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:

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

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

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

$$\Delta\vec{p}_{sys} = \int_{t_i}^{t_f} \sum \vec{F}_{ext}(t)dt$$

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

$$\boxed{\vec{I} = \Delta\vec{p}_{sys} = \int_{t_i}^{t_f} \sum \vec{F}_{ext}(t)dt}$$ Momentum-Impulse Relation

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.

During a collision an object will experience a force that is large in magnitude but only lasts a very short period o time. Such a force is called an impulsive force.

Impulsive force – A large, short duration external force on a object during a collision

Other external forces (friction, gravity, air drag, etc.) acting on particle during collision are often much smaller than the impulsive force and thus can be neglected. Thus, we can say to a good approximation that the impulse delivered to the object is due to the large impulsive force $\boldsymbol{F_{imp}}$:

$$\boxed{\vec{I} = \int_{t_i}^{t_f} \vec{F}_{imp}(t)\, dt}$$ Impulse Approximation

Going back to the Momentum-Impulse Relation:

$$\boxed{\vec{I} = \Delta\vec{p}_{sys} = \int_{t_i}^{t_f} \sum \vec{F}_{ext}(t)dt}$$

For an isolated system $\sum \vec{F}_{ext}(t) = 0$. Thus,

$\boxed{\vec{I} = \Delta\vec{p}_{sys} = 0}$ Conservation of Linear Momentum

Also,

1. If $\sum \vec{F}_{ext}(t)$ is negligibly small, then $\vec{I} = \Delta\vec{p} \approx 0$
2. If $\sum \vec{F}_{ext}(t)$ acts for a very short period of time, then $\vec{I} = \Delta\vec{p} \approx 0$

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

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

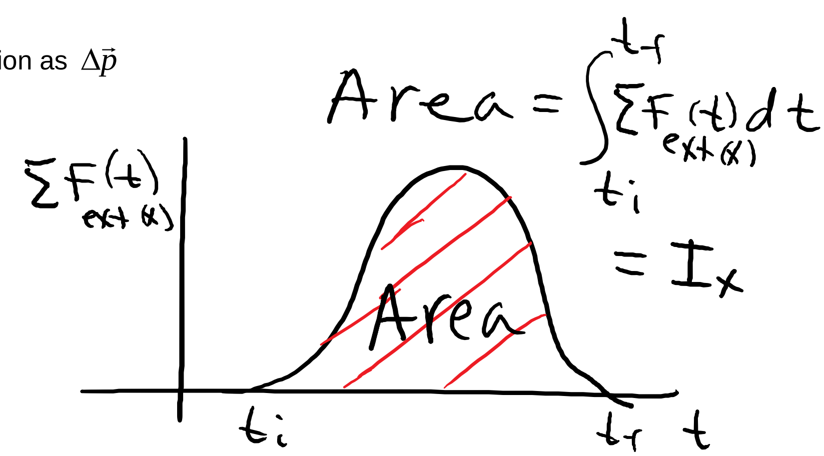
a) the SI unit of $\vec{I}$ is N.s = kg m/s.
b) the direction of $\vec{I}$ is in same direction as $\Delta\vec{p}$

Impulse in component form:

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

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

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



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