

Physics I

April 20 – April 23

Time Allotment: 40 minutes per day

Student Name: _____

Teacher Name: _____

Packet Overview

Date	Objective(s)	Page Number
Monday, April 20	Introduction to Rotational Kinetic Energy	2-4
Tuesday, April 21	Examples of Rotational Kinetic Energy: Rolling plus translation	5-6
Wednesday, April 22	1. More Rotational Kinetic Energy Examples 2. Work Done By Torque	7-9
Thursday, April 23	Rotational Kinetic Energy Quiz	10-11
Friday, April 24	Off	

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:

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

Parent signature:

Monday, April 20

Physics Unit: Rotational Motion

Lesson 1: Rotational Kinetic Energy

Requirements: Read p. 210-211 and complete the guided worksheet below.

Week Overview

This week we are going to wrap up our unit on rotational motion. A common theme we have seen run throughout the chapter is finding equations for rotational motion that look very similar to the equations we have already learned for linear motion (i.e. linear velocity versus angular velocity, inertia versus rotational inertia, etc.). We'll learn this week that in addition to the list of angular quantities we already have, there is such a thing as rotational kinetic energy whose equation looks similar to the equation for kinetic energy, as well as angular momentum, whose equation looks similar to the one we already learned for linear momentum. The question to ponder for this week is do Newton's laws and the laws of conservation of energy apply to objects that are rotating?

Lesson 1 Objective: Be able to do this by the end of this lesson.

1. Review rotational motion concepts from last week.
2. Define rotational kinetic energy. Derive its equation.
3. Show that objects that are simultaneously translating and rolling have both kinetic energy and rotational kinetic energy.

Introduction to Lesson 1

First we'll do some review of earlier sections, so feel free to flip back in your textbook for help with the review section (but see how many you can do without looking first). Then we'll begin our discussion of rotational kinetic energy.

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

$$\theta =$$

$$\omega =$$

$$\alpha =$$

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

$$l =$$

$$v =$$

$$a =$$

$$\theta =$$

$\omega =$

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).

8-7 Rotational Kinetic Energy (p. 210-213)

11. The quantity _____ is the kinetic energy of an object undergoing translational motion.

12. An object rotating about an axis is said to have _____ energy.

13. By analogy with translational kinetic energy, we would expect this to be given by the expression

_____, where I is the _____ and ω is its
_____.

14. Let's prove why that is the case. Consider a rigid rotating object (like the ones you rolled down your ramp last week). Let r represent the distance of any part of the mass to the axis of rotation. What will the equation for the object's linear velocity be?

15. Substitute the equation for the object's linear velocity in terms of ω into the kinetic energy equation. Don't forget to use the Σ symbol to show we're finding the sum of the kinetic energy from all the tiny bits of mass a distance r from the axis of rotation. This will show that the total kinetic energy of the whole object will be the sum of the kinetic energies of all its particles.

16. Now write the rotational kinetic energy in terms of rotational inertia, I (Equation 8-15).

17. What are the units of rotational kinetic energy?

18. An object that rotates while its center of mass undergoes translational motion will have both _____ and _____ kinetic energies.

19. Does Equation 8-15 give you the kinetic energy of an object that only rotating, only translating, or rotating and translating?

20. If the object is rotating and translating, like when you rolled objects down your ramp last week, which equation do you use to find its kinetic energy?

21. Draw arrows to the variables in the equation you wrote above and write a short description of what each variable is.

Physics I

April 20 – April 23

3. In the space below, repeat the steps of Example 8-13 for a thin hoop. Make sure to include a diagram and all equations and steps to solving for the final velocity as well.

4. In the space below, repeat the steps of Example 8-13 for a solid cylinder. Make sure to include a diagram and all equations and steps to solving for the final velocity as well.

5. In a race down a ramp, which object would win, a thin hoop, a solid cylinder, or a sphere? Why?

6. Look back at your lab from last week. Do the velocity calculations you did above match the results you observed as you actually rolled objects down the ramp? Does the radius or mass matter?

7. Two solid cylinders roll down a ramp. Cylinder A is much more massive than Cylinder B. Which cylinder will win the race?

Wednesday, April 22

Physics Unit: Rotational Motion

Lesson 3: Rotational Kinetic Energy and Work Done By Torque

Requirements: Read p. 212-213. Complete guided worksheet below. Do Questions 12 and 13 on p. 218, and do Problems 43 and 45 on p. 221.

Objective: Be able to do this by the end of this lesson.

1. State why objects with greater rotational inertia roll more slowly down ramps than objects with lower rotational inertia.
2. State the conditions when torque does work on a system.

Introduction to Lesson 3

Today we are going to explore some consequences of rotational kinetic energy. You learned yesterday that an object rolling down a ramp can have both translational and rotational kinetic energy. What is interesting is that rotational kinetic energy does not contribute to an object moving down a ramp. In a way, given a constant amount of energy the more an object rotates, the slower it translate. Rotation slows and object down and takes away translational energy. You saw this yesterday when you calculated the final velocities of the thin hoop, solid cylinder, and sphere. Wasn't it interesting that the only factors were the geometry of the object, the height of the ramp and gravity?! We'll take another look at this today, as well as learn when torque does work.

1. Turn to p. 212. Write the entire question for Conceptual Example 8-14: Who's fastest. Answer the question, then summarize the response given in the textbook. Draw Figure 8-25.

2. Read the full paragraph on p. 212. In 3 sentences, summarize the paragraph in your own words.

3. Do rolling objects go down ramps slower than sliding objects because there is more friction? If not, what is the reason?

Work Done by Torque

4. The work done on an object rotating about a fixed axis, such as pulleys, can be written using

_____ quantities.

5. In the space below, draw and label Figure 8-27.

6. As shown in the diagram you just drew, a force F exerting a torque on a wheel does work equal to what when a wheel is rotated a small distance Δl at the application point of the force? ($W = ?$)

7. In the space below, begin with the equation you wrote above. Write the steps you need to take to end up with $W = \tau \Delta\theta$

Answer the following Questions on p. 218:

12)

13)

Work the following Problems on p. 221:

43)

45)

Thursday, April 23

Physics Unit: Rotational Motion

Lesson 4: Quiz on Rotational Kinetic Energy and Angular Momentum

Requirements: Take 10 – 15 minutes to go back through your packet and study for a quiz on the next page.

Introduction to Lesson 4: After your 10-15 minute review, get ready to demonstrate your mastery of rotational kinetic energy and angular momentum!

Physics I – Quiz on 8-7 and 8-8: Rotational Kinetic Energy

Name: _____

1. An object that rotates while its center of mass undergoes translational motion will have both _____ and _____ kinetic energies.
2. Write the equation for the kinetic energy of an object that is rotating and translating.
3. In a race down a ramp, which object would win, a thin hoop, a solid cylinder, or a sphere? Why?
4. Two solid cylinders roll down a ramp. Cylinder A has a greater radius than Cylinder B. Which cylinder will win the race?
5. Calculate the moment of inertia of a bicycle wheel 66.7 cm in diameter. The rim and tire have a combined mass of 1.25 kg.
6. You roll a hollow cylinder down a 3m high incline. How fast is it going at the bottom? (You may consult Figure 8-21 on p. 208 to get the rotational inertia equation for a thin hoop. Also remember that mass and radius miraculously don't matter for this calculation!)

Solutions to Problems

Questions

12) Both will reach the bottom and have the same speed. The ball with the larger mass will have the greater kinetic energy.

13) The sphere will reach the bottom first and have greater speed. It also has greater total kinetic energy, but the solid cylinder has greater rotational kinetic energy.

Problems

43)

Moment of inertial of centrifuge $I = 3.75 \times 10^{-2} \text{ kg m}^2$

Frequency of rotation $f = 8250 \text{ rpm}$

$$= \frac{8250 \text{ rpm}}{60 \text{ s/m}}$$

$$= 137.5 \text{ rev/sec}$$

Angular velocity $\omega = 2\pi f$

$$= 2\pi \times 137.5$$

$$= 864 \text{ rad/s}$$

The Rotational K.E $= \frac{1}{2} I \omega^2$

$$= \left(\frac{1}{2} \times 3.75 \times 10^{-2} \times (864)^2 \right) J$$

K.E $= 1.4 \times 10^4 J$

Energy $= 1.4 \times 10^4 J$

45)

We are given that the mass of ball (m) = 7.3 kg and velocity of the ball is (v) = 3.3 m/s . The total kinetic energy is given by

$$KE = KE_{trans} + KE_{rot}$$

$$K.E = \frac{1}{2}mv_{CM}^2 + \frac{1}{2}I_{CM}\omega^2$$

Since the ball is rolling without slipping so the angular velocity is given by $\omega = v/R$ and the rotational inertia of a sphere about an axis through its center is $I = \frac{2}{5}mR^2$, so

$$\begin{aligned} KE &= \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right)\left(\frac{v}{R}\right)^2 \\ &= \frac{1}{2}mv^2 + \frac{1}{5}mv^2 \\ &= \frac{7}{10}mv^2 \end{aligned}$$

Substituting the values we get

$$\begin{aligned} KE &= \frac{7}{10}\left[(7.3\text{ kg})\times(3.3\text{ m/s})^2\right]\text{J} \\ &= 55.6\text{ J} \end{aligned}$$

The total kinetic energy of the bowling ball $\boxed{= 56\text{ J}}$

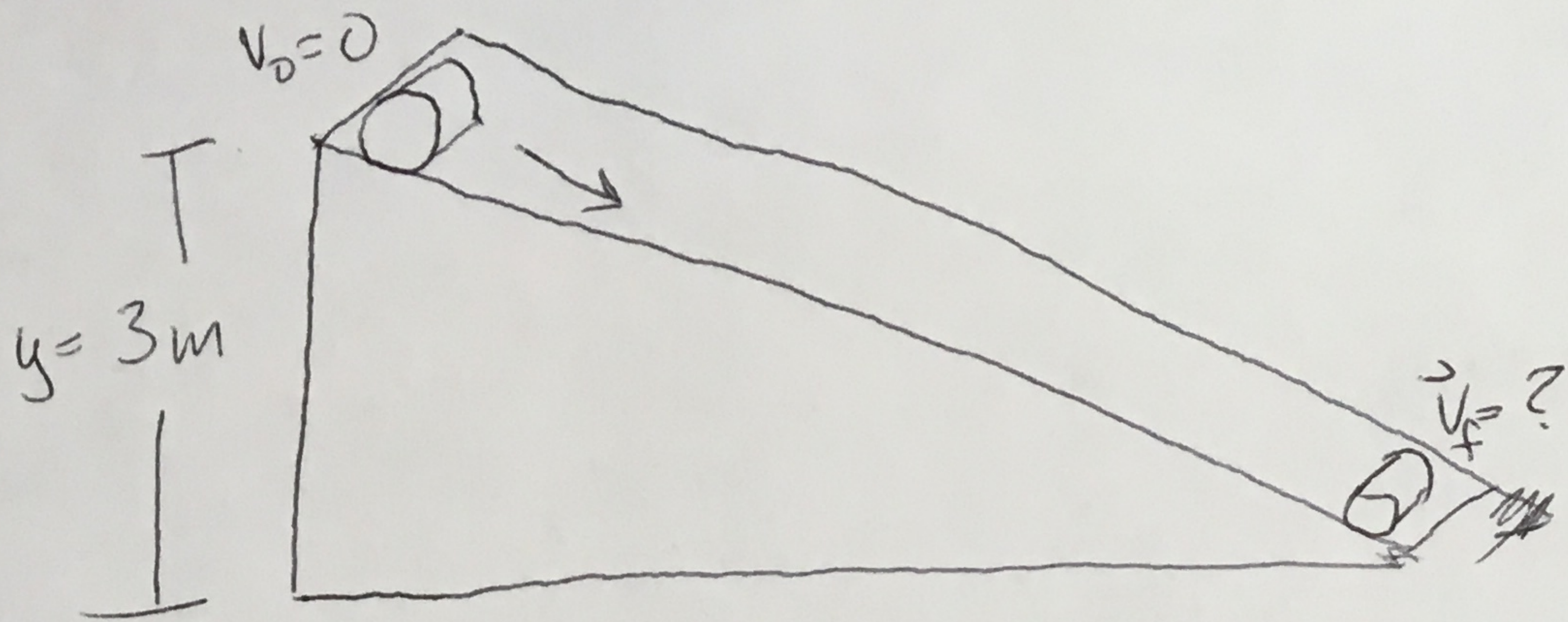
Solutions to Quiz

1-6: Consult packet.

7. $0.319 \text{ kg}\cdot\text{m}^2$

8. See next page.

8)



$$E_0 = E_f$$

$$KE_0 + KE_{\text{rotational}_0} + PE_0 = KE_f + KE_{\text{rotational}_f} + PE_f$$

$$0 + 0 + mgy = \frac{1}{2}mv_f^2 + \frac{1}{2}I\omega_f^2 + 0$$

I for a hollow cylinder is $\boxed{mr^2}$

$$\omega = \boxed{\frac{v}{r}}$$

Plug these two quantities in for I and ω ...

$$mgy = \frac{1}{2}mv_f^2 + \frac{1}{2}(mr^2)\left(\frac{v_f}{r}\right)^2$$

$$gy = \frac{1}{2}v_f^2 + \frac{1}{2}\frac{r^2v_f^2}{r^2}$$

$$gy = \frac{1}{2}v_f^2 + \frac{1}{2}v_f^2$$

$$v_f^2 = gy$$

$$v_f = \sqrt{gy}$$

$$v_f = \sqrt{9.8(3)}$$

$$\boxed{v_f = 5.42 \text{ m/s}}$$