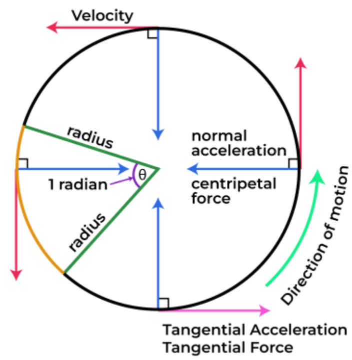
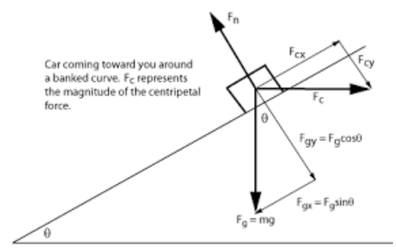
Centripetal Force

- **Centripetal force (F_c)** is a force that makes a body follow a curved path
  - Without a centripetal force, an object in motion continues along a straight-line path.
  - With a centripetal force, an object in motion will be accelerated and change its direction



- Centripetal force is directed **toward the center** of the circle

- **Centripetal force is simply the name given to the NET FORCE on an object in uniform circular motion**

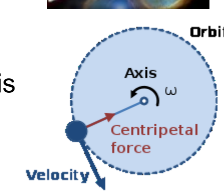


Centripetal Force

- Any type of force or combination of forces can provide this Centripetal force (**NET FORCE)**
  - **Example: Friction** between a race car's tires and circular track is a centripetal force that keeps the car in a circular path

  - **Example: Gravitational force** is a centripetal force that keeps the moon in its orbit

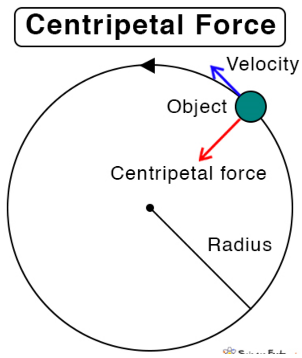
  - **Example:** A mass on a **string** being whirled in a horizontal circular path. The tension in the string is the centripetal force



Analyzing motion in a circle

Centripetal Force

"Centripetal" means "toward the center" - centripetal force and centripetal acceleration are a necessary part of circular motion



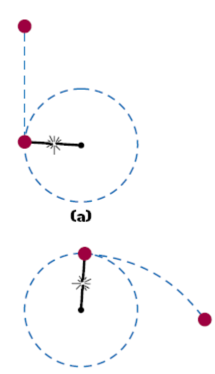
Many things people see or experience as "centrifugal force" are **inertia** - and a centripetal force that isn't big enough to create uniform circular motion

For example, when turning in your car you slide on your seat toward the outside of the curve - there's no force toward the outside - there just isn't enough frictional force to give you the same centripetal acceleration that the car has

Definition:
Centripetal – Center seeking
Centrifugal – Misconception "center fleeing" - Centrifugal is a fictious acceleration present in a rotating frame of reference

Centripetal Forces continued

- If the centripetal force vanishes, the object stops moving in a circular path.
- A ball that is on the end of a string is whirled in a vertical circular path.
  - *If the string breaks at the position shown in **(a)**, the ball will move vertically upward in free fall.*
  - *If the string breaks at the top of the ball's path, as in **(b)**, the ball will move along a parabolic path.*



Forces causing circular motion (centripetal force)

Newton's 2nd Law tells us that all accelerations must be caused by a net force (ΣF)

If an object is in uniform circular motion, it has a centripetal acceleration, which must be caused by a net force.

In circular motion, we call this net force "centripetal force". Using Newton's 2nd Law:

$$\Sigma F = F_{net} = ma$$

$$F_c = ma_c = m \frac{V_t^2}{r}$$

It's important to remember that "Centripetal force" isn't a new force - it's a title that we give to whatever creates the net force that causes circular motion.

For instance, orbits are caused by gravity - the centripetal force on the moon is caused by the force of gravity between the moon and the Earth

Circular Motion - Problems

Steps

- Make a Free body diagram
- Choose coordinate system
  - One positive axis should be toward the center (acceleration)
  - Remember circular motion a and F_{net} are always TOWARD the center
- Customize $F_{net} = ma$
  - Centripetal force is the *NET force*, but not a force, therefor Fc should NEVER appear on FBD

Circular Motion - Problems

Fnet = ma_c

We know $a_c = \frac{V_t^2}{r}$

$F_{net} = m\frac{V_t^2}{r}$ Centripetal Force Fc = $m\frac{V_t^2}{r}$

So F_{net} = Fc

F_{net} = Forces toward the center – Forces away from the center

Resultant forces/Net forces

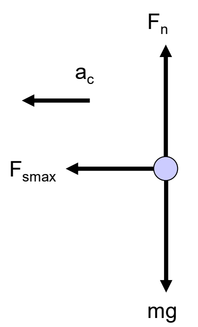
Forces toward the circle	–	Forces away from the circle	$= m\frac{V_t^2}{r}$

Circular motion problems

- **Period (T)** – the time for 1 revolution unit 1 sec
- **Frequency (f)-** the number of revolutions per second, Unit – Hz
- $T = \frac{1}{f}$ (on ap equation sheet)
- Speed magnitude of Velocity: $v = \frac{distance}{time} = \frac{2\Pi r}{T} = 2\Pi rf$
  - Not on ap equation sheet

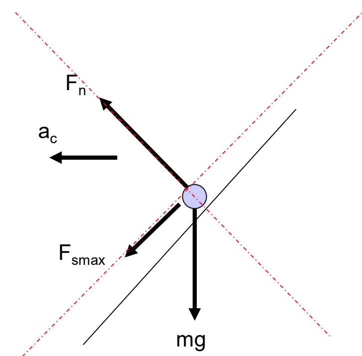
2 Types of Car problems – Fs usually used to find max V_t

- On a flat curve
  - F_{smax} keeps car from sliding off road



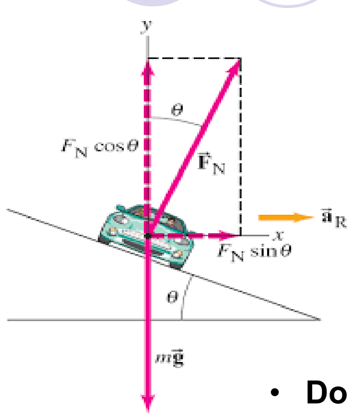
What force keeps the car in the curve without slipping? **Static Friction**

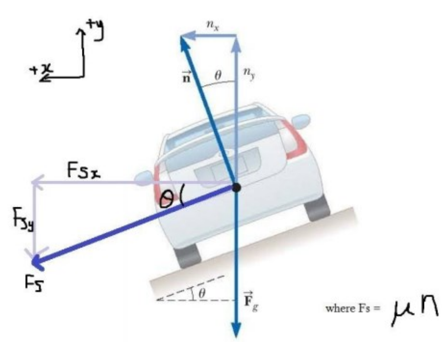
- On a banked curve



What keeps the car in the curve in this diagram? **both static friction and the normal force**

Banked Curve problems





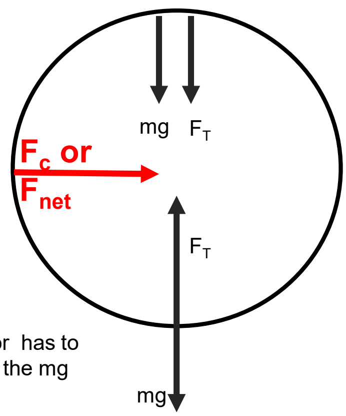
- **Don't break up Fg into components**
- **Break up Fn!! Notice where the Ø is located**

Vertical Circular Motion – Ball on String

- Uniform circular motion, ball on string, but what happens to Tension on string Top vs Bottom

$$F_c = ma_c = m\frac{V_t^2}{r}$$

Fc = Net forces
Fc = forces toward center – forces away from center



$$m\frac{V_t^2}{r} = F_T + mg$$

$$F_T = m\frac{V_t^2}{r} - mg$$

Lower Tension

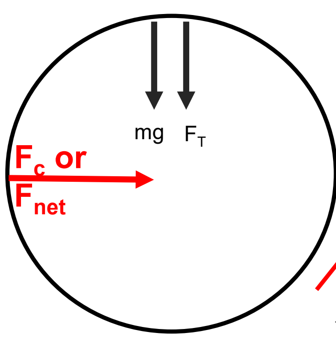
$$m\frac{V_t^2}{r} = F_T - mg$$

$$F_T = m\frac{V_t^2}{r} + mg$$

Higher Tension

Tension vector has to be great than the mg vector

Vertical Circular Motion – Ball on String



$$m\frac{V_t^2}{r} = F_T + mg$$

$$F_T = m\frac{V_t^2}{r} - mg$$

Lower Tension

0

$$F_T = m\frac{V_t^2}{r} - mg$$

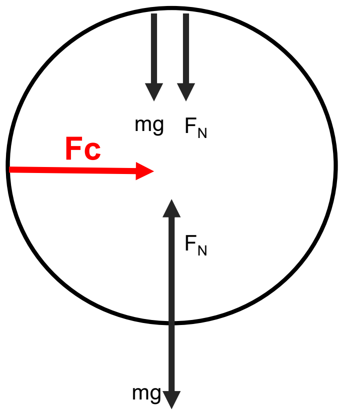
$$\frac{V_t^2}{r} = g$$

$$V_{min} = \sqrt{rg}$$

Special Case: To maintain circular motion, the tension on the string at the top of the path must be at least zero. Solving for the velocity when the tension is zero yields the minimum speed for the object at stay on a circular pat at the top.

Vertical Circular Motion – roller coaster loop

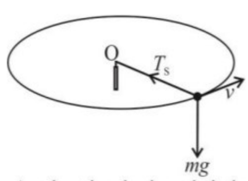
- A vertical circular motion is not uniform since the object's speed and direction change due to gravity. The gravitational force causes the object to speed up as it moves downward and slows down as it approaches the top of the vertical circle



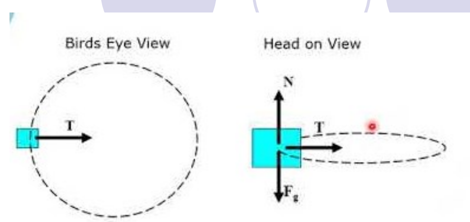
$F_c = F_n + mg$

$F_c = F_n - mg$

Horizontal Circular Motion



An obect in a horizonal circle



- When multiple forces act on an object in circular motion, those forces must add up to a centripetal force
- It is important to understand that **centripetal force is not a separate force that acts on an object. It is a net force which follows a specific rule: it always points towards the center of the circular path.**
- In a horizontal circular motion problem, any forces acting on the object in the vertical direction must balance so that $\Sigma F_{vertical} = 0\ N$ (otherwise the object would accelerate vertically). Only horizontal forces will contribute to the net force causing circular motion.

- **Centripetal Force**
  - **F = ma**
    - $a_c = \frac{v_t^2}{r} = r\omega^2$
  - **F = m** $\frac{v_t^2}{r}$
  - **F= m** $r\omega^2$

Conical Pendulum =>Tetherball