Physics 101

Lecture 5. Wed. Jan. 14, 2004.

Topics: Newton's Laws of Motion
Free-Body Diagram
Some Common forces in Nature

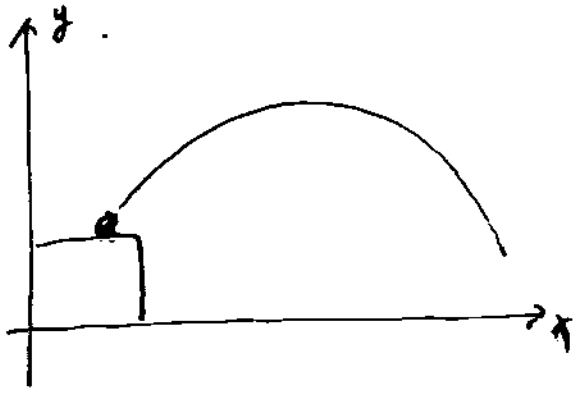
Ref: Ch. 5. 12-1.

Demo: Monkey hunting, Action and Reaction.
Force of a spring.

Last Lecture: Projectile Motion

$$x = x_0 + v_0 \cos\theta \cdot t$$

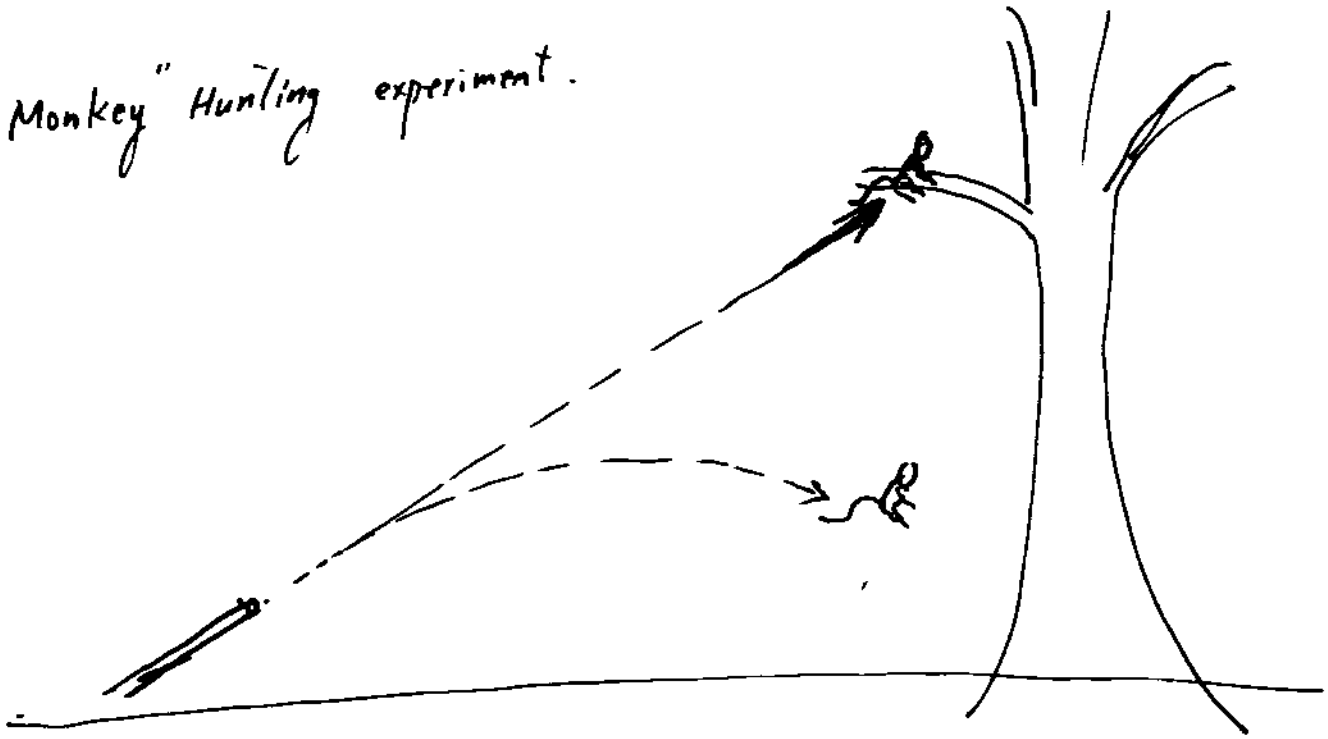
$$y = y_0 + v_0 \sin\theta \cdot t - \underbrace{\tfrac{1}{2} g t^2}_{\text{falling effect due to gravity.}}$$



Free falling: $v_0 = 0$. $x = x_0$.

$$y = y_0 - \underbrace{\tfrac{1}{2} g t^2}_{\text{same falling effect.}}$$

"Monkey" Hunting experiment.



If there were no gravity, the bullet would hit the monkey.

The there is gravity, as long as the bullet is fired at the same time as the monkey falls, it still hits the monkey. because the effect of gravity on y is the same for the ~~bullet~~ bullet and the monkey : $-\frac{1}{2}gt^2$.

- Dynamics. — Newtonian Mechanics.

  — Based on Newton's 3 Laws of Motion

  — Good for macroscopic (much larger than an atom) slow (much slower than the speed of light) motions

- Newton's 2nd Law of motion.

$$\vec{F} = m\vec{a}.$$ Vector eq.

$\vec{F}$ — Net force (The sum of all forces acting on the object m).

- Newton's 1st Law (A special case of 2nd law).

When $\vec{F} = 0$.

$\vec{a} = 0$. No acceleration.

If the object is at rest initially, it will stay at rest.

If the object is moving, it will continue to move at a constant velocity $\vec{v}$. (same speed along a straight line).

e.g. Seat belt.

- Newton's 3rd Law.

Forces always occur in pairs

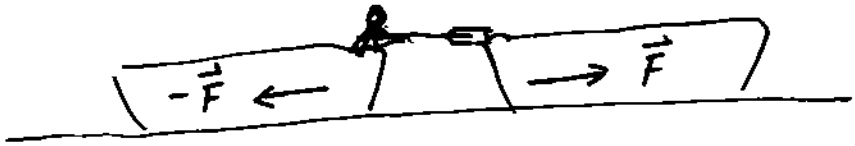
If object A exerts a force $\vec{F}$ on object B,

Then object B exerts a force $-\vec{F}$ on object A.

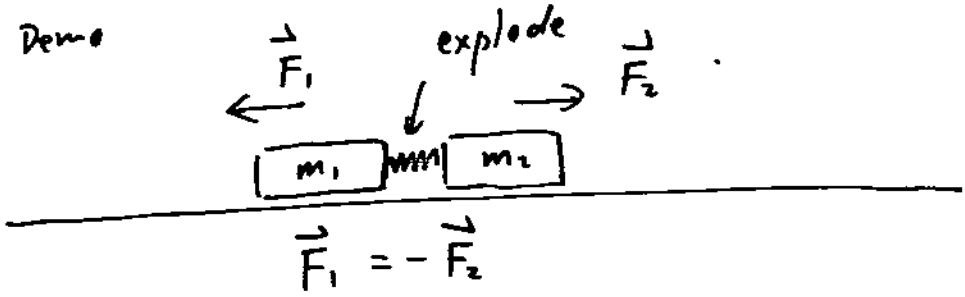
$\vec{F}$ and $-\vec{F}$ — same magnitude
opposite direction
along the same line
act on different objects!

} (action and reaction forces.)

e.g: Canoeing in the middle of a lake.



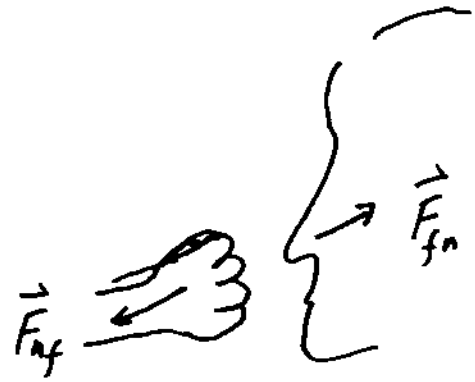
e.g: Demo



$\vec{F}_1 = -\vec{F}_2$

e.g:

e.g: Boxing.



$$\vec{F}_{nf} = -\vec{F}_{fn}$$

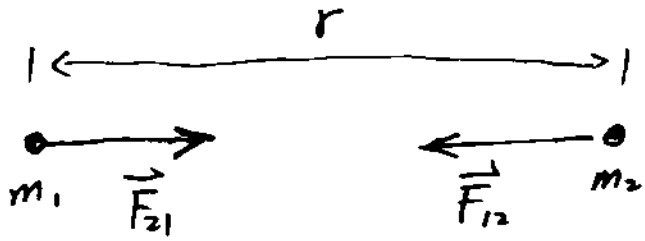
Force of the nose exerting on the fist has the same magnitude as the force of the fist acting on the nose.

But the problem of the nose is: it hurts more!

- Common forces in Nature

① Gravitational force.

Newton's Law of gravity.

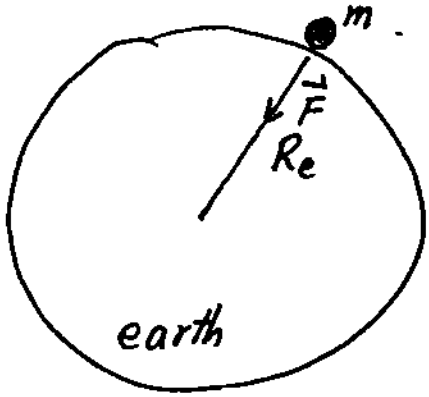


$$\left|\vec{F}_{12}\right| = \left|\vec{F}_{21}\right| = G\frac{m_1 m_2}{r^2}$$

$$G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$$

Near the surface of the earth

object m experiences the gravity due to the earth. $\vec{F}$:



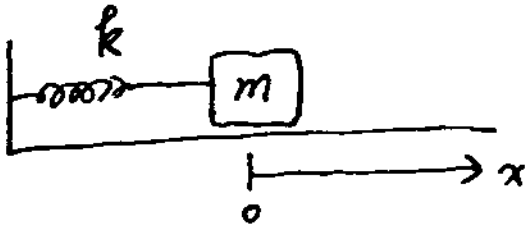
$$|\vec{F}| = G\frac{M_e \cdot m}{R_e^2} = mg$$

where $g = G\cdot\frac{M_e}{R_e^2} = 9.81\ m/s^2$

Compare: $\vec{F} = m\vec{a}$.

$\vec{a} = \vec{g}$ — gravitational acceleration

② . Force of a spring



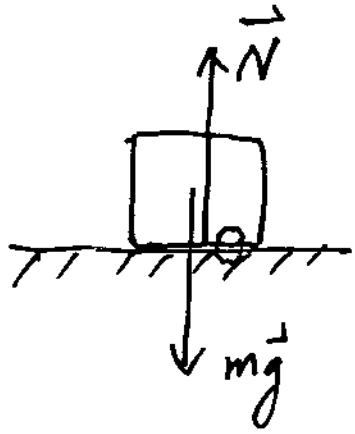
x – displacement from equilibrium position ($x=0$).

Hooke's Law: $F_x = -kx$

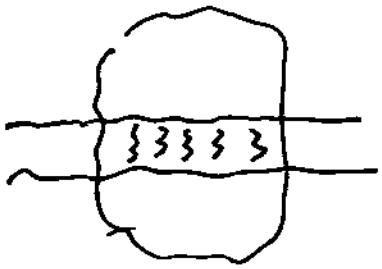
↑ restoring force (always points toward the equilibrium position)

k – spring constant.
(How strong the spring is).

③ . Normal Force .



At the surface



The molecules near the surface act similar to springs.

They compressed, and the force of the "springs"

is perpendicular to the surface — called Normal force.