

Chapter 2:Describing Motion Kinematics in One Dimension

Lecture 4

(First Sem 20/21)

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Free Fall.

Remember $g = 9.81 \text{ m/s}^2$ vertically downwards (\downarrow) towards the center of the earth.

How do we deal with direction along the vertical direction?

Two possibilities :

- ① can take upwards (\uparrow) as positive
- ② can take downwards (\downarrow) as positive .

← Choice ① \uparrow (upwards positive)

- Any vector that points up is positive

- Any vector that points down is negative

Remember $g = 9.81 \text{ m/s}^2 \downarrow$

⇒ use $a = -g \Rightarrow$ eqns of motion

$$v_f = v_i + at \Rightarrow v_f = v_i - gt$$

$$y_f - y_i = v_i t + \frac{1}{2} a t^2 \Rightarrow y_f - y_i = v_i t - \frac{1}{2} g t^2$$

$$v_f^2 - v_i^2 = 2a(y_f - y_i) \Rightarrow v_f^2 - v_i^2 = -2g(y_f - y_i)$$

$$y_f - y_i = v_f t - \frac{1}{2} a t^2 \Rightarrow y_f - y_i = v_f t + \frac{1}{2} g t^2$$

choice ② \downarrow is positive

- Any vector that points up is negative

- Any vector that points down is positive

$$g = 9.81 \text{ m/s}^2 \downarrow$$

⇒ use $a = g$

$$v_f = v_i + gt$$

$$y_f - y_i = v_i t + \frac{1}{2} g t^2$$

$$v_f^2 - v_i^2 = 2g(y_f - y_i)$$

$$y_f - y_i = v_f t - \frac{1}{2} g t^2$$

$$v_f = v_i + at \Rightarrow v_f = v_i - gt$$

$$y_f - y_i = v_i t + \frac{1}{2} a t^2 \Rightarrow y_f - y_i = v_i t - \frac{1}{2} g t^2$$

$$v_f^2 - v_i^2 = 2a(y_f - y_i) \Rightarrow v_f^2 - v_i^2 = -2g(y_f - y_i)$$

$$y_f - y_i = v_f t - \frac{1}{2} a t^2 \Rightarrow y_f - y_i = v_f t + \frac{1}{2} g t^2$$

$$v_f = v_i + gt$$

$$y_f - y_i = v_i t + \frac{1}{2} g t^2$$

$$v_f^2 - v_i^2 = 2g(y_f - y_i)$$

$$y_f - y_i = v_f t - \frac{1}{2} g t^2$$

Remember $\Delta y = y_f - y_i$
displacement which
a vector

Example : A stone is projected vertically upwards from the ground level with an initial speed of 30 m/s. Find :

- ① Its maximum height.
- ② Its Velocity after 2s and 4s.
- ③ Its height at $t = 5$ s.
- ④ The time needed for stone to return to the same launching level.

Need to do two things first:

- choose a positive direction
- choose a point of origin -

Solution:

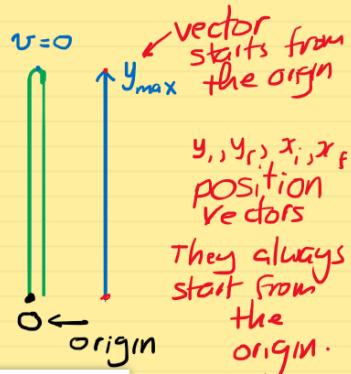
Choose upwards as positive $\uparrow \Rightarrow a = -g$.

It is convenient to choose the point from which the stone was projected to be the point of origin.
(always it is best to have a sketch.)

$$\uparrow \quad [a = -g]$$

NOTE: y_{max} is a vector that starts from the origin and ends at the point of maximum height

① Find y_{max} .



① Find y_{\max} .

$$v_i^2 - v_f^2 = -2g(y_f - y_i)$$

$$0 - (30)^2 = -2(10)(y_{\max} - 0) \Rightarrow y_{\max} = \frac{900}{20} = +45 \text{ m.}$$

Why is y_{\max} positive? Since it is in the same direction as our positive direction.

② v_f after 2s = ?

$$v_f = v_i - gt = (30) - 10(2) = 10 \text{ m/s}$$

positive sign means it is moving up

$$v=0$$

② v_f after 2s = ?

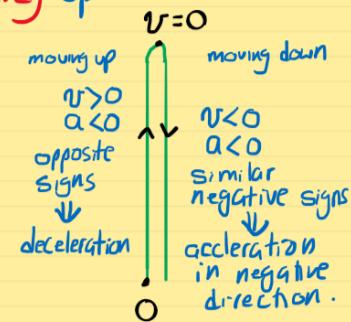
$$v_f = v_i - gt = (30) - 10(2) = 10 \text{ m/s}$$

positive sign means it is moving up

v_f after 4s.

$$v_f = (30) - 10(4) = -10 \text{ m/s}$$

negative sign means it is moving down



③ y at $t = 5\text{ s}$.

$$y_f - y_i = v_i t - \frac{1}{2} g t^2$$

$$0 - 0 = (+30)(5) - \frac{1}{2}(10)(5)^2$$

$$0 = 150 - 125 = 25\text{ m}$$

what does the positive sign mean?

④ Time to return to ground level?

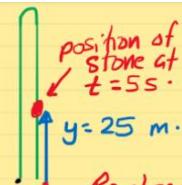
starts from "0" and returns to "0".

$$y_f - y_i = v_i t - \frac{1}{2} g t^2$$

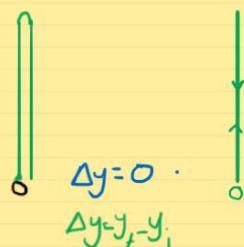
$$0 - 0 = (+30)t - \frac{1}{2}(10)t^2$$

$$0 = 30t - 5t^2$$

$$\therefore 0 = 6t - t^2$$



Remember: position is ALWAYS measured from the origin.



④ Time to return to ground level?

starts from "0" and returns to "0".

$$y_f - y_i = v_i t - \frac{1}{2} g t^2$$

$$0 - 0 = (+30)t - \frac{1}{2}(10)t^2$$

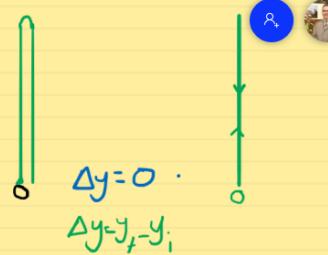
$$0 = 30t - 5t^2$$

$$\therefore 0 = 6t - t^2$$

$$0 = t(6-t)$$

$\Rightarrow t = 0$ (time of launching)

$t = 6\text{ s}$ when it returns to the same point of projection ("0") - NOTE this means $\Delta y = 0$.



Now, do the same question but choosing downwards as positive (\downarrow) $\Rightarrow a = g$.

① Find y_{\max} .

$$v_i^2 - v_f^2 = 2g(y_f - y_i) \Rightarrow 0 - (-30)^2 = 2(10)(y_{\max} - 0)$$

$$\therefore -900 = 20y_{\max} \Rightarrow y_{\max} = -45\text{ m}.$$

what does the negative sign mean?

y_{\max} is opposite to our positive direction.



② v_f at $t = 2s$ = ?

$$v_f = -30 + 10(2) = -10 \text{ m/s}$$

↑ moving upwards

+ $\uparrow v_i = -30 \text{ m/s}$

v_f at $t = 4s$

$$v_f = -30 + 10(4) = +10 \text{ m/s}$$

↑ moving down.

③ y at $t = 5s$.

$$y_f - y_i = v_i t + \frac{1}{2} g t^2 \Rightarrow$$

$$y_f - 0 = (-30)(5) + \frac{1}{2}(10)(5)^2$$

$$y_f = -150 + 125 = -25 \text{ m.}$$



$$y_f - 0 = (-30)(5) + \frac{1}{2}(10)(5)^2$$

$$y_f = -150 + 125 = -25 \text{ m.}$$

what does the negative sign mean?

④ Time to return to the ground.

$$y_f - y_i = v_i t + \frac{1}{2} g t^2$$

$$0 - 0 = -30t + 5t^2$$

$$15 \Rightarrow 0 = -6t + t^2$$

$$0 = t(-6+t)$$

$$\begin{cases} t=0 \\ t=6 \end{cases} \text{ exactly as before.}$$

Example: A stone was projected vertically upwards from the top of a 30 m high building with an initial speed of 20 m/s. Find its velocity just before it hits the ground.

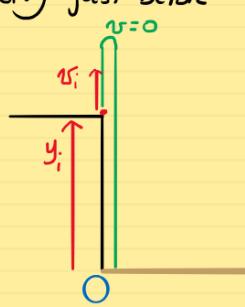
Two things to decide:

① positive direction

Take upwards as positive ↑ $\Rightarrow a = g$

You can choose ↓ $\Rightarrow a = g$ IF YOU LIKE
(Try it)

② choose point of origin.



② choose point of origin.

A) let us try the base of the building to be the origin.

$$v_f^2 - v_i^2 = -2g(y_f - y_i)$$

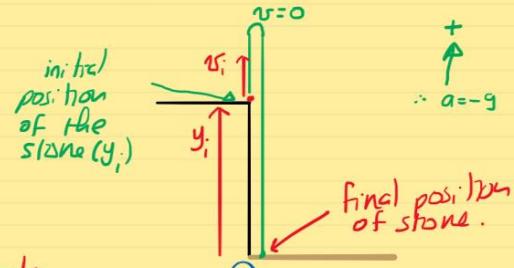
$$v_f^2 - (+20)^2 = -2g(0 - 30)$$

$$v_f^2 - 400 = -2(10)(-30)$$

$$v_f^2 = 400 + 600 = 1000$$

$$\therefore v_f = -\sqrt{1000} = -10\sqrt{10} \text{ m/s}$$

why should we choose the negative sign? because it is moving downwards just before hitting the ground.



Alternatively choose the origin at

point of projection

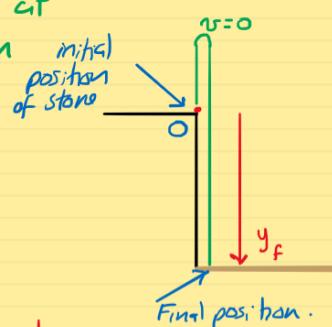
$$\ddagger a = -g$$

$$v_f^2 - v_i^2 = -2g(y_f - y_i)$$

$$v_f^2 - (+20)^2 = -2(10)(-30 - 0)$$

$$v_f^2 - 400 = 600$$

$$v_f = -\sqrt{1000} = -10\sqrt{10} \text{ m/s.}$$



Exercise Do the same question, but take downwards as positive.