Problem 5.5

a.) With a constant acceleration on the ball, we can use kinematics and write:

\[ x_f = x_i + v_{i_x} (\Delta t) + \frac{1}{2} a_x (\Delta t)^2 \]

\[ \Rightarrow x_f = \frac{1}{2} a_x (\Delta t)^2 \]

We can determine the acceleration using:

\[ a_x = \frac{\Delta v_x}{\Delta t} = \frac{(v_x - v_i)}{\Delta t} = \frac{((18.0 \text{ m/s}) - (0 \text{ m/s}))(170 \text{ s})}{106 \text{ m/s}^2} \]

\[ a_x = 106 \text{ m/s}^2 \]

So the distance the ball is accelerated by the pitcher is:

\[ x_f = \frac{1}{2} a_x (\Delta t)^2 = \frac{1}{2}(106 \text{ m/s}^2)(170 \text{ s})^2 = 1.53 \text{ m} \]

Note that you could also do this by writing:

\[ \Delta x_f = v_{avg} (\Delta t) = \frac{v_f + v_i}{2} (\Delta t) = \frac{((18.0 \text{ m/s}) + 0 \text{ m/s})}{2} (170 \text{ s}) = 1.53 \text{ m} \]

This is clearly the easier way. It just isn’t the first way that came to mind!

b.) What is the net force the pitcher exerts?

This is a little tricky in the sense that if the ball is to come out horizontally, the pitcher must not only apply a force to motivate the ball in the horizontal, he/she also has to apply a force that will counteract gravity (this will be in a direction opposite the direction of gravity, or upward).

In any case, we will need the ball’s mass to do the problem. That mass value is:

\[ m = \frac{F_x}{g} = \frac{2.21 \text{ N}}{9.80 \text{ m/s}^2} = .226 \text{ kg} \]

We also need the acceleration of the ball. We inadvertently determine that in Part a, but if we hadn’t, the easiest way to get it at this point would be:

\[ a = \frac{\Delta v}{\Delta t} = \frac{18 \text{ m/s}}{170 \text{ s}} = 106 \text{ m/s}^2 \]

So the net force the pitcher exerts is:

\[ \vec{F} = (F_{\text{to ball}} \hat{i} + F_{\text{to counter gravity}} \hat{j}) \]

\[ = \left[ \left( m \ a_{\text{tot acc ball}} \right) \hat{i} + (2.21 \text{ N}) \hat{j} \right] \]

\[ = \left[ (226 \text{ kg})(106 \text{ m/s}^2) \hat{i} + (2.21 \text{ N}) \hat{j} \right] \]

\[ = (23.9 \text{ N}) \hat{i} + (2.21 \text{ N}) \hat{j} \]

The magnitude of this vector is:

\[ |\vec{F}| = \sqrt{(23.9 \text{ N})^2 + (2.21 \text{ N})^2} = 24.0 \text{ N} \]

and the angle is:

\[ \phi = \tan^{-1} \left( \frac{2.21}{23.0} \right) = 5.28^\circ \]