Problem 5.5

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

$$x_2 = \cancelto{0}{x_1} + \cancelto{0}{v_{1,x}}(\Delta t) + \frac{1}{2}a_x(\Delta t)^2$$

$$\Rightarrow \quad x_2 = \frac{1}{2}a_x(\Delta t)^2$$

We can determine the acceleration using:

$$\begin{aligned} a_x &= \frac{\Delta v_x}{\Delta t} \\ &= \frac{(v_f - v_o)_x}{\Delta t} \\ &= \frac{((18.0 \text{ m/s}) - (0 \text{ m/s}))}{(.17 \text{ s})} \\ &= 106 \text{ m/s}^2 \end{aligned}$$

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

$$\begin{aligned} x_2 &= \frac{1}{2}a_x(\Delta t)^2 \\ &= \frac{1}{2}(106 \text{ m/s}^2)(.170 \text{ s})^2 \\ &= 1.53 \text{ m} \end{aligned}$$

Note that you could also do this by writing:

$$\begin{aligned} \Delta x_2 &= v_{avg}(\Delta t) \\ &= \left(\frac{v_2 + v_1}{2}\right)(\Delta t) \\ &= \left(\frac{(18.0 \text{ m/s}) + 0}{2}\right)(.170 \text{ s}) \\ &= 1.53 \text{ m} \end{aligned}$$

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:

$$\begin{aligned} m &= \frac{F_g}{g} = \left(\frac{2.21 \text{ N}}{9.80 \text{ m/s}^2}\right) \\ &= .226 \text{ kg} \end{aligned}$$

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:

$$\begin{aligned} a &= \frac{\Delta v}{(\Delta t)} \\ &= \left(\frac{18 \text{ m/s}}{.170 \text{ s}}\right) \\ &= 106 \text{ m/s}^2 \end{aligned}$$

So the net force the pitcher exerts is:

$$\begin{aligned} \vec{F} &= (F_{\text{to acc ball}})\hat{i} + (F_{\text{to counter gravity}})\hat{j} \\ &= [(m \, a_{\text{to acc ball}})]\hat{i} + (2.21 \text{ N})\hat{j} \\ &= [(.226 \text{ kg})(106 \text{ m/s}^2)]\hat{i} + (2.21 \text{ N})\hat{j} \\ &= (23.9 \text{ N})\hat{i} + (2.21 \text{ N})\hat{j} \end{aligned}$$

The magnitude of this vector is:

$$\begin{aligned} |\vec{F}| &= \sqrt{(F_x)^2 + (F_y)^2} \\ &= \sqrt{(23.9 \text{ N})^2 + (2.21 \text{ N})^2} \\ &= 24.0 \text{ N} \end{aligned}$$

and the angle is:

$$\begin{aligned} \phi &= \tan^{-1}\left(\frac{2.21}{23.0}\right) \\ &= 5.28^\circ \end{aligned}$$