GreatHearts®

Physics I

April 14 – April 17

Time Allotment: 40 minutes per day

Student Name: ________________________________

Teacher Name: ________________________________

Packet Overview

Date	Objective(s)	Page Number
Monday, March 23	Off	
Tuesday, March 24	Relating Rotational Inertia to Torque	2-3
Wednesday, March 25	Relating Rotational Inertia to Geometries of Objects	4-5
Thursday, March 26	Rotational Intertia Practice Problems	6-7
Friday, March 27	Rotational Inertia Lab	8-10

Additional Notes:

Khan Academy is a great online resource for physics, though this packet does not require access to the Internet. The Physics videos can help with rotational motion concepts, while the algebra and geometry videos can help with the concept of radians.

Another great resource is a YouTube channel called “Doc Schuster”. Dr. Schuster is a high school physics teacher in St. Louis who makes great video lectures with magic markers and paper. His playlist “AP Ch 10 – Rotational Motion and Energy” will be a good review of what we covered in previous packets. This week, “AP Ch 11 – Rotational Mechanics and Torque” will be helpful.

Finally, if you’re wanting to see the bigger picture and put all of these concepts together at the college level, Walter Lewin’s Freshman Physics MIT lectures are as good as they get. Dr. Lewin is so talented at engaging students and preparing exciting demos to add to the lectures. Search on YouTube for “8.01x Lect 19 Walter Lewin” to watch the beginning of his lectures on rotational motion.

Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

Student signature:

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I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

Parent signature:

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Physics I
April 14 – April 17

Tuesday, April 14

Physics Unit: Rotational Motion
Lesson 1: Rotational Inertia
Requirements: Read p. 206-207 and complete the guided worksheet below.

Week Overview

Lesson 1 Objective: Be able to do this by the end of this lesson.
1. Review rotational motion concepts from last week.
2. State the definition of rotational inertia.
3. Derive the equation for rotational inertia.
4. Relate rotational inertia to torque.

Introduction to Lesson 1
First we'll do some review of earlier sections, so feel free to flip back in your packet and textbook for help with the review section (but see how many you can do without looking first). Then we'll review what we learned in Section 8-5 and work an example problem. I hope you have fun today!

Questions to ponder:
What is rotational inertia? How is it similar to or different from inertia we learned about from Newton's *Principia*? How is it similar to or different from mass?

1. Review! We can't practice these enough. Complete the equation for each of these.

θ =

ω =

α =

2. Converting from angular to linear quantities. For each linear quantity, write what it equals in terms of its angular sibling.

l =

v =

a =

θ =

ω =

3. Write the equation for torque.

4. Write the equation for Newton's second law.

Review of Section 8-5: Rotational Dynamics; Torque and Rotational Inertia
5. Write once more the equation for tangential acceleration, a, in terms of α (Equation 8-5).

6. Plugging in the equation for tangential acceleration into Newton's second law gives what result?

7. Finally multiply both sides of the equation you wrote above by r.

8. What equation is this result? (Equation 8-11)

9. What is the mr^2 part called? What symbol do we use to represent that quantity?

10. Finally, write the equation for torque in terms of rotational inertia (Equation 8-14).

In the space below, write the question, draw the diagram, and work all steps for Example 8-10: **Two weights on a bar: different axis, different *I***.

Wednesday, April 15

Physics Unit: Rotational Motion
Lesson 2: Rotational Inertia
Requirements: Review p. 206-207. Read p. 208-209. Complete worksheet below.

Objective: Be able to do this by the end of this lesson.
1. State the definition of rotational inertia.
2. Describe its relation to torque.
3. Describe conceptually why objects with different shapes have different rotational inertia.

Introduction to Lesson 2
Now that we've had some time to think about rotational inertia in general (remember, *moment of inertia* is the same thing as rotational inertia), we will turn to wondering about how to calculate the rotational inertia of objects with different geometries. What do I mean by different geometries? Well, so far, our equation for rotational inertia is $I = mr^2$. But let's think back to how we got that equation.

1) Turn to Figure 8-18 on p. 206. Redraw the diagram and rewrite the steps that combine Newton's second law and tangential acceleration to get Equation 8-14.

2) We derived that equation for rotating a mass on a string. What is another kind of object that rotates with all of its mass distributed at its radius? Maybe draw while you think.

3) Now turn to p. 208 and give yourself a minute or two to look over Figure 8-21. If you look at object (a), the thin hoop, its moment of inertia (or rotational inertia) is mr^2, just like the mass swinging on a string. What is the moment of inertia for a solid cylinder? Why do you think it's less than a hoop?

4) In the space below, copy each column of Figure 8-12 for the thin hoop, solid cylinder, and uniform sphere only. These will be the three objects we will be working with most often.

5) Finally for today, read the steps for problem solving in the tan box on p. 209. Then write the question and work all steps for Example 8-11: A heavy pulley, also on p. 209. Draw the diagram (Figure 8-22) as you complete Step 3.

Thursday, April 16

Physics Unit: Rotational Motion
Lesson 3: Rotational Inertia
Requirements: Do Example 8-12 on p. 210. Do Problems 27-29 on p. 220.

Objective: Be able to do this by the end of this lesson.
1. Be able to solve problems involving rotational inertia

Introduction to Lesson 3
Today we are going to work on some practice problems. Remember, moment of inertia is the same thing as rotational inertia.

1) Turn to p. 210, Example 8-12: Pulley and bucket. In the space below, write down the question being asked, draw a diagram (Figure 8-23), and write down all equations and steps used to solve the problem.

Now turn to p. 220. Do Problems 27-29. For full credit, draw and label a diagram. Write out all knowns and unknowns. Write equations you will start with. Solve for unknown variables algebraically before plugging in numbers. Don't forget your units.

27)

28)

29)

Friday, April 17

Physics Unit: Rotational Motion
Lesson 4: Rotational Kinetic Energy Lab!
Requirements: Follow the steps below for the lab. Complete table on next page. Answer questions that follow.

Objectives: Be able to do this by the end of this lesson.
1. Design an experiment to observe rotational inertia.
2. Connect observations to properties (mass, radius, shape) of rotating objects.
3. Predict which properties will allow objects to roll down a plane fastest.

Introduction to Lesson 4: Today we're going to do a lab! I hope you're excited. I also hope, if possible, you ask members of your family to help you or be involved in the lab. I've done this lab with my family and we had so much fun finding different objects around the house and guessing which one will be the fastest. Also, labs are meant to be done with others. Science is a communal, collaborative project. So go get your family or find a time to get together with them to do this!

Rotational Inertia Race: Which round object will roll down a ramp the fastest and why? You are going to fashion a ramp and find objects around the house to roll down the ramp. What does rotational inertia have to do with the speed objects can achieve? Does it depend on the object's mass? radius? shape?

Materials
- ruler (or measuring device that has metric units)
- scale (if you have one)
- 5 to 6 round objects. Make sure objects have varying masses and radii. Also make sure some objects are hooplike, hollow on the inside, or solid on the inside. When I say solid on the inside, I mean solid like a battery or play-doh or a can of jellied cranberry sauce (see above), not like a can of peas or coconut

milk. Anything that sloshes inside of a can won't work. Cardboard tubes, rolls of tape, and empty cans will work great for hollow cylinders and hoops. Don't forget to add a spherical object or two (marbles, tennis balls, etc.). Lastly, find an interesting object or two that fits these parameters, something no one else might think of.

- Some inclined, hard, flat surface. Get creative with this. Your ramp can look like the photo on the previous page, or if you find something around the house that works better, go for it.
- If you're really proud of your set-up and want to send me pictures or videos of you and your family having fun with the lab, please send them my way. I believe you can also email your photos to chris.ewing@greatheartsnorthernoaks.org to put them on our school Instagram page if you want.

Procedure

1. Fill out the table below (Figure 8-21 on p. 208 should help). Make extra rows if you find more objects to race.
2. Roll objects down ramp two or more at a time. Before each roll, guess which one will win and discuss with your family why you think so.
3. Design enough races so that you find an overall winner and then rank all your objects from fastest to slowest.
4. Answer all questions that follow when you've ranked all of your objects.
5. Make sure you are having fun!

Object	Sketch of Object's Geometry	Mass	Radius	Moment of Inertia	Finish Rank

1) Which object was the fastest? Which was the slowest?

2) Did the object with the greatest radius win? Why or why not?

3) Did the object with the greatest mass win? Why or why not?

4) Did the object with the greatest moment of inertia win? Why or why not?

5) Was there one particular shape that rolled faster than others? Which shape rolled the slowest? Why might that be the case?

6) What do you think is the single most important factor in determining whether an object will win the race? If you can, try to find two objects with similar masses but different radii, two with similar radii but different masses, etc. to rule out whether mass or radius or shape is the most important factor.

This is not required, but after you finish, if you search for "Walter Lewin demonstrates moment of inertia" on YouTube, you will see a nice video demonstration of this lab.

Hope you enjoyed today and have a great weekend!

Solutions to Problems

27)

The moment of inertia of a solid sphere about an axis through its center of mass is

$$I_{CM} = \frac{2}{5}MR^2,$$

Where M is the total distributed mass and R is the radius of the sphere.

We are given that the mass of sphere $(M) = 10.8\ kg$ and the radius of sphere $(R) = 0.648\,m$.

The Moment of inertial of sphere when the axis of rotation is through its center.

$$I = \frac{2}{5}MR^2$$

$$I = \frac{2}{5}(10.8\,\text{kg})(0.648\,\text{m})^2$$

$$= 1.81\,\text{kg}\,\text{m}^2$$

Moment of Inertia $\boxed{I = 1.81\,\text{kg}\,\text{m}^2}$

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28)

Calculate the moment of inertia of the bicycle wheel.

The equation for the radius of the wheel is,

$$r = \frac{D}{2}$$

Here, *D* is the diameter of the wheel.

Substitute 66.7 cm for *D* in above equation.

$$r = \frac{66.7\text{ cm}\left(\frac{10^{-2}\text{ m}}{1\text{ cm}}\right)}{2}$$
$$= 0.3335\text{ m}$$

The equation for the moment of inertia of the bicycle wheel is,

$$I = Mr^2$$

Here, *M* is the combined mass of the rim and tire, and *r* is the radius of the wheel.

According to the question, the mass of the hub can be ignored.

Substitute 1.25 kg for *M* and 0.335 m for *r* in above equation.

$$I = (1.25\text{ kg})(0.3335\text{ m})^2$$
$$= 0.139\text{ kg}\cdot\text{m}^2$$

Therefore, the moment of inertia of a bicycle wheel is $\boxed{0.139\text{ kg}\cdot\text{m}^2}$.

29)

(A) Mass of ball $(M) = 0.650\ kg$

Radius of circle $(r) = 1.2\,m$

Moment of inertia of ball about centre of circle $I = MR^2$

$= [0.650 \times (1.2)^2]\,kgm^2$

$= \boxed{0.936\,kgm^2}$

(B) Force exerted by air $F = 0.020N$

The torque needed to keep the ball rotating $\tau = F \times$ Radius of circle

$= (0.020 \times 1.2)Nm$

$= 0.024\,Nm$

Torque $\boxed{\tau = 2.4 \times 10^{-2}\ N\,m}$