Newton's Laws

Grade 11 Physics

Newton's Laws

Newton's First Law

- All famous Newton's First Law
  - Inertia
    - Resist ANY change in motion.

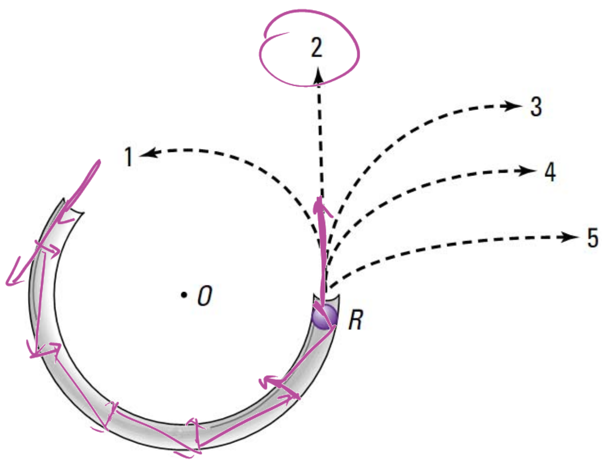
DEFINITION OF INERTIA

Inertia is the natural tendency of an object to remain in its current state of motion. The amount of an object's inertia is directly related to its mass.

Newton's First Law

- Inertia
  - An object at rest or in uniform motion **will remain** at rest or in uniform motion unless acted on by an external force
  - **Inertia exists because a matter has mass.** It does not depends on the velocity, force or anything else.

Example Problem

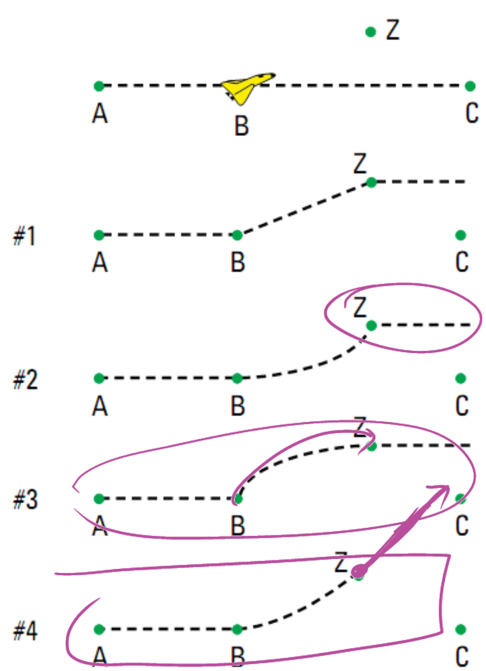


- EX1:

  A marble is fired into a circular tube that is anchored onto a frictionless tabletop. Which of the five paths will the ball take as it exits the tube and moves across the tabletop? Justify your answer.

Example Problem

- EX2:
  - A spacecraft is lost in deep space, far from any objects, and is drifting along from point A toward point C. The crew fires the on-board rockets that exert a constant force exactly perpendicular to the direction of drift. If the constant thrust from the rockets is maintained from point B until point Z is reached, which diagram best illustrates the path of the spacecraft?



Common Forces

- Gravity
  - Based on Newton's Universal Gravitation
  - Affected by
    - the masses of the two objects
    - the distance between two objects
  - Acceleration due to gravity
    - Different based where you are on Earth
    - 9.81m/s² is approximated

$$F_g = G\frac{M_1 M_2}{r^2}$$

universal gravitation constant

Common Forces (Cont.)

- Gravity

Location	Acceleration due to gravity (m/s²)	Altitude (m)	Distance from Earth's centre (km)
North Pole	9.8322	0 (sea level)	6357
equator	9.7805	0 (sea level)	6378
Mt. Everest (peak)	9.7647	8850	6387
Mariana Ocean Trench* (bottom)	9.8331	11 034 (below sea level)	6367
International Space Station*	9.0795	250 000	6628

Common Forces (Cont.)

- Gravity
  -

Location	Acceleration due to gravity (m/s^2)
Earth	9.81
Moon	1.64
Mars	3.72
Jupiter	25.9

Weight – Force of Gravity

- Weight is a FORCE:
  - Force of Gravity

constant → mass of Planet (Earth)

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

→ mass of object

→ distance from Earth center

$$\vec{F}_g = m\vec{g}$$

→ mass of object

Quantity	Symbol	SI unit
force of gravity (weight)	$\vec{F}_g$	N (newton)
mass	m	kg (kilogram)
acceleration due to gravity	$\vec{g}$	m/s^2 (metres per second squared)

Example Problem

- EX3:
  - Calculate the weight of a 4.0kg mass on the surface of the Moon.

$g_{moon} = 1.64 m/s^2$

$F_{g,moon} = 4.0kg \cdot g_{moon}$

$= 4.0kg \cdot 1.64 m/s^2$

$= 6.56\ N$

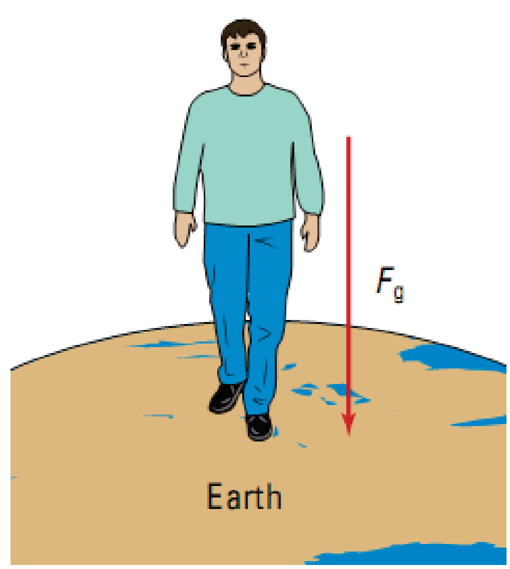
(Newton)

Fundamental Unit:
↳ unit in its most basic form
↳ unit that exits in nature.

Newton
↳ $\boxed{kg \cdot m/s^2}$

Example Problem

- EX4:
  - A student standing on a scientific spring scale on Earth finds that he weighs 825N. Find his mass.



$F_g = 825N$

$= mg$

$m = F_g/g$

Newton's Second Law

- Net Force = Mass x Acceleration

$\Sigma F = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$

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

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

$\Sigma\vec{F} = m\vec{a}$

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

Net => summation

$F_{Net} = \boxed{\Sigma} F$

Summation Notation

Quantity	Symbol	SI unit
force	$\vec{F}$	N (newtons)
mass	m	kg (kilograms)
acceleration	$\vec{a}$	$\frac{m}{s^2}$ (metres per second squared)

Unit analysis

$$(\text{mass})(\text{acceleration}) = (\text{kilogram})\left(\frac{\text{metres}}{\text{second}^2}\right) \text{kg}\frac{\text{m}}{\text{s}^2} = \frac{\text{kg}\cdot\text{m}}{\text{s}^2} = \text{N}$$

Note: The force ($\vec{F}$) in Newton's second law refers to the vector sum of all of the forces acting on the object.

Newton's Second Law (Cont.)

- Net Force = Mass x Acceleration

$$F_{net} = \sum F = ma \text{ (N)}$$

$$W = mg \text{ (N)}$$

WORK

Name of a term

old style notation

weight

F_g

POWER = P

Name of the term

WATT unit

W

Forces

- Force is the interaction between the objects.
  - When there is interaction, then forces are created

- Sate of Equilibrium
  - The net force on an object is 0

- State of Dynamic Equilibrium
  - The object is moving relative to us

- State of Static Equilibrium
  - The object is not moving relative to us

Newton's Third Law

- For every action force on an object (B) due to another object (A), there is a reaction force which is equal in magnitude but opposite in direction, on object (A), due to object (B).

ACTION REACTION
↳ APPLIED ONTO 2 SEPERATE OBJECTS

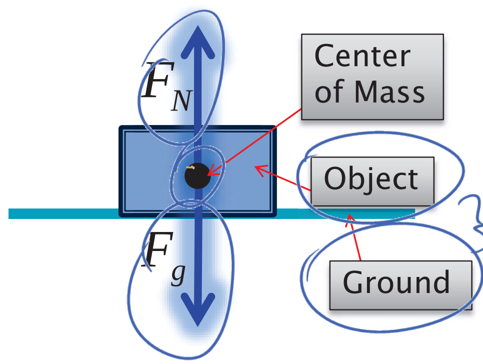
$$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$$

Normal Force

- Normal Force Math: $\perp$
  - Normal Circumstances:
    - Equals to gravity in **magnitude**
    - Opposite to gravity in **direction**
    - Based on Newton's Second Law and Third Law

FREE BODY DIAGRAM
↳ Freely to move

F_N IS NOT the reaction force of F_g

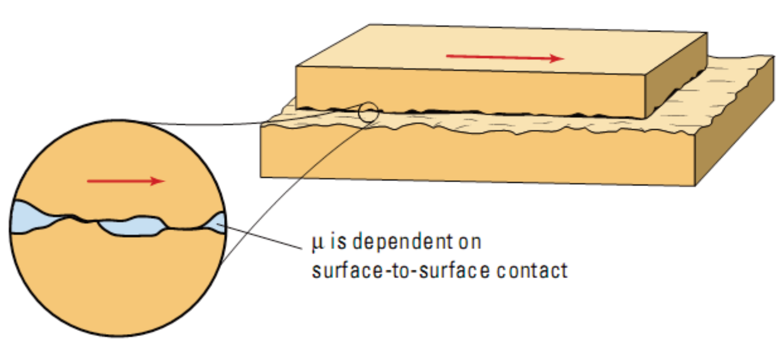


not necessarily to be drawn

$$F_g = mg = F_N$$

Friction

- Friction is a constant force between two surfaces that is responsible for opposing sliding motion.
  - When an object is first moved, the friction plus inertia must be overcome



Friction (Cont.)

- Static friction
  - The friction between the two surfaces before the object start moving
  - The static friction increases along with increasing applied force. It is at max when the object is just about to move.

$$F_{\text{static friction, max}} = \mu_s F_N$$

$\mu_s = \text{coffecient of static friction}$

$F_N = \text{normal force}$

Friction (Cont.)

- Kinetic friction
  - The friction between the two surfaces while the object is moving.
  - The kinetic friction is constant along the path of movement as long as the normal force stays constant.

$$F_{\text{kinectic friction}} = \mu_k F_N$$

$\mu_s = \text{coffecient of kinetic friction}$

$F_N = \text{normal force}$

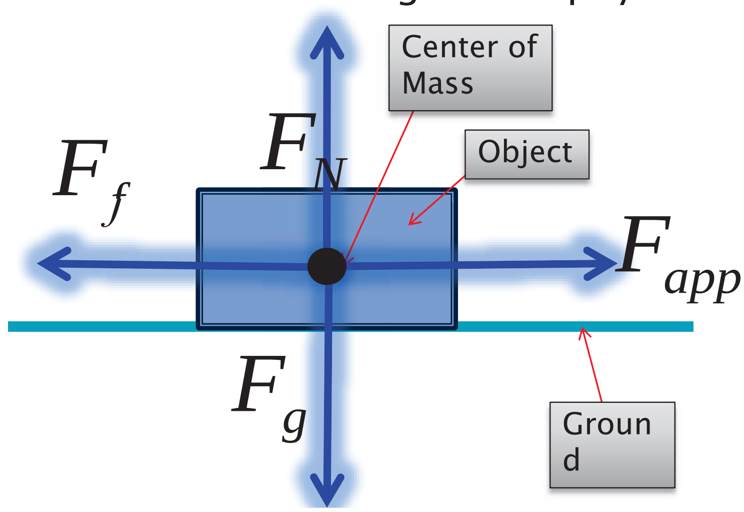
Friction (Cont.)

- Typical Friction Coefficient

Surfaces	Coefficient of Static Friction μ_s	Coefficient of Kinetic Friction μ_k
rubber on dry solid surfaces	1 – 4	1
rubber on dry concrete	1.00	0.80
rubber on wet concrete	0.70	0.50
glass on glass	0.94	0.40
steel on steel (unlubricated)	0.74	0.57
steel on steel (lubricated)	0.15	0.06
wood on wood	0.40	0.20
ice on ice	0.10	0.03
Teflon™ on steel in air	0.04	0.04
lubricated ball bearings	< 0.01	< 0.01
synovial joint in humans	0.01	0.003

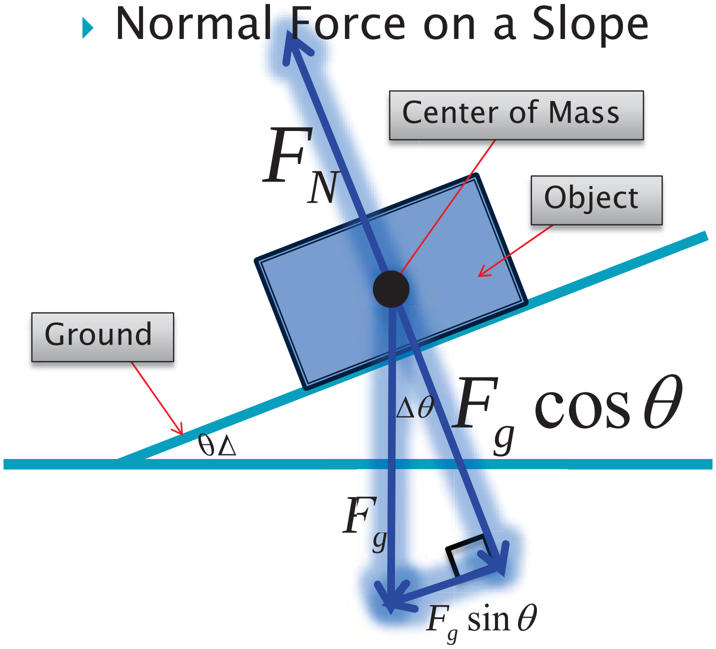
Free Body Diagram

- F.B.D.
  - Very very very **IMPORTANT**
  - Don't try to save a step
  - Always draw FBD for solving classic physics



Free Body Diagram

- Normal Force on a Slope



$$F_N = -F_g \cos\theta$$

Example Problem

- EX5:
  - During the winter, owners of pickup trucks often place sandbags in the rear of their vehicles. Calculate the increased static force of friction between the rubber tires and wet concrete resulting from the addition of 200kg of sandbags in the back of the truck.

Example Problem

- EX6:
  - A horizontal force of 85N is required to pull a child in a sled at constant speed over dry snow to overcome the force of friction. The child and sled have a combined mass of 52kg. Calculate the coefficient of kinetic friction between the sled and the snow.

Example Problem

- EX7:
  - A man is riding in an elevator. The combined mass of the man and the elevator is $7.00\text{x}10^2$kg. Calculate the magnitude and direction of the elevator's acceleration if the tension (T) in the supporting cable is $7.50\text{x}10^3$ (T is the applied force).

Example Problem

- EX8:
  - A curler exerts an average force of 9.50N [S] on a 20.0kg stone. {Assume that ice is frictionless.} The stone started from rest and was in contact with the girl's hand for 1.86s
    - Determine the average acceleration of the stone.
    - Determine the velocity of the stone when the curler releases it.

Four Fundamental Forces

- Strong Nuclear Force
  - Strongest out of all four
  - Overcome the repulsion of positively charge protons by keeping them together.

- Electromagnetic Force
  - Most of "everyday" force other than gravity
  - Contact forces
    - Electrons interacting with each other

Four Fundamental Forces (Cont.)

- Weak Nuclear Force
  - Very weak
  - 10,000 time weaker than strong nuclear force
  - Cause a neutron transforms into a proton

- Gravitational Force
  - An exchanged force with a massless mediating particle called graviton
  - Graviton is never discovered yet
  - Weakest of all forces