Putting Things in Motion

Auburn Mountainview: Physics

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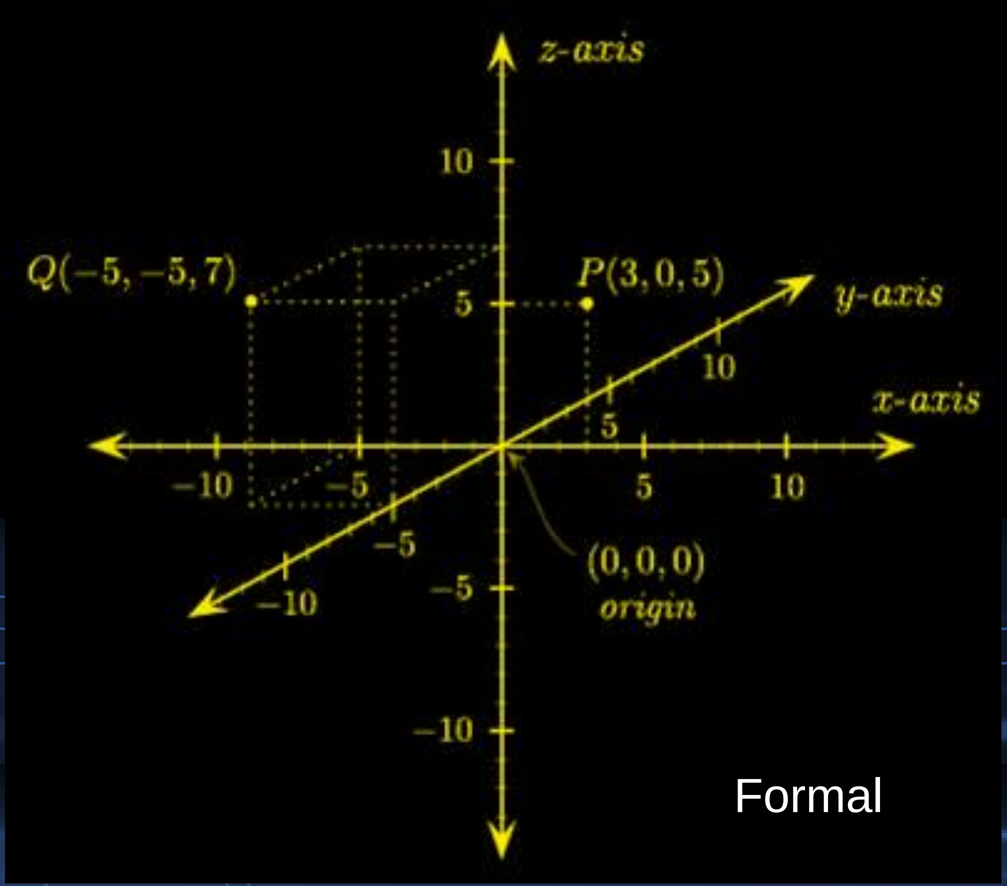
Motion

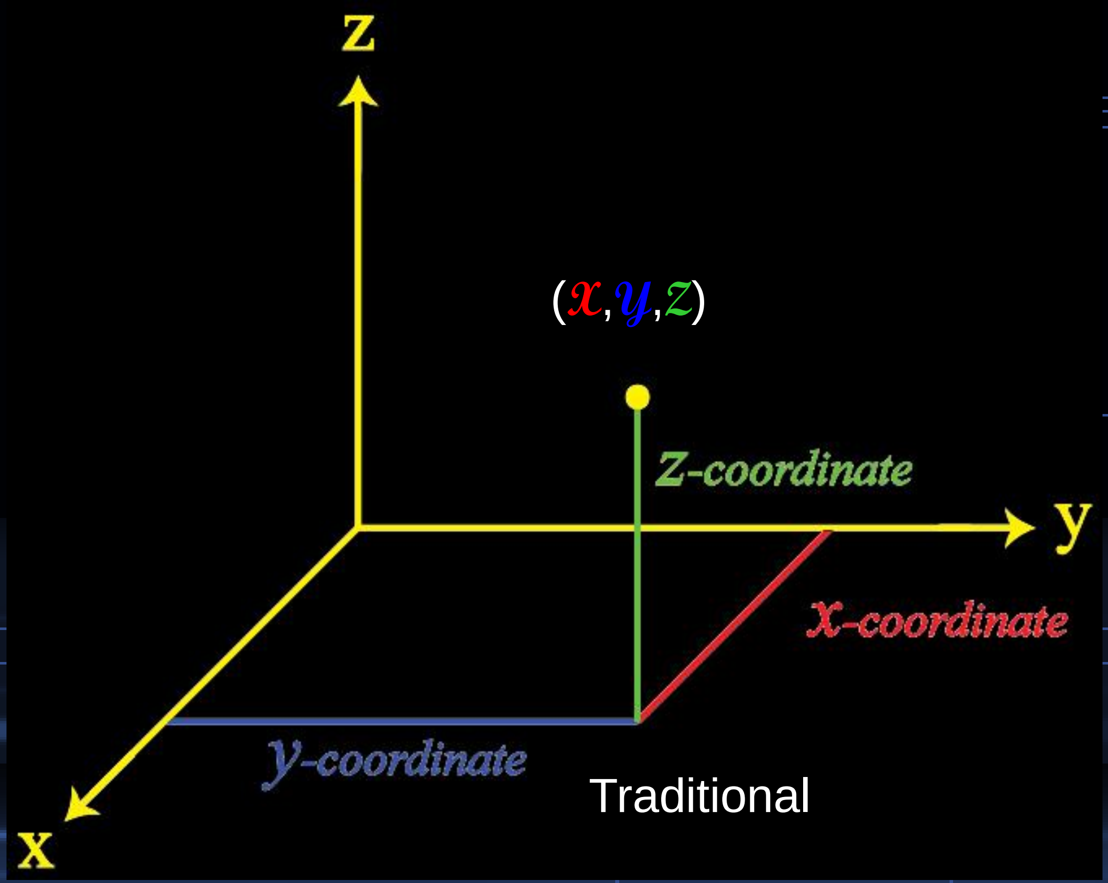
- **Motion:** A continuous change in the position of an object relative to a reference point, as measured by a particular observer in a particular frame of reference.
  - **Observer:** Any person/device that receives information about an object.
  - **Frame of Reference:** The perspective from which an object or system is observed.

Frame of Reference

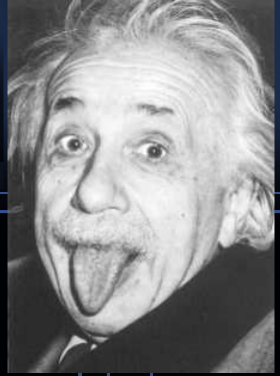
- A coordinate system (Cartesian in this class) is used to track and reference motion.



Formal

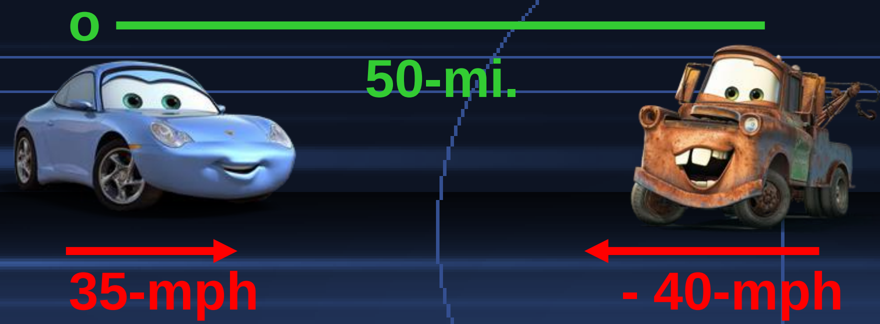


Traditional



Relativity

- Normally people think of Einstein, but the first theory of relativity came from Galileo.
  - Sitting in your desk it may seem you are at rest (not moving)…
    - What about the movement of the Earth? (Astronomy)
    - What about your blood? (Biology)
    - What about atomic movement? (Chemistry)
- Don't stress: Pick a reference point and don't change it.



The A and Ω

- All things have a beginning and all things come to an end.
- The beginning of a situation (origin) is defined by using "$_o$" called naught
- Much of physics uses the same variable at two points, using subscripts helps to keep track of each event and variable.
  - a_o, a_f, p_1, p_2, F_{NET}.
- "Δ" Delta means change, or the difference.
  - $\Delta p = p_f - p_o$

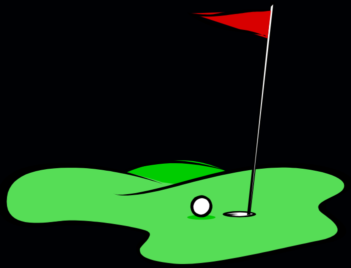
The Origin

- It is important to set an origin and stay with it.

$\Delta d = d_f - d_o = 150 - 0 = 150$-yds.

$x_o = 0$-m

$x = 150$-m



$\Delta d = d_f - d_o = 0 - (-150) = 150$-yds.

$x = -150$-m

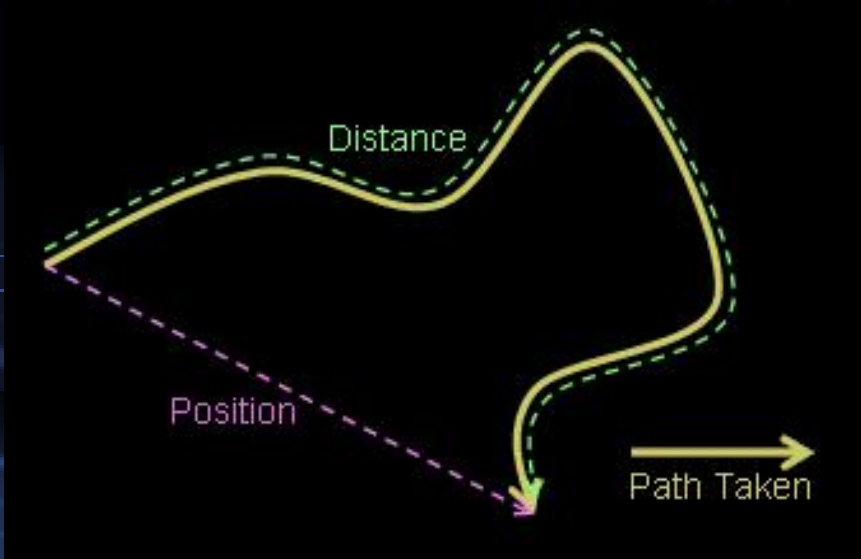
$x_o = 0$-m

- + or - ? It's all a matter of perspective.

Motion Basics

- **Distance (d):** The total length of the path an object takes from one point to another. ([s] SI: meters, m)
- **Position (p):** The displacement of an object from one point to another. ([v] SI: meters, m)
- **Time (t):** The interval between two events.

  ([s] SI: seconds, s).



Motion

- Motion is normally referenced against time.
  - Seconds are most common. ms: 10^{-3}-s, hr: 3600-s
  - Position intervals such as p_1, p_2 or d_1, d_2 …
- There are four main ways to account for motion, all can be used together.

Strobe diagrams

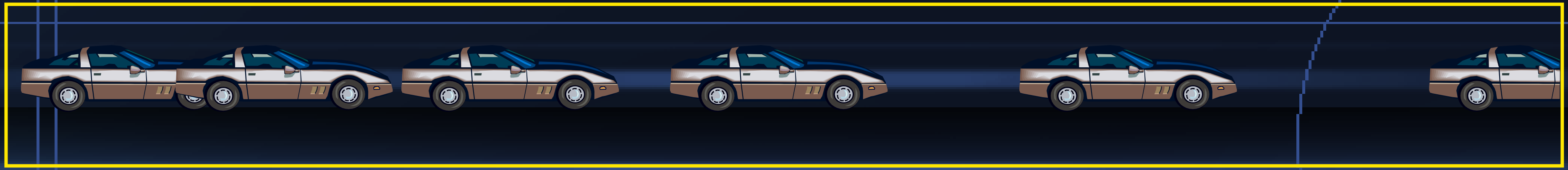
Tables

Graphs

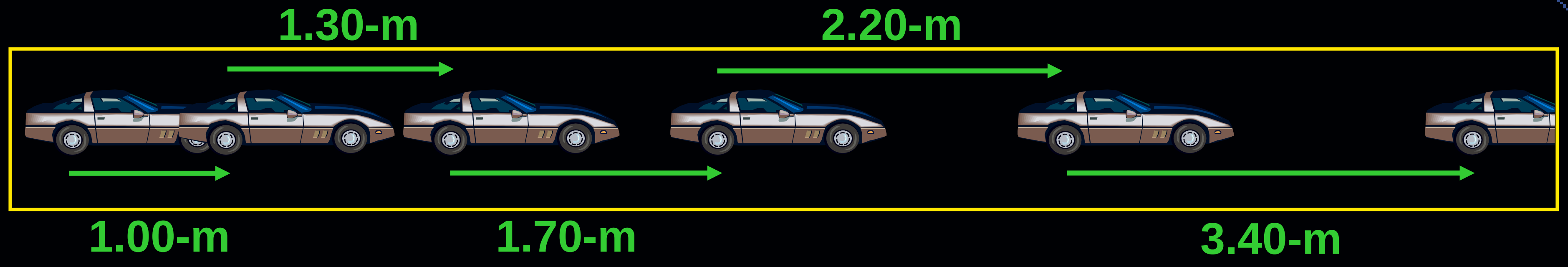
Formulas

Motion Diagrams

- Motion/Strobe Diagrams track a series of images over a set time interval.
- This can be done using a camera with a delay or a strobe light.
- Here is a car leaving an intersection.
- Pictures were taken at 1.00-s intervals.



Motion Diagram



- By measuring the distance (from the same reference point each time) movement can be measured.
- Each second the vehicles distance from the origin is increasing.
  - After… 0-s: 0.00-m 1-s: 1.00-m 2-s: 2.30-m
    3-s: 4.00-m 4-s: 6.20-m 5-s: 9.60-m

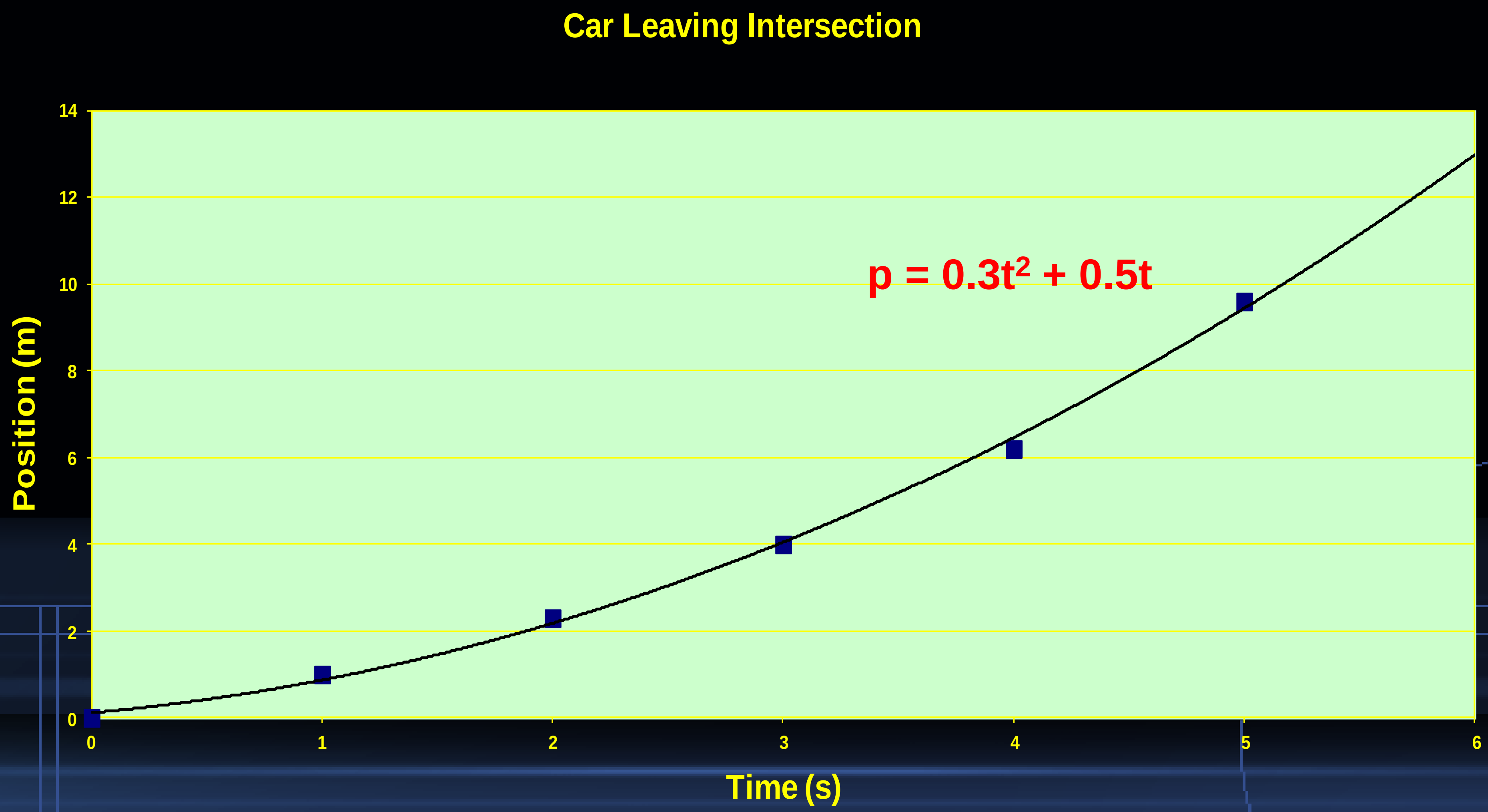
Making a Table

- The previous information was interpreted but is not presented well.
- Making a table can help clean it up.

Car Leaving Intersection		
t (s)	Δp (m)	Σp (m)
0.0		0.0
	1.0	
1.0		1.0
	1.3	
2.0		2.3
	1.7	
3.0		4.0
	2.2	
4.0		6.2
	3.4	
5.0		9.6

Making a Graph

- Graphs can help determine a mathematical relationship.



Velocity

- **Velocity (v): The change in position an object travels per given time.**
  - More common than speed.
  - Direction is important!!!
  - Normally an average velocity given.

$$\overline{v} = \frac{\Delta p}{\Delta t}$$ [v] SI derived unit: m/s

  - A bar over a letter means average: $\overline{v} = \dfrac{v_1 + v_2}{2}$

Adding On

The previous table with velocity added.

Car Leaving Intersection				
t (s)	Δp (m)	Σp (m)	$\bar{v}$ (m/s)	v (m/s)
0.0		0.0		0
	1.0		1.0	
1.0		1.0		2.0
	1.3		1.3	
2.0		2.3		2.6
	1.7		1.7	
3.0		4.0		3.4
	2.2		2.2	
4.0		6.2		4.4
	3.4		3.4	
5.0		9.6		6.8

Motion Example 1

- How far does a jogger run in 1.50 hours (5400.00-s) if her average speed is 2.22-m/s?

$$\bar{v} = \frac{\Delta p}{\Delta t}$$

$$2.22 - \frac{m}{s} = \frac{\Delta p}{5400 - s}$$

$$2.22 \cdot 5400 - m = \Delta p$$

$$\Delta p = 11,988 - m$$

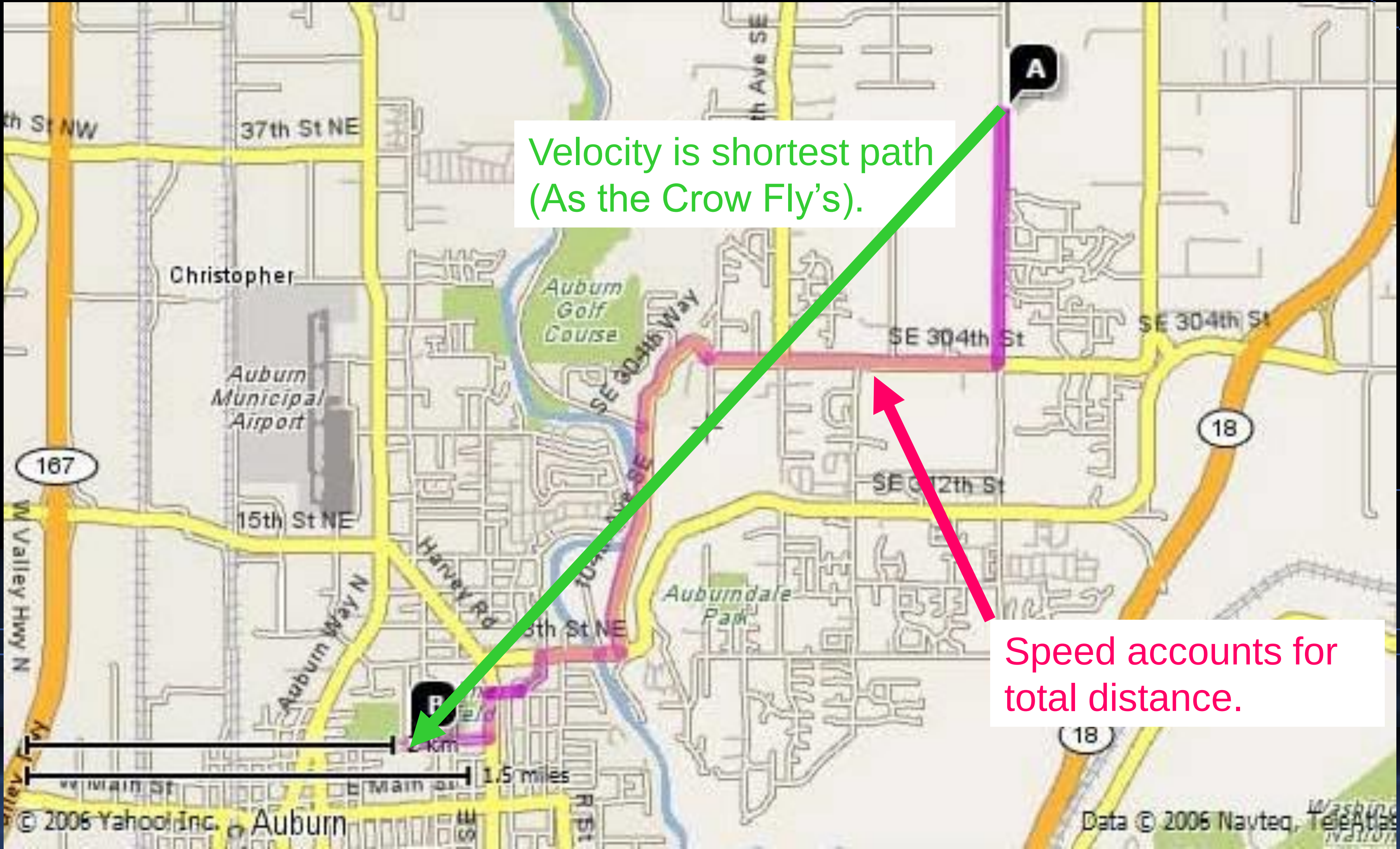
$\bar{v}$ = 2.22-m/s

p = x

t = 5400-s

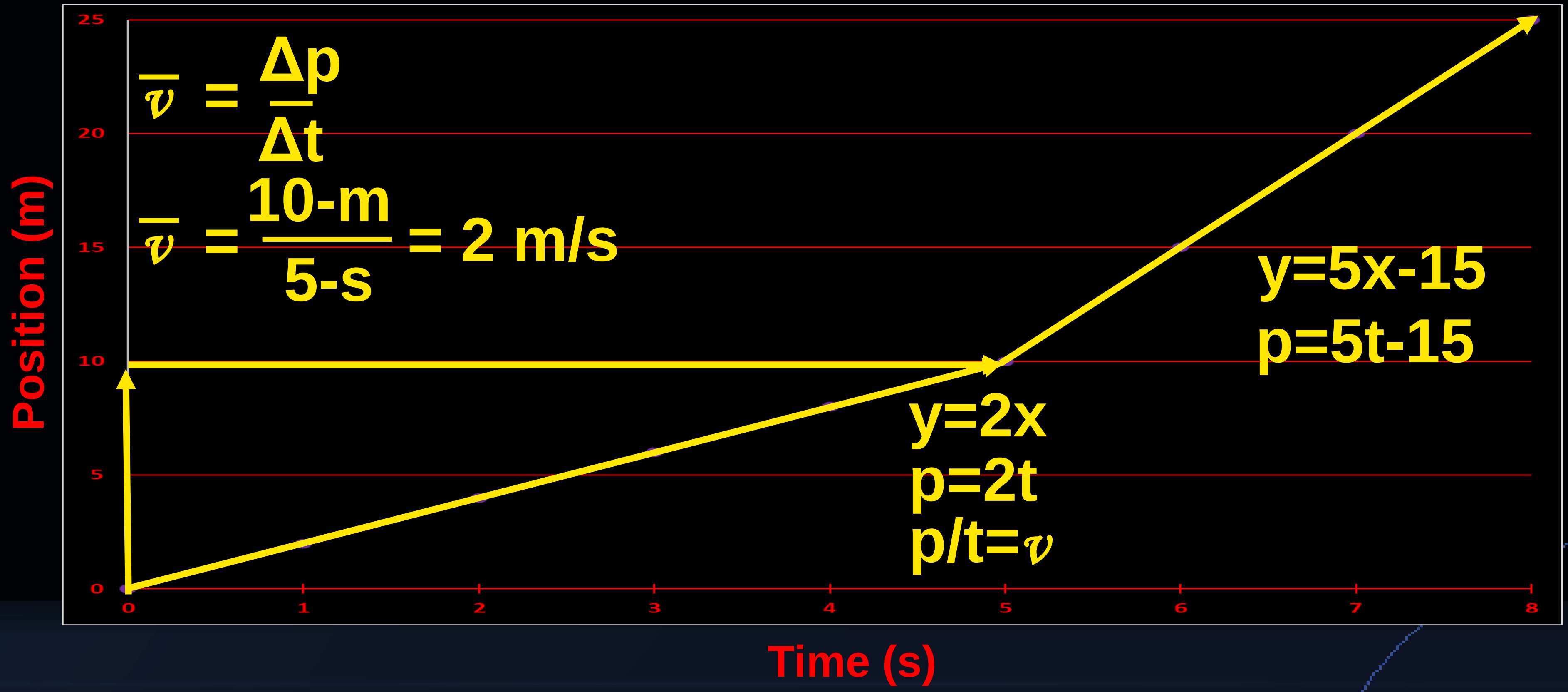
$$\boxed{\Delta p = 1.20x10^4 - m}$$

Speed versus Velocity



Graphical Approach

I-5 Traffic Jam



- A position vs. time graph can find velocity.
- If the equation for the line what is known what is the slope?

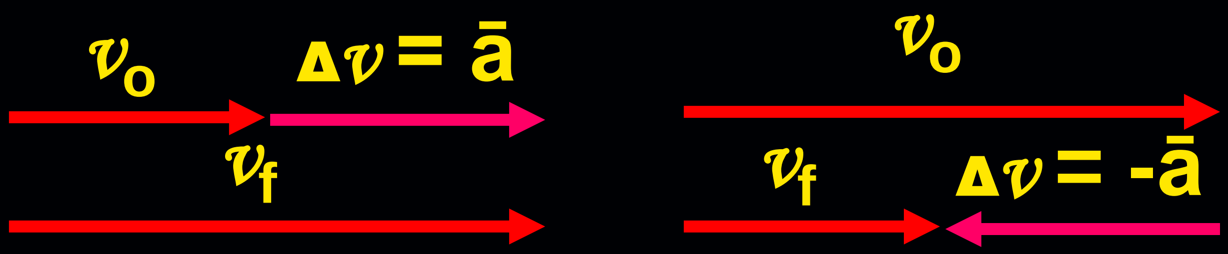
Acceleration

- **Acceleration (a):** The change in velocity an object travels per given time.
  - Direction is still important!!!
  - Normally average acceleration is used so the bar is not needed.

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

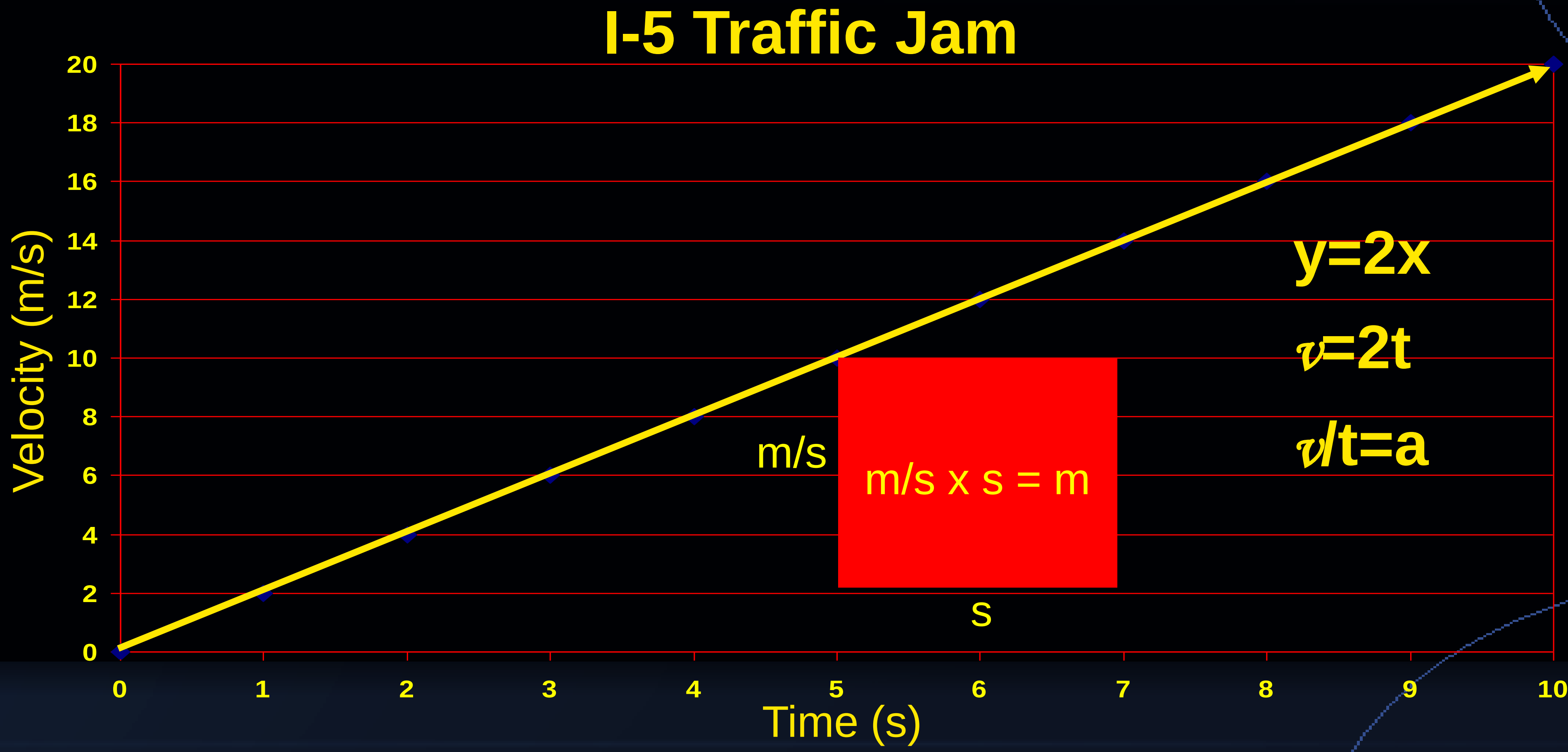
[v] SI derived unit: m/s^2

Acceleration v. Velocity



- If the velocity stays the same (constant) then there is 0 acceleration.
- NOTE: Even with ‘0’ acceleration the object may still be moving.

Graphical Approach Cont



- The slope of a v vs. t graph gives the acceleration.
- The area under the graph is the distance traveled.

Comparative Calculus

Derivation

p = x

$\overline{v}$ = Δp / Δt

a = Δv/ Δt

jerk = Δa / Δt

snap = Δj / Δt

crackle = Δs / Δt

pop = Δc / Δt

Integration

a = x

$\overline{v}$ = ∫ a *dt*

p = ∫ v *dt*

Helpful Formulas

- These equations can be derived from the basic formulas seen so far:

$v_f = v_o + at$ $\bar{v} = .5(v_o + v_f)$ $\Delta p = .5(v_o + v_f)t$

Useful for dropped objects: $\Delta p = v_o t + .5at^2$

When time is not given: $v_f^2 = v_o^2 + 2a\Delta p$

Pay close attention which v is being used: Δv, $\bar{v}$, v_f and v_o can/are all different.

$\bar{v}$

Helpful Table

- Motion is used in almost every chapter this year:

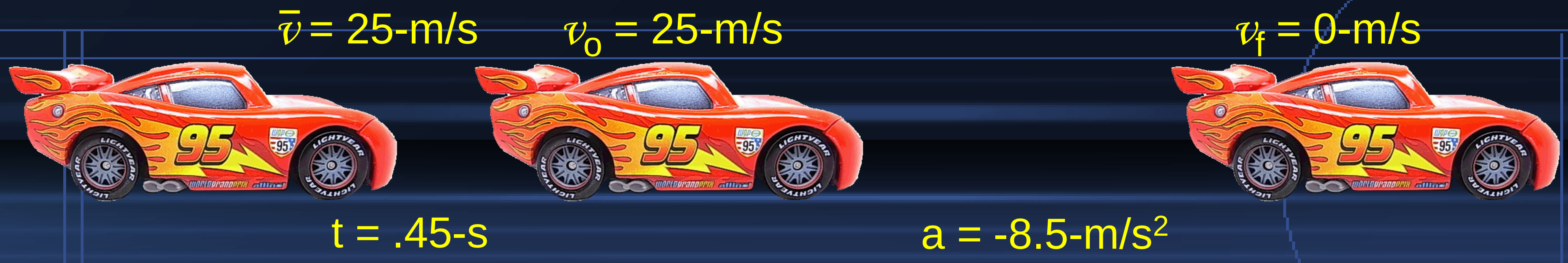
Formula	Δp (m)	v_o (m/s)	v_f (m/s)	$\bar{v}$ (m/s)	Δv (m/s)	a (m/s^2)	Δt (s)
$\Delta x = x_f - x_o$							
$a = \Delta v/\Delta t$					✓	✓	✓
$\bar{v} = \Delta p/\Delta t$	✓			✓			✓
$p = .5(v_o + v_f)t$	✓	✓	✓				✓
$p = v_o t + .5at^2$	✓	✓				✓	✓
$v_f = v_o + at$		✓	✓			✓	✓
$v_f^2 = v_o^2 + 2ap$	✓	✓	✓			✓	
$\bar{v} = .5(v_o + v_f)$		✓	✓	✓			

Put your finger on the unknown variable and move down to a check mark.

Use the equation that has known numbers for all the other check marks.

Motion Example 2

- A car traveling 25.00-m/s sees a child run into the road after a ball. It takes the driver .45-s to react and hit the brakes. Then the car slows with a constant acceleration of -8.50-m/s^2. What is the total distance covered by the car before coming to a complete stop?



ME2: cont

This problem should be broken into two parts: ‘Reaction’ and then ‘Braking’. During reaction the v is constant.

$$\bar{v} = \frac{\Delta p_R}{\Delta t}$$

$$25 - \frac{m}{s} = \frac{\Delta p_R}{.45 - s}$$

$$25 \cdot .45 - m = \Delta p_R$$

$$\Delta p_R = 11.25 - m$$

$\bar{v}$ = 25-m/s

p_R = x

t = .45-s

ME2: cont

v_o = 25-m/s

v_f = 0-m/s

a = -8.5-m/s^2

- A key word in the problem was then… which means something new happened (variables changed).

$$v_f^2 = v_o^2 + 2a\Delta p_B$$

$$0 = (25 - \frac{m}{s})^2 + 2(-8.5 - \frac{m}{s^2})\Delta p_B$$

$$-625 - \frac{m^2}{s^2} = -17 - \frac{m}{s^2}\Delta p_B$$

$$36.764 - m = \Delta p_B$$

$$\Delta p_B = 36.76 - m$$

v_o= 25-m/s
v_f = 0-m/s
a = -8.5-m/s^2
p_B = x

$$\Sigma p = \Delta p_R + \Delta p_B$$

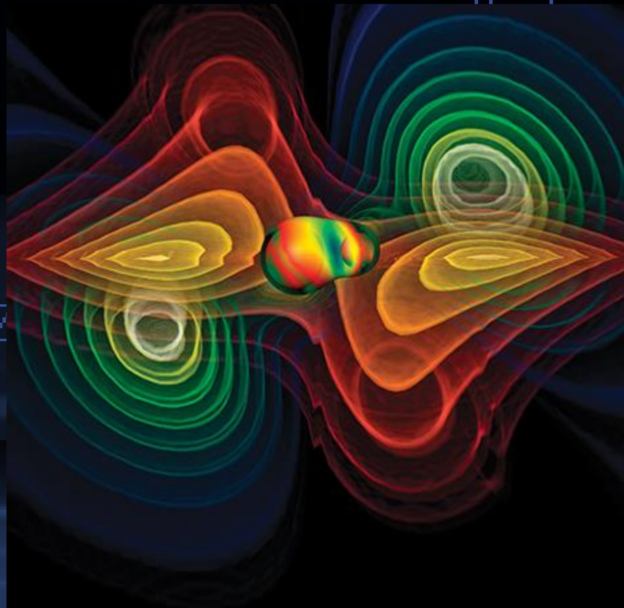
$$\Sigma p = 11.25 - m + 36.764 - m$$

$$\Sigma p = 48.014 - m$$

$$\Sigma p = 48.01 - m$$

Free Falling Objects

- All matter has gravity and will pull/be pulled towards any other object with matter.
  - To be discussed more in depth later.
- In class the magnitude of an object accelerating due to Earth's gravity, without air resistance is 9.80-m/s^2.
  - Remember on Earth!



Motion Example 3: Free Fall Example

- The Big Shot, a ride at the Stratosphere in Las Vegas, pulls 4-G's while it hurtles riders 49.00-m into the air.
  a) What is the maximum speed of the ride?
  b) How long does the ride last from release to land?

ME3: Make Assumptions

- Think holistically (no numbers) about the motion.
  - The ride goes up and will slow (gravity) the higher it goes.
  - As long as is has positive motion it will keep going up.
  - The ride then falls back down speeding up as it falls.
  - Basic Physics: No worry of friction or braking system.

Start

p = 0-m

t = 0-s

v = **max**

a = -9.8-m/s^2

At top

p = max (49-m)

t = half

v = **0-m/s**

a = -9.8-m/s^2

End

p = 0-m

t = max

v = **- max**

a = -9.8-m/s^2

ME3: Continued

Finding Initial Velocity:

$$v_f^2 = v_o^2 + 2a\Delta p_B$$

$$0 = v_o^2 + 2\left(-9.8 - \frac{m}{s^2}\right)49 - m$$

$$v_o^2 = 960.40 - \frac{m^2}{s^2}$$

$$v_o = 30.990 - \frac{m}{s}$$

$$\boxed{v_o = 30.99 - \frac{m}{s}}$$

p = 49.00-m
a = -9.8-m/s²
v_f = 0-m/s
v_o = x

ME3: Continued

Finding time to go up (half the total time):

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

$49.0\text{-m} = 31.0\text{-m/s} \cdot t + \frac{1}{2} \cdot -9.8\text{-m/s}^2 \cdot t^2$

$0 = 4.9t^2\text{-m/s}^2 - 31.0t\text{-m/s} + 49.0\text{-m}$

Using the Quadratic Form:

$0 = (2.21t - 7.00)(2.21t - 7.00)$

$t = 3.16\text{-s} \times 2 = 6.32\text{-s}$

$p = 49.00\text{-m}$
$a = -9.8\text{-m/s}^2$
$v_f = 0\text{-m/s}$
$v_o = 31\text{-m/s}$

ME3 Part b: A Different Approach

- It is often possible to use big ideas to simplify.
- If v_o = 31.0-m/s it should also land at v_f = -31.0-m/s
  - that which goes up *must* come down.

$$v_f = v_o + at$$

$$-30.990 - \frac{m}{s} = 30.990 - \frac{m}{s} - 9.8 - \frac{m}{s^2}t$$

$$9.8 - \frac{m}{s^2}t = 61.980 - \frac{m}{s}$$

$$t = 6.324 - s$$

$$\boxed{t = 6.32 - s}$$

a = -9.8-m/s^2
v_o= 30.990-m/s
v_f= -30.990-m/s
t =

- Big formulas are not always better; remember KISS