In order to find the magnitude of the momentum with which the flour bag hits the floor, we first need to find the speed \( v \) with which it hits the floor. We’ll then multiply the speed by the mass \( m = 2.73 \text{ kg} \) to find the magnitude of the momentum.

We could find \( v \) by using the kinematic equations of motion with constant acceleration, but instead we find it slightly easier to use the CWE theorem. Choose a coordinate system with \( \hat{j} \) pointing straight up and with origin on the floor where the bag lands. The initial position of the bag is with \( y_i = 2.00 \text{ m} \) and \( v_i = 0 \text{ m/s} \). The final position is just before the bag hits the floor, so \( y_f = 0 \text{ m} \) and \( v_f = v \). The only force on the bag is the conservative force of gravity, so the work done by nonconservative forces is zero. Thus

\[
0 \text{ J} = \Delta(KE + PE) = (KE_f + PE_f) - (KE_i + PE_i) = \left( \frac{1}{2} mv^2 + 0 \text{ J} \right) - (0 \text{ J} + mgy_i)
\]

\[
\Rightarrow v = v_f = \sqrt{2gy_i} = \sqrt{2(9.81 \text{ m/s}^2)(2.00 \text{ m})} = 6.26 \text{ m/s}.
\]

Thus, the magnitude of the momentum is

\[
p = mv = (2.73 \text{ kg})(6.26 \text{ m/s}) = 17.1 \text{ kg} \cdot \text{m/s}.
\]

Use the CWE theorem to determine the speed of the cockleshell the instant before impact. Choose a coordinate system with \( \hat{j} \) pointing up, \( \hat{i} \) pointing horizontally in the direction of the gull’s flight, and origin at ground level directly below the release point.

The conservative gravitational force of the Earth is the only force acting on the shell during its fall. There are no nonconservative forces, so their work is zero. The CWE theorem becomes

\[
0 \text{ J} = W_{\text{nonconservative}} = \Delta(KE + PE) = (KE_f + PE_f) - (KE_i + PE_i) = \left( \frac{mv^2_i}{2} + mg(0 \text{ m}) \right) - \left( \frac{mv^2_f}{2} + mgy_i \right)
\]

\[
\Rightarrow v_i = \sqrt{v^2_f + 2gy_i} = \sqrt{(15.0 \text{ m/s})^2 + 2(9.81 \text{ m/s}^2)(20.0 \text{ m})} = 24.8 \text{ m/s}.
\]

The magnitude of the momentum of the shell the instant before impact is

\[
p = mv_i = (0.200 \text{ kg})(24.8 \text{ m/s}) = 4.96 \text{ kg} \cdot \text{m/s}.
\]

Convert \( \text{N} \cdot \text{s} \) to the basic units of kilograms, meters, and seconds.

\[
\text{N} \cdot \text{s} = (\text{kg} \cdot \text{m/s}^2) \text{ s} = \text{kg} \cdot \text{m/s}.
\]

According to Newton’s third law, the magnitude of the force of the nozzle on the water is equal to that of the water on the nozzle. Newton’s second law states that the magnitude of the total force on the water is equal to the magnitude of the time rate at which its momentum changes. This is

\[
(15.0 \text{ kg/s})(20 \text{ m/s}) = (3.0 \times 10^2 \text{ kg} \cdot \text{m/s}^2) = 3.0 \times 10^2 \text{ N}.
\]

The water therefore exerts a force of magnitude \( 3.0 \times 10^2 \text{ N} \) on the nozzle. To keep the nozzle stationary, the firefighters must exert an additional force of magnitude \( 3.0 \times 10^2 \text{ N} \) in the opposite direction.

Choose a coordinate system with \( \hat{i} \) pointing horizontally in the same direction as the ball’s initial horizontal velocity component, \( \hat{j} \) pointing straight up, and origin at the ball’s position before it is whacked. The impulse is equal to the change in the momentum of the ball.

\[
\vec{I} = \Delta \vec{p} = \vec{p}_f - \vec{p}_i.
\]