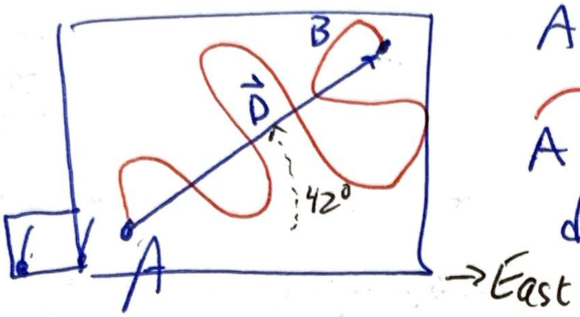
Chapter 2

1-Dimimsional Kinematics

all motion is constrained to a straight line

⊛ Distance vs. Displacement

Dog Park



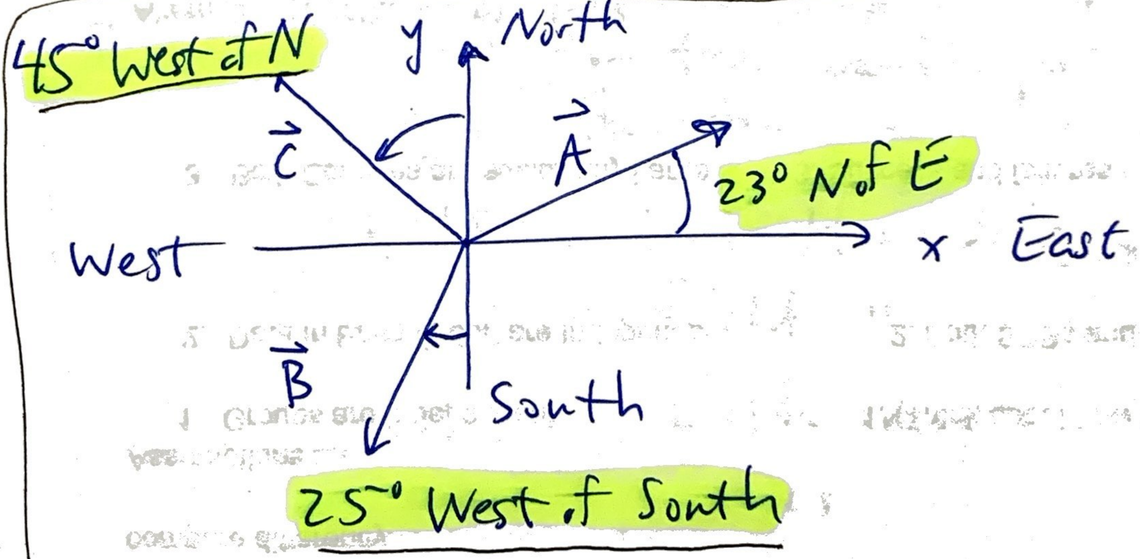
$\vec{AB}$ is displacement

$\overset{\frown}{AB}$ is distance your dog travels.

$\vec{D}$ = vector = magnitude and direction

$\vec{D} = \vec{AB}$

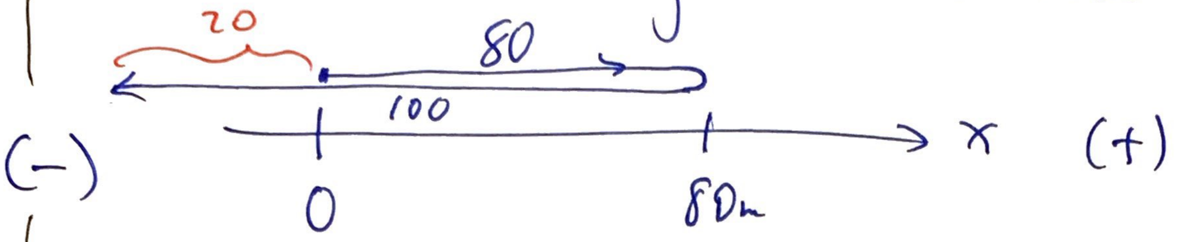
Ex : $\boxed{\vec{D} = 23\,m \text{ @ } 42° \text{ North of East.}}$



Vectors to be discussed Later !!

Ex A runner runs East for 80km then they turn 180° and run West for 100m.

(a) How far did they run? 80+100 = $\boxed{180\text{ m}}$



(b) what is their displacement?

magnitude : 100−80 = 20
direction : West.

$\boxed{\vec{D} = 20\text{m West}}$

-OR- we can use a negative sign to denote the direction

$\boxed{-20\text{m}}$

I use (+) for the word positive
(−) for the word negative

LHS = Left Hand Side
RHS = Right " "
w.r.t. = with respect to
"$\Rightarrow$" = implies

⊛ Speed vs. Velocity

- Speed is the distance, s, divided by time, t.

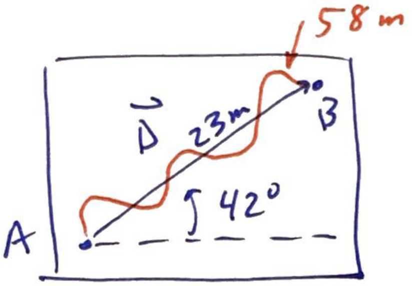
$$\boxed{v = s/t}$$

scalar

- velocity is the displacement, $\vec{D}$, divided by t

$$\boxed{\vec{v} = \vec{D}/t}$$

EX



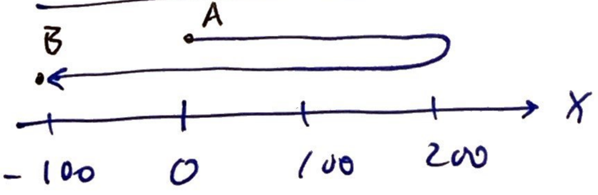
t = 10 s to travel from A to B

$$v_{dog} = \frac{58m}{10s} = \boxed{5.8\,m/s \text{ (scalar)}}$$

$$\vec{v}_{\substack{me\\dog}} = \frac{23m}{10s} = \boxed{2.3\,m/s \text{ @ } 42° \text{ N of E}}$$

$\vec{v}_{ave}$ = average velocity of both of us is 2.3 m/s

EX A cyclist rides 200m E then turns and runs 300 m W. If the entire trip to 60 s what is the (a) ave. speed (b) ave velocity?



$$\text{(a) } v_{ave} = \frac{\Delta s}{\Delta t} = \frac{200+300}{60s} = \boxed{8.33\,m/s}$$

$$\text{(b) } \vec{v}_{ave} = \frac{\vec{D}}{t} = \frac{\text{Final location - Initial}}{\text{time}} = \frac{(-100m)-(0m)}{60s}$$

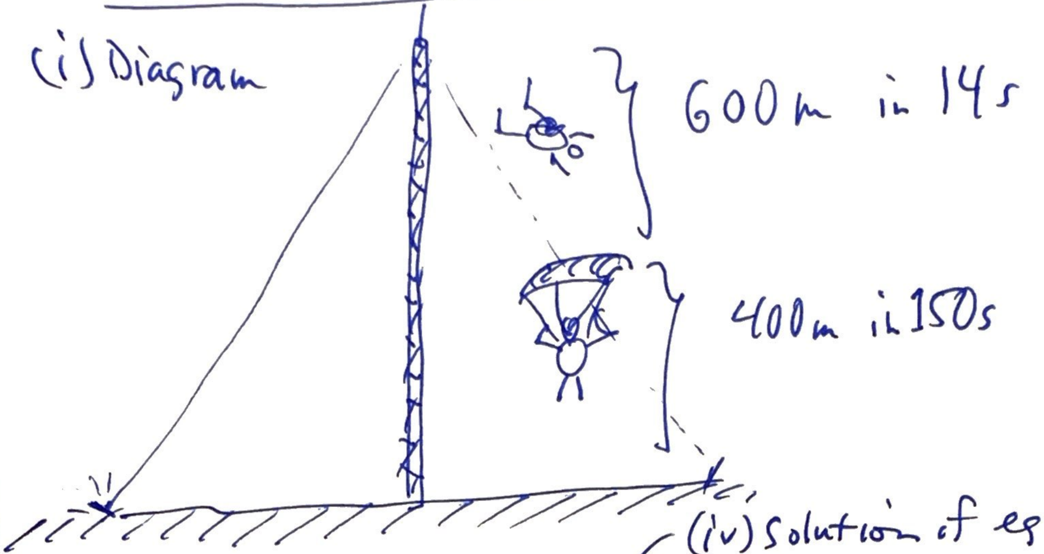
$$= \boxed{-1.67\,m/s}$$

OR 1.67 m/s west

Ex Vertical Motion

A base jumper jumps off of a 1000m high antenna. She free falls 600m 14s and then pulls her shut. She floats 400m and lands 150 s after pulling her parachute. What is the ave speed for the entire jump?

(i) Diagram



(ii)

(iv) solution of eqns.

(iii) eqns

$$V_{ave} = \frac{\Delta s}{\Delta t} = \frac{600+400}{14+150} = \frac{1000\,m}{164\,s} = \boxed{6.10\,m/s}$$

BTW: free fall $= \frac{600\,m}{14\,s} = 42.9\ m/s$

float $= \frac{400\,m}{150\,s} = 2.7\ m/s$

approx

43 m/s

↓

3 m/s

Ex Examples of Speed

Runner : 7 m/s

Car : 25 m/s { 60 m/hr = 88 ft/s ≈ 90 ft/s ≈ $\frac{30\,m}{s}$ }

Jet : 300 m/s {Mach 0.9} Speed of Sound 343 m/s

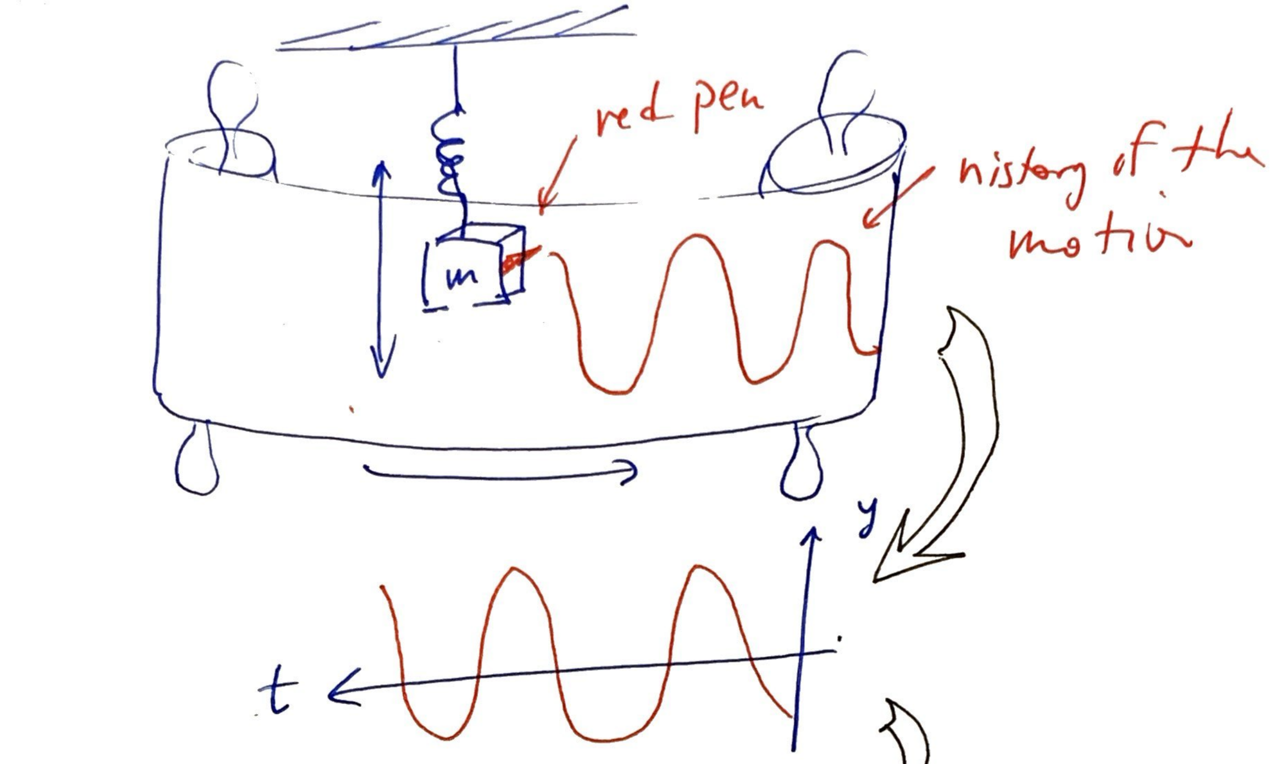
Int'l Space Station : 17,500 mi/hr ≈ 20,000 m/s

Light : 3×10^8 m/s = 300,000,000 m/s

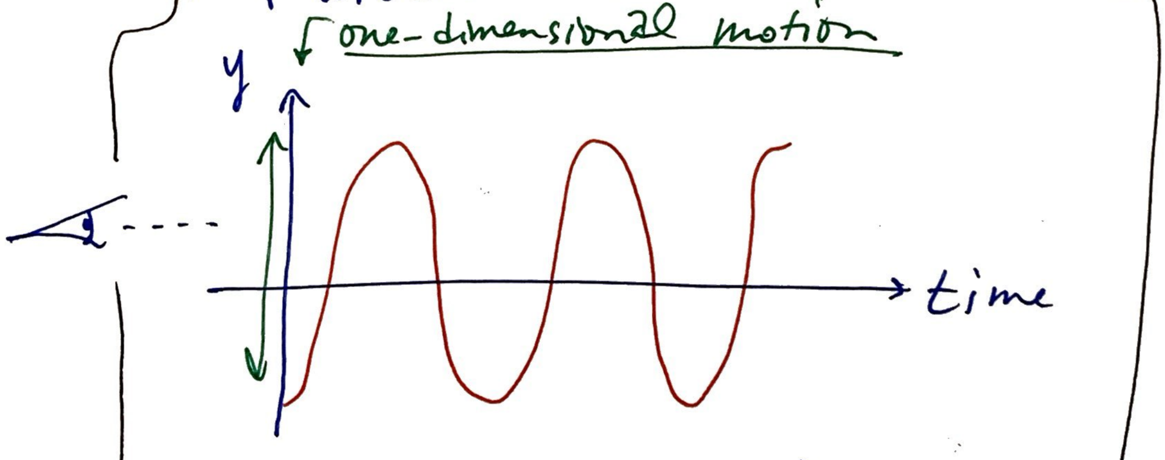
((300 million meets in one second.))

⊛ Plotting speed vs. time

Consider a spring mass hanging from the ceiling

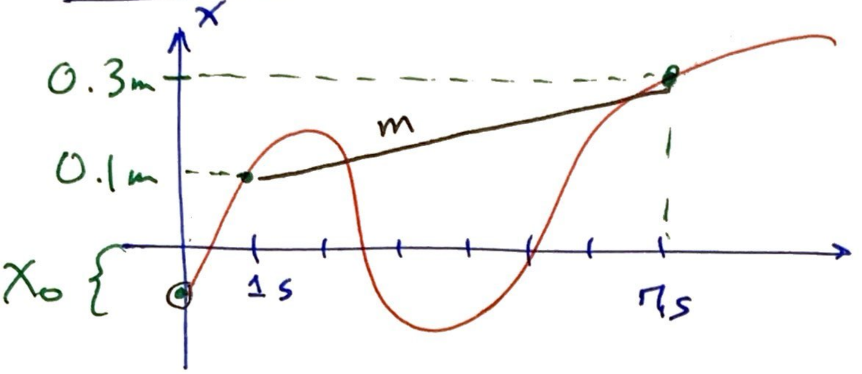


• Flip around



Displacement vs. time

EX Consider the plot below. Calculate the average speed between the time 1s to 7s



- $y = \overset{\text{slope}}{m}x + b$

$$\boxed{x = Vt} + x_0$$

$$m = \frac{\Delta x}{\Delta t} = V$$

$$V_{ave} = \frac{\Delta x}{\Delta t}$$

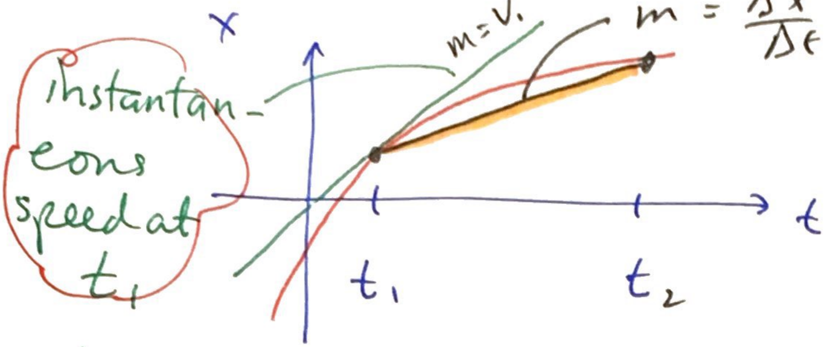
$$= \frac{x_f - x_i}{t_f - t_i}$$

$$= \frac{0.3\,m - 0.1\,m}{7\,s - 1\,s}$$

$$= \frac{0.2\,m}{6\,s}$$

$$= \boxed{0.033\,m/s}$$

⊛ average speed (velocity) vs. instantaneous speed (velocity)



m = $\frac{\Delta x}{\Delta t}$ = ave. speed.

slope of chords.

↳ slope of the tangent line   Calculus

$$V_{inst} = \lim_{t_2 \to t_1} \frac{\Delta x}{\Delta t} = \frac{d\,x(t)}{dt}$$

⊛ acceleration

- Just as the change of position w.r.t. time is the speed (velocity)

Acceleration is the change in velocity w.r.t. time

$$V = \frac{\Delta s}{\Delta t}$$ → rate of change of position

$$\boxed{a = \frac{\Delta v}{\Delta t}}$$ → rate of change of speed.

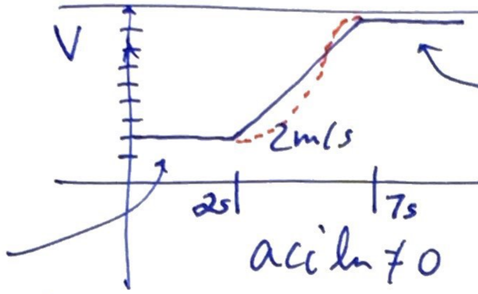
- Acc'ln is the result of an applied force.

Newton's 1st Law : object has const. speed if no forces

3rd Law : acc'ln is proportional to force applied

I.E: Acc'ln comes from Fo (Ch4) $\boxed{F=ma}$

Ex A sail boat is travelling at 2m/s E when a gust of wind speeds the boat up to 8m/s If 5secconds elapsed between between these speeds what is the acc'ln ?



level speed (constant speed) = 0 acc'ln

level ⇒ 0 acc'ln

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

final   initial

$$a = \frac{V_f - V_0}{t_f - t_0}$$

$$= \frac{8m/s - 2m/s}{7s - 2s}$$

$$= \frac{6\,m/s}{5s}$$

0.8m/s change every second

$$= \boxed{1.20\,m/s}/s$$

$$= \boxed{1.20 m/s^2}$$

dimension of a quantity

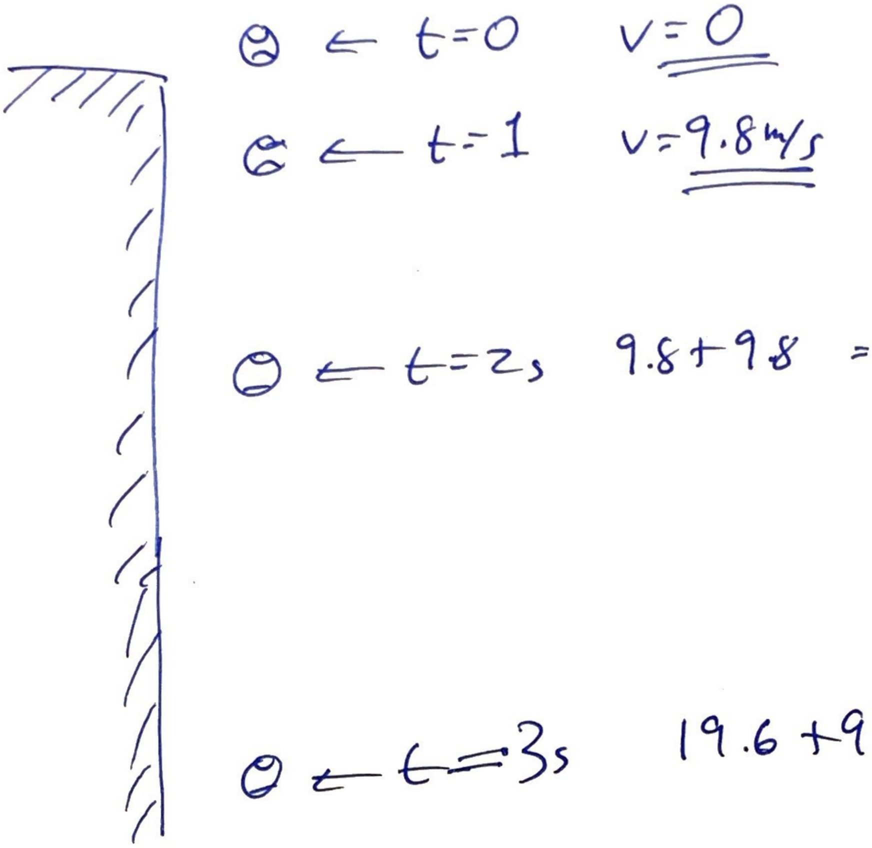
$$[a] = \frac{m}{s^2}$$

Better to think : $[a] = \frac{\overset{\text{speed}}{m/s}}{\underset{\text{time}}{s}}$

ex: $3\,m/s^2$

= 3m/s increase in speed EVERY 1 sec time

EX a falling ball



$t=0$ $\quad v=0$

$t=1$ $\quad v=9.8\,m/s$

$t=2s$ $\quad 9.8+9.8=19.6\,m/s$

$t=3s$ $\quad 19.6+9.8=29.4\,m/s$

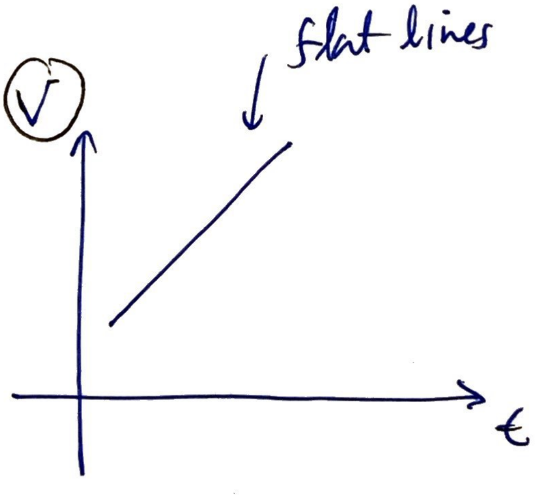
$a_{gravity}=g=9.8\,m/s^2$

B/c we increase speed 9.8 m/s every second.

⊛ In this class we assume constant acc'ln in most problems with non-constant speeds {kinematic chapters}

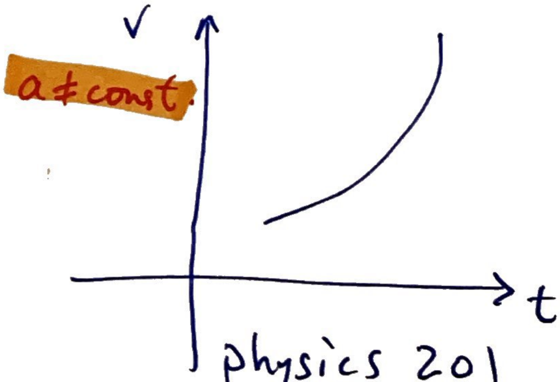
This means

$a=const.$



phys 06

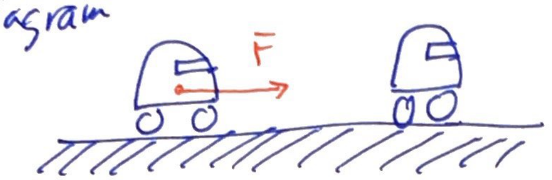
otherwise we need calculus



physics 201

EX A car acc'lts from 8 m/s to 20 m/s in 8s. What is the ave. acc'ln?

(i) Diagram



$t=0$ $\quad$ $t=8s$

$V_0 = 8 m/s$ $\quad$ $V_f = 20 m/s$

(ii) Free-Body Force Diagram

(iii) Formula $\quad$ (iv) Do the math

$$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{20 \, m/s - 8 \, m/s}{8 \, s} = \frac{12 \, m/s}{8 s} = \underline{\underline{1.5 \, m/s}}/s$$

we increase our speed by 3 m/s every second

or $\boxed{\underline{1.5 \, m/s^2}}$

$$\frac{\frac{a}{b}}{c} = \frac{a}{bc}$$

chart out speed

$t=0$	8m/s	+1.5
$t=1$	9.5 m/s	1.5
$t=2$	11.0 m/s	1.5
$t=3$	12.5 m/s	⋮
$t=4$	14.0 m/s	
$t=5$	15.5 m/s	
$t=6$	17.0 m/s	
$t=7$	18.5 m/s	
$t=8$	$\boxed{20.0 \, m/s}$	

—OR— use formula

$$\boxed{v = at + v_0}$$

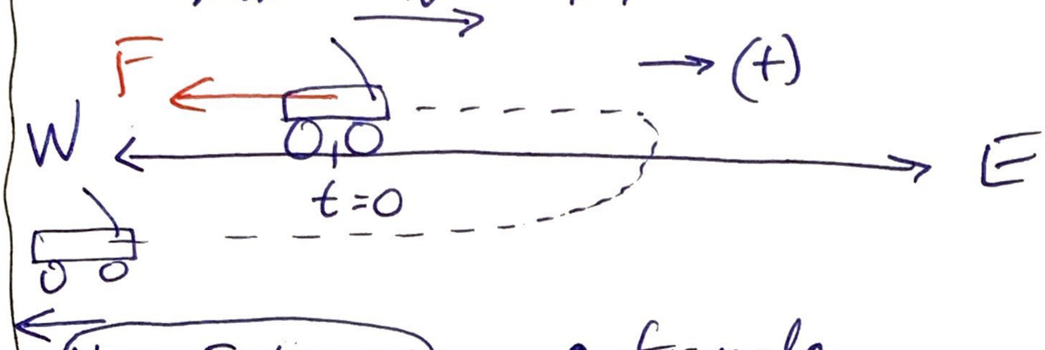
$$V(8) = (1.5 \, m/s^2)(8s) + 8 \, m/s$$

$$= 12.0 \, m/s + 8 \, m/s$$

$$= \boxed{20.0 \, m/s}$$

EX A wagon moving east at 20 m/s encounters a very strong head wind slowing it down and reversing its direction. After 5s it is traveling West at 5 m/s. What is the average acc'ln?

- diagram $V_0 = 20\,m/s$, east



$V_f = 5\,m/s$, west

$t_f = 5s$

velocity

time

- formula

$$a_{ave} = \frac{\Delta v}{\Delta t}$$

$$a_{ave} = \frac{V_f - V_0}{t_f - t_0} = \frac{(-5\,m/s) - (20\,m/s)}{5s - 0s}$$

$$= \frac{-25\,m/s}{5s}$$

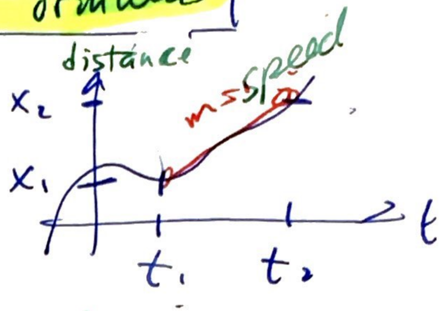
$$= -5\,m/s/s$$

$$= \boxed{-5\,m/s^2} \text{ acc'ln}$$

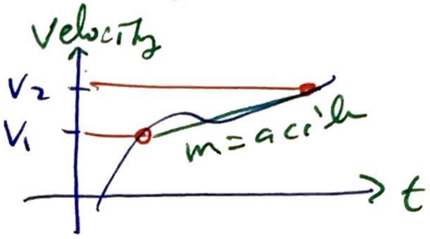
going West.

1-Dim Kinematic Formulas

$$\boxed{V_{ave} = \frac{\Delta x}{\Delta t} = \frac{X_2 - X_1}{t_2 - t_1}}$$



$$\boxed{a = \frac{\Delta v}{\Delta t} = \frac{V_f - V_i}{t_f - t_i}}$$



we typically set $t_i = 0$ & $t_2 = t_{final}$

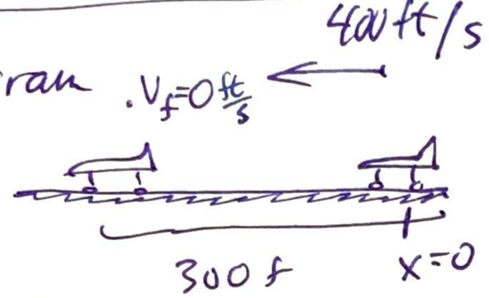
$$\boxed{V_{ave} = \frac{V_0 + V_f}{2}} \qquad \boxed{X_f = X_0 + \left(\frac{V_0 + V_f}{2}\right) t}$$

$$\boxed{V_f = V_0 + at} \qquad \boxed{X_f = X_0 + V_0 t + \frac{1}{2} a t^2}$$

$$\boxed{2a\left(x_f - x_0\right) = V_f^2 - V_0^2}$$

EX A jet flying at 400 ft/s lands on an aircraft carrier and comes to a stop in in 300f. Q: What is the acc'ln?

- diagram



$(+) \longleftarrow$

- data

initial	final
$V_0 = 400$ ft/s	$V_f = 0$ ft/s
$X_0 = 0$	$X_f = 300$ ft

$a_{ave} = ?$

- formula: use $2a(X_f - X_0) = V_f^2 - V_0^2$ since it does not use time.
- populate:

$$2a(300\,ft - 0\,ft) = \left(0\,ft/s\right)^2 - \left(400\,\frac{ft}{s}\right)^2$$

$$a = \frac{-400^2}{2 \cdot 300}$$

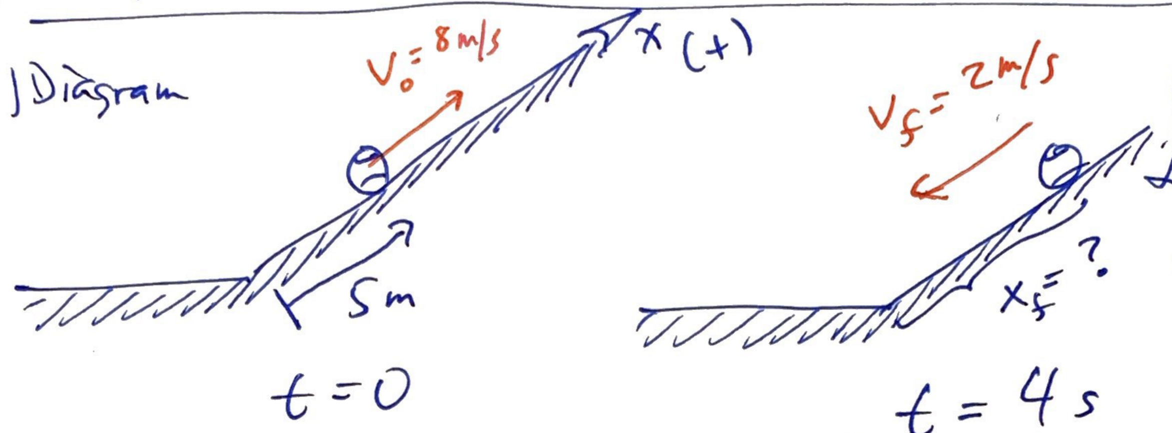
$$\boxed{a = -267\ ft/s^2}$$

decellerating 26ft/s slower every second.

Ex A ball is 5m from the bottom of a ramp but is rolling upwards @ 8m/s. Four seconds later we measure the ball to moving @ 2m/s towards the bottom of the ramp.

(a). How far is the ball from the bottom of the ramp?

(i) Diagram



Variables

$V_0 = 8m/s$

$V_f = -2m/s$

$t_0 = 0s$

$t_f = 4s$

$x_0 = 5m$

$x_f = ?$

(ii) Force diagram (skip in chpt 2&3)

(iii) Equations

$$\boxed{\overset{?\text{ want}}{x_f} = \overset{5m}{x_0} + \left(\frac{\overset{8m/s}{V_0} + \overset{-2m/s}{V_f}}{2}\right)\overset{4s}{t}}$$

(iv) Populate eqn and solve for desired variables
{Do the math}

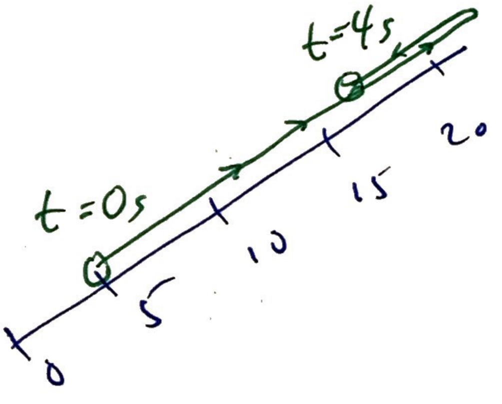
$$x_f = 5m + \left(\frac{8\frac{m}{s} + (-2)\frac{m}{s}}{2}\right)(4s)$$

$$= 5m + \frac{6m/s}{2} \cdot 4s$$

$$= 5m + 3m/\cancel{s} \cdot 4\cancel{s}$$

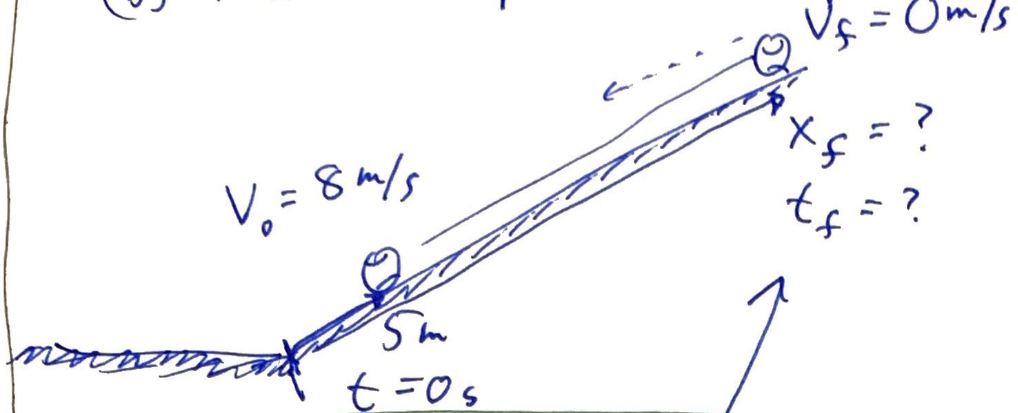
$$= 5m + 12m$$

$$= \boxed{17m \text{ up the ramp}}$$



EX cont.

(b) How far up the ramp did the ball go?



$$\begin{cases} V_0 = 8\,m/s \\ V_f = 0\,m/s \\ X_0 = 5\,m \\ X_f = ? \end{cases}$$

we are missing t_f or a

⊛ we need to calculate one or the other ⊛

Lets use part (a) to get acc'ln, a:

$$\begin{cases} V_0 = 8\,m/s & t_0 = 0 \\ V_f = -2\,m/s & t_f = 4s \end{cases}$$

so use $\boxed{V_f = V_0 + at}$

want

(4s)

know

8 m/s @ t = 0s

-2 m/s @ t = 4s

$$V_f - V_0 = at$$

÷ t

$$\frac{V_f - V_0}{t} = a$$

flip eqn.

$$\boxed{a = \frac{V_f - V_0}{t}}$$

· populate

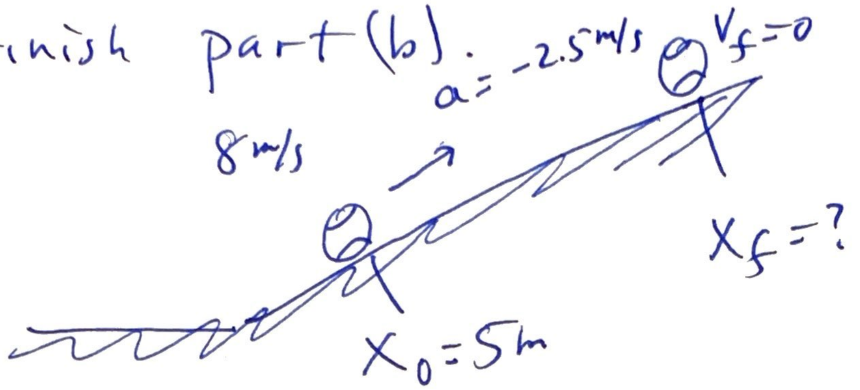
$$a = \frac{(-2\,m/s) - (8\,m/s)}{4s}$$

$$= -\frac{10}{4}\,m/s/s$$

$$\boxed{a = -2.5\,m/s^2}$$

(EX) cont.

Now we have acc'ln and we can finish part (b).



Variable

$x_0 = 5m$
$t_0 = 0s$
$V_0 = 8m/s$
$a = -2.5m/s$
$X_f = ?$
$V_f = 0m/s$
$t_f = ?$

pick $\boxed{2a(x_f - x_0) = V_f^2 - V_0^2}$

Solve for x_f (top of ramp)

÷ 2a: $(x_f - x_0) = \frac{V_f^2 - V_0^2}{2a}$

+ x_0: $\boxed{x_f = \frac{V_f^2 - V_0^2}{2a} + x_0}$

populate:

$$x_f = \frac{(0m/s)^2 - (8m/s)^2}{2(-2.5m/s^2)} + 5m$$

$$= \frac{-64m^2/s^2}{-5m/s^2} + 5m$$

$$= 12.8m + 5m$$

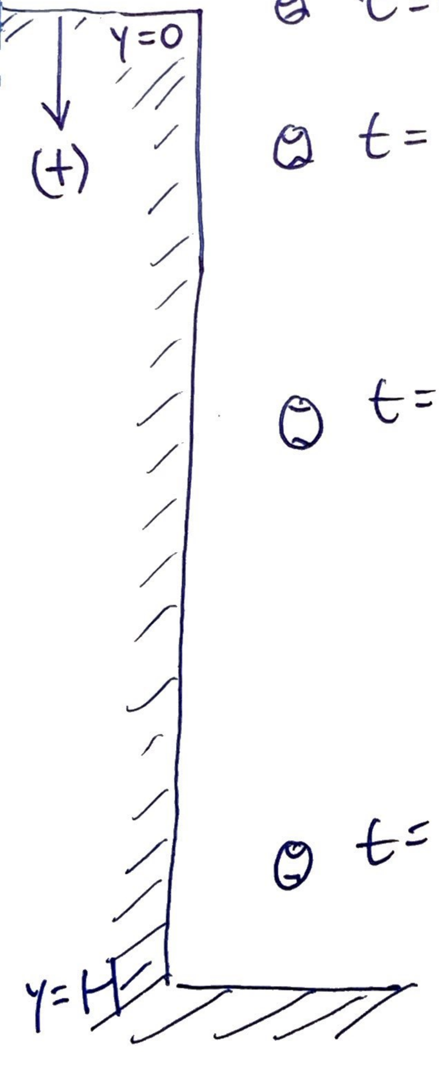
$$\boxed{x_f = 17.8m}$$

- Ball turns around @ x = 17.8m
- Ball V = -2m/s @ x = 17.0m @ 4s

⊛ gravity

we will see in a future chapter that the force of gravity exists between any to objects with mass.

So here near the surface of the earth, we see an object fall, neglecting air friction, at $9.8 m/s^2$ acc'ln. $(32 ft/s^2)$



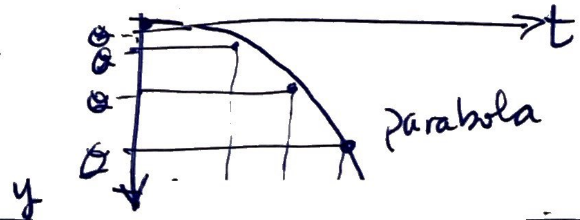
o $t=0$, $\boxed{V_0 = 0 m/s}$

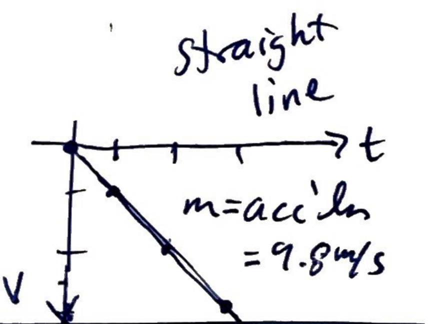
o $t=1s$, $\boxed{V_1 = 9.8 m/s}$

o $t=2s$, $\boxed{V_2 = 19.6 m/s}$
$+ 9.8$

o $t=3s$, $\boxed{V_3 = 29.4 m/s}$

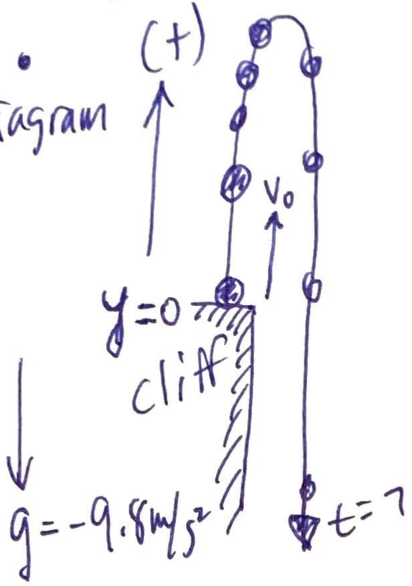
- every second we add 9.8 m/s to our speed. {speed increase is uniform}
- acc'ln = constant
- distance grows in between uniform time intervals.





Ex A ball is thrown vertically upward with an initial velocity of 30m/s. What are the positions and velocity @ 2s, 4s, & 7s? ⑬

- diagram



- data

$V_0 = 30 m/s$ @ $t=0$, $y_0=0$

@ $t=2s$ we want y_2 & V_2

- formulas

$$V_f = V_0 + at \quad , \quad X_f = X_0 + V_0 t + \frac{1}{2}at^2$$

- calculate

@ $t=2s$:

$$V_2 = V_0 + at$$
$$V_2 = 30 m/s - 9.8 \frac{m}{s^2} \cdot 2s$$
$$\boxed{V_2 = 10.4 m/s \text{ up}}$$

$$Y_2 = Y_0 + V_0 t + \frac{1}{2}at^2$$
$$Y_2 = 0 + 30 \cdot 2 - \frac{1}{2} 9.8 \cdot 2^2$$
$$Y_2 = 60m - 19.6m$$
$$\boxed{y_2 = 40.4 m \text{ above ledge}}$$

@ $t=4s$:

$$V_4 = V_0 - 9.8t$$
$$= 30 m/s - 9.8 \frac{m}{s^2} (4s)$$
$$\boxed{V_4 = -9.2 m/s, \text{(down)}}$$

$$X_4 = 0m + 30 \frac{m}{s} \cdot 4s - \frac{1}{2}\left(9.8 \frac{m}{s^2}\right)(4s)^2$$
$$X_4 = 120m - 78.4m$$
$$\boxed{X_4 = 41.6m \text{ above ledge}}$$

@ $t=7s$

$$V_7 = 30 - (9.8)(7)$$
$$\boxed{V_7 = -38.6 m/s}$$

$$X_7 = 0m + 30(7) - \frac{1}{2}(9.8)7^2$$
$$\boxed{X_7 = -30.1m} \text{ below ledge}$$