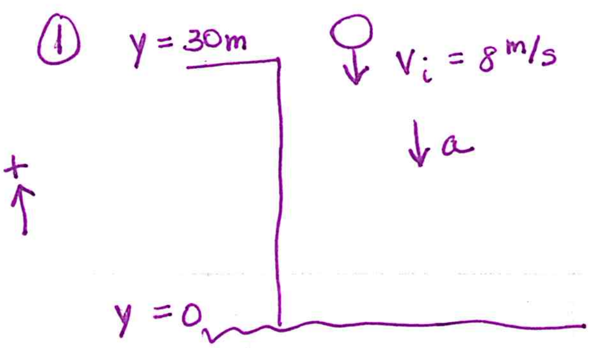
Free Fall Problems

(1)



$$y_f = y_i + v_i t + \tfrac{1}{2} a t^2$$

$$0 = 30 - 8t + \tfrac{1}{2}(-9.8)t^2$$

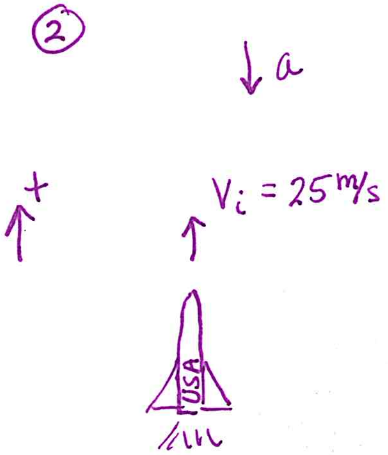
$$4.9t^2 + 8t - 30 = 0$$

$$t = \frac{-8 \pm \sqrt{64 - 4(4.9)(30)}}{2(4.9)}$$

$$t = \frac{-8 + 25.53}{9.8} \qquad t = \frac{-8 - 25.53}{9.8}$$

$$\boxed{t = 1.79\text{s}} \qquad \cancel{t = -3.42\text{s}}$$

(2)



(a) at the maximum height $V_f = 0$

$$V_f^2 = V_i^2 + 2a\Delta y$$

$$\frac{V_f^2 - V_i^2}{2a} = \Delta y = \frac{0^2 - (25)^2}{2(-9.8)}$$

$$\boxed{\Delta y = 31.89\text{m}}$$

(b) $V_f = V_0 + at$

$$\frac{V_f - V_0}{a} = t = \frac{0 - 25}{-9.8}$$

$t = 2.55$s this is the time to reach the peak.

$$t_{total} = 2 \cdot t_{peak}$$

$$\boxed{t_{total} = 5.1 \text{ sec}}$$

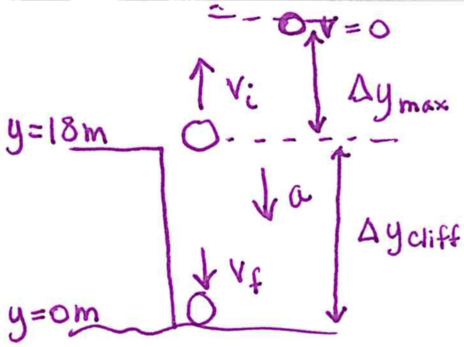
(c) find h when $V_f = 12.5$ m/s

$$V_f^2 = V_i^2 + 2a\Delta y$$

$$\frac{V_f^2 - V_i^2}{2a} = \Delta y = \frac{(12.5)^2 - (25)^2}{2(-9.8)}$$

$$\boxed{\Delta y = 23.9\text{m}}$$

③



ⓐ $\Delta y_{cliff} = y_f - y_i$

$= 0m - 18m$

$= -18m$

$v_f^2 = v_i^2 + 2a\Delta y$

$(48.8)^2 = v_i^2 + 2(-9.8)(-18)$

$v_i^2 = 2028.64$

$\boxed{v_i = 45.04 \text{ m/s}}$

ⓑ at max height $v_f = 0$ m/s

Δy is between cliff top & max height

$v_f^2 = v_i^2 + 2a\Delta y$

$0 = (45.04)^2 + 2(-9.8)\Delta y$

$$\Delta y = \frac{-(45.04)^2}{2(-9.8)}$$

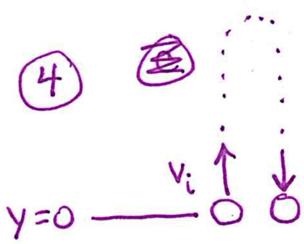
$\Delta y = 103.5m$ = max height − cliff height

max height = 103.5m + cliff height

max height = 103.5m + 18m

$\boxed{\text{max height} = 121.5m}$

④



$\Delta t = 20s$

$a = -9.8 \text{ m/s}^2$

$y_i = 0m$

$y_f = 0m$

ⓐ $y_f = y_i + v_i t + \frac{1}{2}at^2$

$0 = 0 + v_i(20) + \frac{1}{2}(-9.8)(20)^2$

$-20v_i = -1960$

$\boxed{v_i = 98 \text{ m/s}}$

ⓑ at max height $v_f = 0$

$v_f^2 = v_i^2 + 2a\Delta y$

$$\frac{v_f^2 - v_i^2}{2a} = \Delta y = \frac{0-(98)^2}{2(-9.8)}$$

$\boxed{\Delta y = 490 \text{ m}}$

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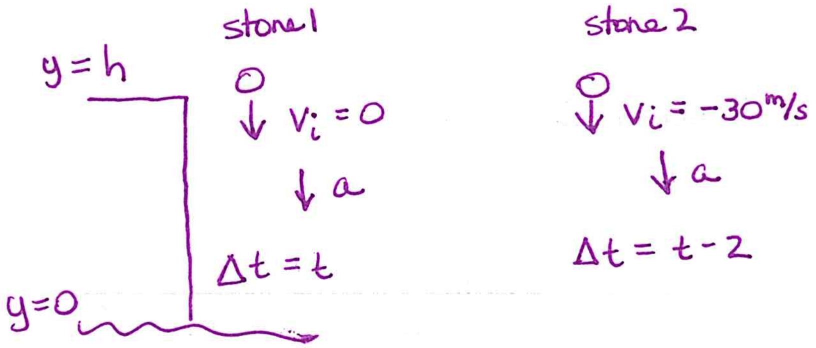


stone 1: $y_f = y_i + v_i t + \frac{1}{2} a t^2$

$0 = h + 0 \cdot t + \frac{1}{2}(-9.8) t^2$

$h = 4.9 t^2$

stone 2: $y_f = y_i + v_i t + \frac{1}{2} a t^2$

$0 = h + (-30)(t-2) + \frac{1}{2}(-9.8)(t-2)^2$

$h = 4.9(t-2)^2 + 30(t-2)$

$$\frac{4.9t^2}{4.9} = \frac{4.9(t-2)^2 + 30(t-2)}{4.9}$$

$t^2 = (t-2)^2 + 6.12(t-2)$

$\cancel{t^2} = \cancel{t^2} - 4t + 4 + 6.12t - 12.24$

$0 = 2.12t - 8.24$

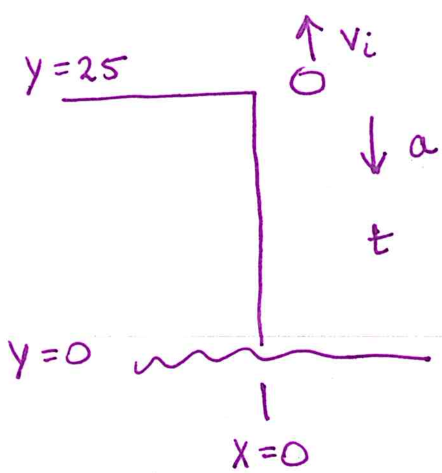
$\boxed{t = 3.89\,s}$

$h = 4.9 t^2$

$= 4.9(3.89)^2$

$\boxed{h = 74\,m}$

6



$x = 30\,m$ $\quad a = 0$

$V_p = ?$

$t_{person} = t_{stone} = t$

Person: $x_f = x_i + v_i t + \cancel{\frac{1}{2}at^2}$

$$0 = 30 + V_p \cdot t$$

$$V_p \cdot t = -30$$

$$V_p = -\frac{30}{t}$$

<u>ball</u>: $y_f = y_i + v_i t + \frac{1}{2}at^2$

$$0 = 25 + 12t + \frac{1}{2}(-9.8)t^2$$

$$4.9t^2 - 12t - 25 = 0$$

$$t = \frac{12 \pm \sqrt{12^2 - 4(4.9)(-25)}}{2(4.9)}$$

$$t = \frac{12 \pm 25.179}{9.8}$$

$\underline{t = 3.8s}$ or $\cancel{t = -1.34s}$

$$V_p = -\frac{30}{t} = -\frac{30}{3.8}$$

$$\boxed{V_p = -7.89\ m/s}$$

negative sign means he is moving to the left.

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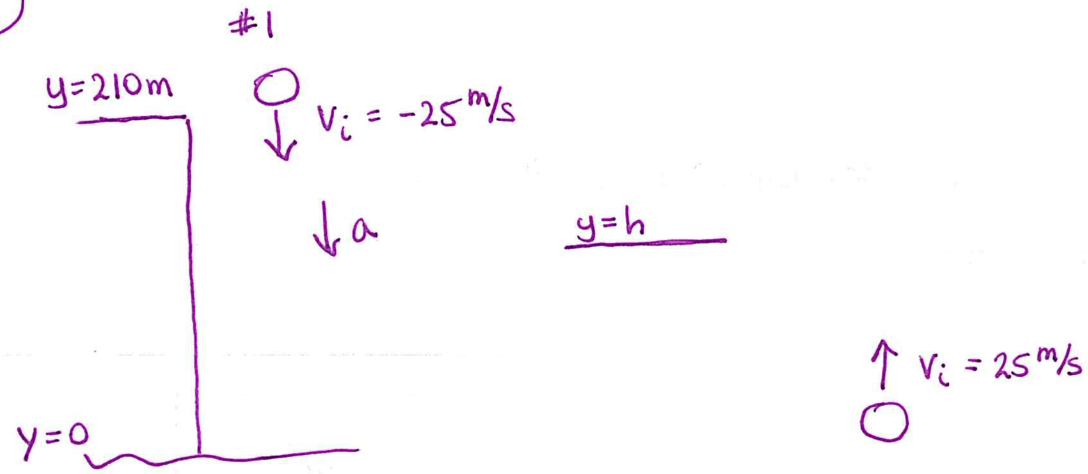


y=h is where the two balls pass each other.

ball 1: $y_f = y_i + v_i t + \frac{1}{2}at^2$

$h = 210 + (-25t) + \frac{1}{2}(-9.8)t^2$

ball 2: $y_f = y_i + v_i t + \frac{1}{2}at^2$

$h = 0 + 25t + \frac{1}{2}(-9.8)t^2$

$210 - 25t - \cancel{4.9t^2} = 25t - \cancel{4.9t^2}$

$210 = 50t$

$\boxed{t = 4.2s}$

$h = 25t - 4.9t^2$

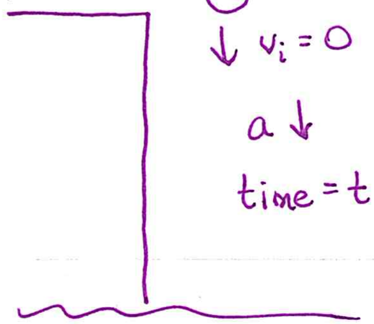
$= 25(4.2) - 4.9(4.2)^2$

$\boxed{h = 18.56m}$

Note: both balls are traveling down when they pass each other.

⑧

$y=0$



tennis ball

$\downarrow v_i = 0$

$a \downarrow$

time $= t$

$y=h$

golf ball

$\downarrow v_i = 15\ m/s$

time $= t-1$

$\downarrow +$ down is positive

$y=h$ is where they pass each other.

tennis ball: $y_f = y_i + v_i t + \frac{1}{2}at^2$

$$h = 0 + 0 \cdot t + \frac{1}{2}(9.8)t^2$$

$$h = 4.9t^2$$

golf ball: $y_f = y_i + v_i t + \frac{1}{2}at^2$

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

$$\frac{4.9t^2}{4.9} = \frac{15(t-1) + 4.9(t-1)^2}{4.9}$$

$$t^2 = 3.06(t-1) + (t-1)^2$$

$$\cancel{t^2} = 3.06t - 3.06 + \cancel{t^2} - 2t + 1$$

$$0 = 1.06t - 2.06$$

$$t = \frac{2.06}{1.06} = 1.94 \text{ sec tennis ball}$$

golf ball travels $\underline{\underline{0.94\,s}}$

$$h = 4.9(t^2)$$

$$= 4.9(1.94)^2$$

$\underline{\underline{h = 18.44\ m}}$ below the top of the bridge

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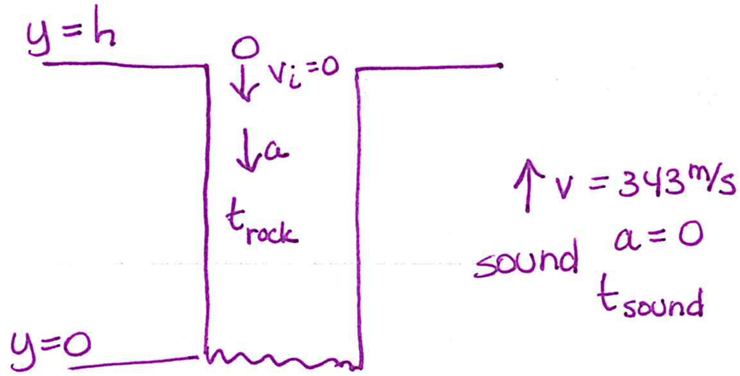

$$t_{rock} + t_{sound} = 2\,s \Rightarrow t_{rock} = 2 - t_{sound}$$
$$t_{sound} = 2 - t_{rock}$$

rock: $y_f = y_i + v_i t + \frac{1}{2}at^2$

$$0 = h + 0 \cdot t_{rock} + \frac{1}{2}(-9.8)\,t_{rock}^2$$

sound: $y_f = y_i + v_i t + \cancel{\frac{1}{2}at^2}$

$$h = 0 + 343\,t_{sound}$$
$$h = 343(2 - t_{rock})$$

$$0 = 343(2 - t_{rock}) + \frac{1}{2}(-9.8)\,t_{rock}^2$$
$$0 = 686 - 343\,t_{rock} - 4.9\,t_{rock}^2$$
$$4.9\,t_r^2 + 343\,t_r - 686 = 0$$
$$t_r = \frac{-343 \pm \sqrt{(343)^2 - 4(4.9)(-686)}}{2(4.9)}$$
$$t_r = \frac{-343 \pm 362.069}{9.8}$$
$$t_r = 1.946\,s \qquad \cancel{t_r = -71.95\,s}$$

$$h = \frac{1}{2}(9.8)\,t_r^2$$
$$= \frac{1}{2}(9.8)(1.946)^2$$
$$\boxed{h = 18.5\,m}$$