Lecture 10: Rotation

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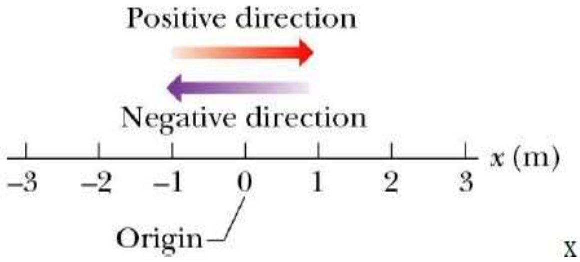
One Dimensional Position x

- ❑What is motion? Change of position over time.
- ❑How can we represent position along a straight line?
- ❑Position definition:
  - ■ Defines a starting point: origin (x = 0), x relative to origin
  - ■ Direction: positive (right or up), negative (left or down)
  - ■ It depends on time: t = 0 (start clock), x(t=0) does not have to be zero.
- ❑Position has units of [Length]: meters.



x = + 2.5 m   x = - 3 m

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Q/ What is motion? Change of ---------- over time.

a) Force
b) Direction
c) Momentum
d) **Position**

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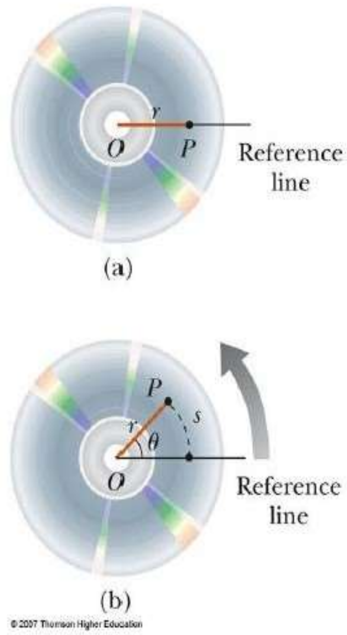
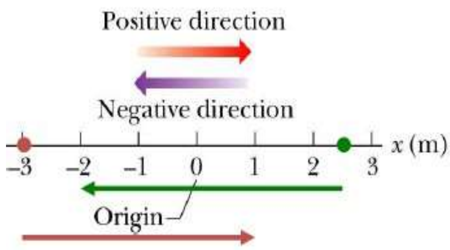
Angular Position

- Axis of rotation is the center of the disc
- Choose a fixed reference line
- Point P is at a fixed distance r from the origin
- As the particle moves, the only coordinate that changes is θ
- As the particle moves through θ, it moves though an arc length s.
- The angle θ, measured in radians, is called the angular position.



Displacement

- Displacement is a change of position in time.
- Displacement: $\Delta x = x_f(t_f) - x_i(t_i)$
  - *f* stands for final and *i* stands for initial.
- It is a vector quantity.
- It has both magnitude and direction: + or - sign
- It has units of [length]: meters.



$$x_1(t_1) = +2.5\text{ m}$$
$$x_2(t_2) = -2.0\text{ m}$$
$$\Delta x = -2.0\text{ m} - 2.5\text{ m} = -4.5\text{ m}$$
$$x_1(t_1) = -3.0\text{ m}$$
$$x_2(t_2) = +1.0\text{ m}$$
$$\Delta x = +1.0\text{ m} + 3.0\text{ m} = +4.0\text{ m}$$

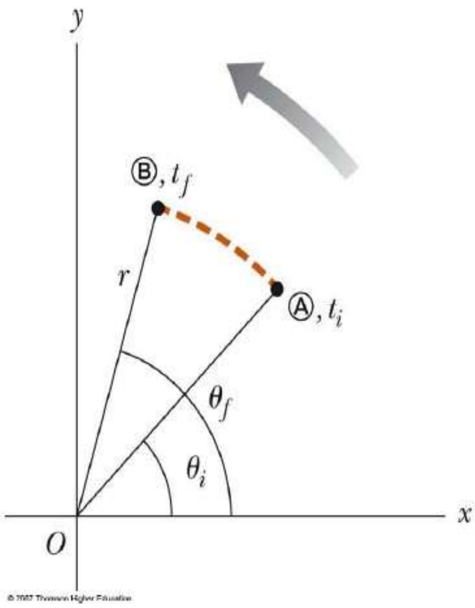
Angular Displacement

- The angular displacement is defined as the angle the object rotates through during some time interval

$$\Delta\theta = \theta_f - \theta_i$$

SI unit: radian (rad)

- This is the angle that the reference line of length *r* sweeps out



Velocity

- Velocity is the rate of change of position.
- Velocity is a vector quantity.
- Velocity has both magnitude and direction.
- Velocity has a unit of [length/time]: meter/second.
- Definition:
  - Average velocity $$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$$
  - Average speed $$s_{avg} = \frac{\text{total distance}}{\Delta t}$$
  - Instantaneous velocity $$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Average Angular Acceleration

The average angular acceleration, a, of an object is defined as the ratio of the change in the angular speed to the time it takes for the object to undergo the change:

$$\alpha_{avg} = \frac{\omega_f - \omega_i}{t_f - t_i} = \frac{\Delta\omega}{\Delta t}$$

Average Acceleration

- ❑Changing velocity (non-uniform) means an acceleration is present.
- ❑Acceleration is the rate of change of velocity.
- ❑Acceleration is a vector quantity.
- ❑Acceleration has both magnitude and direction.
- ❑Acceleration has a unit of [length/time^2]: m/s^2.
- ❑Definition:
  - Average acceleration $a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$
  - Instantaneous acceleration $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d}{dt}\frac{dx}{dt} = \frac{d^2 v}{dt^2}$

Instantaneous Angular Acceleration

- The instantaneous angular acceleration is defined as the limit of the average angular acceleration as the time goes to 0

$$\alpha \equiv \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt}$$

- SI Units of angular acceleration: rad/s²
- Positive angular acceleration is in the counterclockwise.
  - if an object rotating counterclockwise is speeding up
  - if an object rotating clockwise is slowing down
- Negative angular acceleration is in the clockwise.
  - if an object rotating counterclockwise is slowing down
  - if an object rotating clockwise is speeding up

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Q/ SI units of angular acceleration ---------.

a) **rad/s²**
b) s²/rad
c) rad.s²
d) rad².s

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Rotational Kinematics

- A number of parallels exist between the equations for rotational motion and those for linear motion.

$$v_{avg} = \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t} \qquad \omega_{avg} = \frac{\theta_f - \theta_i}{t_f - t_i} = \frac{\Delta \theta}{\Delta t}$$

- Under **constant angular acceleration**, we can describe the motion of the rigid object using a set of kinematic equations
  - These are similar to the kinematic equations for linear motion
  - The rotational equations have the same mathematical form as the linear equations

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Q/ The rotational equations have the ---------- mathematical form as the linear equations.

a) **Same**
b) Different
c) opposite
d) b and c

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