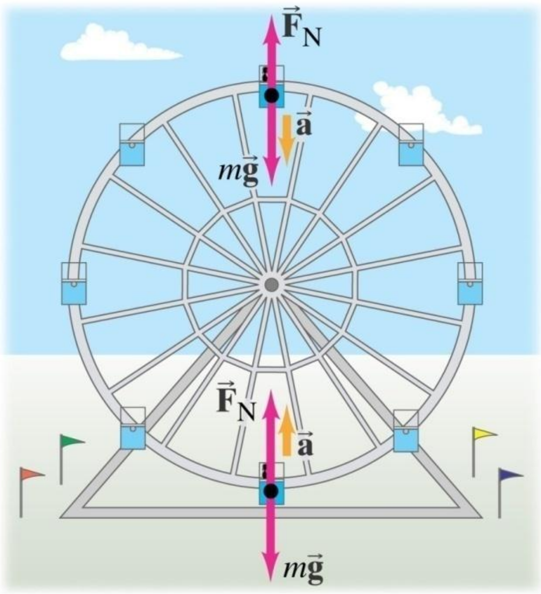
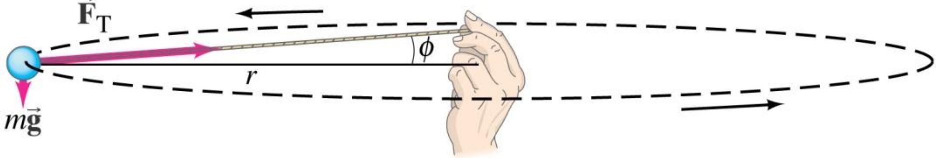
Chapter 5: Uniform Circular Motion


$\vec{F}_N$
$\vec{a}$
$m\vec{g}$
$\vec{F}_N$
$\vec{a}$
$m\vec{g}$


$\vec{F}_T$
ϕ
r
$m\vec{g}$

Periodic Motion

- Repetitive, cyclical motion that occurs along the same path in a fixed period of time
- Uniform Circular Motion (UCM) path = circle
- 1 cycle = 1 revolution

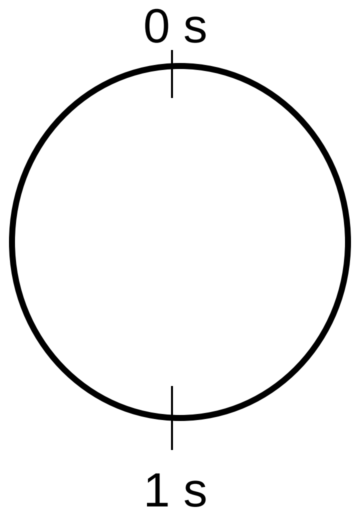
$$T \quad \text{period} = \frac{\text{\# of seconds}}{\text{1 complete revolution}}$$

$$f \quad \text{frequency} = \frac{\text{\# of revolutions}}{\text{1 second (or minute)}}$$

Inverse relationship between T, f $\quad T = \frac{1}{f} \quad f = \frac{1}{T}$

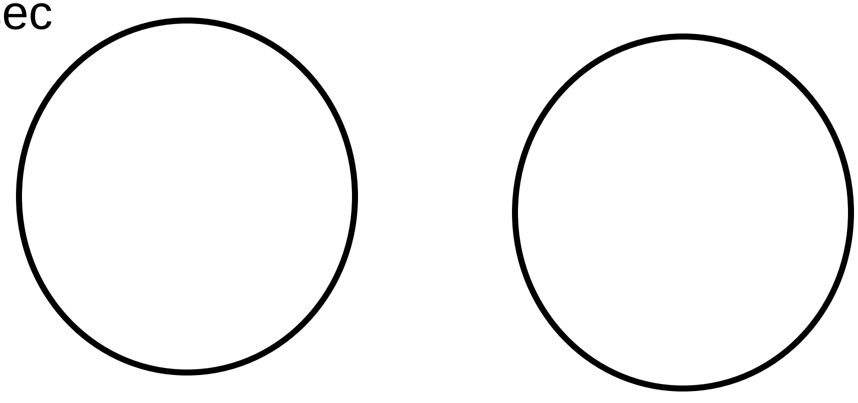
Frequency – Period Relationship

T = 2 s



f = ?

f = 2 revs/sec

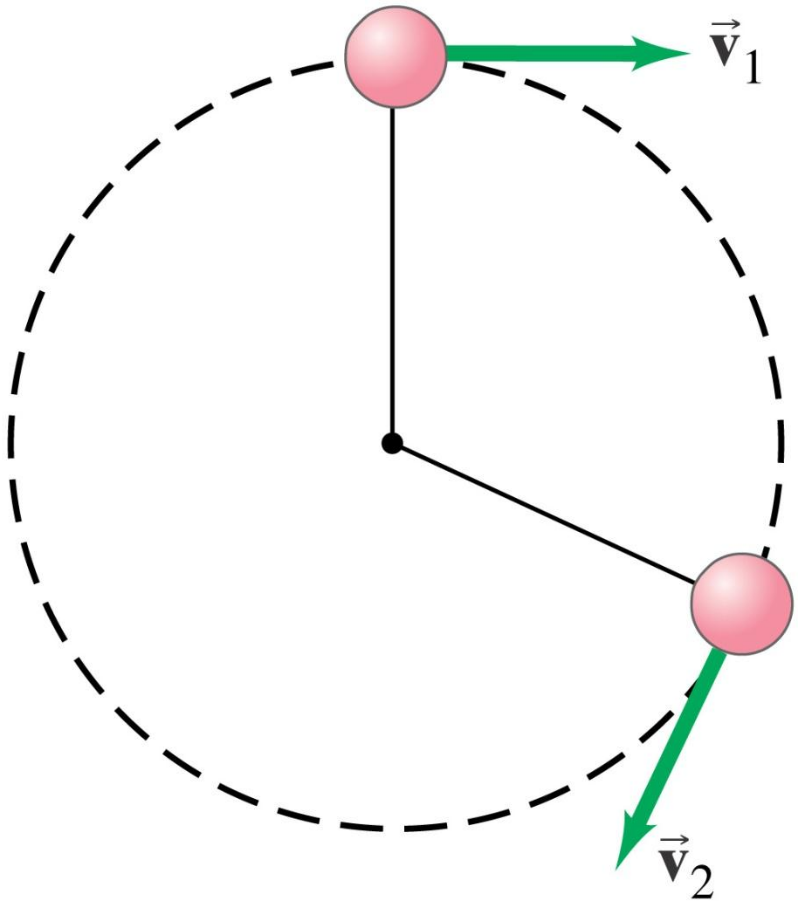


T = ?

5-1 Kinematics of Uniform Circular Motion

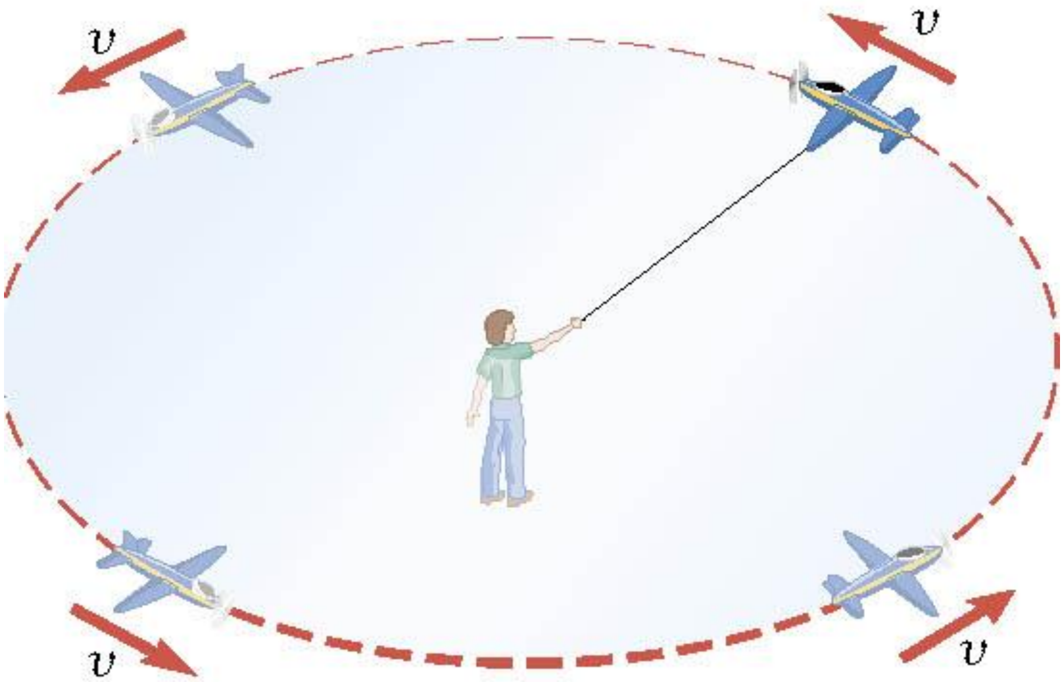
Uniform circular motion: motion in a circle of constant radius at constant speed

Instantaneous velocity is always tangent to circle.



Uniform Circular Motion (UCM)

- Object revolving around a center point in a circular path at a constant speed *v*



$$\textit{Speed} \quad \mathrm{v} = \frac{2\pi\,\mathrm{r}}{\mathrm{T}} = \frac{\textit{circle circumference}}{\textit{period}} \qquad r = \textit{circular path radius}$$

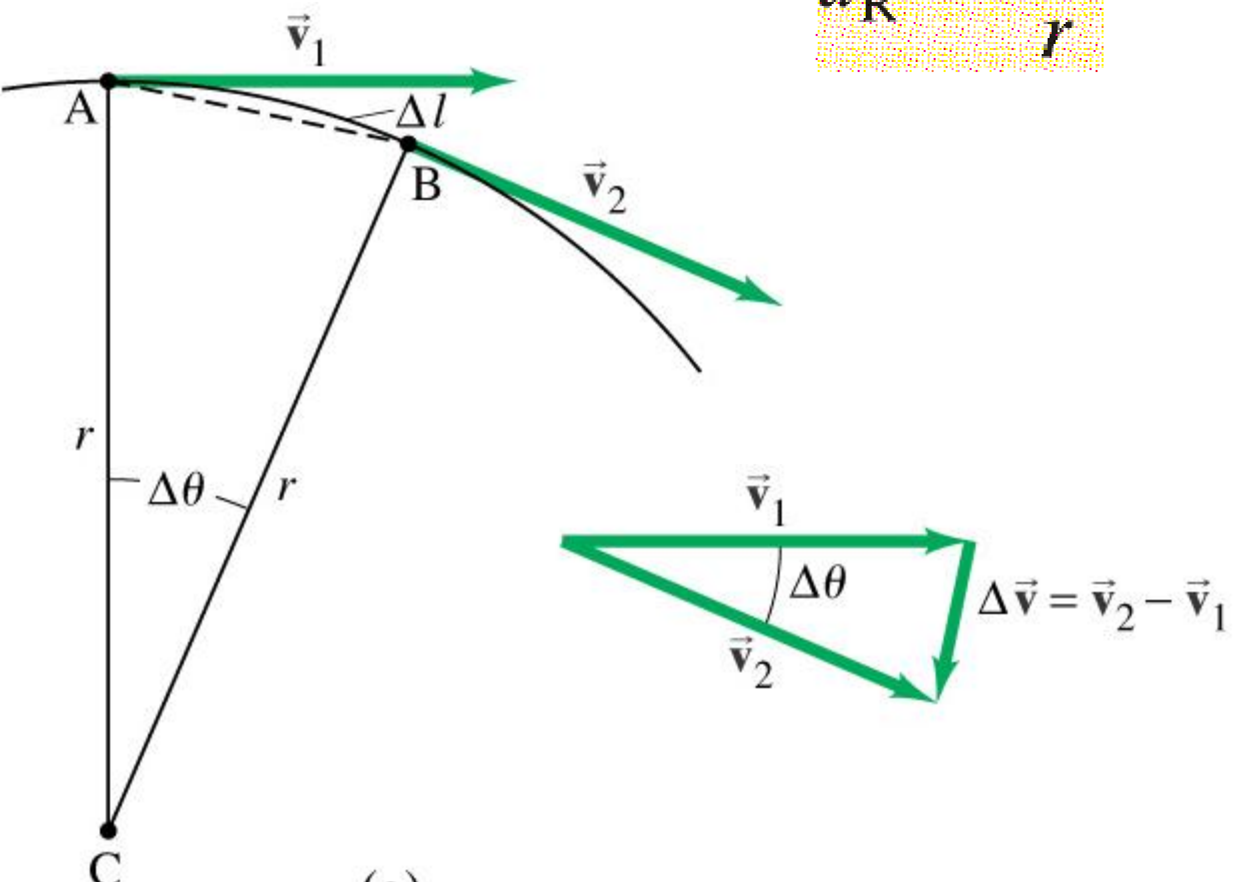
- Can an object moving at constant speed be accelerating?

- Velocity is constantly changing due to its change in direction as it moves around the circle
- Change in velocity means the object is accelerating

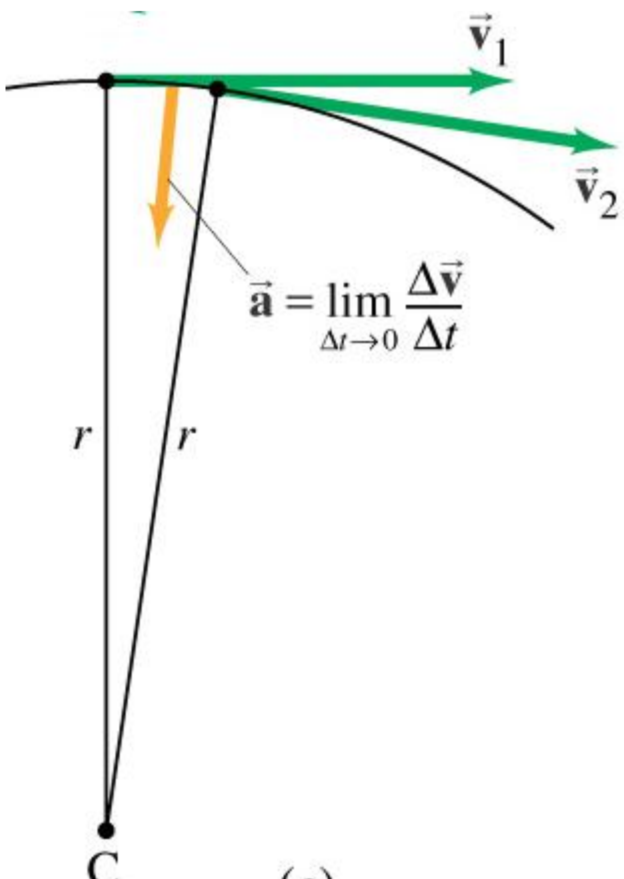
5-1 Kinematics of Uniform Circular Motion

Looking at the change in velocity in the limit that the time interval becomes infinitesimally small, we see that

$$a_R = \frac{v^2}{r} \qquad \textbf{(5-1)}$$



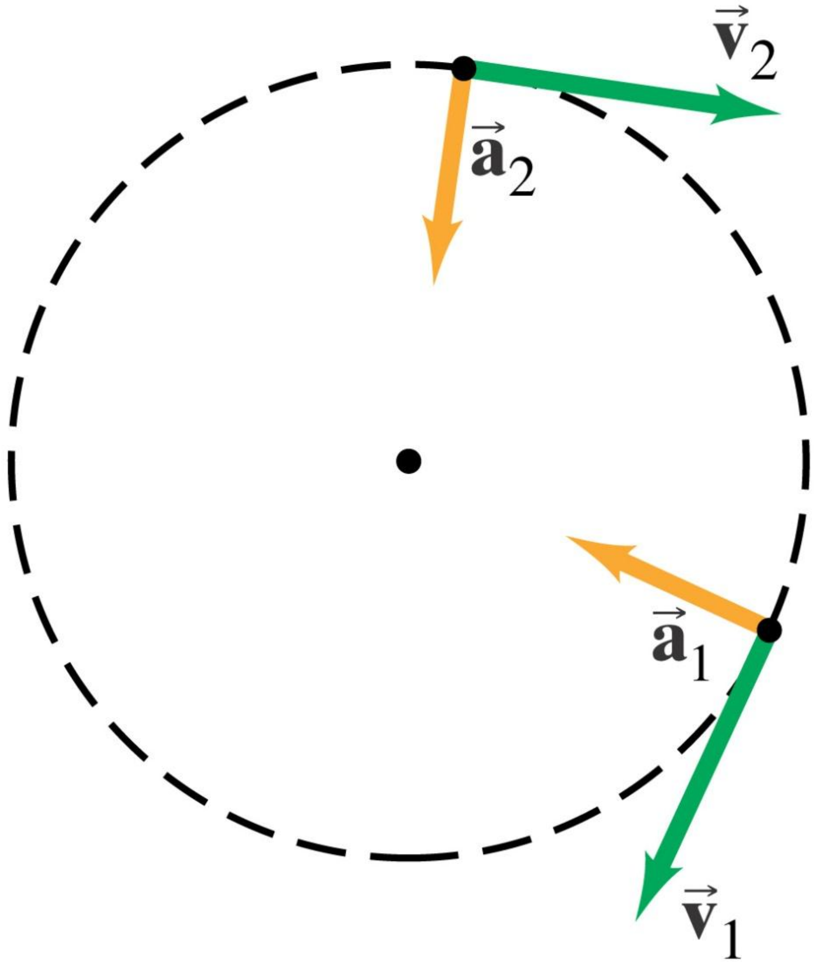
(a)



(c)

5-1 Kinematics of Uniform Circular Motion

This acceleration is called the **centripetal**, or radial, acceleration, and it points towards the center of the circle.



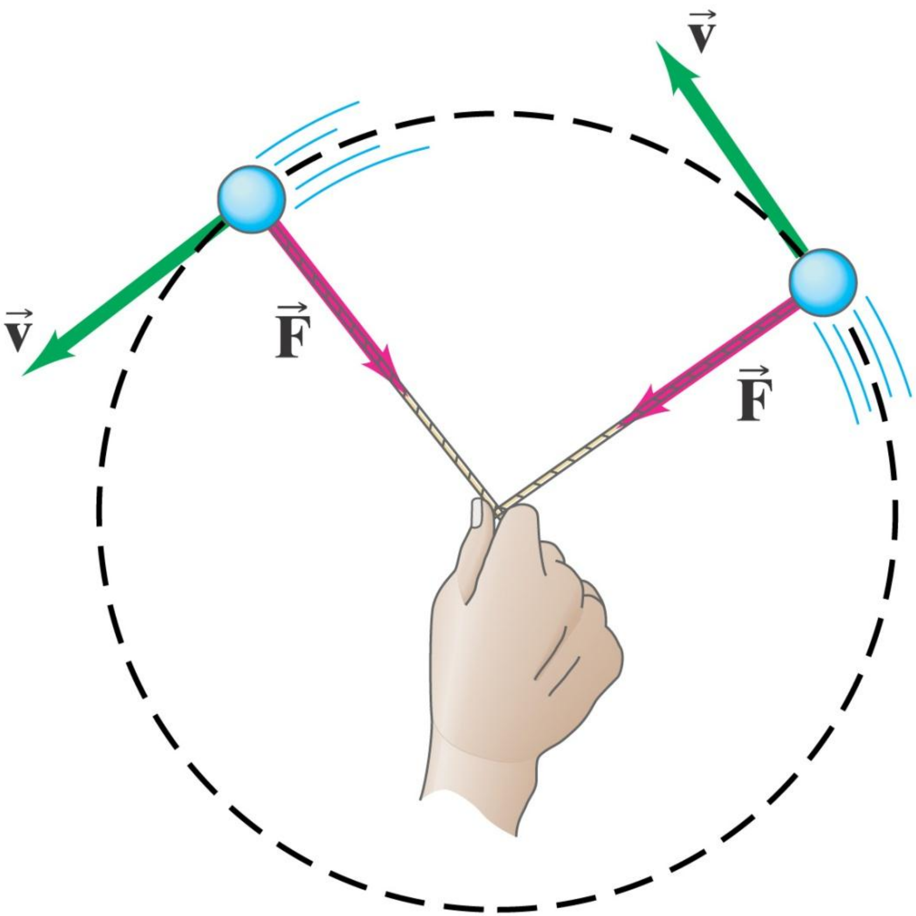
Centripetal Force

- Net force directed radially towards center of circle
- Causes the centripetal acceleration
- Responsible for changing the direction of the velocity vector so object moves in circular path

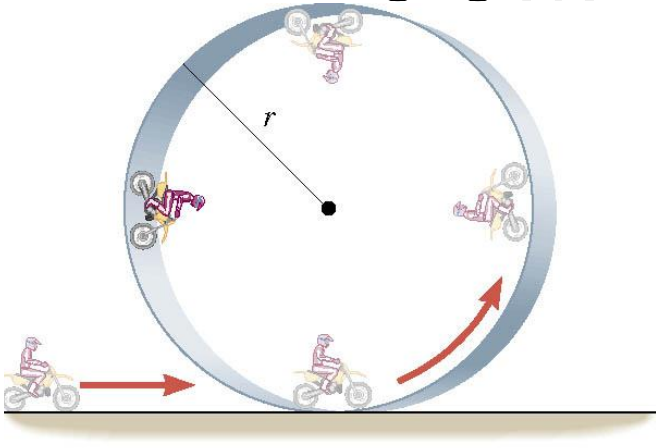
$$\Sigma F_c = ma_c = m\frac{v^2}{r}$$

•You must be able to identify the applied force that provides the centripetal force causing UCM

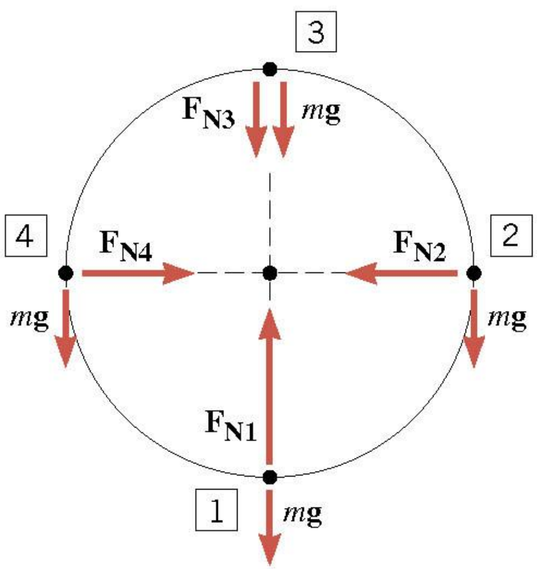
Tension in string creates centripetal force



UCM Vertical Circles



(a)

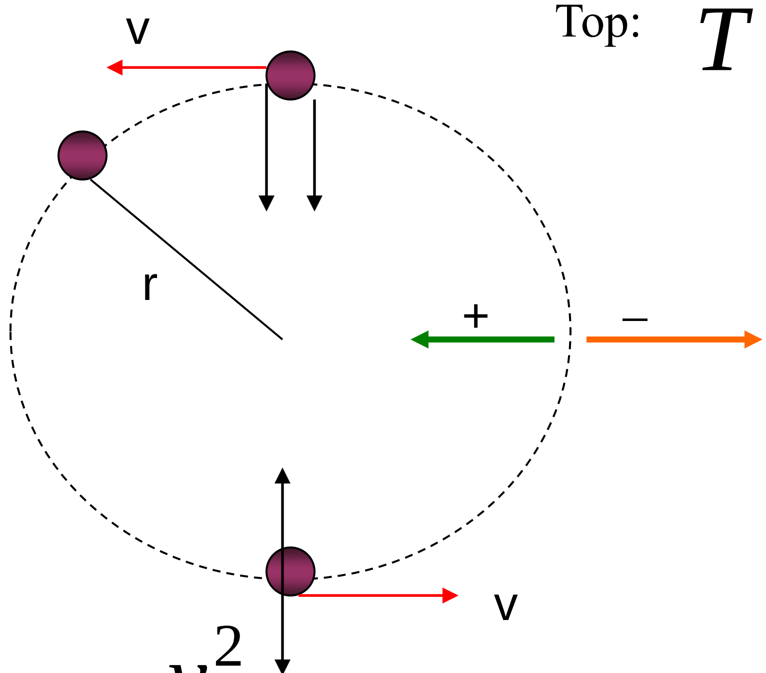


(b)

- Centripetal force provided by a net force of 2 applied forces
- Two different cases
  - vertical “loop-the-loop” track
    - normal force and weight
  - ball on a string
    - Tension and weight

Vertical circle – ball on a string

Top: $$T + mg = m\frac{v^2}{r}$$



Bottom: $$T - mg = m\frac{v^2}{r}$$

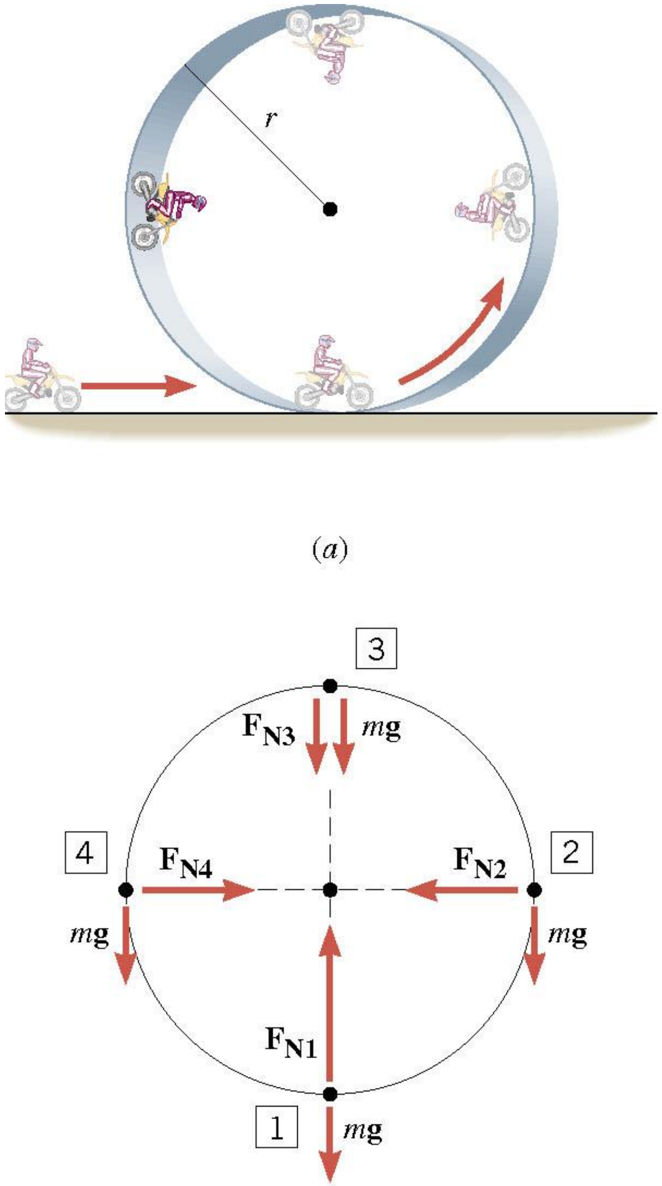
F_c stays constant at all points.

Tension changes due to inclusion of weight force

Approach for solving any UCM problem:

Set net force = mv^2/r

Critical velocity at top of a vertical circle



(a)

(b)

Minimum velocity necessary to keep object in circular path

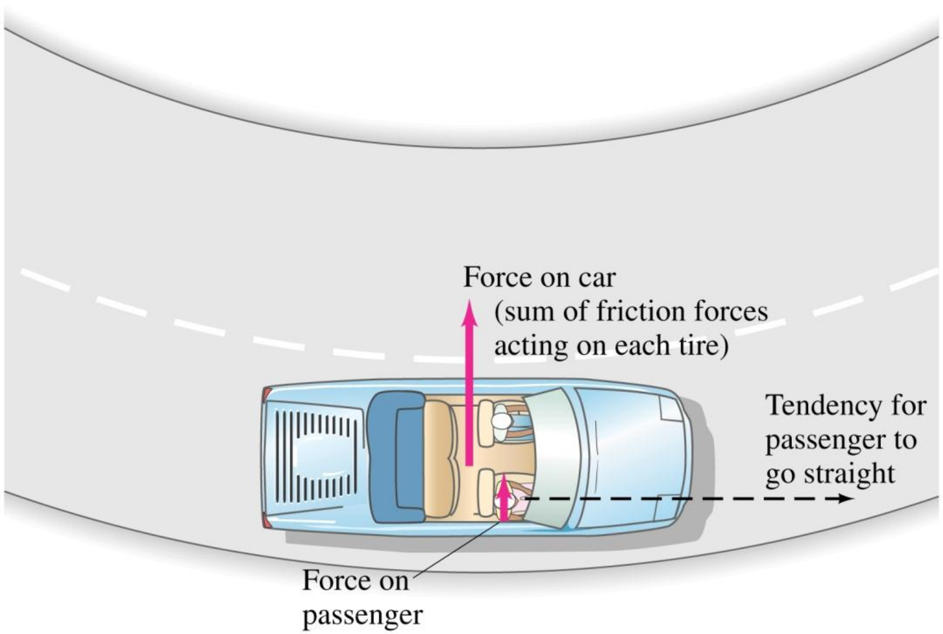
Occurs when the normal force (or tension in string) = 0

$$F_N + mg = \frac{mv^2}{r}$$

$$mg = \frac{mv^2}{r}$$

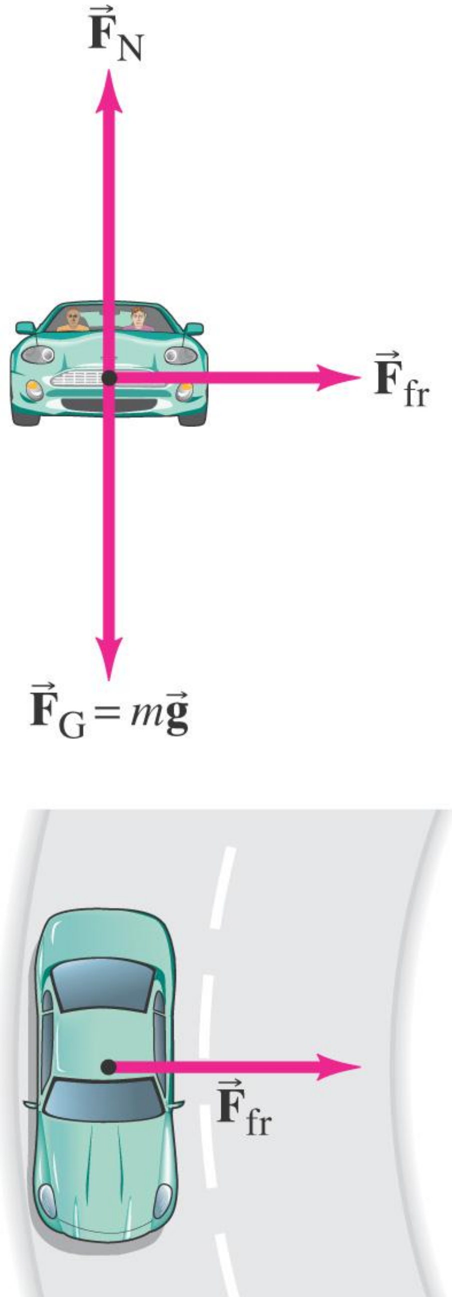
$$v = \sqrt{rg}$$

When a car goes around a curve, there must be a net force towards the center of the circle of which the curve is an arc. If the road is flat, that force is supplied by friction.



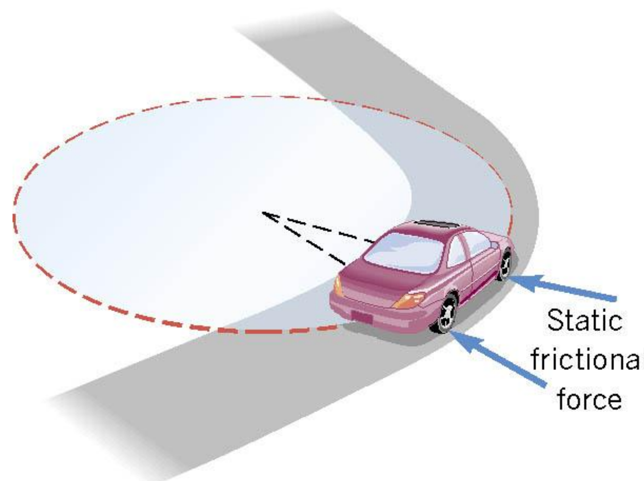
There are no centrifugal forces pushing person against door

Determine maximum speed car can have to round a horizontal circular turn and not skid out of circle



(a)

(b)



Max speed derivation

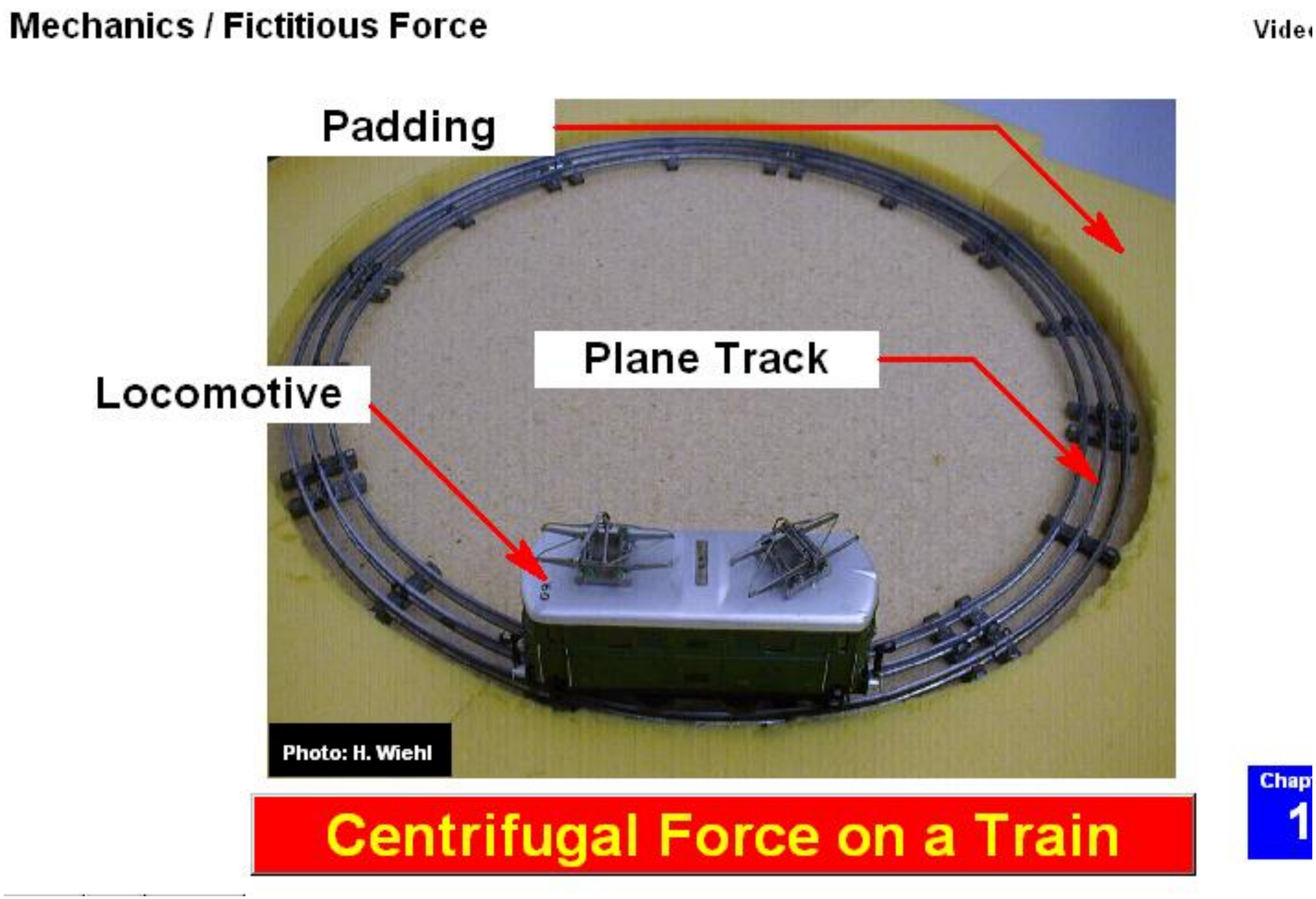
$$f_{s,\max} = F_c$$

$$\mu_s F_N = \frac{mv^2}{r}$$

$$\mu_s mg = \frac{mv^2}{r}$$

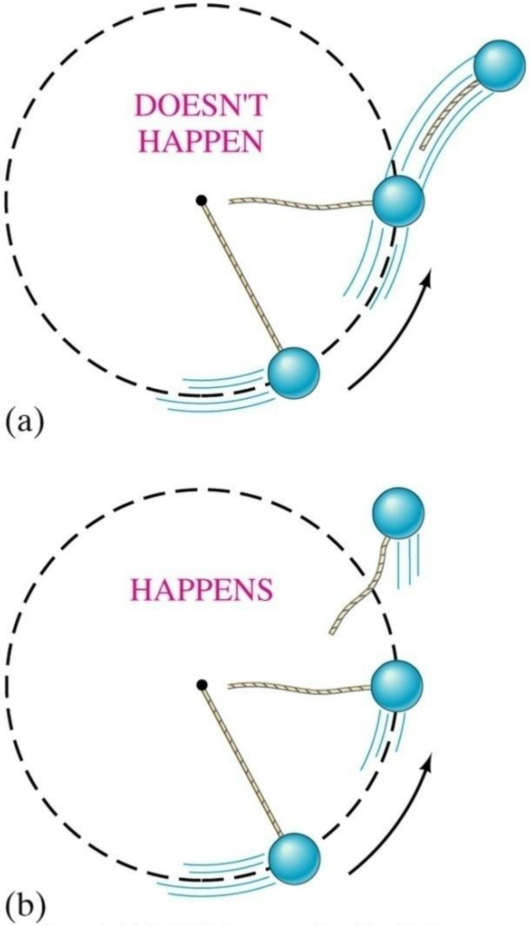
$$\sqrt{u_s rg} = v$$

speed is independent of car's mass


Mechanics / Fictitious Force
Padding
Plane Track
Locomotive
Photo: H. Wiehl
Centrifugal Force on a Train

demo

Predict direction of object upon leaving UCM circle



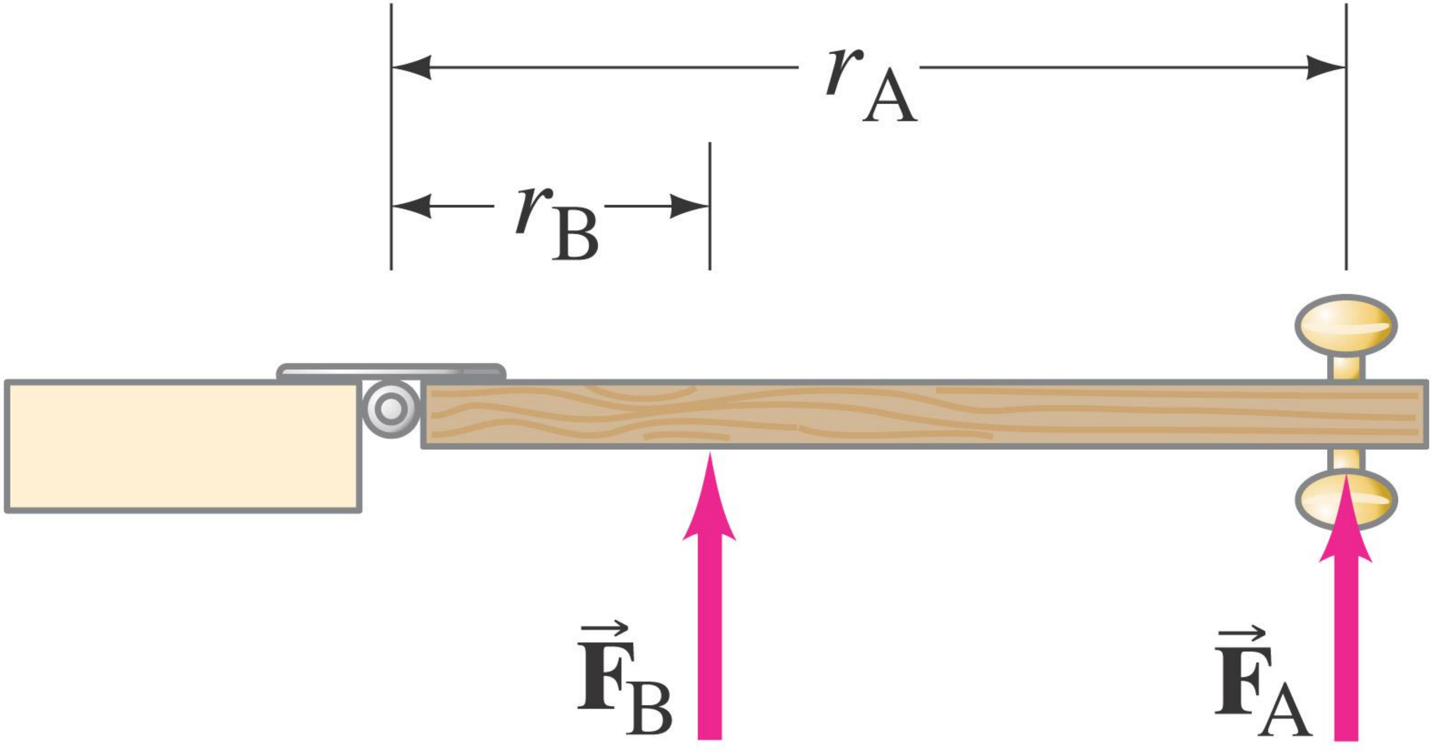
Chapter 8

Rotational Motion

8-4 Torque

To make an object **start** rotating, a **force** is needed; the **position** and **direction** of the force matter as well.

The **perpendicular** distance from the axis of rotation to the line along which the force acts is called the **lever arm**.



8-4 Torque

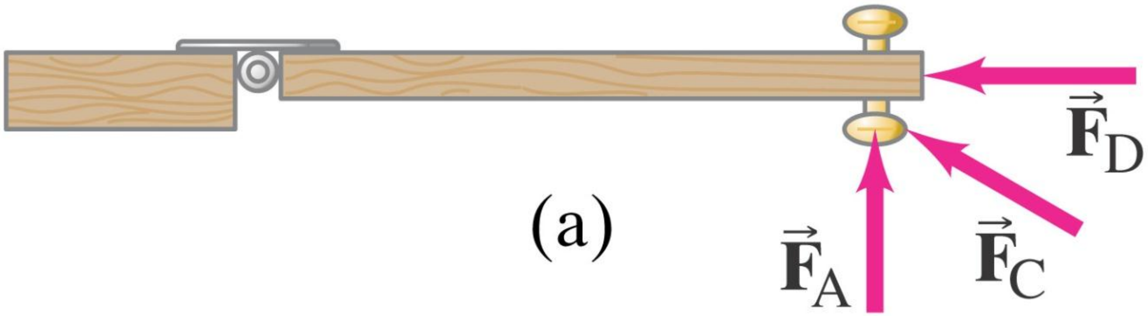
(a)

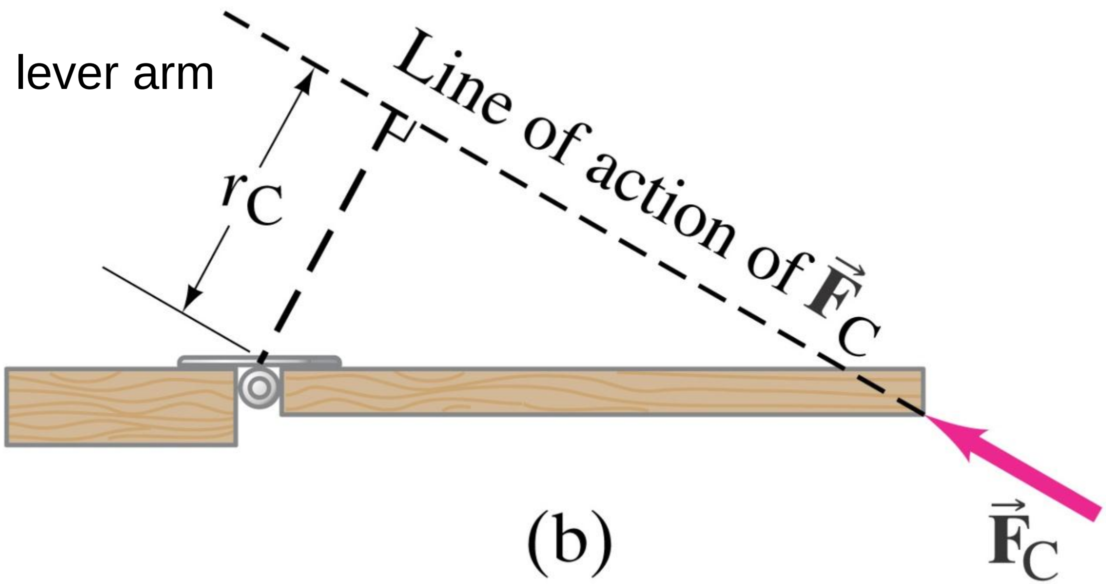
(b)

A **longer** lever arm is very helpful in rotating objects.

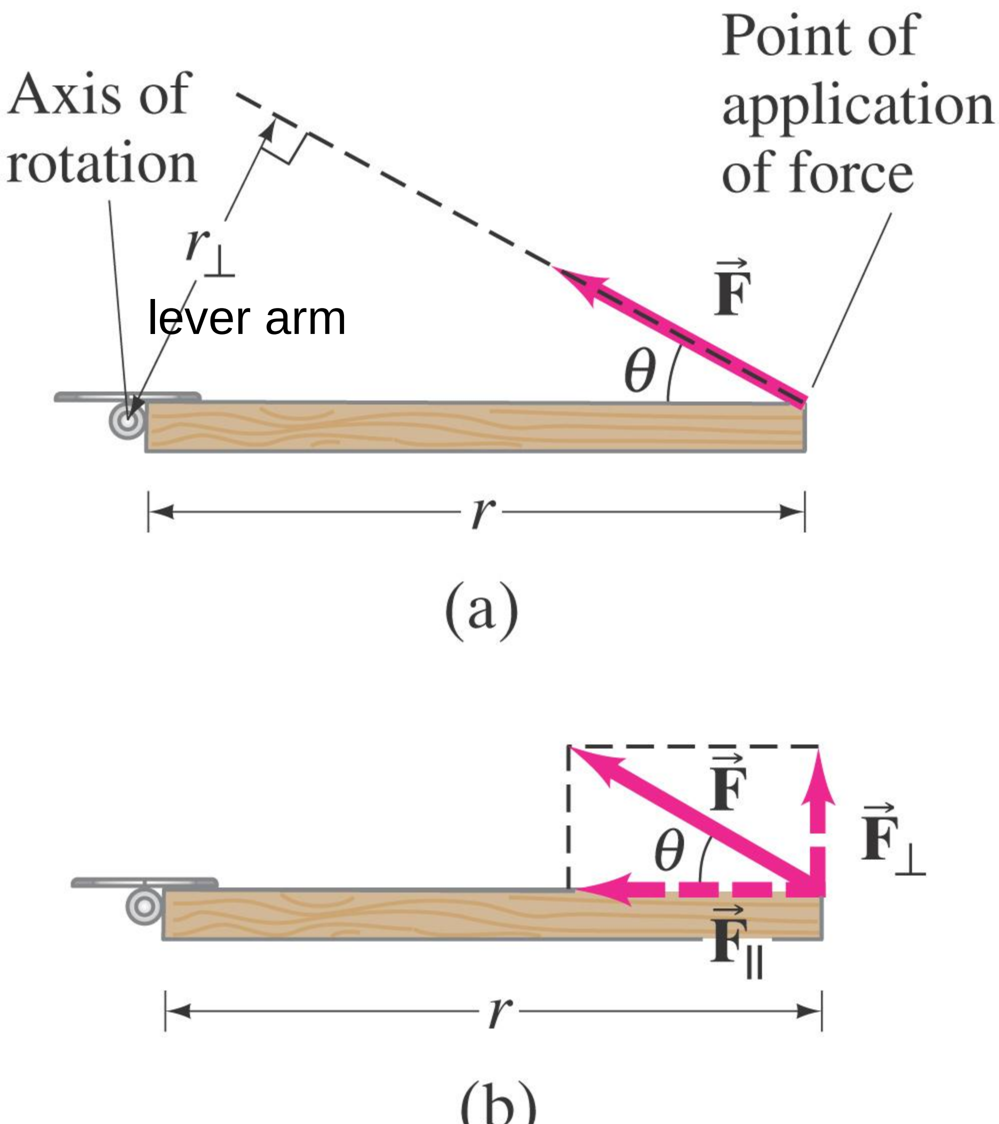
8-4 Torque

Here, the lever arm for F_A is the distance from the **knob** to the **hinge**; the lever arm for F_D is **zero**; and the lever arm for F_C is as shown.





8-4 Torque



The **torque** is defined as:

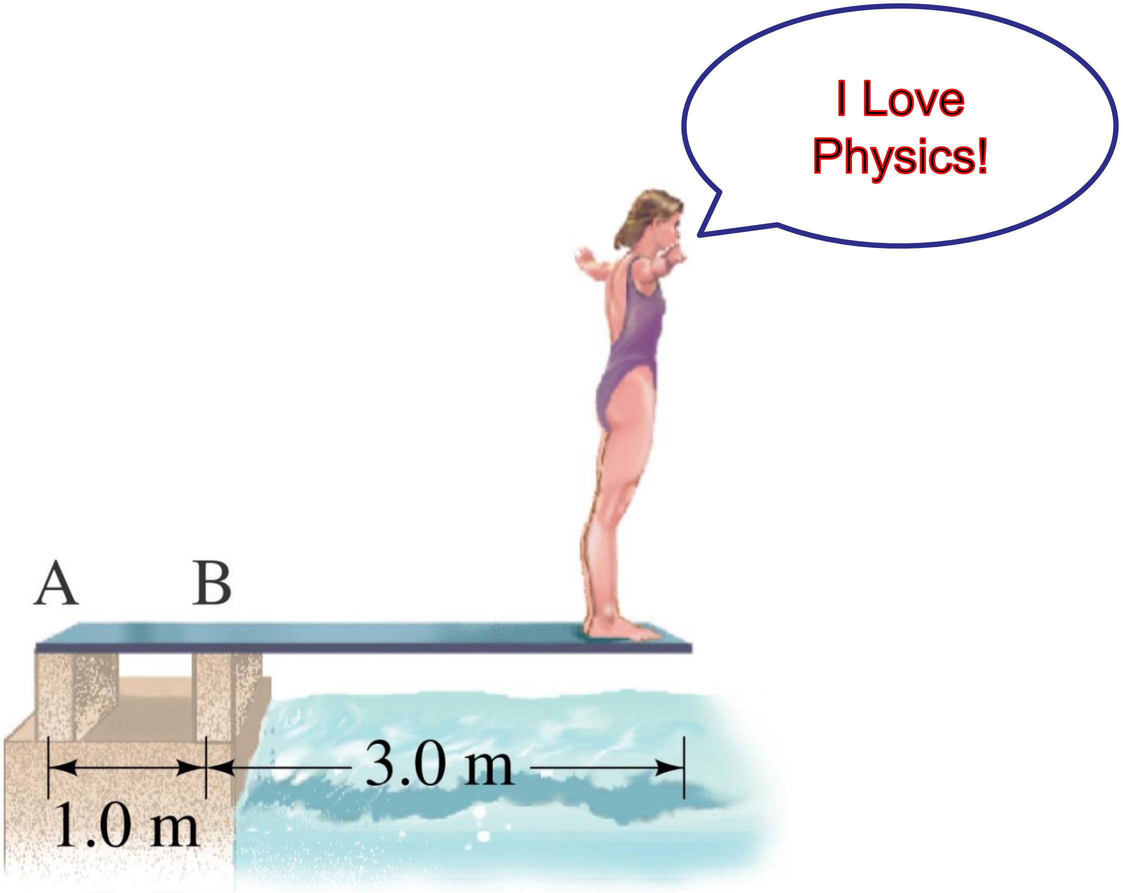
$$\tau = r_\perp F \qquad \textbf{(8-10a)}$$

$\tau = r \sin\theta \bullet F$

$\theta =$ angle between the line from the axis to the point of contact of the force AND the force vector

Chapter 9

Static Equilibrium

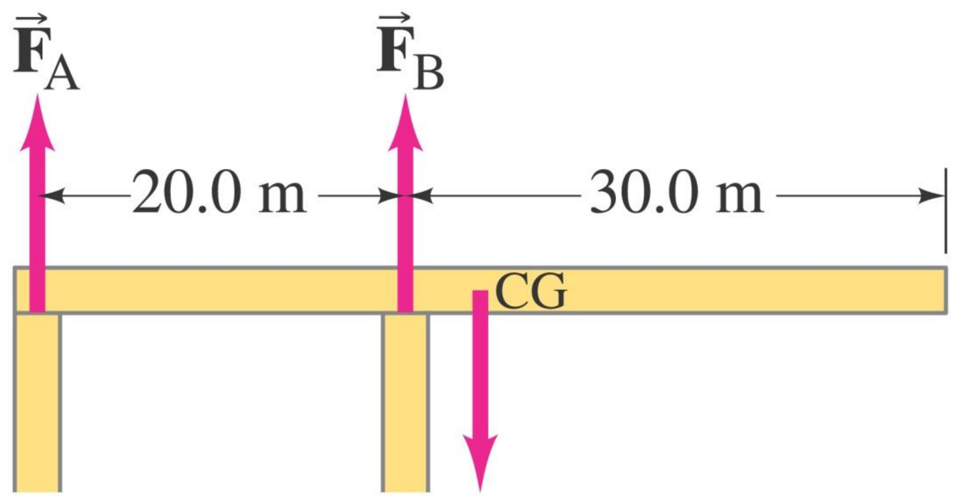


2 conditions for equilibrium

1) $\Sigma F_y = 0$ and $\Sigma F_x = 0$

2) The net torque about any axis = 0

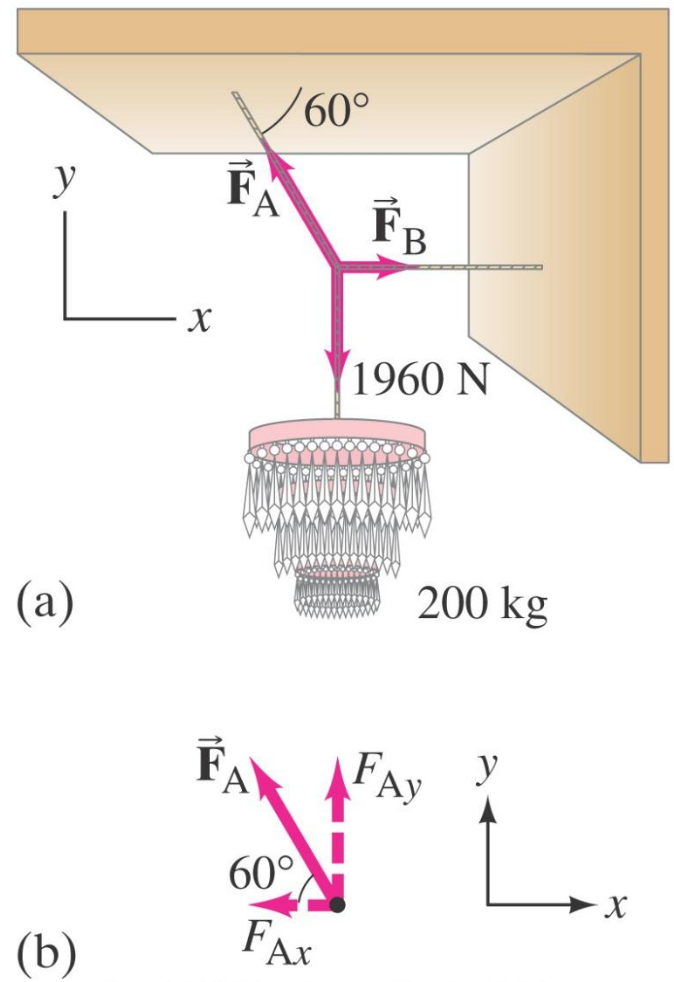
All objects will be in static equilibrium – no motion



3 different types of equilibrium problems in chapter 9

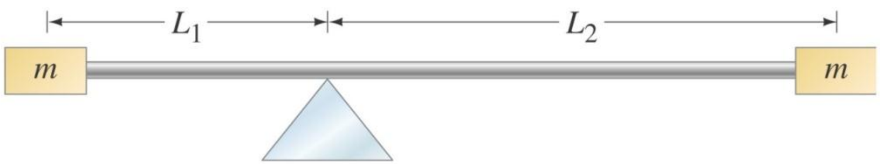
1st type does not have any torques to consider

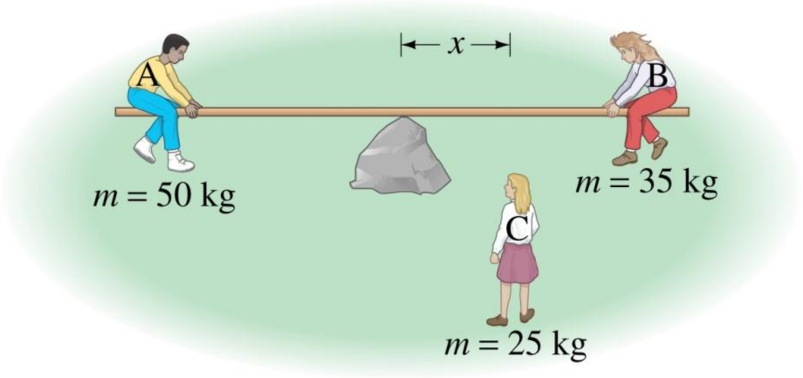
Key is to resolve vectors into x, y components correctly



2nd type is balancing a horizontal beam

- beam does not have any significant mass
- must calculate both forces and torques





3rd type is beam balancing again

• Beam does have significant mass that is concentrated at its center of gravity (CG) = point where all of its weight could be concentrated

• It is convenient to use one end of the beam as the axis of rotation – this causes the lever arm for that force = 0, thus simplifying the net torque calculation.