**
- **Angular Velocity**
- **Angular Acceleration**
- **Frequency**
- **Period**
- **Axis of Rotation**
- **Moment Arm**
- **Torque**
- **Right-Hand Rule**
- **Static Equilibrium**
- **Cantilever**
- **Stable Equilibrium**
- **Unstable Equilibrium**
- **Neutral Equilibrium**
- **Moment of Inertia**
- **Rotational Inertia**
- **Rotational Kinetic Energy**
- **Angular Momentum**

UEQ(s): †How can rotational motion be described in a measurable and quantitative way?; †What factors affect changes in an object's rotational motion?; †How does an object's mass distribution, interaction with other objects, and force at a distance influence the object's motion?

LESSON 6

Rotational Kinetic Energy

UEQ(s): †How can rotational motion be described in a measurable and quantitative way?; †What factors affect changes in an object's rotational motion?; †How does an object's mass distribution, interaction with other objects, and force at a distance influence the object's motion?

TIMED ENDURANCE TRAINING 8.6.0

- **Substitute** $v = r\omega$ **directly into:**

$$K = \tfrac{1}{2}mv^2$$

- **Solution:**

$$\boxed{K = \tfrac{1}{2}mr^2\omega^2}$$

UEQ(s): †How can rotational motion be described in a measurable and quantitative way?; †What factors affect changes in an object's rotational motion?; †How does an object's mass distribution, interaction with other objects, and force at a distance influence the object's motion?

TIMED ENDURANCE TRAINING 8.6.1

- **Substitute** $I = mr^2$ **directly into:**

$$K = \tfrac{1}{2}mr^2\omega^2$$

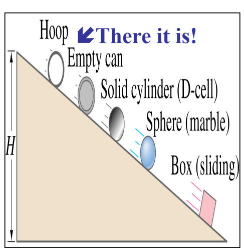
- **Solution:**

$$\boxed{K = \tfrac{1}{2}I\omega^2}$$

Rotational Motion: Rotational Kinetic Energy

EQ(s): **How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?**

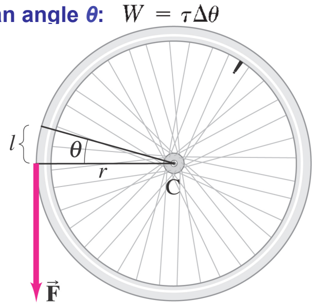
Start: **If you were rolling objects down a hill, what shape would win? Does an increase in mass change its final speed?**



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

8-7 Rotational Kinetic Energy

The torque does **work** as it moves the wheel through an angle θ: $W = \tau\Delta\theta$ (8-17)



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

8-7 Rotational Kinetic Energy

The **kinetic energy** of a rotating object is given by $\text{KE} = \Sigma\left(\frac{1}{2}mv^2\right)$

By substituting the rotational quantities, we find that the rotational kinetic energy can be written:

$$\text{rotational KE} = \frac{1}{2}I\omega^2 \quad (8\text{-}15)$$

An object that has both **translational** and **rotational** motion also has both translational and rotational **kinetic energy**:

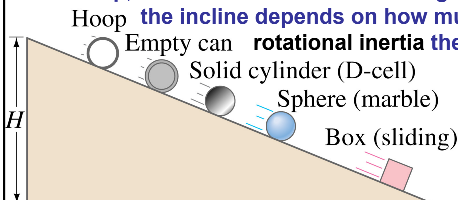
$$\text{KE} = \frac{1}{2}Mv_{CM}^2 + \frac{1}{2}I_{CM}\omega^2 \quad (8\text{-}16)$$

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

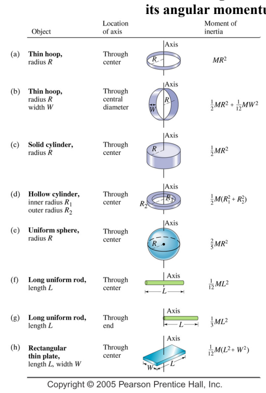
8-7 Rotational Kinetic Energy

When using **conservation** of energy, both **rotational** and **translational** kinetic energy must be taken into account.

All these objects have the same **potential** energy at the top, but the time it takes them to get down the incline depends on how much **rotational inertia** they have.



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?



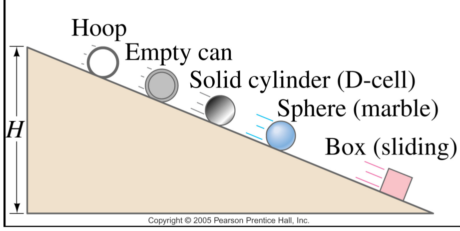
8-5 Rotational Dynamics; Torque and Rotational Inertia

The **rotational inertia** of an object depends not only on its **mass distribution** but also the location of the **axis** of rotation – compare (f) and (g), for example.

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

Demonstration

Which one makes it to the bottom faster?



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

Practice Problem

What is the final velocity of each of the following?

Which one makes it to the bottom faster?

Does the mass affect the acceleration?

Does the radius affect the acceleration?

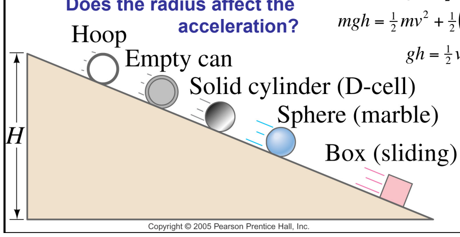
$$PE_{top} = KE_{bottom}$$

$$mgh = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2$$

$$mgh = \tfrac{1}{2}mv^2 + \tfrac{1}{2}\left(nmr^2\right)\left(\tfrac{v}{r}\right)^2$$

$$gh = \tfrac{1}{2}v^2 + n\left(\tfrac{1}{2}v^2\right)$$

$$\boxed{v = \sqrt{\tfrac{2gh}{1+n}}}$$



How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

2x4 Derby Competition

- Important Criteria:
  - Bearings are NOT Allowed
  - Maximum Mass: 1050 g
  - Maximum L x W x H Dimensions: 12” x 8” x 8” (20.35 cm x 15.25 cm x 7.65 cm)
  - The Wheels must be altered from their original design to increase the angular acceleration (and to beat Mr. Roe’s modified car).

- You are allowed to modify the wheels, axles, and body. In fact, it is expected!
- SAFETY: Goggles must be worn!

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

2x4 DERBY REPORT

•*One Report for each group of no more than 4 people.

•Refer to the Laboratory Report Expectations Handout.

UEQ(s): †How can rotational motion be described in a measurable and quantitative way?; †What factors affect changes in an object's rotational motion?; †How does an object's mass distribution, interaction with other objects, and force at a distance influence the object's motion?

2x4 Derby RACE DAY

- Competition Grading Criteria:
  - Passing Score (70%): Your car must beat Mr. Roe’s unmodified car’s time
  - A (93% – 100%): Your Wheels must be altered from their original design to increase the angular acceleration (and it must beat Mr. Roe’s modified car’s time).

- Report Grading Criteria:
  - Refer to the Handout for the Facets of Understanding Criteria
- SAFETY: Goggles must be worn!

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

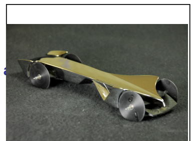
WebAssign/Lab Time

- Work on WebAssign PIM Ch.08F – Rotational Energy Problems or the 2x4 Derby Lab Report
- Final Copy Criteria
  - State the problem (Ex. Find displacement)
  - Draw a picture/diagram
  - Provide a list or table of all given data (Ex. $\Delta t = 2$ s)
  - Solve the problem symbolically (Ex. $v=\Delta x/\Delta t \rightarrow \Delta x = v\Delta t$)
  - Plug in numbers and units to obtain answer. (Ex. $\Delta x = (5 \text{ m/s})(2 \text{ s}) = 10$ m)
- Notes about WebAssign:
  - Positive vs. negative answers (Try a negative sign)
  - Look at the final unit (hours or minutes or seconds)

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

Summary

- Answer the Essential Questions.
- Ticket out the Door:
  - Rank the following objects in terms of their final velocities (from the fastest to the slowest) as they descend down a slope: Thin hoop, solid sphere, solid disk, a hollow sphere
  - Explain your ranking in terms of mass, radius and mass distribution.
  - Draw a picture of an object that would travel faster than all of the above choices.



- HW:
  - WebAssign PIM Ch.08F – Rotational Energy Problems
  - 2x4 Derby Lab Report (Questions and Conclusions)

How can rotational inertia and angular velocity of an object be represented in terms of its angular momentum and kinetic energy?

A VERY CURIOUS CASE: The Soda Can

$$PE_{top} = KE_{bottom}$$

$$m_{soda\ can}gh = \tfrac{1}{2}m_{soda}v^2 + \tfrac{1}{2}I_{can}\omega_c^2$$

$$m_{tot}gh = \tfrac{1}{2}m_s v^2 + \tfrac{1}{2}\left(m_c r_c^2\right)\left(\tfrac{v}{r_c}\right)^2$$

$$m_{tot}gh = \tfrac{1}{2}m_s v^2 + \tfrac{1}{2}m_c v^2$$

$$m_{tot}gh = \tfrac{1}{2}v^2\left(m_s + m_c\right)$$

Note that $m_{tot} = m_s + m_c$, therefore

$$\cancel{m_{tot}}\,gh = \tfrac{1}{2}v^2\left(\cancel{m_s + m_c}\right)$$

$$\boxed{v = \sqrt{2gh}}$$