UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

Unit 8
Rotational Motion

UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

Units of Rotational Motion

- Angular Quantities
- Constant Angular Acceleration
- Rolling Motion (Without Slipping)
- Torque
- Rotational Dynamics; Torque and Rotational Inertia
- Solving Problems in Rotational Dynamics

UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

Units of Rotational Motion

- Rotational Kinetic Energy
- Angular Momentum and Its Conservation
- Vector Nature of Angular Quantities

UEQ #2: What factors affect changes in the rotational motion of an object?

Unit 9

Static Equilibrium

UEQ #2: What factors affect changes in the rotational motion of an object?

Units of Static Equilibrium

- The Conditions for Equilibrium
- Solving Statics Problems
- Applications to Muscles and Joints
- Stability and Balance

UEQ: How can rotational motion be described, measured, and quantified?

VOCABULARY

- Radians
- Angular Displacement
- Angular Velocity
- Angular Acceleration
- Frequency
- Period
- Axis of Rotation
- Moment Arm
- Torque
- Right-Hand Rule
- Static Equilibrium
- Cantilever
- Stable Equilibrium
- Unstable Equilibrium
- Neutral Equilibrium
- Moment of Inertia
- Rotational Inertia
- Rotational Kinetic Energy
- Angular Momentum

UEQ #1: How can the rotational motion be described in a measurable and quantitative way?

LESSON 1

Rotational Motion
Angular Quantities

Rotational Motion: Angular Quantities

EQ(s): How are the rotational measurements analogous to linear measurements?

Start: If a car is accelerating, what is happening to the motion of its tires? Which part of the tire travels faster?

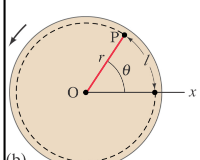
How are the rotational measurements analogous to linear measurements?

8-1 Angular Quantities

Circumference, *C*, is an example the **arc length**:

$$2\pi = \frac{C}{r};$$

$$C = 2\pi r$$



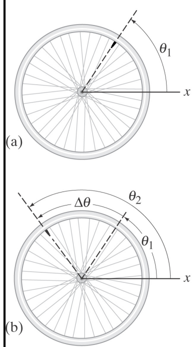
In purely **rotational** motion, all points on the object move in **circles** around the **axis** of rotation ("*O*"). The **radius** of the circle is *r*. All points on a straight line drawn through the axis move through the same **angle** in the same **time**. The **angle** *θ* in **radians** is defined:

$$\theta = \frac{l}{r} \quad \text{(8-1a)}$$

where *l* is the **arc length**.

How are the rotational measurements analogous to linear measurements?

8-1 Angular Quantities



Angular **displacement** (in *rad*):

$$\Delta\theta = \theta_2 - \theta_1$$

The average angular **velocity** is defined as the total angular **displacement** divided by **time**:

$$\bar{\omega} = \frac{\Delta\theta}{\Delta t} \qquad \text{(8-2a)}$$

The **instantaneous** angular velocity (in *rad* / s):

$$\omega = \frac{d\theta}{dt} \qquad \text{(8-2b)}$$

How are the rotational measurements analogous to linear measurements?

8-1 Angular Quantities

The angular **acceleration** is the rate at which the angular velocity changes with time (in *rad* / *s*^{2}):

$$\bar{\alpha} = \frac{\omega_2 - \omega_1}{\Delta t} = \frac{\Delta\omega}{\Delta t} \qquad \text{(8-3a)}$$

The **instantaneous** acceleration:

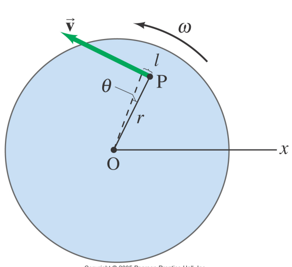
$$\alpha = \frac{d\omega}{dt} \qquad \text{(8-3b)}$$

How are the rotational measurements analogous to linear measurements?

8-1 Angular Quantities

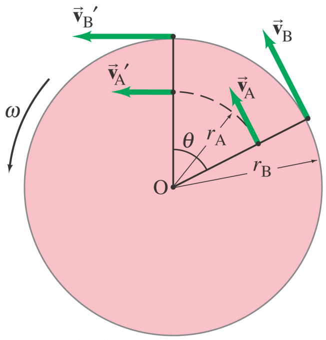
Every point on a rotating body has an **angular velocity** ω and a **linear velocity** v.

They are related: $v = r\omega$ (8-4)



How are the rotational measurements analogous to linear measurements?

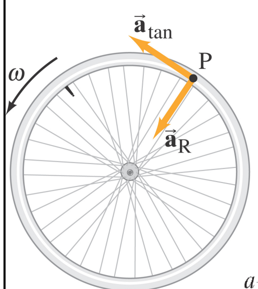
8-1 Angular Quantities



Therefore, objects **farther** from the axis of rotation will move **faster**.

How are the rotational measurements analogous to linear measurements?

8-1 Angular Quantities



If the angular velocity of a rotating object **changes**, it has a **tangential** acceleration:

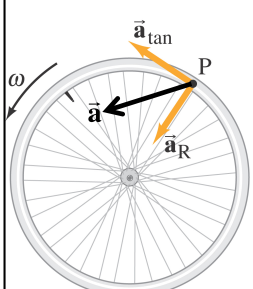
$$a_{\tan} = r\alpha \quad \text{(8-5)}$$

Even if the angular velocity is constant, each point on the object has a **centripetal** acceleration:

$$a_R = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = \omega^2 r \quad \text{(8-6)}$$

How are the rotational measurements analogous to linear measurements?

PRACTICE PROBLEM



Calculate the acceleration acting on point P:

$$a = \sqrt{a_R^2 + a_{\tan}^2}$$

$$a = \sqrt{(r\omega^2)^2 + (r\alpha)^2}$$

$$a = \sqrt{r^2\omega^4 + r^2\alpha^2}$$

$$a = \sqrt{r^2(\omega^4 + \alpha^2)}$$

$$a = r\sqrt{(\omega^4 + \alpha^2)}$$

What happens if the tire stops accelerating?

$$a = r\sqrt{(\omega^4 + \cancel{\alpha^2})} = r\omega^2$$

8-1 Angular Quantities

Here is the **correspondence** between **linear** and **rotational** quantities:

TABLE 8–1 Linear and Rotational Quantities

Linear	Type	Rotational	Relation
x	displacement	θ	$x = r\theta$
v	velocity	ω	$v = r\omega$
a_{tan}	acceleration	α	$a_{tan} = r\alpha$

8-1 Angular Quantities

The **frequency** is the number of complete **revolutions** per second:

$$f = \frac{\omega}{2\pi}$$

Frequencies are measured in **hertz**.

$$1 \text{ Hz} = 1 \text{ s}^{-1}$$

The **period** is the time one revolution takes:

$$T = \frac{1}{f} \quad \text{(8-8)}$$