1-DisVelGraph

January-29-19 9:16 AM

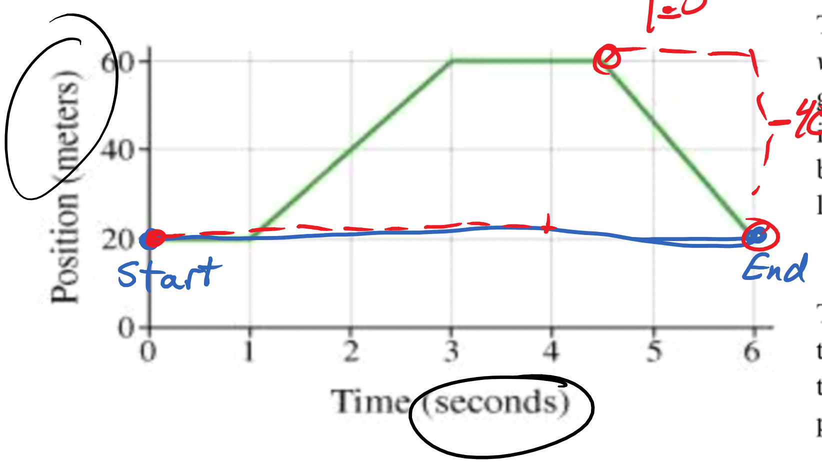
$V = \frac{d}{t}$ $a = \frac{\Delta v}{t}$

Delta
↳ Change in

Displacement/Velocity/Acceleration Graphs

Displacement vs. Time Graphs

This graph describes the motion of an object. (Note: Displacement & Position mean the same thing)



The *instantaneous velocity* is the slope at a given point. If the point is curved, draw your best guess of a tangent line

The *average velocity* is the slope from the start, to the end of a time period.

Find instantaneous velocity at 2s.

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{40m}{2s} = 20\,\frac{m}{s}$$

Find the average velocity over the whole movement.

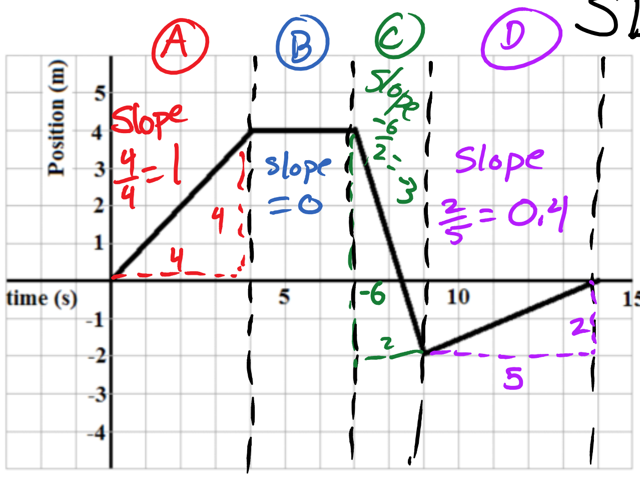
Slope = 0 m/s

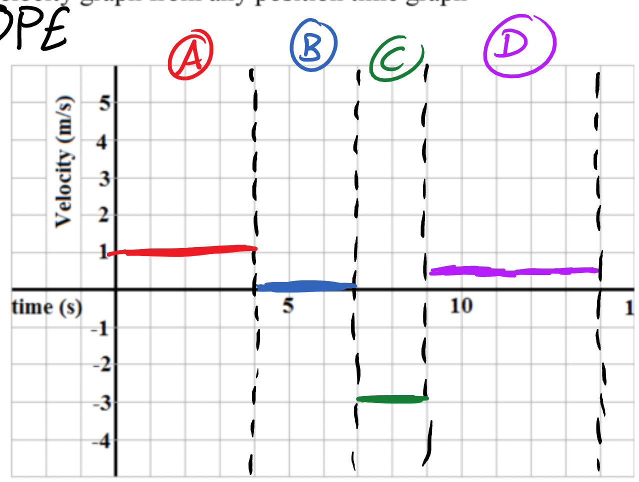
Avg from 0s to 4s?

$\frac{40}{4} = 10$ m/s

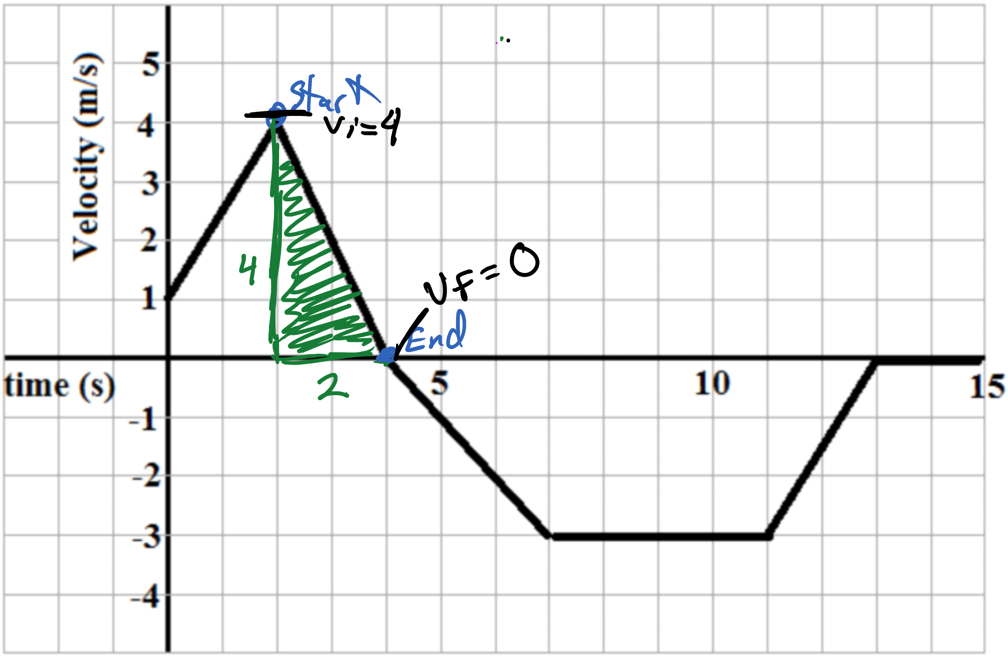
Using instantaneous velocity, we can construct a velocity graph from any position time graph

SLOPE





Velocity vs. Time Graphs



To find the displacement from a Velocity-Time Graph you would find the a*verage velocity* then multiply that by the amount of time it travels at that velocity.

$\vec{V}_{avg} = \dfrac{\vec{v}_i+\vec{v}_f}{2}$

Find the displacement travelled during the 2s to 4s time interval.

*Alternate method. → Find the area under the v-t graph.

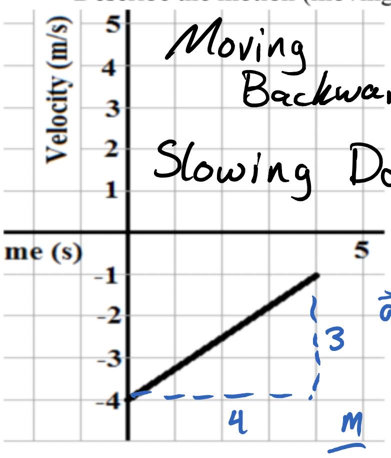
$A = \frac{b \times h}{2} = \frac{2 \times 4}{2} = 4 \quad \vec{d} = 4m$

$V_{avg} = \frac{4+0}{2} = 2 m/s$

$\vec{d} = V_{avg} \cdot t = 2 \times 2_s = +4m$

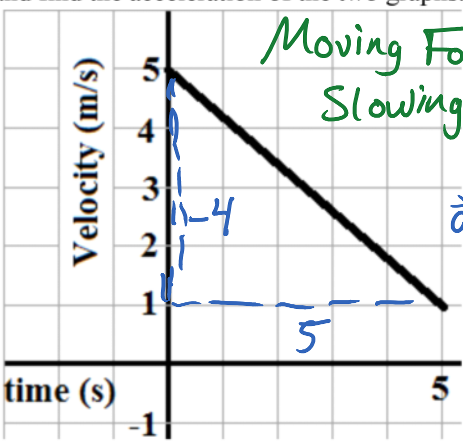
Acceleration is the rate of change of velocity. It is the slope of a Velocity Time Graph.

Describe the motion (moving forward/backward) and find the acceleration of the two graphs.



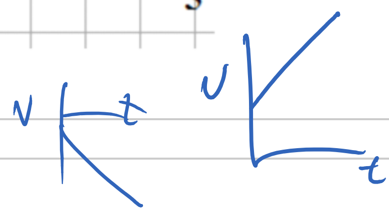
$\vec{a} = \frac{3 m/s}{4 s} = +0.75 m/s^2$

$\frac{m/s}{s} = \frac{m}{s} \times \frac{1}{s} = \frac{m}{s^2}$



Moving Forwards
Slowing Down

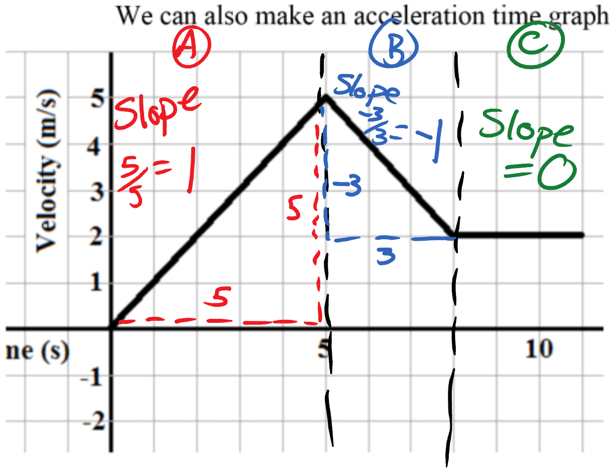
$\vec{a} = \frac{-4}{5} = -0.8 m/s^2$

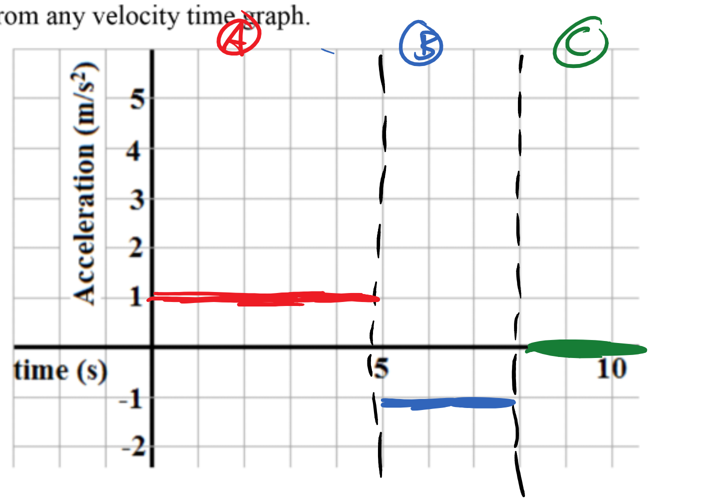


We can also make an acceleration time graph from any velocity time graph.

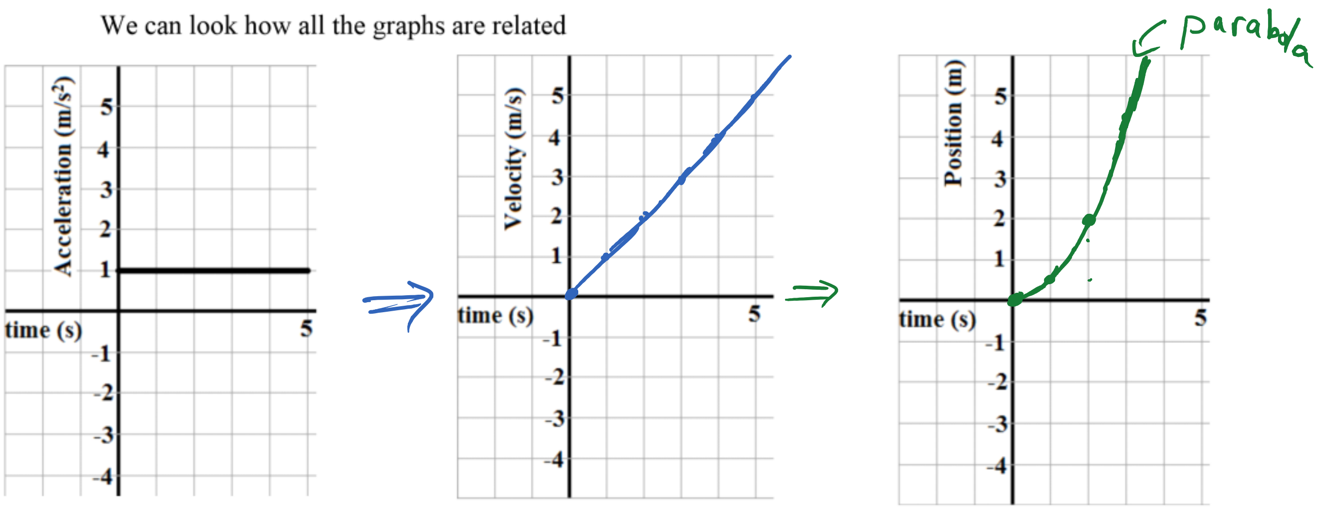
A B C A B C

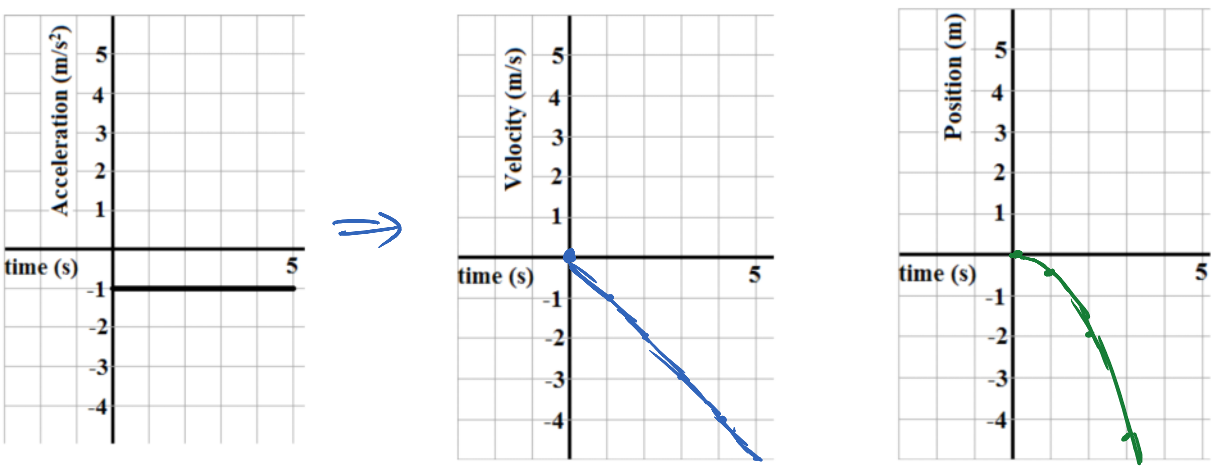
We can also make an acceleration time graph from any velocity time graph.





We can look how all the graphs are related





Accelerated Motion

Whenever a body experiences a change in velocity, that experience is called an acceleration.

Definition:
Acceleration: The rate of change of velocity

$$\vec{a} = \frac{\Delta \vec{v}}{t}$$

$$\boxed{\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}} \quad \#1$$

Δ = Final − Initial

Methods to Solve Problems with Uniform Accelerated Motion:

1. Read the problem and Interpret what is happening.
   * Is it one smooth motion? Are the multiple parts? *And then*
2. Identify your variables.
3. Find the correct formula you need.
4. Solve (need algebra)
5. Provide a full answer.

Ex. Chloe is jogging North at a pace of 3m/s. A velociraptor jumps out in-front of her so she spins around and sprints in the opposite direction, taking only 0.7s to reach her top speed of 10m/s. What was Chloe's acceleration?

N+

S−

$\vec{v}_i = +3 m/s$

$\vec{v}_f = -10 m/s$

$\vec{a} = ?$

$\cancel{\vec{d} =}$

$t = 0.7s$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\vec{a} = \frac{-10 - 3}{0.7}$$

$$\vec{a} = -18.6\ m/s^2$$

Chloe accelerated at $18.6 m/s^2$ South

Ex. The velociraptor is groggy from cryosleep and thus only accelerates at Chloe at a rate of 2.7m/s². How long does it take the dinosaur to match Chloe's speed?

$\vec{v}_i = 0\,m/s$ ← context

$\vec{v}_f = -10\,m/s$

$\vec{a} = -2.7\,m/s^2$

$\cancel{\vec{d}} =$

$t = ?$

$t \times \vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t} \times t$

$\frac{t \times \cancel{\vec{a}}}{\cancel{\vec{a}}} = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

$t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

$t = \frac{-10 - 0}{-2.7} = 3.7\,s$

The dino takes 3.7s to match Chloe's speed.

When the acceleration is uniform (constant) the average velocity can be used to determine the displacement of objects.

$\vec{d} = \vec{v}_{avg} \cdot t$

$\vec{v}_{avg} = \frac{\vec{v}_i + \vec{v}_f}{2}$

$$\boxed{\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right) t}$$ #2

Ex. Tim sacrifices himself to tackle the velociraptor. Tim and the dinosaur fall to the ground and slide to a stop in 2.3s. How far did they slide on the ground?

$\vec{v}_i = -10\,m/s$

$\vec{v}_f = 0\,m/s$

$\cancel{\vec{a}} =$

$\vec{d} = ?$

$t = 2.3$

$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right) t$

$\vec{d} = \left(\frac{-10 + 0}{2}\right)(2.3)$

$\vec{d} = -11.5\,m$

Tim and the dino slid 11.5m South

Accelerated Motion – Part 2

Review:

The variables used in Kinematics are: $\vec{v}_i, \vec{v}_f, \vec{a}, \vec{d}, t$

Our two Kinematics Formulae from last class were:

$$\boxed{\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}} \qquad \boxed{\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t}$$

Use #1 if you don't want the: $\vec{d}$

Use #2 if you don't want the: $\vec{a}$

What can we do if we don't want to use $\mathbf{v_f}$?

Solve for $\vec{v}_f$ in Eq #1 , Substitute into Eq #2

$$t \times \vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t} \times t$$

$$\vec{a}t = \vec{v}_f - \vec{v}_i$$

$+\vec{v}_i \qquad +\vec{v}_i$

$$(\vec{v}_i + \vec{a}t) = \vec{v}_f$$

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$\vec{d} = \left(\frac{\vec{v}_i + (\vec{v}_i + \vec{a}t)}{2}\right)t$$

$$\vec{d} = \left(\frac{2\vec{v}_i + \vec{a}t}{2}\right)t$$

$$\vec{d} = \left(\frac{\cancel{2}\vec{v}_i}{\cancel{2}} + \frac{\vec{a}t}{2}\right)t$$

$$\vec{d} = \left(\vec{v}_i + \tfrac{1}{2}\vec{a}t\right)t$$

$$\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$

$$\boxed{\vec{d} = \vec{v}_i t + \tfrac{1}{2}at^2}$$

Equation #3

Ex. Jacob is driving a car and slams on the brakes. He slides 27m in 3s. He is accelerating at a rate of -4.2m/s². What was Jacob's velocity before slowing down?

$\vec{v}_i = ?$

$\cancel{\vec{v}_f =}$

$\vec{a} = -4.2 m/s^2$

$\vec{d} = 27m$

$t = 3s$

$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

$-\frac{1}{2}at^2 \quad -\frac{1}{2}at^2$

$\frac{\vec{d} - \frac{1}{2}\vec{a}t^2}{t} = \frac{\vec{v}_i \cancel{t}}{\cancel{t}}$

$\vec{v}_i = \frac{\vec{d} - \frac{1}{2}at^2}{t}$

$\vec{v}_i = \frac{27 - \frac{1}{2}(-4.2)(3)^2}{3}$

$\vec{v}_i = 15.3 m/s$

Jacob started at 15.3 m/s Forward

What can we do if we don't want to use **t**?

Solve for t in Eq#1 / Subtitute into Eq#2

$t \times \vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\cancel{t}} \times t$

$\frac{t \times \cancel{\vec{a}}}{\cancel{a}} = \frac{\vec{v}_f - \vec{v}_i}{a}$

$t = \left(\frac{\vec{v}_f - \vec{v}_i}{\vec{a}}\right)$

$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$

$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)\left(\frac{\vec{v}_f - \vec{v}_i}{\vec{a}}\right)$

$\vec{d} = \frac{\cancel{\vec{v}_i\vec{v}_f} - \vec{v}_i^2 + \vec{v}_f^2 \cancel{- \vec{v}_i\vec{v}_f}}{2\vec{a}}$

$2\vec{a} \times \vec{d} = \frac{-\vec{v}_i^2 + \vec{v}_f^2}{2\vec{a}} \times 2\vec{a}$

$2\vec{a}\vec{d} = -\vec{v}_i^2 + \vec{v}_f^2$

$+v_i^2 \quad +v_i^2$

$\vec{v}_i^2 + 2\vec{a}\vec{d} = \vec{v}_f^2$

$$\boxed{\vec{v}_f^2 = \vec{v}_i^2 + 2\vec{a}\vec{d}}$$

Equation #4

Ex. Jeffery throws a water balloon downward at 3.2m/s from on top of a 65m high building. Gravity accelerates it downward at 9.8m/s². What is the velocity of the balloon just before it hits the ground?

up −

down +

$\vec{v}_i = 3.2 m/s$

$\vec{v}_f = ?$

$\vec{a} = 9.8 m/s^2$

$\vec{d} = 65m$

$\cancel{t} =$

$\sqrt{\vec{v}_f^2} = \sqrt{\vec{v}_i^2 + 2\vec{a}\vec{d}}$

$\vec{v}_f = \pm\sqrt{\vec{v}_i^2 + 2\vec{a}\vec{d}}$

$\vec{v}_f = \pm\sqrt{(3.2)^2 + 2(9.8)(65)}$

$\vec{v}_f = \pm 35.8 m/s$

Choose + because + is down

The balloon was going 35.8m/s down as it hit the ground.

$\sqrt{9} = 3$ or -3

$3 \times 3 = 9$

$-3 \times -3 = 9$

Summary

The four Kinematics Equations are:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$$

$$\vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{a}t^2$$

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\vec{d}$$

Extra Notes:

Remember to watch your units! Calculations can only work when using compatible units.

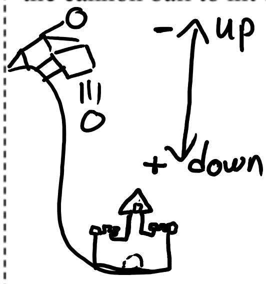
Converting between km/h and m/s: → Velocity only

$$\begin{tikzcd} \frac{km}{h} \arrow[r, bend left, "\div 3.6"] & m/s \arrow[l, bend left, "\times 3.6"] \end{tikzcd}$$

$$\frac{km}{h} \times \frac{1000m}{1km} \times \frac{1h}{3600s} = \frac{m}{s}$$

Using Quadratic Formula in Physics

Ex. Graham is on a 45m tall hill and is shooting a cannon at a castle at the base of the hill. He shoots with a downward velocity of 1.3m/s. The acceleration due to gravity is 9.8m/s^2 downward. How long does it take the cannon ball to hit the castle?



$v_i = 1.3 m/s$

$\cancel{v_f} =$

$a = 9.8 m/s^2$

$d = 45 m$

$t = ?$

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$45 = 1.3t + \frac{1}{2}(9.8)t^2$$

$$45 = 1.3t + 4.9t^2$$
$$-45 \qquad\qquad -45$$

$$0 = 1.3t + 4.9t^2 - 45$$

Note: This does not solve nicely through algebra

The *quadratic formula* is used to help solve for any quadratic (squared) relation.

In Kinematics we use it for equation #3 when we are looking for the time.

The Quadratic Equation

For any quadratic of the form: $at^2 + bt + c = 0$

where a, b, and c are **constants** (numbers), the following equation can be used to solve for the unknown t:

$$\boxed{t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}}$$

Ex. Graham is on a 45m tall hill and is shooting a cannon at a castle at the base of the hill. He shoots with a downward velocity of 1.3m/s. The acceleration due to gravity is 9.8m/s^2 downward. How long does it take the cannon ball to hit the castle?

$v_i = 1.3\,m/s$

~~$v_f =$~~

$a = 9.8\,m/s^2$

down $d = 45\,m$

$+$ $t = ?$

$d = v_i t + \frac{1}{2} a t^2$

$45 = 1.3t + 4.9t^2$

$-$

Step 1 Organize your formula to $0 = at^2 + bt + c$ or $at^2 + bt + c = 0$

$0 = \underbrace{4.9}t^2 + \underbrace{1.3}t \underbrace{-45}$

Step 2: Identify a b and c

Step 3: Plug into the Quadratic Formula $t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$t = \frac{-1.3 \pm \sqrt{(1.3)^2 - 4(4.9)(-45)}}{2(4.9)}$$

$$t = \frac{-1.3 \pm \sqrt{1.69 - (-882)}}{9.8}$$

$$t = \frac{-1.3 \pm \sqrt{883.69}}{9.8}$$

$$t = \frac{-1.3 \pm 29.7}{9.8}$$

$+$ $\frac{-1.3 + 29.7}{9.8} = 2.9s$

$-$ $\frac{-1.3 - 29.7}{9.8}$ $\cancel{= -3.2s}$ Reject

The cannonball hit the castle 2.9s after it was shot.

Projectile Motion and Gravity

(at the Earth's surface)

The accepted value for an object accelerated by Earth's gravity is $9.8\ m/s^2$ downward

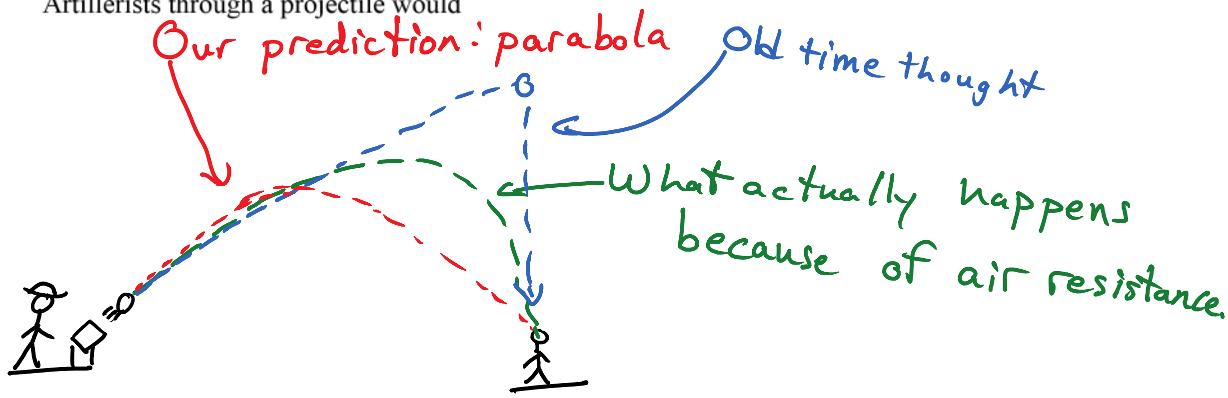
This assumes: No air resistance.

The Shape of a Projectile's Path

Unpowered, experiencing freefall — After the launch and Before it lands

Back in "*ye olde days*"

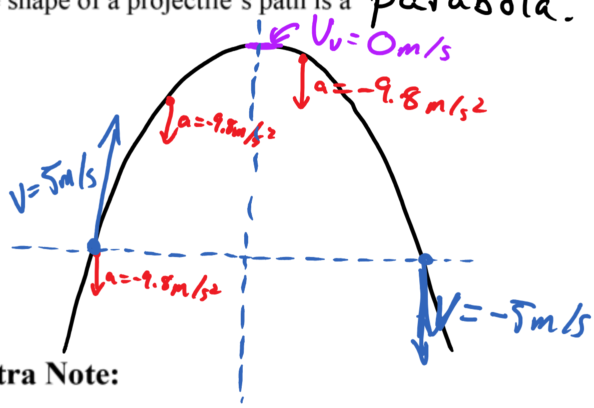
Artillerists through a projectile would



~~It actually looks like~~

In Physics 11 we will ignore air resistance.

The shape of a projectile's path is a parabola.



Key Features:

- Symmetrical about the peak
- Acceleration is the same at all points.
- At the peak the vertical velocity is zero

Extra Note:

When something is *dropped* it means

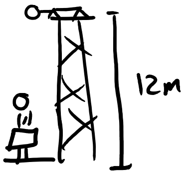
$\hookrightarrow v_i = 0\ m/s$

Ex:

a) A cannonball is launched from the ground upward at a velocity of 25m/s towards Steve. If Steve is standing on a 12m tall scaffold. How long does Steve have to live?

up +

down −



$V_i = 25m/s$

$~~V_f~~ =$

$a = -9.8m/s^2$

$d = 12m$

$t = ?$

$d = v_i t + \frac{1}{2} a t^2$

$12 = 25t + \frac{1}{2}(-9.8)t^2$

$12 = 25t - 4.9t^2$

-12

$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$0 = -4.9t^2 + 25t - 12$

$t = \frac{-25 \pm \sqrt{25^2 - 4(-4.9)(-12)}}{2(-4.9)}$

$t = \frac{-25 \pm \sqrt{389.8}}{-9.8}$

$t = \frac{-25 \pm 19.7}{-9.8}$

$+$: $\frac{-25 + 19.7}{-9.8} = 0.54s$ On the way up

$-$: $\frac{-25 - 19.7}{-9.8} = 4.56s$ On the way back down

b) When does the cannonball reach 32m in height?

Everything is the same except "d".

$0 = -4.9t^2 + 25t - 32$

$t = \frac{-25 \pm \sqrt{25^2 - 4(-4.9)(-32)}}{-9.8}$

$t = \frac{-25 \pm \sqrt{-2.2}}{-9.8}$

Can't do this! This means the cannonball does not reach 32m.

c) What is the maximum height of the cannonball?

peak

$V_i = 25m/s$

$V_f = 0m/s$

$a = -9.8m/s^2$

$d = ?$

$t =$

$V_f^2 = V_i^2 + 2ad$

$-V_i^2 \quad -V_i^2$

$\frac{V_f^2 - V_i^2}{2a} = \frac{2ad}{2a}$

$d = \frac{V_f^2 - V_i^2}{2a}$

$d = \frac{0^2 - (25^2)}{2(-9.8)}$

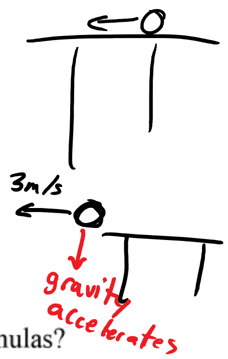
$d = 31.9m$

The maximum height of the cannonball is 31.9m

Projectiles and Vector Direction

Perpendicular vectors act independent of each other

Imagine a ball is rolling on a table to the left at 3m/s.



What would its initial velocity be?

3m/s Left

When it rolls off the table what would be the ball's acceleration?

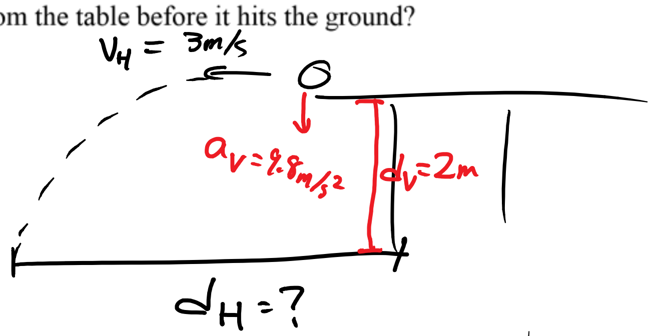
$9.8\ m/s^2$ Down

Consider the directions, can you use these values in our usual formulas?

No. You can't compare left with down.

For all motions you can split the problem into the Horizontal and Vertical parts. The only value that is shared between the two parts is time.

Ex: A ball rolling at 3m/s to the left rolls off of a 2m high table. How far (horizontally) does the ball move away from the table before it hits the ground?



Vertical	Horizontal
$v_{iv} = 0 m/s$	$v_{iH} = 3 m/s$
$v_{fv} =$	$v_{fH} = 3 m/s$
$a_v = 9.8 m/s^2$	$a_H = 0 m/s^2$
$d_v = 2m$	$d_H = ?$
$t =$	$t = 0.639 s$

$d = v_i t + \frac{1}{2} a t^2$

$2 = 0t + \frac{1}{2}(9.8)t^2$

$2 = 4.9t^2$

$t = 0.639s$

$\cancel{v_f^2 = v_i^2 + 2ad}$

$d = \left(\frac{v_f + v_i}{2}\right)t$

$d = \left(\frac{3+3}{2}\right)(0.639)$

$d = 1.92m$

11-Challenge1

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More Challenging Kinematics Problems

Type 1: Lack of Information **OR** Interpreting Solutions

To solve these you have to use CONTEXT and ideas learned in class, like: projectile SYMMETRY or constants like the acceleration of gravity on Earth's surface.

Ex. A)

A dog jumps straight up with a velocity of 2.7m/s. How long is it in the air?

	How do we know this?
v_i= 2.7m/s	← Given in the problem
v_f= -2.7 m/s	← Projectile symmetry
a= -9.8m/s²	← acceleration due to gravity
d= 0m	← The dog falls back to its original position
t= ?	

Ex. B)

A ball is hit into left field and has an initial vertical velocity of 5.2m/s upward. Jim takes 7s to get to the ball. Does he catch it?

How long is it in the air?

$V_i = 5.2 m/s$

$V_f = -5.2 m/s$

$a = -9.8 m/s^2$

$d = 0m$

$t = ?$

$a = \frac{v_f - v_i}{t}$

$t = \frac{v_f - v_i}{a}$

$t = \frac{-5.2 - 5.2}{9.8} = 1.06s$

Jim got to the ball ~6s after it hit the ground.

OR

Where does Jim catch it?

$V_i = 5.2 m/s$

~~V_f~~

$a = -9.8 m/s^2$

$d = ?$

$t = 7s$

$d = v_i t + \frac{1}{2} a t^2$

$d = 5.2(7) + \frac{1}{2}(-9.8)(7)^2$

$d = -203.7m$

underground

No, Jim does not catch this ball.

Type 2: Two Motion Problems

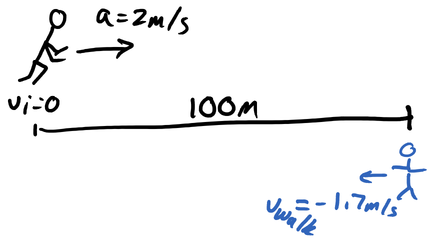
These problems have two separate motions. Either one object moves one way, then another, OR two objects are moving at once. This type of problem doesn't have one set way to solve the problem and will rely on your problem solving abilities.

Helpful Steps:

1. Sketch the situation
2. Split the problem into two motions.
3. Identify values that are the same OR relationships between the two values.
4. Use your critical thinking and problem solving skills to work your way towards a solution.

Ex. C) Easier 2-motion problem

Graham sprints 100m, starting at rest and accelerates at a rate of 2m/s². After his sprint, Graham walks back to his starting point walking at a constant 1.7m/s. How long does it take Graham to do a sprint, then walk back to the starting point?



$t_{sprint} + t_{walk} = t_{Total}$

Sprint	Walk
$v_i = 0m/s$	$v_i = -1.7m/s$
$v_f =$	~~$v_f =$~~
$a = 2m/s^2$	$a = 0m/s^2$
$d = 100m$	$d = -100m$
$t_s = ?$	$t_w = ?$

$d = v_i t + \frac{1}{2}at^2$

$100 = \cancel{0t} + \frac{1}{2}(2)t^2$

$100 = t_s^2$

$t_{sprint} = 10s$

$d = v \cdot t$

$t = \frac{d}{v}$

$t_w = \frac{-100}{-1.7}$

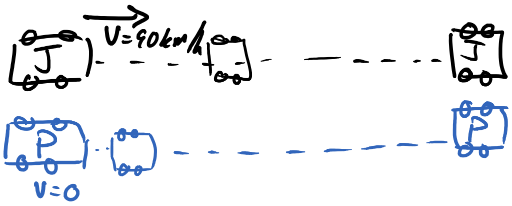
$t_{walk} = 58.8s$

$t_{Total} = 68.8s$

$\boxed{\text{Graham takes 68.8s to do one circuit.}}$

Ex. D) Harder 2-motion problem

Jasmine is speeding, going 90km/h in a 50km/h zone. A police ghost car at rest begins to accelerate the moment Jasmine passes it. If it accelerates at a rate of 2.8m/s², how long does it take the officer to catch up with Jasmine?



Jasmine	Police
$V_{iJ} = 90 km/h = 25 m/s$	$V_{ip} = 0 m/s$
	$V_{fp} =$ * Not the same as Jasmine *
	$a_p = 2.8 m/s^2$
$d_J = d$	$d_p = d$
$t_J = t$	$t_p = t$

same

same

Make a formula for each side using the related variables

$d = V_J \cdot t$

$d = (25t)$

$d = v_{ip}t + \frac{1}{2}a_p t^2$

$d = 0t + \frac{1}{2}(2.8)t^2$

$d = (1.4t^2)$

Use substitution

$$\frac{25\cancel{t}}{\cancel{t}} = \frac{1.4t^{\cancel{2}}}{\cancel{t}}$$

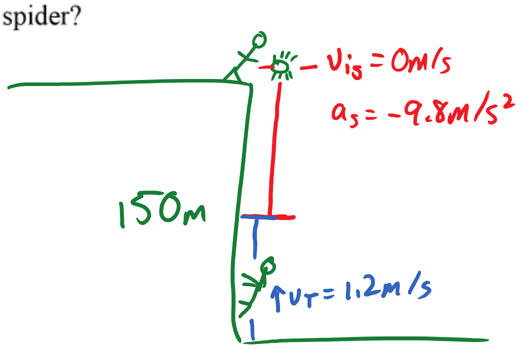
$$\frac{25}{1.4} = \frac{\cancel{1.4}t}{\cancel{1.4}}$$

$t = 17.9 s$

The police take 17.9s to catch up to Jasmine.

Ex. E) Actually Hard 2-motion problem

Thomas is climbing up a 150m cliff at a constant pace of 1.2m/s. Ally is on the top of the cliff, and the moment Thomas starts climbing she drops a spider. How high off the ground is Thomas when he encounters the spider?



Thomas	Spider
$v_{i_T} = 1.2m/s$	$v_{i_S} = 0m/s$
	$v_{f_S} =$
	$a_S = -9.8\ m/s^2$
$d_T =$ ← Relates →	$d_S =$
$t_T = t$ ← Same →	$t_S = t$
$d = v \cdot t$	$d = v_i t + \frac{1}{2} a t^2$
#1 $\boxed{d_T = 1.2t}$	$d_S = 0t + \frac{1}{2}(-9.8)t^2$
	#2 $\boxed{d_S = -4.9t^2}$

going down

$\boxed{d_T + (-d_S) = 150}$ #3

There are multiple paths of substitution to solve from here.

#1 into #2

$\left(\frac{d_T}{1.2}\right) = t \qquad d_S = -4.9t^2$

$d_S = -4.9\left(\frac{d_T}{1.2}\right)^2 \Rightarrow d_S = -\frac{4.9 \cdot d_T^2}{1.44}$

$(d_S = -3.40 d_T^2)$ into #3 $\qquad d_T + (-d_S) = 150$

$d_T + (-(-3.40 d_T^2)) = 150 \rightarrow d_T + 3.40 d_T^2 = 150 \rightarrow \underbrace{3.40}_{a} d_T^2 + \underbrace{d_T}_{b=1} \underbrace{-150}_{c} = 0$

$d_T = \frac{-1 \pm \sqrt{1^2 - 4(3.40)(-150)}}{2(3.4)}$

$d_T = \frac{-1 \pm \sqrt{2041}}{6.8}$

$d_T = \frac{-1 \pm 45.2}{6.8}$ $\xrightarrow{+}$ 6.5m $\qquad \xrightarrow{-}$ $\cancel{-6.8m}$ Reject

The spider landed on Thomas when he was 6.5m above the ground.

$$d_T = \frac{\quad}{6.8}$$

$-6.8m$ Reject