

Dynamics

Branch of mechanics dealing with motion of bodies under the influence of a force

Force: an interaction that, when unopposed will change the motion of an object.

A force can cause an object with mass to change its velocity, i.e. accelerate.

4 Fundamental Forces:

Gravitational

- all masses attract each other 
- on earth we talk about weight of objects. (N)

Electromagnetic

- all charge attracts/repels each other 
- Electric (stationary charge) & magnetic (moving charge)

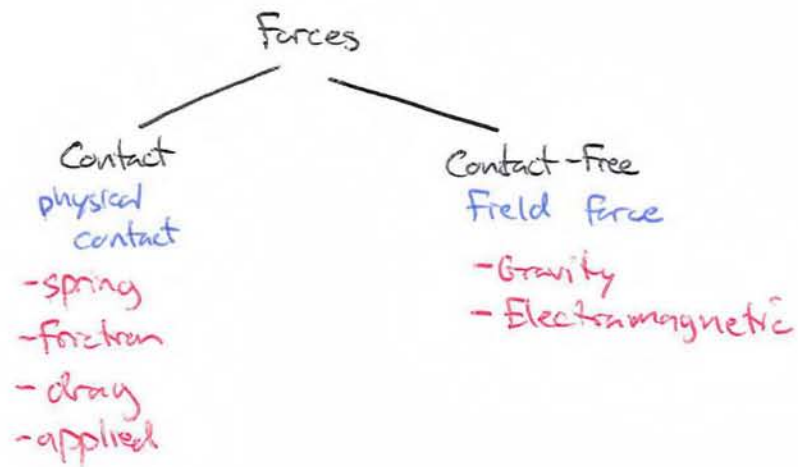
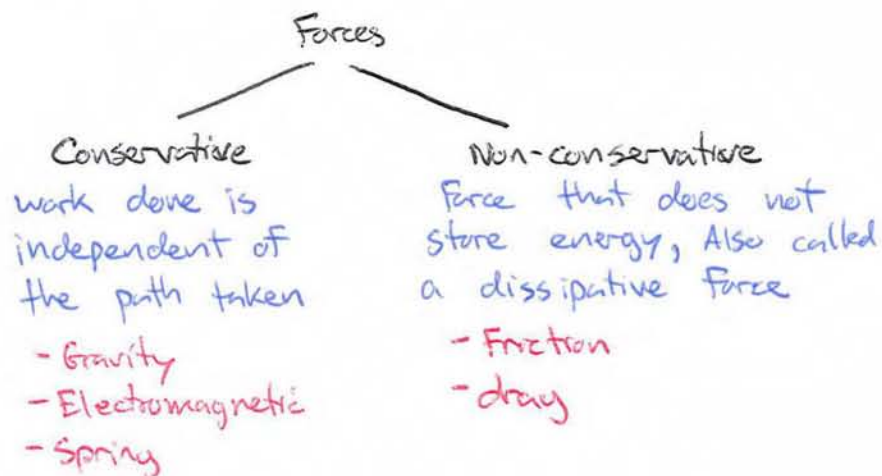
Strong nuclear

- Quantum Mechanics theory for the structural integrity of atomic nuclei 

Weak nuclear

- Quantum Mechanics theory for the decay of atoms into other fundamental particles 

Categories:



Forces are vector quantities and has units.

$$\text{Newton} = [N] = 1 \text{ kg } 1 \text{ m/s}^2$$

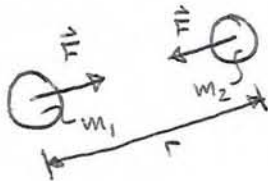
Gravitational Force (Fundamental)

All masses attract.

$$\vec{F} = G \frac{m_1 m_2}{r^2} \quad \text{toward the other object}$$

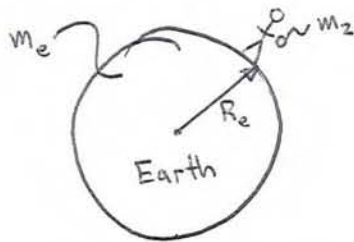
Newton's law of universal gravitation

Example 1:



$$\vec{F} = G \frac{m_1 m_2}{r^2}$$

Example 2:



$$\vec{F} = \left(\frac{G M_e}{R_e^2} \right) m_2$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

$$M_e = 5.98 \times 10^{24} \text{ kg}$$

$$R_e = 6.37 \times 10^6 \text{ m}$$

define weight
(Force of gravity
on an object)

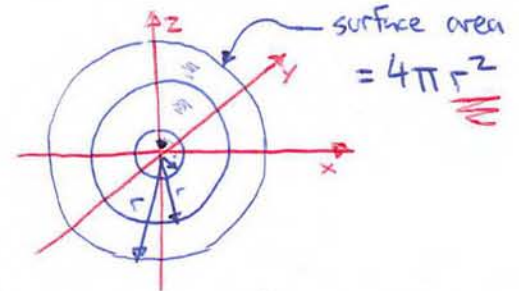
$$\vec{W} = m \vec{g}$$

$$\left(\frac{G M_e}{R_e^2} \right) = 9.8 \text{ m/s}^2 = g$$

Notes:

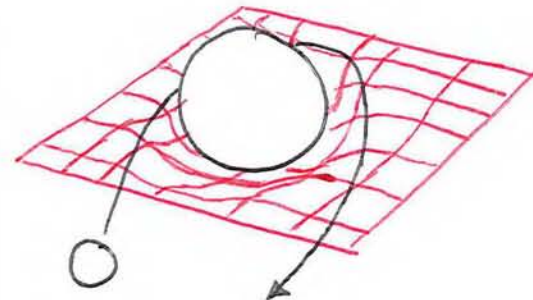
- Gravity, one of the first fundamental forces discovered and now the most difficult to unify with the other fundamental forces.
- Force of gravity is proportional to the inverse of the distance squared. This is called "inverse squared" and shows that gravity is a "field force" or "contact free" force.

$$\vec{F} \propto \frac{1}{r^2}$$



- Gravity keeps all planets, stars, galaxies and you bound to something instead of floating off into space

- Other theory: General Relativity.



Electromagnetic Force (Fundamental)

All charge attracts/repels

$$\vec{F} = q_1 (\vec{E} + \vec{v} \times \vec{B})$$

Lorentz Force Law

charge

electric field

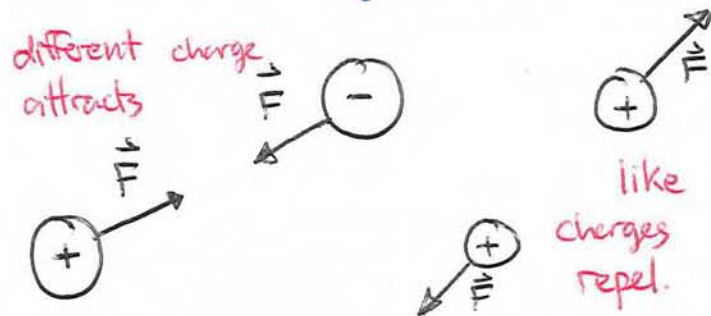
velocity of charge particle

magnetic field

In this course we will not deal with the magnetic field forces. We will talk about magnetic fields in circuits.

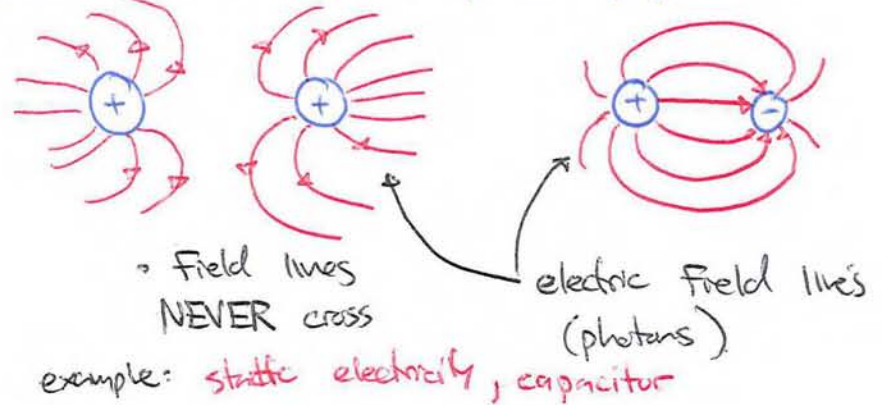
$$\vec{F} = q_1 \vec{E} = K_e \frac{q_1 q_2}{r^2} \quad \text{towards the other charge}$$

$$K_e = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$$

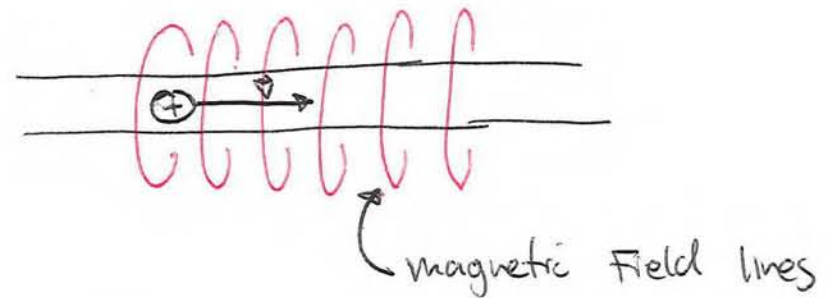


Notes:

Electric Field (stationary charge)

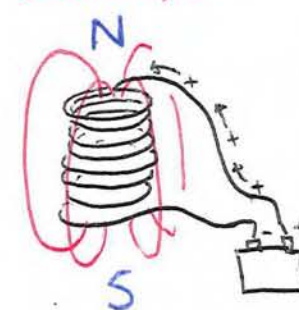


Magnetic Field (moving charge)

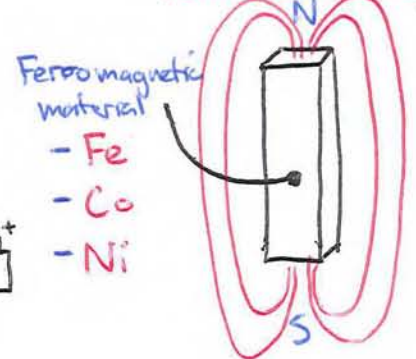


examples:

Electromagnet



Permanent magnet



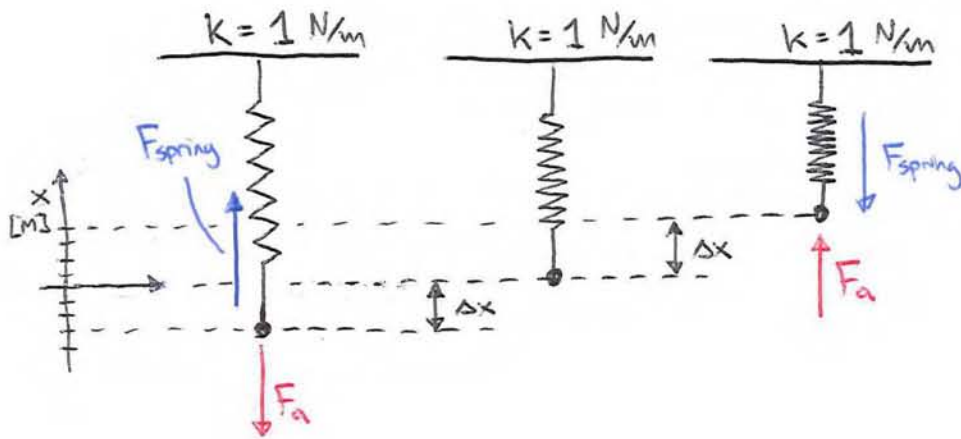
Spring Force

Base fundamental force is electromagnetic

$$\vec{F} = -k \vec{\Delta x}$$

-ive sign because
it opposes motion
in the x-direction

Hooke's Law where k = spring constant
or
spring stiffness

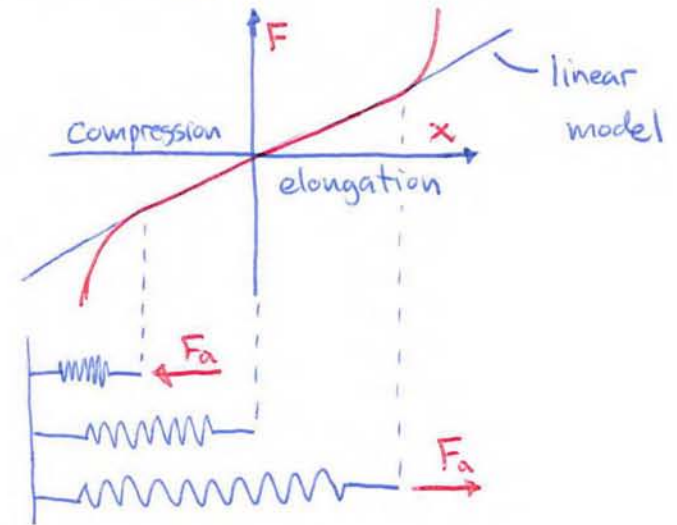


$$\begin{aligned} F_s &= -k \Delta x & F_s &= -k \Delta x & F_s &= -k \Delta x \\ &= -k (x_f - x_i) & &= -k (x_f - x_i) & &= -k (x_f - x_i) \\ &= -(1)(-3 - 0) & &= -(1)(0 - 0) & &= -(1)(4 - 0) \\ &= +3 \text{ N} & &= 0 & &= -4 \text{ N} \end{aligned}$$

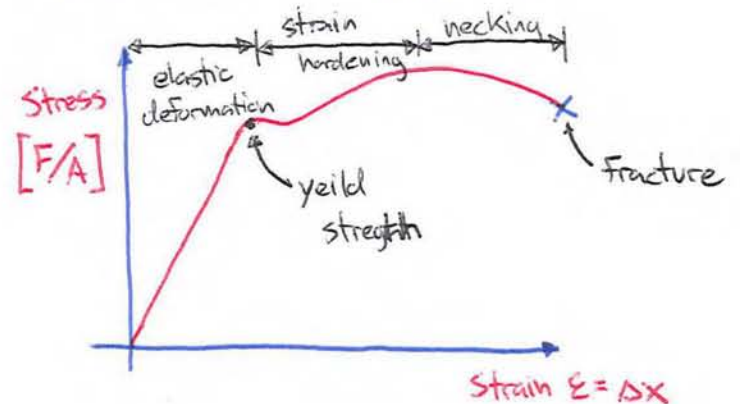
Notes:

• Can only use this model in "elastic deformation", as opposed to "plastic deformation".
example: elastic band
example: playdoh

• Ideal Spring:



• Actual materials (typical)



Normal Force

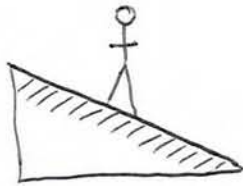
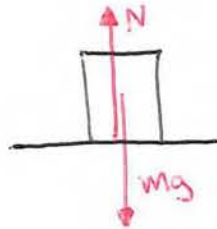
Base force is electromagnetic

$\vec{N}$ normal (or perpendicular)
to a surface of contact

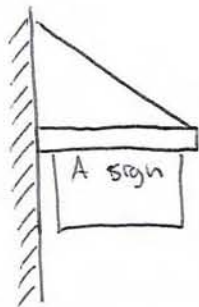
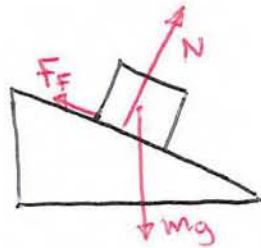
Examples.



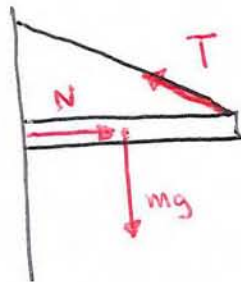
$\equiv$



$\equiv$



$\equiv$



Notes:

- Normal Force is the attraction between molecules that is stopping you from falling through the floor right now
- No equation. The normal force must be solved given the parameters of the problem.
- ALWAYS perpendicular to the surface of contact.

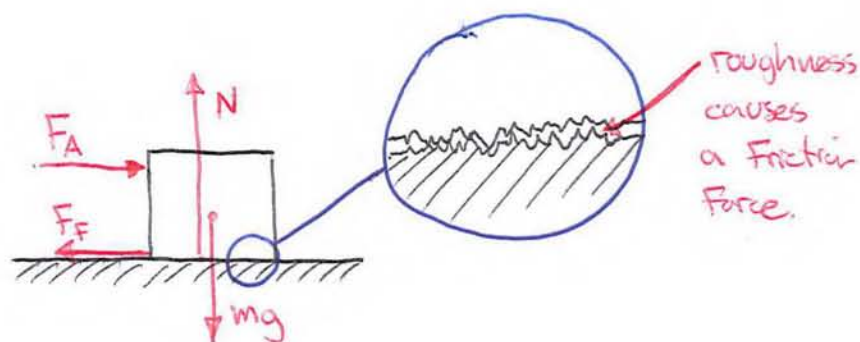
Friction Force

Base force is electromagnetic

$$\vec{F} = \mu N \quad \text{opposing motion of the object}$$

Coulomb's Law of Friction
Amontons'

$\mu = \text{COF}$
(coefficient of friction)



Static Friction

μ_s

$$\vec{F}_{F_{\max}} = \mu_s N$$

before motion starts

Kinetic Friction

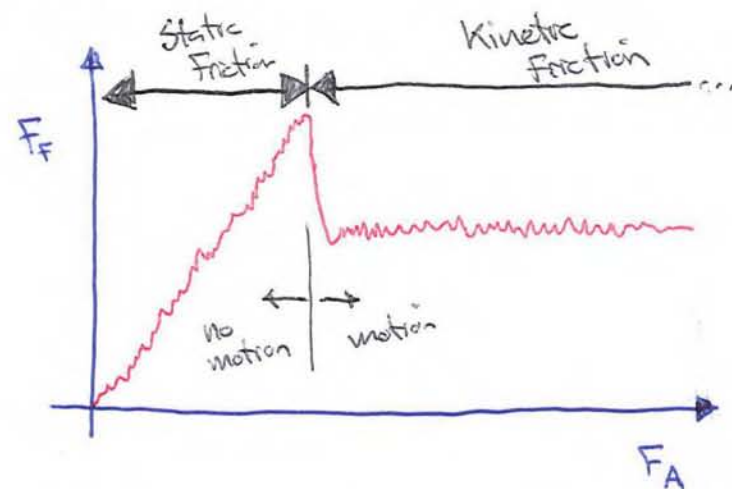
μ_k

$$\vec{F} = \mu_k N$$

after motion starts

$$\mu_s > \mu_k$$

Notes:



- Friction converts kinetic energy into thermal energy (i.e. input work into heat).

- Example COF's

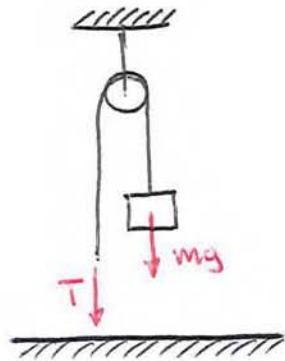
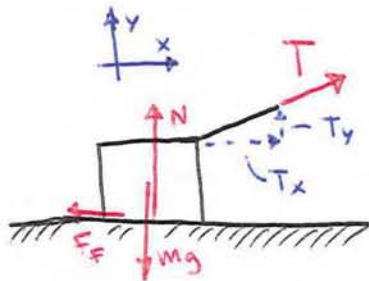
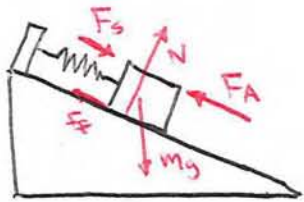
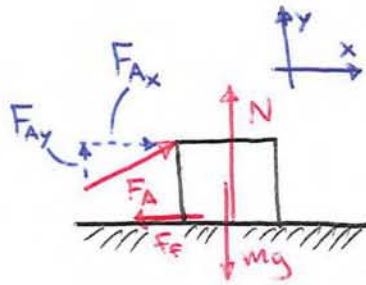
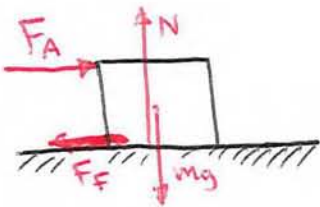
wood - wood	$\mu_s = 0.25 - 0.50$
wood - metal	$\mu_s = 0.2 - 0.60$
concrete - rubber	$\mu_s = 1.0$
ice - ice	$\mu_s = 0.02 - 0.09$

Applied Forces

$$\vec{F}_A \text{ (pushing)}, \vec{T} \text{ (pulling)}$$

↑
tension

Examples:



Notes:

- Usually $\vec{F}_A$ is the applied force when pushing an object and $\vec{T}$ is an applied force transferred through an unstretchable string, rope, chain, rod, ...
- No equation. Is sometimes given. If not, must be solved given the parameters of the problem.

Summary of Forces

Gravity $\vec{F} = G \frac{m_1 m_2}{r^2}$

$$\vec{F} = \vec{W} = m\vec{g} \quad (\text{on earth})$$

Electro-way $\vec{F} = k_e \frac{q_1 q_2}{r^2}$

Spring $\vec{F} = -k \Delta \vec{x}$

Friction $\vec{F} = \mu N \quad (\mu_s \text{ or } \mu_k)$

Normal $\vec{N}$

Applied $\vec{F}_A, \vec{T}$