# Physics 1021

Spring 2012
Chapter 4b

## Announcements

- Movie of the week, circular motion. Find the centripetal acceleration. Measure it and identify it
- Today's class:
  - Relative motion
  - Circular motion, what causes it … centripetal acceleration
  - Circular kinematics, how to describe it … same as linear motion

## *ConcepTest 4.4a-post* Dropping the ball I

From the *same* height (and at the *same* time), one ball is dropped and another ball is fired horizontally. Which one will hit the ground first?

1) the "dropped" ball
2) the "fired" ball
3) they both hit at the same time
4) it depends on how hard the ball was fired
5) it depends on the initial height

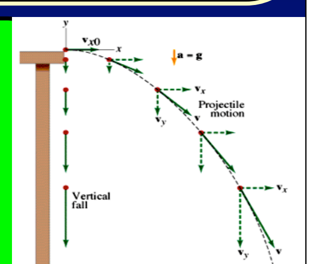


## *ConcepTest 4.4b* Dropping the ball I

From the *same* height (and at the *same* time), one ball is dropped and another ball is fired horizontally. Which one will hit the ground first?

(1) the "dropped" ball
(2) the "fired" ball
(3) they both hit at the same time
(4) it depends on how hard the ball was fired
(5) it depends on the initial height

Both of the balls are falling vertically under the influence of gravity. **They both fall from the same height. Therefore, they will hit the ground at the same time.** The fact that one is moving horizontally is irrelevant --- remember that the x and y motions are independent!




**Follow-up:** Which ball has the greater velocity at ground level?

# Relative Motion

***New Topic***



# General Principles

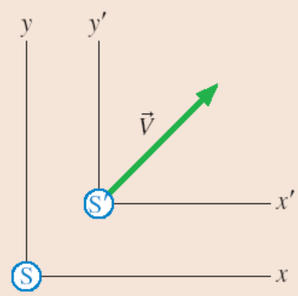
## Motion is relative

### Relative motion

Inertial reference frames move relative to each other with constant velocity $\vec{V}$. Measurements of position and velocity measured in frame S are related to measurements in frame S′ by the Galilean transformations:

$$x' = x - V_x t \qquad v'_x = v_x - V_x$$

$$y' = y - V_y t \qquad v'_y = v_y - V_y$$



## Galileo Experiment

- Cannon ball dropped down the mast of a moving ship
- Of course, a pick up and a shot put are used here.
- Note the trajectories … parabolic, straight down.

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*Doane College*

*Crete, NE*

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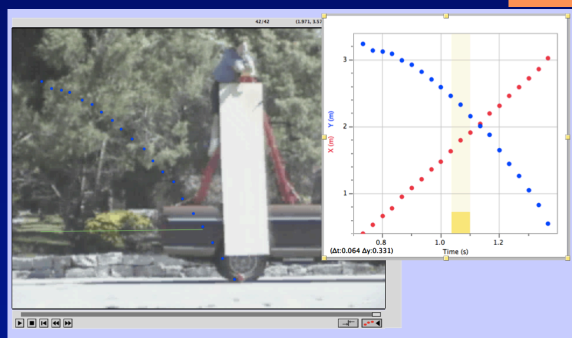




## *ConcepTest 4.5a-post* Throwing the ball I

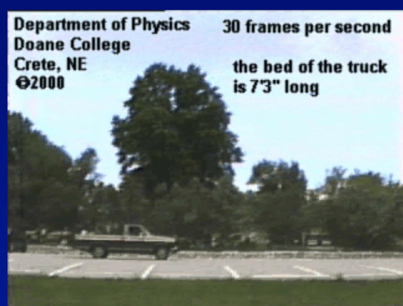
**A kid in the back of a pickup truck travelling at 0 mph gets bored and throws his basketball straight up. The ball lands**

1) the behind the truck
2) In his hands
3) In front of the truck

## *ConcepTest 4.5b* -post Throwing the ball I

A kid in the back of a pickup truck travelling at 0 mph gets bored and throws his basketball straight up. The ball lands

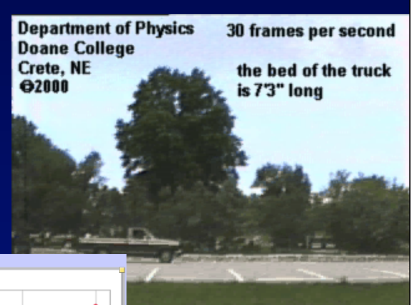
1) the behind the truck
2) In his hands
3) In front of the truck

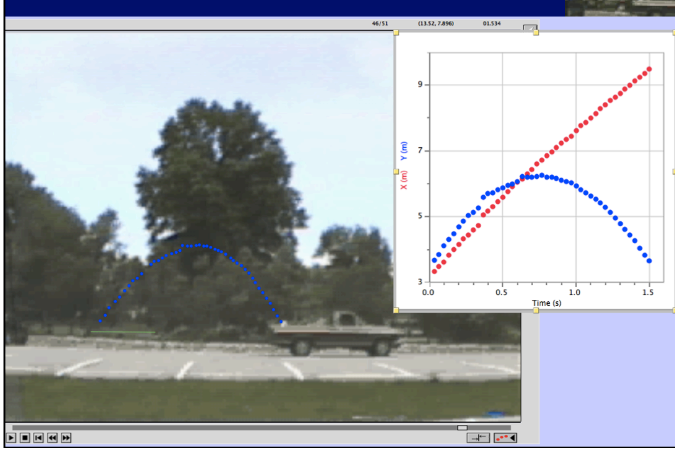



PHYS 1021: Chap. 4, Pg 9

## Tossing the ball

- Throw basketball up from moving truck
- What is the trajectory … parabolic, straight down?




PHYS 1021: Chap. 4, Pg 10

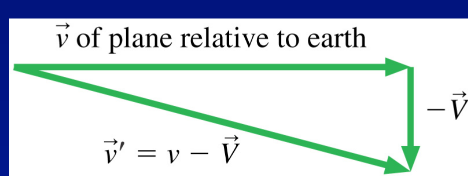
**A plane traveling horizontally to the right at 100 m/s flies past a helicopter that is going straight up at 20 m/s. From the helicopter's perspective, the plane's direction and speed are**

A. right and up, more than 100 m/s.
B. right and up, less than 100 m/s.
C. right and down, more than 100 m/s.
D. right and down, less than 100 m/s.
E. right and down, 100 m/s.



**A plane traveling horizontally to the right at 100 m/s flies past a helicopter that is going straight up at 20 m/s. From the helicopter's perspective, the plane's direction and speed are**

A. right and up, more than 100 m/s.
B. right and up, less than 100 m/s.
✔ **C. right and down, more than 100 m/s.**
D. right and down, less than 100 m/s.
E. right and down, 100 m/s.



## Example: Relative Motion

**A plane traveling horizontally to the right at 100 m/s flies past a helicopter that is going straight up at 20 m/s. What is the magnitude and direction of the plane's velocity from the helicopter's perspective.**



## Numerical Problem: Relative Motion

- A kayaker wants to paddle north across a 100 m wide river. The current in the river is flowing to the east at 2 m/s. The kayaker can paddle in still water at a speed of 3 m/s.
- **In which direction (give the angle) should the kayaker paddle in order to travel to a point directly across the river?**
- **How long will it take the kayaker to cross the river?**

## Ponderable: Acceleration in 2D

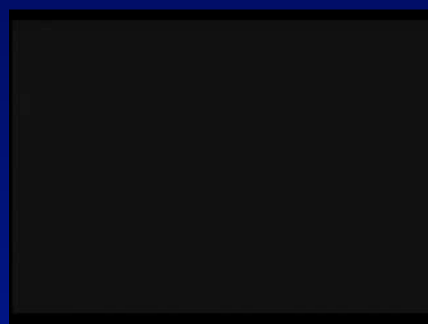
- A sailboat is traveling east at 5.0m/s. A sudden gust of wind gives the boat an acceleration of 0.8 $m/s^2$ 45 degrees north of east. What is the boat's speed and direction after 6s?



## Circular Motion

*New Topic*

## Spinning chain (movie 5-24ab)





## *ConcepTest 4.7.a* What does the chain do?

1. It falls flat
2. It breaks
3. It rolls off the table
4. It flies through the air
5. It slides off the table

## *ConcepTest 4.7b* What does the chain do?

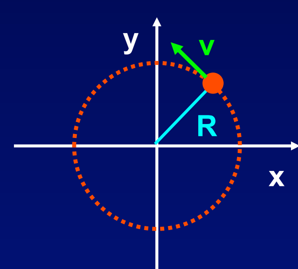
1. It falls flat
2. It breaks
3. It rolls off the table
4. It flies through the air
5. It slides off the table

**This demonstrates that an object (the chain) that is in spinning motion will remain in spinning motion, unless acted upon by an external angular acceleration. The tension on each link provides an inwardly directed component for the centripetal force … note this is an internal force.**



# Uniform Circular Motion

- **Motion in a circle with:**
  - **Constant radius *R***
  - **Constant speed $v = |\mathbf{v}|$ (magnitude of velocity)**

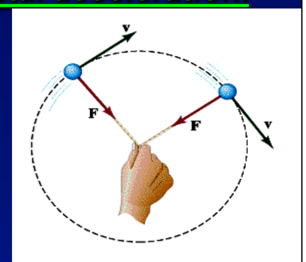



- **Some circular motion terms:**
  - **Recall that 1 revolution = 360° = $2\pi$ radians**
    - **frequency ( f ) = revolutions / second**
    - **period ( P ) = seconds / revolution**

$$f = 1/P$$

# Centripetal (radial) Acceleration

- If you swing a ball in a circle, the *speed* is constant but the velocity is *not* constant, since the direction is changing.
  - must be some acceleration: ***centripetal acceleration!***
  - Magnitude: $a = \frac{v^2}{R}$
  - Direction: toward center of circle

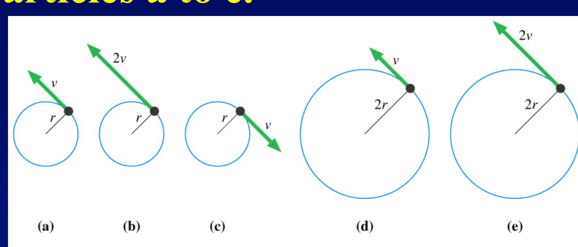



Since an acceleration is needed, then it must be supplied in some way

- magnitude: $a = \frac{v^2}{R}$
- direction: towards the center of the circle

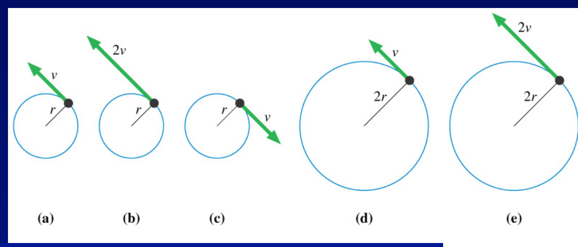


## Rank in order, from largest to smallest, the centripetal accelerations $(a_r)_a$ to $(a_r)_e$ of particles a to e.




A. $(a_r)_b > (a_r)_e > (a_r)_a > (a_r)_d > (a_r)_c$
B. $(a_r)_b > (a_r)_e > (a_r)_a = (a_r)_c > (a_r)_d$
C. $(a_r)_b = (a_r)_e > (a_r)_a = (a_r)_c > (a_r)_d$
D. $(a_r)_b > (a_r)_a = (a_r)_c = (a_r)_e > (a_r)_d$
E. $(a_r)_b > (a_r)_a = (a_r)_c > (a_r)_e > (a_r)_d$

## Rank in order, from largest to smallest, the centripetal accelerations $(a_r)_a$ to $(a_r)_e$ of particles a to e.




A. $(a_r)_b > (a_r)_e > (a_r)_a > (a_r)_d > (a_r)_c$

**B. $(a_r)_b > (a_r)_e > (a_r)_a = (a_r)_c > (a_r)_d$** ✔

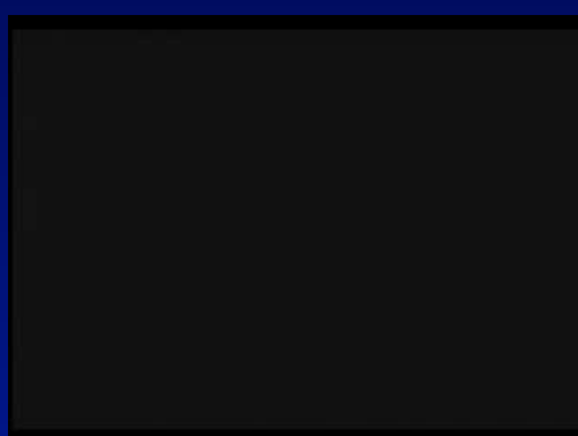
C. $(a_r)_b = (a_r)_e > (a_r)_a = (a_r)_c > (a_r)_d$

D. $(a_r)_b > (a_r)_a = (a_r)_c = (a_r)_e > (a_r)_d$

E. $(a_r)_b > (a_r)_a = (a_r)_a > (a_r)_e > (a_r)_d$



## Spinning erasers (movie 5-15ab)



## *ConcepTest 4.8a* Which eraser goes of first?

- The inner one
- The center one
- The outer one
- All three at once

PHYS 1021: Chap. 4, Pg 25

## *ConcepTest 4.8b* Which eraser goes of first?

- The inner one
- The center one
- The outer one
- All three at once

**All three have the same angular velocity as the disk spins up, the outer one requires the largest centripetal acceleration ($a = \omega^2 r$) to keep it going in a circle. ….**

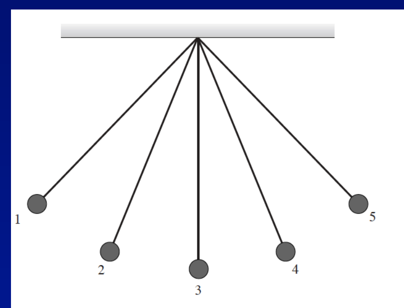
PHYS 1021: Chap. 4, Pg 26

## Ponderable: Swinging Pendulum

A pendulum swings from its end point on the left (point 1) to its end point on the right (point 5). At each of the labeled points:

a. Use a **black pen or pencil to draw and label the** vectors and at each point. Make sure the length indicates the relative size of the vector.

b. Use a **red pen or pencil to draw and label the** total acceleration vector .




PHYS 1021: Chap. 4, Pg 27