Kinematics

AP Physics C

Defining the important variables

Kinematics **is a way of describing the motion of objects without describing the causes. You can describe an object's motion:**

In words Mathematically Pictorially Graphically

No matter HOW we describe the motion, there are several KEY VARIABLES that we use.

Symbol	Variable	Units
t	Time	s
a	Acceleration	m/s/s
x or y	Displacement	m
v_o	Initial velocity	m/s
v	Final velocity	m/s
g or a_g	Acceleration due to gravity	m/s/s

The 3 Kinematic equations

There are 3 major kinematic equations than can be used to describe the motion in **DETAIL.** All are used when the acceleration is *CONSTANT.*

$$v = v_o + at$$

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

$$v^2 = v_o^2 + 2a(x - x_o)$$

Kinematic #1

$$a = \frac{\Delta v}{\Delta t} \rightarrow \frac{v - v_o}{t} \qquad v - v_o = at$$

$$v = v_o + at$$

Kinematic #1

Example: **A boat moves slowly out of a marina (so as to not leave a wake) with a speed of 1.50 m/s. As soon as it passes the breakwater, leaving the marina, it throttles up and accelerates at 2.40 m/s/s**.

a) How fast is the boat moving after accelerating for 5 seconds?

What do I know?	**What do I want?**
v_o= 1.50 m/s	v = ?
a = 2.40 m/s/s	
t = 5 s	

$$v = v_o + at$$

$$v = (1.50) + (2.40)(5)$$

$$v = \quad \textbf{13.5 m/s}$$

Kinematic #2

$$x = x_o + v_{ox}t + \tfrac{1}{2}at^2$$

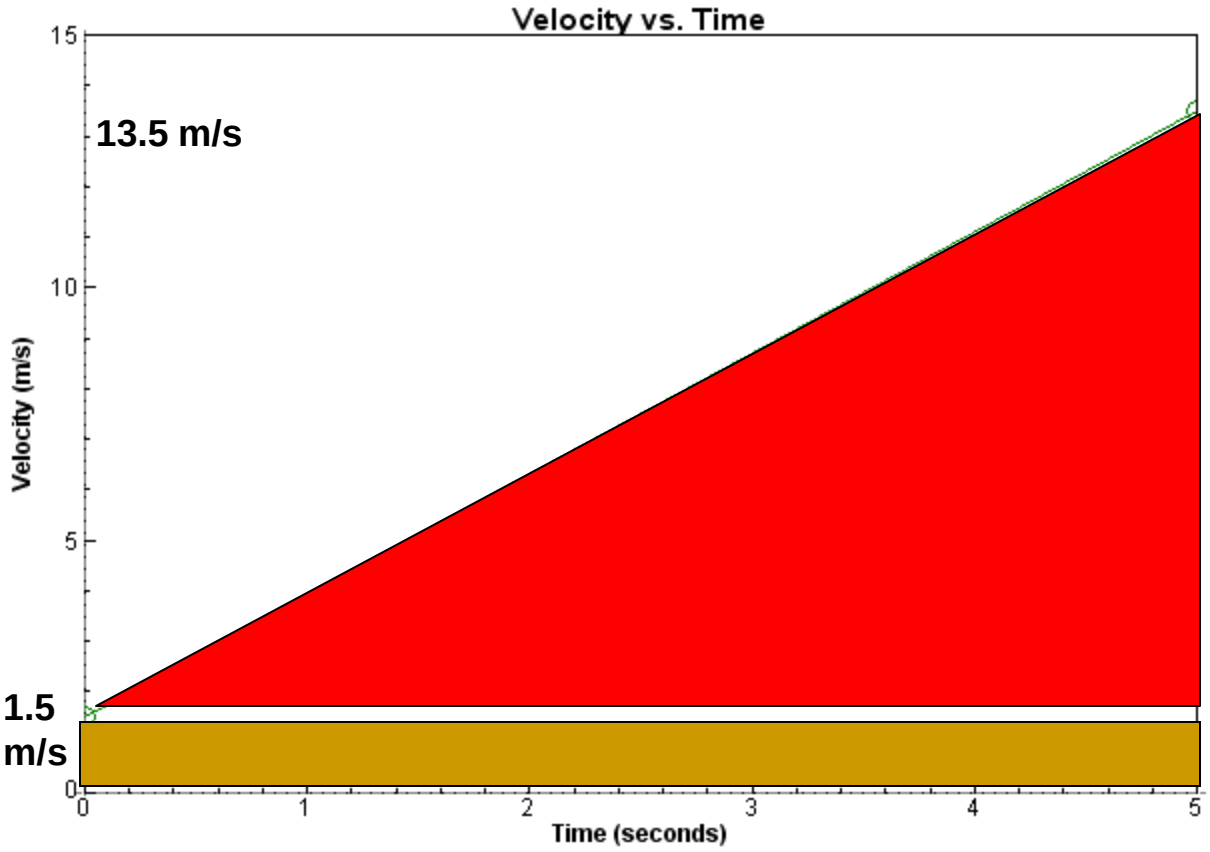
b) How <u>far</u> did the boat travel during that time?

$$x = x_o + v_{ox}t + \tfrac{1}{2}at^2$$

$$x = 0 + (1.5)(5) + \tfrac{1}{2}(2.40)(5^2)$$

$$x = \quad \textbf{37.5 m}$$

Does all this make sense?



$$A = bh \rightarrow A = (5)(1.5)$$

$$A = 7.50\ m$$

$$A = \frac{1}{2}bh \rightarrow \frac{1}{2}(5)(12)$$

$$A = 30\ m$$

Total displacement = 7.50 + 30 = 37.5 m = Total AREA under the line.

Interesting to Note

$$x = x_o + v_{ox}t + \tfrac{1}{2}at^2$$

A = HB

$$x = x_o + v_{ox}t + \tfrac{1}{2}att$$

$$x = x_o + v_{ox}t + \tfrac{1}{2}\Delta vt$$

A=1/2HB

Most of the time, x_o=0, but if it is not don't forget to ADD in the initial position of the object.

Kinematic #3

$$v^2 = v_o^2 + 2a(x - x_o)$$

Example: **You are driving through town at 12 m/s when suddenly a ball rolls out in front of your car. You apply the brakes and begin decelerating at 3.5 m/s/s.**

How far do you travel before coming to a complete stop?

What do I know?	**What do I want?**
v_o= 12 m/s	x = ?
a = -3.5 m/s/s	
V = 0 m/s	

$$v^2 = v_o^2 + 2a(x - x_o)$$

$$0 = 12^2 + 2(-3.5)(x - 0)$$

$$-144 = -7x$$

$$x = \quad \textbf{20.57 m}$$

Common Problems Students Have

I don't know which equation to choose!!!

Equation	Missing Variable
$v = v_o + at$	x
$x = x_o + v_{ox}t + \frac{1}{2}at^2$	v
$v^2 = v_o^2 + 2a(x - x_o)$	t

Kinematics for the VERTICAL Direction

All 3 kinematics can be used to analyze ***one dimensional motion*** in either the X direction OR the y direction.

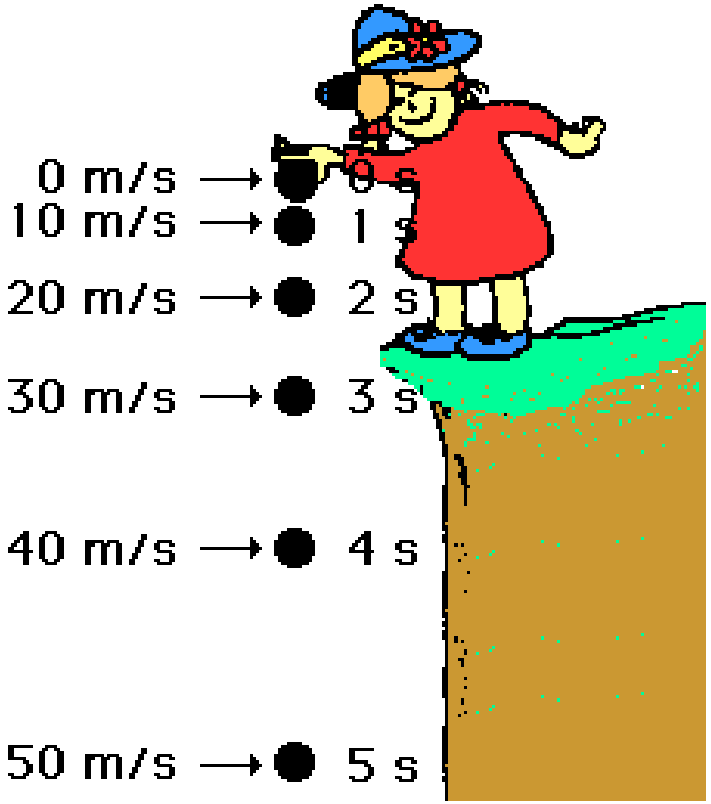
$$v = v_o + at \rightarrow v_y = v_{oy} + gt$$

$$x = x_o + v_{ox}t + \tfrac{1}{2}at^2 \rightarrow y = y_o + v_{oy}t + \tfrac{1}{2}gt^2$$

$$v^2 = v_{ox}^2 + 2a(x - x_o) \rightarrow v_y^2 = v_{oy}^2 + 2g(y - y_o)$$

"g" or a_g – The Acceleration due to gravity

The acceleration due to gravity is a special constant that exists in a VACUUM, meaning without air resistance. If an object is in FREE FALL, gravity will **CHANGE** an objects velocity by 9.8 m/s every second.



$$g = a_g = -9.8\, m/s^2$$

The acceleration due to gravity:

- ALWAYS ACTS DOWNWARD
- IS ALWAYS CONSTANT near the surface of Earth

Examples

A stone is dropped at rest from the top of a cliff. It is observed to hit the ground 5.78 s later. How high is the cliff?

What do I know?	What do I want?
v_{oy}= 0 m/s	y = ?
g = -9.8 m/s^2	
y_o=0 m	
t = 5.78 s	

Which variable is NOT given and NOT asked for?

Final Velocity!

$$y = y_o + v_{oy}t + \tfrac{1}{2}gt^2$$

$$y = (0)(5.78) - 4.9(5.78)^2$$

$y =$ **-163.7 m**

H =163.7m

Examples

A pitcher throws a fastball with a velocity of 43.5 m/s. It is determined that during the windup and delivery the ball covers a displacement of 2.5 meters. This is from the point behind the body when the ball is at rest to the point of release. Calculate the acceleration during his throwing motion.

What do I know?	What do I want?
v_o= 0 m/s	a = ?
x = 2.5 m	
v = 43.5 m/s	

Which variable is NOT given and NOT asked for?

TIME

$$v^2 = v_o^2 + 2a(x - x_o)$$

$$43.5^2 = 0^2 + 2a(2.5 - 0)$$

$$a = \textbf{378.5 m/s/s}$$

Examples

How long does it take a car at rest to cross a 35.0 m intersection after the light turns green, if the acceleration of the car is a constant 2.00 m/s/s?

What do I know?	What do I want?
v_o= 0 m/s	t = ?
x = 35 m	
a = 2.00 m/s/s	

Which variable is NOT given and NOT asked for?

Final Velocity

$$x = x_o + v_{ox}t + \tfrac{1}{2}at^2$$

$$35 = 0 + (0) + \tfrac{1}{2}(2)t^2$$

$t =$ **5.92 s**

Examples

A car accelerates from 12.5 m/s to 25 m/s in 6.0 seconds. What was the acceleration?

What do I know?	What do I want?
v_o= 12.5 m/s	a = ?
v = 25 m/s	
t = 6s	

Which variable is NOT given and NOT asked for?

DISPLACEMENT

$$v = v_o + at$$

$$25 = 12.5 + a(6)$$

$$a = \text{ 2.08 m/s/s}$$

Kinematics and Calculus

Let's take the "derivative" of kinematic #2 assuming the object started at x = 0.

$$x = v_{ox}t + \tfrac{1}{2}at^2$$

$$v = \frac{dx}{dt} = \frac{d(v_{ox}t + \tfrac{1}{2}at^2)}{dt}$$

$$v = v_o + at$$

$$a = \frac{dv}{dt} = \frac{d(v_0 + at)}{dt} = a$$