Oberlin College Physics 103, Fall 2023

Model Solutions to Assignment 1

Problems from *College Physics* by P.P. Urone and R. Hinrichs.

Chapter 1, problem 16

375 mL − 308 mL = 67 mL (The point of this problem is not the arithmetic. The point is that the difference between a term with three significant figures and another term with three significant figures has, in this case, only two significant figures.) ⟦*Grading:* 3 points for correct arithmetic; 4 points for result with two significant figures; 3 points for units "mL".⟧

Chapter 1, problem 17

(a) three; (b) three; (c) two. ⟦*Grading:* 1 point for free; 3 points for each correct answer. For this problem, explanation of reasoning not needed.⟧

Chapter 2, problem 6

The distance traveled in one revolution is $2\pi r$, where $r = 5.00$ m. The time required for one revolution is (1/100) minute or (60.0/100) s = 0.600 s.

(a) Average speed is distance traveled divided by elapsed time, in this case

$$\frac{2\pi(5.00\text{ m})}{0.600\text{ s}} = 52.4\text{ m/s}.$$

⟦If you rounded to 52.3 m/s, full credit. If you wrote 3.14×10^3 m/minute, full credit.⟧

(b) Average velocity over one revolution is zero, because in one revolution it comes back to its starting location. ⟦*Grading:* 2 points for $2\pi r$ expression for circumference; 1 point for invoking definition of average speed; 1 point for arithmetic generating 52.3 or 3.14×10^3; 2 points for units (m/s or m/minute); 2 points for three significant figures (−1 point for 3140 m/minute, −2 points for 3142 m/minute); 2 points for average velocity zero.⟧

Chapter 2, problem 7

$$\frac{500\text{ km}}{3\text{ cm/y}} = \frac{5 \times 10^7\text{ cm}}{3\text{ cm/y}} = 2 \times 10^7\text{ y}.$$

⟦*Grading:* 3 points for setting up the division; 3 points for executing the division arithmetic; 2 points for the unit "y" (or "years"); 2 points for one significant figure.⟧

Chapter 2, problem 11

(a)

$$\text{average speed} = \frac{12.0\text{ km}}{18.0\text{ min}} = 0.667\text{ km/min}.$$

(b)

$$\text{average velocity} = \frac{10.3\text{ km}}{18.0\text{ min}} = 0.572\text{ km/min} \quad \text{directed } 25.0^\circ \text{ south of east}.$$

(c)

$$\text{average speed} = \frac{24.0\text{ km}}{450\text{ min}} = 0.0533\text{ km/min}.$$

(d)

$$\text{average velocity} = 0.$$

⟦*Grading:* For parts (a), (b), and (c): 1 point for setup; 1 point for arithmetic execution; 1 point for correct units and significant figures. For part (d): 1 point.⟧

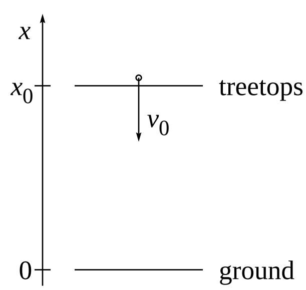
All the **remaining problems** involve motion with constant acceleration. The central equations for this kind of motion are

$$v(t) = v_0 + a_0 t \quad (1)$$
$$x(t) = x_0 + v_0 t + \tfrac{1}{2} a_0 t^2 \quad (2)$$
$$v^2(x) = v_0^2 + 2a_0(x - x_0). \quad (3)$$

Much of the skill in problem solving consists of figuring out which of these equations is the most appropriate to use.

Chapter 2, problem 34: Pilot slowdown

⟦Note that the problem statement contains a lot of irrelevant information, such as the circumstance being World War II, and falling from a particular elevation.⟧ I set up this problem as below, with positive being upward, origin being at ground level, initial velocity $v_0 = -54$ m/s, initial position $x_0 = +3.0$ m. You may set it up differently, but be consistent about how you set it up. (A diagram helps.)



Which of the three equations should we use? Because we are given information about positions and velocities but not about times, it makes sense to use equation (3). The pilot falls from $x = x_0$ to $x = 0$ while velocity changes from v_0 to 0. We have

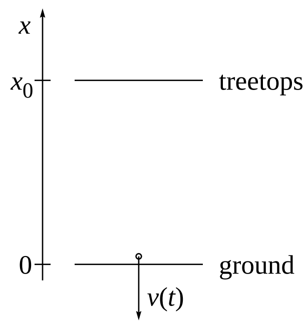
$$\begin{aligned} v^2(x) &= v_0^2 + 2a_0(x - x_0) \\ 0 &= v_0^2 + 2a_0(0 - x_0) \\ 2a_0 x_0 &= v_0^2 \\ a_0 &= \frac{v_0^2}{2x_0} = \frac{(-54\ \text{m/s})^2}{2(3.0\ \text{m})} = 4.9 \times 10^2\ \text{m/s}^2. \end{aligned}$$

(The arithmetic at first gives 486 m/s^2, but there are only two significant figures.) Note that the acceleration is positive, i.e. upward, because the initial velocity is downward, so the change in velocity is upward.

⟦*Grading:* 2 points for diagram; 2 points for using formula $v^2(x) = v_0^2 + 2a_0(x - x_0)$; 2 points for solving this formula for a_0; 2 points for arithmetic to get the right number; 1 point for 2 significant figures (the answer 490 m/s^2 is technically incorrect, but should be given full credit); 1 point for units.⟧

Chapter 2, problem 35: Squirrel fall

(a) I set up this problem as below, with positive being upward, origin being at ground level, initial velocity $v_0 = 0$, initial position $x_0 = +3.0$ m. The acceleration is $a_0 = -g$ where $g = +9.81$ m/s^2. You may set it up differently, but be consistent.



Just as in the problem 34, the most appropriate equation is (3). The squirrel falls from $x = x_0$ to $x = 0$ while velocity changes from 0 to $v(x)$ with $a_0 = -g$. Thus

$$\begin{aligned} v^2(x) &= v_0^2 + 2a_0(x - x_0) \\ &= 0 - 2g(0 - x_0) \\ &= 2gx_0 \\ v(x) &= \sqrt{2gx_0} = \sqrt{2(9.81\ \text{m/s}^2)(3.0\ \text{m})} = 7.7\ \text{m/s}. \end{aligned}$$

(b) The deceleration is determined exactly as it was in problem 34, so we use the same equation

$$a_0 = \frac{v_0^2}{2x_0}$$

but with different numbers

$$a_0 = \frac{v_0^2}{2x_0} = \frac{(7.7\ \text{m/s})^2}{2(0.020\ \text{m})} = 1.5 \times 10^3\ \text{m/s}^2.$$

(The arithmetic at first gives 1482.25 m/s^2, but there are only two significant figures.) The deceleration experienced by the squirrel is three times the deceleration experienced by the pilot.

⟦*Grading:* For part (a): 2 points for diagram; 2 points for using formula $v^2(x) = v_0^2 + 2a_0(x - x_0)$; 1 point for plugging in the correct values to get $v(x) = \sqrt{2gx_0}$; 1 points for arithmetic to get the right number; 1 point for 2 significant figures; 1 point for units. For part (b): 2 points.⟧

Chapter 2, problem 39: Motorcycle

There are two phases of motion: acceleration to reach maximum speed, followed by motion at that constant maximum speed.

Acceleration phase. Rate of acceleration is

$$a_0 = \frac{60.0 \text{ mi/h}}{4.00 \text{ s}} = (15.0 \text{ mi/h})/\text{s}.$$

Time needed at this acceleration to reach speed $v_{\text{max}} = 183.58$ mi/hr. Use equation (1):

$$\begin{aligned} v(t) &= v_0 + a_0 t \\ v_{\text{max}} &= 0 + a_0 t \\ t &= \frac{v_{\text{max}}}{a_0} = \frac{183.58 \text{ mi/hr}}{(15.0 \text{ mi/h})/s} = 12.2 \text{ s.} \end{aligned}$$

Distance traveled during acceleration phase. Use equation (3):

$$\begin{aligned} v^2(x) &= v_0^2 + 2a_0(x - x_0) \\ v_{\text{max}}^2 &= 0 + 2a_0(x - 0) \\ x &= \frac{v_{\text{max}}^2}{2a_0} = \frac{(183.58 \text{ mi/hr})^2}{2(15.0 \text{ mi/h})/\text{s}} = [(183.58)^2/30.0] \text{ mi(s/h).} \end{aligned}$$

But h = 3600s, so s/h = 1/3600, so

$$\begin{aligned} x &= [(183.58)^2/30.0] \text{ mi(s/h)} \\ &= (183.58)^2/[30.0 \times 3600] \text{ mi} \\ &= 0.312 \text{ mi.} \end{aligned}$$

Constant velocity phase. Distance traveled during this phase is

$$5.00 \text{ mi} - 0.312 \text{ mi} = 4.69 \text{ mi.}$$

The time required to travel this distance is

$$\begin{aligned} t &= \frac{\text{distance}}{\text{speed}} \\ &= \frac{4.69 \text{ mi}}{183.58 \text{ mi/hr}} \\ &= 0.0255 \text{ h} \\ &= 92.0 \text{ s.} \end{aligned}$$

Putting the two phases together, total time required is

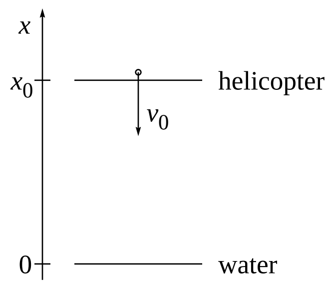
$$12.2 \text{ s} + 92.0 \text{ s} = 104.2 \text{ s.}$$

⟦*Grading:* 5 points for constant acceleration phase; 4 points for constant velocity phase; 1 point for sum.⟧

Chapter 2, problem 44: Tossed life preserver

(a) Known are the initial velocity $v_0 = -1.40$ m/s and the time of striking the water $t_S = 1.8$ s.

(b) Unknown is the height of the helicopter x_0. I set up this problem as below, with positive being upward, origin being at water level, initial velocity $v_0 = -1.40$ m/s, initial position (the unknown) x_0. You may set it up differently, but be consistent about how you set it up. (A diagram always helps.)



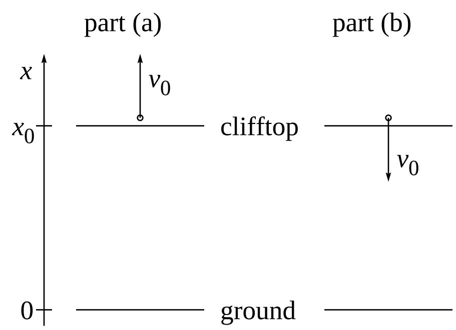
Which of the three equations should we use? Because we are given information about velocities and times, and are asked about positions, it makes sense to use equation (2).

$$\begin{aligned} x(t) &= x_0 + v_0 t + \tfrac{1}{2} a_0 t^2 \\ 0 &= x_0 + v_0 t_S - \tfrac{1}{2} g t_S^2 \\ x_0 &= -v_0 t_S + \tfrac{1}{2} g t_S^2 \\ &= -(-1.40 \text{ m/s})(1.8 \text{ s}) + \tfrac{1}{2}(9.81 \text{ m/s}^2)(1.8 \text{ s})^2 = 19 \text{ m.} \end{aligned}$$

⟦*Grading:* 2 points for part (a); 2 points for diagram; 2 points for picking on equation (2); 2 points for solving for x_0; 2 points for proper number, significant figures, and units.⟧

Chapter 2, problem 47: Thrown ball

(a) *Thrown upward.* Known are the initial velocity $v_0 = +8.00$ m/s and the time of striking the ground $t_S = 12.35$ s. Desired is the height of the cliff x_0.



Which of the three equations should we use? Because we are given information about velocities and times, and are asked about positions, it makes sense to use equation (2).

$$\begin{aligned} x(t) &= x_0 + v_0 t + \tfrac{1}{2} a_0 t^2 \\ 0 &= x_0 + v_0 t_S - \tfrac{1}{2} g t_S^2 \\ x_0 &= -v_0 t_S + \tfrac{1}{2} g t_S^2 \\ &= -(8.00 \text{ m/s})(2.35 \text{ s}) + \tfrac{1}{2}(9.81 \text{ m/s}^2)(2.35 \text{ s})^2 = 8.3 \text{ m}. \end{aligned}$$

(b) *Thrown downward.* Known are the initial velocity $v_0 = -8.00$ m/s and the height of the cliff $x_0 = 8.3$ m. Desired is the time of striking the ground t_S. It again makes sense to use equation (2).

$$\begin{aligned} x(t) &= x_0 + v_0 t + \tfrac{1}{2} a_0 t^2 \\ 0 &= x_0 + v_0 t_S - \tfrac{1}{2} g t_S^2. \end{aligned}$$

Solve for t_S using the quadratic formula:

$$\begin{aligned} t_S &= \left[-v_0 \pm \sqrt{v_0^2 - 4(-\tfrac{1}{2} g) x_0} \right] / 2(-\tfrac{1}{2} g) \\ &= \left[v_0 \mp \sqrt{v_0^2 + 2 g x_0} \right] / g \end{aligned}$$

To make the strike time t_S positive, take the + sign in $\mp$:

$$\begin{aligned} t_S &= \left[v_0 + \sqrt{v_0^2 + 2 g x_0} \right] / g \\ &= \left[(-8.00 \text{ m/s}) + \sqrt{(-8.00 \text{ m/s})^2 + 2(9.81 \text{ m/s}^2)(8.3 \text{ m})} \right] / (9.81 \text{ m/s}^2) \\ &= 0.72 \text{ s}. \end{aligned}$$

⟦*Grading:* 5 points for each part.⟧

Chapter 2, problem 50: Kangaroo jump

(a) We are asked to link position and velocity, with no mention of time, so we use equation (3):

$$\begin{aligned} v^2(x) &= v_0^2 + 2a_0(x - x_0) \\ 0 &= v_0^2 - 2g(\text{height}) \\ v_0 &= \sqrt{2g(\text{height})} \\ &= \sqrt{2(9.81\ \text{m/s}^2)(2.50\ \text{m})} = 7.00\ \text{m/s} \end{aligned}$$

(b)

$$\begin{aligned} x(t) &= x_0 + v_0 t + \tfrac{1}{2}a_0 t^2 \\ 0 &= 0 + v_0 t_S - \tfrac{1}{2} g t_S^2 \\ \tfrac{1}{2} g t_S &= v_0 \\ t_S &= 2v_0/g = 1.43\ \ \text{s.} \end{aligned}$$

⟦*Grading:* 5 points for each part.⟧

Chapter 2, problem 53: Yosemite Half Dome rockfall

(a)

$$\begin{aligned} v^2(x) &= v_0^2 + \tfrac{1}{2}a_0(x - x_0) \\ v^2 &= 0 - \tfrac{1}{2}g(0 - x_0) \\ v^2 &= 2gx_0 \\ v &= -\sqrt{2g(\text{height})} \\ &= -\sqrt{2(9.81\ \text{m/s}^2)(250\ \text{m})} = -70.0\ \text{m/s.} \end{aligned}$$

That's about 140 mph.

(b) Time required for rock to strike ground is called t_S:

$$\begin{aligned} v(t) &= v_0 + a_0 t \\ v &= 0 - g t_S \\ -\sqrt{2g(\text{height})} &= -g t_S \\ t_S &= \sqrt{\frac{2(\text{height})}{g}} = 7.14\ \text{s.} \end{aligned}$$

Time required for sound to reach tourist:

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{250\ \text{m}}{335\text{m/s}} = 0.746\ \text{s.}$$

Reaction time is given as 0.300 s.

Thus time tourist has to get away is

$$7.14\ \text{s} - 0.746\ \text{s} - 0.300\ \text{s} = 6.09\ \text{s}$$

⟦*Grading:* 5 points for velocity of fallen rock; 3 points for time required for rock to strike ground; 1 point for time required for sound to reach tourist; 1 point for time to get away.⟧