Test 1 Review

Newton's 2^{nd} Law ("the momentum principle")

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$

$$\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t}$$

$$\vec{F}_{net} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}_{net} = m\frac{d\vec{v}}{dt}$$

* All of these are equivalent *

$$\Delta\vec{p} = \vec{F}_{net}\,\Delta t$$ ← impulse formula

$$\vec{p}_f = \vec{p}_i + \vec{F}_{net}\,\Delta t$$ ← momentum update formula

$$\vec{v}_f = \vec{v}_i + (\vec{F}_{net}/m)\,\Delta t$$ ← velocity update formula

Displacement, velocity, acceleration

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$$

$$\vec{v}_{Avg} \equiv \frac{\Delta\vec{r}}{\Delta t} \; ; \quad \vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{d\vec{v}}{dt} = \frac{\Delta\vec{v}}{\Delta t} = \frac{d^2\vec{r}}{dt^2}$$

Position update

$$\vec{r}_f = \vec{r}_i + \vec{v}_{Avg}\,\Delta t$$

$$\vec{v}_{Avg} = \frac{\vec{v}_i + \vec{v}_f}{2}$$ only for constant forces

$$\vec{v}_{Avg} \approx \vec{v}_f$$ for non-constant forces

* A force is non-constant if it depends on position, velocity, or time

Spring Force

$$\vec{F}_s = -k(L - L_o)\,\hat{L}$$

- ✓ k = spring stiffnes (a constant with units of N/m)
- ✓ L = the current length of the spring (can be found based on the position of the attached mass)
- ✓ L_o = relaxed length of the spring
- ✓ $\hat{L}$ = a vector that <u>ALWAYS</u> points from the fixed end of the spring to the moving end of the spring
- ✓ The minus sign indicates that $\vec{F}_{spring}$ is a <u>restorative force</u>: a stretched spring wants to get smaller, and a compressed spring wants to get bigger

Weight Force

$$\vec{F}_g = \langle 0, -mg, 0 \rangle$$
$$= mg(-\hat{y})$$

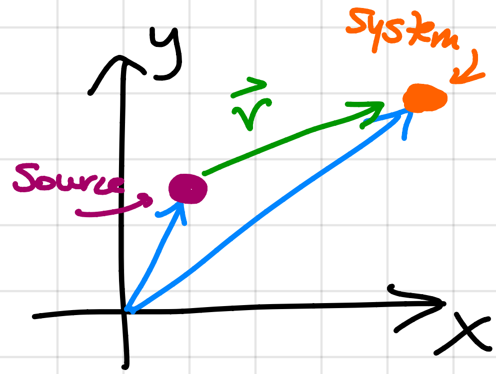
- ✓ Also known as "gravity on Earth"
- ✓ Constant force pointing down
- ✓ m = mass in kg
- ✓ g = acceleration due to gravity at the surface of Earth

$$g = \frac{GM_{Earth}}{R_{Earth}^2} = 9.8\ m/s^2$$

$$(G = 6.7e{-11}\ Nm^2/kg^2)$$

- ✓ Can calculate "g" for other planets or moons if given their mass and radius

Gravitational Force



$$\vec{F}_{grav} = \frac{G m_1 m_2}{r^2}(-\hat{r})$$

✓ $G = 6.7 \times 10^{-11}\ Nm^2/kg^2$

✓ m_1, m_2 = masses in kg

✓ $\vec{r}$ = relative position vector, which points from the source (in the surroundings) to the system (the thing that feels the force)

$$\vec{r} = \vec{r}_{system} - \vec{r}_{source}$$

$|\vec{r}|$ = magnitude of $\vec{r}$

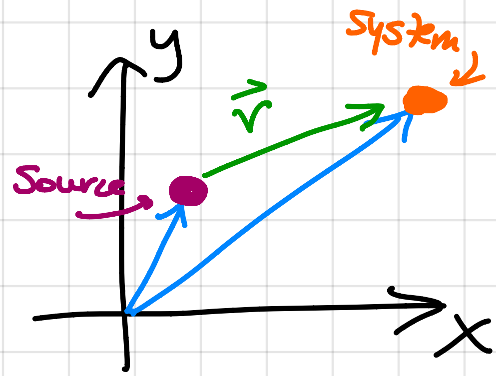
$\hat{r}$ = unit vector for $\vec{r}$

✓ $\vec{F}_{grav}$ goes in the direction $-\hat{r}$ because the force is <u>attractive</u>

(the force on the system points towards the source)

Electrostatic Force

$$\vec{F}_e = \frac{k q_1 q_2}{r^2} (\hat{r})$$



✓ $k = 9 \times 10^9 \, Nm^2/C^2$

✓ q_1, q_2 = charges in Coulombs; can be positive or negative

✓ $\vec{r}$ = relative position vector, which points from the source (in the surroundings) to the system (the thing that feels the force)

$$\vec{r} = \vec{r}_{system} - \vec{r}_{source}$$

$|\vec{r}|$ = magnitude of $\vec{r}$

$\hat{r}$ = unit vector for $\vec{r}$

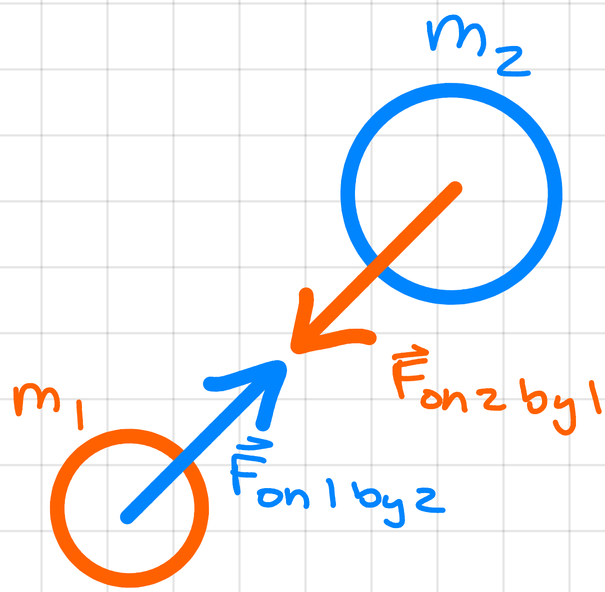
✓ Equal charges repel

✓ Opposite charges attract, and when this happens, $\vec{F}_e$ behaves exactly the same way as $\vec{F}_{grav}$

Reciprocity

- ✓ Also known as Newton's 3rd Law

- ✓ Forces between two objects come in pairs



$$\vec{F}_{on\,1\,by\,2} = -\vec{F}_{on\,2\,by\,1}$$

Same magnitude

opposite direction

Units

- ✓ numerical answers need units (example: $F = 23\,N$)

- ✓ symbolic answers don't need units (example: $F = mg$)