Oberlin College Physics 110, Fall 2011

Model Solutions to Assignment 2

HRW problem 2–6: *Bicycle speed record*

$$\text{average speed} = \frac{\text{distance traveled}}{\text{time elapsed}},$$

so Huber's speed was

$$\frac{200.0 \text{ m}}{6.509 \text{ s}} = 30.73 \text{ m/s} = 110.6 \text{ km/hr}.$$

Thus Whittingham's speed was

$$110.6 \text{ km/hr} + 19.9 \text{ km/hr} = 130.5 \text{ km/hr} = 36.25 \text{ m/s}$$

and Whittingham's time was

$$\text{time elapsed} = \frac{\text{distance traveled}}{\text{average speed}} = \frac{200.0 \text{ m}}{36.25 \text{ m/s}} = 5.517 \text{ s}.$$

(Note: four significant figures.)

Additional problem 19: *A fly and two trains*

There is no need to sum an infinite series. The zig-zag flight starts when the trains are 40 miles apart, and each train travels at 20 mi/hr, so the time from the start of flight to the train crash is 1 hour. A fly that travels at 30 mi/hr for 1 hr covers a distance of 30 miles.

Additional problem 24: *Proton in motion*

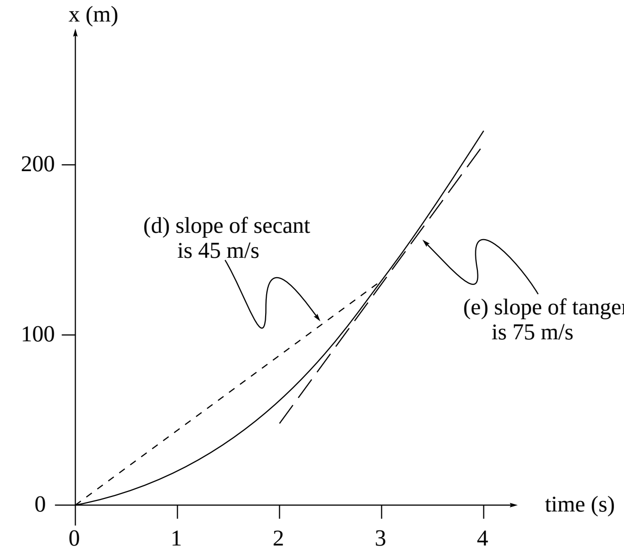
$$\begin{aligned} x(t) &= (15 \text{ m/s})\, t + (10 \text{ m/s}^2)\, t^2 && (1) \\ v(t) = \frac{dx}{dt} &= 15 \text{ m/s} + (20 \text{ m/s}^2)\, t && (2) \\ a(t) = \frac{dv}{dt} &= 20 \text{ m/s}^2 && (3) \end{aligned}$$

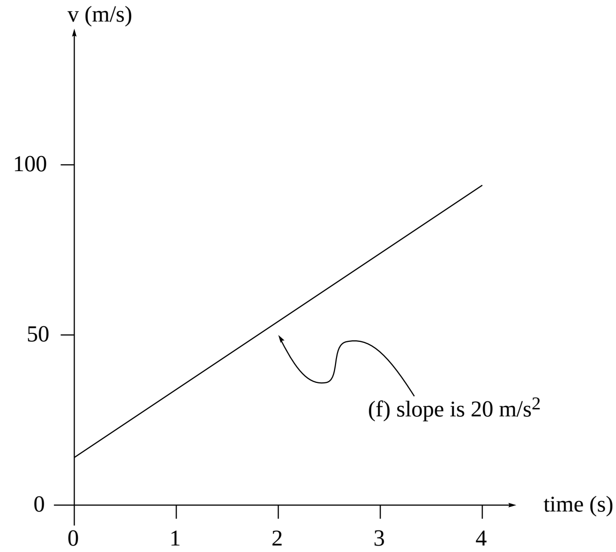
(a) From equation (1) above, $x(0.0 \text{ s}) = 0$ m, while $x(3.0 \text{ s}) = 135$ m. Thus

$$\text{average velocity} = \frac{\Delta x}{\Delta t} = \frac{135 \text{ m}}{3.0 \text{ s}} = 45 \text{ m/s}$$

(b) From equation (2) above, $v(3.0 \text{ s}) = 75$ m/s.

(c) From equation (3) above, $a(3.0 \text{ s}) = 20 \text{ m/s}^2$.





⟦Note: There's no need for you to produce an elaborate and quantitatively accurate computer graphic like the above. A simple sketch would be fine, and that's what I'd do myself if I weren't posting these solutions on the Internet.⟧

Additional problem 25: *Car vs. rattlesnake*
For constant acceleration with zero initial velocity, $v(t) = a_0 t$. The desired final velocity is

$$100 \text{ km/hr} = \frac{100 \text{ km}}{\text{hr}} \left(\frac{1000 \text{ m}}{\text{km}}\right) \left(\frac{\text{hr}}{3600 \text{ s}}\right) = 27.8 \text{ m/s},$$

while $a_0 = 50 \text{ m/s}^2$. Thus the time needed would be

$$\frac{v}{a_0} = \frac{27.8 \text{ m/s}}{50 \text{ m/s}^2} = 0.56 \text{ s}.$$

Additional problem 26: *Bullet*
We use $v^2 = v_0^2 + 2a_0(x - x_0)$ to find the acceleration a_0, then $v = v_0 + a_0 t$ to find the time t. (In this case v_0 and x_0 are both zero.) First $a_0 = v^2/(2x)$, then

$$t = \frac{v}{a_0} = \frac{2x}{v},$$

or, plugging in numbers,

$$t = \frac{2(1.20 \text{ m})}{640 \text{ m/s}} = 3.75 \text{ ms}.$$

Additional problem 28: *Starting and stopping*
For start up, use $v = v_0 + a_0 t$ to find

$$a_0 = \frac{v - v_0}{t} = \frac{60.0 \text{ mph} - 0.0 \text{ mph}}{10.1 \text{ s}} = 5.94 \text{ mph/s}.$$

(Compare this acceleration to $g \approx 20$ mph/s.) For slow down, use $v^2 = v_0^2 + 2a_0(x - x_0)$ to find

$$\begin{aligned} a_0 &= \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(0.0 \text{ mph})^2 - (60.0 \text{ mph})^2}{2(118 \text{ ft})} = -(60.0 \text{ mph})\frac{30.0 \text{ mi/hr}}{118 \text{ ft}} \\ &= -(60.0 \text{ mph})\frac{30.0 \text{ mi/hr}}{118 \text{ ft}} \times \left(\frac{5280 \text{ ft}}{1 \text{ mi}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) = -22.4 \text{ mph/s}. \end{aligned}$$

⟦If you are under the misimpression that you must expression accelerations in SI units, then the answers are 2.66 m/s^2 and -10.0 m/s^2.⟧

Additional problem 31: *The acceleration of gravity*
The acceleration due to gravity is $g = 22$ mph/sec; so after two seconds the ball will be going 44 mph; it will exceed the 65 mph speed limit in just 3 sec.

Additional problem 32: *Dropped from Peters Hall*

a. The height y changes with time according to

$$y(t) = y_0 + v_0 t - \tfrac{1}{2} g t^2.$$

In this case $y_0 = h$ (the height of Peters Hall), $v_0 = 0$, and I want to find the time T when the ball hits, namely when $y(T) = 0$. Thus

$$0 = h - \tfrac{1}{2} g T^2,$$

or, solving for the drop time T,

$$T = \sqrt{\frac{2h}{g}}.$$

b. Checks:

- The dimensions are
$$\sqrt{\frac{\text{length}}{\text{length/time}^2}} = \sqrt{\text{time}^2} = \text{time}.$$
- The drop time T predicted through this formula increases with h and decreases with g, as expected.
- When $h = 0$ the ball hits instantly, so $T = 0$, as predicted.
- When $g = 0$, the ball does not drop, so $T = \infty$, as predicted.

c. I measured one sandstone block to be 0.3 meter tall, and I counted 66 courses up to the top. This gives a height of $h = 20$ m. Using this height and taking $g = 10$ m/sec^2, we find $T = 2$ sec. This time seems surprisingly but not outrageously short to me. (If, for example, I had calculated a drop time of 2 milliseconds, then I would have suspected an error on my part.)

d. In this case $v(t) = gt$, where $g = 22$ mph/sec, so the pencil hits the ground at 44 miles/hour.

Additional problem 33: *Dropping time*

The ball will be moving *faster* during the second half of its fall than it did during the first half of its fall. So even though it covers twice the distance, it takes *less than* twice the time. (I don't know of any way to convince someone like George that it would take exactly 1.414 times as much time, but he should be able to see that it will take less than twice as much time.)

HRW problem 2–68: *Salamander tongue*

The speed at the end of the acceleration phase is just the area under the curve.

$$\begin{aligned}
\text{speed} &= \text{area under curve} \\
&= \left[\text{area for time from 0 ms to 10 ms}\right] + \left[\text{area for time from 10 ms to 20 ms}\right] + \\
&\quad \left[\text{area for time from 20 ms to 30 ms}\right] + \left[\text{area for time from 30 ms to 40 ms}\right] \\
&= \left[0\right] + \left[\tfrac{1}{2}(0.010\text{ s})(100\text{ m/s}^2)\right] + \\
&\quad + \left[(0.010\text{ s})(100\text{ m/s}^2) + \tfrac{1}{2}(0.010\text{ s})(300\text{ m/s}^2)\right] + \left[\tfrac{1}{2}(0.010\text{ s})(400\text{ m/s}^2)\right] \\
&= 5.0\text{ m/s}
\end{aligned}$$