Momentum

An object in motion will tend to stay in motion. What two factors affect how difficult it is to stop an object that is moving?

Mass Velocity

The momentum of an object is: $p = mv$

A bullet shot from a gun has a lot of momentum because it is fast

A freight train slowly moving in the train yard has a lot of momentum because it is very heavy

Example 1: Calculate the momentum of a 1100 kg car travelling along the highway at 15 m/s.

$$p = mv = 1100\,kg \times 15\,\frac{m}{sec} = 16500\,\frac{kg \cdot m}{sec}$$

$$\approx 17000\,\frac{kg \cdot m}{sec}$$

Example 2: Calculate the momentum of a 1.2 kg ball thrown at 13.9 m/s.

$$16.68\,\frac{kg \cdot m}{s} \approx 17\,\frac{kg \cdot m}{sec}$$

Example 3: Determine the change in momentum of a 48 kg runner who speeds up from 5.0 m/s to 7.0 m/s.

$$\Delta p = p_f - p_i = mv_f - mv_0$$

$$= m(v_f - v_0)$$

$$= m\,\Delta v$$

$$= 48\,kg \times 2.0\,\frac{m}{s}$$

$$= 96\,\frac{kg \cdot m}{sec}$$

Example 4: Determine the change in momentum of a 0.142 kg baseball that was moving at 22 m/s in one direction and is now moving 22 m/s in the opposite direction.

$\Delta p = m\Delta v = 0.142\text{kg} \times 44\text{m/s}$

$= 6.2 \frac{\text{kg·m}}{\text{sec}}$ in direction the ball ends up going

Impulse

Recall Newton's second law: $F_{net} = ma$

We can modify this to be about momentum.

$F_{net} = m\left(\frac{\Delta v}{t}\right) = \frac{m\Delta v}{t}$

$= \frac{\Delta p}{t}$

Doing a slight rearrangement, we get $F_{net} \cdot t = \Delta p$

Impulse is defined a certain force applied for a certain amount of time, and as shown above it is equal to change in momentum.

Example 5: What is the impulse required to increase the speed of a 48 kg runner from 5.0 m/s to 7.0 m/s?

96 Ns see #3

Example 6: What is the impulse if a 6.0 N force is applied for 5.0 seconds?

30 Ns

Example 7: What is the impulse if a 600.0 N force is applied for 0.050 seconds?

30 Ns

Example 8: A 25 kg ball is moving at 3.6 m/s.

a) What force would need to be applied to stop it in 0.20 seconds?

$\Delta p = m\Delta v = 25kg\,(0-3.6\,m/s) = -90\ \frac{kg\cdot m}{sec}$

$\Delta p = F\cdot t \rightarrow \frac{\Delta p}{t} = F \rightarrow \frac{-90Ns}{0.20sec} = -450\,N$

b) What force would need to be applied to stop it in 0.050 seconds?

$\frac{-90Ns}{0.050sec} = -1800\,N$

c) How long would it take to stop by applying a 45 N force?

$\Delta p = F\cdot t \rightarrow \frac{\Delta p}{F} = t \rightarrow \frac{-90\ \frac{kg\cdot m}{sec}}{-45\,N} = 2.0sec$