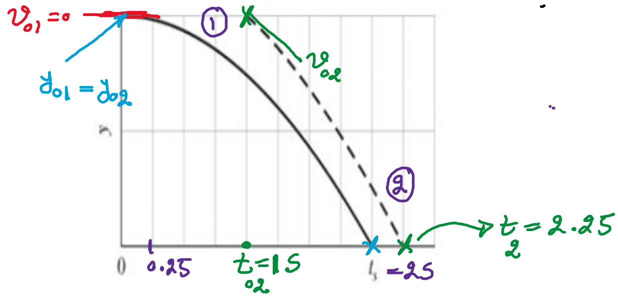
50 M At time $t = 0$, apple 1 is dropped from a bridge onto a roadway beneath the bridge; somewhat later, apple 2 is thrown down from the same height. Figure 2.18 gives the vertical positions y of the apples versus t during the falling, until both apples have hit the roadway. The scaling is set by $t_s = 2.0$ s. With approximately what speed is apple 2 thrown down?



$a = -g = -9.8\ m/s^2$

$y_1 = -\frac{1}{2} g t_1^2 + v_{01} t + y_{01}$

$t = 2\ s \longrightarrow y_1(t=2) = 0$

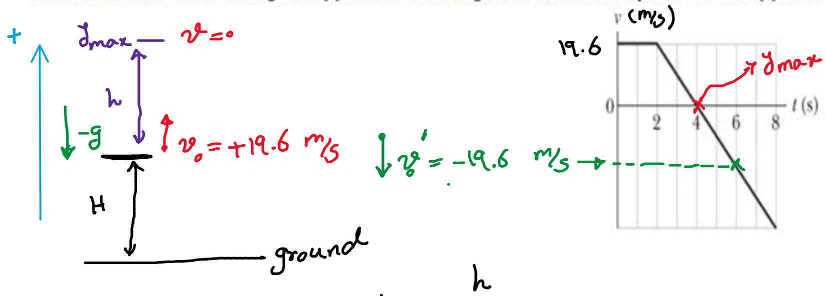
$0 = -\frac{1}{2} \times 9.8 \times 2^2 + 0 + y_{01} \longrightarrow y_{01} = 19.6\ m = y_{02}$

apple 2 : $y_2 = -\frac{1}{2} g (t_2 - t_{02})^2 + v_{02}(t_2 - t_{02}) + y_{02}$

$0 = -\frac{1}{2} \times 9.8 \times \underbrace{(2.25-1)^2}_{(1.25)^2} + v_{02} \underbrace{(2.25-1)}_{1.25} + 19.6$

$\longrightarrow 1.25\, v_{02} = -11.94 \longrightarrow v_{02} \simeq -9.56\ m/s \longrightarrow S_{02} = 9.6\ m/s$

51 M As a runaway scientific balloon ascends at 19.6 m/s, one of its instrument packages breaks free of a harness and free-falls. Figure 2.19 gives the vertical velocity of the package versus time, from before it breaks free to when it reaches the ground. (a) What maximum height above the break-free point does it rise? (b) How high is the break-free point above the ground?



a) $h = ?$; $v^2 - v_0^2 = -2g\,\Delta y$ ($v = 0$, $\Delta y = h$) $\longrightarrow -(19.6)^2 = -2 \times 9.8 \times h \longrightarrow h = 19.6 \simeq 20\ m$

b) $H = ?$

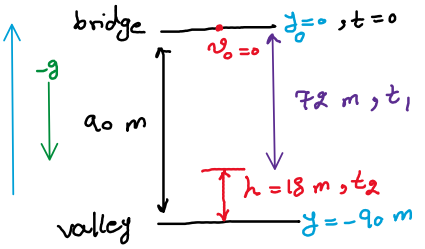
$t = 6 \rightsquigarrow$ starting point

$t = 8 \rightsquigarrow$ ground

$\longrightarrow t' = 8 - 6 = 2\ s$

$\Delta y = -\frac{1}{2} g t'^2 + v_0' t' \Longrightarrow H = -\frac{1}{2} \times 9.8 \times 2^2 - 19.6 \times 2 = -58.8 \simeq -59\ m$

52 M GO A bolt is dropped from a bridge under construction, falling 90 m to the valley below the bridge. (a) In how much time does it pass through the last 20% of its fall? What is its speed (b) when it begins that last 20% of its fall and (c) when it reaches the valley beneath the bridge?



$h = 20\% \times 90 = 18$ m

a) $y = -\frac{1}{2}gt^2 + v_0 t + y_0$ ($v_0 t = 0$, $y_0 = 0$)

$\rightarrow -90 = -\frac{1}{2} \times 9.8\, t^2 \rightarrow t = 4.286$ s

$y = -\frac{1}{2}gt^2 + v_0 t + y_0 \rightarrow -72 = -\frac{1}{2} \times 9.8\, t_1^2 \rightarrow t_1 = 3.833$ s

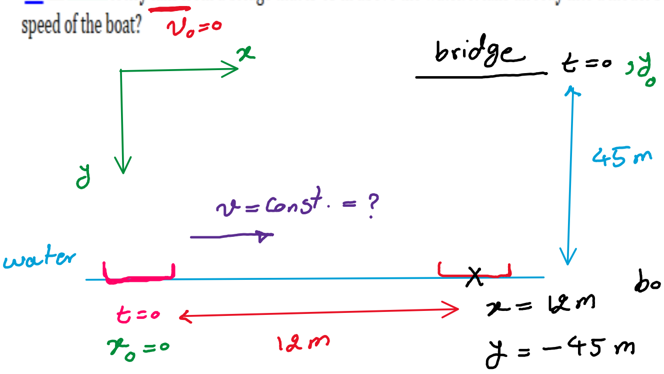
$\rightarrow t_2 = t - t_1 = 4.286 - 3.833 \simeq 0.45$ s

b) $v^2 - v_0^2 = -2g\,\Delta y = -2g(y - y_0) = -2 \times 9.8 \times (-72) = 1411.2 \Rightarrow v = -37.56$ m/s

speed $\simeq 38$ m/s

c) $v = -gt + v_0 = -9.8 \times 4.286 \simeq -42.00$ m/s $\rightarrow$ speed $\simeq 42$ m/s

53 M SSM A key falls from a bridge that is 45 m above the water. It falls directly into a model boat, moving with constant velocity, that is 12 m from the point of impact when the key is released. What is the speed of the boat? $v_0 = 0$

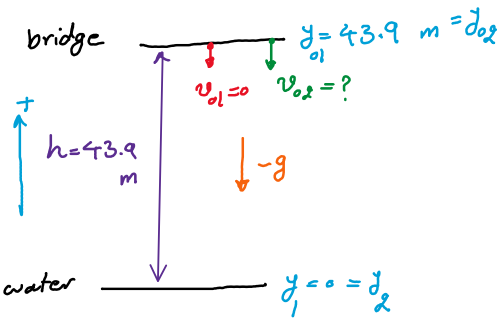


key : $y = -\frac{1}{2}gt^2 + v_0 t + y_0$ ($v_0 t = 0$, $y_0 = 0$)

$-45 = -\frac{1}{2} \times 9.8 \times t^2 \rightarrow t \simeq 3.03$ s

boat : $x = vt + x_0$ ($x_0 = 0$) $\rightarrow v = \frac{12}{3.03} \simeq 4.0$ m/s

54 M GO A stone is dropped into a river from a bridge 43.9 m above the water. Another stone is thrown vertically down 1.00 s after the first is dropped. The stones strike the water at the same time. (a) What is the initial speed of the second stone? (b) Plot velocity versus time on a graph for each stone, taking zero time as the instant the first stone is released.



a) $y_1 = -\frac{1}{2}gt_1^2 + v_{01}t_1 + y_{01}$

$0 = -\frac{1}{2} \times 9.8 \times t_1^2 + 0 + 43.9$

$\rightarrow t_1^2 = \frac{43.9}{4.9} \rightarrow t_1 = 2.99$ s

$t_2 = 2.99 - 1.00 = 1.99$ s

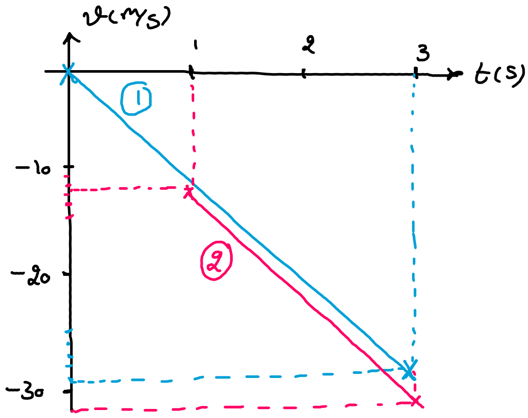
$y_2 = -\frac{1}{2}gt_2^2 + v_{02}t_2 + y_{02} \rightarrow 0 = -\frac{1}{2} \times 9.8 \times (1.99)^2 + v_{02} \times 1.99 + 43.9 \rightarrow v_{02} = -12.3$ m/s

($-\frac{1}{2} \times 9.8 \times (1.99)^2 = -19.40$)

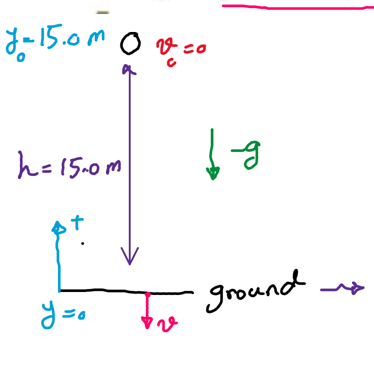
b) $v = at + v_0$ $\xrightarrow[a=-g]{t=2.99\text{ s}}$ $\begin{cases} v_1 = -9.8 \times 2.99 + 0 \simeq -29.3 \text{ m/s} \\ v_2 = -9.8 \times (2.99 - 1) - 12.3 \simeq -31.8 \text{ m/s} \end{cases}$

$t = 0$: $v_{01} = 0$

$t = 1$: $v_{02} = -12.3$ m/s



55 M SSM A ball of moist clay falls 15.0 m to the ground. It is in contact with the ground for 20.0 ms before stopping. (a) What is the magnitude of the average acceleration of the ball during the time it is in contact with the ground? (Treat the ball as a particle.) (b) Is the average acceleration up or down?



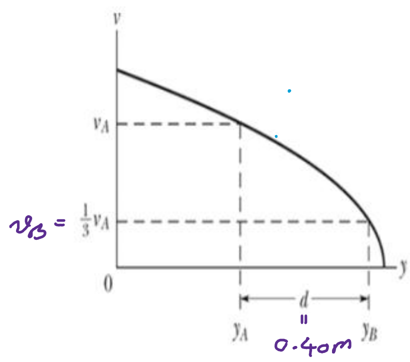
a) $v^2 - v_0^2 = -2g\,\Delta y$ ($v_0 = 0$; $\Delta y \to (y - y_0)$)

$v^2 = -2 \times 9.8 \times (0 - 15) = 294 \rightarrow v = \mp 17.15$ m/s ($+$ unacceptable)

t, $v = -17.15$ m/s; $a = ?$; $t + 20$ ms, $v = 0$ $\longrightarrow a = \dfrac{\Delta v}{\Delta t} = \dfrac{0 - (-17.15)}{20 \times 10^{-3}} \simeq 857$ m/s²

b) up

56 M GO Figure 2.20 shows the speed v versus height y of a ball tossed directly upward, along a y axis. Distance d is 0.40 m. The speed at height y_A is v_A. The speed at height y_B is $\frac{1}{3}v_A$. What is speed v_A?



$v^2 - v_0^2 = -2g(y - y_0)$

$\downarrow$

$v_B^2 - v_A^2 = -2g(y_B - y_A)$

$\downarrow$

$(\frac{1}{3}v_A)^2 - v_A^2 = -2 \times 9.8 \times 0.40$

$\frac{1}{9}v_A^2 - v_A^2 = -\frac{8}{9}v_A^2$

$\rightarrow v_A^2 = \dfrac{9 \times 2 \times 9.8 \times 0.40}{8} = 8.82 \Rightarrow v_A \simeq 2.97 \simeq 3.0$ m/s