Physics 101: Mechanics
Lecture 7

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Lets remember Uniform Circular Motion

Figure 6.1
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Figure 6.2
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Uniform circular motion

Constant speed, or,
constant magnitude of velocity

Motion along a circle:
Changing direction of velocity

Uniform Circular Motion: Observations

- Object moving along a curved path with **constant speed**
  - Magnitude of velocity: same
  - Direction of velocity: changing
  - Velocity $\vec{v}$: changing
  - Acceleration is NOT zero! Therefore Net force acting on an object is NOT zero
  - "**Centripetal force**"

$$\vec{F}_{net} = m\vec{a}$$

Uniform Circular Motion

- Magnitude:

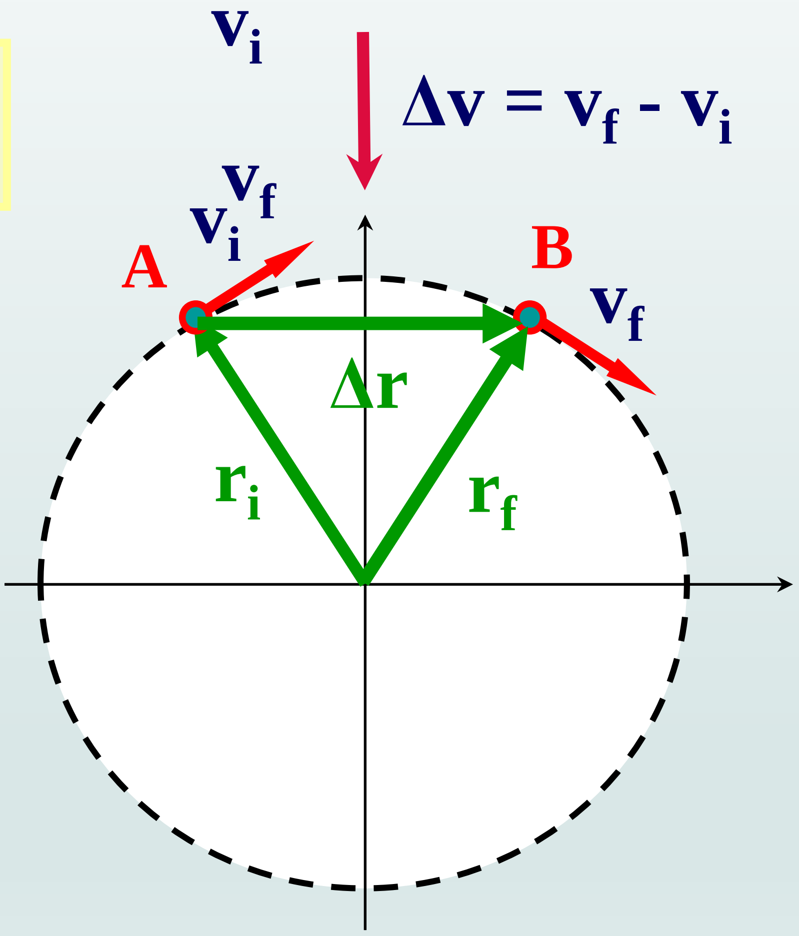
$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i \qquad \vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

$$\frac{\Delta v}{v} = \frac{\Delta r}{r} \quad \text{so,} \quad \Delta v = \frac{v\Delta r}{r}$$

$$\frac{\Delta v}{\Delta t} = \frac{\Delta r}{\Delta t}\frac{v}{r} = \frac{v^2}{r}$$

$$a_r = \frac{\Delta v}{\Delta t} = \frac{v^2}{r}$$

- Direction: **Centripetal**

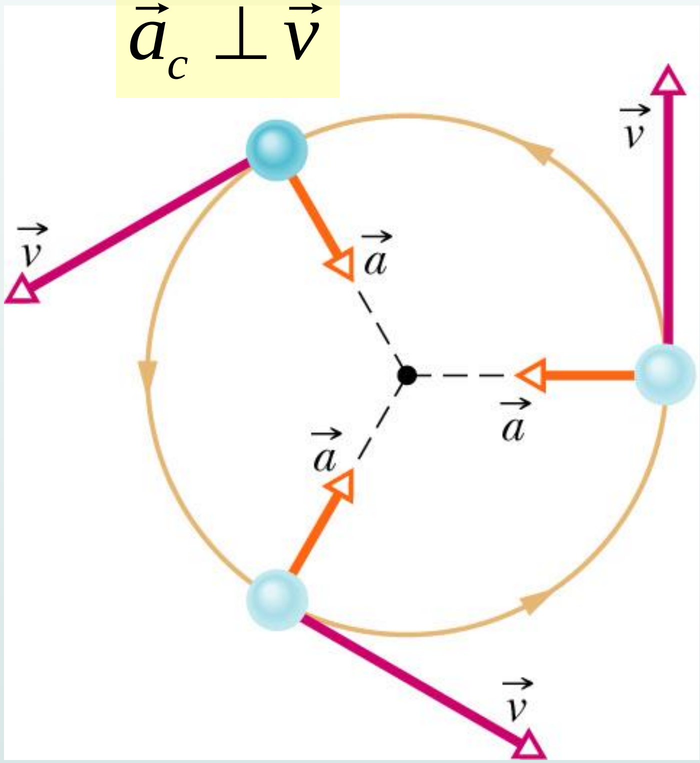


Uniform Circular Motion

- Velocity:
  - Magnitude: constant *v*
  - The direction of the velocity is tangent to the circle
- Acceleration:
  - Magnitude: $$a_c = \frac{v^2}{r}$$
  - directed toward the center of the circle of motion
- Period:
  - time interval required for one complete revolution of the particle

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

$$\vec{a}_c \perp \vec{v}$$

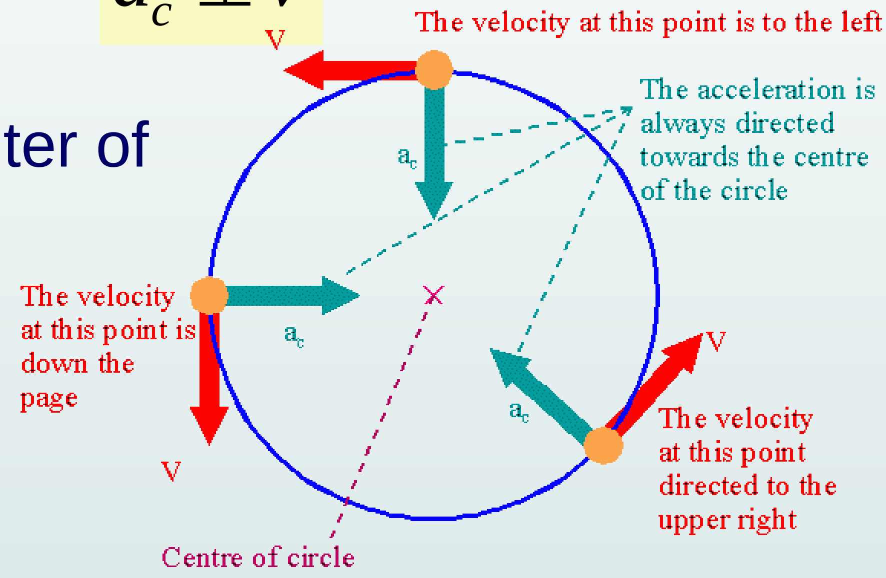


Centripetal Force

- Acceleration:
  - Magnitude: $$a_c = \frac{v^2}{r}$$
  - Direction: toward the center of the circle of motion

$$\vec{a}_c \perp \vec{v}$$

$$\vec{F}_{net} \perp \vec{v}$$



- Force:
  - Newton's 2[nd] Law says

$$\vec{F}_{net} = m\vec{a}$$

  - Magnitude:

$$F_{net} = ma_c = \frac{mv^2}{r}$$

  - Direction: toward the center of the circle of motion

$$\vec{a}_c \parallel \vec{F}_{net}$$

What provide Centripetal Force ?

- not a new kind of force
- The centripetal force represents any force that follows the object in a circular path

$$F_c = ma_c = \frac{mv^2}{r}$$

- Centripetal force
  - Gravitational force **mg**: downward to the ground
  - Normal force **N**: perpendicular to the surface
  - Tension force **T**: along the cord and away from object
  - Static friction force: $f_s^{max} = \mu_s N$
- is a combination of 4 forces

What provide Centripetal Force ?

Figure 6.2
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$$F_{net} = N - mg = ma$$

$$N = mg + m\frac{v^2}{r}$$

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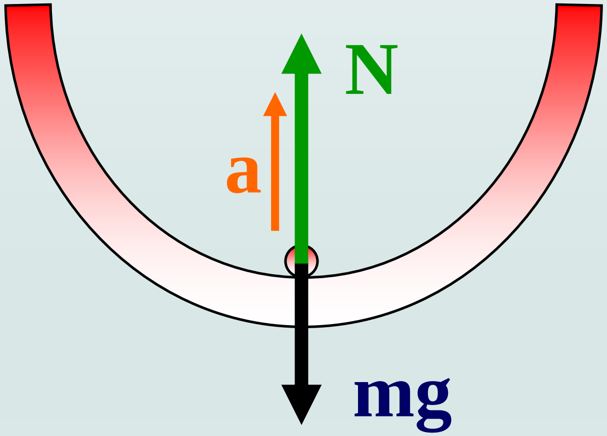

$$F_{net} = T = ma$$

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

The Conical Pendulum

- A small ball of mass m is suspended from *a* string of length L. The ball revolves with constant speed v in a horizontal circle of radius r. Find an expression for v and a

$$m = 5\ kg \quad L = 10\ m \quad r = 4\ m$$

$$\sum F_y = T\cos\theta - mg = 0$$

$$T\cos\theta = mg$$

$$\sum F_x = T\sin\theta = ma_c = \frac{mv^2}{r}$$

$$\sin\theta = \frac{r}{L} = 0.4$$

$$\tan\theta = \frac{r}{\sqrt{L^2 - r^2}} = 0.44$$

Figure 6.4
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The Conical Pendulum

- Find v and a

$$m = 5\ kg \quad L = 10\ m \quad r = 4\ m$$

$$\sum F_y = T\cos\theta - mg = 0$$

$$T\cos\theta = mg$$

$$\sum F_x = T\sin\theta = \frac{mv^2}{r}$$

$$\sin\theta = \frac{r}{L} = 0.4$$

$$\tan\theta = \frac{r}{\sqrt{L^2 - r^2}} = 0.44$$

$$T\sin\theta = \frac{mv^2}{r}$$

$$T\cos\theta = mg$$

$$\tan\theta = \frac{v^2}{gr}$$

$$v = \sqrt{rg\tan\theta}$$

$$v = \sqrt{Lg\sin\theta\tan\theta} = 2.9\ \mathrm{m/s}$$

$$a = \frac{v^2}{r} = g\tan\theta = 4.3\ \mathrm{m/s}^2$$

Level Curves

- A 1500 kg car moving on a flat, horizontal road negotiates a curve as shown. If the radius of the curve is 35.0 m and the coefficient of static friction between the tires and dry pavement is 0.523, find the maximum speed the car can have and still make the turn successfully.

Figure 6.5
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Level Curves

- The force of static friction directed toward the center of the curve keeps the car moving in a circular path.

$$f_{s,\max} = \mu_s N = m\frac{v_{\max}^2}{r}$$

$$\sum F_y = N - mg = 0$$

$$N = mg$$

$$v_{\max} = \sqrt{\frac{\mu_s N r}{m}} = \sqrt{\frac{\mu_s m g r}{m}} = \sqrt{\mu_s g r}$$

$$= \sqrt{(0.523)(9.8m/s^2)(35.0m)} = 13.4m/s$$

Banked Curves

- A car moving at the designated speed can negotiate the curve. Such a ramp is usually banked, which means that the roadway is tilted toward the inside of the curve. Suppose the designated speed for the ramp is to be 13.4 m/s and the radius of the curve is 35.0 m. At what angle should the curve be banked?

Figure 6.6
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Banked Curves

$$v = 13.4\ \text{m/s} \qquad r = 35.0\ \text{m}$$

$$\sum F_r = n\sin\theta = ma_c = \frac{mv^2}{r}$$

$$\sum F_y = n\cos\theta - mg = 0$$

$$n\cos\theta = mg$$

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{13.4\ \text{m/s}}{(35.0\ \text{m})(9.8\ \text{m/s}^2)}\right) = 27.6^\circ$$

Motion in Accelerated Frames

Figure 6.11 – 6.12
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What caused him to go to the door? This is commonly referred to as "centrifugal force" but is an imaginary force due to the acceleration associated with the changing direction of the vehicle's velocity vector

He slides toward the door, not because of an outward force, but it is not good enough to allow the friction force to pass through the circular path that the car tracks.