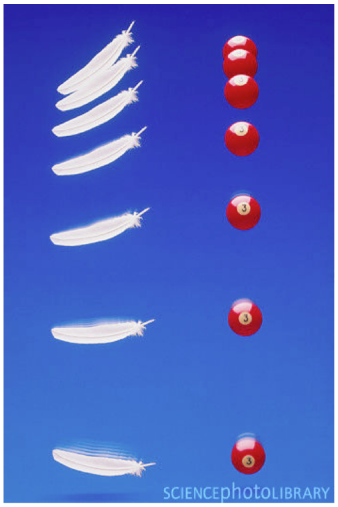
Welcome back to Physics 215



Today's agenda:

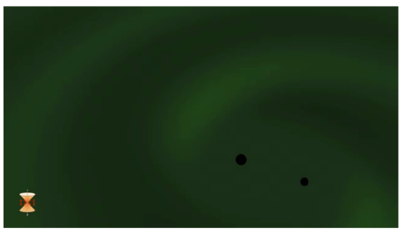
- *motion with constant acceleration and free fall*
- *Vectors in Mechanics*
- *Motion in two dimensions*

Stuff you need to do this week:

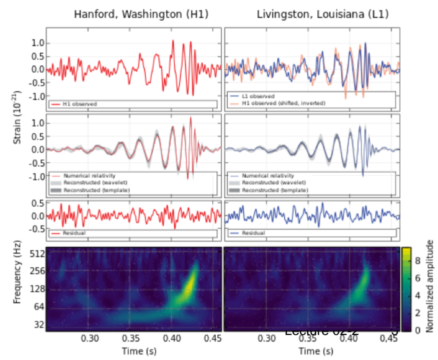
- Complete the SAGE survey
- HW for week 2 due at the beginning of recitation
- Reading before class (always available on the course website under the "assignments" tab)
- Reading for next Tuesday:
  - Open Stax: Projectile Motion, 4.1-4.3

Ask a physicist!!!

What are they?

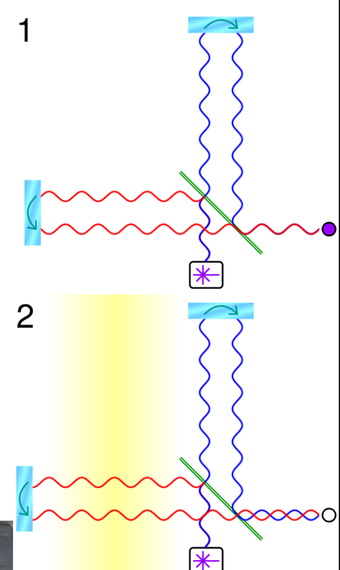


So, gravity waves: Are they ripples in spacetime? Why do black-holes colliding make them occur (or occur so strongly)? What is the big deal in general? Why are they so important?



Ask a physicist!!!

How can you measure them?



Ask a physicist!!!

Why would you care?

- Is general relativity the correct theory of gravity?
- How does matter behave under extreme densities and pressures?
- How abundant are stellar-mass black holes?
- What is the central engine driving gamma ray bursts?
- What happens when a massive star collapses?

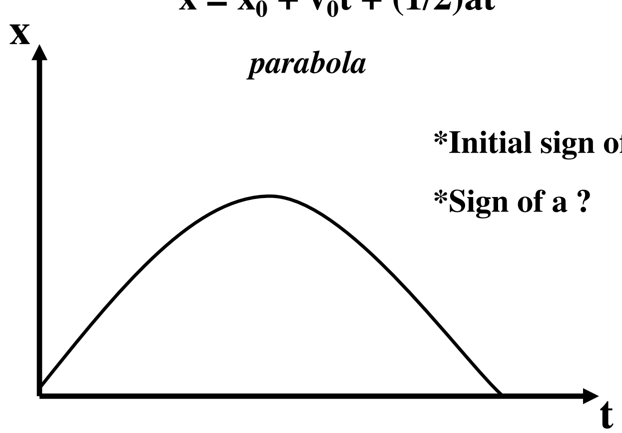
Multi-messenger astronomy: this is a “new lens” on the world! Imagine biology before the invention of the microscope!

Also: technology transfer (like NASA). Quantum measurement (largest source of noise is quantum vacuum fluctuations)

x(t) graph- constant acceleration

$$\mathbf{x = x_0 + v_0 t + (1/2)at^2}$$

parabola



***Initial sign of v ?**

***Sign of a ?**

4^{th} constant acceleration equation

- Can also get an equation independent of t
- Substitute $t = (v - v_0)/a$ into

$$x - x_0 = (1/2)(v + v_0)t$$

we get:

or:

SG : An object moves with constant acceleration, starting from rest at t = 0 s. In the first 8 metronome beats, it travels 5 cm.
What will be the displacement of the object in the following eight metronome beats(mb) (*i.e.* between t = 8 mb and t = 16 mb)?

A. 10 cm
B. 15 cm
C. 20 cm
D. 25 cm

SG: An object moves with constant acceleration, starting from rest at $t = 0$ s. In the first 8 mb, it travels 5 cm.
What will be the displacement of the object between $t = 16$ mb and $t = 24$ mb?

A. 10 cm
B. 15 cm
C. 20 cm
D. 25 cm

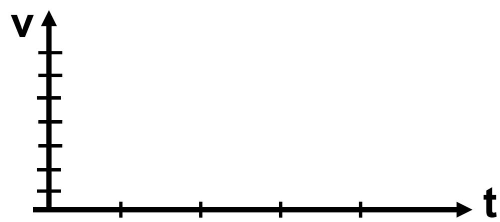
Rolling disk demo

- How far apart were the green painted lines?
- What is a plot of x vs. t?

SG: Rolling disk demo

- Compute average velocity for each section of motion (between marks)
- Measure time taken (metronome)
- Compare v at different times

(i) 5 cm **(ii) 20 cm** **(iii) 45 cm**



Motion with constant acceleration:

1. $v = v_0 + at$

2. $v_{av} = (^1/_2)(v_0 + v)$

3. $x = x_0 + v_0 t + (^1/_2)\, a\, t^2$

4. $v^2 = v_0^2 + 2a\,(x - x_0)$

***where x_0, v_0 refer to time = 0 s ;**

x, v to time *t*

Freely Falling Bodies:

- Near the surface of the earth, neglecting air resistance and the earth's rotation, all objects experience the same downward acceleration due to their gravitational attraction with the earth:

$$\mathbf{g = 9.8\ m/s^2}$$

  – Near = height small relative to radius of earth

Example of constant acceleration:

- ***Free fall demo***

- Compare time taken by feather and billiard ball to fall to the ground from the same height

- Influence of air in room?

Sample problem

- A brick is dropped (zero initial speed) from the roof of a building. The brick strikes the ground in 2.50 s. Ignore air resistance, so the brick is in free fall.
  - How tall, in meters, is the building?
  - What is the magnitude of the brick's velocity just before it reaches the ground?
  - Sketch a(t), v(t), and y(t) for the motion of the brick.

Motion with **constant** acceleration:

1. $v = v_0 + at$
2. $v_{av} = (^1/_2)\ (v_0 + v)$
3. $x = x_0 + v_0 t + (^1/_2)\ a\ t^2$
4. $v^2 = v_0^2 + 2a\ (x - x_0)$

*where x_0, v_0 refer to time = 0 s;

x, v to time *t*

Motion in more than 1 dimension

- Have seen that 1D kinematics is written in terms of quantities with a magnitude and a sign
- Examples of 1D **vectors**
- To extend to d > 1, we need a more general definition of vector

Vectors: basic properties

- are used to denote quantities that have magnitude *and* direction
- can be added and subtracted
- can be multiplied or divided by a number
- can be manipulated **graphically** (*i.e.,* by drawing them out) or algebraically (by considering components)

Vectors: examples and properties

- Some <u>vectors</u> we will encounter:
- Vectors commonly denoted by boldface letters, *or* sometimes arrow on top
- Magnitude of **A** is written |**A**|, *or* no boldface and no absolute value signs
- Some quantities which are <u>not</u> vectors:

Drawing a vector

- A vector is represented graphically by a line with an arrow on one end.
- Length of line gives the **magnitude** of the vector.
- Orientation of line and sense of arrow give the **direction** of the vector.
- Location of vector in space does not matter -- two vectors with the same magnitude and direction are equivalent, independent of their location

Adding vectors

To add vector **B** to vector **A**

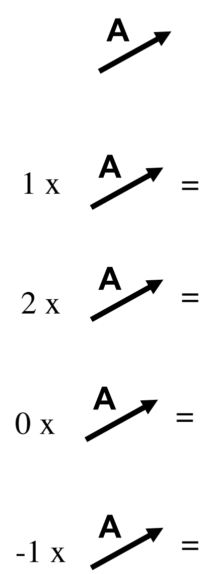
- Draw vector **A**

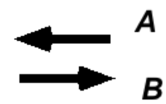
- Draw vector **B** with its tail starting from the tip of **A**

- The sum vector **A**+**B** is the vector drawn from the tail of vector **A** to the tip of vector **B**.

Multiplying vectors by a number

- Direction of vector not affected (care with negative numbers – see below)
- Magnitude (length) scaled, e.g.
  - 1***A**=**A**
  - 2***A** is given by arrow of twice length, but same direction
  - 0***A** = **0** null vector
  - **-A** = **-1*A** is arrow of same length, but reversed in direction



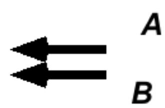


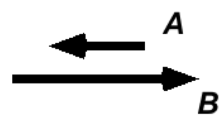
***A* + *B* =**

***B* - *A* =**

***A* + *B* =**

***A* - *B* =**





***A* + *B* =**

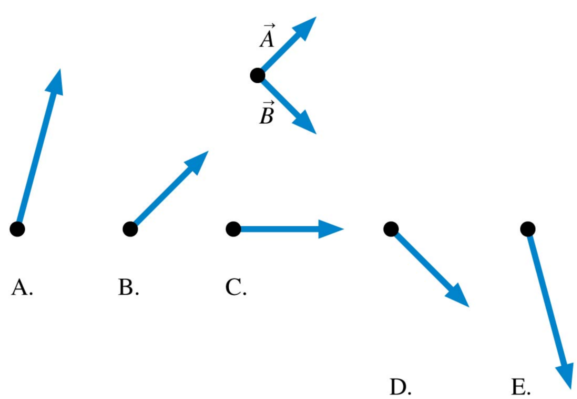
***B* - *A* =**

***A* + *B* =**

***A* - *B* =**

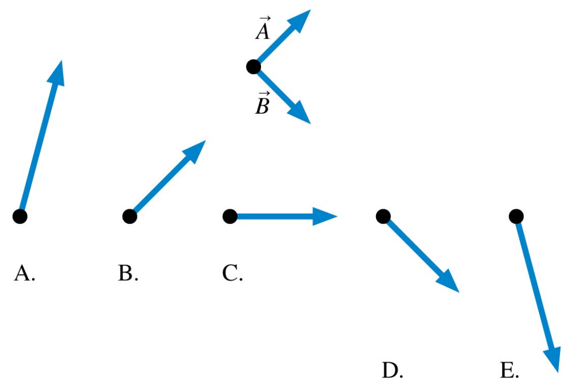
SG 2-2.1:

Which of the vectors in the second row shows $\vec{A} + \vec{B}$?



SG 2-2.2:

Which of the vectors in the second row shows $2\vec{A} - \vec{B}$?



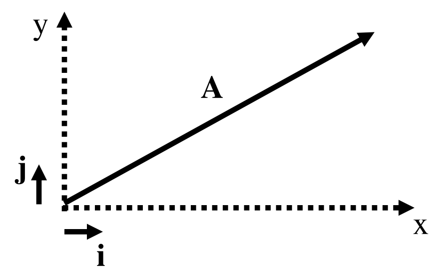
Projection of a vector

"How much a vector acts along some arbitrary direction"

Component of a vector

Projection onto one of the coordinate axes *(x, y, z)*

Components



A = $\mathbf{A_x} + \mathbf{A_y}$

A = $a_x\mathbf{i} + a_y\mathbf{j}$

i = *unit vector* in x direction

j = *unit vector* in y direction

<u>Projection</u> of **A** along coordinate axes

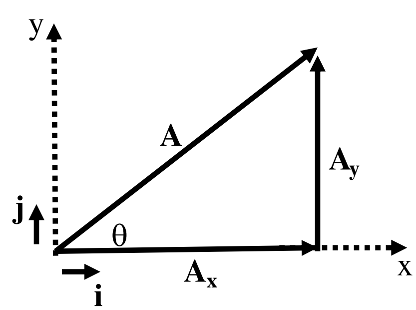
a_x, a_y = *components* of vector **A**

More on vector components

- Relate components to direction (2D):

  $a_x = |\mathbf{A}|\cos\theta$,

  $a_y = |\mathbf{A}|\sin\theta$



or

- *Direction:* $\tan\theta = a_y/a_x$
- *Magnitude:* $|A|^2 = a_x^2 + a_y^2$

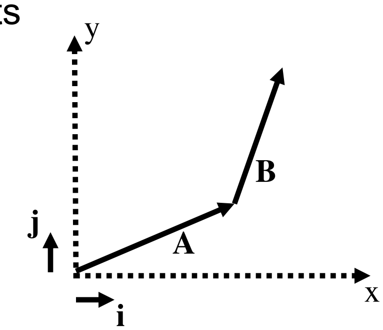
SG question: A bird is flying along a straight line in a direction somewhere East of North. After the bird has flown a distance of 2.5 miles, it is 2 miles North of where it started.

How far to the East is it from its starting point?

A. 0 miles
B. 0.5 miles
C. 1.0 mile
D. 1.5 miles

Why are components useful?

- *Addition:* just add components
  e.g. if **C** = **A** + **B**
  $c_x = a_x + b_x$; $c_y = a_y + b_y$
- *Subtraction* similar
- *Multiplying* a vector by a number – just multiply components: if **D** = n***A**
  $d_x = n*a_x$; $d_y = n*a_y$
- Even more useful in 3 (or higher) dimensions



SG question

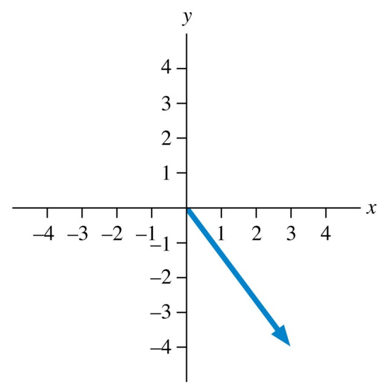
What are the *x*- and *y*-components of this vector?

A. 3, 4

B. 4, 3

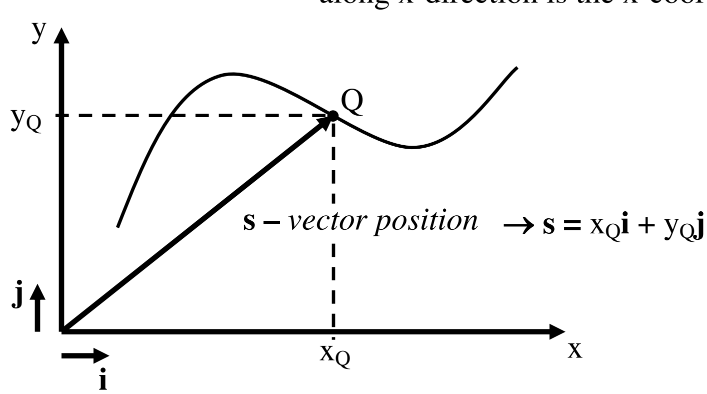
C. –3, 4

D. 3, –4



2D Motion in components

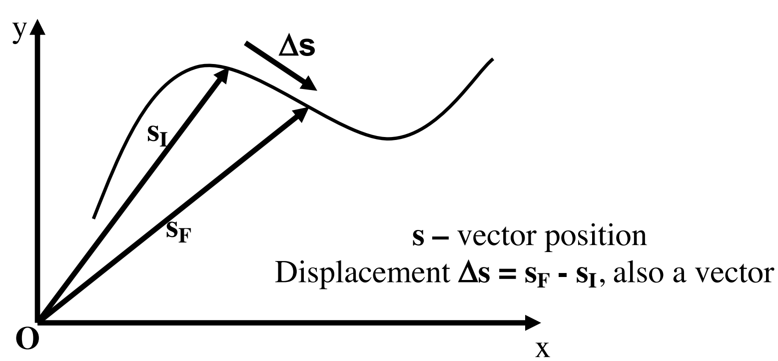
Note: component of position vector along x-direction is the x-coordinate!



Reading assignment

- Reading for next Tuesday:
  - Open Stax: Projectile Motion, 4.1-4.3

Displacement in 2D Motion



Describing motion with vectors

- Positions and displacements

  $\boldsymbol{s}$, $\Delta \boldsymbol{s} = \boldsymbol{s}_F - \boldsymbol{s}_I$

- Velocities and changes in velocity:

  $\boldsymbol{v}_{av} = \text{——}$, $\boldsymbol{v}_{inst} = \lim_{\Delta t \to 0} \text{——}$

  $\Delta \boldsymbol{v} = \boldsymbol{v}_F - \boldsymbol{v}_I$

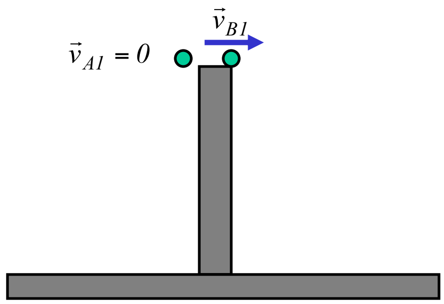
- Acceleration: $\boldsymbol{a}_{av} = \text{——}$, $\boldsymbol{a}_{inst} = \lim_{\Delta t \to 0} \text{——}$

2D Motion in components

- x and y motions *decouple*
- $v_x = \Delta x/\Delta t$; $v_y = \Delta y/\Delta t$
- $a_x = \Delta v_x/\Delta t$; $a_y = \Delta v_y/\Delta t$
- If acceleration is only non-zero in 1 direction, can choose coordinates so that 1 component of acceleration is zero
  - e.g., motion under gravity

SG Question:

Ball A is released from rest. Another identical ball, ball B is thrown horizontally at the same time and from the same height. Which ball will reach the ground first?



A. Ball A

B. Ball B

C. Both balls reach the ground at the same time.

D. The answer depends on the initial speed of ball B.

Motion under gravity

$a_y = -g$

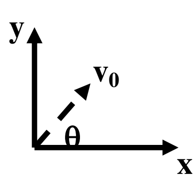
$v_y = v_{0y} - gt$

$y = y_0 + v_{0y}t - (1/2)gt^2$

$a_x = 0$

$v_x = v_{0x}$

$x = x_0 + v_{0x}t$



$v_{0y} = v_0\sin(\theta)$

$v_{0x} = v_0\cos(\theta)$

Projectile motion…