Answer on Question 72586, Physics / Mechanics | Relativity

Question

Ball having a mass of 0.5 kg is moving towards the east with a speed of 8.0 ms-1.

After being hit by a bat it changes its direction and starts moving towards the north with a speed of 6.0 ms−1. If the time of impact is 0.1 s, calculate the impulse and average force acting on the ball.

Solution.

Momentum of a ball is

$$\vec{p} = m\vec{v}$$

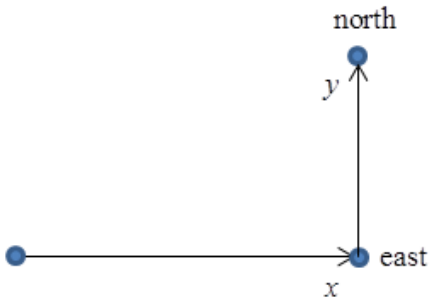
where m is a mass of the ball, $\vec{v}$ is a velocity of the ball. Momentum $\vec{p}$ is a vector having the same direction as the velocity $\vec{v}$.

Impulse is the change in momentum

$$\Delta\vec{p} = \vec{p}_f - \vec{p}_i = m\Delta\vec{v} = m\left(\vec{v}_f - \vec{v}_i\right)$$

where subscripts i and f mean the initial and final values.

Let the direction to the east be the x axis, and the direction to the north be the y axis as shown in the figure



Since at first the ball moved towards the east, then $v_i = v_{ix} = 8.0\text{m/s}$ and $v_{iy} = 0\text{m/s}$. After being hit by a bat it moved towards the north, then $v_{fx} = 0\ \text{m/s}$ $v_f = v_{fy} = 6.0\text{m/s}$.

Then for x -component of momentum we have

$$p_i = p_{ix} = mv_{ix} = 0.5\text{kg} \cdot 8.0\text{m/s} = 4\ \text{kg} \cdot \text{m/s}$$

$$p_{fx} = mv_{fx} = 0\ \text{kg} \cdot \text{m/s}$$

for y -component of momentum we have

$$p_{iy} = mv_{iy} = 0\ \text{kg} \cdot \text{m/s}$$

$$p_{fy} = mv_{fy} = 0.5\text{kg} \cdot 6.0\text{m/s} = 3\ \text{kg} \cdot \text{m/s}$$

The x -component of impulse is

$$\Delta p_x = p_{2x} - p_{1x} = 0 - 4 = -4\ \text{kg} \cdot \text{m/s}$$

The y -component of impulse is

$$\Delta p_y = p_{2y} - p_{1y} = 3 - 0 = 3\ \text{kg} \cdot \text{m/s}$$

Magnitude of impulse is defined as

$$\Delta p = |\Delta\vec{p}| = \sqrt{\Delta p_x^2 + \Delta p_y^2} = \sqrt{(-4)^2 + 3^2} = \sqrt{25} = 5\ \text{kg} \cdot \text{m/s}$$

Average force acting on the ball is defined as

$$\vec{\mathrm{F}}_{av} = \frac{\Delta\vec{\mathrm{p}}}{\Delta t}$$

Magnitude of average force acting on the ball is

$$\mathrm{F}_{av} = \left|\vec{\mathrm{F}}_{av}\right| = \frac{|\Delta\vec{\mathrm{p}}|}{\Delta t}$$

Substituting $|\Delta\vec{p}| = 5\ \mathrm{kg \cdot m/s}$ and the time of impact $\Delta t = 0.1\ \mathrm{s}$ we get average force

$$\mathrm{F}_{av} = \frac{5\ \mathrm{kg \cdot m/s}}{0.1\ \mathrm{s}} = 50\ N$$

Answer: impulse of the ball is $\Delta p = 5\ \mathrm{kg \cdot m/s}$, average force acting on the ball is $\mathrm{F}_{av} = 50\ N$