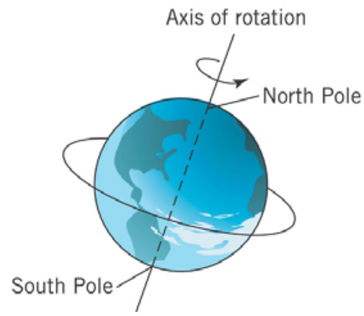
Chap 7 Rotational Motion of an Object

Rotational Motion

Axis of Rotation

Speed of Rotation

period and frequency

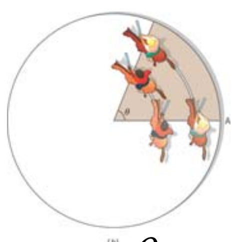


$$T = \frac{1}{f} \qquad f = \frac{1}{T}$$

hertz = 1/sec

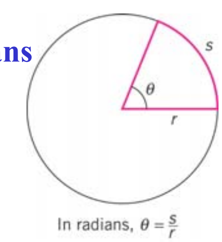
What is the frequency of the Earth's rotation in hertz?

Angular Speed and Frequency



$$\omega = \frac{\theta}{t}$$

angle in radians



$$\theta = \frac{s}{r}$$

How many radians is in one full rotation?

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

Examples

1. **A.** What is the rotational speed in revolutions per second (hertz) of a CD in the following situations?

   a. The disc makes four revolutions in 48 seconds (this speed is much slower than that of a normal CD).

   b. The disc rotates six times in 240 seconds.

   c. The disc makes 1000 revolutions in 2 minutes.

   B. What are the velocities in radians per second for parts a, b, and c?

   C. What are the velocities in degrees per second for parts a, b, and c?

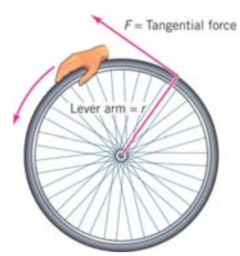
   D. How large a displacement in degrees occurs in each of parts a, b, and c if these discs spin for 30 seconds at the same speed? In radians?

Torque

Torque:

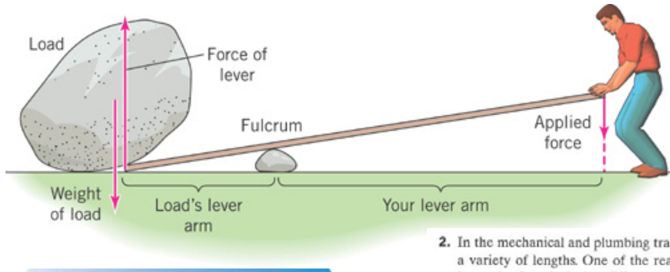
is the tangential force being applied times the perpendicular distance from the axis of rotation.

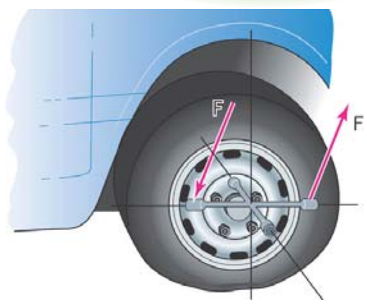
is the force multiplied by the 'lever arm'.



$$\tau = r \times F$$

Torque Examples





2. In the mechanical and plumbing trades, many tools come in a variety of lengths. One of the reasons they are available in varying lengths is that different torques can be generated depending on the lengths of these tools.
   a. If you hold a 0.2-m wrench at its end and exert a force of 30 N, how much torque will you generate?
   b. If you use a 0.5-m wrench and exert a force of 45 N, how much torque can you generate?
   c. If a plumber needs to generate a torque of 160 N-m to unscrew a rusted pipe and can only generate a maximum force that day of 20 N because she has been out too late the night before, what length wrench is the smallest that she can use?
   d. What effect does the length of the handle of a wrench have on the torque that can be generated by it?
   e. To achieve the maximum torque from a given applied force to a lever arm such as a wrench, at what angle should the force be applied to the lever or wrench?

Moment of Inertia

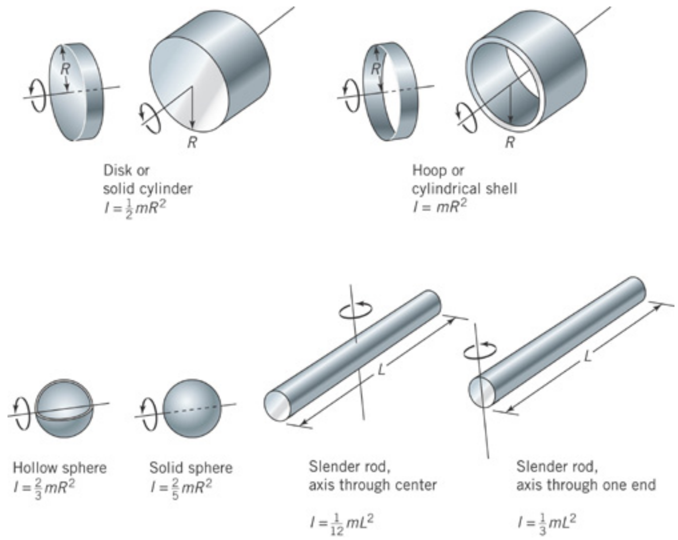
When a net torque is applied to a body, there is an angular acceleration. How much of an angular acceleration? We used to know $F = ma$

What is the equivalent of Newton's 2nd Law for angular systems?

The "moment of inertia" of a rotational object reflects the degree of difficulty with which the rotation of this object can be changed. It is a product of the mass of the object and the average of the "distance squared" of the mass distribution about a rotation axis.

Moment of inertia depends on the axis of rotation used.

Common Moments of Inertia



Angular Momentum

Angular Momentum

is the product of moment of inertia and angular speed

$$L = I \cdot \omega$$

Angular Momentum and Torque:

The rate of change of angular momentum of an object equals the next external torque on that object.

$$\tau = \frac{\Delta L}{\Delta t}$$

Examples

4. What is the moment of inertia of each of the following objects?
   a. A hollow sphere with mass 5 kg and radius 0.5 m
   b. A solid ball that weighs 3 lb and has a radius of 1 foot
   c. A 200-kg satellite in a circular orbit around a small planet at a distance 5000 km from the planet's center (Consider the satellite to be a point mass; the moment of inertia of a single particle is MR^2.)
   d. A large truck tire of 0.75-m radius and mass 20 kg (assume all the mass is concentrated on the outer edge)
5. What is the angular momentum of the rotating objects in Problem 4 under the following circumstances?
   a. When the spheres in parts a and b rotate at 2 revolutions per second?
   b. When the spheres in parts a and b rotate at 1 radian per second?
   c. When the satellite in part c makes 1 revolution every 90 minutes?
   d. When the tire in part d spins at a rate of 1 revolution per second?

Conservation of Angular Momentum

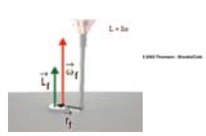
$$\tau = \frac{\Delta L}{\Delta t}$$

From left equation, angular momentum cannot change unless there is an external torque!

In the absence of an external torque, the angular momentum of any system must stay constant over time.

initial ang. mom. = final ang. mom.

$$I_i \omega_i = I_f \omega_f$$



Conservation of Angular Momentum

8. Several children are playing on a merry-go-round in a park. Initially four of them, each weighing 20 kg, sit on the edge, 3 m from the center.

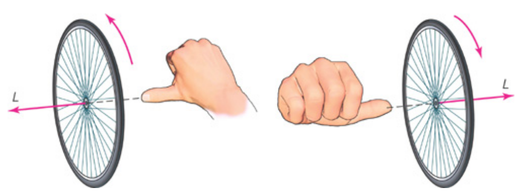
a. If you neglect the weight of the merry-go-round, wh the initial angular momentum if it spins at a rate revolutions per minute?

b. Not comfortable sitting on the edge of a spinning c the four children decide to walk to the center an halfway between the center and the edge, at 1.5 m. the angular velocity of the merry-go-round change so, what is the new angular velocity?

c. Was angular momentum conserved when the chil moved?

Direction of Rotation

Right-Hand Rule



6. In what direction does the angular momentum vector point for the following situations (remember the right-hand rule)?

a. A Ferris wheel spinning clockwise as you look at it
b. A CD that spins counterclockwise as you look at it
c. A bicycle wheel as the bike moves straight in a forward direction
d. The left rear tire of a car moving straight backward in reverse
e. The right rear tire of a car moving straight backward in reverse

7. If the direction of the angular momentum vector is pointed straight at you, in what direction does an object rotate?

Exam #1

100.0		79.0
98.0		74.0
95.0		74.0
95.0		74.0
93.0		72.0
91.0		69.0
91.0		69.0
88.0		67.0
88.0		66.0
86.0		52.0
		45.0
AVG = 79.3		