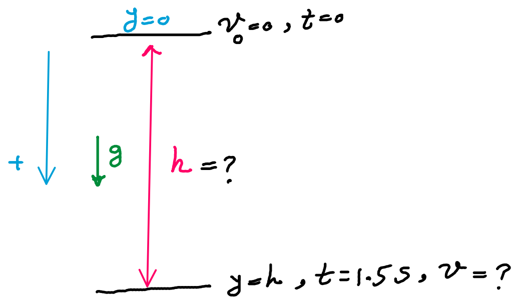
105 *Falling wrench.* A worker drops a wrench down the elevator shaft of a tall building. (a) Where is the wrench 1.5 s later? (b) How fast is the wrench falling just then?



a) $y = \frac{1}{2}gt^2 + \cancel{v_0}t + \cancel{y_0}$, with $v_0 = 0$ and $y_0 = 0$

$h = \frac{1}{2} \times 9.8 \times (1.5)^2 = 11.025 \simeq 11 \text{ m}$

b) $v = gt + \cancel{v_0}$, with $v_0 = 0$ $\Rightarrow v = 9.8 \times 1.5 = 14.7 \simeq 15 \text{ m/s}$

106 *Crash acceleration.* A car crashes head on into a wall and stops, with the front collapsing by 0.500 m. The driver is firmly held to the seat by a seat belt and thus moves forward by 0.500 m during the crash. Assume that the acceleration is constant during the crash. What is the magnitude of the driver's acceleration in *g* units if the initial speed of the car is (a) 35 mi/h and (b) 70 mi/h?

$\Delta x = 0.500 \text{ m}$

Appendix D: $1 \text{ mi/h} = 0.4470 \text{ m/s}$

a) $v_0 = 35 \text{ mi/h} = 35 \times 0.4470 = 15.645 \text{ m/s}$

$v = 0$

$\cancel{v^2} - v_0^2 = 2a\Delta x$, with $v = 0$ $\Rightarrow -(15.645)^2 = 2 \times a \times 0.500 \Rightarrow a = -244.766 \text{ m/s}^2$

$\Rightarrow |a| = 244.766 \div 9.8 \simeq 24.976g \simeq 25.0\,g$

b) $v_0 = 70 \text{ mi/h} = 70 \times 0.4470 = 31.29 \text{ m/s}$

$v = 0$

$\cancel{v^2} - v_0^2 = 2a\Delta x$, with $v = 0$ $\Rightarrow -(31.29)^2 = 2a \times 0.500 \Rightarrow a \simeq -979.06 \text{ m/s}^2$

$\Rightarrow |a| = 979.06 \div 9.8 \simeq 99.9g \simeq 100g$

107 *Billboard distraction.* Highway billboards have long been a possible source of driver distraction, especially the modern electronic billboards with moving parts or with flipping from one scene to another within a few seconds. If you are traveling at 31.3 m/s (70 mi/h), how far along the road do you move if you look at a colorful and animated billboard for (a) 0.20 s (a glancing look), (b) 0.80 s, and (c) 2.0 s? Answer in both meters and in yards (to give you a feel for how your travel would be along an American football field).

$v = 31.3 \text{ m/s}$

a) $\Delta t = 0.20 \text{ s} \Rightarrow d = v.\Delta t = 31.3 \times 0.20 = 6.26 \text{ m} \rightarrow \frac{1}{0.9144} \text{ yd} \Rightarrow d \simeq 6.85 \text{ yd}$

m

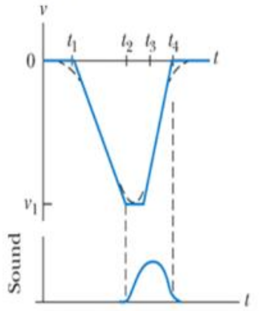
Appendix D: $1 \text{ yd} = 3 \text{ ft}$, $1 \text{ ft} = 0.3048 \text{ m}$ $\Rightarrow 1 \text{ yd} = 3 \times 0.3048 = 0.9144 \text{ m}$

b) $\Delta t = 0.80 \text{ s} \Rightarrow d = v.\Delta t = 31.3 \times 0.80 \simeq 25.0 \text{ m} \quad \frac{1}{0.9144} \text{ yd} \rightarrow d \simeq 27.4 \text{ yd}$

c) $\Delta t = 2.0 \text{ s} \Rightarrow d = v.\Delta t = 31.3 \times 2.0 = 62.6 \text{ m} \rightarrow d = 68.5 \text{ yd}$

108 BIO CALC *Remote fall detection.* Falling is a chronic danger to the elderly and people subject to seizure. Researchers search for ways to detect a fall remotely so that a caretaker can go to the victim quickly. One way is to use a computer system that analyzes the motions of someone on CCTV in real time. The system monitors the vertical velocity of someone and then calculates the vertical acceleration when that velocity changes. If the system detects a large negative (downward) acceleration followed by a briefer positive acceleration and accompanied by a sound burst for the onset of the positive acceleration, a signal is sent to a caretaker. Figure 2.39 gives an idealized graph of vertical velocity v versus time t as determined by the system: $t_1 = 1.0$ s, $t_2 = 2.5$ s, $t_3 = 3.0$ s, $t_4 = 4.0$ s, $v_1 = -7.0$ m/s. (The plot on a more realistic graph would be curved.) What are (a) the acceleration during the descent and (b) the upward acceleration during the impact with the floor?

$$a = \frac{dv}{dt} = \frac{\Delta v}{\Delta t}$$



$t_1 = 1.0$ s

$t_2 = 2.5$ s

$t_3 = 3.0$ s

$t_4 = 4.0$ s

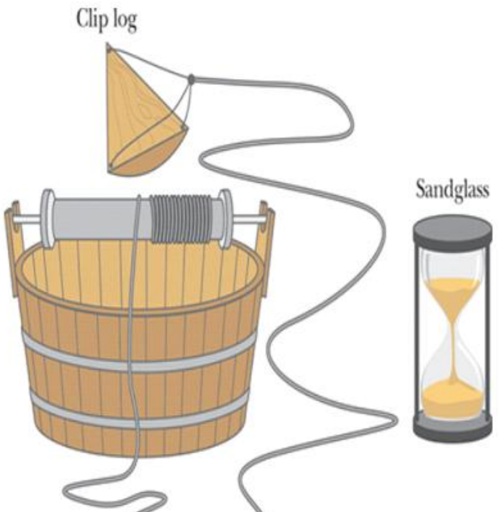
$v_1 = -7.0$ m/s

a) $a = \frac{\Delta v}{\Delta t} = \frac{v_1 - 0}{t_2 - t_1}$

$$a = \frac{-7.0 - 0}{2.5 - 1.0} = \frac{-7.0}{1.5} \simeq -4.7 \text{ m/s}^2$$

b) $a = \frac{\Delta v}{\Delta t} = \frac{0 - v_1}{t_4 - t_3} = \frac{0-(-7.0)}{4.0 - 3.0} = 7.0 \text{ m/s}^2$

109 *Ship speed in knots.* Before modern instrumentation, a ship's speed was measured with a line that had small knots tied along its length, separated by 47 feet 3 inches. The line was attached by three cords to a wood plate (a *clip log*) in the shape of a pie slice as shown in Fig. 2.40. One sailor threw the plate overboard and then allowed the force of the water against the plate to pull the line off a reel and through his hand so that he could detect the periodic passage of knots. Another sailor inverted a sandglass so that sand flowed from its upper chamber into the lower chamber in 28 s. During that interval the first sailor counted the number of knots passing through his hand. The result was the ship's speed in knots (abbreviated as kn). If 17 knots passed, what was the ship's speed in (a) knots, (b) miles per hour, and (c) kilometers per hour?



a) $v = 17$ kn

$\Delta t = 28$ s

d = 47 ft, 3 in

d

$l = 17d = 17 \times (47 \text{ ft}, 3 \text{ in})$

$\frac{1}{12}$ ft

$= 17 \times (\underbrace{47 \text{ ft} + \frac{3}{12} \text{ ft}}_{47.25 \text{ ft}})$

$\rightarrow l = 803.25$ ft

$$v = \frac{l}{\Delta t} = \frac{803.25 \text{ ft}}{28 \text{ s}} = 28.6875 \text{ ft/s}$$

b) $v = ?$ mi/h

Appendix D: 1 ft/s = 0.6818 mi/h $\rightarrow v = 28.6875 \times 0.6818 \simeq 19.559 \simeq 20$ mi/h

mi

c) $v = ?$ km/h

Appendix D: 1 ft/s = 1.097 km/h $\rightarrow v = 28.6875 \times 1.097 \simeq 31.47 \simeq 31$ km/h