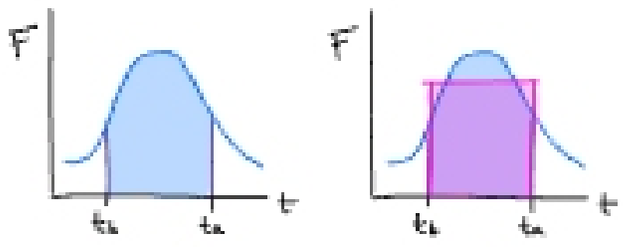
Lecture 9

Single particle: $\vec{F} = m\,\vec{a}$
New idea compare time before to time after ΔT
Impulse causes momentum change

System of particles: Combine Newton's Second and Third Laws $\vec{F} = \frac{d\vec{P}_{tot}}{dt}$



Momentum of a single part $\vec{p} = m\,\vec{v}$ kg m S^{-1}
Force: $\vec{F} = m\,\vec{a} = m\frac{d\vec{v}}{dt} = \frac{d\vec{p}}{dt}$
Newtons Second Law: $\int \vec{F} dt = \int d\vec{p}$
Impulse = momentum (time after) - momentum (time before)

Momentum and Impulse
Obeys a conservation law
Simplifies complicated motions
Describes Collisions
Basis of rocket propulsion and space travel

System of particles: Newton's Second Law
The momentum of a system of N particles is defined as the sum of individual momenta of the particles
$\vec{P}_{sys} \equiv \sum_{i=1}^{N} \vec{p}_i = \sum_{i=1}^{N} m_i \vec{v}_i$
Force changes the momentum of the system
$\vec{F} = \frac{d\vec{P}_{sys}}{dt} \vec{F}_i = \sum_{i=1}^{N} \frac{d\vec{p}_i}{dt} = \frac{d\vec{P}_{sys}}{dt}$

Internal forces in a system of particles is zero
The internal force on the ith particle is sum of the internal interaction forces with all the other particles
$\vec{F}_{int,i} = \sum_{j=1}^{N} \vec{F}_{ji}$
The sum of the internal forces on each particle in the system is
$\vec{F}_{int} = \sum_{i=1}^{N} \vec{F}_{int,i} = \sum_{j=1}^{N} \vec{F}_{ji}$
Newton's Third Law: internal forces cancel in pairs
$\vec{F}_{ij} = -\vec{F}_{ji}$
So the sum of the internal forces on the system is zero
$\vec{F}_{int} = \vec{0}$

Newton's second and third laws for system of particles
Newton's third law: the force on a system of particles is the external force because internal forces cancel in pairs $\vec{F} = \vec{F}_{ext} + \vec{F}_{int} = \vec{F}_{ext}$
Newton's second law: The total external force is equal to the rate of change of the momentum of the system $\vec{F}_{ext} = \frac{d\vec{P}_{sys}}{dt}$

Position of center of mass system of particles
Mass for collection of discrete bodies (system): $M_{sys} = \sum_{i=1}^{N} m_i$
Position of center of mass $\vec{R}_{cm} = \frac{1}{M_{sys}} \sum_{i=1}^{N} m_i \vec{r}_i$