

Rotational Motion Test

Multiple Choice:

Write the letter that best answers the question. Each question is worth 2pts.

_____ 1. Angular momentum is:

- A.) The sum of moment of inertia and angular velocity
- B.) The square root of angular velocity
- C.) The difference of angular velocity and momentum
- D.) The product of moment of inertia and angular velocity
- E.) The square root of the moment of inertia

Answer: D

_____ 2. The units for moment of inertia are _____.

- A.) N
- B.) $\text{Kg} * \text{m}^2$
- C.) $\text{Kg}^2 * \text{m}$
- D.) Kg/m
- E.) $\text{Kg} * \text{N}^2$

Answer: B

_____ 3. What is the symbol for angular momentum?

- A.) N
- B.) A
- C.) L
- D.) F
- E.) M

Answer: C

_____ 3. Which equation should be used for the moment of inertia of a ring about an axis?

- A.) $\frac{1}{12} M \cdot R^2$
- B.) $\frac{1}{2} M \cdot R^2$
- C.) $M \cdot R$
- D.) $\frac{1}{2} M \cdot R$
- E.) $M \cdot R^2$

Answer: E

_____ 4. An ice skater is spinning fast with her arms tight against her body. When she extends her arms, which of the following statements is not true?

- A.) She increases her moment of inertia.
- B.) She decreases her angular velocity.
- C.) Her moment of inertia remains constant.
- D.) Her total angular momentum will remain constant.
- E.) She will spin slower.

Answer: C

_____ 5. What does the moment of inertia describe?

- A.) The average position of mass in an extended object.
- B.) How the mass of an object is distributed about a rotational axis.
- C.) How a force can rotate an object.
- D.) The tendency of an object to move in a straight line.
- E.) The linear acceleration of an object.

Answer: B

_____ 6. A carousel with radius r is initially at rest. The carousel begins to accelerate to constantly until it reaches an angular velocity of ω , which takes two revolutions. What is the angular acceleration of the carousel during this time?

- A.) $\frac{\omega^2}{8\pi}$
- B.) $\frac{\omega^2}{4\pi}$
- C.) $\frac{\omega}{4\pi}$
- D.) $\frac{\omega}{8\pi}$
- E.) $\frac{\omega^2}{16\pi}$

Answer: A

_____ 7. A disc rotates through 10 radians in 4 seconds. The disc experienced uniform acceleration. If the disc starts from rest, what is the angular velocity after four seconds?

- A.) 2.5 rad/s
- B.) 5 rad/s
- C.) 40 rad/s
- D.) 3 rad/s
- E.) 42 rad/s

Answer: B

_____ 8. A 1000 N car skids on a wet concrete road. If the road is horizontal, what is the friction force on the car?

- A.) 1000 N
- B.) 2.8×10^2 N
- C.) 5.8×10^2 N
- D.) 500 N
- E.) 6.0×10^2 N

Answer: C

_____ 9. A 53 kg model car slowed by friction, has an acceleration of -0.10 m/s^2 .
What is the force of friction on the model car?

- A.) -53 N
- B.) -530 N
- C.) -0.53 N
- D.) -0.053N
- E.) -5.3 N

Answer: E

_____ 10. Which would be harder to stop, a moving bowling ball, or a moving baseball?

- A.) The bowling ball.
- B.) The baseball.
- C.) Both objects are difficult to stop.
- D.) Depends on the velocity of each object.
- E.) Neither object is difficult to stop.

Answer: D

True/False:

*Read the statement completely and determine if the statement is true or false.
In the blank provided, write "True" for a true statement and "False" for a false statement. Each True/False question is worth 3 points.*

False 1. Newton's First Law does not apply to rotating objects.

False 2. Rotational inertia depends on the force of gravity.

True 3. According to the Law of Inertia, rotating objects tend to keep rotating.

False 4. Rotational motion is always constant.

True 5. Any moving object has momentum.

Short Answer:

Write 3-5 complete sentences to fully answer the prompts below.

1. A coin and a ring, each having the same mass and radius are placed at the top of an incline. If both objects are released at the same time, which object will reach the bottom of the incline first? Why? (10 pts.)

Answer: The coin will reach the bottom first because it has a smaller moment of inertia due to the distribution of the mass. Moment of inertia inhibits movement.

2. A cylinder is rolling without slipping down an incline plane. Describe the friction at the point where the cylinder contacts the incline plane. (15 pts.)

Answer: The friction at the contact point is static and points up the inclined plane. This friction produces a torque about the center of mass that points into the plane of the figure.

Essay:

Choose one of the following prompts to write about. Be sure to organize your thoughts in a logical order and write in complete sentence. You may use the back of the test if you need more space for your response. (20 pts.)

1. A skater spins in the counterclockwise direction, as seen from above. In what direction does the vector representing the angular momentum of the skater point? Why?
2. A child jumps on a rotating merry-go-round. The angular velocity increases as the child moves closer to the center. Finally, the merry-go-round stops due to friction. How can we apply the Law of Conservation of Angular Momentum in this case?

Answer:

1. To find the direction of the angular momentum one must use the right hand rule in the same way it is used for angular velocity. For a rotating object, if the right-hand fingers follow the curve of a point on the object, then the thumb points along the axis of rotation in the direction of the angular velocity vector. Thus, if one looks down on the skater, and curls their fingers around in the counterclockwise direction, one's thumb points up. Thus the angular momentum of the skater is pointing upwards.
2. The Law of Conservation of Angular Momentum states that for a collision occurring between object 1 and object 2 in an isolated system, the total momentum of the two objects before the collision is equal to the total momentum of the two objects after the collision. The angular momentum of the merry-go-round plus person has changed when things come to a stop. The missing angular momentum must have been transferred to the Earth as a whole, which will then spin a tiny bit differently. However, that transfer occurs slowly. On a shorter time scale, the merry-go-round and person's combined angular momentum is approximately. So when the person moves toward the middle, lowering the moment of inertia, the angular speed must go up to keep the product constant.

Demonstration of the Content:

- SWAT make calculations using the equations for moment of inertia, angular momentum, and angular velocity.
- SWAT recognize various types of cylinders and the appropriate moment of inertia equations that coincide with each object.
- SWAT describe and analyze the interactions between objects and the relationships to the Law of Conservation of Momentum.
- SWAT provide units and correct symbols for friction, moment of inertia, angular velocity, angular acceleration, and angular momentum.

Essential Questions:

1. How does the moment of inertia of a car differ with the design of the wheel?
2. What factors influence a wheel to undergo a rolling with slipping condition?
3. How does the angular momentum of a wheel vary based on the diameter?

Knows:

- Moment of inertia for a wheel with spokes (I=Moment of Inertia, R=radius, M=mass)

$$I = MR^2$$

- Moment of inertia for a solid tire (I=Moment of Inertia, R=radius, M=mass)

$$I = \frac{1}{2}MR^2$$

- *Moment of Inertia*-measure of inertial resistance of the object to change in its rotational motion about the axis.
- Units for moment of inertia
- An object slips while rolling when, $V_{cm} \neq R\omega$. Kinetic friction takes over until $V_{cm} = R\omega$ and rolling friction takes place.
- Rolling with slipping involves only translational motion
- Applying brakes to the wheels of a car, or sliding on an icy surface result in rolling with slipping
- Use the following equation to calculate the time the cars will experience rolling with slipping.

$$\omega = \frac{\mu_k g t}{R}$$

- Use the following equation to calculate the distance the car will travel during time period.

$$\Delta x = v_o + \frac{1}{2}at^2$$

- Use the following equation to solve for the angular momentum of a system rotating about an axis of symmetry.

$$\vec{L} = I\vec{\omega}$$

- Law of Conservation of Angular Momentum: If the net external torque acting on a system about some point is zero, the total angular momentum of the system about that point remains constant.
- Direction of the angular momentum by using the right-hand rule

$$\vec{L} = \vec{r} \times \vec{p}$$

- Units for angular momentum

Dos:

- Research the mass of a spoke wheel and a modern tire
- Measure the radius of a spoke wheel and a modern tire
- Compare the moment of inertia between the spoke wheel and a modern tire
- Calculate the time and distance both an antique and a modern car would travel with slipping once applying the brakes
- Compare the stopping time and distance between the two cars
- Research the mass of an antique car
- Research the mass of a modern car
- Calculate the angular momentum of a spoke wheel and a modern tire.
- Compare the angular momentum between the two tires

Previous Knowledge:

- Calculating the radius given the diameter
- Definition of inertia, axis of rotation
- Units for mass, distance, and moment of inertia
- Definition of friction, angular velocity

- Know the symbol for angular velocity
- Solving an equation for an unknown variable
- Using substitution to solve for a variable
- The importance of vectors
- Labeling a vector vs. a scalar quantity
- Cross product of two vectors

Standards:

3.2.12.B1:

- Analyze the principles of rotational motion to solve problems relating to angular momentum and torque.

3.2.10.B1:

- Analyze the relationships among the net forces acting on a body, the **mass** of the body, and the resulting acceleration using Newton's Second Law of Motion.
- Apply Newton's Law of Universal Gravitation to the forces between two objects.
- Use Newton's Third Law to explain forces as interactions between bodies.
- Describe how interactions between objects conserve momentum.

3.2.10.B7:

- Compare and contrast scientific theories.
- Know that both direct and indirect observations are used by scientists to study the natural world and universe.
- Identify questions and concepts that guide scientific investigations.
- Formulate and revise explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.

Performance Tasks

1. Using your knowledge of rotational motion, develop a wheel that would minimize rotation inertia. Write a 1-2 page paper about some concerns you would have about applying this wheel to a car.
2. Toyota would like to change their wheel design to spoke wheels. Write a persuasive essay for or against this decision.

Benchmarks:

- The students will test two different cylinders of the same mass, but of a different mass distribution. They will make predictions as to which cylinder will reach the bottom of an incline plane first due to a lower moment of inertia.
- The students will work with their lab partners to discuss the factors that influence the conditions of both rolling and slipping friction. Each group will share their response with the class.
- After measuring the diameter of several different wheels, the students will use this to calculate the angular momentum. They will then graph angular momentum as a function of time and describe the correlation.
- The students will use these equations to solve for the moment of inertia for various wheel designs. They will then use this calculated data to compare and contrast antique and modern cars. The students will have to explain their results based on their calculations.
- Individually, the students will be asked to draw a picture representing the moment of inertia. The students will also be asked to draw a cartoon representing the Law of Conservation of Momentum. Both drawings will be presented to the class.
- In small groups, the students will work together to solve for the units of the moment of inertia and angular momentum. They must show the use of dimensional analysis and proper metric conversions. Each group will submit their work for a grade.
- Individually, the students will be given a specific situation about a car traveling on a wet highway. They will have to explain the two possible outcomes that could occur once the brakes are applied.

- The students will need to be able to show equation substitution and solving for an unknown variable using these three equations. Each group will present one set of data to the class. The other calculations will be turned in for a grade.
- The students will physically measure the wheel using a meter stick. They will measure the inner and outer diameters of both an antique and a modern car wheel. The students will record their measurements in a data table and measure to the nearest 0.001m.
- The students will have to calculate the stopping time and displacement of the car by using the data they have collected. All data will be entered into an Excel sheet for grading.
- The students will use substitution to calculate the angular momentum of the tires. Each lab group will display their work on the front board for critique.
- Using a Venn Diagram, the students will compare and contrast the spoke wheel and the modern tire.
- The students will gather data and use their data in multiple equations. The students will develop a chart to organize the information between the two time periods. This information will be referenced throughout the unit.
- Individually, the students will draw an example of how momentum is conserved according to the Law of Conservation of Momentum. The students will share their response with their table partners and during class discussion.
- The students will be asked to make a hypothesis as to which car they think will have the greatest moment of inertia. They must include the definition of the moment of inertia in their response. After the lab, the students will develop a conclusion and revise their previous hypothesis.

Lesson 1:

Topic Rotational Motion Class 10th Grade Physics

Date 10/23

Essential Questions: What is the moment of inertia?

Objectives: SWAT use the appropriate equations to solve for the moment of inertia of various objects. SWAT measure and calculate the moment of inertia of various wheels.

Standards:

3.2.10.B1:

- Analyze the relationships among the net forces acting on a body, the mass of the body, and the resulting acceleration using Newton's Second Law of Motion.
- Apply Newton's Law of Universal Gravitation to the forces between two objects.
- Use Newton's Third Law to explain forces as interactions between bodies.
- Describe how interactions between objects conserve momentum.

Activating Strategy:

Journal Activity: What are the units for moment of inertia? (Hint: Use the equation for moment of inertia)

Demonstration: Two cylinders with the same mass and radius will be rolled down an incline. The distribution of the mass is different between the two cylinders. Students are asked to make a prediction as to which cylinder will reach the bottom on the incline first.

Game Plan: Step-by-Step

- As a class, show how to solve for the units of moment of inertia.
- Think/Pair/Share about the predictions for the demonstration.
- Discuss what equation for measuring moment of inertia should be used for a wheel.
- I Do, You Do, We Do-Practice measuring the moment of inertia of a sample wheel as a class. The students may then work with a partner to measure the second wheel. The third wheel they will be required to measure on their own.

Summarizing Strategy

- Ask the class: Why the solid cylinder reached the bottom of the incline first?
- Ticket Out: Write down the definition for moment of inertia.

Assessment/Assignment & Materials needed

HW: Complete the worksheet that contains the wheel diagrams. Find the moment of inertia for every wheel. Make sure the students show all of their work.

Materials: ruler, calculator, incline plane, solid cylinder, hollow cylinder, wheel worksheet

Differentiation

- Some students will receive a small 3-D model of a wheel to measure. These students are hands-on, tactile learners, or students with disabilities.
- The students have the option on which wheel they would like to work on with a partner. They do not have to start with the second wheel. Some partners may choose to tackle a harder wheel design, while others may still need more simplistic versions.