Lesson 4

Momentum

Momentum = mass × velocity

- Vector quantity
- Units of kg·m/s
- Direction of momentum is same as direction of velocity.

Example:
What is the momentum of a 2.0×10^3 kg car that has a velocity of 12.8 m/s (E)?

Example:
What is the velocity of a 50.0 g bullet that has a momentum of 24.75 kg·m/s (N)?

Impulse

Which is heavier, a 15 N feather pillow or a 15 N brick?
Which would you rather be hit on the head with? Why?

Consider how long it takes for each to stop.

Brick ~ 0.010 s
Pillow ~ 0.50 s (fifty times longer than brick)

Consider two other factors:

- The force applied to your head
- The time over which the force is applied

Impulse = force × time

$J = F_{net}\Delta t$
(units of N·s)

But
$F_{net} = ma$
and
$a = \frac{\Delta v}{\Delta t}$
and
$p = mv$

Thus
$F_{net}\Delta t = ma\Delta t$
$F_{net}\Delta t = m\frac{\Delta v}{\Delta t}\Delta t$
$F_{net}\Delta t = m\Delta v$
$J = F_{net}\Delta t = \Delta p$

So impulse = change in momentum.
The impulse of a force is equal to the change in momentum of the object that is experiencing the impulse.

So if the impulse for the pillow and the brick is the same, we can see that a longer time to stop results in a smaller force to the head.

Example:
A 100.0 g golf ball leaves the tee at 100.0 m/s. The club is in contact with the ball for 0.040 s. Determine the force exerted on the ball by the club.

Example:
A 180 g baseball travelling at 30.0 m/s (E) is struck by a bat. It then travels at 35.0 m/s (W).
a) What is the impulse given to the ball by the bat?
b) How long is the bat in contact with the ball if it exerts a force of 8.0×10^3 N (W) on the ball?

Example:
Explain why it is easier to drive a nail with a steel hammer than with a rubber mallet.

The steel hammer has less give (i.e shorter stopping time) and thus for the same change in momentum will give a greater net force.

Example:
Explain why when you jump from a height, you should always bend your knees as you land.

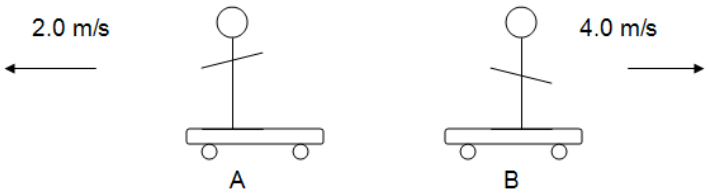
To increase your stopping time and lessen the force on your legs.

Note that the area under a graph of force versus time will give the impulse (see p. 283-287).

Conservation of Momentum

Recall: p=mv

Consider the situation below:



Show that momentum is conserved in this situation.

Example:
Cart A has a mass of 2.0 kg and is travelling at 10.0 m/s to the right. Cart B has a mass of 3.0 kg and is moving to the left at 4.0 m/s. The carts collide and stick together. With what velocity will the carts move after they stick together?

Try:
Cart A has a mass of 2.0 kg and is travelling at 10.0 m/s to the right. Cart B has a mass of 3.0 kg and is moving to the left at 6.0 m/s. Cart B collides with cart A which causes cart A to rebound at 4.0 m/s. What is the velocity of cart B after the impact? (Ans: 3.3 m/s)

The law of conservation of momentum is typically stated as:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

There are several possible scenarios:

- Objects bounce off one another
- Objects both move in the same direction
- One object stops
- Objects stick together

Example:
A 50.0 g bullet is shot from a 4.0 kg rifle. The bullet leaves the rifle at 400.0 m/s. What is the recoil velocity of the rifle?