College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Announcements

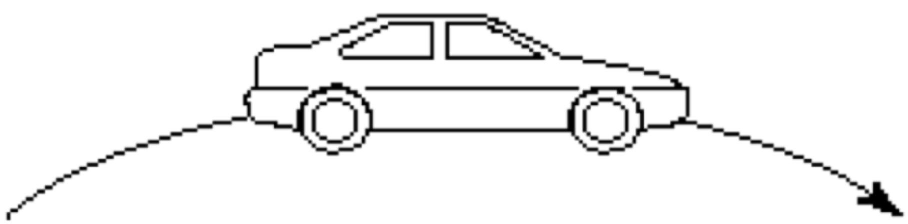
- All labs and discussion sections will meet this week, and homework is due Thursday as usual
- I will be gone Wednesday
  - Prof. Baalrud will substitute
  - Office hours extended this Tuesday to 1:30-4:00
  - Office hours canceled Wednesday & Thursday
  - Available by e-mail
  - Back Friday

Announcements

- Midterm #1 Equation Sheet Posted (on notes page)
- Sample problems will be posted the week before the midterm

Concept Check

A car rounds a curve while maintaining a constant speed. Is there a net force on the car as it rounds the curve?



A: No—its speed is constant.
B: Yes.
C: Depends

Concept Check

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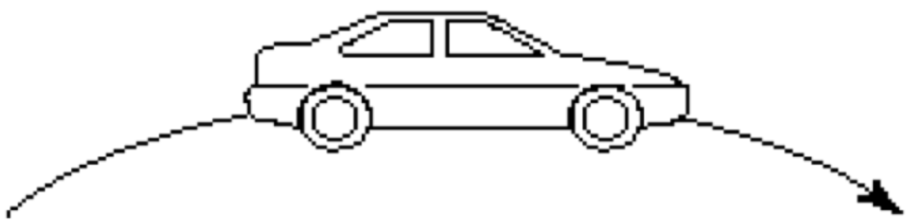

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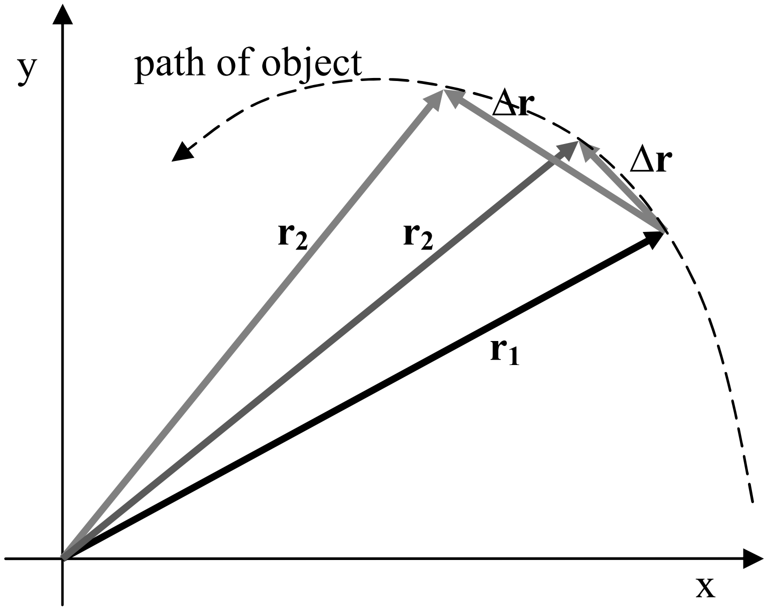
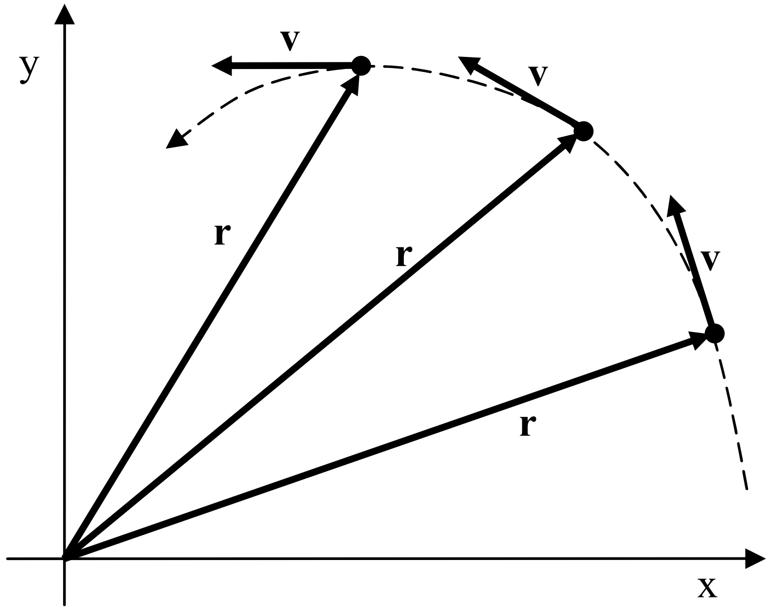
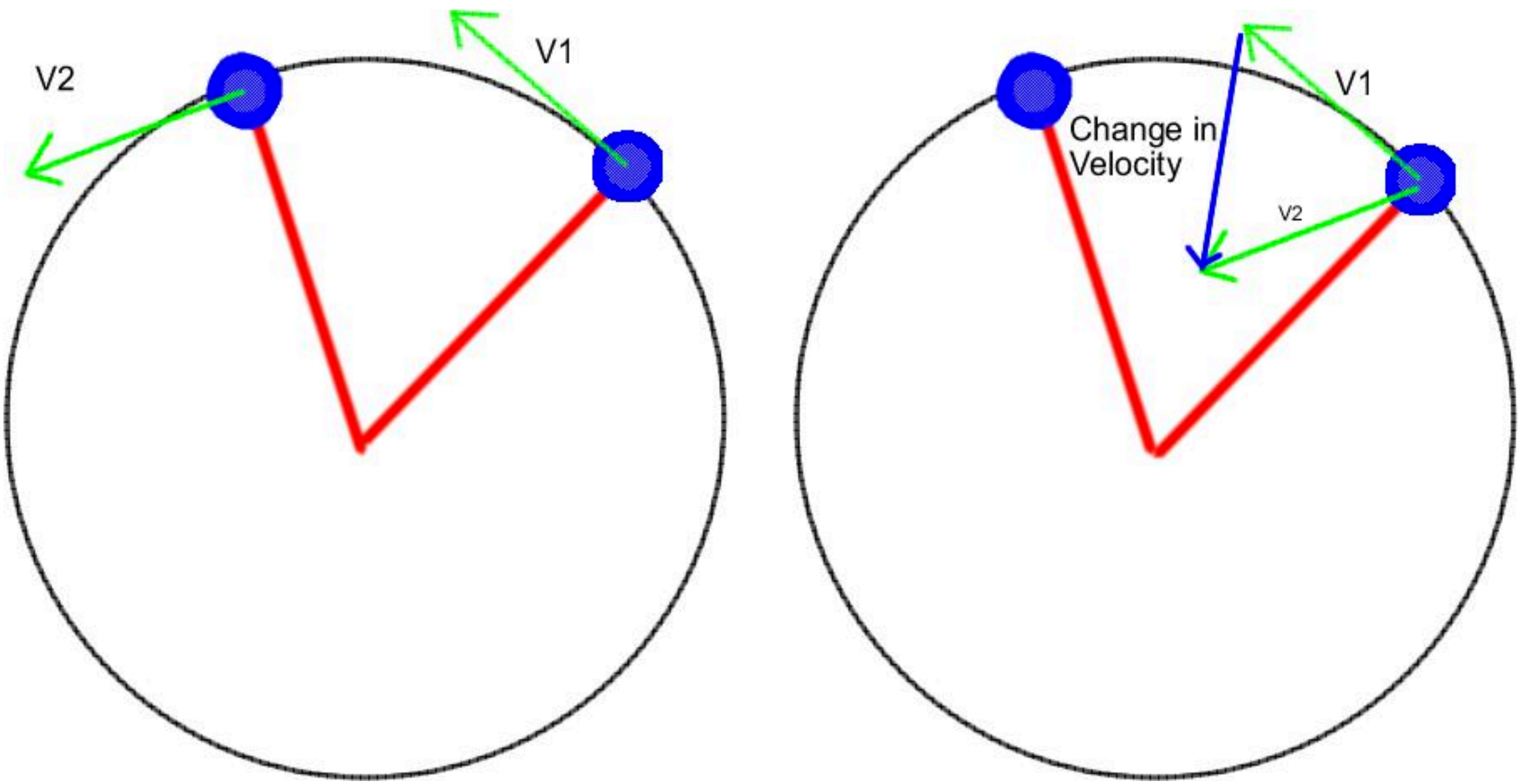
Position/Velocity in Circular Motion

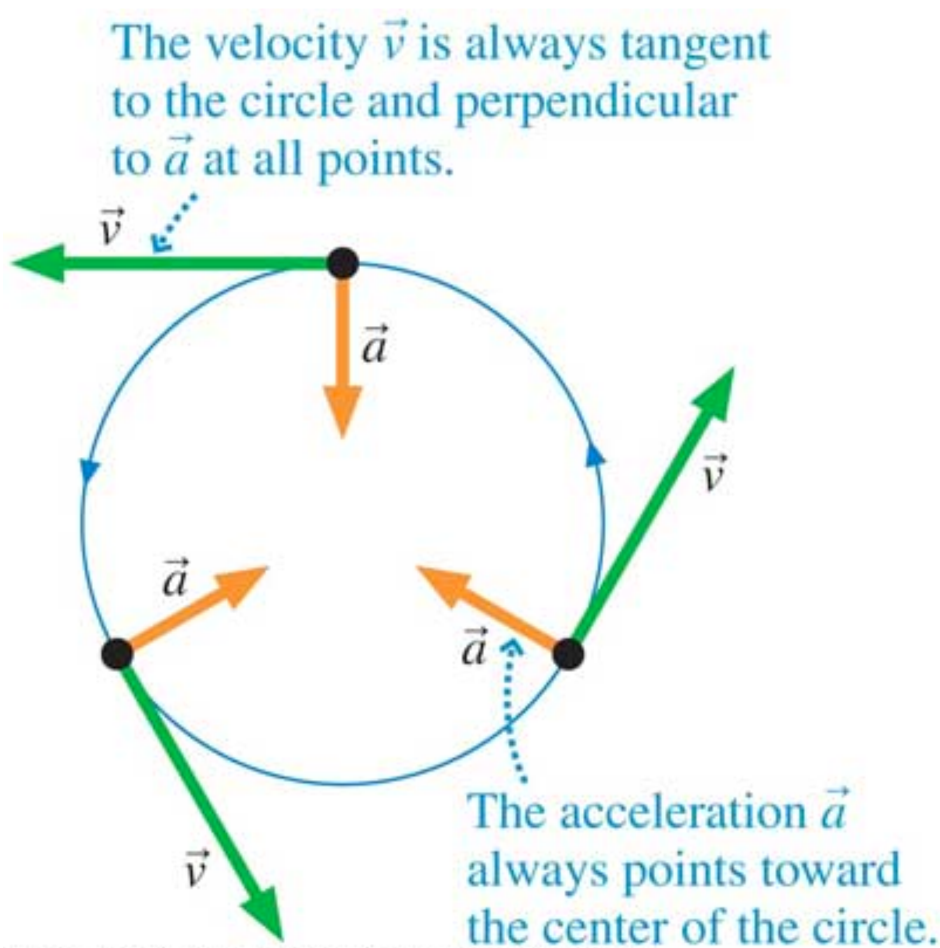




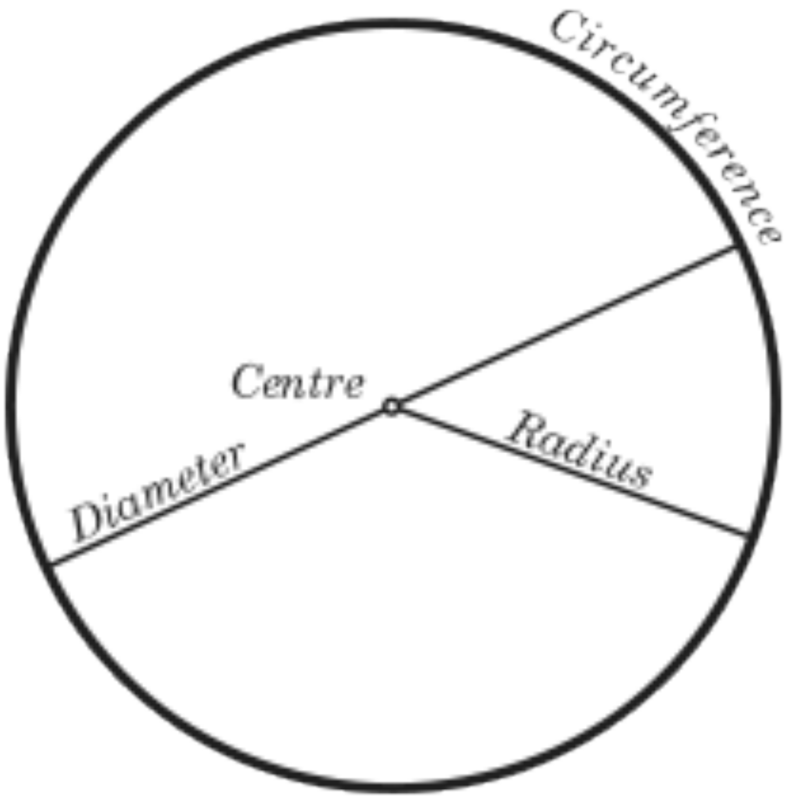
Acceleration in Circular Motion

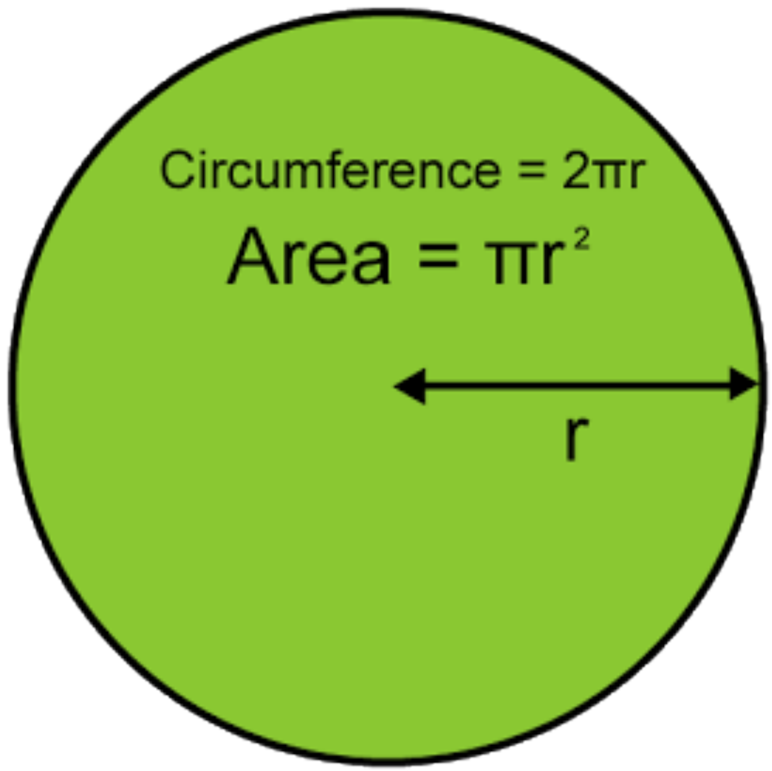


Acceleration in Uniform Circular Motion

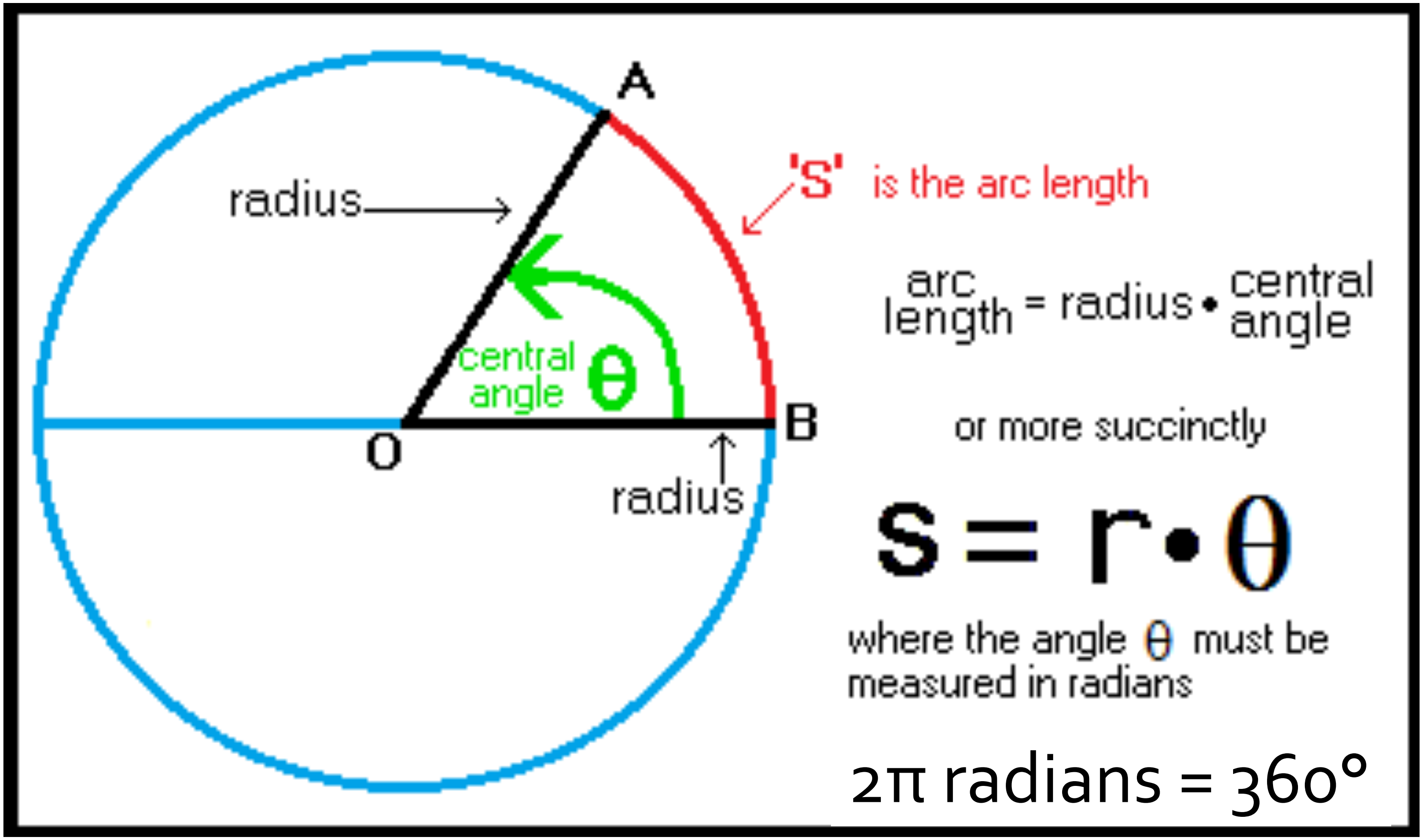


Circles: Radius and Circumference





Circles: Arc Length and Angle

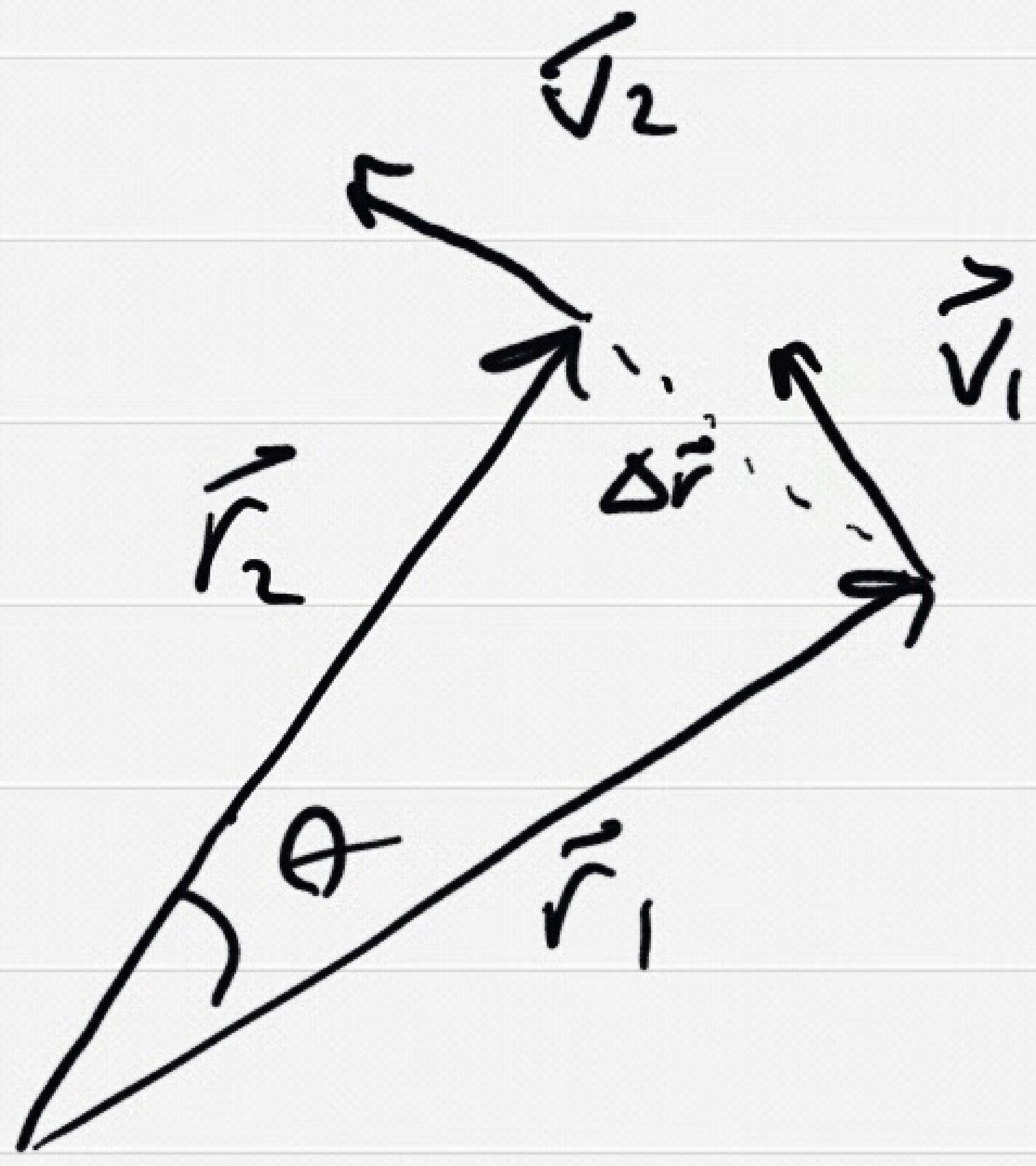


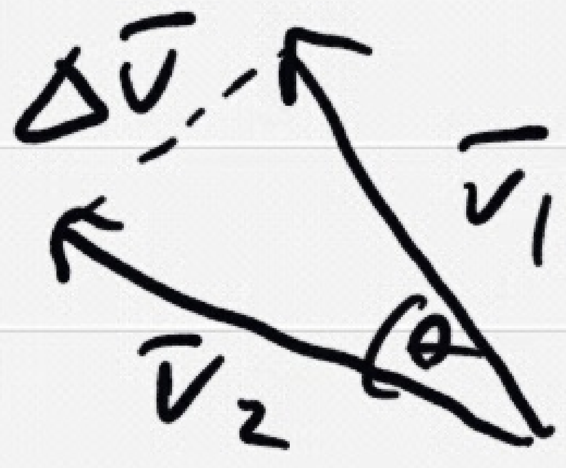
2π radians = 360°

Speed/Velocity of Circular Motion

- Average speed $|v|$ = distance/time
  - Average speed for an arc $|v| = S/\Delta t$
  - Average speed for the whole circle $|v| = 2\pi r/T$
    - (T = period of revolution)
- Note that the average **velocity** over a full circle is zero (since displacement = 0)
  - Later in the course we will learn about "angular velocity"

Centripetal Acceleration





$$\theta = S/r \sim \frac{|\Delta\vec{r}|}{r} = \frac{v\Delta t}{r}$$

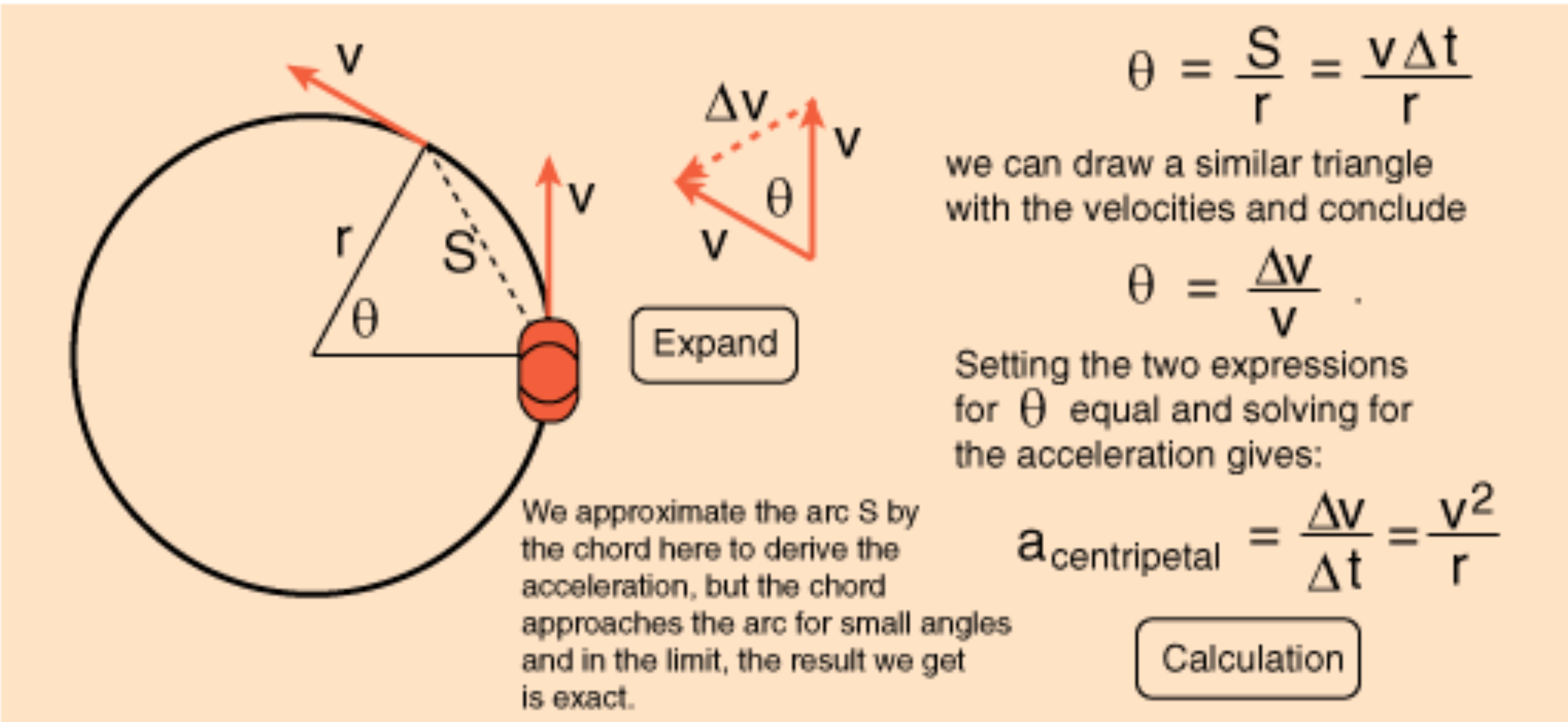
$$\theta = |\Delta\vec{v}|/v$$

$$\Delta v/v = \frac{v\Delta t}{r}$$

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

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

Acceleration of Uniform Circular Motion



Small angle approximation: θ ~ sinθ ~ tanθ for small θ

Centripetal Force

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

Note that to stay in circular motion,
there must be a constantly applied force!

Circular Motion

In equilibrium:

$$\vec{F}_{net} = \sum \vec{F} = 0$$

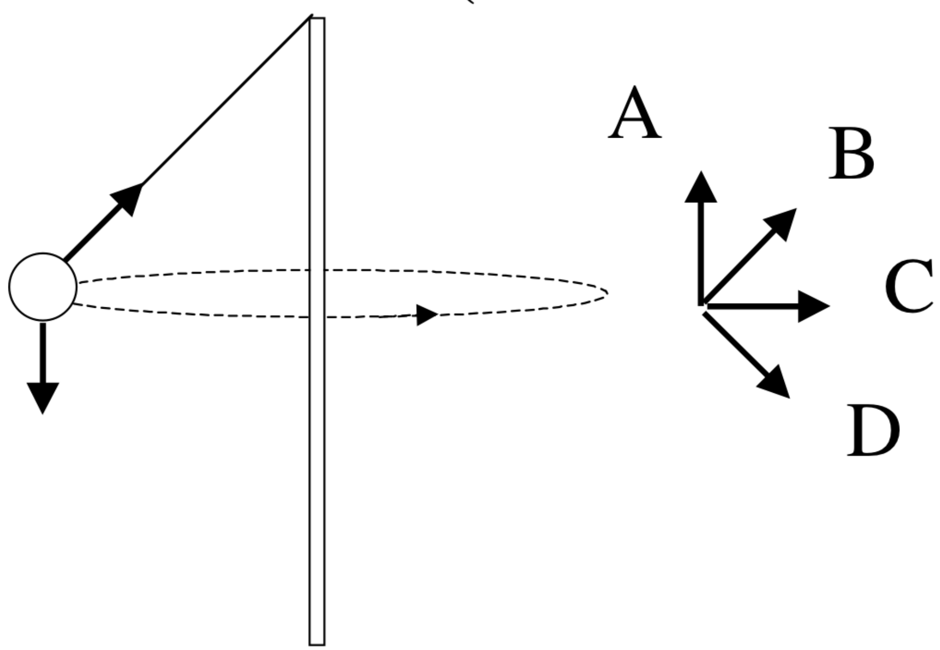
Circular motion is not equilibrium:

$$\vec{F}_{net} = \sum \vec{F} = m a_c = mv^2/r = F_c$$

If force removed, an object follows Newton's first law and goes straight

Concept Check

In a game of tetherball, a ball is tied to a pole with a string. While the ball whirls around the pole, in what direction is the acceleration of the ball (at the moment shown?)



(E: Some other direction, not shown.)

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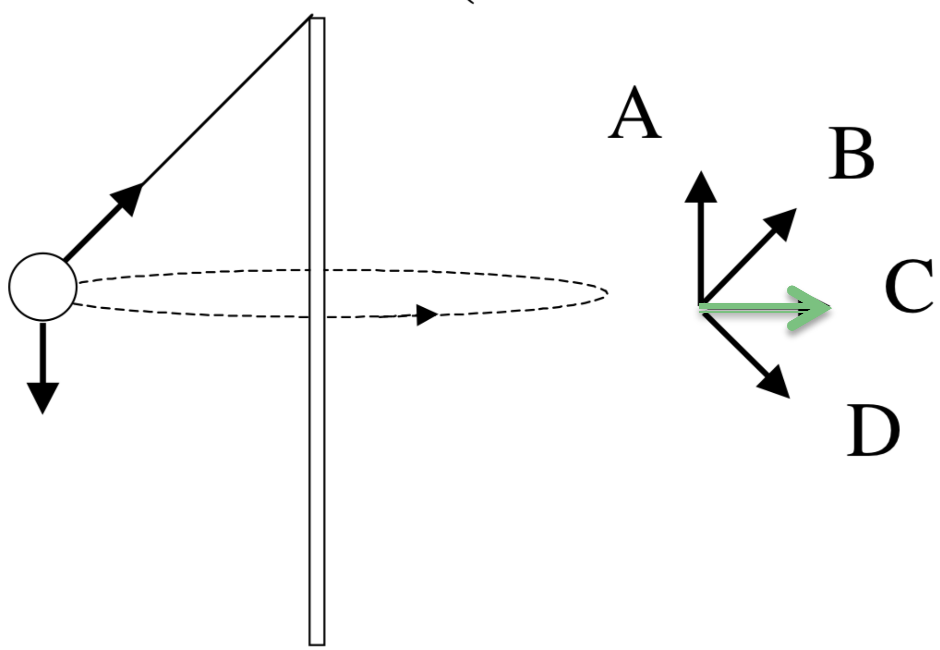

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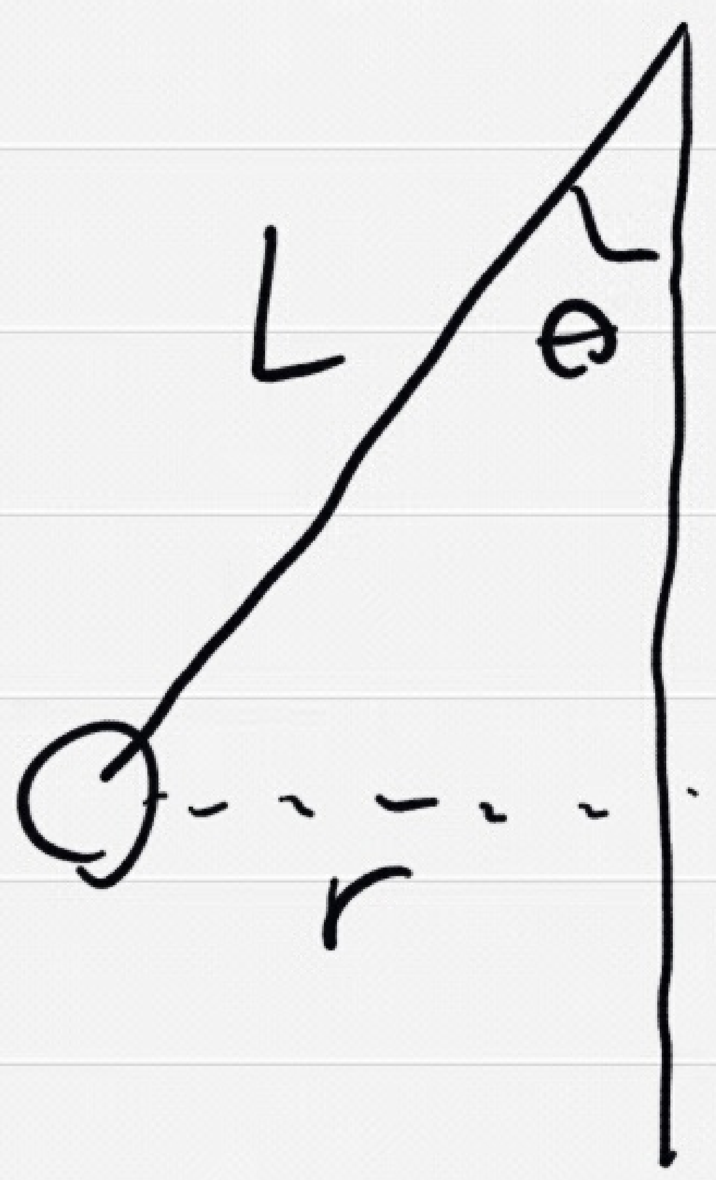
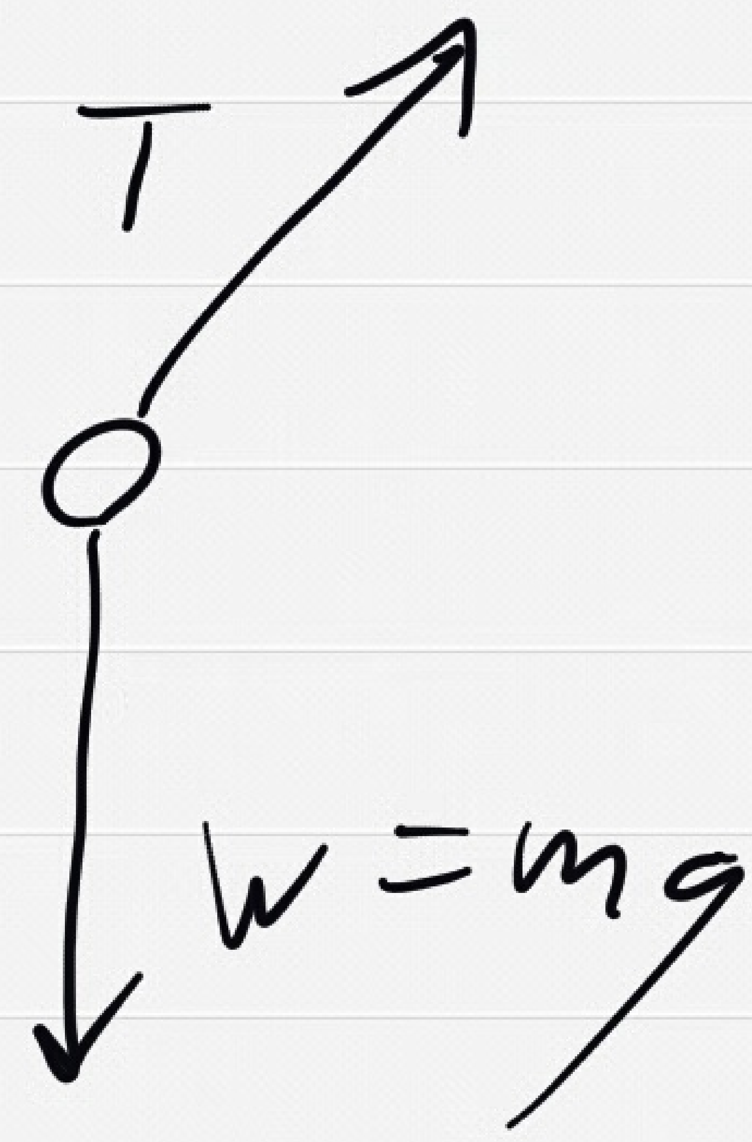
Tether ball

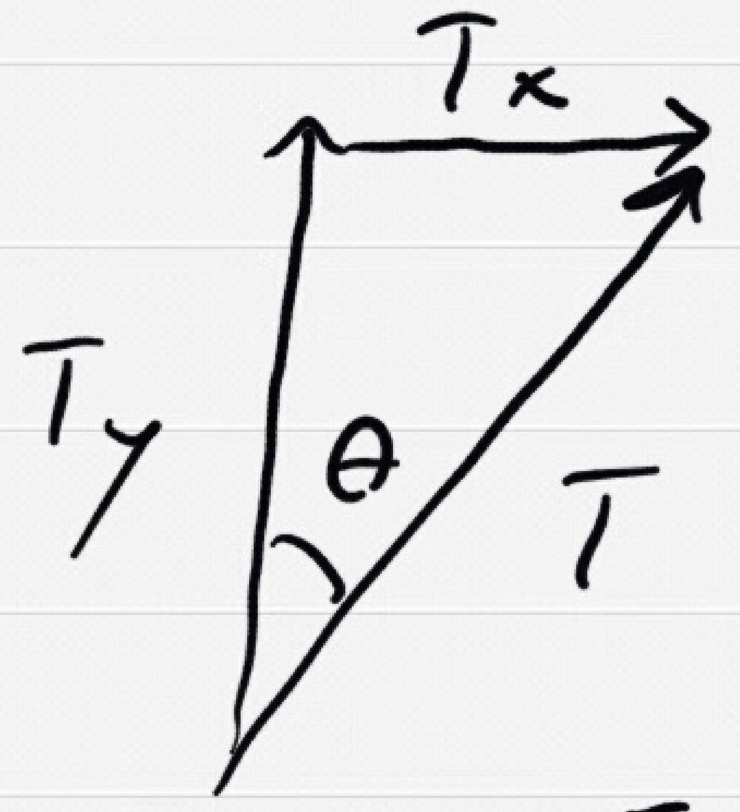


Free-body



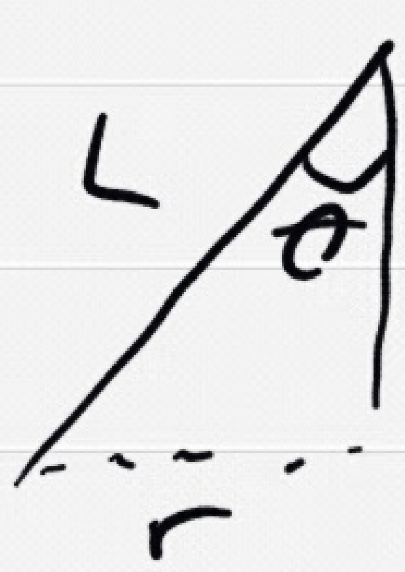
$$F_c = mv^2/r = F_{net}$$

(not an individual force but the net force)



$$T_x = T \sin\theta$$
$$T_y = T \cos\theta$$

$$F_{x_{net}} = F_c = \frac{mv^2}{r} = T \sin\theta$$



$$r = L \sin\theta$$

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

$$mv^2 = TL \sin^2\theta$$

$$F_{y\,net} = T\cos\theta - mg = 0$$

$$\Rightarrow mg = T\cos\theta$$

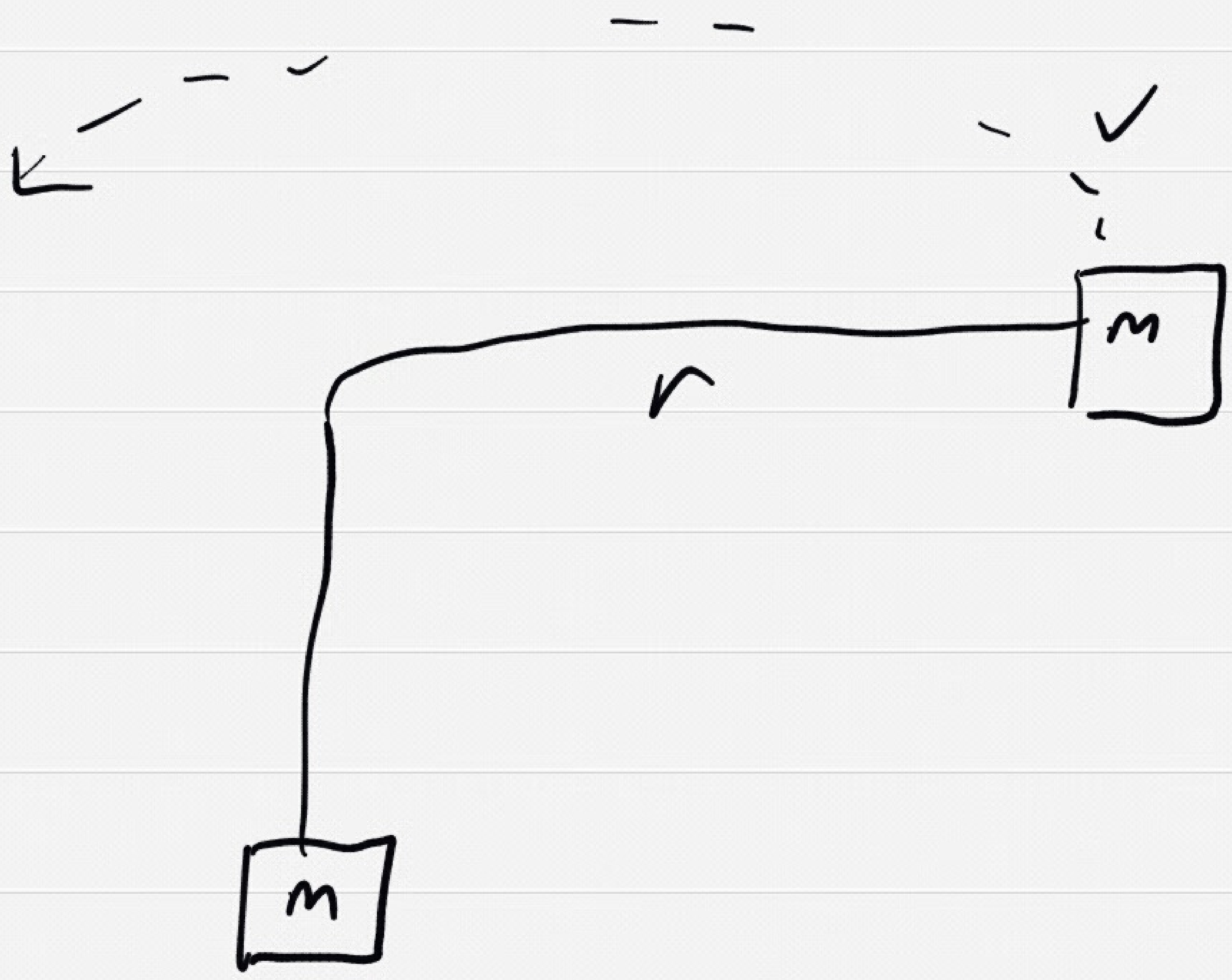
$$\Rightarrow T = mg/\cos\theta$$

Plug into F_x

$$mv^2 = \frac{mg}{\cos\theta} \cdot L\sin^2\theta$$

If v^2 goes up, θ must go up to provide needed centripetal force

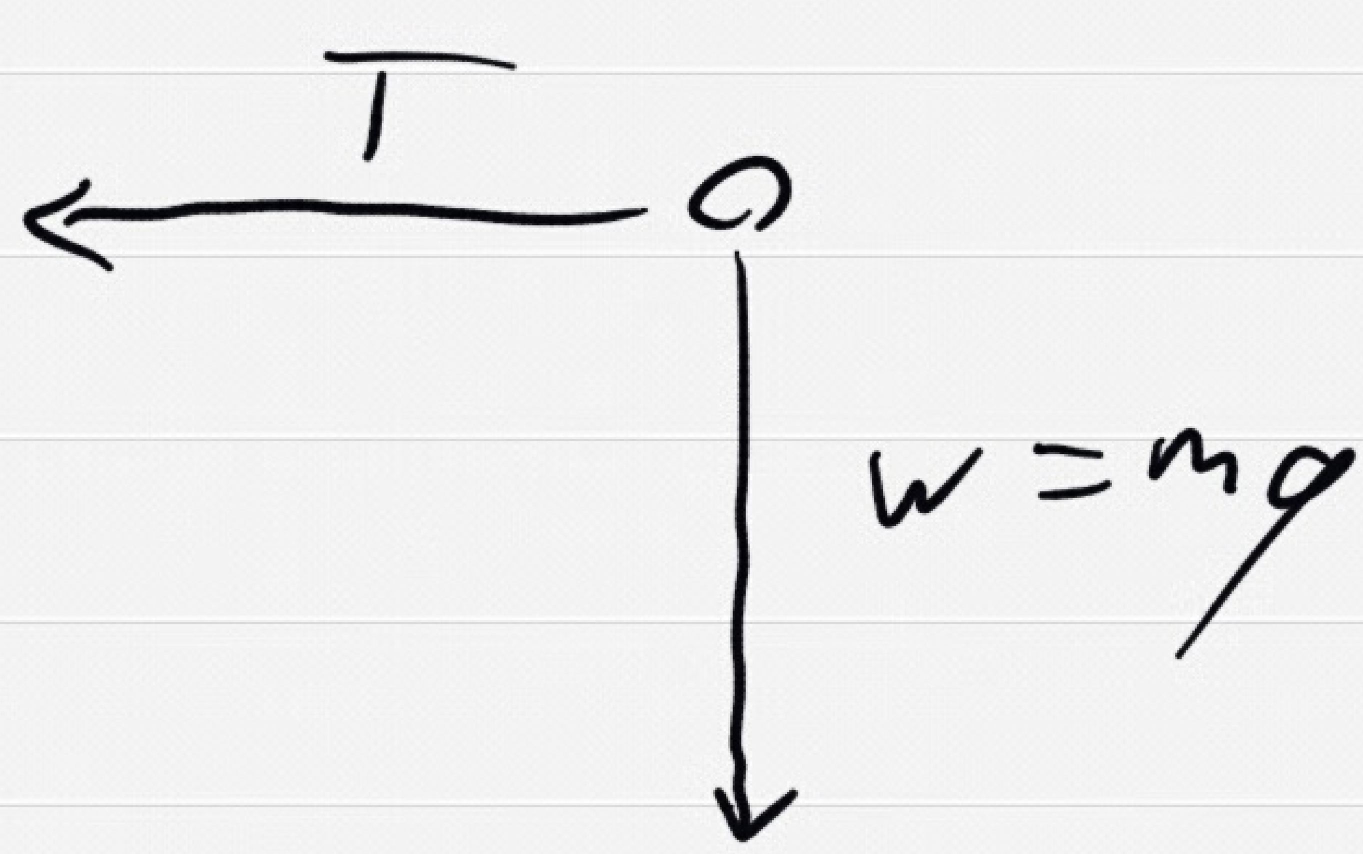
Whirligig



Hanging mass

$T = mg$

Whirling mass



$F_{x\,net} = F_c$

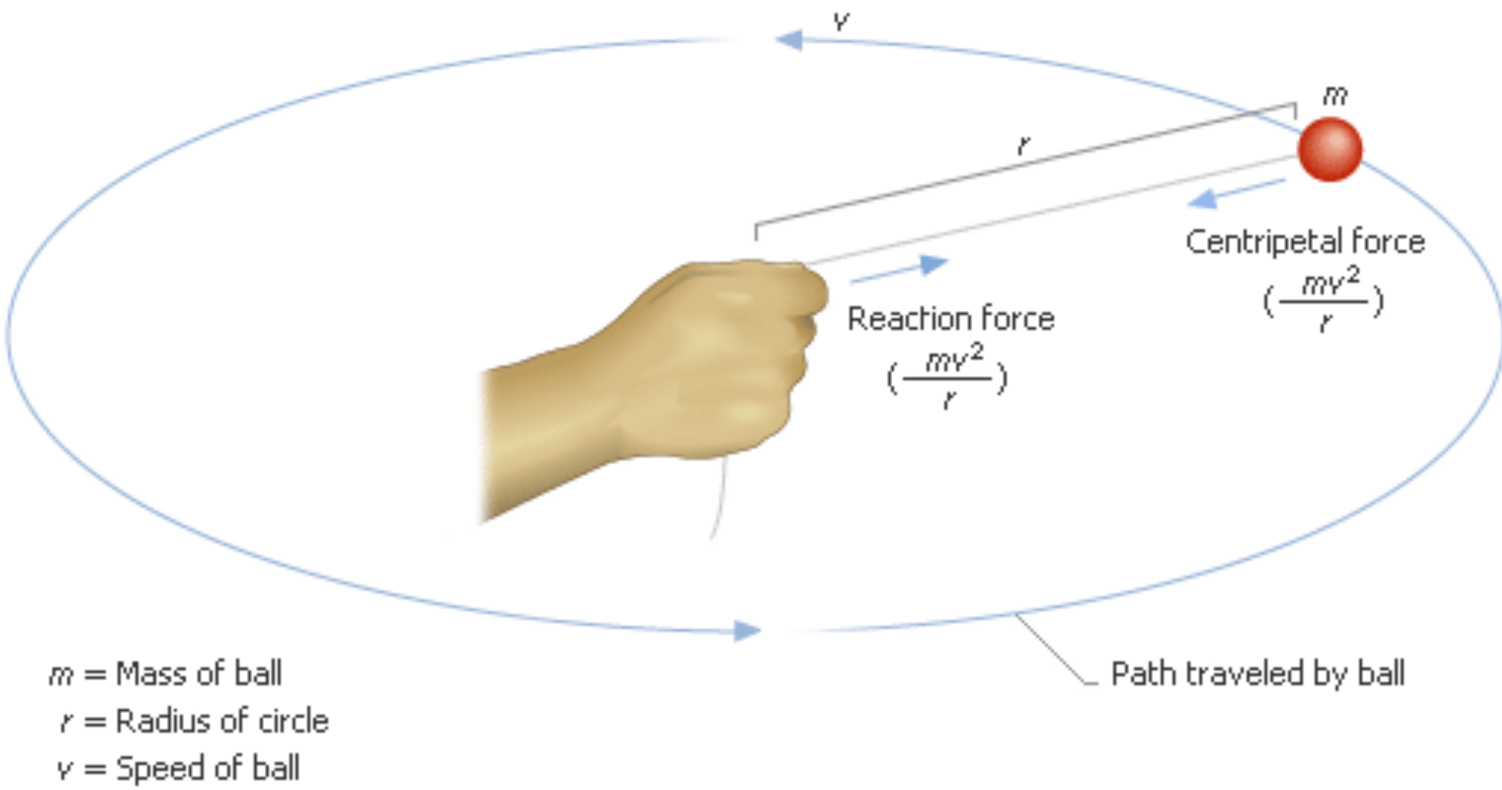
$= mv^2/r$

$= T$

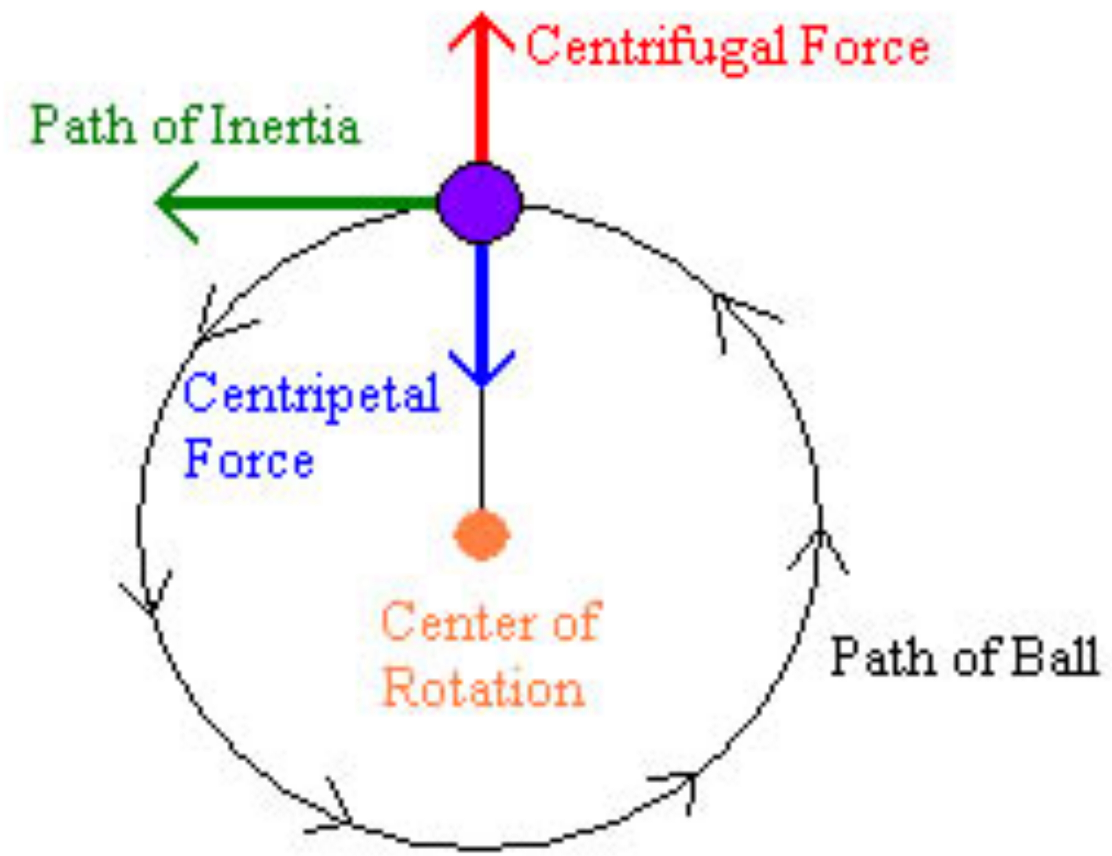
$= mg \Rightarrow v^2/r = g$

Centripetal acceleration $= g$!

Centripetal Force: Real



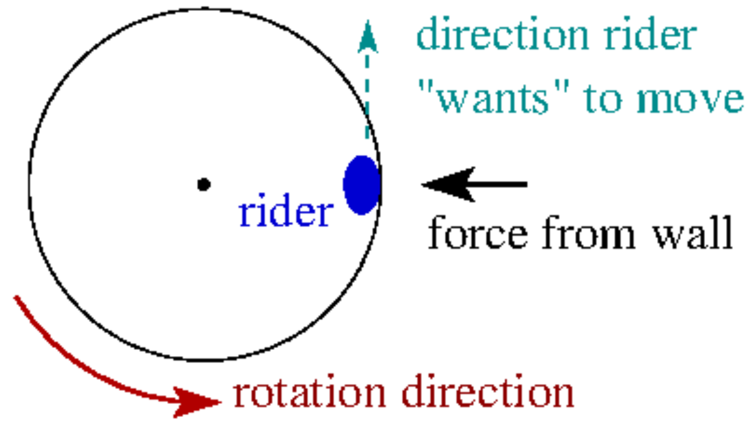
Centrifugal Force: Not Real



Non-Inertial Reference Frames

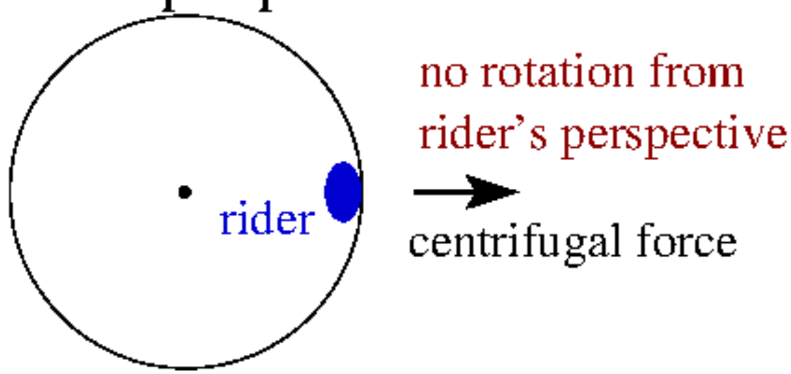
Inertial Frame

Outsider's perspective



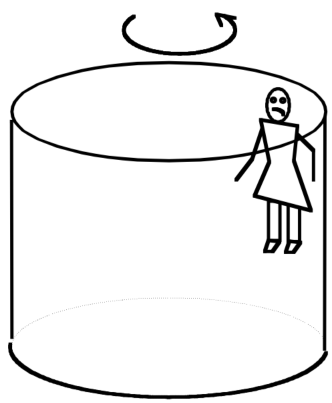
Non-Inertial Frame

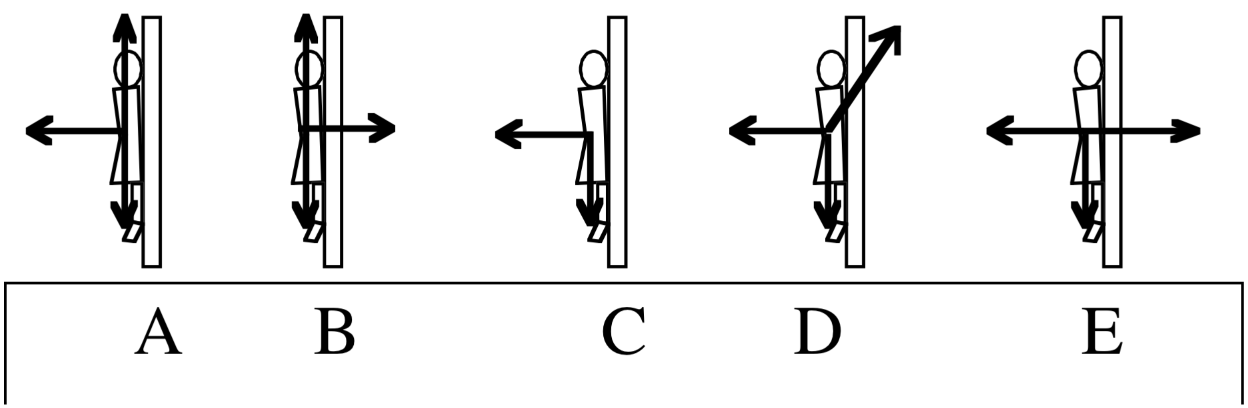
Rider's perspective



Concept Check

A rider in a "barrel of fun" finds herself stuck with her back to the wall. Which diagram correctly shows the forces acting on her?





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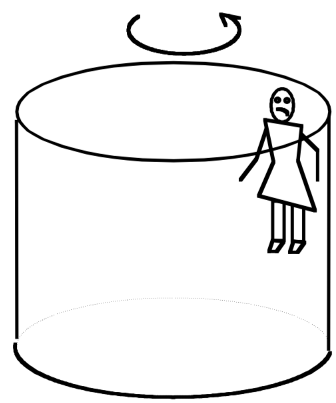
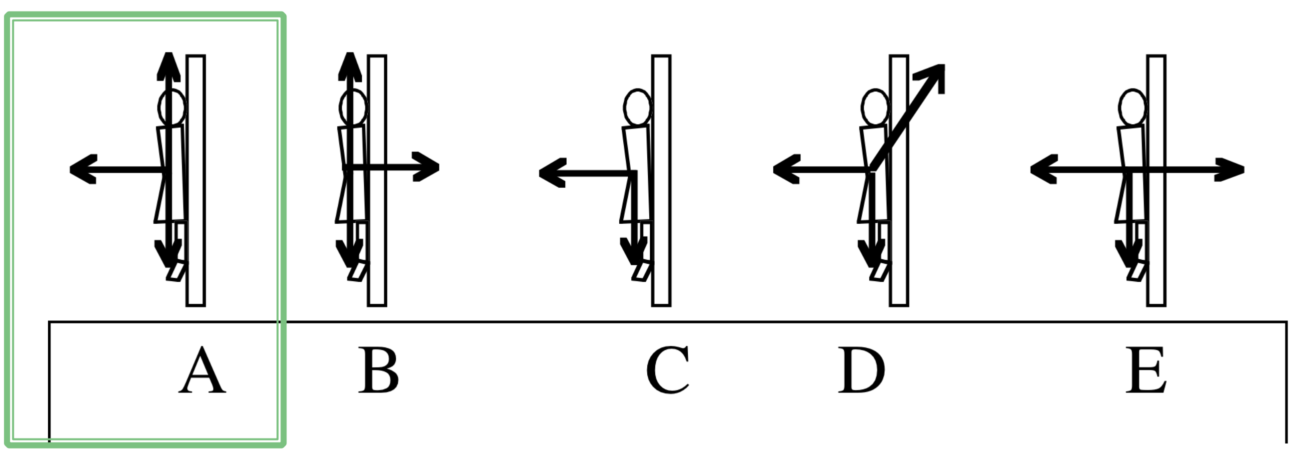
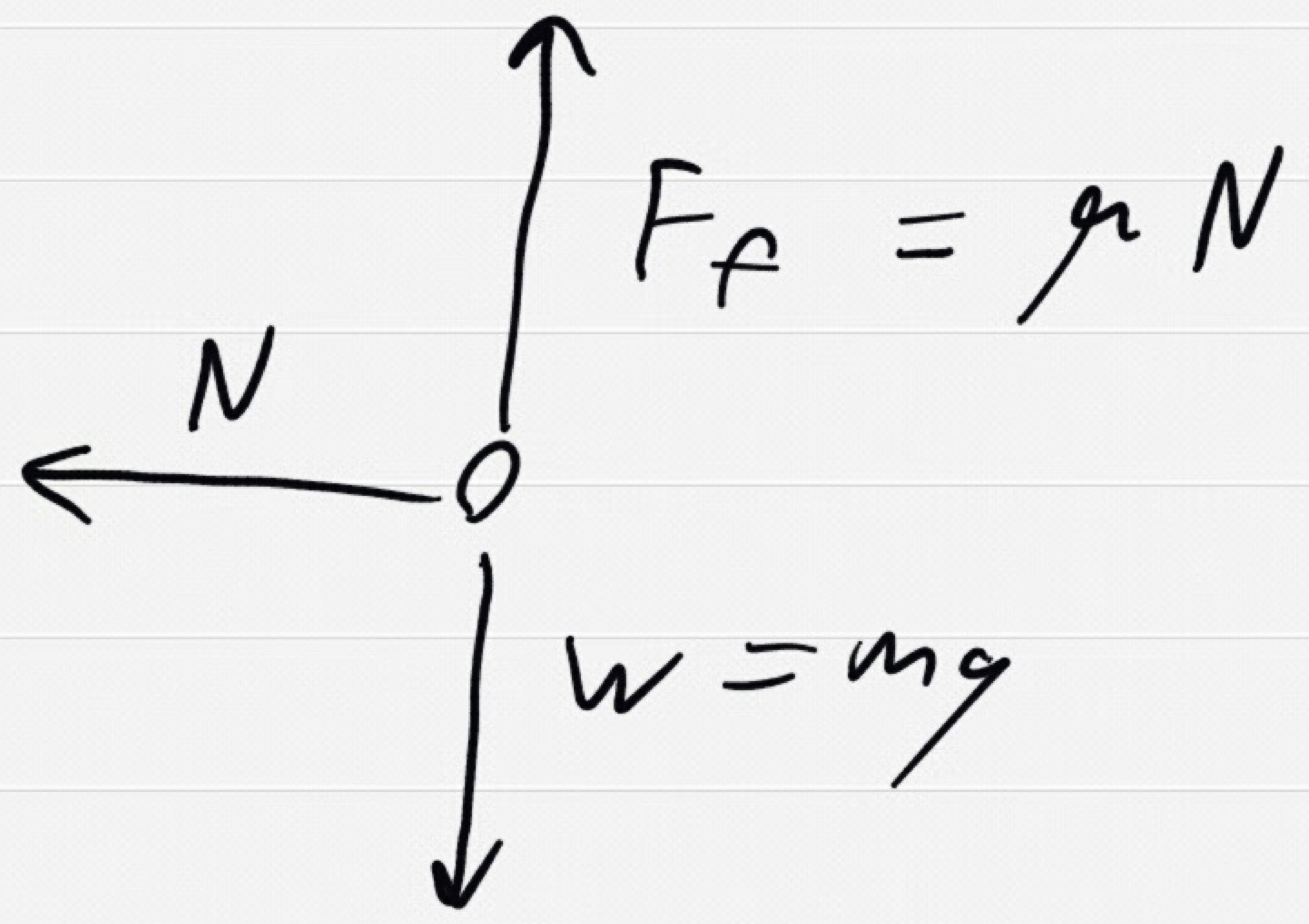




Barrel of Fun



$$F_{net} = N = mv^2/r$$

$$F_f = \mu N = \mu mv^2/r$$

To balance W and keep rider from slipping, need:

$$\mu mv^2/r = mg$$

or $$\mu v^2/r = g$$