Physics 1408/1420 – General Physics 1

Week of October 3rd, 2022

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Hello Fellow Physicists,

I am Jorge Martinez-Ortiz, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring session, so be sure to visit the tutoring center or visit https://baylor.edu/tutoring.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Mondays from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

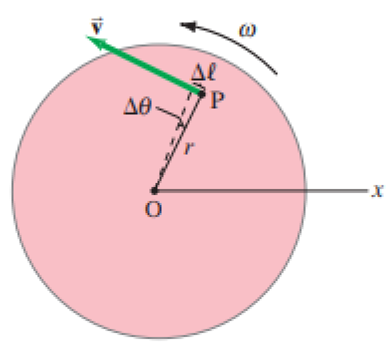
Over the last week, your professors will have covered momentum. This week, you will explore Rotational Motion.

Keywords: Rotation, Torque, Moment of Inertia

Important Notes
Important Conventions

Topic of the Week: Rotational Motion

Highlight 1: Angular Kinematics:



Angular kinematics analyzes rotational motion. The distinction between rotational motion and circular motion is very important. The motion of earth around the sun is circular motion. The movement of earth on its axis is rotation. Much like how we can analyze linear motion, we can use kinematic variables and equations with rotation. Our variables do change. When looking at rotation, the change in the angle is equivalent to the displacement, velocity is equivalent to angular velocity, and acceleration is equivalent to angular acceleration. The easiest way to

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understand the motions is to compare them to one another. The equations all work the same way but only in different scenarios.

Angular	Linear
$\omega = \omega_0 + \alpha t$	$v = v_0 + at$
$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$	$x = v_0 t + \frac{1}{2}at^2$
$\omega^2 = \omega_0^2 + 2\alpha\theta$	$v^2 = v_0^2 + 2ax$

$$\omega = 2\pi f.$$

$$T = \frac{1}{f}.$$

$$1\ \text{Hz} = 1\ \text{rev/s}.$$

x	displacement	θ
v	velocity	ω
a_{tan}	acceleration	α

$$x = r\theta$$

$$v = r\omega$$

$$a_{tan} = r\alpha$$

The rotational variables can also relate to tangential linear motion variables. These are also shown above. Let's look at an example problem.

<u>Example</u>

A centrifuge rotor is accelerated for 30 s from rest to 20,000 rpm (revolutions per minute).

(a) What is its average angular acceleration?
(b) Through how many revolutions has the centrifuge rotor turned during its acceleration period?

Solution

(a)

$\omega_0 = 0$ rad / s

$\omega = 2\pi f$

$= 2\pi\ (20{,}000 / 60)$

$= 2100$ rad / s

$\alpha = (\omega - \omega_0) / \Delta t$

$= (2100 - 0) / 30$

(b)

$\Theta = \omega_0 t + (1/2)\alpha t^2$

$= 0\,(30) + (1/2)(70)(30)^2$

$= 3150$ rad

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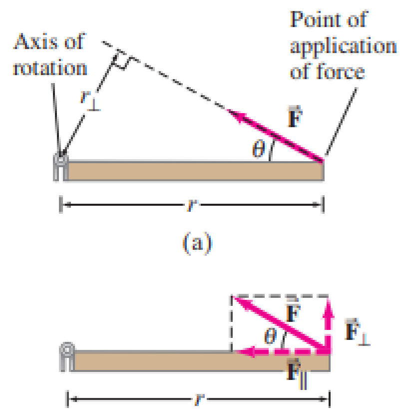
$= 70 \text{ rad} / s^2$

Highlight 2: **Torque:**

Torque is the equivalent of force in terms of rotation. One thing I will point out is that they are equivalent but not the same. This description is so that you can better visualize these variables and use concepts you are already familiar with to understand this new concept. Torque is applied to rotate an object. Every single one of us experiences and applies torque. Have you ever wondered why we put doorknobs at the opposite perimeter of the bracket that attaches the door to the wall? That is because that exerts the most amount of torque. The torque exerted is the product of the perpendicular force and the distance from the axis of rotation. This can vary as it can also be the perpendicular distance from the axis of rotation. Therefore, torque can be calculated using the following



$$\tau = rF_\perp, \qquad \tau = r_\perp F, \qquad \tau = rF\sin\theta$$

Highlight 3: **Moment of Inertia:**

Now we come to what we can think of a mass for a rotating object. Moment of inertia is the rotational inertia of a rotating object. Generally, moment of inertia is represented by mr^2, but different objects have different moments of inertia. Here's a fun experiment you can do to understand how moment of inertia affects rotation: get in a rollie chair and start spinning. First extend your arms and legs, then bring them closer together. You will see that you spin faster. This is because your moment of inertia increases. Moment of Inertia is related to torque as well. If you relate the force equation and the torque equation, you get

$$\Sigma\tau = \left(\Sigma mr^2\right)\alpha \qquad \Sigma\tau = I\alpha.$$

Angular Momentum:

This quantity is the analog of linear momentum with rotation. Angular momentum also follows the law of conservation. The total angular momentum of a rotating object remains constant if the net torque acting on it is zero.

$$L = I\omega, \qquad \Sigma\tau = \frac{\Delta L}{\Delta t},$$

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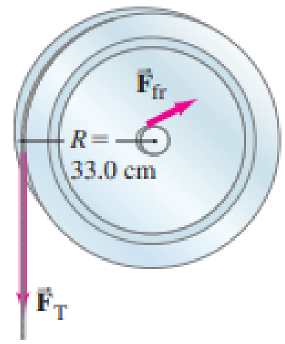
Example:

A 15 N force is applied to a cord wrapped around a pulley of mass = 4 kg and radius R = 33 cm. The pulley accelerates uniformly from rest to an angular speed of 30 rad / s in 3 s. If there is a frictional torque of 1.1 m.N at the axle, determine the moment of inertia of the pulley.



Solution

$\sum \tau = \tau_{tension} - \tau_{pully}$

$= F_{tension} R - \tau_{pully}$

$= (0.33)(15) - (1.1)$

$= 3.85$ m.N

$\alpha = (\Delta\omega / \Delta t)$

$= 30 / 3$

$= 10 \text{ rad} / s^2$

$I = (\sum\tau / \alpha)$

$= 3.85 / 10$

$= 0.385 \text{ kg} . m^2$

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CHECK YOUR LEARNING

1. A grinding wheel 0.2 m in diameter rotates at 1000 rpm. Calculate its angular velocity in rad/s. What are the linear speed and acceleration of a point on the edge of the wheel?
2. How fast (rpm) must a centrifuge rotate if a particle 10 cm from the axis of rotation is to experience an acceleration of 200,000 g's?
3. A person exerts a horizontal force of 20 N on the end of a door 0.5 m wide. What is the magnitude of torque if the force exerted is (a) perpendicular to the door and (b) at a 30 ° angle to the face of the door?

THINGS YOU MAY STRUGGLE WITH

1. Imagining rotational motion and dealing with problems involving kinematics can be tough. It's a bit difficult getting used to seeing rotational motion and using the kinematic equations to understand its motion. Remember, all that has changed from linear to rotational motion is the change in the variables you are considering. Distance and velocity are now considered in terms of angles rather than length, but all the relationships remain the same between these kinematic variables. Remember to compare the motion to how you did linear motion when you started the semester. Keeping this in mind will make it easier to work the problem.
2. A common mistake is not being able to identify the force that produces the torque. Remember, it is the tangential force that exerts the force for torque. This fact implies that the force should be PERPENDICULAR to the edge of the object experiencing torque, which is important to remember when multiple forces are at play.
3. The relationship between moment of inertia, angular acceleration, and torque. Remember that there are two main relationships to keep in mind when torque is considered. The first one involves the perpendicular force at distance r away from the axis of rotation. The other is moment of inertia I, and angular acceleration (this should look familiar. *Hint:* F = ma)

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring

Answers: 1. 104.72 rad/s, 21 m/s, 2193.2 m/s^2, 2. 42,277 rpm, 3. 10 N.m, , 5 N.m

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