Kinematics Note

July 9, 2019 8:05 AM

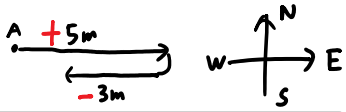
Unit 1: Kinematics in 1D

1 – Vector and Scalar, Distance and Position

There are two types of measurement: with Direction or without. [ ] - direction.

Scalars: Magnitude only		Vectors: Magnitude and direction	
m mass (ex, 56 kg)	E Energy	$\vec{F}$ Force (20 N [right])	$\vec{a}$ acceleration (m/s^2)
v speed (m/s)	distance / length (m)	$\vec{v}$ velocity (20 m/s [South])	
t time		$\vec{d}$ Displacement (30 m [N])	
T temperature (°C)			

- **Kinematics**: The study of an object's motion.



Position, Distance and Displacement

- **Distance (d)**: the separation between two points. Ex, the length of an object. Usually measures in meter. No direction needed

ex) 

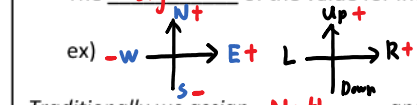
X = 30 cm

- **Displacement (Δd or $\vec{d}$)**: A measure of the change in *position*. Needs direction → vector (need direction)

Δd = final position – initial position.

↳ delta → change in

The sign of the value for indicates the direction.

ex) 

Traditionally we assign North and East as positive (+) and South and West as negative.

$\vec{d}$ = 10 m [E] $\vec{d}$ = 10 m [W] or d = -10 m [E]

Ex 1: A student walks 5 m east and then 3 m west.

a) What is the distance (scalar) travelled?

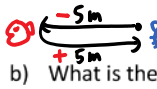
dist = $5_m + 3_m$ = 8 m

b) What is the student's displacement (vector)?

$\vec{d} = +5m + (-3m) = 2m$ [E]

Ex 2: A cat walks 5 m left to get a snack (gold fish?) and then 5 m right to go back to bed.

a) What is the distance (scalar) travelled?



d = 5m + 5m = 10 m

b) What is the displacement (vector)?

$\vec{d} = -5m + 5m = \emptyset$

Worksheet 1a – Distance and displacement

1. Frank is driving along a straight highway when he notices a marker that says "260km". He continues to the 150-km marker and then turns around and goes back to the 175-km marker.
   a) What is the total distance travelled?
   b) What is the total displacement for the whole trip?

2. A physics book is moved once around the perimeter of a table of dimensions 1.0 m by 2.0 m.
   a) What is the resultant displacement of the book?
   b) What is the distance travelled by the book?

Answer: 1) 135 km, 85km forward 2) 0 m, 6 m

Speed vs Velocity

Speed (v): change in distance per time

$V = \frac{d}{t}$ ← distance (m)

(m/s) ← time (sec)

- Speed is a scalar

Velocity ($\vec{v}$): change in position (displacement) per time

Avg Velocity $\vec{V} = \frac{\vec{d}}{t}$

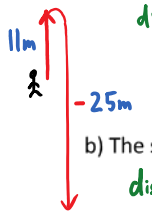
$\vec{d} = \vec{V} \cdot t$

$t = \frac{\vec{d}}{\vec{V}}$

- Velocity is a vector

Ex1): A student travels 11 m north and then turns around and travels 25 m south. If the total time of travel is 12 s, find:

a) The student's average speed.



dist = 11 m + 25 m = 36 m

$V = \frac{d}{t} = \frac{36\text{m}}{12\text{s}} = 3\text{ m/s}$ (speed)

b) The student's average velocity.

displacement = 11 m − 25 m = −14 m

$\vec{V} = \frac{\vec{d}}{t} = \frac{-14\text{m}}{12\text{s}} = -1.17\text{ m/s}$

1.17 m/s [S]

1) How long does it take a car traveling at 45km/h to travel 100.0 m?

45 km/h → (÷3.6) 12.5 m/s

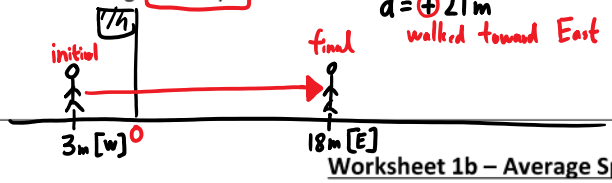
$t = \frac{\vec{d}}{\vec{V}}$ $t = \frac{100\text{ m}}{12.5\text{ m/s}} = 8\text{ sec}$

2) How far does a skateboarder travel in 22 s if his average velocity is 12.0 m/s?

V = 12 m/s, t = 22 s

$V = \frac{d}{t}$ $12 = \frac{d}{22}$ 264 m = d

3) A shopping cart moves from a point 3.0 m West of a flagpole to a point 18.0 m East of the flagpole in 2.5 s. Find its average velocity.



$\vec{d} = +21\text{ m}$ walked toward East

$\vec{V} = \frac{\vec{d}}{t} = \frac{+21\text{m}}{2.5\text{ sec}} = 8.4\text{ m/s [E]}$

Worksheet 1b – Average Speed and Velocity

1. A high school bus travels 240 km in 6.0 h. What is its average speed for the trip? (in km/h)
2. A spider travels across a driveway 3.6 m wide with a speed of 14 cm/s. How long will it take to cross the driveway?
3. A basketball player steals the ball and runs the length of the court in 8.5 sec at a speed of 5.0 m/s. How long is the court?
4. if a car is traveling at 25 m/s, how far does it travel in 1.0 hour?
5. A caterpillar travels across the length of a 2.00 m porch in 6.5 minutes. What is the average velocity of the caterpillar in m/s?

Worksheet 1b – Average Speed and Velocity

6. A motorist traveling on a straight stretch of open highway sets his cruise control at 90.0 km/h. How far will he travel in 15 minutes?

t
× 60 = 900 sec

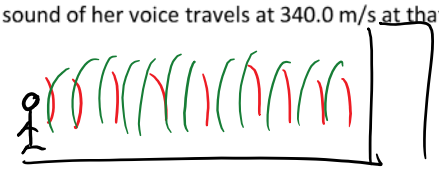
$V = \frac{d}{t}$ $\quad 25 = \frac{d}{900}$

V d=?
÷3.6
25 m/s

d = 22500 m ⇒ 2.25 km

7. A motorcycle travels 90.0 km/h. How many seconds will it take the motorcycle to cover $2.10 \times 10^3\ m$?

8. *A hiker is at the bottom of a canyon facing the canyon wall closest to her. She is 280.5 m from the /wall and the sound of her voice travels at 340.0 m/s at that location. How long after she shouts will she hear her echo?



d = 280.5 × 2 = 561 m
v = 340 m/s

$V = \frac{d}{t}$ $\quad 340 = \frac{561}{t}$ $\quad t = \frac{561}{340}$

t = 1.65 sec

9. **A woman from Pasadena makes a trip to a nearby shopping mall that is located 40.0 km from her home. On the trip to the mall she averages 80.0 km/h but gets a speeding ticket upon her arrival. On the return trip she averages just 40.0 km/h. What was her average speed for the entire trip?

Avg Speed : $V = \frac{\text{Total distance traveled}}{\text{Total time.}} = \frac{80\ km}{1.5\ hr} = 53.3\ km/hr$

Home → mall: 40 km, $V_1 = 80$ km/h
mall → Home: $V_2 = 40$ km/h

$t_1 = \frac{d}{V_1} = \frac{40\ km}{80\ km/h} = 0.5\ hr$

$t_2 = \frac{40\ km}{40\ km/h} = 1\ hr$

10. ***A cross-country rally car driver sets out on a 100.0 km race. At the halfway marker (50.0 km), her pit crew radios that she has averaged only 80.0 km/h. How fast must she drive over the remaining distance in order to average 100.0 km/h for the entire race?

$V_2 = \frac{d_2}{t_2} = \frac{50\ km}{0.375\ hr} = 133\ km/hr$

$V_1 = 80$ km/hr $\quad V_2 = ?$

$V_1 = \frac{d_1}{t_1}$ $\quad 80 = \frac{50}{t_1}$ $\quad t_1 = 0.625$ hr

50 km $\quad$ 100 km

$t_2 = 0.375$ hr

$V_{avg} = 100\ km/h = \frac{\text{Total dist}}{\text{Total time}} = \frac{100\ km}{\text{total time}}$

total time = 1 hr

Ans 1) 40 km/h 2) 26 s 3) 43 m 4) 9×10^4 m 5) 5.1×10^{-3} m/s 6) 23000 m 7) 84 s 8) 1.650 s 9) 53.3 km/h 10) 133 km/h

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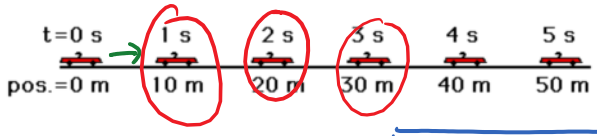
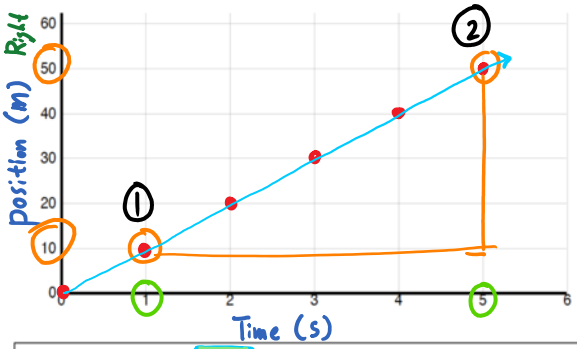
2 – Position-time graph and Velocity-time graph

Position-time ($\vec{d}$-t) graphs show an object's position as a function of time.
Independent variable (x-axis) is time. The dependent variable (y-axis)is position.

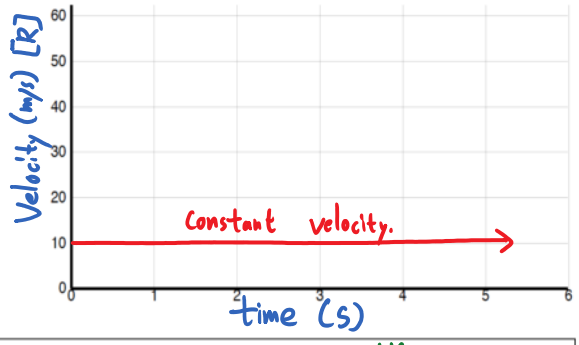


Title.

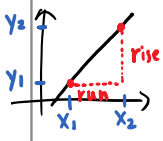
Position vs Time Graph



Velocity vs Time Graph



Lets calculate the slope for the line made by the dots:



slope = $\frac{rise}{run}$ ⇒ $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{40\ m}{4\ s}$

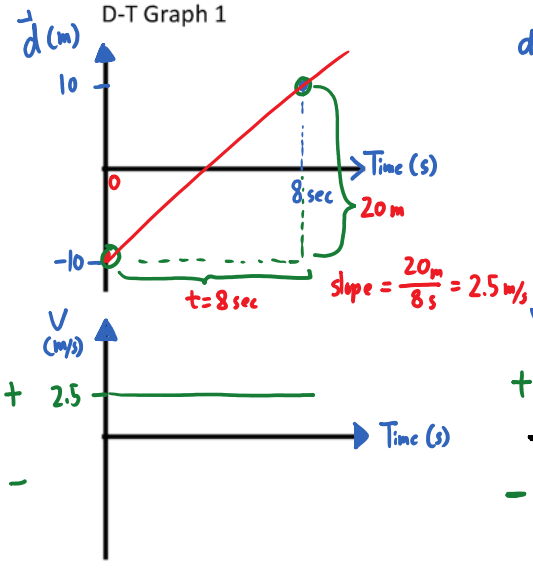
∴ slope = 10 $\frac{m}{s}$ ← velocity !!!

Slope of d-t graph = Velocity !!!!

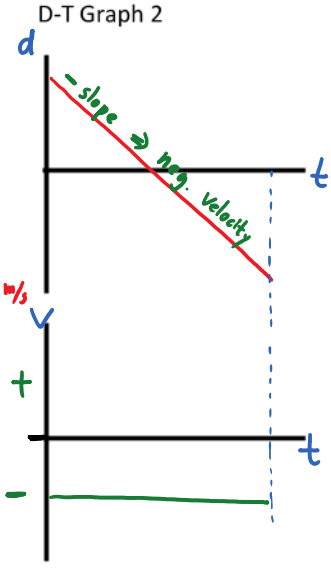
If d-t graph shows a straight line → constant slope → Constant speed/ Velocity

Relating Position-Time Graph to Velocity-Time Graph

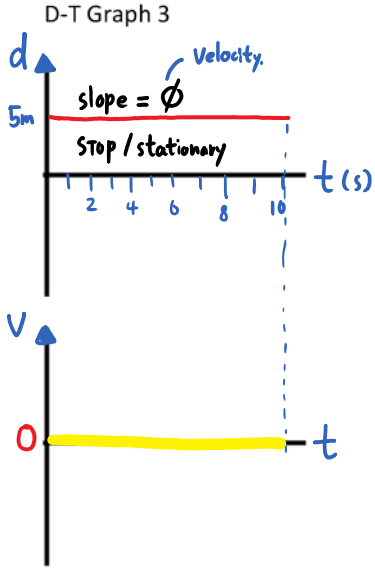
D-T Graph 1



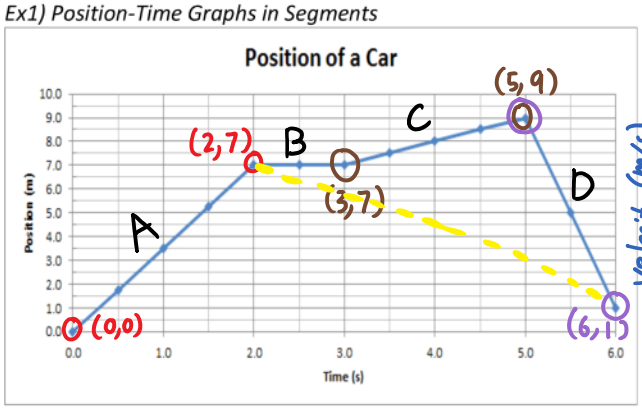
D-T Graph 2

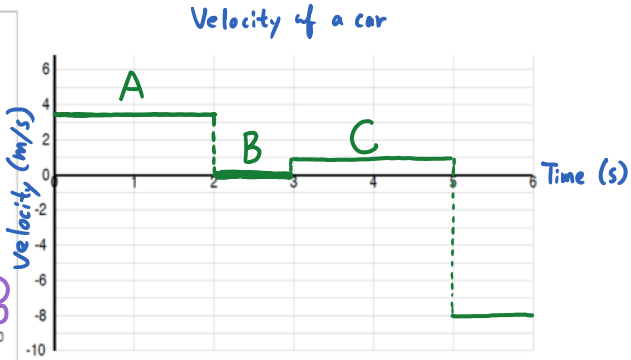


D-T Graph 3



Ex1) Position-Time Graphs in Segments





For practice, find average velocity from:

t = 0s to t = 2s (A)

$V = \frac{7-0}{2-0} = 3.5$ m/s

t = 5s to t = 6s (D)

$V = \frac{9-1}{5-6} = \frac{8}{-1} = -8$ m/s

t = 2s to t = 3s (B)

$V = 0$ m/s

t = 2s to t = 6s

$V = \frac{7-1}{2-6} = \frac{6\text{m}}{-4\text{s}} = -1.5$ m/s

t = 3s to t = 5s (C)

$V = \frac{9-7}{5-3} = \frac{2\text{m}}{2\text{s}} = 1$ m

t = 3s to t = 6s

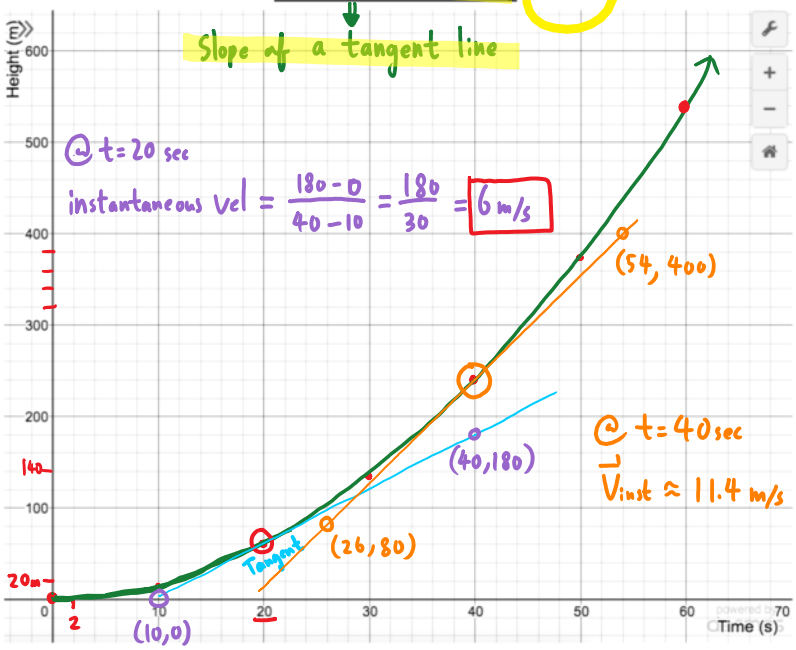
-2 m/s

Ex2) A rocket takes off and the height is recorded as follows.

a) Find the average velocity.

b) Graph the position vs time and find the instantaneous velocity at 20 and 40 seconds.

h (m)	t (s)
0	0
15	10
60	20
135	30
240	40
375	50
540	60

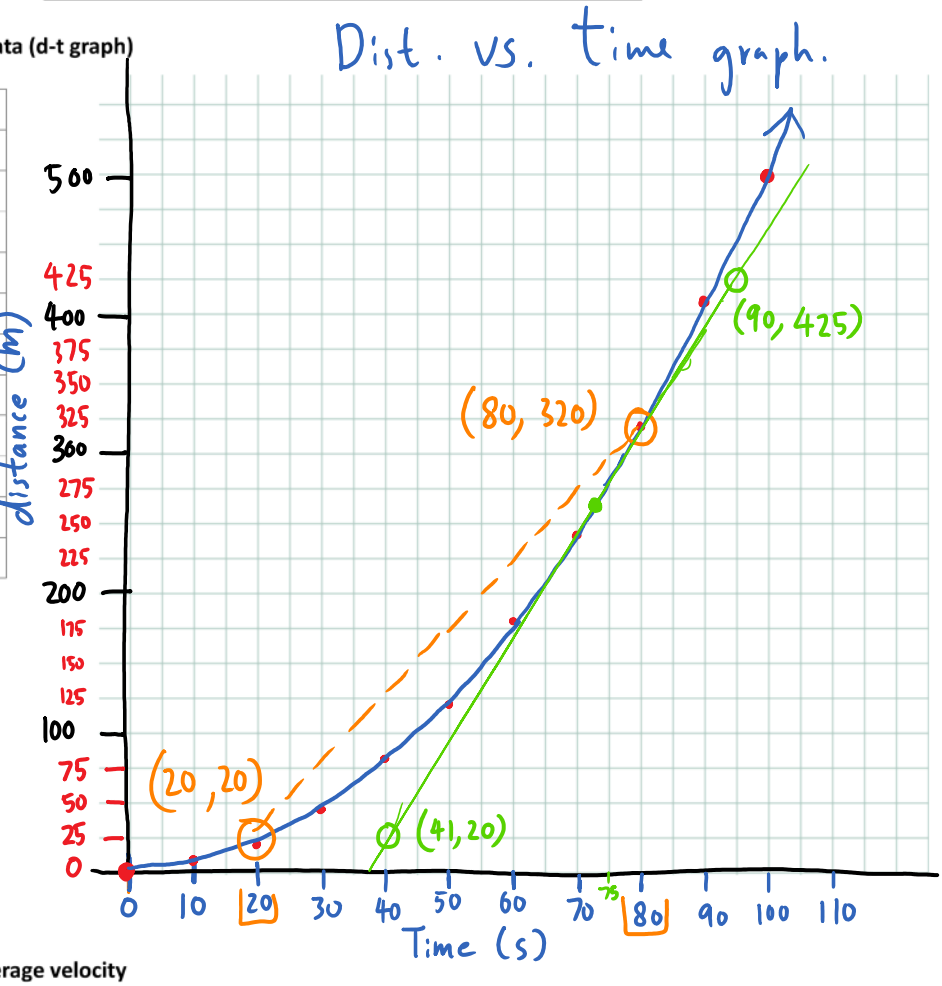


Worksheet 1.2 - Graphing Exercise: D-t graph to Velocity

Part 1: Graph the data (d-t graph)

Data:

d(m)	t(s)
0	0
5	10
20	20
45	30
80	40
120	50
180	60
240	70
320	80
410	90
500	100



Questions:

1. Find the **average velocity**
   a) in the first 20 seconds
   b) from 20 seconds to 80 s
   c) for the whole trip

b) $V = \frac{320-20}{80-20} = \frac{300}{60} = 5\ m/s$

2. Find the **instantaneous velocity** at
   a) 20 seconds,
   b) 40 seconds,
   c) 73 seconds

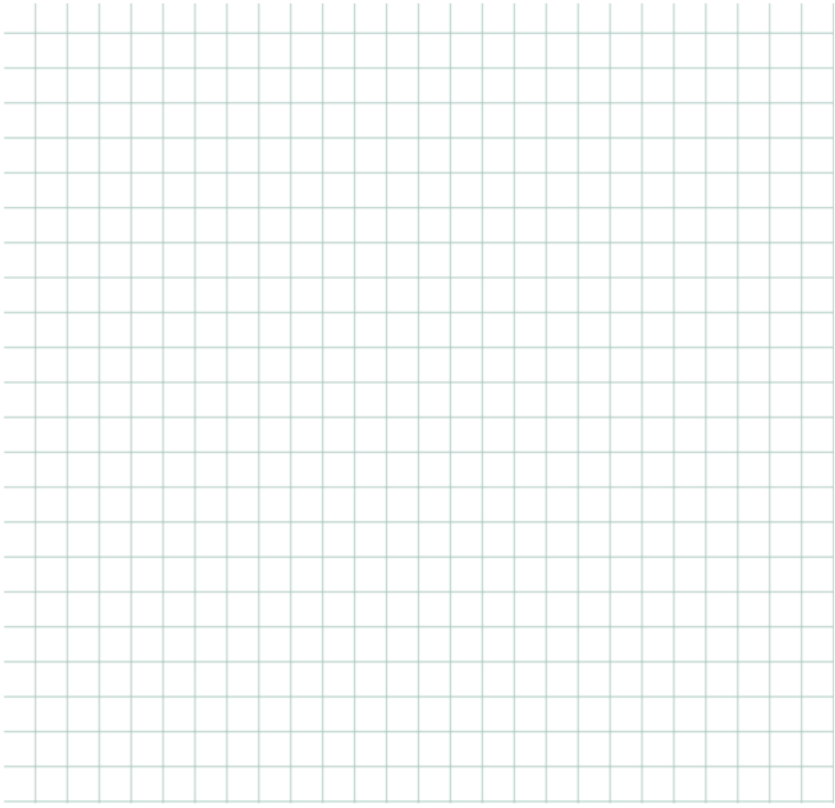
c) $V = \frac{425-20}{90-41} = \frac{405}{49} = 8.3\ m/s$

Answer: 1a) 1m/s b) 5 m/s c) 5 m/s 2a) 2 m/s b) 4 m/s c) 7.3 m/s

Part 2: Graph the data (d-t graph)

Data:

d(m)	t(s)
10	0
13.1	0.5
16	1
18.1	1.5
19.5	2
20	2.5
19.5	3
18.1	3.5
15.9	4
13.1	4.5
10	5
6.9	5.5
4.1	6
1.9	6.5
0.5	7
0	7.5
0.5	8
1.9	8.5
4.1	9
6.9	9.5
10	10



Graph the data

1. Find the average velocity a) in the first 2 seconds, b) from 2 seconds to 8 s, c) for the whole trip

2. Find the instantaneous velocity at a) 1.0 seconds, b) 3.0 seconds, c) 5.0 seconds and d) 1.7 seconds

3. When is the object at rest?

4. When is the object speeding up?

5. Describe the motion of the object in detail

Answer: ***1a) 4.8 m/s. b) -3.2 m/s c) 0 2a) 5 m/s b) -2 m/s c) -7 m/s d) 1.7 m/s***
3) 2.5s and 7.5 s 4) 2.5 → 5 s and 7.5 → 10 s
5. – slows down, stops -speeds up backwards - slows down backwards, stops -speeds up forwards

Physics 11 | **Unit 1: Kinematics in 1D**

3 – Velocity and Acceleration Time Graph

Speed up / slow down

Acceleration

A vector quantity that describes change in velocity. Denoted **a** or $\vec{a}$.

- Conceptually, acceleration is to velocity as velocity is to displacement.
- For this class we will always assume that acceleration is constant
- Note that any object with zero acceleration has constant velocity. ($a = \emptyset$)
- The units of acceleration: m/s/s. This is usually written as m/s^2.

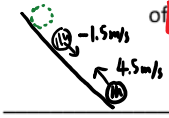
$$\vec{a}_{avg} = \frac{\Delta V}{t} = \frac{V_f - V_i}{t}$$ (final, initial)

$$\vec{v}_{avg} = \frac{\Delta d}{t}$$

unit $\frac{V}{t} \rightarrow \frac{(m/s)}{s} \rightarrow m/s^2$

Example: A child rolls a ball up a hill at 4.5 m/s [forward]. After 5.00 seconds, the ball is rolling back with a velocity of -1.5 m/s [forward]. What is the ball's acceleration?

$V_i = +4.5\ m/s$, $V_f = -1.5\ m/s$, $t = 5\ s$

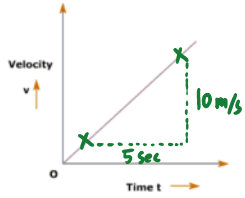


$$a_{avg} = \frac{V_f - V_i}{t} = \frac{-1.5\ m/s - 4.5\ m/s}{5\ sec} = \frac{-6\ m/s}{5\ s} = -1.2\ m/s^2 = 1.2\ m/s^2\ [\text{Down hill}]$$

Velocity-Time Graphs

V (+), a (+)	V (+), a (−)	V (−), a (−)	V (−), a (+)
Speed Up	Slow Down	su in ⊖ dir.	Slow Down

Lets look at the slope calculation for such a graph



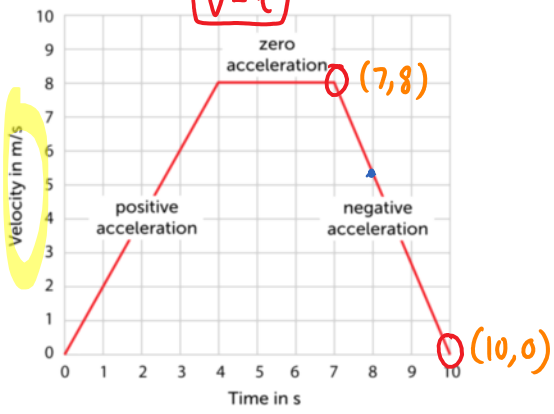
$$m = \frac{rise}{run} = \frac{\Delta y}{\Delta x} = \frac{10\ m/s}{5\ sec} = 2\ m/s^2$$

slope of v-t graph → acceleration

* Slope of d-t graph = Velocity

Slope of V-T graph = Acceleration

V-t



Example: Use the graph to determine...

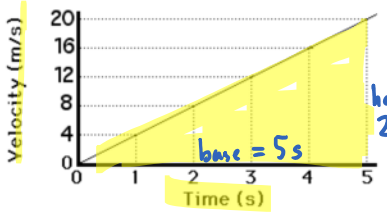
a) Velocity at t = 2s, 5s, 8s?

4 m/s, 8 m/s, 5.3 m/s

b) Acceleration from

t = 0.0 – 4.0s	t = 4.0 – 7.0s	t = 7.0 – 10.0s
$a = \frac{\Delta V}{t} = \frac{8\ m/s}{4\ s}$	$\vec{a} = \emptyset$	$\vec{a} = \frac{8-0}{7-10} = \frac{8}{-3}$
$\vec{a} = 2\ m/s^2$ [forward]		$\vec{a} = -2.7\ m/s^2$

Calculating Displacement from Velocity-Time Graphs



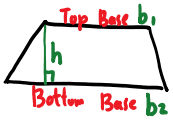
Let's calculating the total area under the curve for the **v**-t graph.

$$\text{Area} = \frac{1}{2} b.h = \frac{1}{2}(5\ s)(20\ m/s) = 50\ s \cdot \frac{m}{s} = 50\ m$$

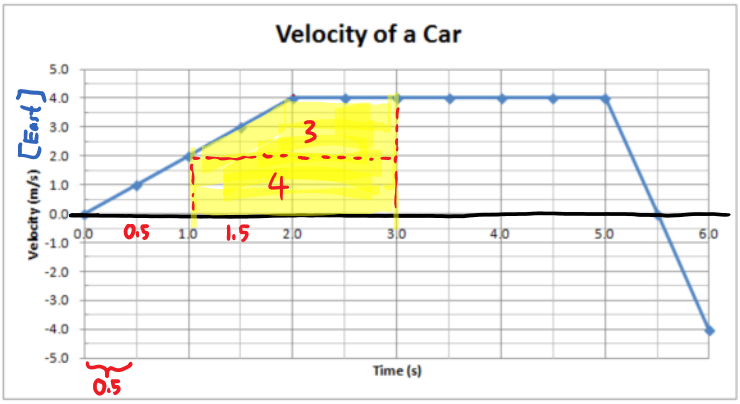
displacement

Area under the V-T graph to the x-axis = displacement

$A_{rectangle} = l \cdot w$ $\quad A_{triangle} = \frac{1}{2} b \cdot h$

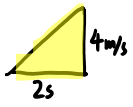
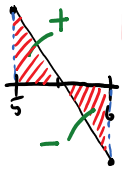


$$A = \frac{(b_1 + b_2) \cdot h}{2}$$

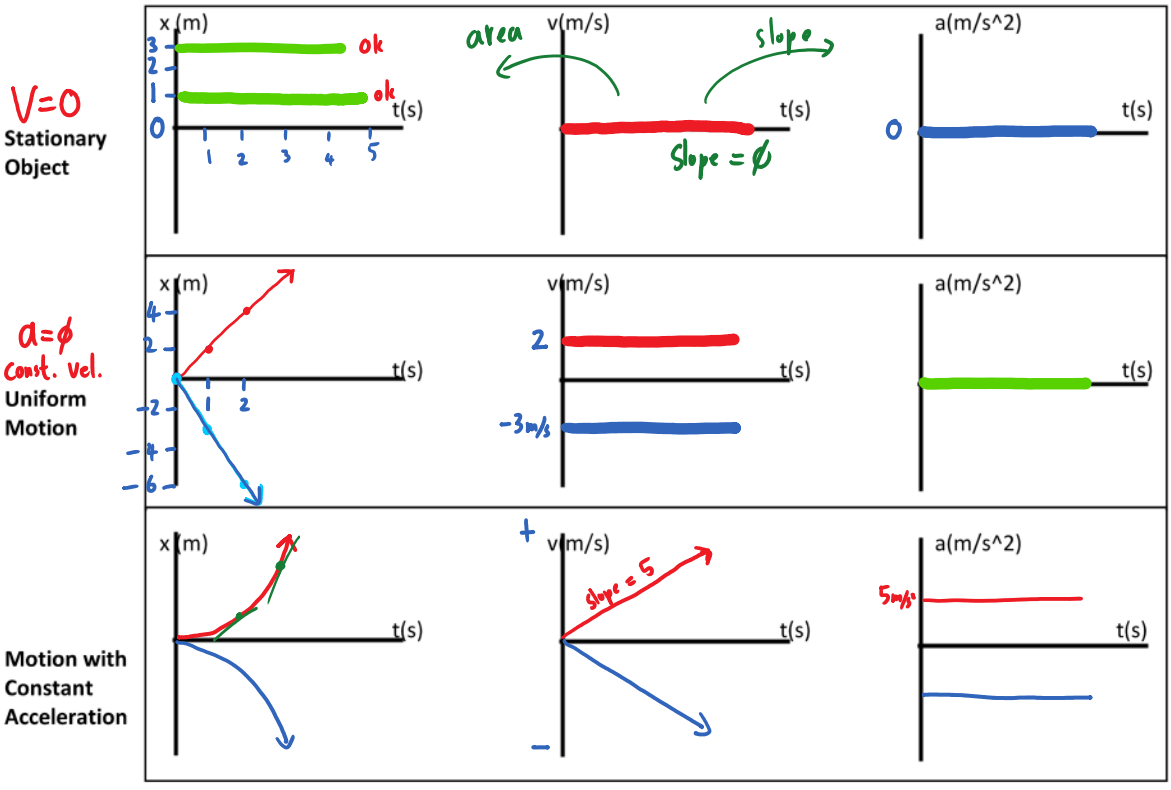


Important!! if part of the graph is below the x-axis under the 0 m/s line (that is, the velocity is negative), the displacement for that segment is also negative.

Example: Find the total displacement of the car whose velocity-time graph is shown above between:

t = 0.0 and t = 2.0	t = 2.0 and t = 5.0	t = 5.0 and t = 6.0	t = 0.0 and t = 6.0
 $\vec{d} = \frac{1}{2}(2)(4) =$ 4m [E]	 $\vec{d} = 3(4) =$ 12m [E]	 $\vec{d} = \emptyset$ m	t=1 and t=3 Try ☺ 7m [East]

From Velocity-Time Graph to Displacement-Time Graph and Acceleration-time graph



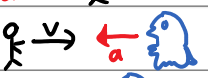
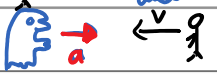
Physics 11 **Unit 1: Kinematics in 1D**

5 – Position, Velocity and Acceleration Graph

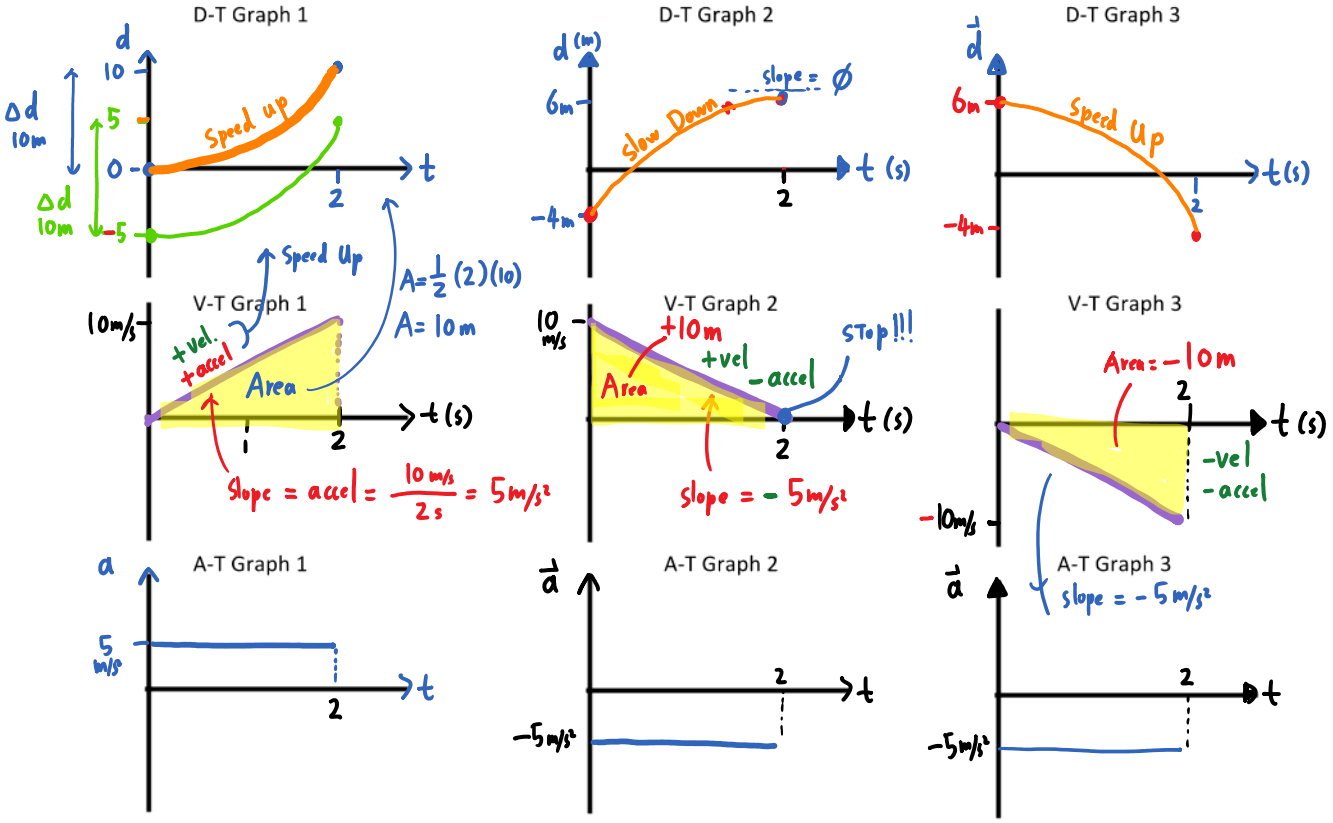
Lets summarize what we have learned about d-t, v-t and a-t graph so f

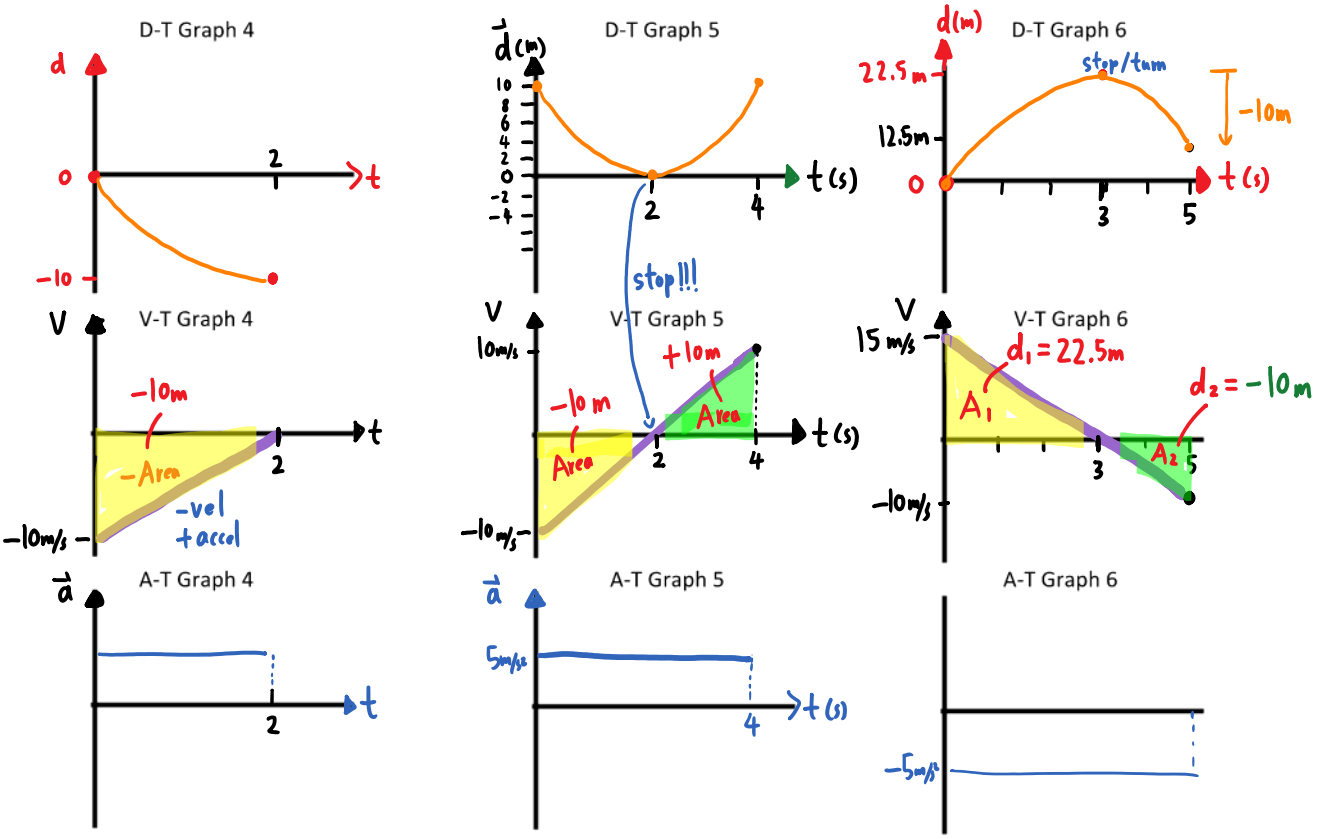
For d vs. t graphs	For v vs. t graphs
• $Slope = \frac{rise}{run} = \frac{displacement}{time} =$	• $Slope = \frac{rise}{run} = \frac{velocity}{time} =$ • $Area\ under\ graph = velocity \times time =$

A) Signs on velocity and acceleration: Speeding up or slowing down?

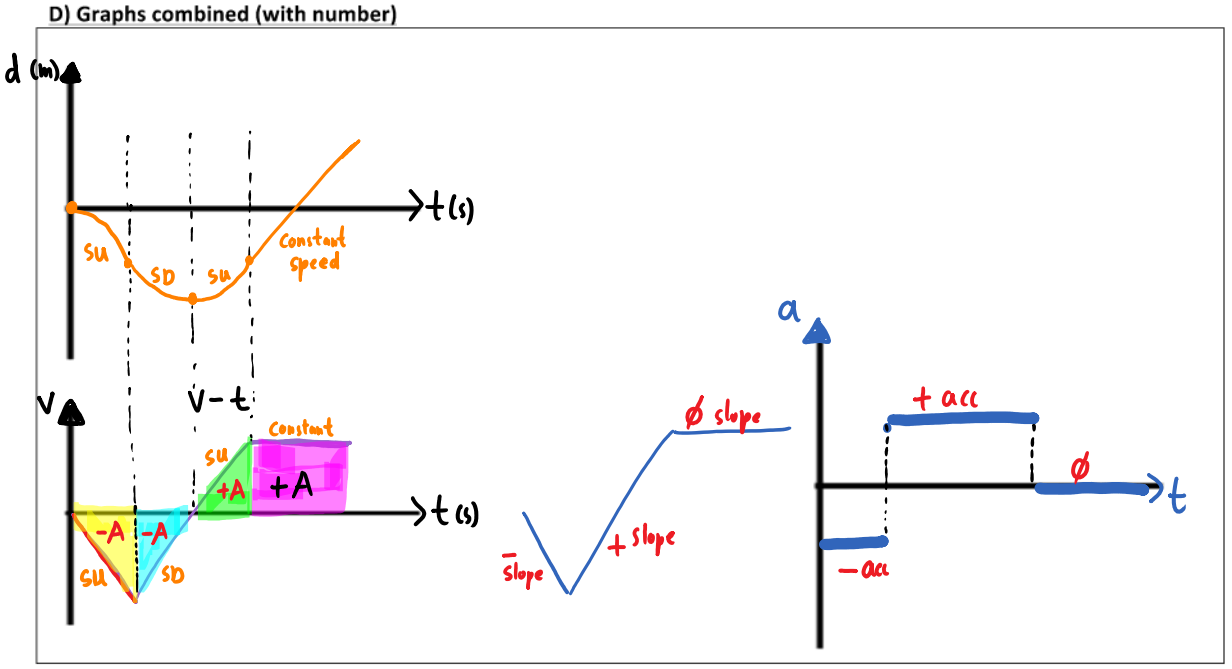
Velocity	Acceleration	Speeding up/down?	Ex.
+	+	SU	
+	−	SD	
−	−	SU	
−	+	SD	

B) From Velocity-Time Graph to Displacement-Time Graph and Acceleration-time graph





D) Graphs combined (with number)



Worksheet 1.3 - V-t graph and acceleration

1. Given the following velocity vs time graph

Find

a) acceleration at 1.0 seconds

b) acceleration at 3.0 seconds

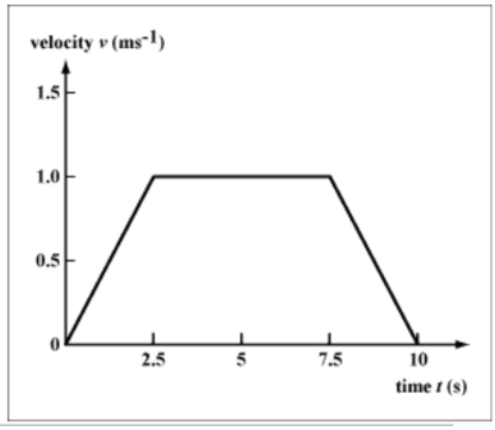
c) acceleration at 7.7 seconds

d) total displacement

e) displacemeny after 5 seconds

f) describe the motion

g) draw a position vs time graph for the motion



2. Given the following velocity vs time graph

Find

a) acceleration at 1.0 seconds

b) acceleration at 3.0 seconds

c) acceleration at 15 seconds

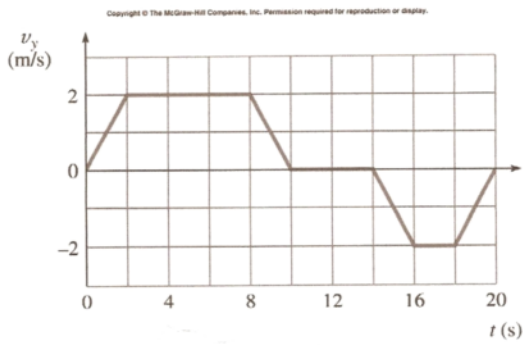
d) total displacement

e) displacemeny after 5 seconds

f) displacemeny after 16 seconds

g) describe the motion

h) draw a position vs time graph for the motion



3. Draw velocity and displacement vs time graphs for the following scenarios

a) A car accelerates from rest then decelerates to a slower constant speed

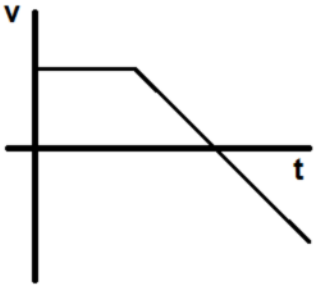
b) An object is thrown upwards and caught on the way down

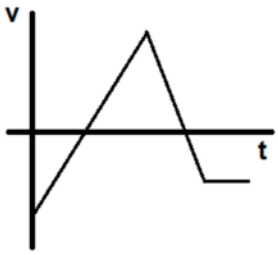
c) A baseball is pitched and hit

d) A wingsuit base jumper makes his jump

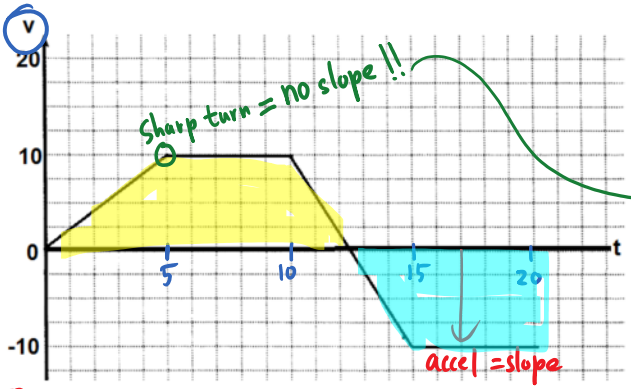
e) An object is dropped from a great height

4. For each v vs t graph: describe the motion in detail and draw the corresponding d vs t graph





5. In the following v vs t graph where each square is 1.0 seconds on the time axis, and v is in m/s



a) the velocity at 2, 7, 10 and 17 seconds

t=2 v= 3.5m/s

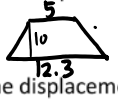
b) the acceleration at 2, 5, 10 and 17 seconds

t=17s a=∅

t=5s a=undefine

c) the displacement for the first 5 seconds

d) the displacement for the first 20 seconds



$A_1 = \frac{(5+12.3)10}{2} = 86.5\,m$

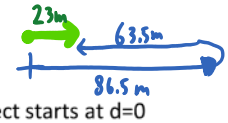
$A_2 = -\frac{(7.7+5)10}{2} = -63.5\,m$

$\therefore$ Total $\vec{d} = 23\,m$

e) the displacement over the final 10 seconds

f) the average velocity

$$V_{avg} = \frac{\text{total displacement}}{\text{total time}} = \frac{23\,m}{20\,sec} = 1.15\,m/s$$



g) draw the corresponding d vs t graph assuming the object starts at d=0

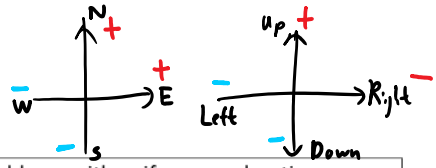
$\vec{a} = \frac{\Delta V}{t}$ $\quad \vec{a}t = V_f - V_i$

$\vec{a}t + V_i = V_f$

Physics 11

Unit 1: Kinematics in 1D

4 – Kinematic Equations: The big three



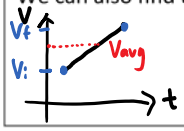
Lets summarize what we have learned about d-t, v-t and a-t graph so far

If an object is accelerating then the formula:

$V = \frac{\Delta d}{t}$ Gives us only the average velocity

$a = \phi$

We can also find the average velocity using:



$V_{avg} = \frac{V_f + V_i}{2}$

In order to solve problems with uniform acceleration we need to use 3 formulae. These 3 formulae use the variables:

v_f = final velocity (m/s) d = displacement (m) → ⊕ or ⊖

v_i = initial vel (m/s) t = time (s) always positive ⊕

a = acceleration (m/s²)

1) $\vec{V_f} = \vec{V_i} + \vec{a}t$

Ex: a car traveling at 7.0 m/s East speeds up to 22.0 m/s East in 1.7 s. What is its acceleration?

$V_i = 7$ m/s

$V_f = 22$ m/s

$t = 1.7$ sec

$a = ?$

$V_f = V_i + at$

$22 = 7 + a(1.7)$

$\frac{15}{1.7} = \frac{1.7a}{1.7}$

$a = 8.8$ m/s² [East]

2) $\vec{d} = \vec{V_i}t + \frac{1}{2}\vec{a}t^2$

Ex: A sprinter starts from rest and accelerates uniformly. He travels 100.0 m south in 9.69 s. What was his acceleration?

$V_i = \phi$

$d = -100$ m

$t = 9.69$ sec

$a = ?$

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

$-100 = \phi + \frac{1}{2}a(9.69)^2$

$-100 = 46.95a$

$a = -2.13$ m/s²

$\vec{a} = 2.13$ m/s² [South]

3) $\vec{V_f}^2 = \vec{V_i}^2 + 2\vec{a}\vec{d}$

Ex: A banana boat accelerates from 15.0 km/h at 2.00 m/s^2. How far has it traveled when it reaches 30.0 km/h?

÷3.6 4.17 m/s ÷3.6 8.33 m/s

$a = 2$ m/s²

$V_i = 4.17$ m/s

$d = ?$

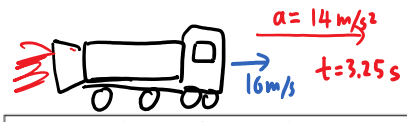
$V_f = 8.33$ m/s

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

$(8.33)^2 = (4.17)^2 + 2(2)d$

$52 = 4d$

$d = 13$ m



Ex 1: A Rocket Truck is traveling at 16.0 m/s when a plane passes it. It immediately hits the jets and accelerates at 14.0 m/s^2 for 3.25 s

	V_i	V_f	a	t	d
$V_f = V_i + at$	✓	✓	✓	✓	
$d = V_i t + \frac{1}{2}at^2$	✓		✓	✓	✓
$V_f^2 = V_i^2 + 2ad$	✓	✓	✓		✓

a) What final velocity does it reach?

$V_i = 16$ m/s
$a = 14$ m/s²
$t = 3.25$ s
$V_f = ?$

$V_f = V_i + at$
$V_f = 16 + 14(3.25)$
$V_f = 61.5$ m/s

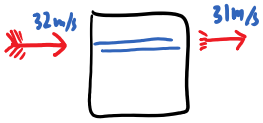
b) how far does it travel in this time?

$d = ?$

$d = V_i t + \frac{1}{2}at^2$
$d = 16(3.25) + \frac{1}{2}(14)(3.25)^2$
$d = 126$ m

Ex 2: An arrow strikes a can at 32.0 m/s and exits at 31.0 m/s. If the arrow is 42 cm long find its acceleration as it pierced the can. Ignore the width of the can.

÷100 ↳ 0.42

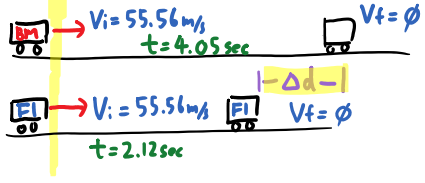


$V_i = 32$ m/s
$V_f = 31$ m/s
$d = 0.42$ m
$a = ?$

$V_f^2 = V_i^2 + 2ad$
$31^2 = 32^2 + 2a(0.42)$
$-63 = 0.84a$
$a = -75$ m/s²

→ ÷3.6 ⇒ 55.56

Ex 3: A BMW and an F1 car both cross the finish line traveling at 200.0 km/h. The BMW comes to a stop in 4.05 s and the F1 in 2.12 s. How much further did the BMW travel while stopping than the F1 car?



BMW

$V_f = V_i + at$
$0 = 55.56 + a(4.05)$
$= -13.72$ m/s²

$d = V_i t + \frac{1}{2}at^2$
$d = 55.56(4.05) + \frac{1}{2}(-13.72)(4.05)^2$
$d = 112.5$ m stopping dist. for BMW

F1

. . . . . .

. . . . . .

. . . . . .

$d = 58.9$ m

$\Delta d = 112.5 - 58.9 = 53.6$ m

Method #2

for both cars: 55.56 m/s (V_i) → 0 m/s (V_f)

$\therefore V_{avg} = \frac{V_i + V_f}{2} = \frac{55.56 + 0}{2}$

$V_{avg} = 27.78$ m/s

BMW: $t = 4.05$ s → $d = V_{avg} t$, $d = 27.78(4.05)$, $d = 112.5$ m

F1: $t = 2.12$ → $d = V_{avg} \cdot t$, $d = 27.78(2.12)$, $d = 58.9$ m

$\Delta d = 53.6$ m

Worksheet 4 - Kinematic Equations

1. A ball rolling down a hill was displaced 19.6 m while uniformly accelerating from rest. If the final velocity was 5.00 m/s. what was the rate of acceleration?

0.638 m/s²

2. A car starts from rest and accelerates uniformly to reach a speed of 21 m/s in 7.0 s. What was the speed of the object after 2.0 seconds?

6.0 m/s

(!!) 3. A bike rider accelerates uniformly at 2.0 m/s² for [illegible] If the rider starts from rest, calculate the distance traveled in the **fourth** second.
(i.e. between t = 3 s and t = 4 s).

$V_i = 0$ $\quad$ $V_i = 11$
$a = 2\ m/s^2$ $\quad$ $a = 11$
$t = 3s$ $\quad$ $t = 4s$
$d_1 = ?$ $\quad$ $d_2 = ?$

7 m

4. If a bullet leaves the muzzle of a rifle at 600.0 m/s, and the barrel is 0.90 m long, what was the acceleration of the bullet while in the barrel?

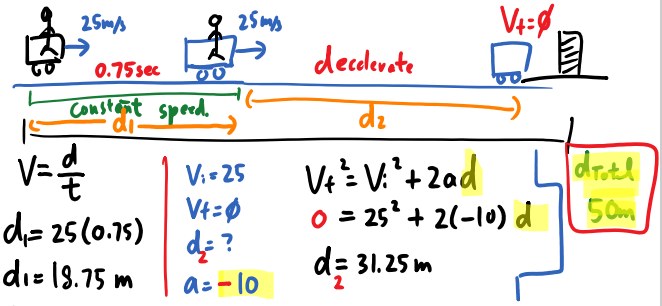
$2x10^5$ m/s

5. The Jamaican bobsled team hit the brakes on their sled so that it decelerates at a uniform rate of 0.43 m/s². How long does it take to stop if it travels 85 m before coming to rest?

20 sec

Bonus: A driver of a car going 90 km/h (25 m/s) suddenly sees the lights of a barrier 40.0 m ahead. It takes the driver 0.75 s before he applies the brakes (this is known as reaction time). Once he does begin to brake, he decelerates at a rate of 10.0 m/s².

a) Does he hit the barrier?

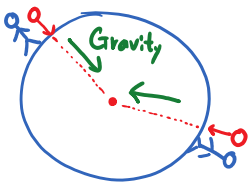


$V = \frac{d}{t}$
$d_1 = 25(0.75)$
$d_1 = 18.75\ m$

$V_i = 25$
$V_f = 0$
$d_2 = ?$
$a = -10$

$V_f^2 = V_i^2 + 2ad$
$0 = 25^2 + 2(-10)\,d$
$d_2 = 31.25\ m$

b) SUPER-BONUS: What would be the maximum speed at which the car could travel and NOT hit the barrier 40.0 m ahead?



① $V_f = V_i + at$ ② $V_f^2 = V_i^2 + 2ad$ ③ $d = V_i t + \frac{1}{2}at^2$

Physics 11

Unit 1: Kinematics in 1D

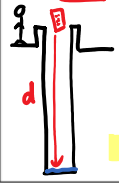
5 – Acceleration Due to Gravity

- In the absence of air friction... all objects accelerate at the same rate.
- Near Earth's surface the acceleration is

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

↑acceleration due to gravity.

Example: A student drops their homework down a wishing well. After 2.4 s it hits the water at the bottom. How deep is the well?



$V_i = 0$, $t = 2.4$, $d = ?$, $a = -9.8\ m/s^2$

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

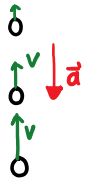
$d = \frac{1}{2}(-9.8\ m/s^2)(2.4)^2$

$d = -28\ m$ down

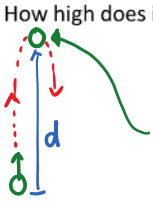
The well is 28 m deep

Example:
A football is kicked straight up in the air at 15 m/s.

max height $V = 0$



a) How high does it go?



$V_i = +15\ m/s$, $a = -9.8\ m/s^2$, $V_f = 0$ *@ max height, $d = ?$

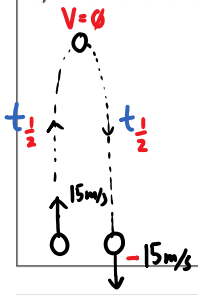
$V_f^2 = V_i^2 + 2ad$

$0 = 15^2 + 2(-9.8)d$

$-225 = -19.6\,d$

$d_{max} = 11.5\ m$

b) What is its total hangtime? / airtime.



Method #1

$V_i = 15$, $a = -9.8$, $t_{\frac{1}{2}} = ?$, $V_f = 0$ max height

$V_f = V_i + at$

$0 = 15 + (-9.8)t$

$t_{\frac{1}{2}} = 1.53$ sec ×2

∴ Total $t = 3.06$ s

Method #2

$V_i = 15\ m/s$, $a = -9.8$, $t = ?$, $V_f = -15\ m/s$

$V_f = V_i + at$

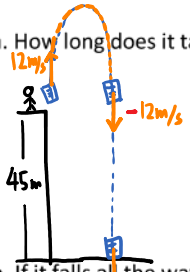
$-15 = 15 + (-9.8)t$

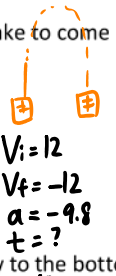
$-30 = -9.8\,t$

$t = 3.06$ s

Example: A student stands on the edge of a 45.0 m high cliff. They throw their physics homework straight up in the air at 12.0 m/s.

a. How long does it take to come back down to the same height as the student?





$V_i = 12$, $V_f = -12$, $a = -9.8$, $t = ?$

$V_f = V_i + at$

$-12 = 12 + (-9.8)t$

$-24 = -9.8\,t$

$t = 2.45$ sec

C) Airtime Option 1

$d = -45\ m$, $V_i = 12$, $a = -9.8$, $t = ?$

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

$-45 = 12t + \frac{1}{2}(-9.8)t^2$

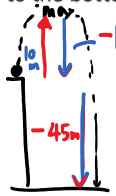
$0 = -4.9t^2 + 12t + 45$

$0 = ax^2 + bx + c$

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

b. If it falls all the way to the bottom of the cliff, how fast is it traveling when it hits the ground?

$V_i = 12$, $V_f = ?$, $a = -9.8$, * $d = -45\ m$



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

$V_f^2 = 12^2 + 2(-9.8)(-45)$

$V_f^2 = 1026$

$V_f = -32.03\ m/s$

(down !! force a negative)

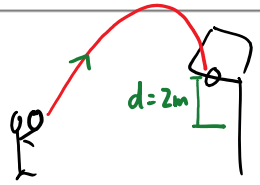
C) Air time.

$V_f = V_i + at$

$-32.03 = 12 + (-9.8)t$

$t = 4.5$ sec

* To get total time: 1st get V_f 2nd $V_f = V_i + at$ for time.



Worksheet 1.5 – Uniform Accelerated Motion

1) Bumblebee jumps straight upwards with a velocity of 14.0 m/s. What is his displacement of after 1.80 s?

(9.32 m)

2) A surprisingly spherical decepticon is rolled up a constant slope with an initial velocity of 9.3 m/s. What is the acceleration of the decepticon if its displacement is 1.9 m up the slope after 2.7 s?

($-6.4 m/s^2$)

3) Optimus Prime coasts up a hill initially at 11.0 m/s. After 9.3 s he is rolling back down the slope at 7.3 m/s. What is his acceleration?

($-2.0 m/s^2$)

4) Sonic (you know, the Hedgehog) rolls up a slope at 9.4 m/s. After 3.0 s he is rolling back down at 7.4 m/s. How far up the hill is he at this time?

(3.0 m)

5) Luigi jumps straight upwards at 15.0 m/s. How high is he when he is travelling at:

a) 8.0 m/s upwards?

(8.2 m)

b) 8.0 m/s downwards?

(8.2 m, weird huh?)

6) Sick of his guff, Optimus decides to throw Megatron down off the top of a building at 5.0 m/s. Megatron hits the ground traveling at 32.0 m/s.
a. How long does it take to hit the ground?

(2.8 s)

b. How far does he fall?

(- 51 m)

7) Mario rolls a coin up a slope at 2.0 m/s. It travels 2.7 m, comes to a stop and rolls back down. What is the coin's entire time of travel?

(5.4 s)

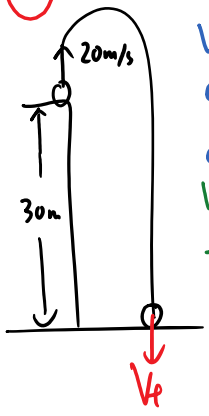
8) While strolling along on Planet X an astronaut decides to throw a hammer and a feather upwards at 5.0 m/s. They both return to the point of release in 3.0 s. What is the acceleration due to gravity on Planet X.

(-3.3 m/s^2)

9) Princess Toadstool stands on the edge of a 30.0 m high cliff. She throws Bowser upwards at 20.0 m/s. If Bowser falls all the way to the bottom of the cliff, find:
a. his velocity when he hits the ground.

(-31.4 m/s)

b. the time it takes to hit the ground.



$V_i = 20\ m/s$
$a = -9.8\ m/s^2$
$d = -30\ m$
$V_f = -31.43\ m/s$
$t =$

$V_f^2 = V_i^2 + 2ad$
$V_f^2 = 20^2 + 2(-9.8)(-30)$
$V_f = -31.43\ m/s$

$V_f = V_i + at$
$-31.43 = 20 + (-9.8)t$
$-51.43 = -9.8t$

(5.24 s)