Impulse and Momentum

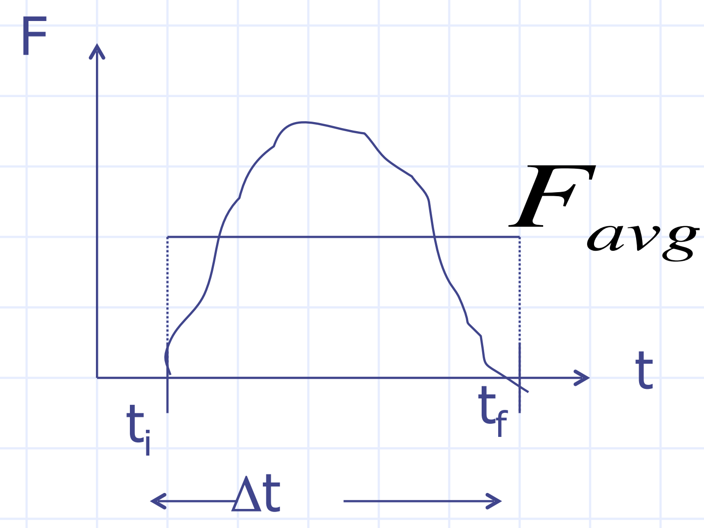
- Lets consider a force which has a time duration (usually short) and with a magnitude that may vary with time – examples: a bat hitting a baseball, a car crash, a asteroid or comet striking the Earth, etc.

- It is difficult to deal with a time-varying force, so we might take the mean value

- Define a new quantity, the impulse

$$\vec{F}_{avg}\Delta t = \vec{J}$$

- a vector, points in the same direction as the force
- has units of N s



$$\sum \vec{F} = m\vec{a} = m\frac{d\vec{\mathbf{v}}}{dt} = \frac{d(m\vec{\mathbf{v}})}{dt}$$

$$\boxed{\sum \vec{F} = \frac{d\vec{p}}{dt}}$$

- Assume only one force acts (or net force), then

$$d\vec{p} = \vec{F}dt \Rightarrow \int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}dt$$

$$\vec{p}_f - \vec{p}_i = \int_{t_i}^{t_f} \vec{F}dt \quad \text{or} \quad \boxed{\vec{J} = \int_{t_i}^{t_f} \vec{F}dt = \Delta\vec{p}}$$

- The Impulse-momentum Theorem

- Alternatively, consider the definition of acceleration

$$\vec{a} = \frac{\vec{\mathrm{v}}_f - \vec{\mathrm{v}}_\mathrm{i}}{\Delta \mathrm{t}} \Rightarrow m\vec{a} = \frac{m\vec{\mathrm{v}}_f - m\vec{\mathrm{v}}_\mathrm{i}}{\Delta \mathrm{t}}$$

$$\vec{F}\Delta t = \vec{p}_f - \vec{p}_i \quad \text{or} \quad \boxed{\vec{J} = \Delta\vec{p}}$$

- The Impulse-Momentum Theorem says that if an impulse (force*time duration) is applied to an object, its momentum changes

- In this example, the impact of the car with the wall applies an impulse to the car → car's p changes

$$\vec{J} = \vec{p}_f - \vec{p}_i = (-75.0\hat{i}) - 7.50\text{x}10^3\hat{i}$$

$$= \boxed{-7.58\text{x}10^3 \frac{\text{kg m}}{\text{s}} \hat{i}}$$