Chapter 2: 1D Kinematics

Tuesday, June 8, 2021 12:17

<u>kinematics</u> – study of motion WITHOUT considering its causes.

2.1) <u>position</u> – where something is
– relative to another object

<u>VECTORS</u>
has a direction

<u>displacement</u> – change in position

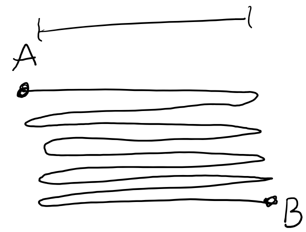
$$\Delta x = x_f - x_0$$

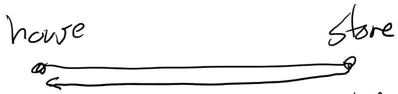
Δx: displacement; x_f: final position; x_0: initial position

– SI unit: meter (m)

<u>distance</u> – magnitude of displacement
NO DIRECTION (SCALAR)

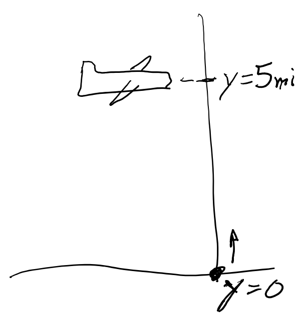
<u>distance traveled</u>
length of path (>> distance)

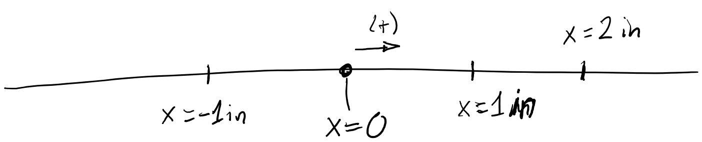


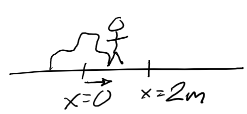


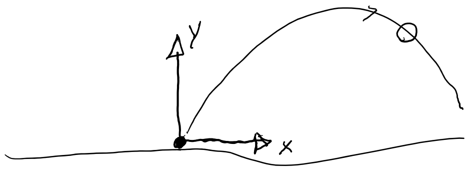
dist. = 0 dist. travelled = 10 mi

2.2) coordinate system
- pick what you are relative to
- pick a direction (+)

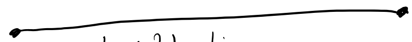








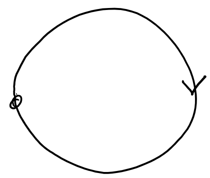
when is distance = magnitude of displacement and distance traveled the same?



no movement

when is magnitude of displacement equal to displacement?

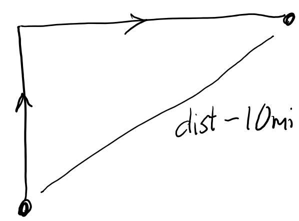
$\Delta x = 0$



mag. of disp. / disp. $\Big\}$ same $\Delta x = 0$

dist. traveled $\}$ $d > 0$

DISTANCE $\neq$ DISTANCE TRAVELED



2.3 | <u>time</u> - when something happens (SI unit: second (s))

<u>elapsed time</u> - how long did the event take

$$\underbrace{\Delta t}_{\text{elapsed time}} = \underbrace{t_f}_{\text{final time}} - \underbrace{t_0}_{\text{initial time}}$$

set $t_0 = 0$ then $\Delta t = t_f = t$

<u>velocity</u> - how fast something is going (VECTOR)
rate of change of position
SI unit: m/s

<u>average velocity</u> = $\dfrac{\text{displacement}}{\text{elapsed time}}$ $\quad \bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{x_f - x_0}{t_f - t_0}$

<u>instantaneous velocity</u> - make elapsed time smaller + smaller

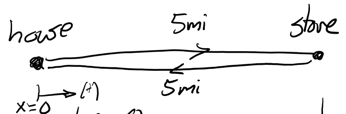
$$v = \frac{dx}{dt} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$ ← math you don't really need to know.

<u>speed</u> $\neq$ velocity (SCALAR)

instantaneous speed – magnitude of instantaneous velocity

average speed = $\dfrac{\text{distanced traveled}}{\text{elapsed time}}$

(NOT magnitude of average velocity)



5 min

displacement : 0 elapsed time : 10min

distance : 0

distance traveled : 10mi

instantaneous velocity =

$\dfrac{5\text{mi east}}{5\text{min}} = 1\dfrac{\text{mi}}{\text{min}}$ east $= +1\,\text{mi/min}$

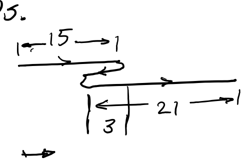
$\dfrac{5\text{mi west}}{5\text{min}} = 1\dfrac{\text{mi}}{\text{min}}$ west $= -1\,\text{mi/min}$

average velocity : $\dfrac{0}{10\text{min}} = 0$

instanteous speed : $1\,\text{mi/min}$

average speed : $\dfrac{10\text{mi}}{10\text{min}} = 1\,\text{mi/min} \neq$ magnitude of average velocity

a quarterback runs 15m down the field in 2.50s.
then he is pushed back by 3.00m in 1.75s.
then runs forward 21.0m in 5.20s.
Calculate his average velocity for
(a) each section individually.
(b) for the total movent combined.



a) $\bar{v} = \dfrac{\Delta x}{\Delta t}$ $\quad \dfrac{15\text{m}}{2.50\text{s}} = 6.00\,\text{m/s}$ $\quad \dfrac{-3.00\text{m}}{1.75\text{s}} = -1.71\,\text{m/s}$

displacement $\quad \dfrac{21.0\text{m}}{5.20\text{s}} = 4.04\,\text{m/s}$

b) $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{15\text{m} - 3.00\text{m} + 21\text{m}}{2.50\text{s} + 1.75\text{s} + 5.20\text{s}} = \dfrac{33\text{m}}{9.45\text{s}} = 3.45\,\text{m/s}$

2.4) acceleration – rate of change of velocity

SI unit : m/s^2 (VECTOR)

average acceleration = $\dfrac{\text{change in velocity}}{\text{elapsed time}}$

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$$

nonzero acceleration mean either

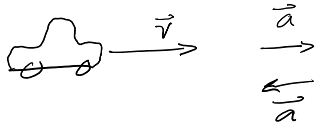
a) a change in SPEED or

$\vec{v_f}$

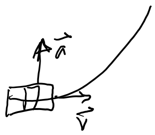
b) a change in DIRECTION or
c) BOTH.

$v_0 \uparrow$ $\searrow \Delta\vec{a}$

acceleration is <u>NOT ALWAYS</u> in direction of motion.



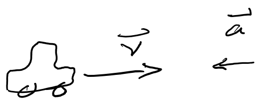
getting faster
getting slower (deceleration)

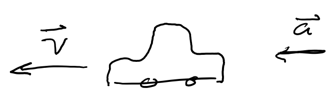


turning a corner (a is perpendicular to v)

deceleration $\neq$ negative acceleration

decreases speed — acceleration in negative direction

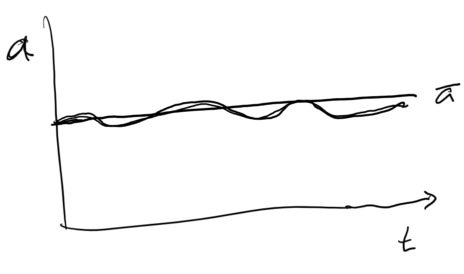


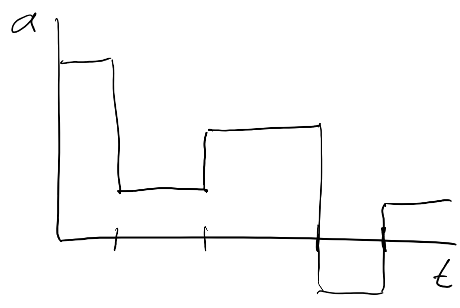


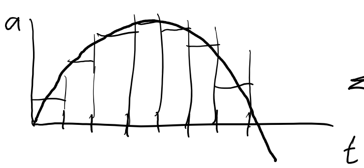
$\rightarrow (+)$ $v > 0$	$\rightarrow (+)$ $v < 0$
$a < 0$	$a < 0$
deceleration	NOT deceleration
negative acceleration	negative acceleration

<u>instantaneous acceleration</u> - make elapsed time smaller in average acceleration.

$$a = \frac{dv}{dt} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \leftarrow \text{Calculus (don't need)}$$







$\leftarrow$ would need calculus

- a cheetah can accelerate from rest to a speed of 30.0 m/s in 7.00 s. What is its acceleration?

$$a = \frac{\Delta v}{\Delta t} = \frac{30.0\,m/s - 0\,m/s}{7.00\,s} = 4.29\,m/s^2$$

- Can you have constant speed and nonzero acceleration?
  yes! changing direction (going in a circle)
- can you have constant velocity an nonzero acceleration?
  NO! acceleration = change in velocity over time

2.5 assume constant acceleration

$$\bar{a} = a = \text{constant.}$$

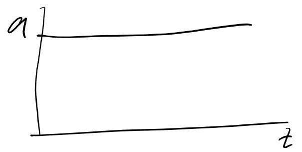
$$t_0 = 0\,,\quad t_f = \Delta t = t\,,\quad \Delta x = x - x_0\,,\quad \Delta v = v - v_0$$

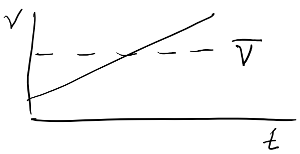
$$\boxed{\bar{v} = \frac{v_0 + v}{2}}$$

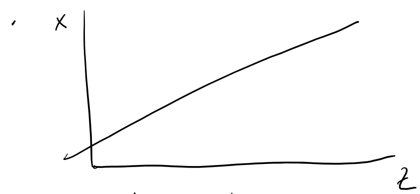
$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t}$$

$$x - x_0 = \bar{v} t$$

$$\boxed{x = x_0 + \bar{v} t}$$







Constant velocity position vs. time graph is a straight line

$$a = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t}$$

$$t a = v - v_0$$

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

$a = 0$ means $v = v_0$

$a < 0$ means $v < v_0$

$$\bar{v} = \frac{v + v_0}{2} = \frac{2v_0 + at}{2} = v_0 + \frac{1}{2}at \qquad \bar{v} = v_0 + \frac{1}{2}at$$

$$x = x_0 + \bar{v}t = x_0 + \left(v_0 + \frac{1}{2}at\right)t = x_0 + v_0 t + \frac{1}{2}at^2$$

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

often you can define coordinates so that $x_0 = 0$.

often the problem is motion starting from rest ($v_0 = 0$)

$v = v_0 + at \qquad v - v_0 = at \qquad t = \frac{v - v_0}{a}$

$$x = x_0 + \bar{v}t = x_0 + \left(\frac{v_0 + v}{2}\right)\left(\frac{v - v_0}{a}\right) = x_0 + \frac{v^2 - v_0^2}{2a}$$

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

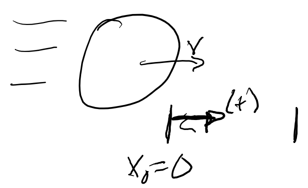
SUMMARY:

$$\boxed{\begin{array}{ll} x = x_0 + \bar{v}t & x = x_0 + v_0 t + \frac{1}{2}at^2 \\ \bar{v} = \frac{v + v_0}{2} & v^2 = v_0^2 + 2a(x - x_0) \\ v = v_0 + at & \end{array}}$$

2.6 How to solve a problem.

1. what physical principals are involved?
   sketch a picture, choose coordinates
2. what quantaties do you know or can infer? (knowns)
   (initial time is $t_0 = 0$ at rest $\Rightarrow v = 0$
   initial position is $x_0 = 0$)
3. what quantaty are we trying to find? (unknown)
4. which equations should you use.
   want an equation with one unknown
5. plug in your numbers (with units)
   IF THE UNITS DON'T WORK, YOU DID SOMETHING WRONG!
6. check if your answer makes sense!!!!

a ball is caught. IF deceleration is $2.10 \times 10^4\ m/s^2$ and $1.85\ ms$ elapses, what was the initial velocity of the ball?



what do we know?

$t = 1.85 \times 10^{-3}\ s$

$a = -2.10 \times 10^4\ m/s^2$

$v = 0\ m/s$

$x_0 = 0\ m$

what are we finding?

v_0

$v = v_0 + at$

$$v_0 = v - at = 0\ m/s - (-2.10 \times 10^4\ m/s^2)(1.85 \times 10^{-3}\ s)$$

$$\boxed{= 38.9\ m/s}$$

$[m/s^2 \cdot s = m/s]$

$\approx 87\ mph$

2.7 gravity

IF THERE IS NO AIR RESISTANCE OR FRICTION THEN ALL FALLING THINGS HAVE ~~THE~~ THE SAME ACCELERATION!

$$[\, g = 9.80\ m/s^2 \text{ down} \,]$$

(varies between $9.78\ m/s^2$ and $9.83\ m/s^2$)
on earth

$\uparrow (+)$

y

$a = -g$

$$\left[\begin{aligned} v &= v_0 - gt \\ y &= y_0 + v_0 t - \tfrac{1}{2} g t^2 \\ v^2 &= v_0^2 - 2g(y - y_0) \end{aligned}\right]$$