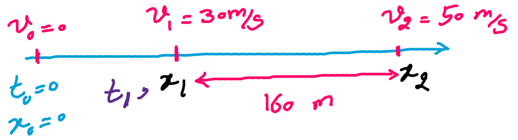
80 A train started from rest and moved with constant acceleration. At one time it was traveling 30 m/s, and 160 m farther on it was traveling 50 m/s. Calculate (a) the acceleration, (b) the time required to travel the 160 m mentioned, (c) the time required to attain the speed of 30 m/s, and (d) the distance moved from rest to the time the train had a speed of 30 m/s. (e) Graph *x* versus *t* and *v* versus *t* for the train, from rest.

$\longrightarrow a = \text{const.}$



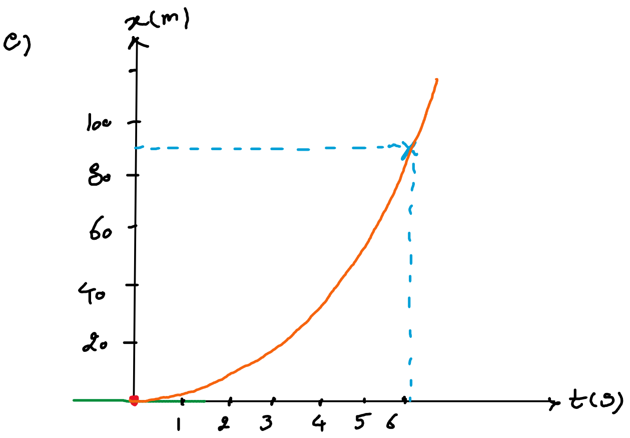
a) $v_2^2 - v_1^2 = 2a(x_2 - x_1) \Rightarrow 50^2 - 30^2 = 2a \times 160 \Rightarrow a = \frac{2500 - 900}{2 \times 160} = 5.0\ m/s^2$

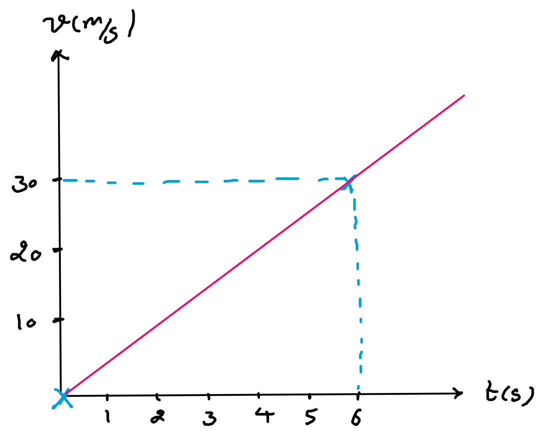
b) $a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t} \Rightarrow \Delta t = \frac{50 - 30}{5.0} = 4.0\ s$

c) $a = \frac{\Delta v}{\Delta t} = \frac{v_1 - \cancelto{0}{v_0}}{t_1 - \cancelto{0}{t_0}} \Rightarrow t_1 = \frac{30}{5.0} = 6.0\ s$

d) $x_1 = \frac{1}{2} a t_1^2 + \cancelto{0}{v_0 t_1} + \cancelto{0}{x_0} \Rightarrow x_1 = \frac{1}{2} \times 5.0 \times (6.0)^2 = 90\ m$

e)





81 CALC SSM A particle's acceleration along an *x* axis is $a = 5.0t$, with *t* in seconds and *a* in meters per second squared. At $t = 2.0$ s, its velocity is +17 m/s. What is its velocity at $t = 4.0$ s?

$a = \frac{dv}{dt} \longrightarrow v = \int a\,dt$

$\frac{d}{dt}\left(\frac{1}{2}t^2 + C\right) = \frac{1}{2} \times 2t + 0 = t$

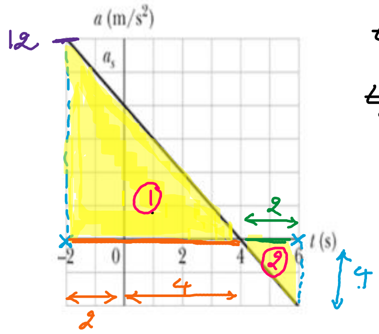
$a = 5t \Rightarrow v = \int 5t\,dt = 5\underbrace{\int t\,dt}_{\frac{1}{2}t^2 + C} = \frac{5}{2}t^2 + C$

$v = \frac{5}{2}t^2 + C \xrightarrow[v = 17\ m/s]{t = 2\ s} 17 = \frac{5}{\cancel{2}} \times \cancelto{2}{2^2} + C \Rightarrow C = 17 - 10 = 7$

$\Rightarrow v = \frac{5}{2}t^2 + 7 \xrightarrow{t=4} v(t=4) = \frac{5}{\cancel{2}} \times \cancelto{8}{4^2} + 7 = 47\ m/s$

82 CALC Figure 2.29 gives the acceleration a versus time t for a particle moving along an x axis. The a-axis scale is set by $a_s = 12.0\ m/s^2$. At $t = -2.0$ s, the particle's velocity is 7.0 m/s. What is its velocity at $t = 6.0$ s?

$$a = \frac{dv}{dt} \longrightarrow v = \int a\,dt$$



$t_1 = -2s$; $v(t_1) = 7\ m/s$

$t_2 = 6\ s$; $v(t_2) = ?$

$$* \quad v(t_2) - v(t_1) = \underbrace{\int_{t_1=-2}^{t_2=6} a\,dt}$$

$S_1 = \frac{1}{2} \times 12 \times 6 = 36$

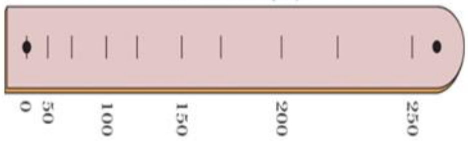
$S_2 = \frac{1}{2} \times 2 \times (-4) = -4$

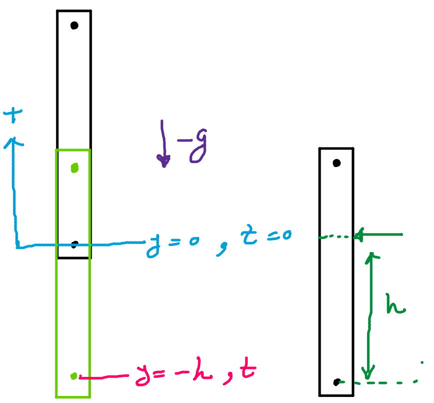
$\longrightarrow S_1 + S_2 = 36 - 4 = 32$

$$\longrightarrow \int_{t_1=-2}^{t_2=6} a\,dt = 32\ m/s \xrightarrow{*} v(t_2) - \overbrace{v(t_1)}^{7} = 32 \longrightarrow v(t_2 = 6) = 39\ m/s$$

83 BIO Figure 2.30 shows a simple device for measuring your reaction time. It consists of a cardboard strip marked with a scale and two large dots. A friend holds the strip *vertically*, with thumb and forefinger at the dot on the right in Fig. 2.30. You then position your thumb and forefinger at the other dot (on the left in Fig. 2.30), being careful not to touch the strip. Your friend releases the strip, and you try to pinch it as soon as possible after you see it begin to fall. The mark at the place where you pinch the strip gives your reaction time. (a) How far from the lower dot should you place the 50.0 ms mark? How much higher should you place the marks for (b) 100, (c) 150, (d) 200, and (e) 250 ms? (For example, should the 100 ms marker be 2 times as far from the dot as the 50 ms marker? If so, give an answer of 2 times. Can you find any pattern in the answers?)

Reaction time (ms)





a) $t = 50\ ms = 50 \times 10^{-3}\ s$

$y = -\frac{1}{2} g t^2 + \cancel{v_0 t} + \cancel{y_0}$

$-h = -\frac{1}{2} g t^2 \longrightarrow h = \frac{1}{2} \times 9.8 \times (5 \times 10^{-2})^2 = 0.01225\ m$

$\longrightarrow h = 1.23\ cm$

b) $t_1 = 100\ ms = 100 \times 10^{-3} = 0.1\ s$ $= 2t$

$h_1 = \frac{1}{2} g t_1^2 \longrightarrow h_1 = \frac{1}{2} \times 9.8 \times (0.1)^2 = 0.049\ m \longrightarrow h_1 = 4.9\ cm$ $= 4h$ $= 2^2 h$

c) $t_2 = 150\ ms = 150 \times 10^{-3} = 0.15\ s$ $= 3t$

$h_2 = \frac{1}{2} g t_2^2 \longrightarrow h_2 = \frac{1}{2} \times 9.8 \times (0.15)^2 = 0.11025\ m \longrightarrow h_2 \simeq 11\ cm$ $= 9h$ $= 3^2 h$

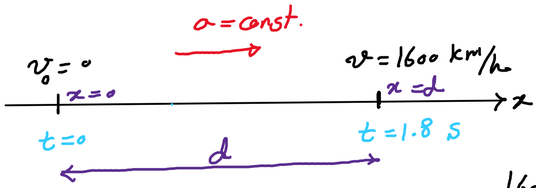
d) $t_3 = 200\ ms = 200 \times 10^{-3} = 0.2\ s$ $= 4t$

$h_3 = \frac{1}{2} g t_3^2 \longrightarrow h_3 = \frac{1}{2} \times 9.8 \times (0.2)^2 = 0.196\ m \longrightarrow h_3 \simeq 19.6\ cm$ $= 16h$ $= 4^2 h$

e) $t_4 = 250\ ms = 250 \times 10^{-3} = 0.25\ s$ $= 5t$

$h_4 = \frac{1}{2} g t_4^2 \longrightarrow h = \frac{1}{2} \times 9.8 \times (0.25)^2 = 0.30625\ m \longrightarrow h_4 \simeq 30.6\ cm$ $= 25h$ $= 5^2 h$

84 BIO FCP A rocket-driven sled running on a straight, level track is used to investigate the effects of large accelerations on humans. One such sled can attain a speed of 1600 km/h in 1.8 s, starting from rest. Find (a) the acceleration (assumed constant) in terms of g and (b) the distance traveled.



a) $a = \dfrac{\Delta v}{\Delta t} = \dfrac{v - v_0}{t - \cancel{t_0}} = \dfrac{1600 \times \frac{10^3\ m}{3600\ s}}{1.8\ s} \simeq 246.9\ m/s^2 \div 9.8 = 25.2\,g \simeq 25g$

b) $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{x - x_0}{t - \cancel{t_0}}$; $\bar{v} = \frac{1}{2}(v + v_0)$

$\rightarrow x = \frac{1}{2}(v + v_0)\,t + \cancel{x_0} \longrightarrow d = \frac{1}{2}\left(1600 \times \frac{10}{36}\right) \times 1.8 = 400\ m$

85 *Fastball timing.* In professional baseball, the *pitching distance* of 60 feet 6 inches is the distance from the front of the pitcher's plate (or rubber) to the rear of the home plate. (a) Assuming that a 95 mi/h fastball travels that full distance horizontally, what is its flight time, which is the time a batter must judge if the ball is "hittable" and then swing the bat? (b) Research indicates that even an elite batter cannot track the ball for the full flight and yet many players have described seeing the ball-bat collision. One explanation is that the eyes track the ball in the early part of the flight and then undergo a *predictive saccade* in which they jump to an anticipated point later in the flight. A saccade suppresses vision for 20 ms. How far in feet does the fastball travel during that interval of no vision?

$v = 95\ mi/h = 95 \times \dfrac{5280\ ft}{3600\ s} = 139.3\ ft/s$

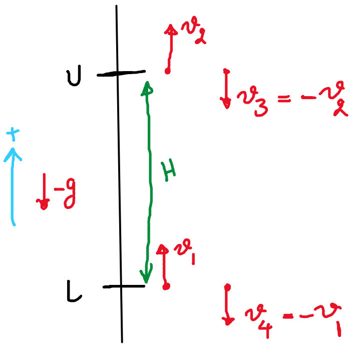
$d = 60\,ft + 6\,in = 60 + \frac{6}{12} = 60.5\ ft$

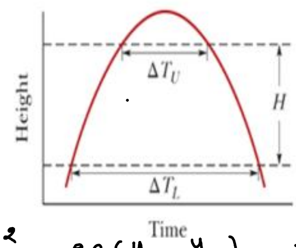
Appendix D: $\frac{1}{12}$ ft

a) $d = vt \longrightarrow t = \dfrac{d}{v} = \dfrac{60.5}{139.3} \simeq 0.434\ s$

b) $\Delta t = 20\ ms = 20 \times 10^{-3}\ s \longrightarrow d = v\Delta t = 139.3 \times 0.02 \simeq 2.79\ ft$

86 *Measuring the free-fall acceleration.* At the National Physical Laboratory in England, a measurement of the free-fall acceleration g was made by throwing a glass ball straight up in an evacuated tube and letting it return. Let ΔT_L in Fig. 2.31 be the time interval between the two passes of the ball across a certain lower level, ΔT_U the time interval between the two passages across an upper level, and H the distance between the two levels. What is g in terms of those quantities?





$v_U^2 - v_L^2 = -2g(y_U - y_L) \Longrightarrow v_2^2 - v_1^2 = -2g \times H$ *

$v_f = -gt + v_i$

f : 3 , i : 2 , $t = \Delta T_u \longrightarrow \overset{-v_2}{v_3} = -g \times \Delta T_u + v_2 \longrightarrow 2v_2 = g\Delta T_u \Rightarrow v_2 = \frac{1}{2} g \Delta T_u$

f : 4 , i : 1 , $t = \Delta T_L \longrightarrow \overset{-v_1}{v_4} = -g \times \Delta T_L + v_1 \longrightarrow 2v_1 = g\Delta T_L \Rightarrow v_1 = \frac{1}{2} g \Delta T_L$

* : $(\frac{1}{2} g \Delta T_u)^2 - (\frac{1}{2} g \Delta T_L)^2 = -2gH \longrightarrow \frac{1}{4} g^{\cancel{2}} \{\Delta T_u^2 - \Delta T_L^2\} = -2\cancel{g} H \Longrightarrow g = \dfrac{-8}{\Delta T_u^2 - \Delta T_L^2}$