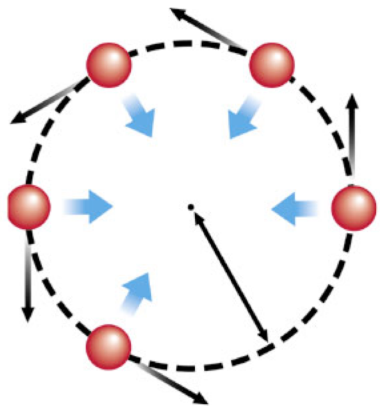
Welcome back to Physics 215



Today's agenda

- *Acceleration on curved path*
- *Motion along curved paths, circles*
- *Tangential and radial components of acceleration*
- *Rotations*

Midterm 1: in less than 2 weeks! (9/24)

- In Phys 208 (here!) at the usual lecture time
- Material covered:
  - **Textbook** chapters 1 – 4
  - **Lectures** up through next Tuesday (slides online)
  - **Wed/Fri recitation activities**
  - **Homework assignments**
- You will be given a **formula sheet** at the exam. A copy of this sheet will be available on the course website
- You should bring a **calculator**, but you must bring your own, and it can not be a phone. You may not store any equations in memory, and midterm proctors may request to see your calculator during the exam.
- Exam accommodations: must take exam at ODS
  - I need the request form by NEXT TUESDAY

What type of problems should I practice?

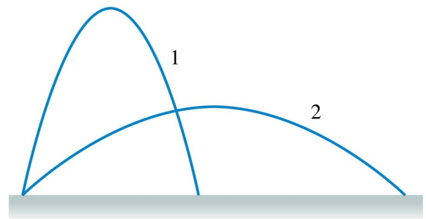
- Everything we covered in lecture/homeworks is fair game!
- 1D motion:
  - Reading and understanding x(t), v(t), a(t) graphs, converting between them
  - Constant acceleration problems (fan cart, free fall)
  - speed vs. velocity, displacement vs. distance
- Projectile motion:
  - throwing ball into the air, cannon shot off a cliff
- Vector manipulations:
  - Graphical and algebraic: going from components to angles and magnitudes and vice-versa
- Angular motion problems (today and next Tuesday)
  - slowing down a rotating DVD
  - centripetal acceleration for uniform circular motion

Reading assignment for next Tuesday

- Review circular motion: Ch 4.4 in textbook
- Relative motion: Ch 4.5
- Review for Midterm 1 !

SG

Projectiles 1 and 2 are launched over level ground with the same speed but at different angles. Which hits the ground first? Ignore air resistance.



A. Projectile 1 hits first.

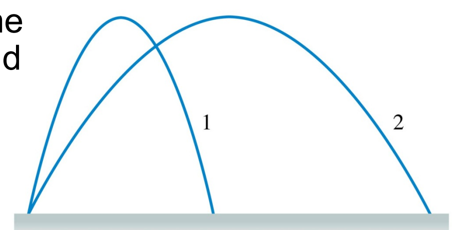
B. Projectile 2 hits first.

C. They hit at the same time.

D. There's not enough information to tell.

SG

Projectiles 1 and 2 are launched over level ground with different speeds. Both reach the same height. Which hits the ground first? Ignore air resistance.



A. Projectile 1 hits first.

B. Projectile 2 hits first.

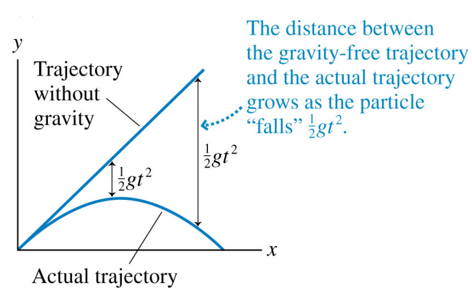
C. They hit at the same time.

D. There's not enough information to tell.

Hunter and “coconut” demo

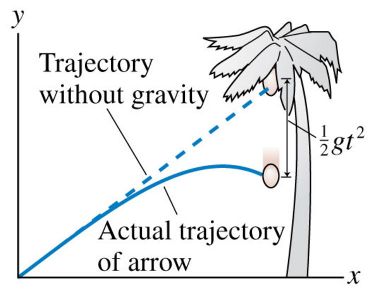
Why does the arrow hit the coconut?

- Without gravity, the arrow would follow a straight line.
- Because of gravity, the arrow at time *t* has “fallen” a distance $\frac{1}{2}gt^2$ below this line.
- The separation grows as $\frac{1}{2}gt^2$, giving the trajectory its parabolic shape.

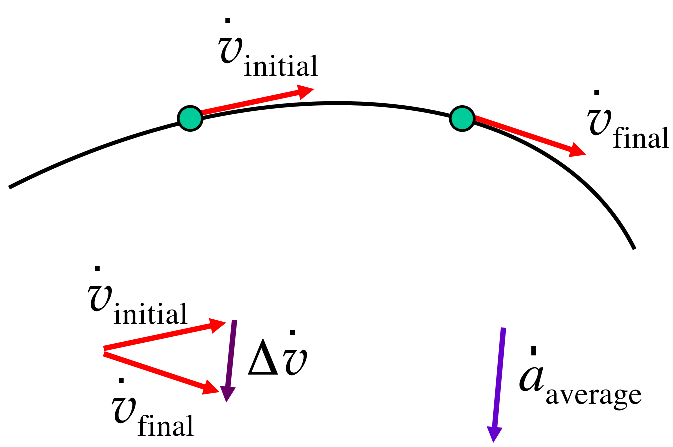


Why does the arrow hit the coconut?

- Had the coconut stayed on the tree, the arrow would have curved under its target as gravity causes it to fall a distance ½gt^2 below the straight line.
- But ½gt^2 is also the distance the coconut falls while the arrow is in flight.
- So *yes*, the arrow hits the coconut!



Motion on a curved path at constant speed



Subtracting vectors

Recall that $v_F + (-v_I) = \Delta v$

SG: For which of the following motions of a car does the net change in velocity vector have the greatest magnitude? (All motions occur at the same constant speed.)

A. A 90° right turn at constant speed

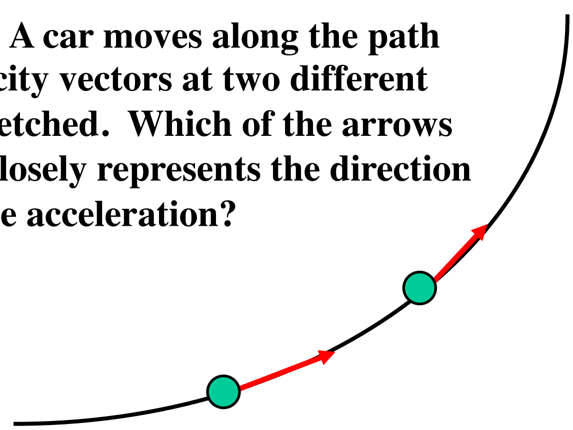
B. A U-turn at constant speed

C. A 270° turn on a highway on-ramp at constant speed

D. The change in velocity is zero for all three motions.

For an object moving at constant *speed* along a curved path, the acceleration is ***not*** zero.

Small group: A car moves along the path shown. Velocity vectors at two different points are sketched. Which of the arrows below most closely represents the direction of the average acceleration?



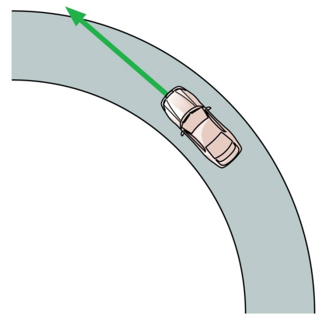
A. 

B. 

C. 

D. 

SG: A car is traveling around a curve at a steady 45 mph. Is the car accelerating?

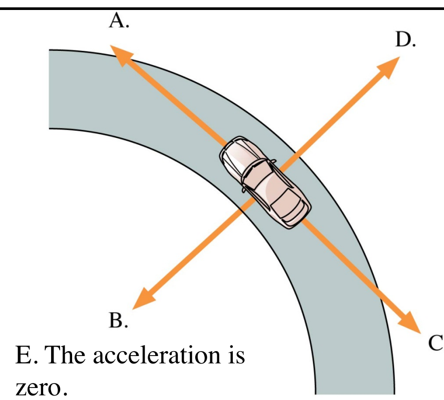


A. Yes

B. No

Physics 215 – Fall 2019 Lecture 03-2 15 Slide 4-27

SG: A car is traveling around a curve at a steady 45 mph. Which vector shows the direction of the car's acceleration?

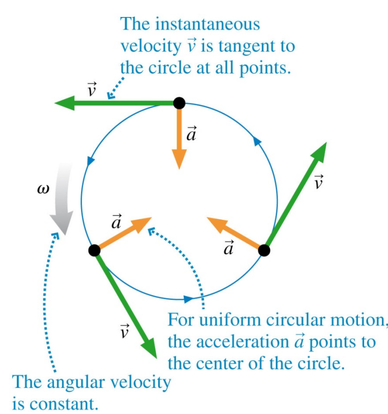


Physics 215 – Fall 2019 Lecture 03-2 16 Slide 4-29

Dog on a string demo

Centripetal Acceleration

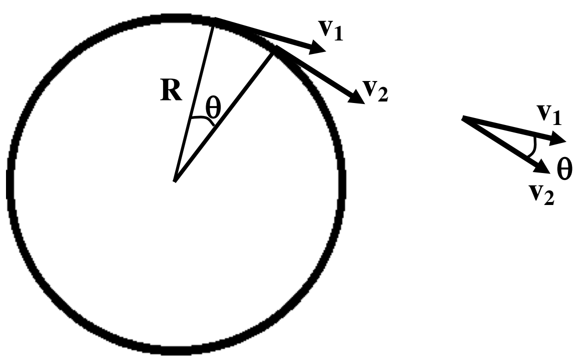
- **Uniform circular motion:**
  - speed is constant
  - Velocity is changing
- The direction of the centripetal acceleration is toward the center of the circle.
- The magnitude is constant



Summary

- For motion at **constant speed**, instantaneous acceleration vector is perpendicular to velocity vector
- Points ``inward''
- What is the **magnitude** of the acceleration vector?

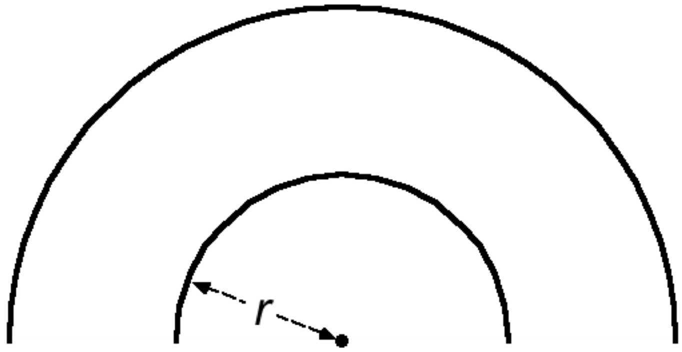
Acceleration vectors for ball swung in a horizontal circle at *constant* speed v



What is the magnitude of the acceleration?

$$|a| = v^2/R$$

Acceleration of object moving at constant speed on a circular path: $a = \dfrac{v^2}{r}$



Acceleration depends on radius of circle.

SG: Two cars are moving at different constant speeds on a curved road. One after the other, they are passing the same point on the road: Car A at V_A mph; car B at (2 V_A) mph. If car A's acceleration is 2 m/s^2, car B's acceleration is:

A. 1 m/s^2
B. 2 m/s^2
C. 4 m/s^2
D. 8 m/s^2

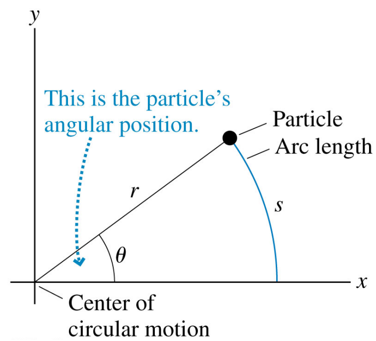
Angular Position

- The angle may be measured in degrees, revolutions (rev) or **radians** (rad), that are related by:

$$1 \text{ rev} = 360° = 2\pi \text{ rad}$$

- Radians are awesome! Because:

$$s = r\theta \qquad (\text{with } \theta \text{ in rad})$$

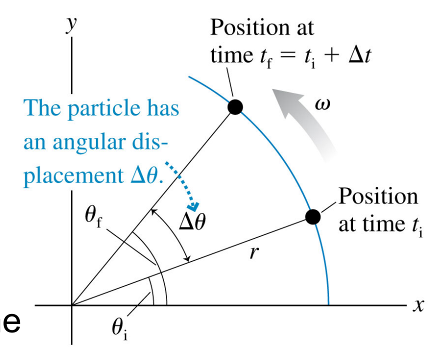


Angular velocity

- $\Delta\theta = \theta_f - \theta_i$

  $\Delta t = t_f - t_i$.
- In analogy with linear motion, we define:

  $\boldsymbol{\omega}_{\mathbf{avg}} =$



- As the time interval Δt become arrive at the definition of instantaneous **angular velocity**.

  $\boldsymbol{\omega} =$
- Counterclockwise is ________________

Units of angle are a pain!

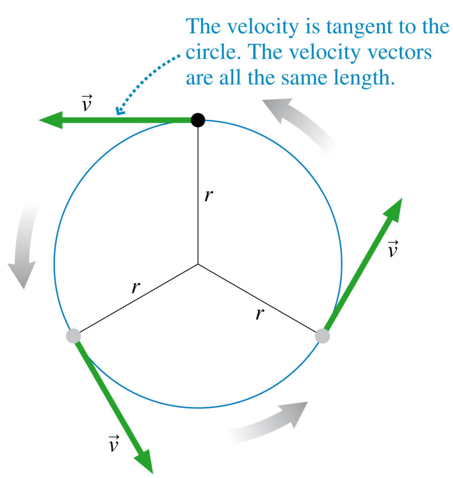
- Note that the radian is a ratio between two lengths, which makes it a *pure number*
- The units of angles are just a NAME to remind us we are dealing with an angle
- Angular velocities can be given in
  - rev/min, rad/s, degrees/hour, etc.
  - Just figure out what you need for a given problem
  - Practice problems help!

Angular velocity and linear velocity:

- The time interval to complete one revolution is called the period, T.
- The rate of revolution (i.e. rpm, rph) is ___
- The period T is related to the speed v:

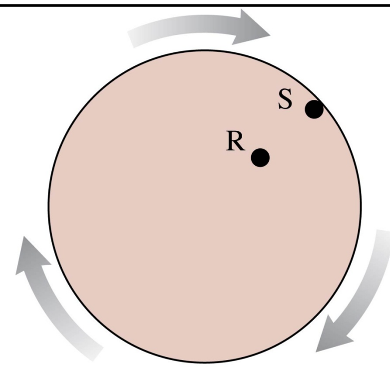
$$v = \frac{1 \text{ circumference}}{1 \text{ period}} = \frac{2\pi r}{T}$$

- ω r =



Small group

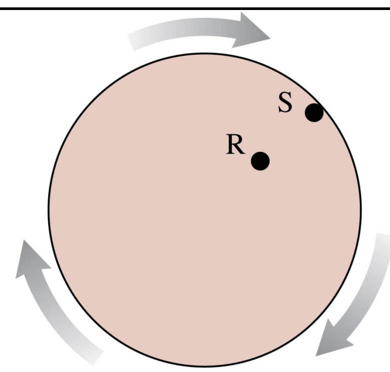
Rasheed and Sofia are riding a merry-go-round that is spinning steadily. Sofia is twice as far from the axis as is Rasheed. Sofia's angular velocity is ______ that of Rasheed.



A. half
B. the same as
C. twice
D. four times
E. We can't say without knowing their radii.

Individual

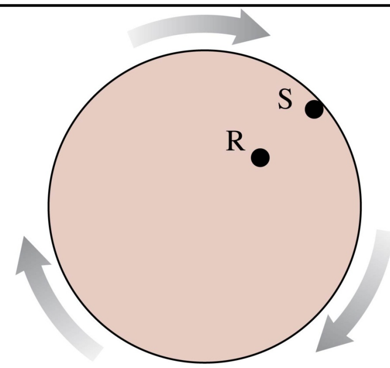
Rasheed and Sofia are riding a merry-go-round that is spinning steadily. Sofia is twice as far from the axis as is Rasheed. Sofia's speed is ______ that of Rasheed.



A. half
B. the same as
C. twice
D. four times
E. We can't say without knowing their radii.

Small group

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 acceleration is ______ that of Rasheed.

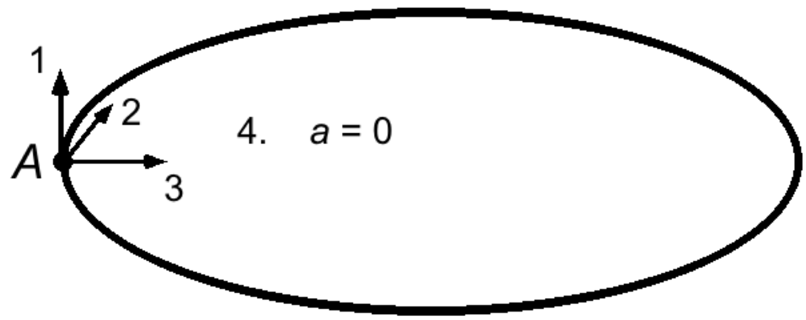


A. half
B. the same as
C. twice
D. four times
E. We can't say without knowing their radii.

But what if the speed is changing?

All those equations were for circular motion under constant speed

Small group: What is the acceleration vector for object speeding up from rest at point *A* ?



1=A, 2=B, 3=C, 4=D

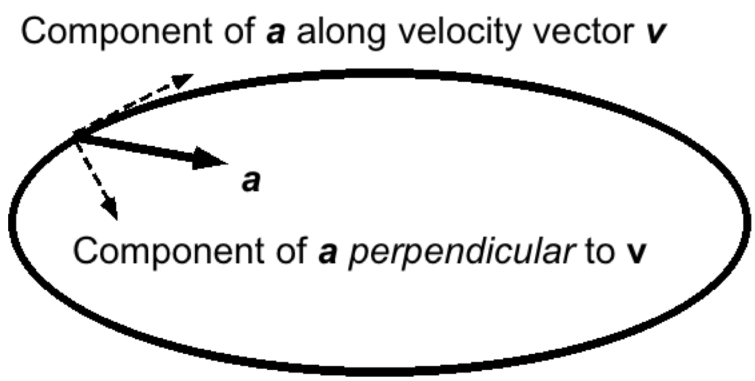
What if the speed is changing?

- Consider acceleration for object on curved path *starting from rest*
- Initially, $v^2/r = 0$, so no radial acceleration
- But a is not zero! It must be **parallel** to velocity

Acceleration vectors for object speeding up:

Tangential and radial components

(or parallel and perpendicular)



Summary

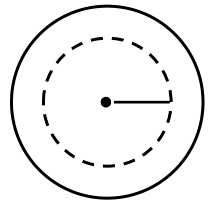
Components of acceleration vector:

- Parallel to direction of velocity:
  (Tangential acceleration)
  - "How much does speed of the object increase?"

- Perpendicular to direction of velocity:
  (Radial acceleration)
  - "How quickly does the object turn?"

Relating linear and angular kinematics

- Linear speed: $v = (2\pi r)/T = \omega r$
- Radial acceleration: $a_{rad} = v^2/r = \omega^2 r$
- Tangential acceleration: $a_{tan} = r\alpha$



$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

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

Sample problem

A small steel roulette ball rolls around inside of a 30-cm diameter roulette wheel. It is spun at 150 rpm, but it slows down to 60 rpm over an interval of 5.0s. Assume constant angular acceleration. How many revolutions does the ball make during these 5.0s?

Reading assignment

- Relative motion
- 4.4 in textbook
- Review for Midterm 1 !