

Vectors

$$\vec{v} = \langle v_x, v_y, v_z \rangle$$

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2} \quad \hat{v} = \frac{\vec{v}}{|\vec{v}|}$$

$$\vec{w} = \langle w_x, w_y, w_z \rangle$$

$$\vec{v} \cdot \vec{w} = |\vec{v}| |\vec{w}| \cos \theta = v_x w_x + v_y w_y + v_z w_z$$

$$\vec{v} \times \vec{w} = |\vec{v}| |\vec{w}| \sin \theta = \text{vector}$$

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$$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t} = \frac{\vec{r}_f - \vec{r}_i}{t_f - t_i} = \frac{v_i + v_f}{2}$$

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{p} = \gamma m \vec{v} \quad ; \quad \gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

Momentum Principle

$$\Delta \vec{p} = \vec{F}_{\text{net}} \Delta t \Rightarrow \vec{p}_f = \vec{p}_i + \vec{F}_{\text{net}} \Delta t$$

$$\vec{F}_{\text{net}} = \frac{\Delta \vec{p}}{\Delta t} \Rightarrow \frac{d\vec{p}}{dt} = m\vec{a}$$

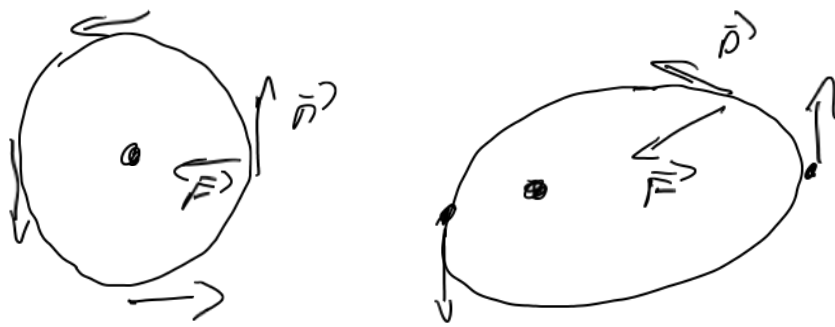
$$\frac{d\vec{p}}{dt} = \frac{d|\vec{p}|}{dt} \hat{p} + |\vec{p}| \frac{d\hat{p}}{dt}$$

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Change in
speed

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Change in
direction



$$F_{12} = -F_{21} \Rightarrow \text{momentum conservation}$$

$$\text{Young's Modulus} = \frac{\text{Stress}}{\text{Strain}} = \frac{\frac{F}{A}}{\frac{\Delta L}{L}} = \frac{k_{s,i}}{d}$$

$k_{s,i} \equiv$ interatomic spring constant $\neq F = k_{s,i} \Delta L$
 $d \equiv$ interatomic bond length

$$\rho = \frac{M}{V} \quad \text{convert } M \text{ (moles)} \rightarrow M \text{ per atom}$$

$\Rightarrow d^3$

$$E = \gamma mc^2 = mc^2 + K$$

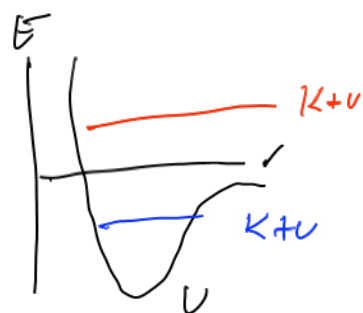
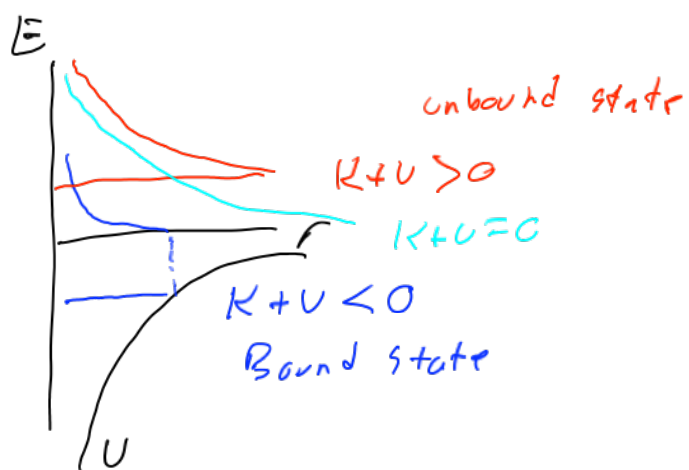
$$\text{for } v \ll c \quad K \approx \frac{p^2}{2m} = \frac{1}{2}mv^2$$

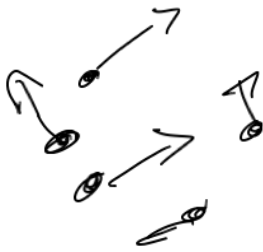
Energy Principle

$$\Delta E_{\text{sys}} = W_{\text{sur}}$$

$$W = \vec{F} \cdot \Delta \vec{r} = \sum \vec{F} \cdot \Delta \vec{r} = \int_C^f \vec{F} \cdot d\vec{r}$$

$$F = \frac{dU}{dx}$$





$$\vec{r}_{cm} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2 + \dots}{m_1 + m_2 + \dots}$$

$$\vec{P}_{tot} = M \vec{v}_{cm}$$

$$K_{cm} = \frac{1}{2} M v_{cm}^2$$

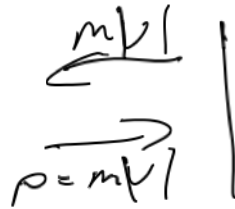
$$K_{tot} = K_{trans} + K_{rel}$$

||
 K_{cm}

Elastic collisions $\Delta E_{int} \approx 0$

Inelastic collisions $\Delta E_{int} \neq 0$

$$P_f = P_i$$



$p = mv$

$$\Delta P = 2p$$