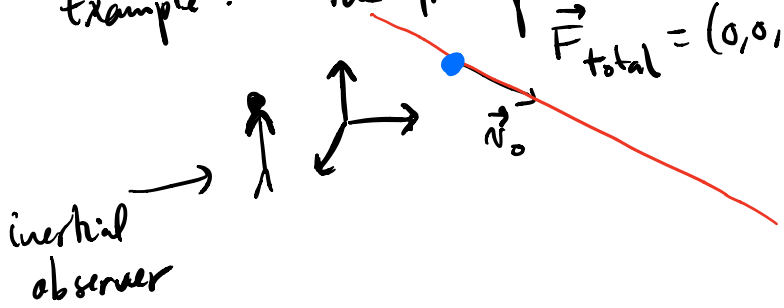
Lecture 8: Newton's 3rd laws. Normal force and friction force.

- Reviews of the first two postulates of Newton's theory.

1) With respect to an inertial observer, an object remains at rest or continues to move at a constant velocity unless acted upon by a force.

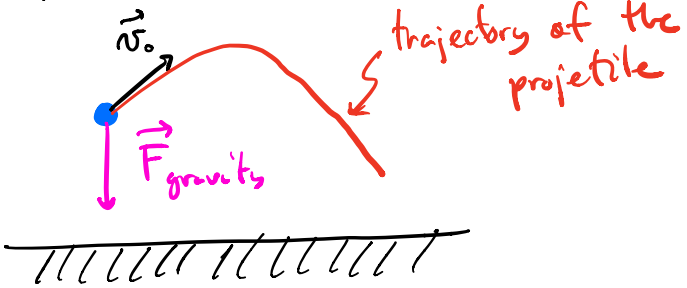
Example: the "free" particle



2) w.r.t an inertial observer, the acceleration of an object of mass m is related to the total force acting on it by the formula

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

Example: projectile motion



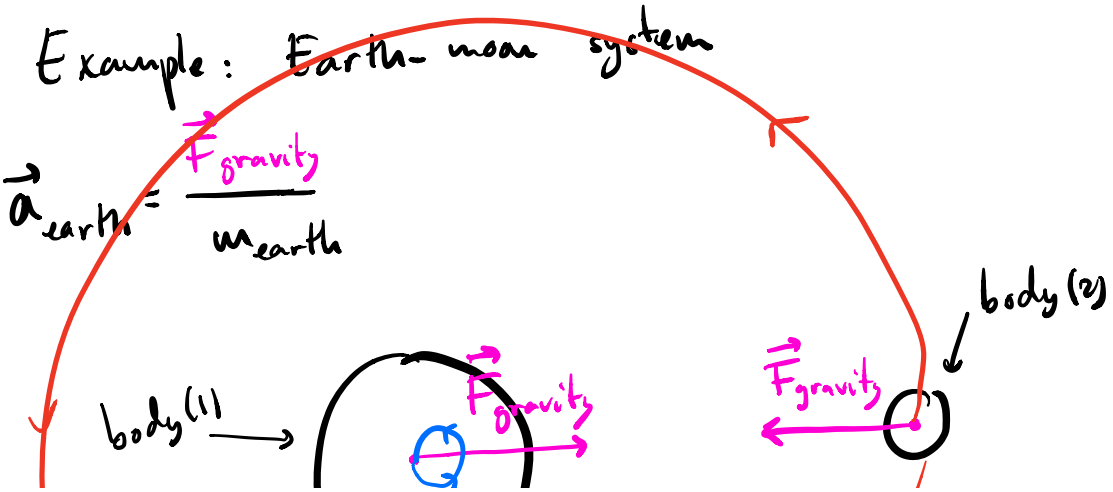
The third postulate of Newton's theory:
"Action-reaction".

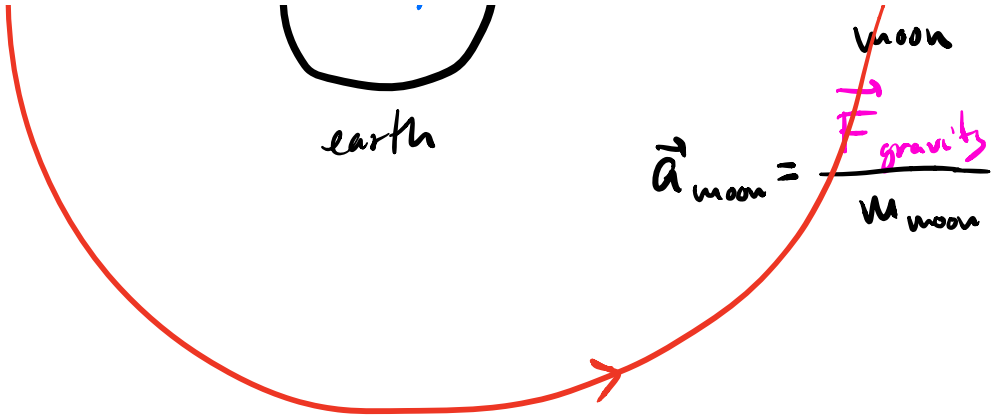
3) When a body (1) exerts a force on a second body (2), the second body exerts a force equal in magnitude and opposite in direction on the first one.

$$\vec{F}_{(1)\to(2)} = -\vec{F}_{(2)\to(1)}$$

Example: Earth-moon system

$$\vec{a}_{earth} = \frac{\vec{F}_{gravity}}{m_{earth}}$$





- So far we have seen as an example of a force, the force of gravity:

$$\vec{F}_{gravity} = -G\frac{m_1 \cdot m_2}{|\vec{s}|^3}\vec{s} \xrightarrow[\text{of the earth}]{\text{near the surface}} m_2\vec{g}$$

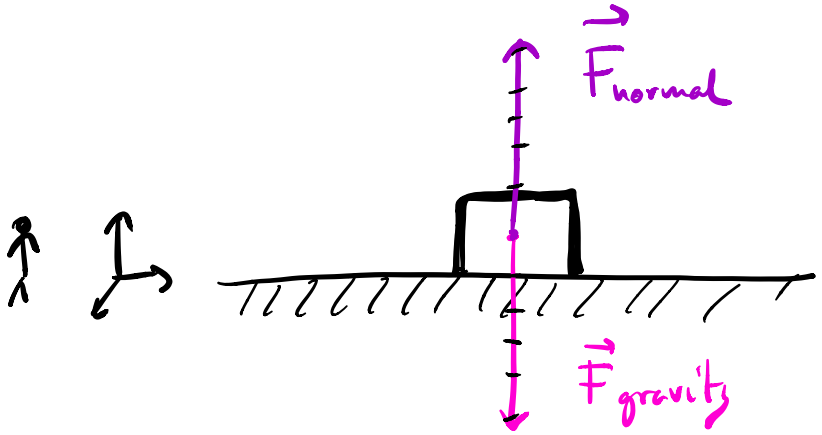
$\vec{g} = (0, -9.8)\ m/s^2$

- Other examples of forces are: spring force, friction force, normal force, electric force, magnetic force, nuclear force, ...

- **Normal force $\vec{F}_{normal}$ (sometimes $\vec{N}$)**: It is the contact force perpendicular to the surface of contact that prevents

the object from sinking through it.

Example



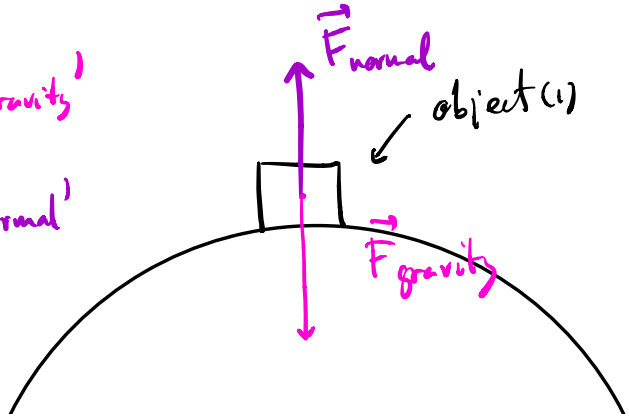
$$m\vec{a}_{object} = \vec{F}_{total} = \vec{F}_{gravity} + \vec{F}_{normal} = (0,0,0)$$

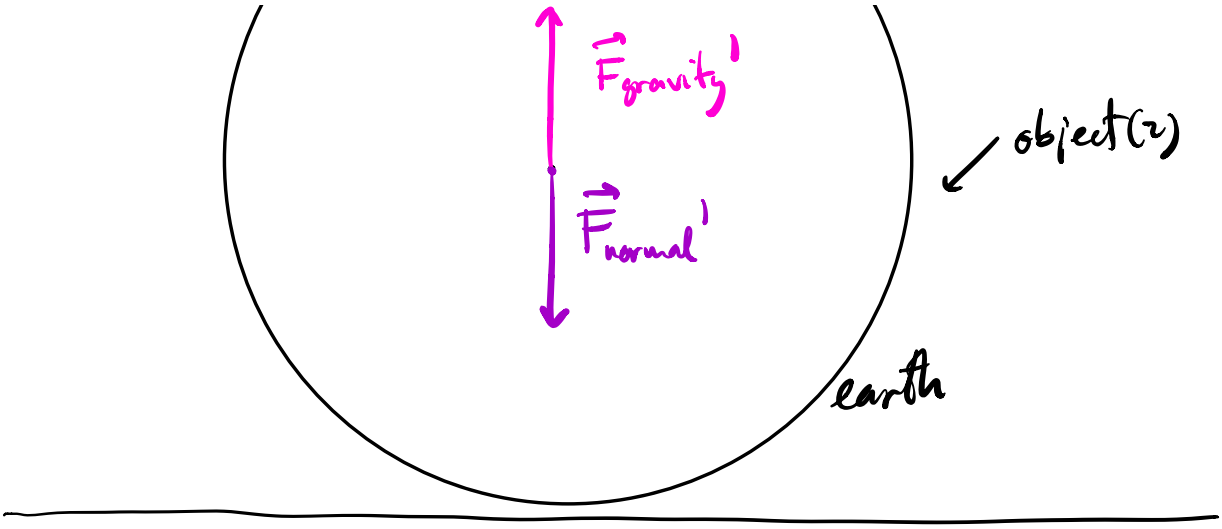
$$\vec{a}_{object} = (0,0,0) \rightarrow \vec{v} = \begin{cases} (0,0,0) \\ \vec{v}_0 \text{ (constant)} \end{cases}$$

What are the corresponding pairs to these forces according to the 3rd law?

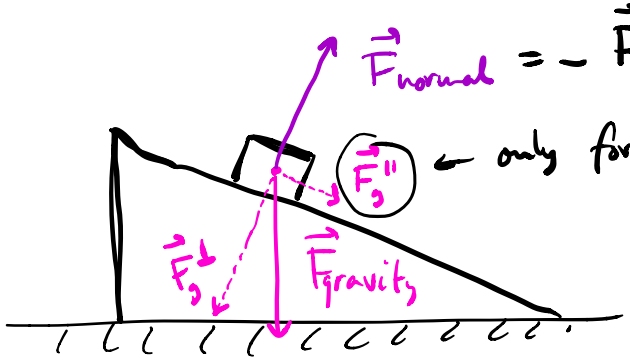
$\vec{F}_{gravity} = -\vec{F}_{gravity}'$

$\vec{F}_{normal} = -\vec{F}_{normal}'$





Comment: inclined plane



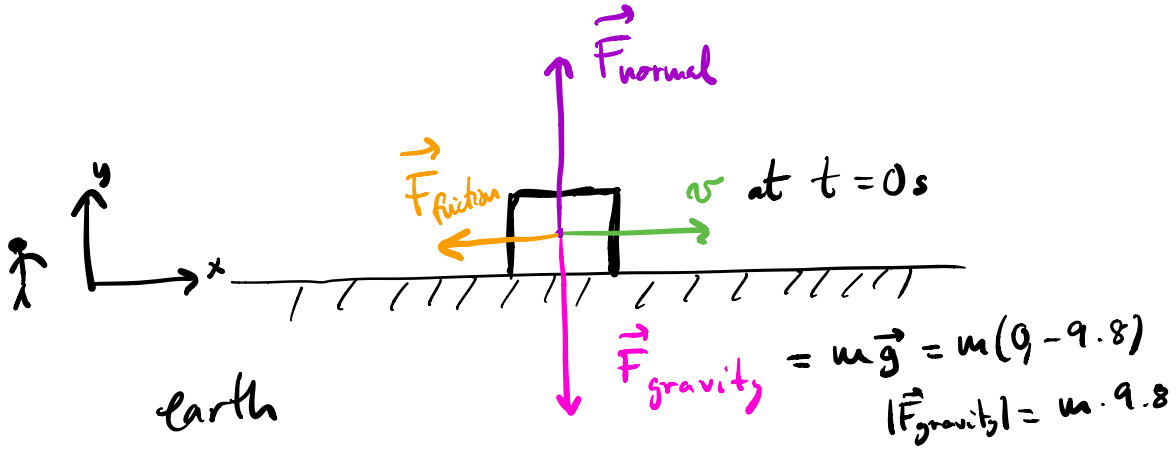
- Friction force $\vec{F}_{friction}$ due to contact with a surface:

Constant force opposite to the direction of motion (velocity). It has a magnitude of

friction coefficient (depends on material)

$$|\vec{F}_{friction}| = \mu \cdot |\vec{F}_{normal}|$$

Example: object slowing down due to friction



$$|\vec{F}_{friction}| = \mu\, |\vec{F}_{normal}| = \mu\, |\vec{F}_{gravity}|$$

$$m\vec{a}_{object} = \vec{F}_{total} = \vec{F}_{gravity} + \vec{F}_{normal} + \vec{F}_{friction}$$

$$\Rightarrow \vec{a}_{object} = \frac{\vec{F}_{friction}}{m} = \frac{(-\mu |\vec{F}_{gravity}|, 0)}{m}$$

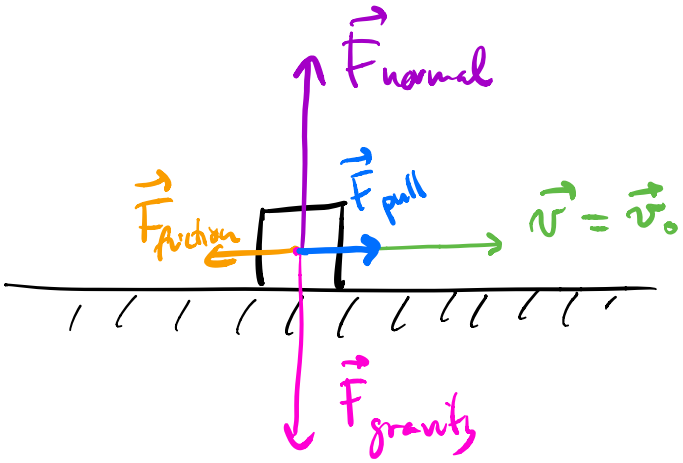
$$\Rightarrow \begin{cases} a_x = -\dfrac{\mu |\vec{F}_{gravity}|}{m} = -\dfrac{\mu \cdot m \cdot 9.8}{m} = -9.8\mu \\ a_y = 0 \end{cases}$$

$$\Rightarrow v_x = v_{x_0} + a_x t = v_{x_0} - 9.8\mu t$$

$$\Rightarrow \quad x = x_0 + v_0 \cdot t + \frac{1}{2} a_x t^2$$

$$= x_0 + v_0 \cdot t - \frac{9.8}{2} \mu t^2$$

For the object to continue to move at a constant velocity we need to cancel the friction force.



$$\vec{F}_{total} = \cdots = (0,0,0)$$

$$\Rightarrow \quad \vec{a} = (0,0,0)$$

$$\Rightarrow \quad \vec{v} = \vec{v}_0 \text{ (constant)}$$

What are the "reaction" forces according to 3rd law?