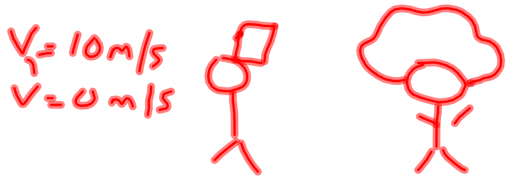
Section 19: Impulse

1. What is heavier, a 15 N pillow or a 15 N brick?

2. What would you rather have land on your head if dropped from the same height: the ~~feather~~ pillow or the brick?



Brick & pillow experience the same change in momentum.

When answering the above question, we must consider the time it takes the pillow and the brick to crash into your head. The brick hits you in the head with a sharp quick knock. The pillow sticks to your head and begins to settle around your head before it comes to a complete stop. The stopping time for the pillow is 50 times larger than for the brick. Therefore the impact force of the pillow is 50 times less than that of the brick.

If something falls on your head, you will be concerned with 2 factors: the **force** that the object applies to your head and the **time** that the force is acting.

Impulse is defined as the product of the unbalanced force or net force and the time that the force is acting.

$$\textbf{Impulse} = F_{net}\,\Delta t$$

same impulse → ↓ ↑

When an unbalanced force is applied over a given period of time (i.e. the object is given an impulse), the momentum of the object is changed . This means that impulse can also be defined as the change in momentum.

$$\text{Impulse} = \Delta p$$

$$\textbf{Impulse} = \Delta p = mv_2 - mv_1$$

* ***The greater the force acting on the object, the greater the impulse and the greater the change in the velocity of the object.***

$$\textbf{Impulse} = F_{net}\,\Delta t$$

From this formula Fnet α 1/Δt.
This means that if we increase the contact time, we can decrease the impact force acting on an object (assuming the impulse does not change.)

$$\textbf{Impulse} = \Delta p = mv_2 - mv_1$$

The unit for impulse is N.s or kg.m/s

$$N\cdot s = \frac{kg\,m}{s^2}\cdot s = kg\cdot m/s$$

So, $F_{net}\,\Delta t = mv_2 - mv_1$

$$\frac{F_{net}\,\Delta t}{\Delta t} = \frac{m(v_2 - v_1)}{\Delta t}$$

$$F_{net} = m\left(\frac{v_2 - v_1}{\Delta t}\right)$$

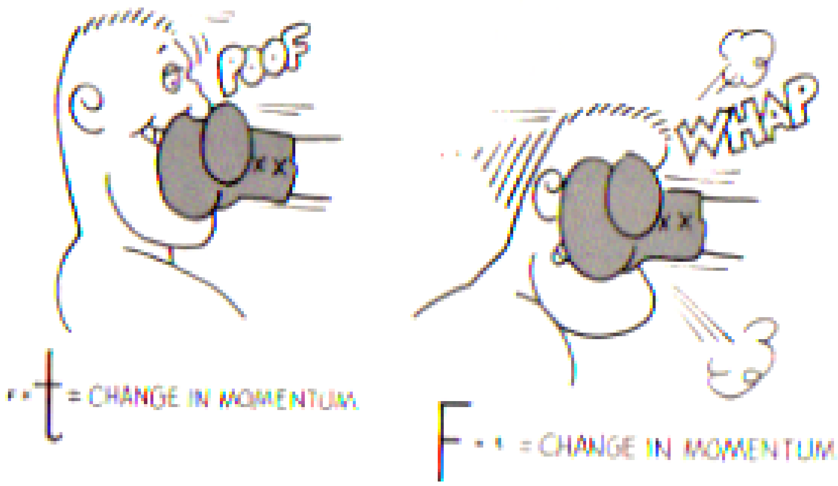
$$\rightarrow F_{net} = ma$$

Whenever there is an impact or collision between objects, the **impulse** has great significance. In a **collision**, the car and its passengers change momentum rapidly as the car come to a stop. In a car where a passenger is not protected by a seat belt or an air bag, the passenger might strike the dashboard and come to a stop very quickly - possibly 0.07 s. In a similar collision, a passenger protected by an air bag or seat belt would undergo the same change in momentum and impulse. But the inflated air bag or seat belt brings the passenger to a stop much more slowly. Therefore the impact force is less. (i.e **Even though the impulse or change in momentum is the same, the larger Δt means F_{net} will be smaller.**)

To change the momentum of a body we have to consider the impulse, that is the amount of force and the time of contact. A golf player hits a ball with greater force to impart momentum to the ball; but to get maximum momentum he must follow through on his swing, extending the time of contact of the force on the ball. A large force multiplied by a large time is a greater impulse, which produces a greater change in the momentum of the ball and hence a greater change in velocity, which means the ball will travel a greater distance. **Any time we wish to impart the greatest momentum possible to an object, we simply apply the greatest force possible and extend the time of contact.** The same is true in baseball.

Even if the **time of contact is short**, a very **large force** can produce a **large change in momentum**. If a **large momentum is stopped suddenly, the force required would have to be very large**. This is true of many violent blows and crashes where a large slowdown of momentum occurs in a short time. If F(small t) = large change in momentum then F must be very large. When a car crashes into a concrete wall, the time of contact is very small, resulting in a very large force. The idea of a short time of contact explains why a karate expert can sever a thick board with the blow of his bare hand. He brings his hand down with great speed, which results in his hand having considerable momentum. This momentum is changed to zero when he delivers an impulse to the board. The impulse is the force of his hand against the board multiplied by the time his hand makes contact with the board. By making the time of contact as short as possible, he makes the force of impact huge.

Often we wish to **change the momentum of an object with as small a force** as possible. A boxer confronted with a high-momentum punch is interested in **minimizing the force of impact**. If he cannot avoid being hit, he at least has a choice between ***F*** and ***t*** in providing the impulse that will absorb and change the incoming momentum of his opponent's punch. The **force of impact is lessened by extending the time of contact**; hence, he "rides or rolls with the punch." If he is hit when approaching his opponent, the time of contact is reduced, resulting in an increased force. This force is further increased because of the additional impulse produced when his momentum of approach is stopped. This increased impulse and short time of impact result in forces that account for many knockouts.



Other Examples

A person jumping from an elevated position to a floor below bends his knees upon making contact, thereby extending the time during which his momentum is being reduced by ten to twenty times that of a stiff-legged, abrupt landing. The forces absorbed by the bones are reduced by ten to twenty limes by such knee bending.

A person is better off falling on a wooden floor than a concrete floor. This is because a wooden floor with “give” allows for a longer time of impact and therefore a lesser force of impact than a concrete floor with little "give." A safety net used by acrobats provides an obvious example of small impact force over a long time to provide the required impulse to reduce the momentum of the fall.