General announcements

- Your **lab write-up** is due soon . . .

- Need help on the lab or the homework/XtraWrk?
  - Extra help, A, D, E, F

- Clarifications/reminders!
  - "blurb" means brief descriptions of what you're doing in each part. WE have blurbed questions 1, 2, and 3 for you on the template – YOU have to blurb parts a-e for questions 4 and 5.
  - The "write-up" is your cover sheet + answers to any analysis/calculation questions + graphs of data. Basically the template + your two graphs stapled to the back.
  - Remember to mark clearly on your graphs the two points you used for your calculations!

- About that homework . . . (look at example of "good" work)

Announcements (con't.)

- First test is **Wednesday, 9/6** – will cover graphs of motion and 1D kinematics
  - We've covered graphs: how to use slope, x/y values, shape of graph to determine changing position, rate of velocity, acceleration, etc. (e.g. Figure 2.24 - today)
  - See class Website – class pdfs→1D Kinematics for resources (e.g. multiple choice questions, more practice problems) plus your textbook and the XtraWrk
  - Expect: 4-5 multiple choice, a page of graph analysis and 2-4 kinematic problems that will require ALL 3 equations (know them!)
  - Come talk to me today or tomorrow if you receive extra time

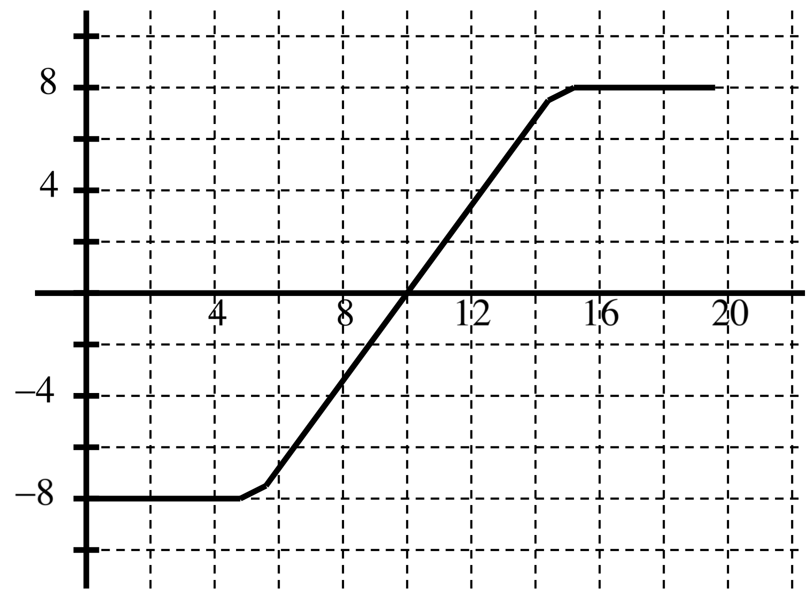
Figure 2.24 on p51

- What does this graph represent if it is a:

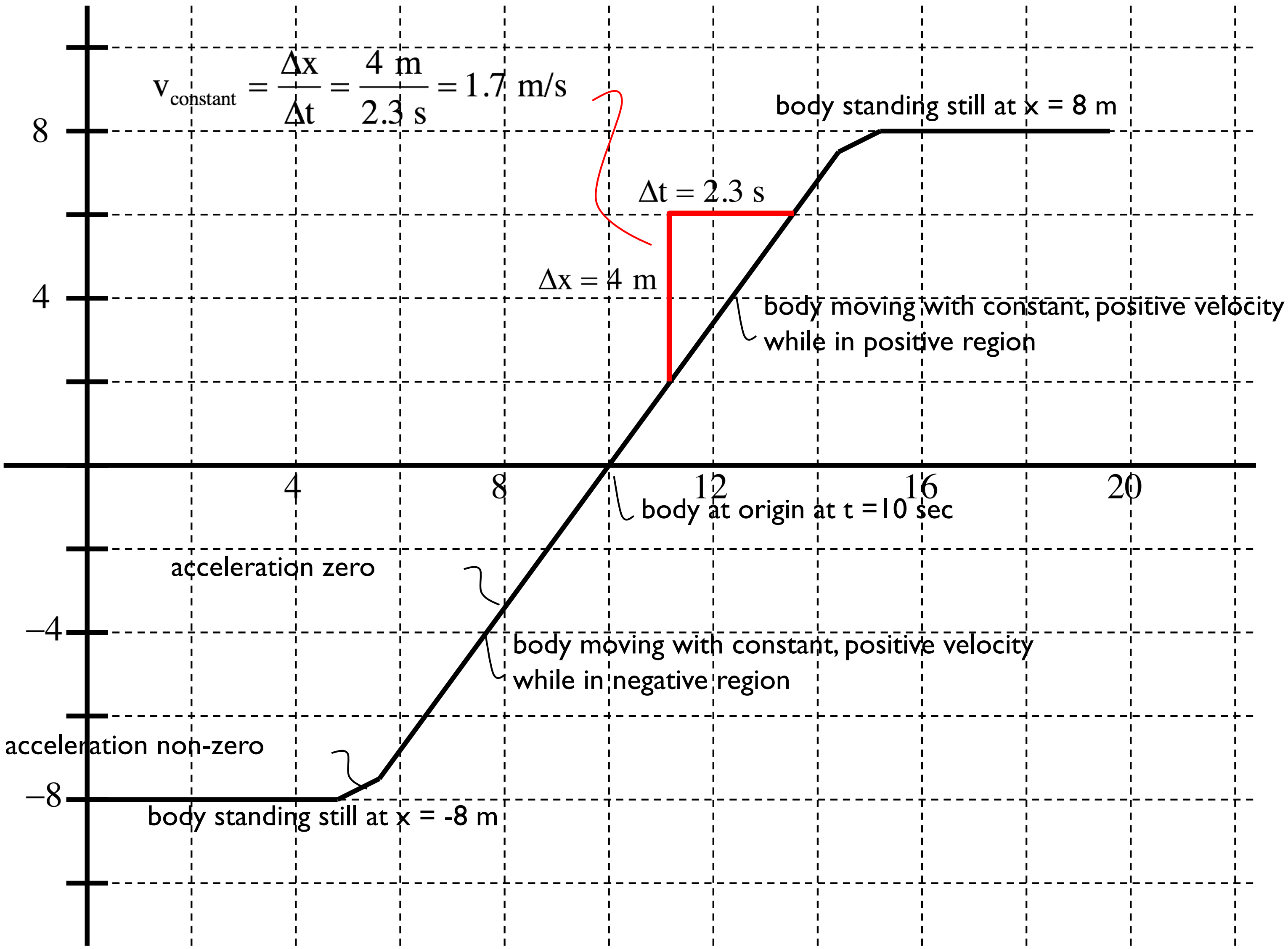
- Position vs. time graph?

- Velocity vs. time graph?

- Acceleration vs. time graph?



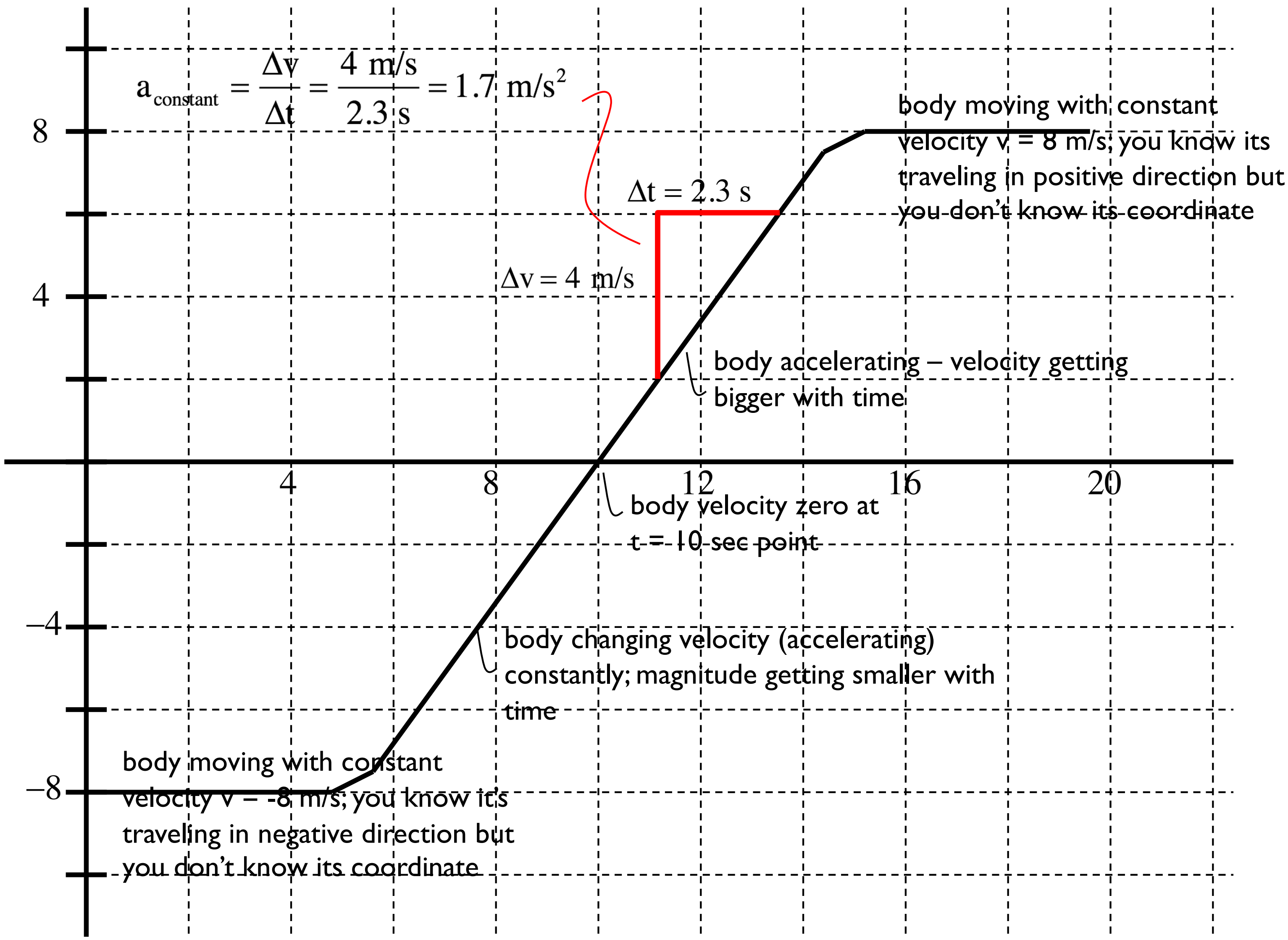
1.) As *position versus time* graph:



2.)

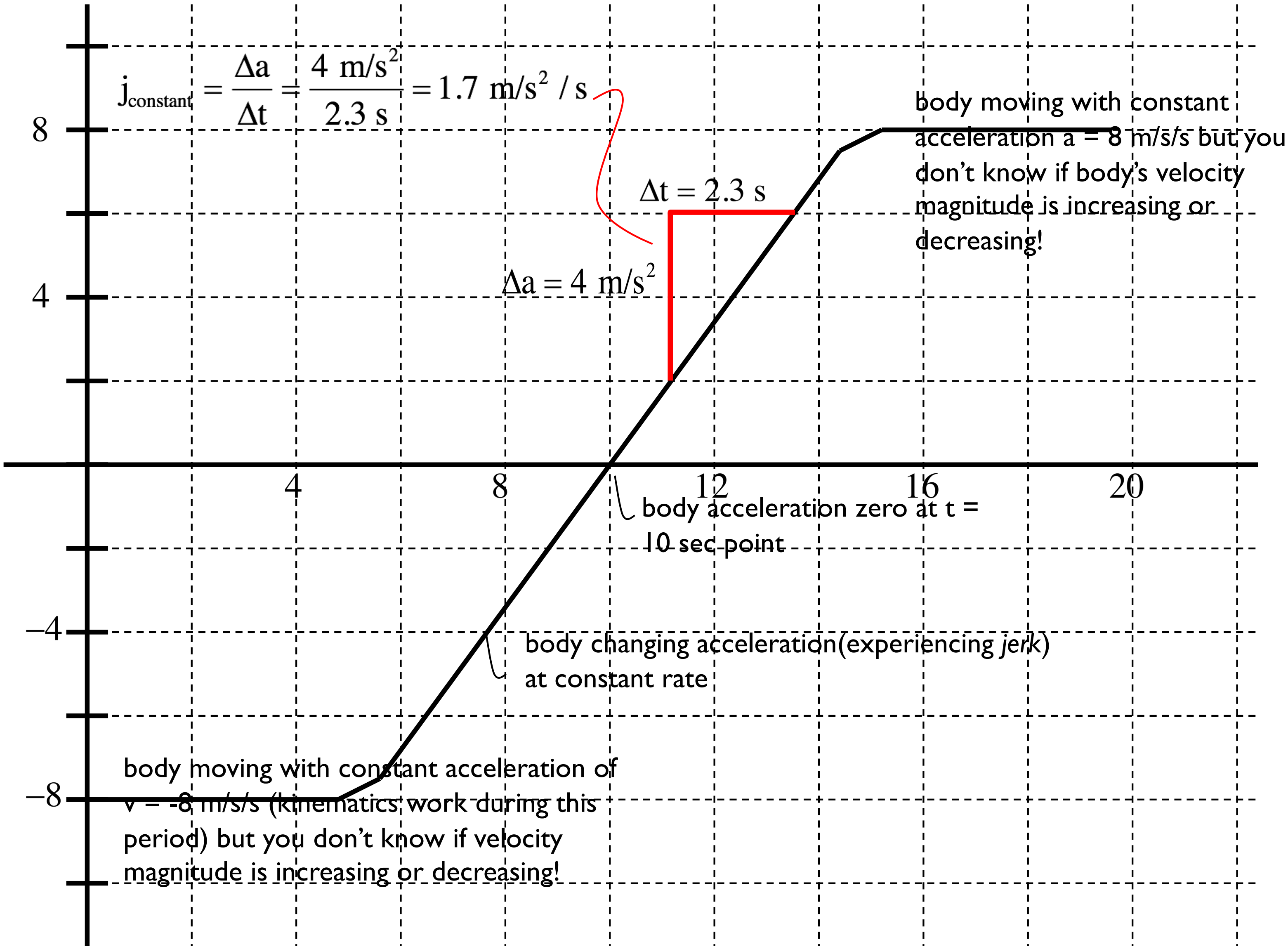
4.)

1.) As *velocity versus time* graph:



3.)

1.) As *acceleration versus time* graph:



4.)

6.)

Sign conventions

- The sign of a vector quantity indicates its **direction**.
- This requires that you clearly indicate your coordinate axes!
- What does it mean to have:
  - A positive velocity but negative position?

    Moving in + direction, on – side of origin
  - Negative displacement and a positive position?

On the + side of origin moving in the - direction

  - A positive velocity and positive acceleration?

    Moving in the + direction and speeding up
  - Negative velocity but positive acceleration?

    Moving in the – direction and slowing down

When v and a have same sign, object speeds up

When v and a have opposite signs, object slows down

Using kinematic equations

- 3 main kinematic equations:

$$v_2 = v_1 + a(\Delta t)$$

$$x_2 = x_1 + v_1(\Delta t) + \frac{1}{2}a(\Delta t)^2$$

$$(v_2)^2 = (v_1)^2 + 2a(x_2 - x_1)$$

- What assumption did we make in order to get these equations?
  - Constant acceleration
  - These equations work for linear motion (1-d) and for 2-d motion (requires a little more set-up but we'll get there)

- Remember to use proper sign conventions!

Reminders about kinematic equations

- We are assuming **uniformly (constant) accelerated motion**
  - For now, that means magnitude and direction are constant
  - Later, we'll talk about changing direction with constant magnitude

  - Subscripts 1 and 2 indicate values at two points in time
  - **x** is position (Δx means displacement, or change in position)
  - **v** is velocity (so v_2 is velocity at time 2, etc)
  - **a** is acceleration (assumed to be constant)

How to solve problems with kinematic equations--
First--the quick and perilous way

- Read the problem. Twice.
- Pick the equation(s) you need based on what you know and what you want.
- Plug in numbers and check your units and signs.
- **Show all of your work.**

Example #2 - sea anemone

- 1.) The stinger covering sea anemone tentacles accelerates from zero to 80 mph (approx. 40 m/s) in 700 nanoseconds. What is the acceleration?

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{(40\ \text{m/s}) - 0}{(700 \text{x} 10^{-9}\ \text{s})}$$

$$= 57 \text{x} 10^{6}\ \text{m/s}^2$$

How to solve problems with kinematic equations--
Second--the Safe Way

- Read the problem. Twice.
- Draw a picture and indicate your frame of reference, including where your axes are and which way is +.
- Write down all the known quantities (with their units) and the unknown quantity you are solving for. A chart is really helpful here (like the lab). Circle the unknowns.
- Do any necessary unit conversions now.
- Pick the equation(s) you need based on what you know and what you want.
- Plug in numbers and check your units and signs.
- **Show all of your work.**

Example #2 – sea anemone

- The stinger covering sea anemone tentacles accelerates from zero to 80 mph (approx. 40 m/s) in 700 nanoseconds. What is the acceleration?

In this case, you don't really need a picture. I wouldn't hurt to identify the parameters, though, so:

$$v_1 = 0$$
$$v_2 = 40.0 \text{ m/s}$$
$$t = 700 \text{ ns} = 7\text{x}10^{-7}\text{s}$$
$$a = ?$$

The kinematic equation that does the job for us is:

$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{(40 \text{ m/s}) - 0}{(700\text{x}10^{-9}\text{s})}$$
$$= 57\text{x}10^{6} \text{ m/s}^2$$

Example #3 – funny car

- 2.) In 2007, it took 4.77 seconds for a funny car to cover a quarter of a mile (approximately 400 meters) with a top end of 317 mph (approximately 160 m/s).

  a.) Assume the acceleration is constant and without using the elapsed time, determine the car's acceleration.

  b.) Assume acceleration was constant and determine it using a second approach.

  c.) Why the discrepancy?

3.) In 2007, it took 4.77 seconds for a funny car to cover a quarter of a mile (approximately 400 meters) with a top end of 317 mph (approximately 160 m/s).

a.) Assume the acceleration is constant and without using the elapsed time, determine the car's acceleration.

$$v_2^{\,2} = v_1^{\,2} + 2a\left(x_2 - x_1\right)$$

$$\Rightarrow \ a = \frac{v_2^{\,2} - v_1^{\,2}}{2\left(x_2 - x_1\right)}$$

$$\Rightarrow \quad = \frac{(160 \text{ m/s})^2 - (0)^2}{2\left(400 \text{ m} - 0\right)}$$

$$= 32 \text{ m/s}^2$$

b.) Assume acceleration was constant and determine it using a second approach.

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{(160 \text{ m/s}) - 0}{(4.77 \text{ s})}$$

$$= 33.5 \text{ m/s}^2$$

c.) Why the discrepancy?

Acceleration was not constant in real life.

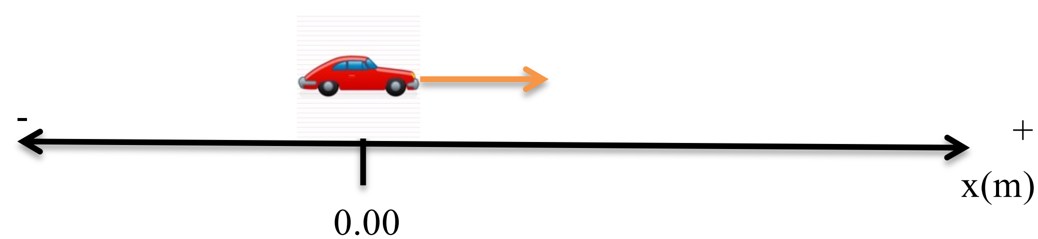
4.)

How to solve problems with kinematic equations—Two ways—The safe way

- Read the problem. Twice.
- Draw a picture and indicate your frame of reference, including where your axes are and which way is +.
- Write down all the known quantities (with their units) and the unknown quantity you are solving for. A chart is really helpful here (like the lab). Circle the unknowns.
- Do any necessary unit conversions now.
- Pick the equation(s) you need based on what you know and what you want.
- Plug in numbers and check your units and signs.
- **Show all of your work.**

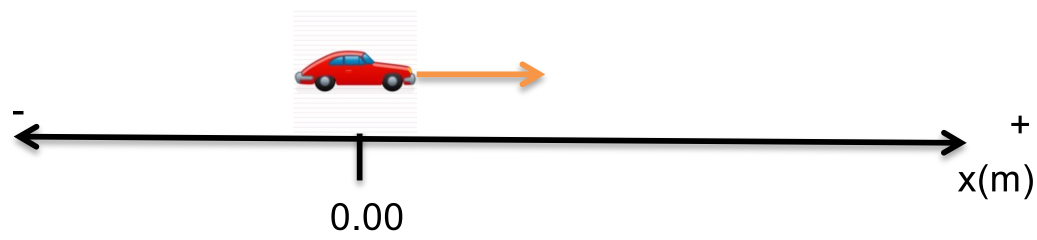
Example #1 – car

- A car starts from rest and accelerates at 4.0 m/s^2 for 15 s. How far has the car traveled in 15 s and what is its velocity at that time? (Do this "the safe way," which means you start with a sketch.)



example #1 - The safe way

- A car starts from rest and accelerates at 4.0 m/s^2 for 15 s. How far has the car traveled in 15 s and what is its velocity at that time?



$x_o = 0.00 m$

$x = ?$

$v_o = 0.00 m/s$

$v = ?$

$a = 4.0 m/s^2$

$t = 15 s$

$$x = x_o + v_o t + \frac{1}{2} a t^2$$

$$x = 0.00 + 0.00(15) + \frac{1}{2}(4)(15^2)$$

$$x = 450 m$$

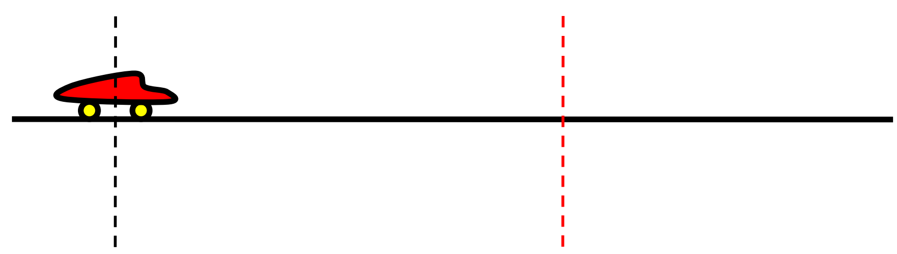
$$v = v_o + at$$

$$v = 0.00 + 4(15)$$

$$v = 60 m/s$$

Back to the car…

- Assume a hotrod accelerates from rest at a rate of 32 m/s/s.
  - A) Where is it, relative to its starting position, after 2 sec?
  - B) How fast is it going after 2 seconds?

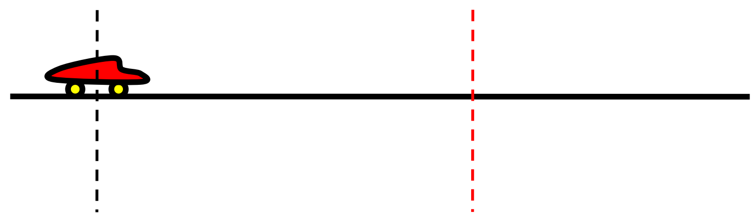


$v_1 = 0$	$v_2 = ?$
$x_1 = 0$	$x_2 = ?$
$a = 32\ m/s^2$	$a = 32\ m/s^2$
$t_1 = 0$ sec	$t_2 = 2$ seconds

3.) Assume the hotrod accelerates from rest at a rate of 32 m/s/s.

a.) Where is it, relative to the start position, after 2 seconds?

$$x_2 = \cancel{x_1}^{\,0} + \cancel{v_1}^{\,0}\Delta t + \frac{1}{2}a(\Delta t)^2$$
$$= \frac{1}{2}\left(32\ \text{m/s}^2\right)\left(2\ \text{s}\right)^2$$
$$= 64\ \text{m}$$



$v_1 = 0$ | $v_2 = ?$

$x_1 = 0$ | $x_2 = ?$

$a = 32\ \text{m/s}^2$ | $a = 32\ \text{m/s}^2$

$t_1 = 0\ \text{sec}$ | $t_2 = 2\ \text{seconds}$

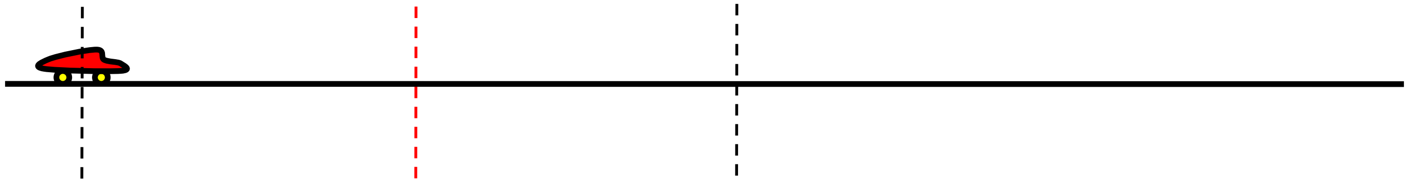
b.) How fast is it going after 2 seconds?

$$v_2 = v_1 + a(\Delta t)$$
$$= \left(32\ \text{m}/\text{s}\right)(2\ \text{s})$$
$$= 64\ \text{m}/\text{s}$$

or

$$v_2^{\,2} = v_1^{\,2} + 2a\left(x_2 - x_1\right)$$
$$= \left(0\ \text{m/s}\right)^2 + 2\left(32\ \text{m/s}^2\right)\left(64\ \text{m} - 0\right)$$
$$= 64\ \text{m/s}$$

Back to the car...



$v_1 = 0$	$v_2 = 64 \text{ m/s}$	$v_3 = ?$
$x_1 = 0$	$x_2 = 64 \text{ m}$	$x_3 = ?$
$a = 32 \text{ m/s}^2$	$a = 32 \text{ m/s}^2$	$a = 32 \text{ m/s}^2$
$t_1 = 0 \text{ sec}$	$t_2 = 2 \text{ seconds}$	$t_3 = 3 \text{ seconds}$

- c.) The hotrod travels another second passed the 2 second point. How fast is it traveling then?

$$a = \frac{v_3 - v_2}{\Delta t}$$

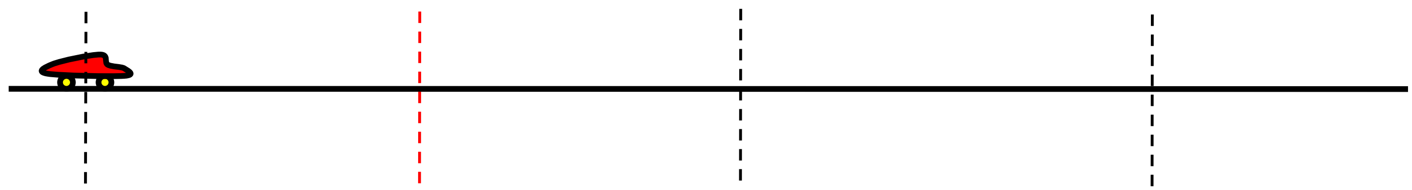
$$\Rightarrow \ v_3 = v_2 + a\Delta t$$

$$\Rightarrow \ v_3 = (64 \text{ m/s}) + (32 \text{ m/s}^2)(1 \text{ s})$$

$$= 96 \text{ m/s}$$

Back to the Car...

- d.) The hotrod travels 100 meters passed its position at the 2 second point. How fast is it going?



$v_1 = 0$	$v_2 = 64\text{ m/s}$	$v_3 = 96\text{ m/s}$	$v_4 = ?$
$x_1 = 0$	$x_2 = 64\text{ m}$	$x_3 = ?$	$x_4 = x_2 + (100\text{ m}) = 164\text{ m}$
$a = 32\text{ m/s}^2$	$a = 32\text{ m/s}^2$	$a = 32\text{ m/s}^2$	$a = 32\text{ m/s}^2$
$t_1 = 0\text{ sec}$	$t_2 = 2\text{ seconds}$	$t_3 = 3\text{ seconds}$	$t_4 = ?$

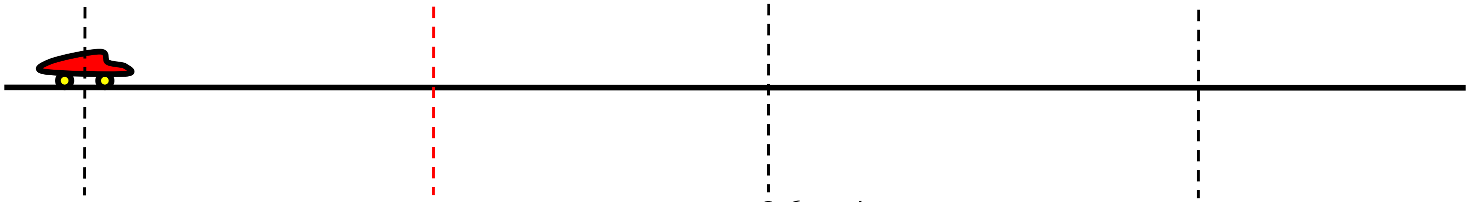
$$v_4^2 = v_2^2 + 2a\Delta x$$

$$= (64\text{ m/s})^2 + 2(32\text{ m/s}^2)[(164\text{ m}) - (64\text{ m})]$$

$$\Rightarrow \quad v_4 = 102\text{ m/s}$$

Back to the car...

- e.) How long did it take to get to the 100 meter mark passed the t = 2 second point?



$v_1 = 0$
$x_1 = 0$
$a = 32\ \text{m/s}^2$
$t_1 = 0\ \text{sec}$

$v_2 = 64\ \text{m/s}$
$x_2 = 64\ \text{m}$
$a = 32\ \text{m/s}^2$
$t_2 = 2\ \text{seconds}$

$v_3 = 96\ \text{m/s}$
$x_3 = ?$
$a = 32\ \text{m/s}^2$
$t_3 = 3\ \text{seconds}$

$v_4 = 102\ \text{m/s}$
$x_4 = x_2 + (100\ \text{m}) = 164\ \text{m}$
$a = 32\ \text{m/s}^2$
$t_4 = ?$

$$a = \frac{v_4 - v_2}{\Delta t}$$

$$\Rightarrow \Delta t = \frac{v_4 - v_2}{a}$$

$$\Rightarrow \Delta t = \frac{(102\ \text{m/s}) - (64\ \text{m/s})}{(32\ \text{m/s}^2)}$$

$$= 1.19\ \text{seconds}$$

How to tackle complex problems

- Sometimes you'll end up with two objects, multiple equations, and multiple unknowns, or just multi-stage problems that take some thinking. It's good to know how to set up and solve these types of equations.

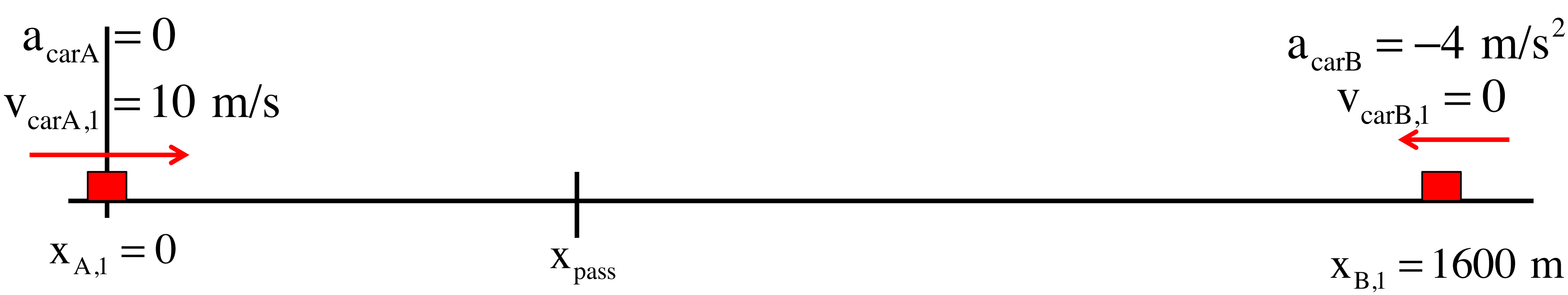
- This is where **drawing a picture**, **indicating your axes**, and **keeping consistent signs** is critical!

Two Car problem: the set-Up

- The Question: Two cars traveling in opposite directions start out 1600 meters apart. Car A moves with constant velocity 10 m/s. Car B starts from rest and accelerates toward Car A picking up speed at a rate of 4 m/s/s.
  - a.) Relative to where Car A started, where do they pass?
  - b.) How long did it take for them to pass?
  - c.) How fast is Car B moving when they pass?

Two car problem: the set-up

- 1. Sketch the set-up and put a coordinate axes on the sketch.
  - Indicate the known and unknown values for both cars on the sketch.
  - Note that car B's acceleration is <u>negative</u> so $a_{carB} = -4 \text{ m/s}^2$
  - Note that each car will take the same amount of time to reach the "pass point"



The Two car problem: parts a+b

- 2. We're looking for displacement of car A, essentially, so we need an equation for car A:

$$x_2 = x_1 + v_1\Delta t + \frac{1}{2}a(\Delta t)^2$$

$$\Rightarrow \quad x_{pass} = x_{A,1} + v_{A,1}\Delta t + \frac{1}{2}a_A(\Delta t)^2$$

$$\Rightarrow \quad x_{pass} = 10t$$

- We also need an equation for car B:

$$x_2 = x_1 + v_1\Delta t + \frac{1}{2}a(\Delta t)^2$$

$$\Rightarrow \quad x_{pass} = x_{B,1} + v_{B,1}\Delta t + \frac{1}{2}a_B(\Delta t)^2$$

$$\Rightarrow \quad x_{pass} = (1600) + \frac{1}{2}(-4)t^2$$

The two-car problem: parts a+b

3. Now we combine the equations to solve simultaneously:

$$x_{pass} = 10t \qquad \text{(from Car A)}$$

$$x_{pass} = (1600) + \frac{1}{2}(-4)t^2 \qquad \text{(from Car B)}$$

Equating:

$$10t = (1600) + \frac{1}{2}(-4)t^2$$

$$\Rightarrow \quad t = 25.8 \text{ sec}$$

Now, find how far A travels in that time:

$$\Rightarrow \quad x_{pass} = 10t$$

$$= (10 \text{ m/s})(25.8 \text{ sec})$$

$$= 258 \text{ m}$$

The two-car problem: part C

c) how fast is car B moving when they pass?

We now know the time in which they travel, so for car B:

$$\begin{aligned} v_{B,pass} &= v_{B,1} + a_B(\Delta t) \\ &= \left(-4 \text{ m/s}^2\right)(25.8 \text{ sec}) \\ &= -103.2 \text{ m/s} \end{aligned}$$

OR

$$\begin{aligned} \left(v_{B,pass}\right)^2 &= \left(v_{B,1}\right)^2 + 2a_B\left(x_{B,pass} - x_{B,1}\right) \\ &= 2\left(-4 \text{ m/s}^2\right)\left[(258 \text{ m}) - (1600 \text{ m})\right] \\ &= \pm 103.6 \text{ m/s} \end{aligned}$$

and you have to put the sign in manually . . .

Why all these steps?

- The "two-car" problem is a great example for why you should be methodical in your solutions and follow all these steps.
  - You are less like to make a silly mistake or get lost.
  - Your reader is less likely to be confused or be unable to follow your work.
  - Both result in more likely correct answers (and points)

- *Bottom line:* even on simple problems, practice all steps of this technique, because when things get nasty, it's the thing that allows you to make progress even when feeling confused!