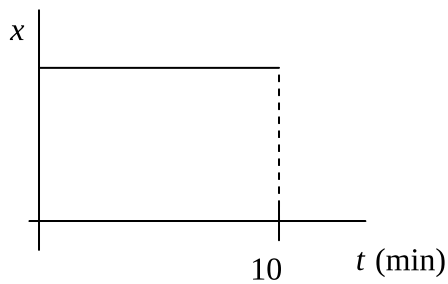
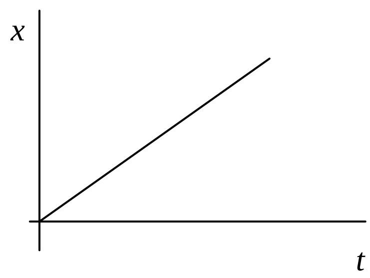
**Assignment #2**

Chapter 3 Questions:

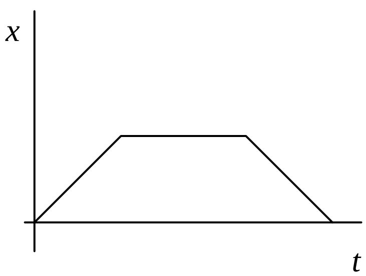
3.17



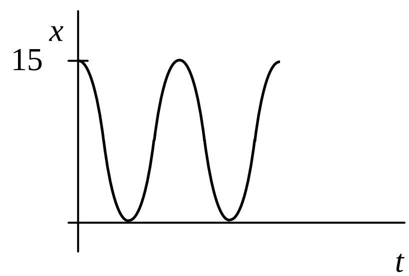

(a)




(b)



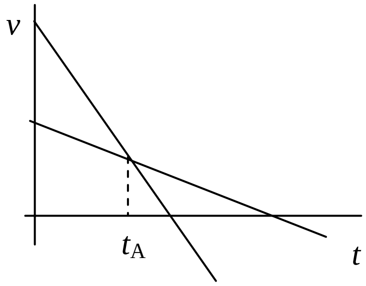

(c)




(D)

3.27 a) Situation (a)
b) Situations (b) and (c)
c) Situations (a), (b), and (c)
d) None
e) None
f) Situations (a), (b), and (c)
g) Situation (b)
h) Situation (c)
i) Situtation (c)
j) Situation (b)

3.28



Chapter 3 Problems:

**3.1**

a) Since the dog returns to the same point in space, the initial and final position vectors of the dog are the same. Hence $\Delta\vec{r} \equiv \vec{r}_{\text{final}} - \vec{r}_{\text{initial}} = 0\ \text{m}$.

b) The total distance traveled by the dog is the round-trip distance: $25\ \text{m} + 25\ \text{m} = 50\ \text{m}$.

c) The average speed of the dog is the total distance divided by the elapsed time: $v_{\text{average}} = 50\ \text{m}/12\ \text{s} = 4.2\ \text{m/s}$.

d) The average velocity is the change $\Delta\vec{r}$ in the dog's position vector divided by the elapsed time: $\vec{v}_{\text{average}} = \frac{1}{12\ \text{s}}\mathbf{0}\ \text{m} = \mathbf{0}\ \text{m/s}$.

**3.8** You have 60 min to drive the remaining 40 km. During the first 20 min, your average speed is only 25 km/h, so you cover only a distance of $(25\ \text{km/h})(20\ \text{min}) = (25\ \text{km/h})(20\ \text{min})\left(\frac{1\ \text{h}}{60\ \text{min}}\right) = 8.3\ \text{km}$. You must cover the remaining $40\ \text{km} - 8.3\ \text{km} = 32\ \text{km}$ in the remaining 40 min. Hence, your average speed for the remainder of the trip must be $\frac{32\ \text{km}}{40\ \text{min}} = \left(\frac{32\ \text{km}}{40\ \text{min}}\right)\left(60\frac{\text{min}}{\text{h}}\right) = 48\ \text{km/h}$.

**3.13** First convert 30.0 km/h to meters per second and 15.00 min to seconds:

$$30.0\ \text{km/h} = \left(30.0\frac{\text{km}}{\text{h}}\right)\left(10^3\frac{\text{m}}{\text{km}}\right)\left(\frac{\text{h}}{3\,600\ \text{s}}\right) = 8.33\ \text{m/s}, \qquad 15.00\ \text{min} = 15.00\ \text{min}\left(60\frac{\text{s}}{\text{min}}\right) = 900.0\ \text{s}.$$

a) Choose $\hat{\imath}$ to be in the direction of motion of the super tanker, and let $t = 0\ \text{s}$ be when the tanker starts to slow down. Then the initial velocity of the tanker is $\vec{v}_0 = (8.33\ \text{m/s})\hat{\imath}$, so the equation of motion for the tanker is

$$\vec{v}(t) = (8.33\ \text{m/s})\hat{\imath} + \vec{a}t.$$

When $t = 900.0\ \text{s}$, the velocity is $\mathbf{0}$ m/s and the equation $v_x = v_{x0} + a_x t$ becomes

$$0\ \text{m/s} = (8.33\ \text{m/s}) + a_x(900.0\ \text{s}) \implies a_x = (-9.26 \times 10^{-3}\ \text{m/s}^2).$$

So the acceleration is $\vec{a} = -9.26 \times 10^{-3}\ \text{m/s}^2\,\hat{\imath}$.

b) The equation for the $x$-component of the position vector, for motion with a constant acceleration component $a_x$, is

$$x(t) = x_0 + v_{x0}t + a_x\frac{t^2}{2}.$$

Choose the origin of the coordinate system to be the point at which the tanker begins to slow down. Then

$$x_0 = 0\ \text{m}, \quad v_{x0} = (8.33\ \text{m/s}), \quad \text{and } a_x = (-9.26 \times 10^{-3}\ \text{m/s}^2),$$

and

$$x(t) = 0\ \text{m/s} + (8.33\ \text{m/s})t + (-9.26 \times 10^{-3}\ \text{m/s}^2)\frac{t^2}{2}.$$

Hence, when $t = 900.0\ \text{s}$,

$$x(t) = 0\ \text{m/s} + (8.33\ \text{m/s})(900.0\ \text{s}) + (-9.26 \times 10^{-3}\ \text{m/s}^2)\frac{(900.0\ \text{s})^2}{2} = (3.75 \times 10^3\ \text{m}).$$

So the tanker moved 3.75 km before stopping.

**3.18** Choose $\hat{\mathrm{i}}$ along the runway and the origin where the plane begins its takeoff.

a) In this system $x_0 = 0$ m and $v_{x0} = 0$ m/s, so when $t = 40$ s,

$$x = x_0 + v_{x0} + \frac{a_x t^2}{2} \implies 1.70 \times 10^3 \text{ m} = 0 \text{ m} + (0 \text{ m/s})(40.0 \text{ s}) + \frac{a_x (40.0 \text{ s})^2}{2}.$$

Solving for the $x$-component of the acceleration, we have $a_x = 2.13 \text{ m/s}^2$.

b) The velocity component is

$$v_x = 0 \text{ m/s} + a_x t = (40.0 \text{ s})(2.13 \text{ m/s}^2) = 85.2 \text{ m/s}.$$

Converting the speed from m/s to km/h:

$$v = 85.2 \text{ m/s} = \left(85.2 \frac{\text{m}}{\text{s}}\right)\left(\frac{\text{km}}{1000 \text{ m}}\right)\left(\frac{3600 \text{ s}}{\text{h}}\right) = 307 \text{ km/h}.$$

**3.29** Set up a coordinate system whose origin is at the place where the brakes are first applied and with $\hat{\mathrm{i}}$ in the direction of motion of the car. We are told that $x_0 = 0$ m, $v_{x0} = 30.0$ m/s, and that when $t = 5.0$ s, $v_x = 15.0$ m/s. Substitute these values into the general equation $v_x(t) = v_{x0} + a_x t$ and solve for $a_x$ to find $a_x = -3.0 \text{ m/s}^2$.

a) The time the car stops can now be found from the velocity component equation:

$$v_x(t) = 30.0 \text{ m/s} + (-3.0 \text{ m/s}^2)t.$$

The car is stopped when the left-hand side is zero, so

$$0 \text{ m/s} = 30.0 \text{ m/s} + (-3.0 \text{ m/s}^2)t \implies t = 10 \text{ s}.$$

b) The position of the car when $t = 10$ s is found from

$$x(10 \text{ s}) = 0 \text{ m} + (30.0 \text{ m/s})(10 \text{ s}) - (3.0 \text{ m/s}^2)\frac{(10 \text{ s})^2}{2} = 150 \text{ m}.$$

Since the car began braking 160 m from the bridge, it is a comfortable 10 m from the bridge when it stops.

**3.36**

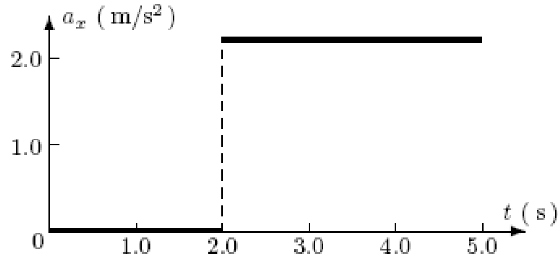
a) The chicken is instantaneously at rest when its velocity is **0** m/s. From the graph, this is at about $t = 3.4$ s, at which time it is actually changing direction.

b) The acceleration component is the *slope* of the $v_x$ versus $t$ graph. The slope appears to be constant from $t = 2.0$ s to $t = 5.0$ s. Over this interval,

$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{3.5 \text{ m/s} - (-3.0 \text{ m/s})}{5.0 \text{ s} - 2.0 \text{ s}} = 2.2 \text{ m/s}^2.$$

so, $\vec{\mathrm{a}} = 2.2 \text{ m/s}^2\, \hat{\mathrm{i}}$.

c)




d) This question can be solved either geometrically or algebraically.

*Geometric solution:* The change in position is the area below the curve of the velocity component when it is positive, and the *negative* of the area above that curve when the velocity component is negative.

From $t = 0$ s until $t = 3.4$ s the velocity component is negative, and the area above the curve is $(2.0\text{ s})(3.0\text{ m/s}) + \frac{1}{2}(1.4\text{ s})(3.0\text{ m/s}) = 8.1\text{ m}$, so in this interval of time the chicken's position has changed by $-8.1$ m. In the next interval, the velocity component is positive, and the area under the curve is $\frac{1}{2}(1.6\text{ s})(3.5\text{ m/s}) = 2.8\text{ m}$. So the total change in position is $(-8.1\text{ m}) + (2.8\text{ m}) = -5.3\text{ m}$.

*Algebraic solution:* When $t = 0$ s, the chicken's position is $x_0 = 0$ m, its velocity component is $v_{x0} = -3.0$ m/s, and throughout the interval from $t = 0$ s to $t = 2.0$ s, the acceleration component is constant at $a_x = 0\text{ m/s}^2$. Hence, throughout this time interval the equations for $v_x(t)$ and $x(t)$ are

$$v_x(t) = v_{x0} + a_x t = -3.0\text{ m/s} + (0\text{ m/s}^2)t = -3.0\text{ m/s}, \qquad \text{and}$$

$$x(t) = x_0 + v_{x0}t + a_x\frac{t^2}{2} = 0\text{ m} + (-3.0\text{ m/s})t + (0\text{ m/s}^2)\frac{t^2}{2} = (-3.0\text{ m/s})t.$$

Thus, when $t = 2.0$ s, the velocity component is $v_x(2.0\text{ s}) = -3.0$ m/s and the position is $x(2.0\text{ s}) = -6.0$ m.

During the interval from $t = 2.0$ s to $t = 5.0$ s, the acceleration component of the chicken is constant when $a_x = 2.2\text{ m/s}^2$. Hence, during this interval of time the chicken's velocity component and position are given by

$$v_x(t) = v_x(2.0\text{ s}) + a_x(t - 2.0\text{ s}) = -3.0\text{ m/s} + (2.2\text{ m/s}^2)(t - 2.0\text{ s}) = -3.0\text{ m/s}, \qquad \text{and}$$

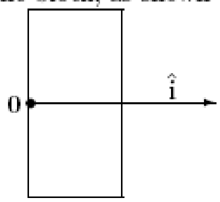
$$x(t) = x(2.0\text{ s}) + v_x(2.0\text{ s})(t - 2.0\text{ s}) + a_x\frac{(t - 2.0\text{ s})^2}{2} = -6.0\text{ m} + (-3.0\text{ m/s})(t - 2.0\text{ s}) + (2.2\text{ m/s}^2)\frac{(t - 2.0\text{ s})^2}{2}.$$

So, when $t = 5.0$ s, the chicken's position is

$$x(5.0\text{ s}) = -6.0\text{ m} + (-3.0\text{ m/s})(5.0\text{ s} - 2.0\text{ s}) + (2.2\text{ m/s}^2)\frac{(5.0\text{ s} - 2.0\text{ s})^2}{2}. = -5.1\text{ m}.$$

This disagrees slightly with the geometric approach because of rounding errors associated with the acceleration component.

**3.39** Choose $\hat{\imath}$ to be along the line of flight of the bullet within the block, with the origin at the edge of the block, as shown below:




Let $t = 0$ s be the instant the bullet begins its impact with the block. The initial velocity component of the bullet is $v_{x0} = (350 \text{ m/s})$, and the initial position is $x_0 = 0$ m. Therefore the position and velocity component equations for the bullet while it is moving through the block of wood are:

$$x(t) = 0 \text{ m} + (350 \text{ m/s})t + a_x \frac{t^2}{2}, \qquad \text{and} \qquad v_x(t) = (350 \text{ m/s}) + a_x t.$$

Let $t_f$ be the time that the bullet stops, so $v_x(t_f) = 0$ m/s and $x(t_f) = 6.0 \times 10^{-2}$ m. Using these values in the position and velocity equations we have

$$6.0 \times 10^{-2} \text{ m} = (350 \text{ m/s})t_f + a_x \frac{t_f^2}{2}, \qquad \text{and} \qquad 0 \text{ m/s} = (350 \text{ m/s}) + a_x t_f.$$

From the second of these equations, $a_x = \dfrac{-350 \text{ m/s}}{t_f}$. Substitute this value for $a_x$ is the first equation to get $6.0 \times 10^{-2} \text{ m} = (350 \text{ m/s})t_f + \left(\dfrac{-350 \text{ m/s}}{t_f}\right)\dfrac{t_f^2}{2}$, and then solve for $t_f$:

$$t_f = 3.4 \times 10^{-4} \text{ s}.$$

This is the time it takes for the bullet to stop. Now use this value for $t_f$ in $a_x = \dfrac{-350 \text{ m/s}}{t_f}$ to get $a_x = -1.0 \times 10^6 \text{ m/s}^2$. Thus, the acceleration of the bullet is $\vec{a} = (-1.0 \times 10^6 \text{ m/s}^2)\hat{\imath}$, and the magnitude of the acceleration is $1.0 \times 10^6 \text{ m/s}^2$.

**3.43**

a) Choose $\hat{\imath}$ to be in the direction the ambulance is moving and the origin at the initial position of the lawyer. Let $t = 0$ s be the instant the ambulance is beside the lawyer. (This is when the stopwatch is started.)

b) For the ambulance: $x_0 = 0$ m, $v_0 = 50$ m/s, and $a_x = 0 \text{ m/s}^2$. Hence,

$$x_{\text{ambulance}}(t) = (50 \text{ m/s})t.$$

c) For the lawyer: $x_0 = 0$ m, $v_0 = 0$ m/s, and $a_x = 1.0 \text{ m/s}^2$. Hence,

$$x_{\text{lawyer}}(t) = (1.0 \text{ m/s}^2)\frac{t^2}{2}.$$

d) Let $t_f$ be the time at which the lawyer catches up to the ambulance. At this time, they both have the same $x$-coordinate, hence $x_{\text{ambulance}}(t_f) = x_{\text{lawyer}}(t_f)$. Using b) and c),

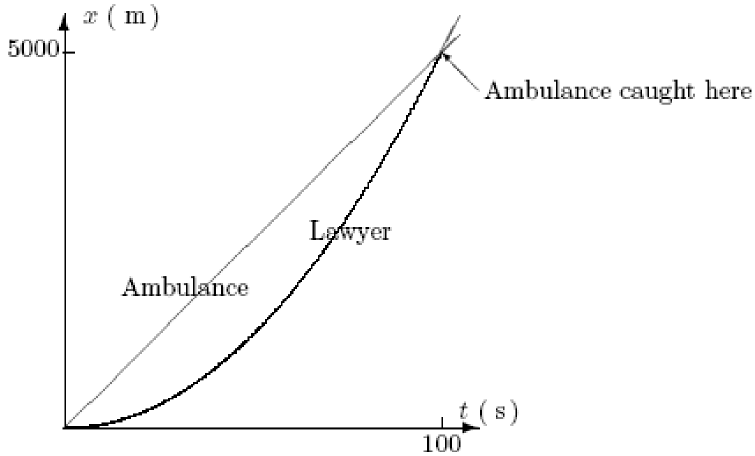
$$(50 \text{ m/s})t_f = (1.0 \text{ m/s}^2)\frac{t_f^2}{2}.$$

Solve this for $t_f$ to get $t_f = 1.0 \times 10^2$ s.

e) Use either position coordinate equation to find the distance —we use the ambulance's:

$$x_{\text{ambulance}}(t_f) = (50 \text{ m/s})t_f = (50 \text{ m/s})(1.0 \times 10^2 \text{ s}) = 5.0 \times 10^3 \text{ m}.$$

f) The position of the ambulance increases linearly with time. The position of the lawyer is a quadratic function of time. They are shown below.




**3.56** Choose a coordinate system with $\hat{\imath}$ in the direction of travel and the origin at the initial position. During the first 10.0 s interval we have $x_0 = 0$ m, $v_{x0} = 0$ m/s, and $a_x = 1.50\ \text{m/s}^2$. The position equation is

$$x(t) = x_0 + v_{x0}t + a_x\frac{t^2}{2} = (1.50\ \text{m/s}^2)\frac{t^2}{2}.$$

So, when $t = 10.0$ s, the position is $x = 75$ m.

The equation for the velocity component is

$$v_x(t) = v_{x0} + a_x t = (1.50\ \text{m/s}^2)t.$$

So, when $t = 10.0$ s, the velocity component is $v_x = 15.0$ m/s. During the next 30.0 s, the velocity component remains constant at 15.0 m/s. Hence, it travels an additional distance of (15.0 m/s)(30.0 s) = 450 m.

Now shift the origin of the coordinate system to the place where the car begins to slow down. During the slow-down, $x_0 = 0$ m, $v_{x0} = 15.0$ m/s, and $a_x = -2.00\ \text{m/s}^2$. The equation for the velocity component is

$$v_x(t) = v_{x0} + a_x t = 15.0\ \text{m/s} - (2.00\ \text{m/s}^2)t.$$

When the car is at rest, its velocity component is zero, so

$$0\ \text{m/s} = 15.0\ \text{m/s} - (2.00\ \text{m/s}^2)t.$$

Solving for $t$,

$$t = 7.50\ \text{s}.$$

The equation for the position is

$$x(t) = x_0 + v_{x0}t + a_x\frac{t^2}{2} = (15.0\ \text{m/s})t - (2.00\ \text{m/s}^2)\frac{t^2}{2}.$$

So, when $t = 7.5$ s the position is $x = 56.0$ m.

Therefore, the total distance traveled by the car is 75.0 m + 450 m + 56.0 m = 581 m.