Pre-AP Physics Notes - Ch. 2 Motion in One Dimension

I. The nature of physical quantities: scalars and vectors

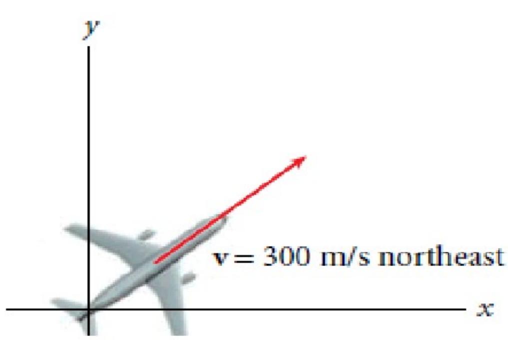
A. Scalar—quantity that describes only magnitude (how much or amount or size), **NOT including** direction: Scalar quantities have no direction associated with them; ex. mass, temperature, time, volume, distance, speed, color, etc. It makes no sense to say an object has a mass of 2kg, West!

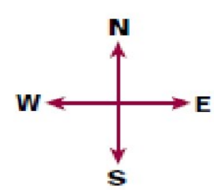
B. Vector—A quantity that has both magnitude (amount) and direction (angle, or left/right, etc.); ex. displacement, velocity, force, etc.

1. Speed is the magnitude (amount) of velocity; velocity must include both magnitude (speed) and direction.
2. For example, if someone tells you they are going to apply a 20 pound force on you, you would want to know the direction of the force, that is, whether it will be a push or a pull. So, force is a vector, since direction is important in specifying a force. The table below lists some vectors and scalars you will be using.
3. On diagrams, **arrows are used to represent vector quantities**; the direction of the arrow or the angle at which it points gives the direction of the vector and the **magnitude or amount of the vector is proportional to the length of the arrow.**

Vectors (usually in Bold)	*Scalars (not in bold)*
displacement	*distance*
velocity	*speed*
acceleration	*mass*
force	*time*
weight	*volume*
momentum	*temperature*
	work and energy

Frames of reference—A standard for comparison; any movement of position, distance, or speed is made against a frame of reference; "with respect to Earth" is most common. To remind you of all the motion you are currently experiencing - http://www.gecdsb.on.ca/d&g/astro/music/galaxy.mp3





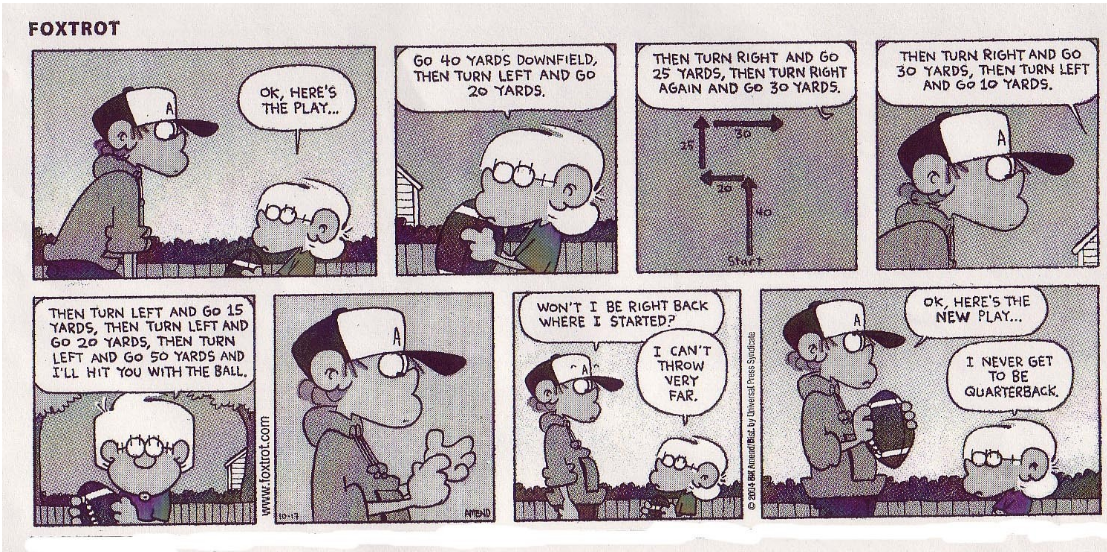
******We can say it is "northeast" because it is exactly 45 degrees from each axis BUT if it were 35 degrees above the x axis instead?? We would need to say 35 degrees North of East!***

II. Distance vs. Displacement

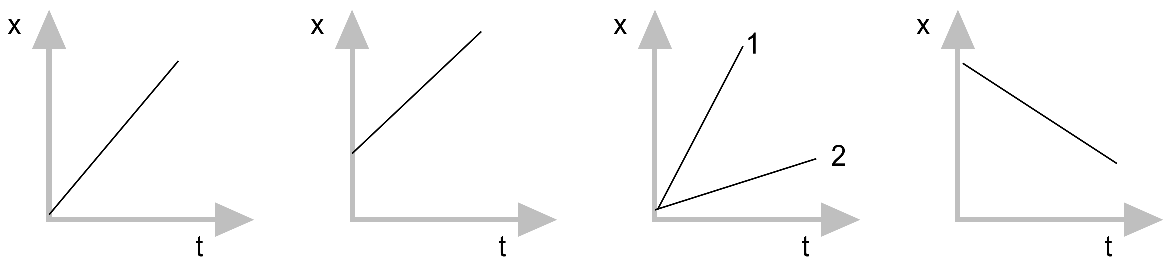
- **Distance** d **or** Δx— is the total length moved or total "ground" covered; a scalar quantity…No direction necessary! If you ran around the track, you would go a ***distance d*** of 400 meters.
- **Displacement Δx — is Defined as the change in position (Δx or delta "x" means x_f-x_i or final position (x_f) minus initial position** (x_i or x_o)**with respect to a reference point. It is a vector quantity**. If you ran around the track, your **displacement would be "ZERO" meters**

because you start and end at the same position! We can use displacement and distance interchangeably in this course, but they are not necessarily the same thing.

- **Note** – ***displacement is not always equal to the distance traveled***



Some graphs of position versus time:



Questions:

Which graph(s) show a starting position "x" away from and moving farther away from the origin in the positive direction?

Which graph(s) show an object returning toward the starting position?

III. Velocity vs. *Speed*

- ***Average speed*—total distance covered divided by the total time taken**; **scalar quantity**

- **Average velocity—displacement or Δx /time; vector quantity**. Since velocity is a vector, we must define it in terms of another vector, displacement. Oftentimes average speed and average velocity are interchangeable for the purposes of the AP Physics B exam. Speed is the magnitude of velocity, that is, speed is a scalar and velocity is a vector. For example, if you are driving west at 50 miles per hour, we say that your speed is 50 mph, and your velocity is 50 mph west. **<u>We will use the letter *v* for both speed and velocity in our calculations</u>, and will take the direction of velocity into account whenever necessary.**

$$v = \frac{\Delta x}{t} \text{ or } \frac{d}{t}$$

Ques: If you are going around a corner at a constant 20 mph, is your velocity constant?

- **Instantaneous velocity** (slope of a position vs. time graph) is the velocity at a specific time which ***may be different from the average velocity*** (unless the object has constant velocity!).

Example #1 : Let's say you traveled 25 meters North in 2 minutes, stopped for 10 minutes, then continued in the same direction going 400 meters in 8 minutes…calculate your average velocity for the trip.

IV. **Acceleration:** In this course we will only calculate with constant accelerations. (In order to work well with changing accelerations, you would need to use calculus.)

a=Δv/Δt units are *m/s/s=m/s²*

- **Average acceleration is the rate of change of velocity**; change in velocity with time (**a** = Δ**v**/Δt) if an object's velocity is changing, it IS accelerating—**even if it's slowing down** and even if the only thing changing is its direction of travel. **An object traveling in a circle at a constant speed is still changing its velocity because its direction is changing constantly…SO it is accelerating!!**

Example # 2 : If a car goes from rest to 48 mph (miles per hour) in 4 seconds, calculate its acceleration.

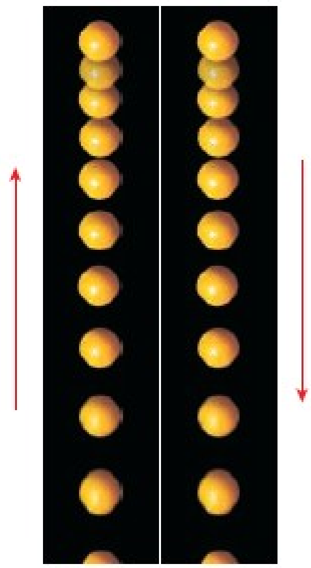
- **Note –** ***At first you might think that + acceleration is speeding up and negative acceleration is slowing down – NOT necessarily. You only have negative acceleration when the direction of the acceleration is opposite to the direction that is defined as positive. It's all about the direction of the acceleration – not speed up or slow down***.

V. Free Fall – We say an object is in free fall when its motion is controlled by gravity.

$$a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}$$

In the picture to the right, a ball is thrown upward with some initial velocity. As it goes up, its speed decreases until it instantaneously becomes zero at the top. Then it speeds up as it falls back down. If "up" has been defined as positive, then **the balls <u>velocity</u>** is:

- positive as it moves upward slowing down;
- becomes zero at the top
- negative as it moves downward gaining speed



BUT, the ball's acceleration has the same negative value and direction at all positions!

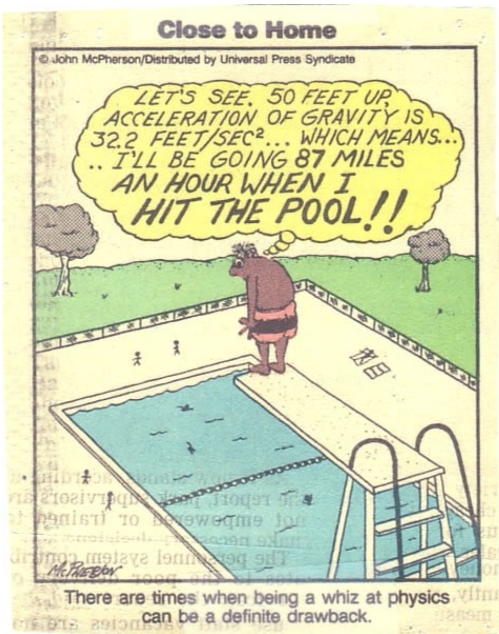
Try it using the formula!! $a = \frac{v_f - v_i}{t}$

Ex: initial speed going up is 40 m/s and it travels upward for 4 seconds and stops momentarily then falls for 4 seconds and reaches a final speed of 40 m/s. Using the signs for up and down motion (given above), **calculate the average acceleration for each part of the trip, then the average acceleration for the total trip.**

<u>This acceleration is also present at the top EVEN WHEN the instantaneous speed is ZERO!</u> **<u>This acceleration is due to gravity</u>** and (when "a" is this special case, due to gravity – we label it "g" and call it "free fall" acceleration). **Gravity does not take a holiday just because the object reached the top of its trajectory!**

- **On Earth, g = 32 ft/s^2 = 32 Feet per second each second. This is the same as 9.81 meters per second each second (that is or 9.81 m/s^2 (we regularly round it to 10 m/s^2 to make calculations easier).** Do not use values in feet unless you are specifically asked to do so!!

Example #3: A ball is dropped from the top of a cliff. How fast will it be traveling after 1 , 2, and 3 seconds? How high is the cliff if the ball hits the bottom in 5 seconds?



- **In the <u>absence</u> of air resistance*, all objects, regardless of their mass or volume, dropped near the surface of a planet fall with the same constant acceleration.***
- Look at the picture above. The feather and the apple in a vacuum chamber fall at the same rate!

In the **<u>presence</u> of air resistance**, objects dropped will initially accelerate at *g* and then the acceleration will decrease to zero as ***terminal velocity*** is reached. Does this mean that it slows down?

See the kinematic formulas (last page of these notes) for use in these examples. Be sure to compare these formulas to the **official formula sheet** that you will get on the chapter tests and the EOC.

Example # 4 : A rocket traveling at 88 m/s is accelerated uniformly to 132 m/s over a 15 s interval. What is the displacement during this time?

Example # 5 : A flowerpot falls from rest on a windowsill 25.0 m above the sidewalk.

a. How fast is the flowerpot moving when it strikes the ground?

b. How much time does a bug on the sidewalk below have to move out of the way before the flowerpot hits the ground or the bug?

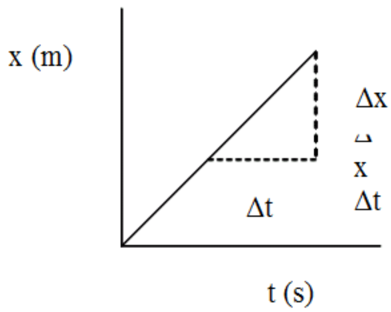
VI. Graphs of Motion

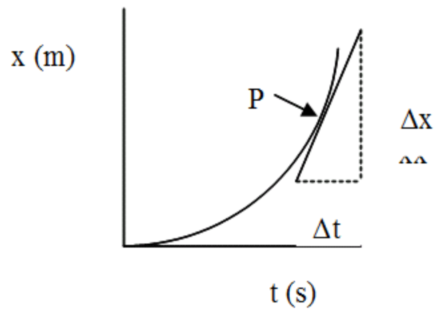
- Graphical analysis is a concept fundamental to physics, as well as all math, science, economics, etc. courses. In analyzing any graph you should determine the significance, if any, of the ***slope*** (derivative) and the ***area under the curve*** (integral). This can be done by simply looking at the units of the vertical and horizontal axis (for slope, divide the two and, for area, multiply the two).
- With kinematics there are three important types of graphs you will need to be able to interpret:

position vs. time, *velocity vs. time*, and *acceleration vs. time*.

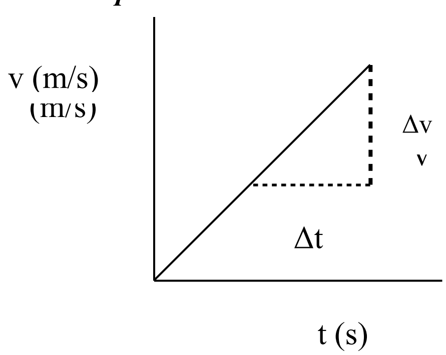
- ***Position vs. time***

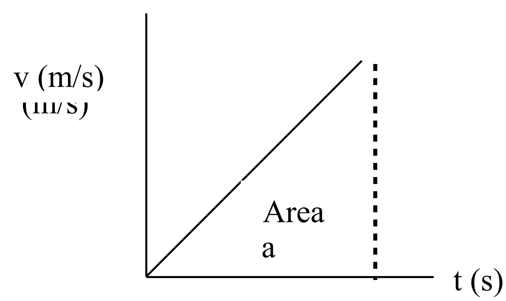
Analysis of the position vs. time graphs below shows that the *slope Δx/Δt is velocity*. The lower left graph is linear which indicates that the slope is constant and therefore the velocity is constant (no acceleration). The curved graph on the right indicates that the slope is changing. The slope of the curved graph is still velocity, even though the velocity is changing, indicating the object is accelerating. The *instantaneous velocity* at any point on the graph (such as point P) can be found by drawing a tangent line at the point and finding the slope of the tangent line.



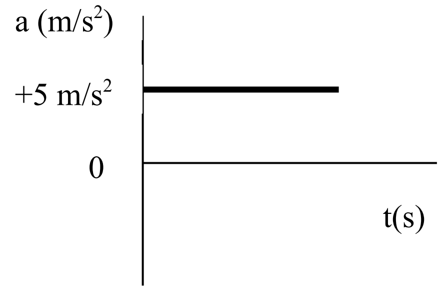


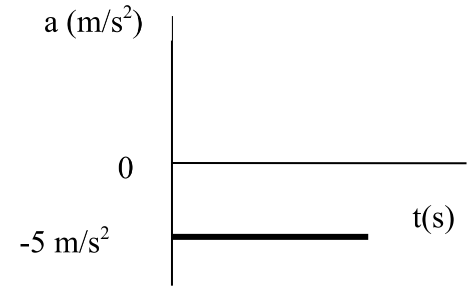
- ***Velocity vs. time***
  - Analysis of a velocity vs. time graph would show that the ***slope Δv/Δt is acceleration.*** And, unlike a position vs. time graph where the area was not significant, the ***area of a velocity vs. time***, as shown in the figure below right, would have units of (m/s)(s) = m and is therefore ***displacement***.





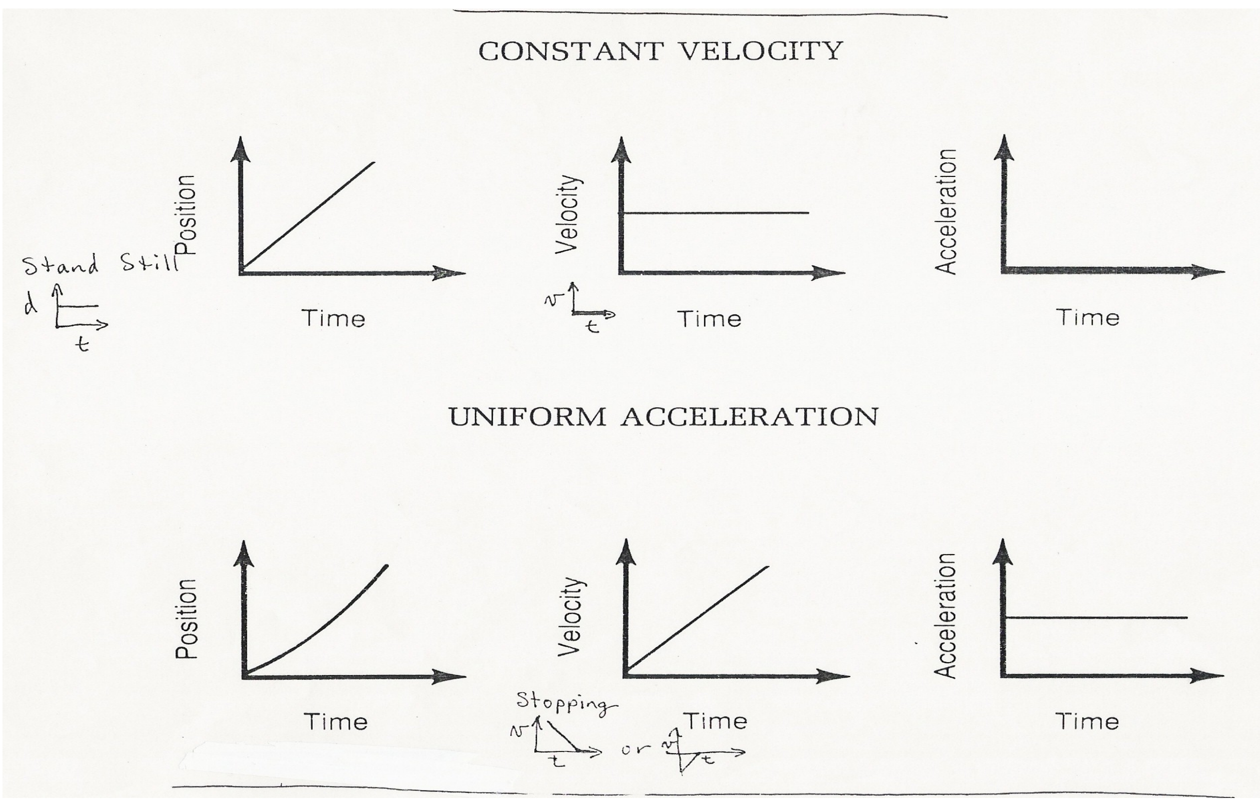
- ***Acceleration vs. time***
  - For this class, you will not need to worry about the slope and area for acceleration vs. time graphs. Analysis would show that the slope would have the units of m/s^3 (jerk) and the area would have the units of m/s (velocity). ***Since most problems related to the motion graphs will deal with constant acceleration, any graph of acceleration vs. time in this class would likely be a straight horizontal line.*** The lower left graph tells us that the acceleration of this object is positive. If the object were accelerating negatively, the horizontal line would be below the time axis, as shown in the graph on the right.





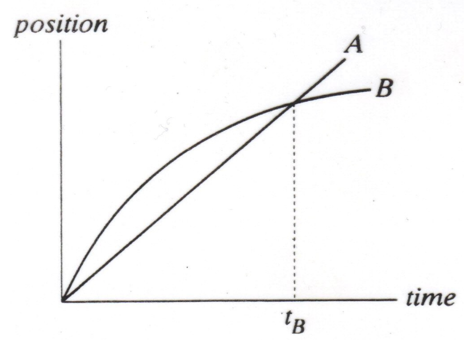
Relationship among position time, velocity time, and acceleration time graphs

- **Given any one of the motion graphs you should be able to sketch the other two that relate to the first. Since AP Physics B typically deals with constant velocity or constant acceleration, the trends will be similar to the ones below.**
- ***Constant velocity must have a linear position vs. time, horizontal velocity vs. time, and a horizontal line on zero for acceleration vs. time. Constant acceleration must have a parabolic position vs. time, linear velocity vs. time, and horizontal acceleration vs. time.*** **Whether the values are positive or negative depends upon the frame of reference.**



***Example #6*:** The graph below shows position as a function of time for two trains running on parallel tracks. Which is true?

1. At time t_B, both trains have the same speed.
2. Both trains speed up all the time.
3. Both trains have the same speed at some time before t_B.
4. Both trains have the same acceleration at some time before t_B.



Simple Kinematic Formulas

[For cases where the object starts from rest; in other words, the initial velocity (v_i or v_o)is 0.)]

$$\Delta x = v_{average} \times t$$

200mi = 50mi/hr X 4hrs. 50mi/hr **MUST be the average velocity** for the whole trip. **Do not** use this formula for instantaneous velocity or to try to find a velocity at a particular moment.

****

$$v_f = at$$

Use this formula to find the **velocity** at a particular moment (instantaneous velocity), the **acceleration**, or the **time** if the other terms are known.

$$a = \frac{\Delta v}{t}$$

Use this to find **acceleration**, the change in **velocity**, or the elapsed **time** if the other terms are known.

$$\Delta x = \tfrac{1}{2}at^2$$

Use this to find the **displacement** (change in position,) the **acceleration**, or the **time** when the other terms are known.

General Kinematic Formulas: The Big Three Formulas for uniformly accelerated motion

{The formulas below are general. If the object starts from rest then the initial velocity is 0 and the formulas may be simplified to the forms above.}

$$v_f = v_i + at$$

Use this to find the **final velocity**, the **original velocity**, the **acceleration**, or the elapsed **time** when the other terms are known.

$$v_f^2 = v_i^2 + 2a\Delta x$$

Use this to find the **final velocity**, the **original velocity**, the **acceleration**, or the **displacement** when the other terms are known. (notice time is unnecessary)

$$\Delta x = v_i t + \tfrac{1}{2}at^2$$

Use this to find the **displacement**, the **original velocity**, the elapsed **time**, or the **acceleration** when the other terms are known.

Pre-AP physics Text Problems Ch. 2: #s 10,11,14,17,22-34,38,39,41,45,49,51

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