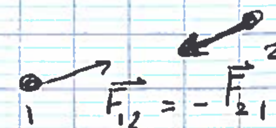
L4

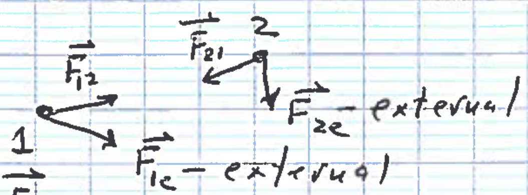
The third Newton's law



$$\vec{F}_{12} = -\vec{F}_{21}$$

– Conservation of total momentum

* 2 particles



$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{1e}$$
$$\vec{F}_2 = \vec{F}_{21} + \vec{F}_{2e}$$

write second law as: $\dot{\vec{P}}_1 = \vec{F}_1 \quad \dot{\vec{P}}_2 = \vec{F}_2$

total momentum $\vec{P} = \vec{P}_1 + \vec{P}_2$

total momentum rate of change: $\dot{\vec{P}} = \dot{\vec{P}}_1 + \dot{\vec{P}}_2$

$$\dot{\vec{P}} = \underbrace{\vec{F}_{12} + \vec{F}_{21}}_{=0} + \vec{F}_{1e} + \vec{F}_{2e} = \vec{F}_e$$

if $\vec{F}_e = 0 \qquad \dot{\vec{P}} = 0$ – conservation of t

* many particles

$$\vec{F}_\alpha = \sum_{\beta \neq \alpha} \vec{F}_{\alpha\beta} + \vec{F}_{\alpha e}$$

$$\dot{\vec{P}} = \sum \dot{\vec{P}}_\alpha = \sum_\alpha \sum_{\beta \neq \alpha} \vec{F}_{\alpha\beta} + \sum_\alpha \vec{F}_{\alpha e}$$

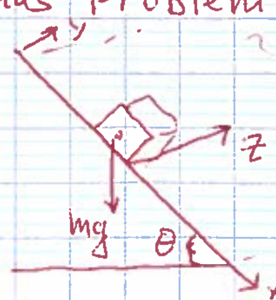
contains $N \cdot (N-1)$ terms → always ev

$$\sum_\alpha \sum_{\beta \neq \alpha} \vec{F}_{\alpha\beta} = \sum_\alpha \sum_{\beta > \alpha} \vec{F}_{\alpha\beta} + \vec{F}_{\beta\alpha} = \emptyset$$

* Principle of Conservation of Momentum

if $\vec{F}_{ext} = 0 \qquad P = const.$

– Bonus Problem [5 pts]



$\mu = tg\alpha$ – the friction coeffic

at $t=0$ we push block

along Z direction wit

velocity $u = V_z(t=0)$

What is the direction and

magnitude of velocity $\vec{V}(t \to \infty)$

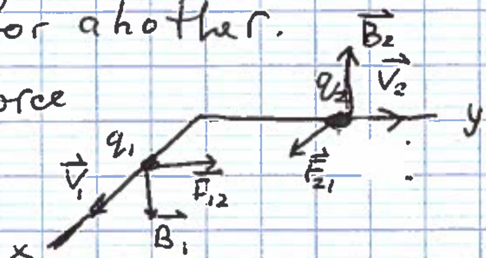
L4

Validity of the third law.

in the domain of CM all 3 Newton's law are considered to be "exact" — valid with some accuracy.

* For $v \sim c$ they break down
For example, the 3d law assumes
$\vec{F}_{12}(t) = -\vec{F}_{21}(t)$ at the same moment of time t
it could be true for one observer, but false for another.

* "non-central" force



$\vec{F}_{12} \sim \vec{V}_1 \times \vec{B}_1$ $\quad\vec{F}_{21} = \vec{V}_2 \times \vec{B}_2$ use "right corkscrew" rule

* Problem 1.32

- electric field at position 1 due to charge 2

$$\vec{E}(\vec{r}_1) = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{|\vec{r}_1 - \vec{r}_2|^2}\,\vec{e}_{\vec{r}_1-\vec{r}_2}$$

ε_0 — permitivity

- magnetic field

$$\vec{B}(\vec{r}_1) = -\frac{\mu_0}{4\pi}\cdot\frac{q_2}{|\vec{r}_1-\vec{r}_2|^2}\left[\vec{e}_{\vec{r}_2-\vec{r}_1} \times V_2\right]$$

μ_0 → permeability

$\vec{F}_{12\,el} = q_1 \vec{E}_1(\vec{r}_1)$ $\quad \vec{F}_{12\,B} = q_1\left[V_1 \times \vec{B}(\vec{r}_1)\right]$

assuming that $\vec{V}_1 \perp \vec{V}_2 \rightarrow \vec{V}_1 \perp \vec{B}(\vec{r}_1)$

$$|F_{12E}| = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{|\vec{r}_1-\vec{r}_2|^2} \qquad |\vec{F}_{12B}| = \frac{\mu_0}{4\pi}\frac{q_1 q_2}{|\vec{r}_1-\vec{r}_2|^2} V_1 V_2$$

$$\frac{|\vec{F}_{12E}|}{|F_{12B}|} = \frac{V_1 V_2}{c^2} \ll 1$$ we can ignore the violation of the 3d law

$\frac{V^2}{c} \sim 1 \longrightarrow$ need relativistic mechanics