IMPULSE

Often we are interested in the change in momentum that a particle experiences during a collision due to the net external force. We will call the change in momentum the *impulse*.

Impulse - A measure of the change in momentum that a particle experiences during a collision due to the net external force.

When we say that that an impulse is given to a particle we imply that momentum is transferred to the particle by an external force acting on the particle.

To obtain an expression for impulse let's consider a net external force $\sum \vec{F}_{ext}(t)$ acting on a particle during a time interval $\Delta t = t_f - t_i$. The change in momentum of the particle is given by N2L:

$$\sum \vec{F}_{ext}(t) = \frac{d\vec{p}}{dt}$$

$$\int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \sum \vec{F}_{xt}\ \ t\ \ dt$$

$$\vec{p}_f - \vec{p}_i = \int_{t_i}^{t_f} \sum \vec{F}_{ext}\ \ t\ \ dt$$

$$\boxed{\vec{I} = \int_{t_i}^{t_f} \sum \vec{F}_{ext}\ \ t\ \ dt} \text{ Impulse due to } \Sigma \vec{F}(t)$$

The impulse delivered to a particle by the net resultant force $\Sigma \vec{F}_{ext}(t)$ acting on a particle during a given time interval is equal to the change in momentum of the particle.

$$\boxed{\vec{I} = \Delta \vec{P}_{sys}} \text{ Impulse-Momentum Theorem}$$

The change in momentum of a system is equal to the impulse delivered by the net force on the system

In component form:

$$I_x = \Delta P_x = \int_{t_i}^{t_f} \sum F_x(t)\ dt$$

$$I_y = \Delta P_y = \int_{t_i}^{t_f} \sum F_y(t)\ dt$$

$$I_z = \Delta P_z = \int_{t_i}^{t_f} \sum F_z(t)\ dt$$

If the net external force is constant:

$$\sum \vec{F}_{ext}(t) = \vec{F} = \text{constant,}$$

$$\vec{I} = \vec{F} \int_{t_i}^{t_f} dt = \vec{F} \Delta t$$

$\boxed{\vec{I} = \vec{F}\Delta t}$ Impulse due to a constant force

a) the SI unit of $\vec{I}$ is N.s = kg m/s.
b) the direction of $\vec{I}$ is in same direction as $\Delta\vec{p}$

For an isolated system :

$$\vec{I} = \Delta\vec{P}_{sys} = \int_{t_i}^{t_f} \sum \vec{F}_{ext}\ \ t\ \ dt = 0$$

Thus,

$$\boxed{\Delta\vec{P}_{sys} = 0}$$

For any given external force $\vec{F}_{ext}$, the change in momentum due to the force is given by:

$$\boxed{\Delta\vec{P} = \vec{I} = \int_{t_i}^{t_f} \vec{F}_{ext}\ \ t\ \ dt}$$

1. If $\vec{F}_{ext}$ is negligibly small, then $\vec{I}$ is also going to be negligibly small and thus $\Delta\vec{p} \approx 0$
2. If $\vec{F}_{ext}$ acts for a very short period of time, then $\vec{I}$ is going to be negligibly small and thus $\Delta\vec{p} \approx 0$

In both cases the impulse due to $\vec{F}_{ext}$ can be neglected and thus the system would be an isolated system!

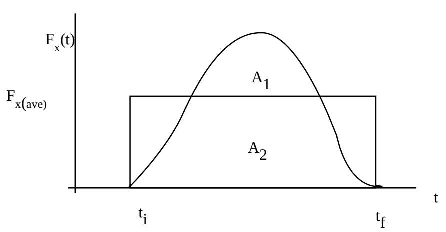
Often during the collision between two or more objects the force during the collision occurs for a very short period of time. Such a force is called an impulsive force.

__Impulsive Force__ – A strong, short duration external force on a particle during a collision.

Other external forces present are usually much smaller than the impulsive force and thus can be neglected since their impulse would be negligible.

__Impulse has a geometric interpretation.__

Consider a force $F_x(t)$ acting on a particle along the x-axis.



$$A_1 = \int_{t_i}^{t_f} F_x(t)dt = I_x$$

__In a F(t) vs. t graph the area between the curve and the time axis equals the impulse during the corresponding time interval.__

We also define a constant external force $F_{x(ave)}$ that gives the same impulse as $F_x(t)$:

$$A_2 = A_1$$

$$F_{x(ave)}\Delta t = \int_{t_i}^{t_f} F_x(t)dt$$

$$\boxed{F_{(x)ave} = \frac{1}{\Delta t}\int_{t_i}^{t_f} F_x(t)dt}$$