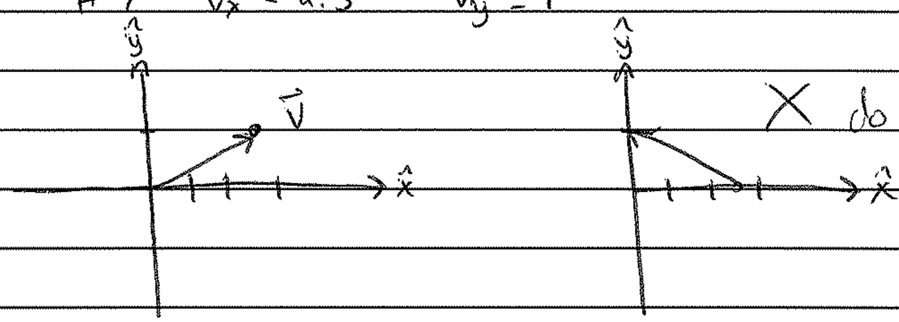
# Comments on Vector worksheet

- Show all work

- Don't forget units / Directions
  - i.e. m/s or N of E

- Always draw vectors starting from the origin.

#7 $V_x = 2.5$ $V_y = 1$




X do not do this

# Solving Kinematics Problems - step by step

1) mental visualization
   - Identify # of stages (usually # of different $a$'s) or # of objects or # of Dimensions
2) Draw a picture
   - include $\vec{x}$, $\vec{v}$, and $\vec{a}$ vectors for all stages
3) Define knowns / unknowns (# of sets = # of stages or # of objects or # of dimensions)
   - $x_f, x_i, v_f, v_i, t_f, t_i, a$
   - identify connections between stages
4) Find @ least same # of equations as # of unknowns

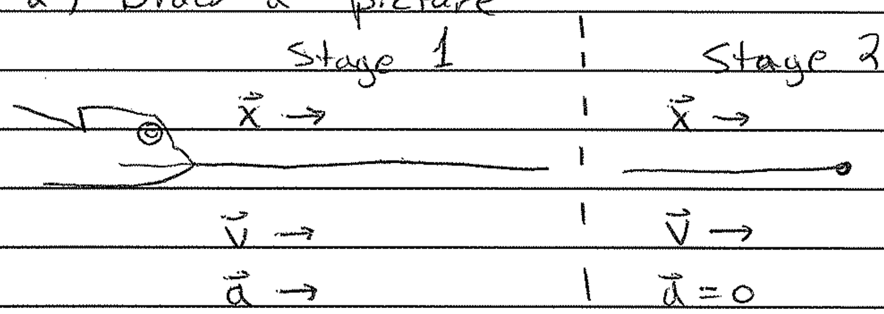
(1) $x_f = x_i + v_{ix}\Delta t + \frac{1}{2} a_x (\Delta t)^2$ (3) $v_f^2 = v_i^2 + 2a_x \Delta x$

(2) $v_f = v_{ix} + a_x \Delta t$

Chameleons catch insects with their tongues, which they can rapidly extend to great lengths. In a typical strike the chameleons tounge accelerates at a remarkable $250\ m/s^2$ for 20 ms, then travels at a constant speed for another 30 ms. During this total time, $1/20$ of a second, how far does the tongue reach?

1) Mental visualisation - Demonstration...
   - Identify # of stages = 2

2) Draw a picture




3) Knowns / unknowns

| Stage 1 Knowns | Stage 1 Unknowns | Stage 2 Knowns | Stage 2 Unknowns |
|---|---|---|---|
| $a = 250\ m/s^2$ | $V_f$ | $a = 0$ | $V_i = V_{f1}$ |
| $t_i = 0$ | $X_f$ | $t_i = 20\ ms$ | $X_i = X_{f1}$ |
| $t_f = 20\ ms$ | | $t_f = 30\ ms$ | $X_f$ |
| $V_i = 0$ | | $V_f = V_i$ | |
| $X_i = 0$ | | | |

4) Find at least same # of equations as # of unknowns

(1) $x_f = x_i + v_{ix}\Delta t + \frac{1}{2} a_x \Delta t^2$

(2) $v_f = v_i + a_x \Delta t$

(3) $v_f^2 = v_i^2 - 2a_x \Delta x$

Stage 1

$\Rightarrow$ 2 unknowns $(x_f, v_f)$

$\Rightarrow$ Need 2 equations

$\Rightarrow$ try (1) and (2)

(1) $x_f = \cancel{x_i}^{\,0} + \cancel{v_{ix}}^{\,0} \Delta t + \frac{1}{2} a_x \Delta t^2$

$= \frac{1}{2} a_x (\Delta t)^2$

$= \frac{1}{2}(250\ m/s^2)\left(20\ ms\left(\frac{1s}{1000ms}\right)\right)^2$

$= \frac{1}{2}(250)\left(\frac{2}{100}\right)^2$

$= \frac{1}{2}(25 \cdot 10)\left(\frac{1}{2 \cdot 25}\right)\left(\frac{1}{5 \cdot 10}\right)$

$= \frac{1}{2}\left(\frac{1}{2}\right)\left(\frac{1}{5}\right) = \frac{1}{20}\ m = \boxed{0.05\ m}$

(2) $v_{fx} = \cancel{v_{ix}}^{\,0} + a_x \Delta t$

$= a_x \Delta t = (250\ m/s^2)\left(\frac{1}{50}s\right) = (25 \cdot 10)\left(\frac{1}{5 \cdot 10}\right)$

$= \boxed{5\ m/s}$

Stage 2

⇒ # unknowns = 3

⇒ 2 come from stage 1

⇒ # unknowns = 1 ($x_f$)

⇒ Need 1 equation

⇒ try (1)

$$x_f = x_i + v_{ix}\Delta t + \frac{1}{2}\cancel{a_x}^{0}\Delta t^2$$

$$= x_i + v_{ix}\Delta t$$

$$= (0.05\text{ m}) + (5\text{ m/s})\left(30\text{ ms}\left(\frac{1\text{ s}}{1000\text{ ms}}\right)\right)$$

$$= \left(\frac{1}{20}\right) + (5)\left(\frac{3}{100}\right) = \frac{1}{20} + \frac{3}{20}$$

$$= \frac{4}{20} = \frac{1}{5} = 0.2\text{ m}$$

A light rail train going from one station to the next on a straight section of track accelerates from rest @ 1.1 m/s² for 20 s. It then proceeds @ constant speed for 1100 m before slowing down @ 2.2 m/s² until it stops @ the station.

(a) Distance between stations?

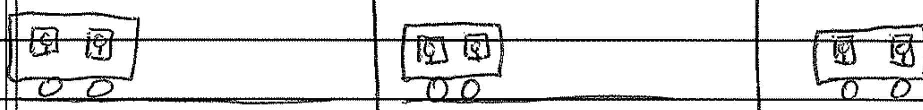
(b) time to travel from one station to the next

1) Mental visualization - walk it out

- # of stages
  - # of accelerations = 3 ⇒ # of stages

2) Draw a picture

| Stage 1 | Stage 2 | Stage 3 |
|---|---|---|
| $\vec{X}_1 \rightarrow$ | $\vec{X}_2 \rightarrow$ | $\vec{X}_3 \rightarrow$ |



| Stage 1 | Stage 2 | Stage 3 |
|---|---|---|
| $\vec{V}_1 \rightarrow$ | $\vec{V}_2 \rightarrow$ | $\vec{V}_3 \rightarrow$ |
| $\vec{a}_1 \rightarrow$ | $\vec{a}_2 = 0$ | $\vec{a}_3 \leftarrow$ |

3) Knowns / unknowns

Stage 1

| Knowns | unknowns |
|---|---|
| $a_1 = 1.1\ m/s^2$ | $V_{f1}$ |
| $t_f = 20\ s$ | $X_{f1}$ |
| $t_i = 0$ | |
| $V_i = 0$ | |
| $X_i = 0$ | |

Stage 2

| Knowns | Unknowns |
|---|---|
| $a_2 = 0$ | $t_{f2}$ |
| $t_i = 20\ s$ | $V_{f2} = V_{i2} = V_{f1}$ |
| | $X_{i2} = X_{f1}$ |
| | $X_{f2} = X_{i2} + 1100\ m$ |
| | $= X_{f1} + 1100\ m$ |

Stage 3

| Knowns | Unknowns |
|---|---|
| $a_3 = -2.2\ m/s^2$ | $t_f$ |
| $V_{f3} = 0$ | $t_{i3} = t_{f2}$ |
| | $V_{i3} = V_{f2} = V_{f1}$ |
| | $X_{i3} = X_{f2} = X_{f1} + 1100\ m$ |
| | $X_{f3}$ |

$(3)_{v_i}$

4) Equations

(1) $x_f = x_i + v_i \Delta t + \frac{1}{2} a_x \Delta t^2$

(2) $v_f = v_i + a_x \Delta t$

(3) $v_f^2 = v_i^2 - 2 a_x \Delta x$

Stage 1

⇒ # of unknowns = 2

⇒ Need 2 equations

⇒ try (1) and (2)

(1) $x_f = \cancel{x_i}^{0} + \cancel{v_i}^{0} \Delta t + \frac{1}{2} a_x \Delta t^2$

$= \frac{1}{2} a_x \Delta t^2 = \frac{1}{2}(1.1\ m/s^2)(20\ s)^2 = 220\ m$

(2) $v_f = \cancel{v_i}^{0} + a_x \Delta t$

$= a_x \Delta t = (1.1\ m/s^2)(20\ s) = 22\ m/s$

Stage 2

⇒ # of unknowns = 1

⇒ Need 1 equation

⇒ try (1)

(1) $x_f = x_i + v_i \Delta t + \frac{1}{2} \cancel{a_x}^{0} \Delta t^2$

$= x_i + v_i \Delta t = (220\ m) + (22\ m/s)(t_f - 20\ s)$

⇒ $(220\ m + 1100\ m) = 220\ m + (22\ m/s) t_f - 440\ m$

$t_f = \frac{1100 + 440}{22} = 70\ s$

Stage 3

$\Rightarrow$ # unknowns 2

$\Rightarrow$ Need 2 equations

$\Rightarrow$ try (3) and (2)

(3) $\cancel{V_f^2}^{0} = V_i^2 - 2a\Delta X$

$$\Rightarrow \quad 0 = V_i^2 - 2a(X_f - X_i)$$

$$0 = (22\,m/s)^2 + 2(-2.2\,m/s^2)(X_f - (220\,m + 1100\,m))$$

$$-2(2.2)(X_f - 1320) = (22)^2$$

$$X_f - 1320 = \frac{(22)^2}{2(2.2)}$$

$$X_f = 1320 + \frac{(22)^2}{2(22)} = \boxed{1430\ m}$$

(2) $V_f = V_i + a_x \Delta t$

$$\Rightarrow \quad 0 = (22\,m/s) + (-2.2)(t_f - 70\,s)$$

$$2.2(t_f - 70) = 22$$

$$t_f - 70 = 10$$

$$t_f = 80\ s$$

~~A catapult is setup on top of a castle wall. The catapult launches a stone at an angle of $\theta$, with an initial velocity $V_i$. At the same time the stone is launched, another stone is droped from the castle wall, and hits the ground @ t seconds later.~~

A student standing on the ground throws a ball straight up. The ball leaves the student's hand with a speed of 15 m/s when the hand is 2.0 m above the ground. How long is the ball in the air before it hits the ground?

1) Mental visualisation → demonstration
   - # of stages
     - # of accelerations = 1 = # of stages

2) Draw a picture

$\vec{y} \downarrow$
$\vec{v} \downarrow$
$\vec{a} \downarrow$

$\vec{y} \uparrow$
$\vec{v} \uparrow$
$\vec{a} \downarrow$

3) Knowns / unknowns

| Knowns | unknowns |
|---|---|
| $a = -9.8\ m/s^2$ | $t_f$ |
| $t_i = 0$ | $V_f$ |
| $V_i = 15\ m/s$ | |
| $X_f = 0$ | |
| $X_i = 2\ m$ | |

4) Equations
   ⇒ # unknowns = 2
   ⇒ try equation (1)

(1) $x_f = x_i + V_i \Delta t + \frac{1}{2} a \Delta t^2$

$$\Rightarrow 0 = (2m) + (15\,m/s)(t_f - \cancel{t_i}^{0}) - \frac{1}{2}(9.8)(t_f - \cancel{t_i})^2$$

$$\Rightarrow 0 = 2 + 15t - \frac{1}{2}(9.8)\, t_f^2$$

$$t_f = \frac{-15 \pm \sqrt{15^2 - 4(-\frac{1}{2}(9.8))(2)}}{2(-\frac{1}{2}(9.8))}$$

$$= \frac{15}{9.8} \mp \frac{\sqrt{15^2 + 4(9.8)}}{9.8} = 3.19\ s$$

The longest recorded pass in an NFL game traveled 83 yards in the air from the quarter back to the receiver. Assuming that the pass was thrown at an optimal 45° angle, what was the speed at which the ball left the quarter backs hand?

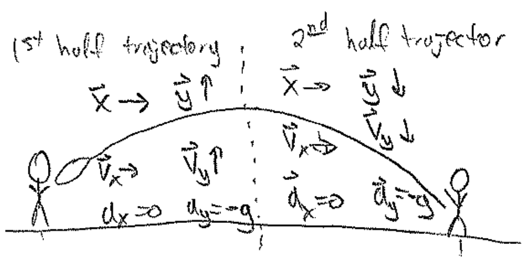
1) Visualise quarterback throwing football.

$\Rightarrow$ # objects = 1

$\Rightarrow$ # D = 2

$\Rightarrow$ # Stages = 1

2) Picture




- Find $V_{ix}$ and $V_{iy}$

3) Knowns/unknowns

$\Rightarrow$ Need 2 tables

$\Rightarrow$ 1 for x and 1 for y

x

| Known | Unknown |
|---|---|
| $X_f = 83$ yrd $= 75.9$m | $V_{fx} = V_{ix}$ |
| $X_i = 0$ | $t_{fx} = t_{fy}$ |
| $t_{ix} = 0$ | |
| $a_x = 0$ | |

look up conversion

y

| Known | Unknown |
|---|---|
| $y_f = y_i = 0$ | $V_{fy} = -V_{iy}$ |
| $a_y = -9.8$ m/s² | $t_{fy} = t_{fx}$ |

$\vec{V}_i$, 45°

$V_{iy} = |\vec{V}_i| \sin 45° = \frac{1}{\sqrt{2}} |\vec{V}_i|$

$V_{ix} = |\vec{V}_i| \cos 45° = \frac{1}{\sqrt{2}} |\vec{V}_i|$

- This is what the book calls using the geometry to simplify unknowns.

4) Equations

$\Rightarrow$ Start with y-direction to find $t_{fy}$

$\Rightarrow$ Use equation (1)

(1) $y_f = y_i + V_{iy} \Delta t + \frac{1}{2} a_y \Delta t^2$

$\Rightarrow 0 = V_{iy} t_{fy} - \frac{1}{2} g t_{fy}^2 = t_f (V_{iy} - \frac{1}{2} g t_{fy})$

$\Rightarrow t_{fy} = 0$ or $V_{iy} = \frac{1}{2} g t_{fy}$

$\Rightarrow t_{fy} = \frac{2 V_{iy}}{g}$

$\Rightarrow$ Use $t_{fy} = t_{fx}$ in equation (1) for x-direction

(1) $X_f = \cancel{X_i}^{0} + V_{ix} \Delta t + \frac{1}{2} \cancel{a_x}^{0} \Delta t^2$

$= V_{ix} t_{fx} = V_{ix} \left( \frac{2 V_{iy}}{g} \right)$

$\Rightarrow \frac{1}{2} g X_f = V_{ix} V_{iy} = \frac{1}{2} |\vec{V}_i|^2$

$\Rightarrow |\vec{V}_i|^2 = g X_f \Rightarrow \boxed{|\vec{V}_i| = \sqrt{g X_f} = 27.27 \text{ m/s}}$

$\boxed{\vec{V}_i = \langle 19.28, 19.28 \rangle \text{ m/s}}$