2.3 - One Dimensional Kinematics Equations

Three AP Equations to Rule Them All

With constant acceleration, the following equations hold true:

Position: $x = x_0 + v_0 t + \frac{1}{2}at^2$

Velocity: $v = v_0 + at$

A third (called the "sandbag equation") can be derived from the previous two equations: $v^2 = v_0^2 + 2a(x - x_0)$

Note: it's called the "sandbag equation" because the acceleration of a bullet fired into a sandbag can be found. It does not have time as a component.

Think of these equations as weapons in your physics arsenal, tools in your physics tool bag, or crayons in your physics coloring box.

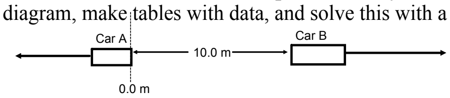
Strategy: determine and list explicit and implicit parameters (both initial and final): time, position, velocity, and acceleration to solve others.

Consider making a table:

	Initial	Final
time		
position		
velocity		
acceleration		

Ex. 1.

Two resting cars (A & B) start moving simultaneously in opposite directions, starting 10.0 m apart. They both accelerate at a constant rate of 2.0 m/s². How far apart will they be after 3.0 s? Draw a diagram, make tables with data, and solve this with a partner.



Car A

	Initial	Final
time		
position		
velocity		
acceleration		

Car B

	Initial	Final
time		
position		
velocity		
acceleration		

Use the position equation for both cars separately.

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

Ex. 1.

Compute positions of both cars, then add their absolute distances.

Car A: $x_A = x_{0A} + v_{0A}t + \frac{1}{2}a_A t^2$

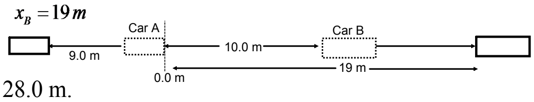
$$x_A = 0.0m + 0.0m/s \cdot 3.0s + \frac{1}{2}(-2.0m/s^2)\cdot(3.0s)^2$$

$$x_A = -9.0m$$

Car B: $x_B = x_{0B} + v_{0B}t + \frac{1}{2}a_B t^2$

$$x_B = 10.0m + 0.0m/s \cdot 3.0s + \frac{1}{2}(2.0m/s^2)\cdot(3.0s)^2$$

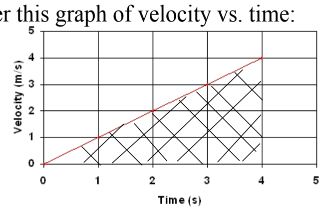
$$x_B = 19m$$



Total: 28.0 m.

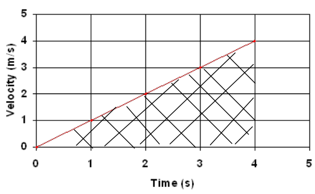
Graphical Analysis.

Consider this graph of velocity vs. time:



What does the slope equal? Acceleration - you've seen this.
What about the shaded area? Distance traveled - Prove it.

Graphical Analysis.



What is the area of a triangle?

$$Area = \frac{1}{2}\cdot base \cdot height$$

Units: base = seconds, height = m/s

Dimensional analysis: triangle's area has units of meters. (Not m^2 - Ironic!)

Graphical Transformation

When you substitute graphical quantities for the area of a triangle:

Base (x) = time (s)
Height (y) = velocity (m/s) = acceleration X time

$$Area = \frac{1}{2} \bullet base \bullet height = \frac{1}{2} \bullet t \bullet v$$

$$substitute\ for\ velocity = \frac{1}{2} \bullet t \bullet a \bullet t = \frac{1}{2} \bullet a \bullet t^2$$

Importance: This analysis shows how the final term in the position equation yields displacement.

New Problem - Slowing Down.

A car traveling at 15.0 m/s slows down and comes to rest in 50.0 meters. What is the car's acceleration during this time?

Ever considered a career as a crash test dummy?

New Problem - Slowing Down.

A car traveling at 15.0 m/s slows down and comes to rest in 50.0 meters. What is the car's acceleration during this time?

Data:

	Initial	Final
time	0.0 s	?
position	0.0 m	50.0 m
velocity	15.0 m/s	0.0 m/s
acceleration	?	

Which equation should we use to find acceleration?

The "sandbag equation:" total time is unknown.

New Problem - Slowing Down.

	Initial	Final
time	0.0 s	?
position	0.0 m	50.0 m
velocity	15.0 m/s	0.0 m/s
acceleration	?	

$$v^2 = v_0^2 + 2a(x - x_0)$$

Algebraic Shuffle:

$$a = \frac{v^2 - v_0^2}{2(x - x_0)}$$

$$a = \frac{(0.0m/s)^2 - (15.0m/s)^2}{2(50.0m - 0.0m)}$$

Parenthesis are Important!

$$a = -2.25\frac{m}{s^2}$$

Ex. 3.

A boat starts at rest and accelerates linearly at 3.0 m/s² for 8.0 seconds. How far does it travel during this time?

1. Find all data values:

	Initial	Final
time		
position		
velocity		
acceleration		

2. Use the position equation: $x = x_0 + v_0 t + \frac{1}{2}at^2$

Ex. 3.

	Initial	Final
time	0.0 s	8.0 s
position	0.0 m	? m
velocity	0.0 m/s	? m/s
acceleration	3.0 m/s²	

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$x = 0.0m + 0.0m/s \bullet 8.0s + \frac{1}{2} \bullet 3.0m/s^2 \bullet (8.0s)^2$$

$$x = 96m$$

Homework
Read 2.5 in your book
2.3 Problems in your Booklet
Due: Next Class