Circular Motion and Rotational Mechanics

Group #1

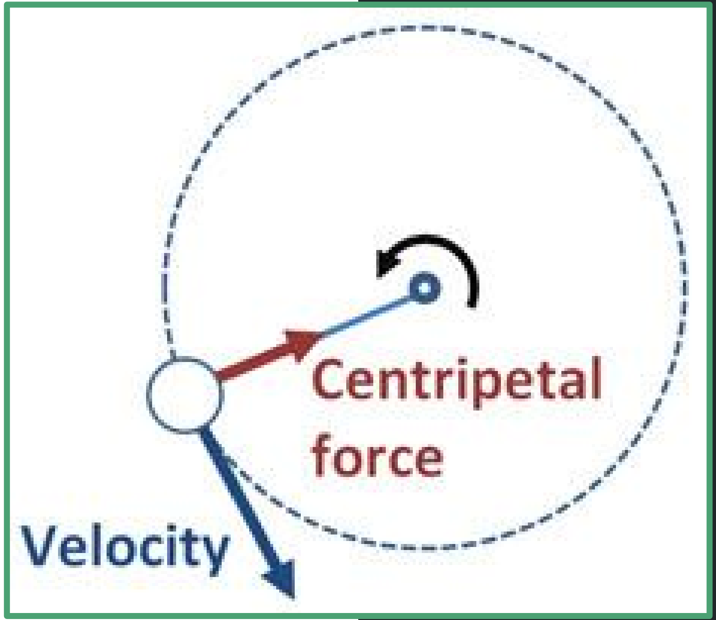
Circular Motion Terminology:

- Uniform circular motion = when an object moves in a circle at a constant speed (v)
  - Direction is changing
- Rotation = when a body turns about an **internal** axis
- Revolution = when a body turns around an **external** axis

Radial:

Behavior towards and away from the center of the circle

In this case, the centripetal force is behaving radially



Tangential:

Behavior along the edge of the circle

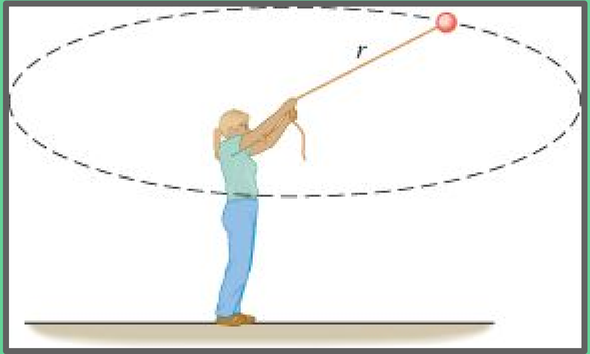
In this case, the velocity is tangential (v_t)

Centripetal Forces (F_c)

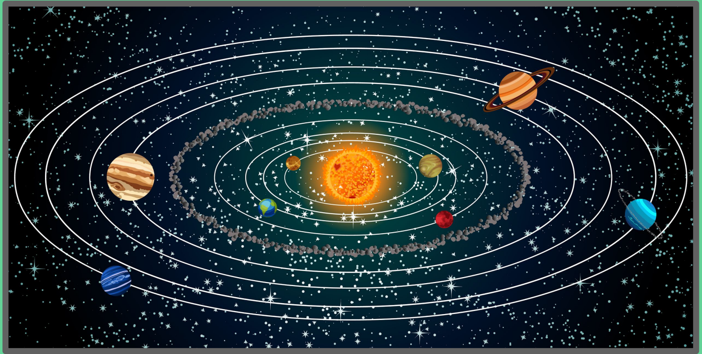
- "Center seeking"
- A force that points towards the center of a rotation

Examples in everyday life:

Ball on a string



Orbit of planets



Roller coaster car on a loop

Determining F_c :

1. Mass (m)
2. Velocity (v)
3. Object's distance from the center (r)

$$\left.\begin{aligned} F_c &= m \times a_c \\ A_c &= v^2 / r \end{aligned}\right\} \quad F_c = \frac{m \times v^2}{r}$$

More Terminology:

- **Frequency** (f) = the number of revolutions per second
    - Measured in Hertz (Hz)
- **Period** (T) = the time required to make one full revolution
    - Measured in seconds (s)
- **Centrifugal Force** = a fictitious force experienced because your reference frame is accelerating
    - "Center feeling"

$$T = 1/f$$

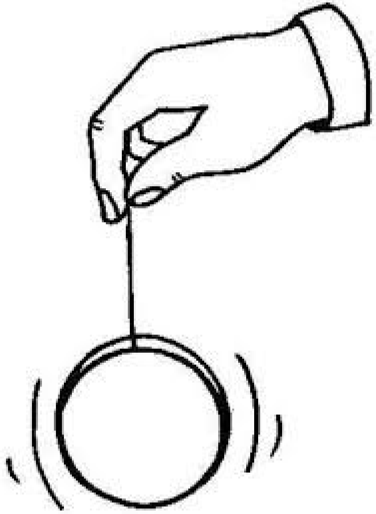
Equations Overview:

$$F_c = \frac{m \times v^2}{r}$$

$$T = 1/f$$

$$V = \frac{2\pi r}{T}$$

Example Problem



You have a .5 kg yoyo attached to a 2 meter long string. You swing this yoyo at a speed of 23 m/s. What is the force of tension in the string?

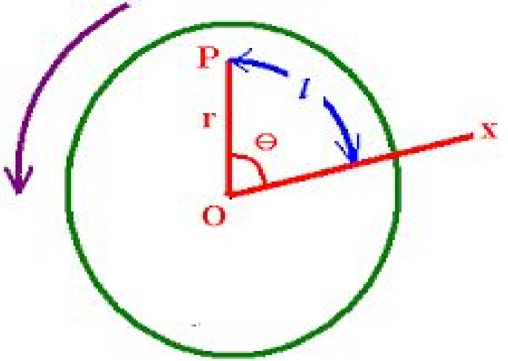
$$F_c = \frac{m \times v^2}{r}$$

Rotational Mechanics

Angular v. Linear Quantities

Quantity	Linear	Angular	Relationship
position	*l* in meters	Θ in radians	$\Theta=l/r$
velocity	*v* in m/s	ω in rad/s	$\omega=v/r=\Delta\Theta\Delta t$
acceleration	*a* in m/s	α in rad/s^2	$\alpha=a/r=\Delta\omega/\Delta t$

- Linear = how fast
- Angular = how much and how quickly something rotates



Angular Quantities

- Centripetal acceleration and Frequency in terms of angular velocity
- Centripetal acceleration: $a_c = \omega^2 r$
- Frequency: $\omega = 2\pi f$

Kinematic Equations

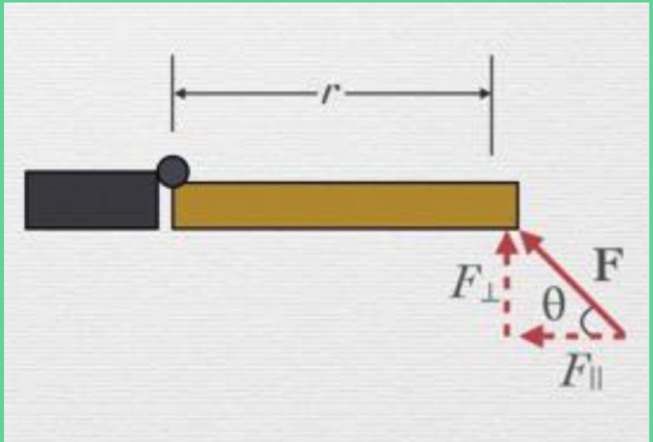
Angular	Linear
$\omega_f = \omega_i + a\Delta t$	$v_f = v_i + a\Delta t$
$\Delta\Theta = \omega_i\Delta t + 1/2a\Delta t^2$	$\Delta x = v_i\Delta t + 1/2a\Delta t^2$
$\omega_f^2 = \omega_i^2 + 2a\Delta\Theta$	$v_f^2 = v_i^2 + 2a\Delta x$

Note: Kinematic Equations only work for <u>constant</u> accelerations

Torque and Doors:

- The “twisting” force that causes rotation
- τ = r x F
- τ = r x F x Sin θ

Lever arm = the distance between the force and the axis of rotation



Rotational Inertia:

- Moment of Inertia = rotational inertia
    - A measure of a body's resistance to a change in its rotation
    - Depends on mass and mass distribution in relation to the axis of rotation
- F = ma
- F = mra
- $\tau = mr^2a$
    - mr^2 = moment of inertia ($kg \times m^2$)
- $\Sigma \tau = I \times \alpha$
    - Newton's second law for rotation

Practice Problem

Find the number of revolutions the wheel of a Razor scooter makes when it has a diameter of 98 mm and travels a distance of 2.3 miles (1 mi = 1609.34 m).

Three Common Misconceptions

1. If a point is on the edge of a circle and another near the center, a) which would have the greater linear speed; b) which would have the greater angular speed?

a) The point on the edge
b) BOTH the points
- angular velocity is the same for all points of a rotating object

2. Objects in circular motion experience an outward force

- FALSE, because of **Newton's first law of motion** (objects in motion tend to stay in motion with the same speed and direction unless acted upon by an unbalanced force)
- the unbalanced force is the *centripetal force*, which is a net force acting towards the center which causes objects to seek the center

3. A cylinder with a larger radius will start rolling easier than a cylinder with a mass equal to that of the previous but a smaller radius

- The cylinder with the larger radius will have a greater rotational inertia, which means it would be harder to start and stop