Physics 2A: Lecture 6

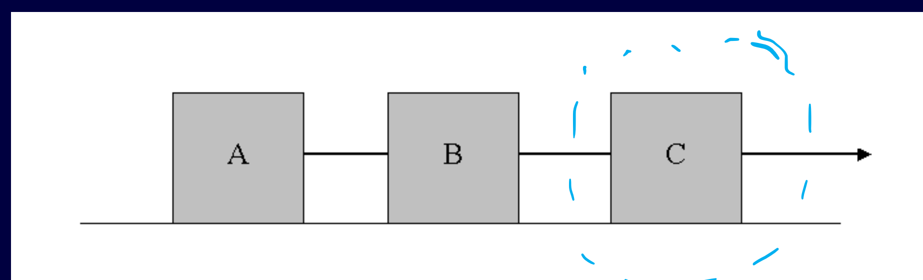
Today's Agenda

- Uniform Circular Motion
- Centripetal acceleration
- Examples
  - Car on track
  - Carnival ride
  - Loop-de-loop

Start Recording!

Conceptual Problem 5:

Three blocks each have a mass of 3 kg and are being pulled over a frictionless surface by a force of 20 N. What is the tension between blocks B and C, T_{BC}?



a) 3.32 N
b) 6.67 N
c) 13.34 N
d) 20 N
e) 26.7 N

Three blocks each have a mass of 3 kg and are being pulled over a frictionless surface by a force of 20 N.

What is the tension between blocks B and C, T_{BC}?

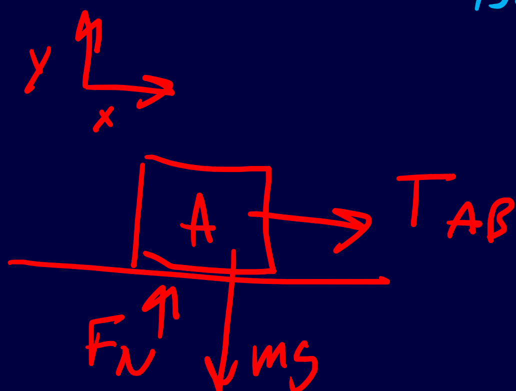
A) 3.32 N

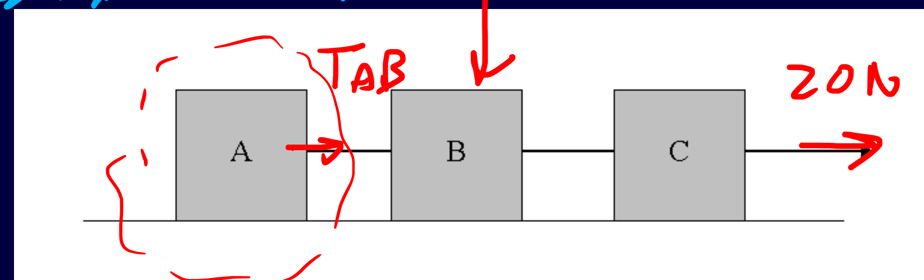
B) 6.67 N

C) 13.34 N

D) 20 N

A B T_{AB}





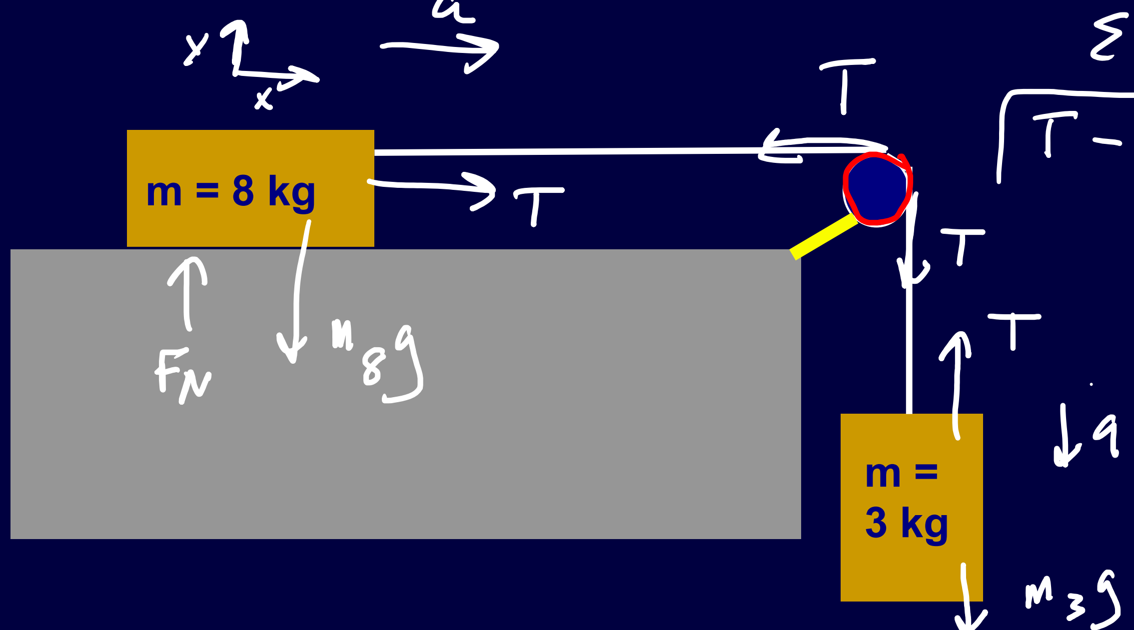
$$\Sigma F_x = m_A a_x$$

$$T_{AB} = (3\ kg)(2.22\ m/s^2)$$

$$= 6.67\ N$$

Example

- Assume two blocks are set up as below. There is no friction between the top block and the table. What is the acceleration of the blocks?



pulleys
massless

$\Sigma F_y = m_8 a_y = 0$

$F_N - m_8 g = 0$

$F_N = m_8 g$

$\Sigma F_x = m_8 a_x$

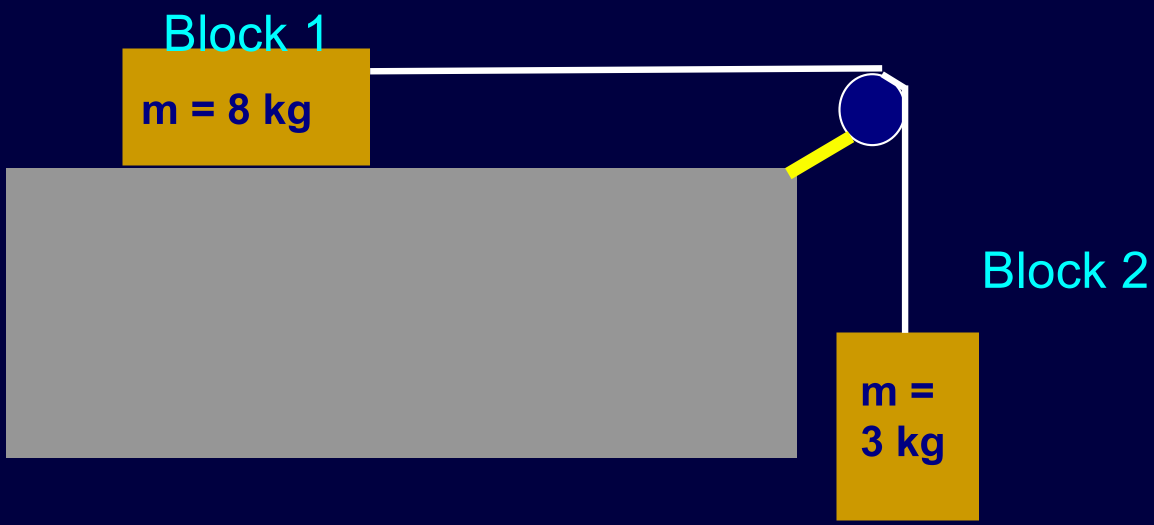
$T = m_8 a$

$\Sigma F_y = m_3 a_y$

$T - m_3 g = -m_3 a$

Example

- Step 1: Select the objects of interest.
- The two blocks, must work with both of them.



Example

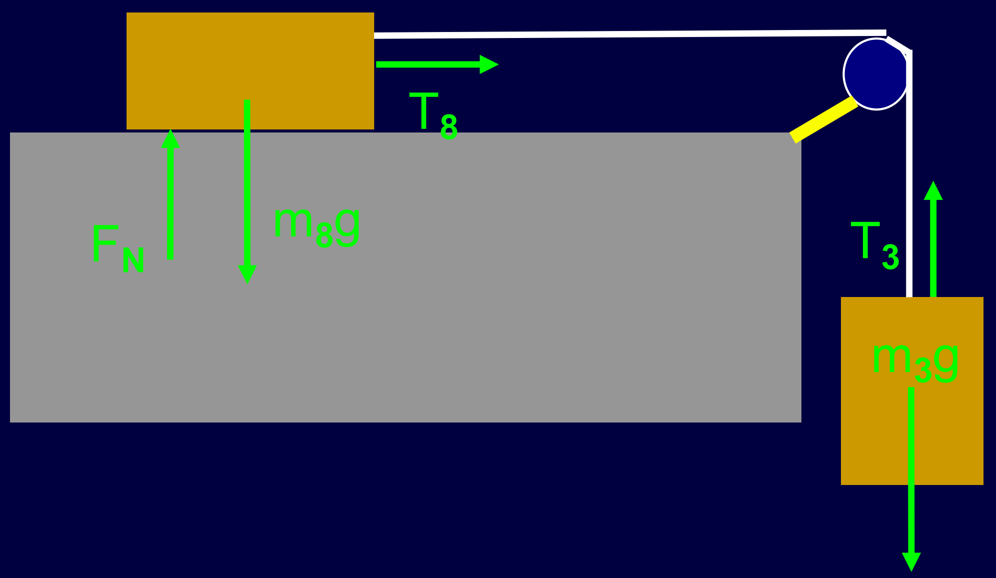
- Step 2: Draw a Free Body Diagram

1.) Weight due to gravity

What Forces act on the blocks?

2.) Normal Force on block 1

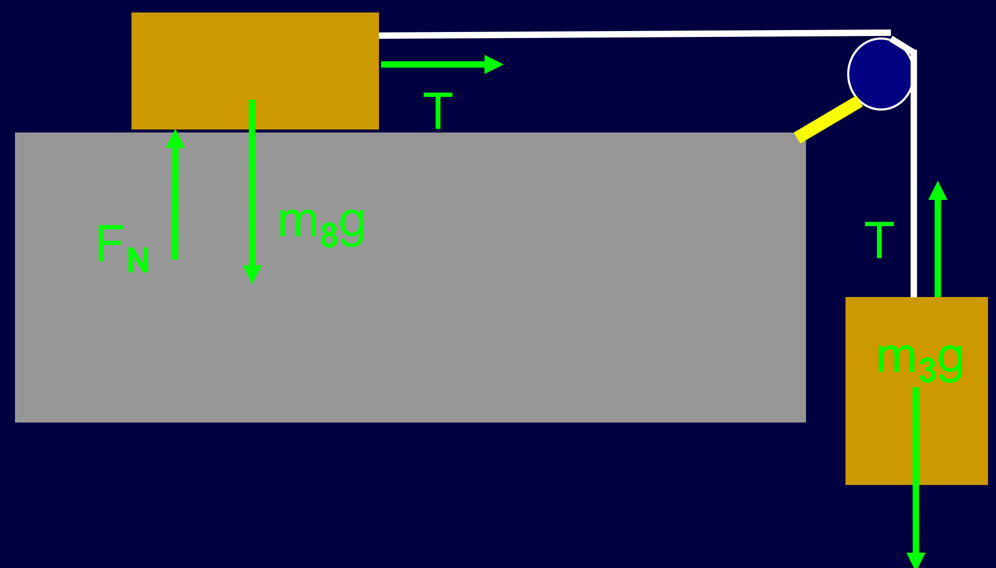
3.) Tensions



Acceleration constraint!

Example

Step 5: Apply Newton's Second law.



$a = ?$

Example

Step 5: Apply Newton's Second law.

a) $1.33\ m/s^2$
b) $3.14\ m/s^2$
c) $2.67\ m/s^2$
d) $5.13\ m/s^2$
e) $1.78\ m/s^2$

$ma = \Sigma F$ T a

$T = m_8 a$

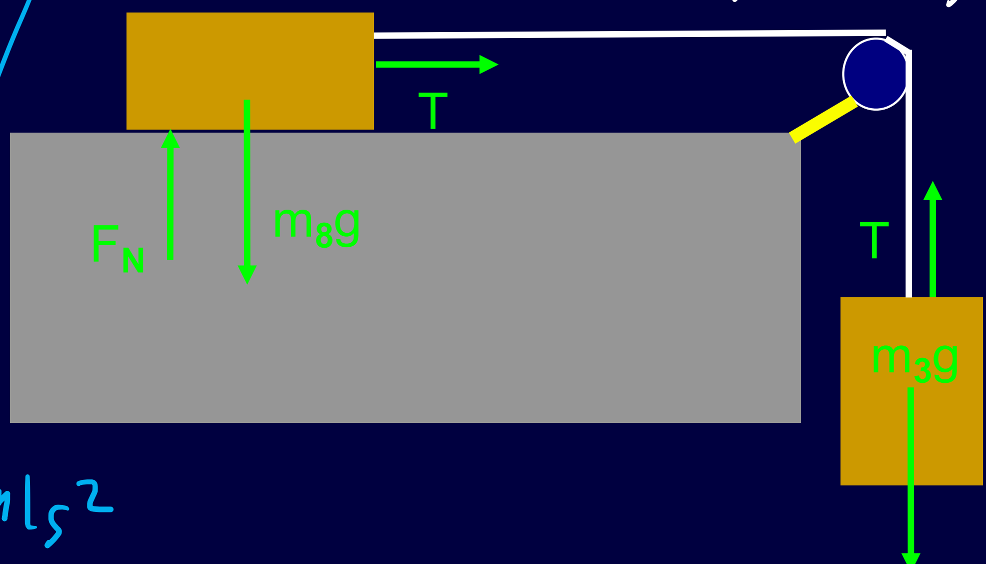
$T - m_3 g = -m_3 a$

$m_8 a - m_3 g = -m_3 a$

$m_8 a + m_3 a = m_3 g$

$a(m_8 + m_3) = m_3 g$

$a = \frac{m_3 g}{m_8 + m_3} = 2.67\ m/s^2$



$a = 2.67\ m/s^2$

Clicker Question 6:

Assume two blocks are set up as below. There is no friction between the top block and the table. What is the tension in the rope?

$T = m_8 a = 8\,kg\,(2.67\ m/s^2)$

$= 21.4\ N$

a) 8.0 N
b) 13.4 N
c) 21.4 N
d) 29.37 N
e) 33.33 N

$T - m_3 g = -m_3 a$

$T = m_3 g - m_3 a = 21.4\ N$

Clicker Question 1:

Bob pushes on a cart of mass 50 kg with a horizontal force F_{push}. There is no friction. The cart has an acceleration of 5 m/s^2.

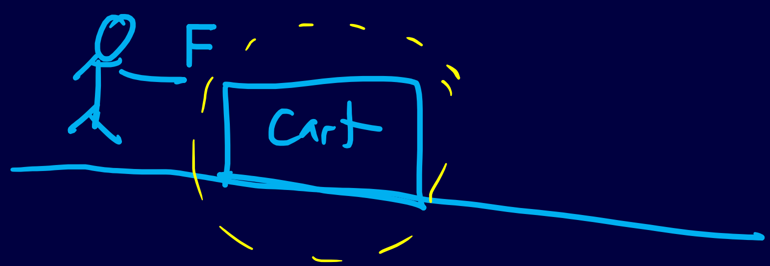
Which one of the following statements is true?

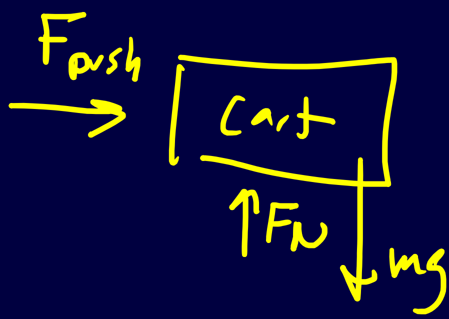
(a) By Newton's third law, the cart applies an equal and opposite force of magnitude F_{push} on Bob.
(b) The cart applies an opposite force on Bob, but it is smaller in magnitude than F_{push} because of the acceleration force.
(c) The force the cart applies on Bob is responsible for the acceleration of the cart.
(d) The cart applies no force on Bob, because it is not pushing back on him.
(e) The cart applies an opposite force on Bob and it is larger in magnitude than F_{push}.

Student: If the answer to problem 1 is A , I don't really understand how the cart can accelerate positively if the net force if the horizontal direction is zero. Or maybe the net force in the horizontal direction is not equal to zero and I missing why the horizontal net force is not equal to zero?

Clicker Question 1:

Student: If the answer to problem 1 is A , I don't really understand how the cart can accelerate positively if the net force if the horizontal direction is zero. Or maybe the net force in the horizontal direction is not equal to zero and I missing why the horizontal net force is not equal to zero?





Clicker Question 2:

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a massless rope around a frictionless pulley as pictured below. Which equation below would be a result of applying Newton's second law correctly to either block 1 or block 2? Call the tension acting on block 1 T_1 and the tension acting on block 2 T_2.

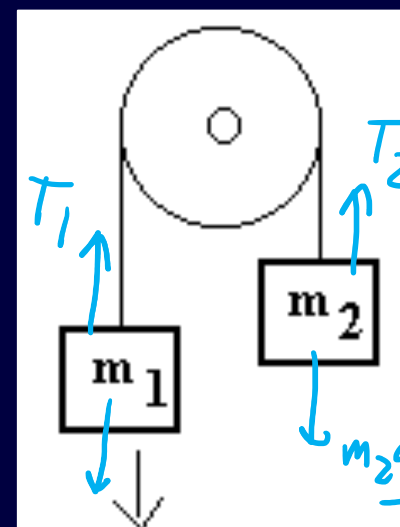
(A) $T_1 - m_1 g = m_1 a_1$

(B) $-T_1 - m_1 g = -m_1 a_1$

(C) $-T_1 + m_1 g = +m_1 a_1$

(D) $-T_2 + m_2 g = -m_1 a_2$

(E) $T_2 - m_2 g = -m_2 a_2$



m_1: $\Sigma F = m_1 a$

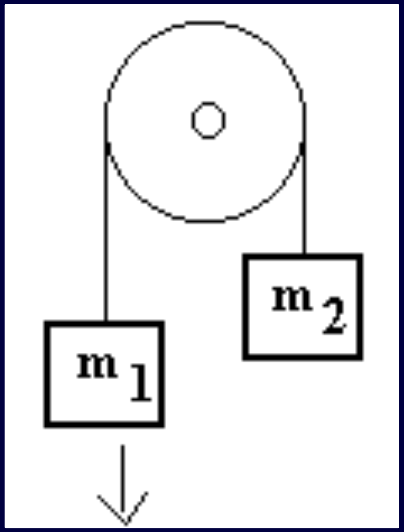
$(T_1 - m_1 g) = -m_1 a$

$-T_1 + m_1 g = m_1 a$

m_2: $\Sigma F = m_2 a$

$T_2 - m_2 g = m_2 a$

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a massless rope around a frictionless, massless pulley as pictured below. Which equation below would be a result of applying Newton's second law correctly to either block 1 or block 2? Call the tension acting on block 1 T_1 and the tension acting on block 2 T_2.



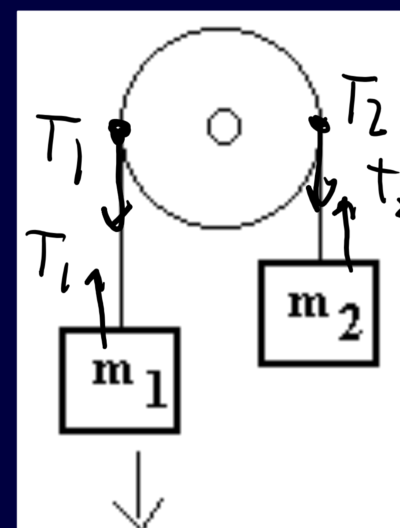
Clicker Question 3:

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a massless rope around a frictionless, massless pulley as pictured below. Call the tension acting on block 1 T_1 and the tension acting on block 2 T_2. Which statement is correct?

(A) $T_1 > T_2$

(B) $T_1 = T_2$

(C) $T_1 < T_2$



Clicker Question 4:

a = same

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a rope around a frictionless, massless pulley as pictured below. What is the acceleration of block 1?

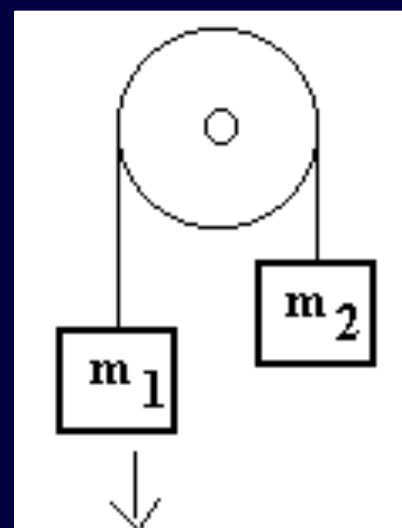
a) 18.0 m/s^2

b) 8.19 m/s^2

c) 3.90 m/s^2

d) 2.45 m/s^2

e) 1.17 m/s^2



$T - m_1 g = -m_1 a$

$T - m_2 g = m_2 a$

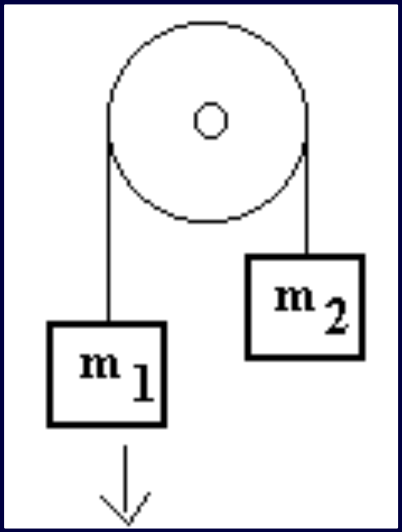
$T = m_2 a + m_2 g$

$m_2 a + m_2 g - m_1 g = -m_1 a$

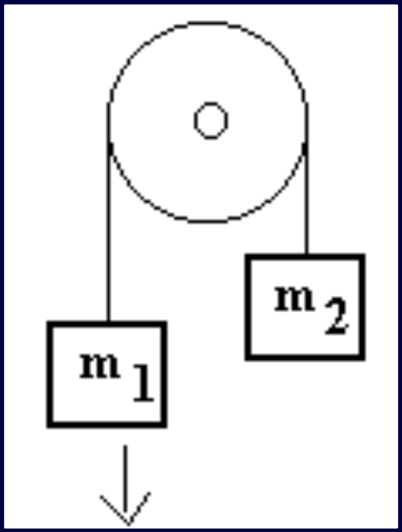
$(m_1 a + m_2 a) = m_1 g - m_2 g$

$a = \dfrac{m_1 g - m_2 g}{m_1 + m_2} =$

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a massless rope around a frictionless pulley as pictured below. What is the acceleration of block 1?



Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a massless rope around a frictionless, massless pulley as pictured below. What is the acceleration of block 1?



$\Sigma F = ma$

$m_1 > m_2$

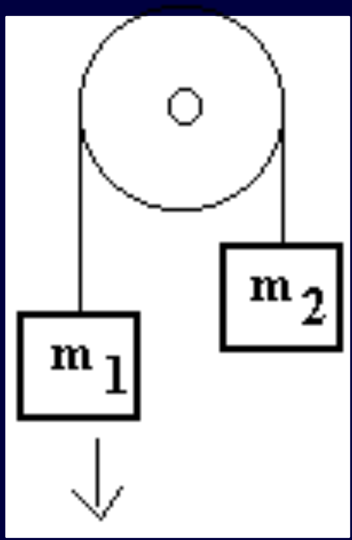
Clicker Question 5:

Two blocks, m_1 = 5 kg and m_2 = 3 kg, are connected by a rope around a frictionless, massless pulley as pictured below. Which statement is true about the magnitude of the net force on m_2?

(a) It's greater than the magnitude of the net force on m_1.

(b) It's equal to the magnitude of the net force on m_1.

(c) It's less than the magnitude of the net force on m_1.



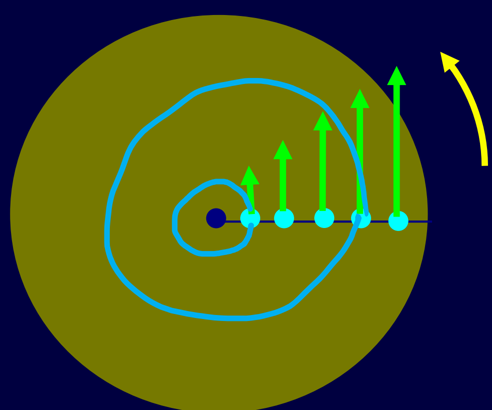
$m_1 a > m_2 a$

$T - m_1 g$ $T - m_2 g$

Rotational motion

- When dealing with a rotating object our 'old-fashioned' variables come up short.
  - Every point goes a different distance
  - Every point has a different speed and accel.

Outside points must go faster to make one revolution in same amount of time!



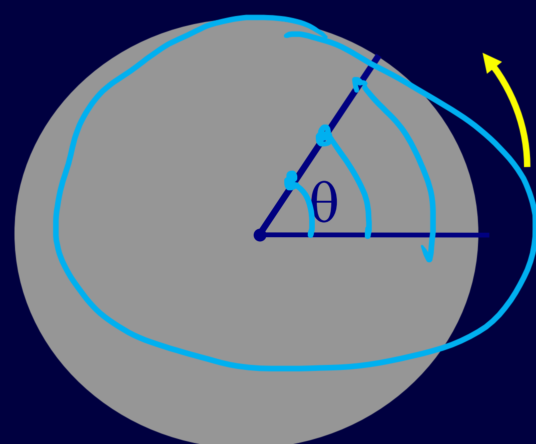
$\theta = \frac{s}{r}$

$\theta = \frac{2\pi r}{r} = 2\pi$

Angular Displacement

- Angular Displacement: Angle through which an object rotates about a fixed axis

All points on object have same angular displacement!



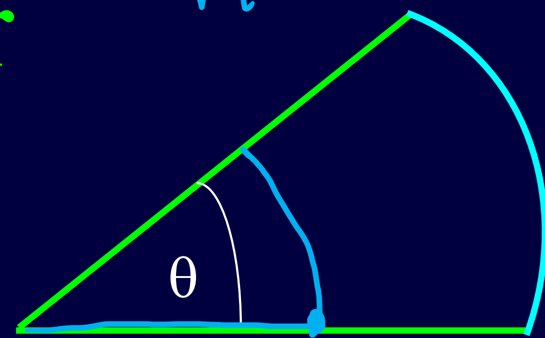
We draw a line and observe the angle the line moves through.

- $\Delta\theta = \theta_f - \theta_i$ (usually measured in radians)
- Positive if counterclockwise; Negative if clockwise

Definition of radians

$$\theta = \frac{s}{r} = \frac{m}{m} \Rightarrow \underline{\text{unitless}}$$

$$S = r\,\theta$$



Bigger radius more arc length with same angle!!

Angular Velocity

- Angular Velocity: How fast an object rotates.
- Denoted with Greek letter ω omega

$$\omega_{av} = \frac{\Delta\theta}{\Delta t} = \frac{\theta_f - \theta_i}{t_f - t_i}$$

$\frac{rad}{s}$

- Units (radian/s) Analog of linear velocity
- Positive if counterclockwise; Negative if clockwise

Tangential vs. angular

- Tangential distance vs. angular distance
  - $s = \theta R$
- Tangential velocity vs. angular velocity
  - $v_T = \omega R$
- Tangential acceleration vs. angular acceleration
  - $a_T = \alpha R$
- Angular values are same for all points, tangential are not!!!

$$s = \theta R$$

$$\frac{ds}{dt} = \frac{d\theta}{dt} R$$

$$v = \omega R$$

The ‘viewer’ equation

- We can start with this equation and develop an equation to relate angular velocity and tangential velocity

$$s = \theta r$$

$$\frac{s}{t} = \frac{\theta}{t} r$$

$$v_T = \omega r$$

- Tangential values are larger the farther out the radius r is

Clicker 6:

$$\omega = \frac{\Delta\theta}{\Delta t}$$

Rasheed and Sofia are riding a merry-go-round that is spinning steadily. Sofia is twice as far from the axis as is Rasheed. Sofia's angular velocity is ______ that of Rasheed.

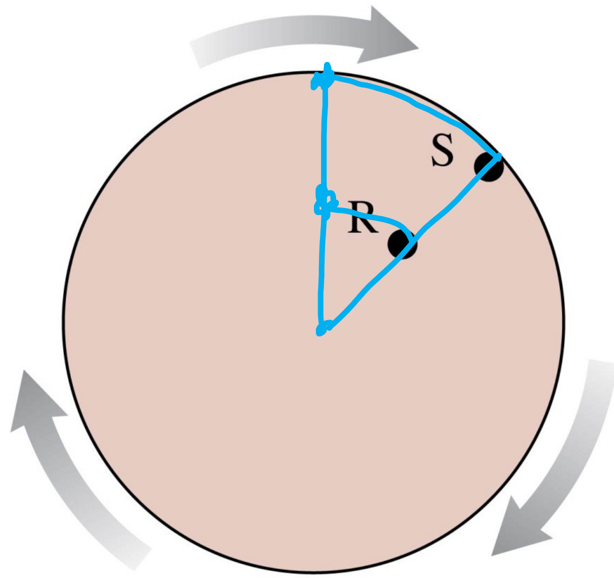
A. half

B. the same as

C. twice

D. four times

E. We can't say without knowing their radii.



Clicker 7:

Rasheed and Sofia are riding a merry-go-round that is spinning steadily. Sofia is twice as far from the axis as is Rasheed. Sofia's speed is _______ that of Rasheed.

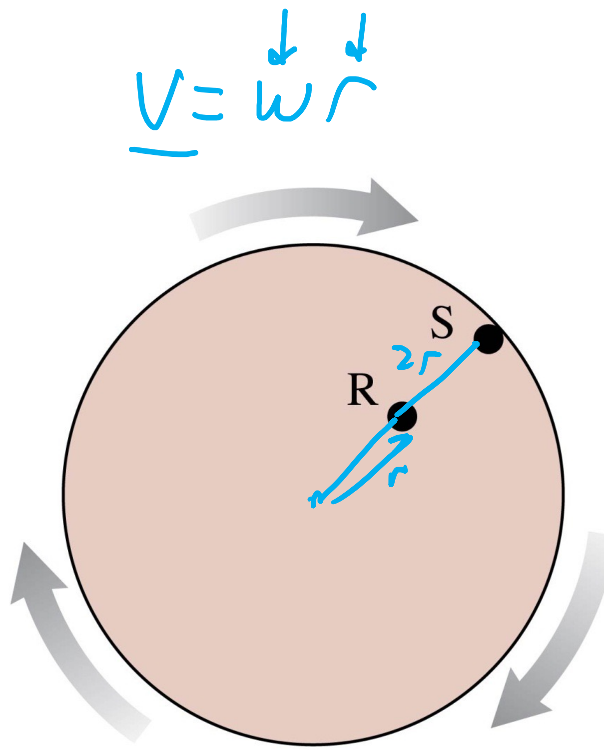
A. half

B. the same as

C. twice

D. four times

E. We can't say without knowing their radii.



Equations of Rotational Kinematics

- Equations of Rotational Kinematics
  - $\theta_F = \omega_0 t + \frac{1}{2}\alpha t^2$
  - $\omega_F = \omega_0 + \alpha t$
  - $\omega_F^2 = \omega_0^2 + 2\alpha\Delta\theta$
- Only good when α is constant
- Use in a similar manner as the linear equations

Clicker Question 8:

A rotor in a car's brake system has an angular velocity of 50 rad/s. By applying the brakes the brake pads produce an angular acceleration of 15 rad/s^2. How many turns will the rotor make in the meantime?

(a) 13.26 rev

(b) 83.33 rev ←

(c) 24.56 rev

(d) 18.79 rev

(e) 34.78 rev

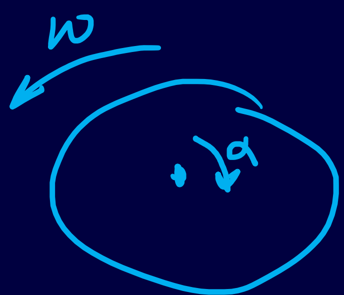
83,33 rad

$$N = \frac{83{,}33\ \text{rad}}{2\pi\ \frac{\text{rev}}{\text{rad}}} = 13{,}26\ \text{rev}$$

A rotor in a car's brake system has an angular velocity of 50 rad/s. By applying the brakes the brake pads produce an angular acceleration of 15 rad/s^2. How many turns will the rotor make in the meantime?

$\omega_0 = 50 \frac{rad}{s}$

$\alpha = -15 \frac{rad}{s^2}$



$$\omega_f^2 = \omega_0^2 + 2\alpha(\Delta\theta)$$

$$0 = \omega_0^2 + 2\alpha\Delta\theta$$

$$\Delta\theta = \frac{\omega_0^2}{-2\alpha} = \frac{(50\ rad/s)^2}{2(15\ \frac{rad}{s^2})} = 83.33\ rad$$

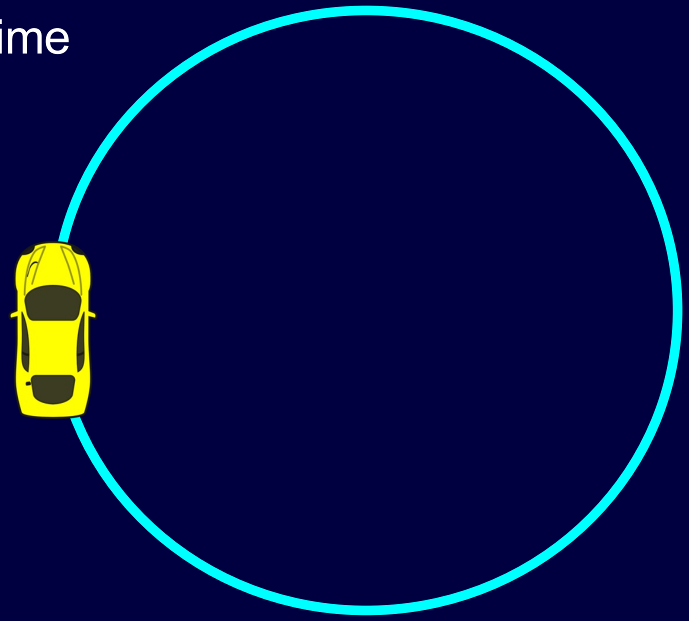
Clicker Question 9:

Below we have a car that is circling around some point moving at a constant speed. Is the car accelerating?

(a) Yes

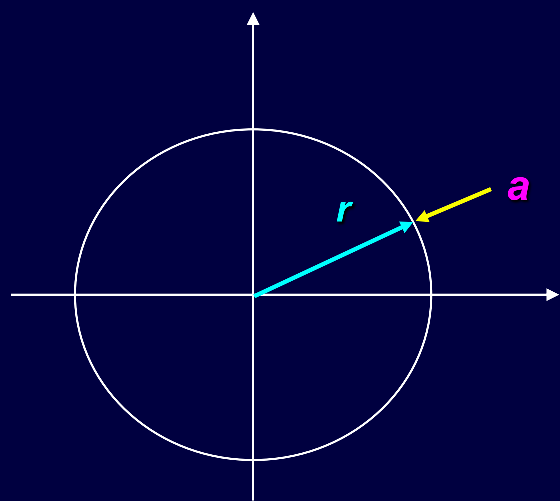
(b) No

(c) Yes, but only part of the time



Acceleration in UCM:

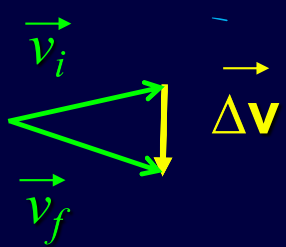
- UCM results in acceleration:
  - This is called Centripetal Acceleration
  - Direction: (toward center of circle)
  - Magnitude:

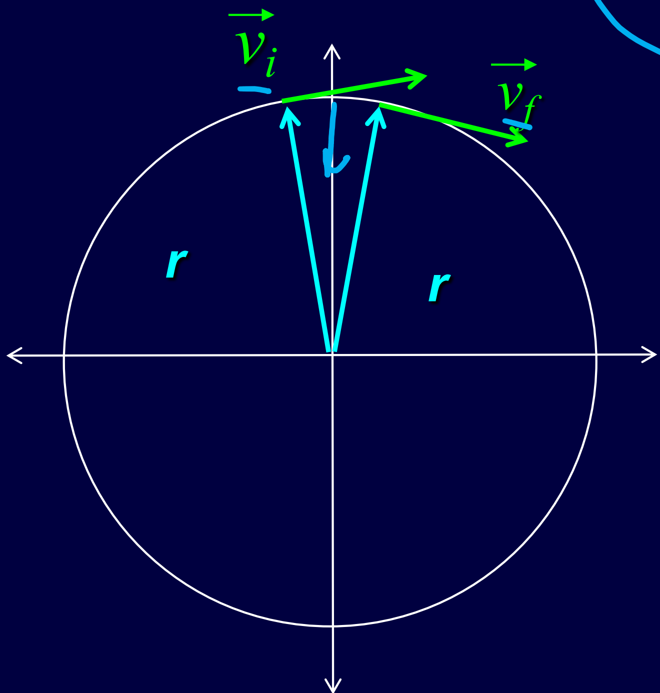


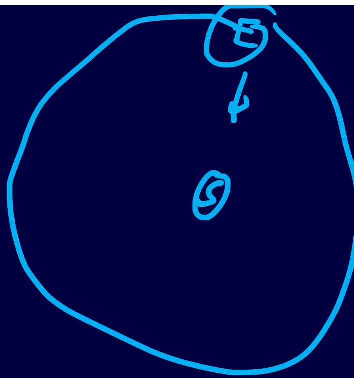
$$a_C = \frac{v^2}{r} = \omega^2 r$$

Acceleration in UCM:

- Consider average acceleration in time Δt



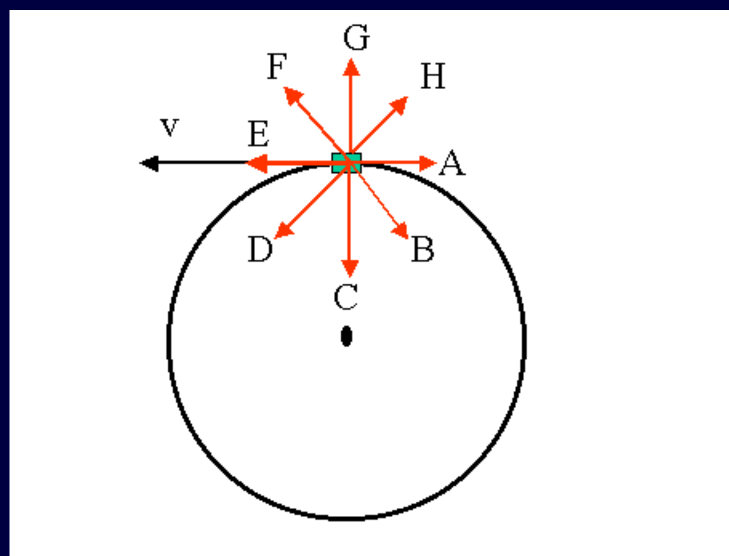


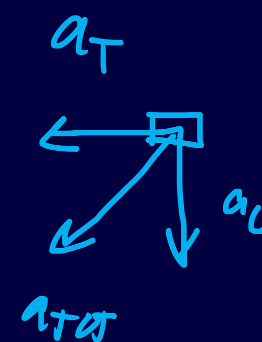


- Acceleration is towards the center of the circular path

Clicker 10:

An object is rotating in a circle. As it is rotating it's speed is increasing. What direction is it's acceleration vector pointing? A, B, C, D, E, F, G, or H

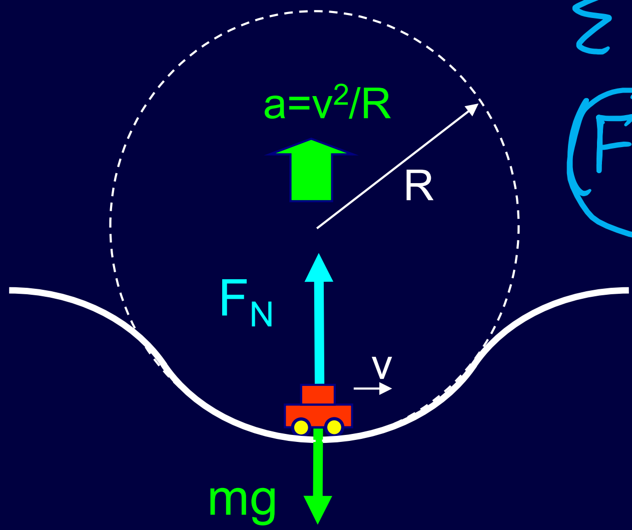




Clicker Question 11:

Suppose you are driving through a valley whose bottom has a circular shape. If your mass is m, what is the magnitude of the normal force F_N exerted on you by the car seat as you drive past the bottom of the hill?

A. $F_N < mg$
B. $F_N = mg$
C. $F_N > mg$



$\Sigma F_y = ma$

$(F_N - mg) = +ma$