Video 703 (7:08)

Circular Motion and Gravity

Name: ________________________

axis: line about which circular motion occurs

rotation:

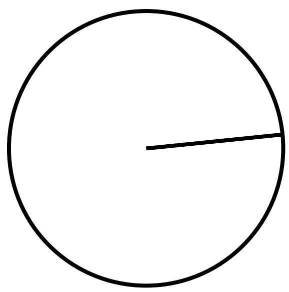
revolution:

Video 706 (6:04)

Angular Kinematics

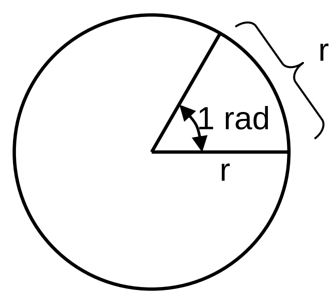
angular displacement:

A spinning circle of radius r…



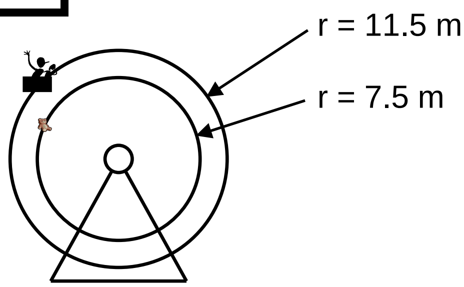
The angular displacement $\Delta\theta$ of any part (or ALL) of a rotating object…

radian: the angle subtended by an arc that is the same length as the circle's radius



Video 709 (4:01)

If arc subtended by basket between loadings is 3.8 m, find angular displacement, in rad.



Ferris wheel

Through what arc length does bear move, between stops?

Video 712 (8:08)	If Ferris wheel rotates at constant angular speed, it takes 18 s to go around once. Find avg. ang. speed.	In linear kinematics…	In angular kinematics…

EX. Same Ferris wheel takes 2.2 s to go from rest to its avg. ang. vel. Find mag. of its ang. accel.

In linear kinematics…

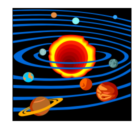
In angular kinematics…

Video 715 (4:58)

Find ang. speed of Earth:

-- spinning on its axis

-- revolving around Sun



<u>Angular Kinematics</u>

$$\overleftrightarrow{\omega}_{avg} = \frac{\Delta\overleftrightarrow{\theta}}{\Delta t} = \tfrac{1}{2}(\overleftrightarrow{\omega}_f + \overleftrightarrow{\omega}_i)$$

$$\overleftrightarrow{\alpha} = \frac{\Delta\overleftrightarrow{\omega}}{\Delta t} = \frac{\overleftrightarrow{\omega}_f - \overleftrightarrow{\omega}_i}{\Delta t}$$

$$\overleftrightarrow{\omega}_f^{\,2} = \overleftrightarrow{\omega}_i^{\,2} + 2\,\overleftrightarrow{\alpha}\,\Delta\overleftrightarrow{\theta}$$

$$\Delta\overleftrightarrow{\theta} = \overleftrightarrow{\omega}_i\,\Delta t + \tfrac{1}{2}\,\overleftrightarrow{\alpha}\,(\Delta t)^2$$

$$\Delta\overleftrightarrow{s} = \Delta\overleftrightarrow{\theta}\; r$$

<u>Linear Kinematics</u>

$$\vec{v}_{avg} = \frac{\Delta\vec{d}}{\Delta t} = \tfrac{1}{2}(\vec{v}_f + \vec{v}_i)$$

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\,\vec{a}\,\Delta\vec{d}$$

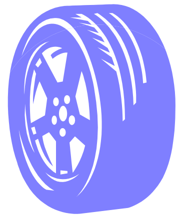
$$\Delta\vec{d} = \vec{v}_i\,\Delta t + \tfrac{1}{2}\,\vec{a}\,(\Delta t)^2$$

Sign Conventions for $\Delta\theta$, ω, and α...

Video 718 (8:02)

Car wheel initially rotates at 52 rad/s. After braking for 7.3 s, wheel is at rest. Find…

a. …wheel's avg. ang. accel.



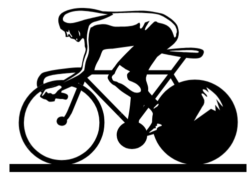
b. …wheel's ang. displ.

EX. Find mag. of ang. accel. of Earth… …spinning on its axis.

…revolving around Sun.

Video 721 (7:37)

Bike wheel ^{w}/outer radius 36 cm has init. ang. speed 5.2 rad/s. Wheel's speed increases to 9.8 rad/s. The ang. accel. has mag. 0.68 rad/s^2.



a. How much time elapses?

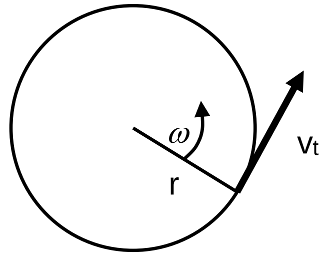
b. Find ang. displ. over this time.

c. Wheel goes around how many times?

d. What linear distance is covered?

Video 724 (5:50)

$$\text{tangential speed} = \frac{\text{linear distance}}{\text{time}}$$

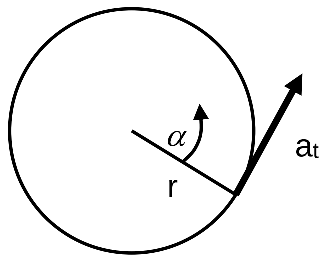


period, T: time (in s) to go around once

frequency, f: # of cycles in one second (Hz)

Since $\omega = \frac{\Delta\Theta}{\Delta t}$, then… and…

tangential acceleration:

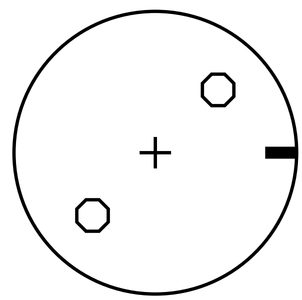


Video 727 (5:20)

Bike wheel spinning initially at 5.8 rad/s speeds up to 9.3 rad/s over 15 s. Find tangential acceleration for reflector and valve stem. (r_{stem} = 41 cm; $r_{reflector}$ = 32 cm)

valve stem…

reflector…

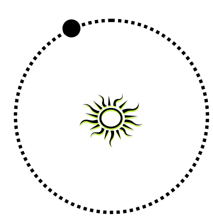


EX. Find tangential speed after 15 s for both valve stem and reflector.

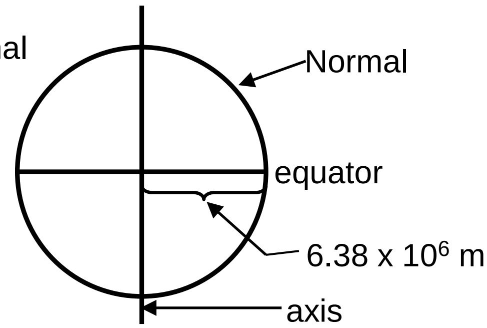
valve stem… reflector…

Video 730 (7:20)

Earth-Sun distance is 1.5 x 10^{11} m. Find Earth's linear speed around Sun, in m/s.

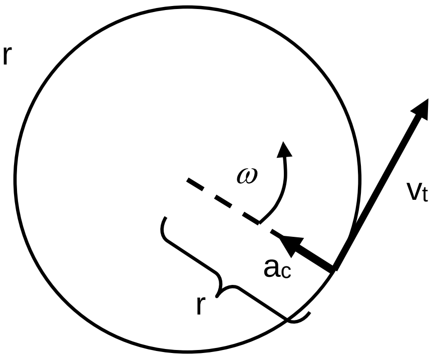


EX. Normal, IL is at 40.5° N latitude. Find tangential speed of Normal around Earth's axis. Earth's radius is 6.38 x 10^6 m.



Video
733
(9:36)

centripetal acceleration (a_c): acceleration toward the center



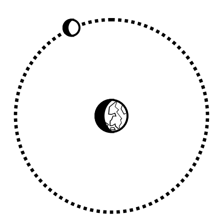
For circular motion, tangential acceleration (a_t) may be zero or nonzero…

(i.e., when $\alpha = 0$)

but…

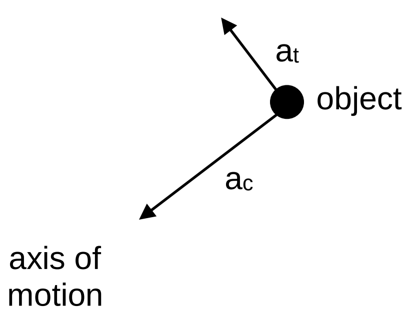
EX. Earth-Moon distance is 3.84 x 10^8 m.

a. Find tangential and centripetal accelerations of Moon around Earth.

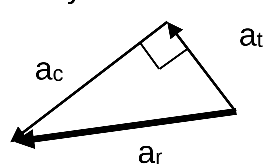


b. Find resultant (i.e., the **net**) acceleration of Moon.

a_t and a_c are ⊥ component vectors of the net accel.



Add like any two ⊥ vectors.

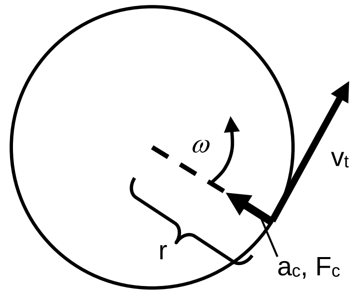


c. Find tangential speed of Moon around Earth.

d. With what force does Earth pull on Moon? Mass of Moon is 7.36×10^{22} kg.

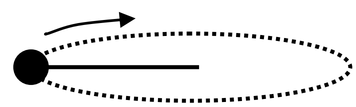
Recall Newton's 2nd Law:

<u>centripetal force</u>:



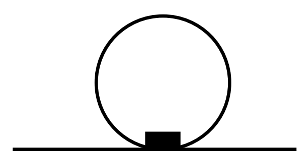
Video
736
(3:27)

2.6 kg stone at end of 0.74 m rope is whirled in horizontal circle at constant rate. Period is 1.1 s. Find rope's tension.



Video
739
(3:02)

At bottom of circular loop of radius 16 m, roller coaster car (m = 250 kg) travels at 13 m/s. Find force of track on car.



Video
742
(6:18)

Centrifugal Force

<u>centrifugal</u> =

"Centrifugal force": --

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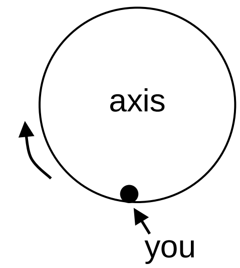
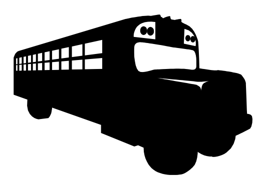
(aerial view)



Consider an amusement park ride:

FROM YOUR FRAME OF REFERENCE	FROM A BIRD'S FRAME OF REFERENCE
axis ●	axis ●

EX. Student (m = 55 kg) rides bus moving 15 m/s around curve of radius 16 m and is pressed against window. Find "centrifugal force" student senses.



Video
745
(6:43)

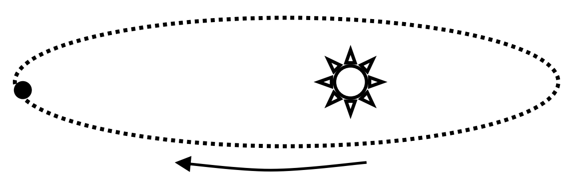
Gravity Brahe:

Kepler:

<u>Kepler's Laws</u>:

1.

2.



3.

EX. Earth is 1.50×10^{11} m from Sun; Jupiter is 7.78×10^{11} m from Sun.
How long does it take Jupiter to go once around Sun?

Video 748 (4:50)

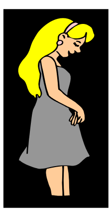
Newton:

Newton's Law of Gravity

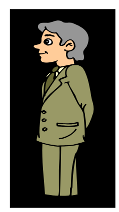
m = objects' masses (kg)
r = separation between objects' centers of mass (m)
G =

Cavendish:

EX.

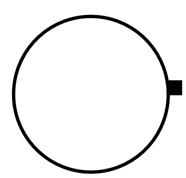


45 kg girl and 53 kg boy are 14 m apart at jr. high dance. Find force of gravity acting to bring them together.



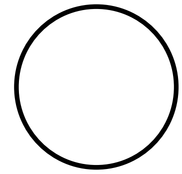
Video 751 (7:06)

Earth has mass 5.97×10^{24} kg and radius 6.38×10^{6} m. Find force of gravity on 34.0 kg rock.



For any object of mass m and mean radius r:

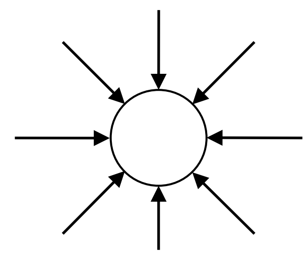
EX. Mars has radius 3.40×10^6 m. If a 12.0 kg rover weighs 44.5 N on Mars, find mass of Mars.



What is g on Mars?

Video 754
(8:07)

Gravitational Field



-- arrow direction shows how a dropped object would accelerate

--

At the Earth's surface…

Einstein's Idea of Gravity: The General Theory of Relativity

Masses don't attract other masses via gravity. Masses (especially, large ones) alter the "curvature" of space (and time) around them. The paths of nearby objects are then affected by this curvature of space. Thus, a dropped pencil falls – NOT because there is a force between its mass and that of the Earth – but because the space around the Earth is "curved" in a particular direction (i.e., downward) and the pencil must follow the curvature of space.