PhyzGuide: Graphing Motion

For a particle moving in one dimension, there are three quantities that (for us) give a complete kinematic profile. **Kinematics** is simply the mathematical description of motion. Kinematics itself is not physics; it is math. The value of kinematics is that it gives us clues to the physics *behind* the motion. Since understanding motion is something of a big deal in this course, understanding kinematics is something of a big deal as well.

The three quantities of interest are **position**, **velocity**, and **acceleration.** But since our particle can change its position, velocity, and acceleration, we must record these quantities with respect to **time** (see sidebar).

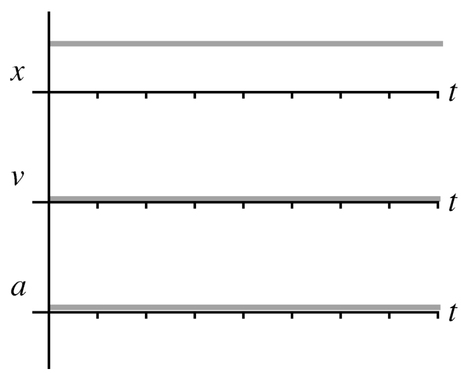
To gain an understanding of motion we must learn how position, velocity, and acceleration are related (or unrelated). We will do this by graphing position, velocity, and acceleration *simultaneously***.**

The basics may seem easy, but as motions become more complicated, you may be surprised or perplexed at the way these quantities interrelate.

Well, enough talk. Let's see how it's done. Read through the following examples with great care. Your success in kinematics depends on a clear understanding of these graphs.

THE 4th DIMENSION!
Suppose you've set up a hot date with a totally happ'nin' (girl/guy). You decide to meet at Penguin's (thus, you have specified a point in space at which to meet). But your meeting plans are not complete: you might show up on Friday at 4:00pm, and your date might show up on Saturday at 8:00pm. So to set up the date, you must specify a point in time *as well as* a point in space. Time is the fourth dimension, no less important than the first, second, and third dimensions of space. The FIFTH dimension was a groovin' 60's band who climbed the charts with their 1969 hit "Age of Aquarius/Let the Sunshine In."

(1) **REST** Suppose a particle just sits at some position, *p*. Time marches on, but the particle stays at *p*.



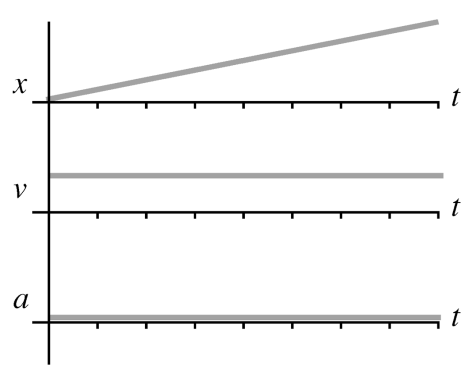
1. At any point in time, the particle is at position *p*.

2. If the particle is not moving, it has 0 velocity.

3. If the particle's velocity is **NOT *CHANGING*,** its acceleration is 0.

PLEASE, PLEASE NOTICE I said that since the particle's velocity is **NOT *CHANGING*,** its acceleration is zero. **I DID NOT SAY** that since the velocity is zero, the acceleration is zero. *This would not be true!!!*

(2) **UNIFORM MOTION** (No, silly, not the motion of uniforms!) Suppose our particle starts at position *x*=0m, and moves with constant positive velocity.



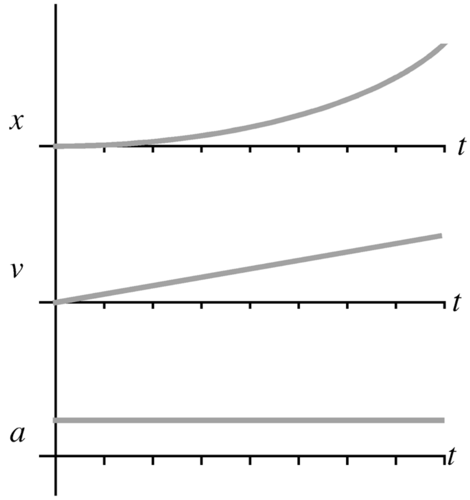
Start by drawing *v vs. t*. There's no "Rule of the Universe" that says you must draw the *x* graph first...

2. The **VALUE** of the *v vs. t* graph is the **SLOPE** of the *x vs. t* graph
The **SLOPE** of the *x vs. t* graph is the **VALUE** of the *v vs. t* graph
Therefore, the slope of *x vs. t* is numerically equivalent to the constant velocity.

1. Constant velocity: at any point in time, the velocity has the same value.

3. If the particle's velocity is **NOT *CHANGING*,** its acceleration is 0.
PLEASE, PLEASE NOTICE that I said that since the particle's velocity is **NOT *CHANGING*,** its acceleration is zero.

(3) **UNIFORM ACCELERATED MOTION** Suppose a particle starts at *x* = 0m and at rest (v=0m/s) and increases its speed by 1m/s during each second. The acceleration is thus 1m/s per second or 1m/s/s = 1m/s2.



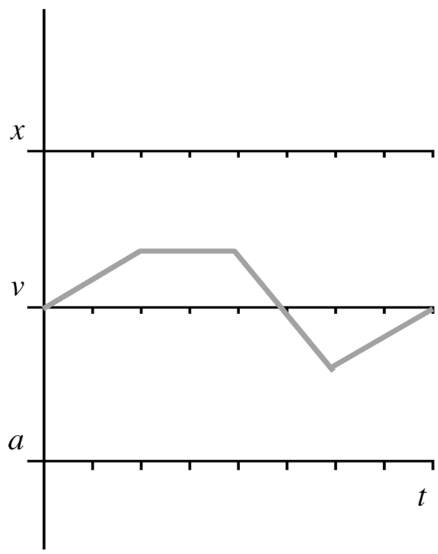
3. Since the **VALUE** of the *v vs. t* graph starts at zero, the initial **SLOPE** of the *x vs. t* graph is zero. As the **VALUE** of velocity **increases,** the **SLOPE** of the *x vs. t* graph **increases,** thus the upward curve.

2. Since the **VALUE** of *a vs. t* is 1 m/s2, the **SLOPE** of the *v vs. t* graph is 1m/s/s for the entire time interval. Now onto the *x vs. t* graph:
The **VALUE** of the *v vs. t* graph at a specific point is equal to the **SLOPE** of the *x vs. t* graph at that point.
The **SLOPE** of the *x vs. t* graph at a specific point is equal to the **VALUE** of the *v vs. t* graph at that point.

1. *a vs. t* is easy enough--for the whole time interval, *a* = 1 m/s2.
After plotting the horizontal *a vs. t* graph, we can get *v vs. t:*
The **VALUE** of the *a vs.t* graph at any point is equal to the **SLOPE** of the *v vs.t* graph at that point.
The **SLOPE** of the *v vs. t* graph at a specific point is equal to the **VALUE** of the *a vs. t* graph at that point.

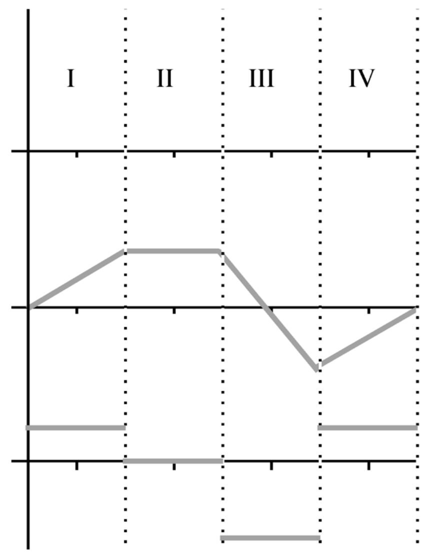
PhyzExample: Kinematics Graphing

Given a *v vs.t* graph as shown (which shows a particle accelerating from rest for two seconds; then maintaining a constant velocity for two seconds; then accelerating at a greater rate in the negative direction for two seconds, then accelerating in the positive direction for two seconds) graph the *a vs.t* and *x vs.t* graphs.



Here's the graph as given.
Our task is to derive the acceleration and position graphs.

I've chosen to attack the *a vs.t* graph first.
First break up the graph into easily identifiable segments.

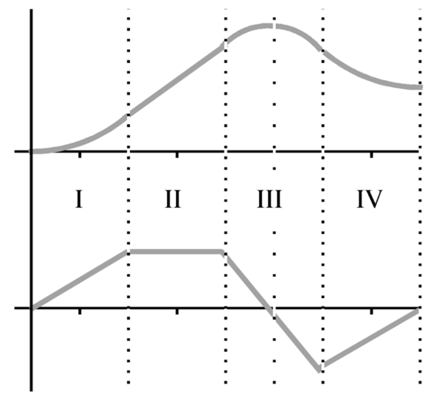


I - *v vs.t* has a positive SLOPE, so *a vs.t* has a positive VALUE.

II - *v vs.t* has a zero SLOPE, so *a vs.t* has zero VALUE.

III - *v vs.t* has a steep negative SLOPE, so *a vs.t* has a big negative VALUE.

IV - *v vs.t* has a positive SLOPE, so *a vs.t* has a positive VALUE.



I - *v vs.t* has an increasing positive VALUE so *x vs.t* has an increasing positive SLOPE.

II - *v vs.t* has a single positive VALUE so
x vs.t has a single positive SLOPE.

III - *v vs.t* has a decreasing VALUE, so *x vs.t* has a decreasing SLOPE, which starts out positive and becomes negative, passing through zero where the value of *v* = 0.

IV - *v vs.t* has a negative but increasing VALUE, so *x vs.t* has a negative but increasing SLOPE.

