Minds•On Physics Activity

AT•21

Identifying Energy in Rotational Systems

Purpose and Expected Outcome

This is the sixth in a series of activities about rotational motion. We have covered rotational kinematics and dynamics. In this activity, you will learn about the energy in rotating systems, and its similarities and differences with forms of energy you have learned about already.

Prior Experience / Knowledge Needed

You should know linear kinematics, linear dynamics, and Conservation of Energy applied to non-rotating systems. You should know the definitions of work, kinetic energy, and potential energy.

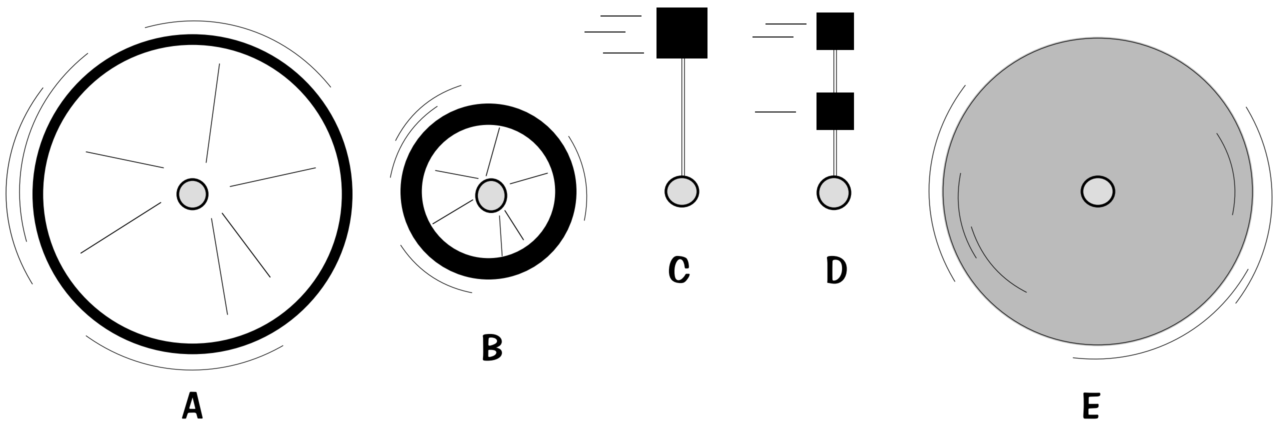
You should be familiar with rotational kinematics and rotational dynamics. You should be familiar with rotational quantities, such as angular position, angular velocity, angular acceleration, torque, and moment of inertia.

Explanation of Activity

There are two parts in this activity.

PART A: Comparing the Kinetic Energy in Different Situations

Consider the five arrangements of mass shown below. All five have the same total mass M. Arrangements A and E have the same radius R, but in A, the mass is concentrated at the rim, while in E, the mass is uniformly distributed. Arrangement B is also a wheel, but its radius is half that of A and E. Arrangement C is a mass M attached a distance R from the pivot, and arrangement D has two masses (each $\frac{1}{2}M$) spinning as shown. All five arrangements are spinning with the same angular velocity ω.



Use what you <u>already know</u> about kinetic energy to reason out your responses.

A1. Which arrangement has the larger kinetic energy, A or B? Explain.

A2. Which has the larger kinetic energy, A or C? Explain.

A3. Which has the larger kinetic energy, A or D? Explain.

A4. Which has the larger kinetic energy, A or E? Explain.

A5. Which arrangement has the largest kinetic energy? Explain.

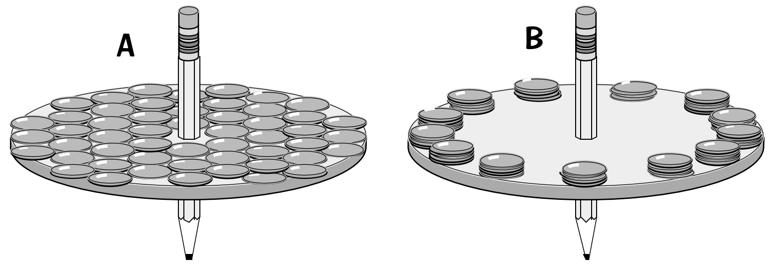
A6. Which arrangement has the smallest kinetic energy? Explain.

A7. Put the five arrangements in order of their kinetic energies, from smallest to largest. Explain your reasoning.

PART B: Analyzing More Situations

Answer the following questions about the energy in various situations.

B1. Imagine two different arrangements of the same materials. Coins are securely attached to a cardboard disk, and a pencil is poked through its center. The same number of coins is used for each, but in A, the coins are spread evenly over the cardboard, and in B, the coins are stacked near the outer edge. Which disk has more energy when it has an angular speed of 2π rad/s? Explain.



B2. Two identical wheels are spinning, but wheel A is spinning twice as fast as the other (B).

(a) Which wheel has more kinetic energy? Explain.

(b) By what factor does this wheel have more kinetic energy? Explain.

B3. Nickels (5 grams each) are securely attached to a light piece of cardboard as shown in the scale drawing below. The arrangement spins around its center at 2 revolutions per second.

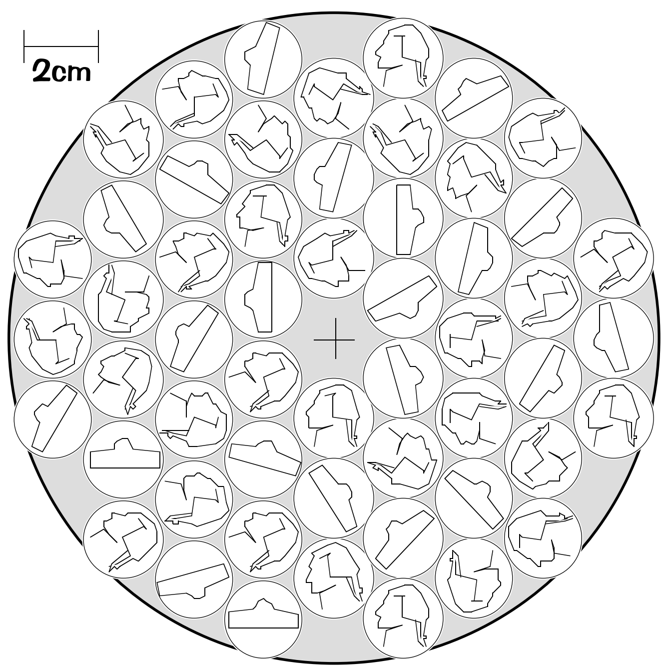
(a) What is the total mass of the arrangement?

(b) Estimate the kinetic energy of one of the outermost nickels. Explain your estimate.

(c) Estimate the kinetic energy of one of the innermost nickels. Explain your estimate.

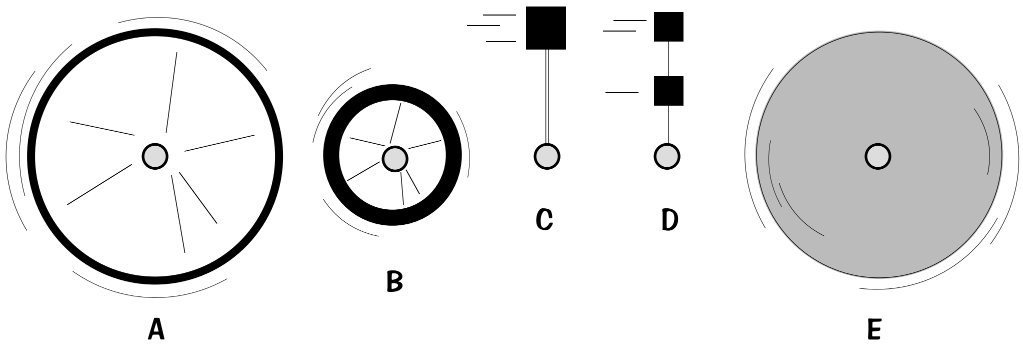
(d) Estimate the total kinetic energy of the arrangement.

(e) If the arrangement were spinning only half as fast, by what factor would the kinetic energy change? Explain.



Reflection

R1. Reconsider the situations used for part A, in which 5 different arrangements of mass are spinning at the same rate ω.



(a) Of A and E, which arrangement has the larger mass? Explain.

(b) Of A and E, which has the larger moment of inertia? Explain.

(c) Of A and E, which requires the larger torque about its center to keep it spinning? Explain.

(d) Of A and E, which has the larger kinetic energy? Explain.

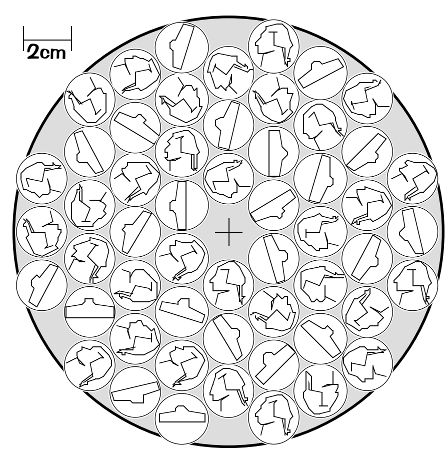
R2. The front wheel of a standard mountain bike is about 26 inches (about 66cm) in diameter and has a weight of about $3^1/_2$lb (mass about 1600g).

(a) Estimate the wheel's moment of inertia about its center.

(b) How much energy is needed to get the wheel spinning at 2rev/s?

R3. What features of a rigid object determine its total kinetic energy?

R4. Reconsider situation B3, in which nickels are attached to a piece of cardboard and the arrangement is spun through its center at 2 revolutions per second.



(a) How many nickels are there in the arrangement?

Imagine making a list consisting of the kinetic energy of each individual nickel.

(b) How many unique values for the kinetic energy would there be in your list? Explain how you determined this number.

(b) How many nickels have the smallest kinetic energy? Which ones?

(c) How many nickels have the largest kinetic energy? Which ones?