⇒ त्वरण , {Graph} , NLM

SAFALTA CLASS™

An Initiative by अमर उजाला

KINEMATICS

Relative Velocity

- Relative velocity of one object with respect to another object is the time rate of change of relative position of one object with respect to another object.

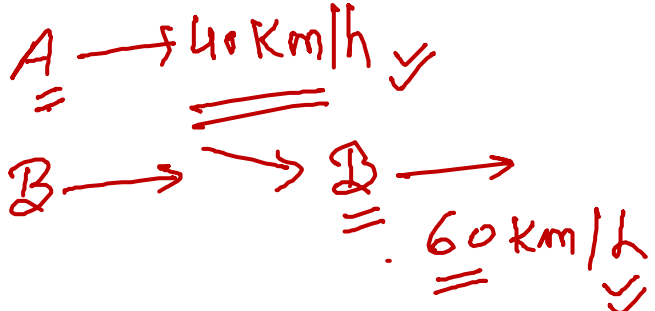
(आपेक्षिक वेग)

- Relative velocity of object A with respect to object B

$$V_{AB} = V_A - V_B$$

किसी वस्तु का सापेक्ष वेग दूसरी वस्तु के संबंध में, किसी वस्तु के सापेक्ष स्थिति के परिवर्तन की समय दर दूसरी वस्तु के संबंध में होती है।

ऑब्जेक्ट B के संबंध में ऑब्जेक्ट A के सापेक्ष वेग



$V_{AB} = V_A - V_B$

20 Km/h

- When two objects are moving in the same direction, then

$$V_{AB} = V_A - V_B$$

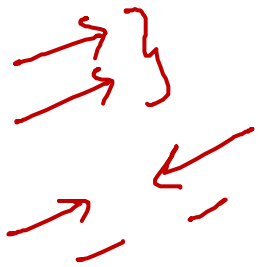
$v_{AB} = v_A - v_B$

- When two objects are moving in opposite direction, then

v_A v_B (-)

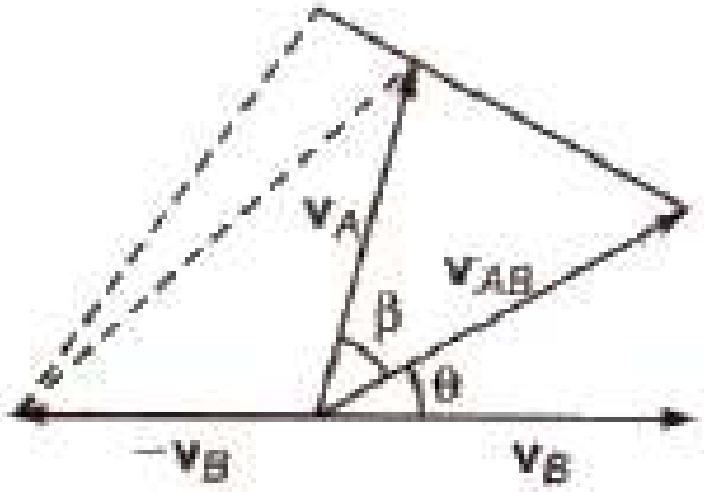
$$V_{AB} = V_A + V_B$$

$v_{AB} = v_A + v_B$

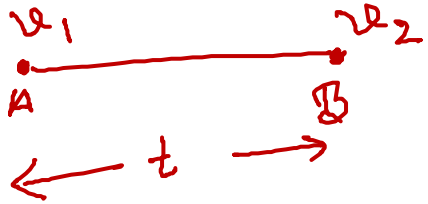


- When two objects are moving at an angle, then

- and tan β = vB sin θ / vA – vB cos θ



$$v_{AB} = \sqrt{v_A^2 + v_B^2 - 2v_A v_B \cos\theta}$$



Acceleration

- **Acceleration** (Vector): ANY change in velocity
  - Speeding up (final velocity is a larger magnitude than the initial velocity)
  - Slowing down (final velocity is a smaller magnitude than the initial velocity)
  - Changing directions (the direction of the vector is changing)

$$\vec{a} = \frac{v_2 - v_1}{t}$$

- **Average Acceleration**: the rate at which velocity is changing

- Units = $^{m}/_{s^2}$ = $m \cdot s^{-2}$

$$\Rightarrow \frac{\Delta v}{\Delta t} = \frac{m/s}{s} = m/s^2$$

$$a = \frac{\Delta v}{t} = \frac{v_2 - v_1}{t}$$

$$\vec{a} = \frac{v_f - v_i}{time}$$

D.F. $\Rightarrow$

- त्वरण (वेक्टर): वेग में कोई परिवर्तन $\vec{a} = [LT^{-2}]$

- तेजी (अंतिम वेग प्रारंभिक वेग की तुलना में एक बड़ा परिमाण है)

- धीमा होना (अंतिम वेग प्रारंभिक वेग की तुलना में एक छोटा परिमाण है)
बदलती दिशाएं (वेक्टर की दिशा बदल रही है)

- औसत त्वरण: जिस दर पर वेग बदल रहा है

$$a = \frac{\Delta v}{t} = \frac{v_2 - v_1}{t}$$

- इकाइयाँ = m / s2 = m · s-2

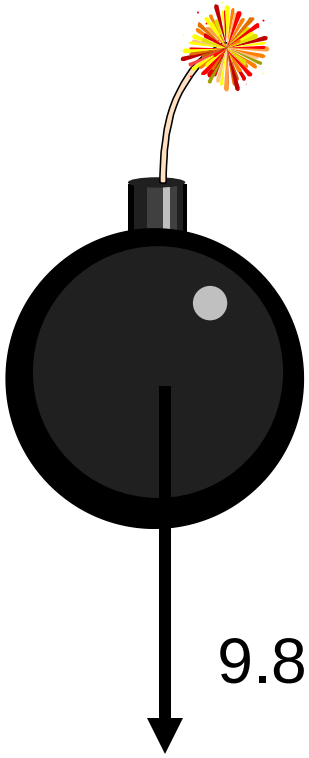
Velocity & Acceleration Sign Chart ⇒ Vector सदिश

		VELOCITY	
		+	-
ACCELERATION	+	Moving forward; Speeding up	Moving backward; Slowing down
	-	Moving forward; Slowing down	Moving backward; Speeding up

Acceleration due to Gravity

Near the surface of the Earth, all objects accelerate at the same rate (ignoring air resistance).

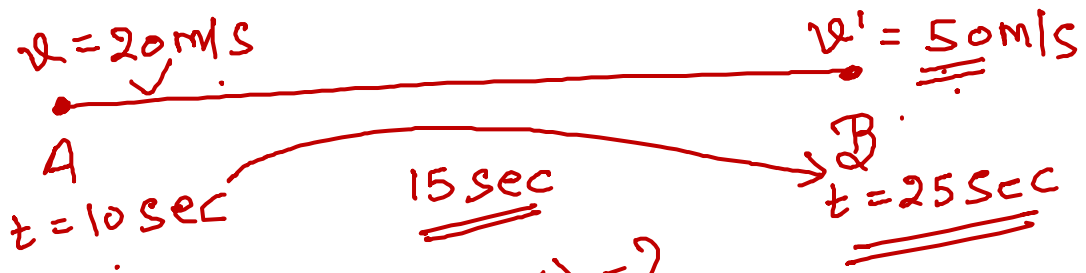
$\boldsymbol{a} = -\boldsymbol{g} = -9.8\ m/s^2$



9.8 m/s²

This acceleration vector is the same on the way up, at the top, and on the way down!

Interpretation: Velocity decreases by 9.8 m/s each second, meaning velocity is becoming less positive or more negative. Less positive means slowing down while going up. More negative means speeding up while going down.



$\vec{a}$ (त्वरण) = ?

$$\Rightarrow \quad \vec{a} = \frac{v_f - v_i}{\Delta t}$$

$$= \frac{50 - 20}{15} = \frac{30}{15}$$

$$\vec{a} = 2\ m/s^2$$

$x = 2t^2 + 5t + 2$

x ↓ Disp / विस्थापन

$5t$ ↓ समय

$\Rightarrow \vec{v} = \frac{d\vec{s}}{dt}$ ✓

$\vec{v} = \frac{d}{dt}(2t^2 + 5t + 2)$

$\vec{v} = 4t + 5$

$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}(4t + 5)$

$\vec{a} = 4\ m/s^2$ ✓

$\vec{a} = ?$

$v = 100\ m/s$ at A, $t = 10\ sec$

$v' = 50\ m/s$ at B, $t' = 25\ sec$

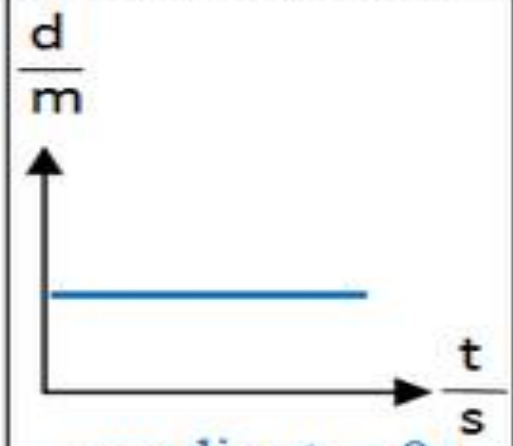
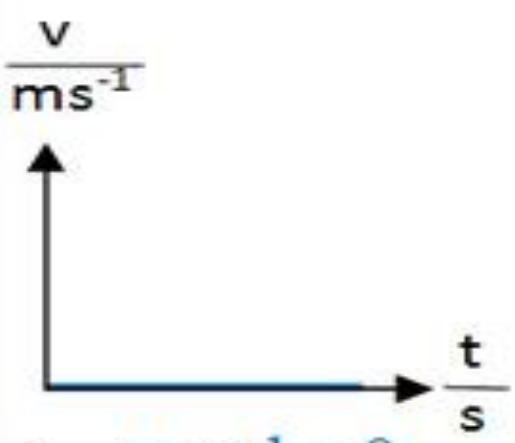
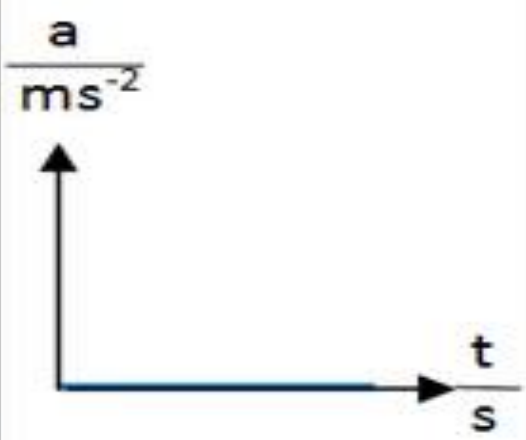
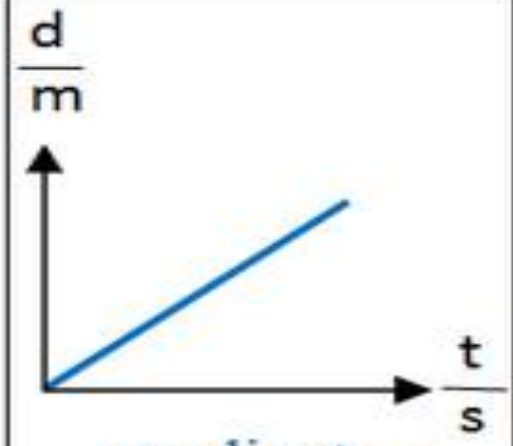
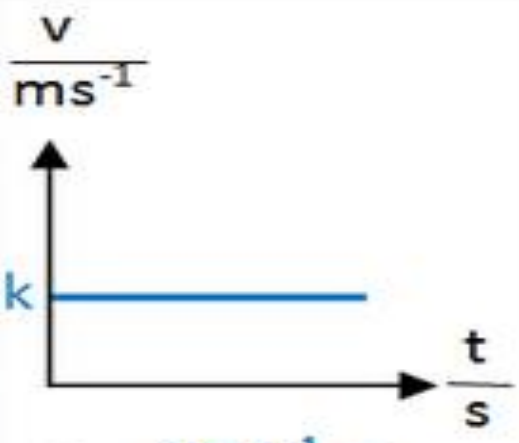
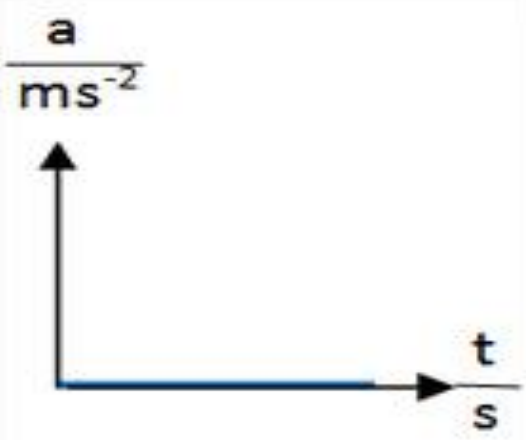
$\vec{a} = ?$

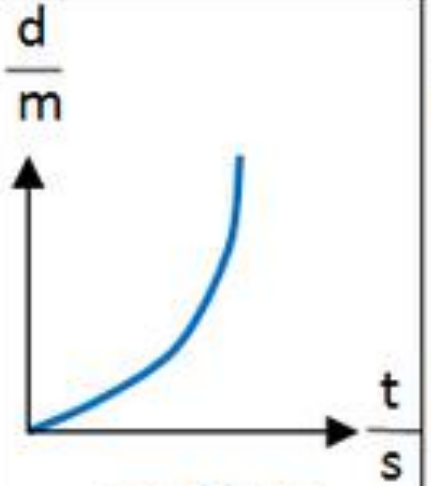
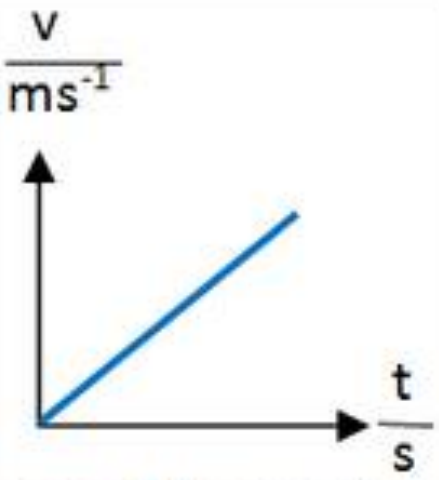
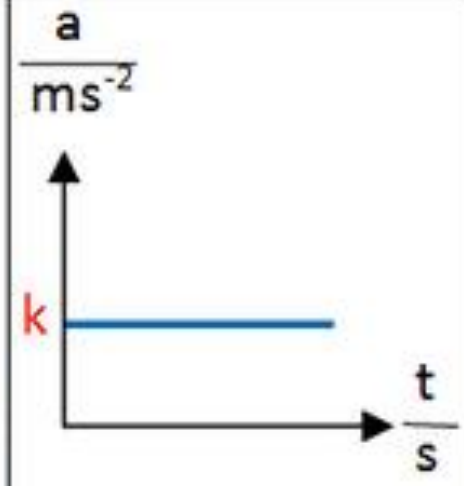
$\vec{a} = \frac{50 - 100}{15}$

$= -\frac{50}{15} = \ominus \frac{10}{3}\ m/s^2$

↓ मंदन

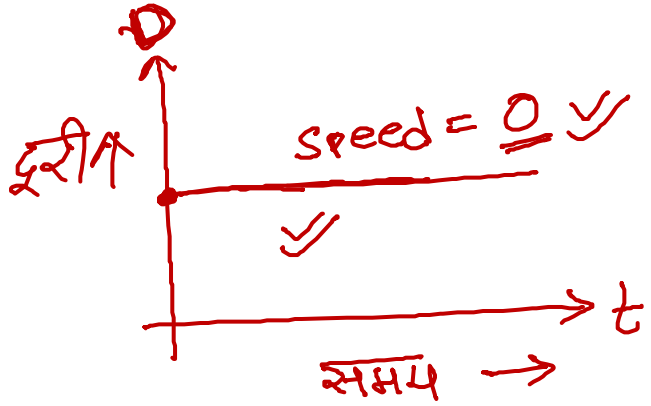
GRAPH

Motion of object	Distance-Time graph	Speed-Time graph	Acceleration-Time graph
At rest	 gradient = 0	 speed = 0 gradient = 0	 acceleration = 0
At constant speed or uniform speed	 gradient = constant, k	 speed = constant, k gradient = 0	 acceleration = 0

Uniform acceleration	 gradient varying	 speed increasing uniformly gradient = constant, k	 acceleration = constant, k

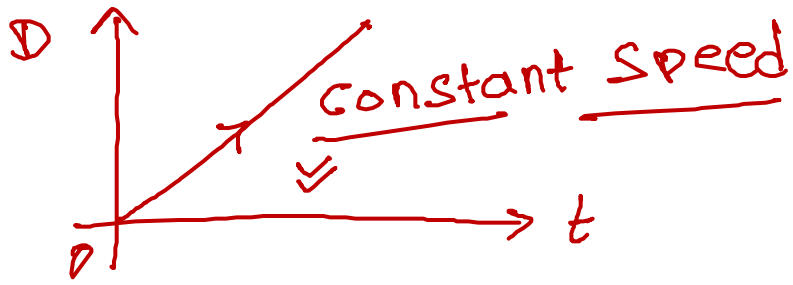
* Distance - Time :- ⇒ Speed चाल

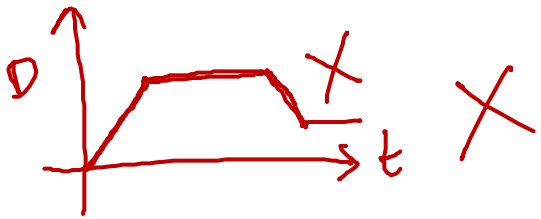
दूरी - समय ⇒

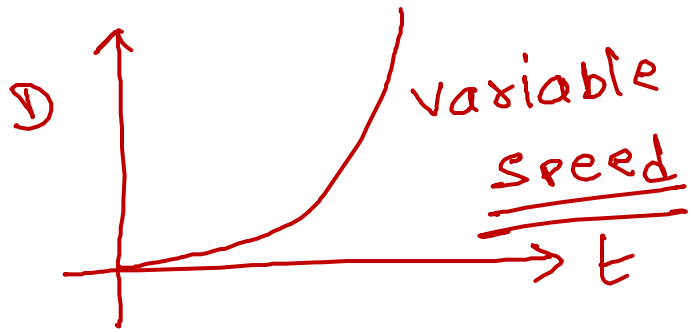


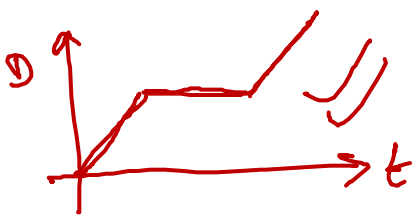
①

②



③ 

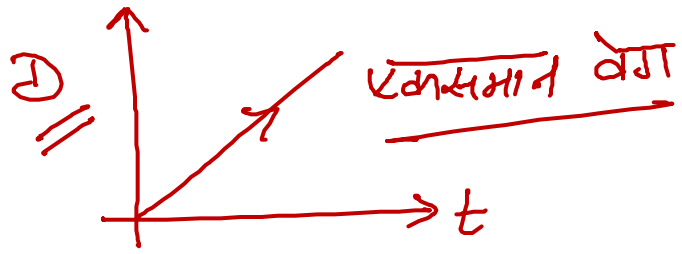


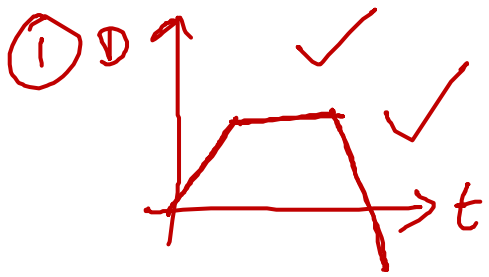
④ 

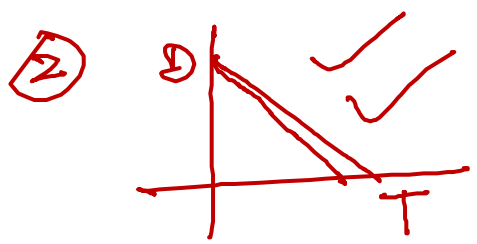
possible

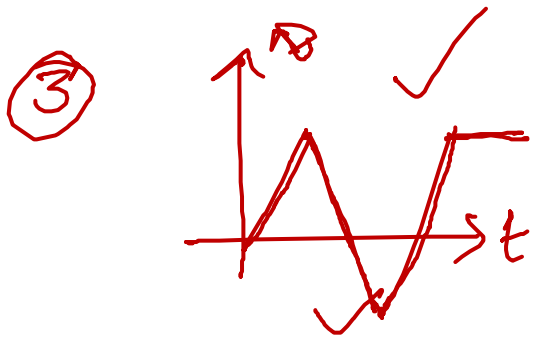
* Disp - Time:- विस्थापनसमय:- ⇒ velocity (वेग)

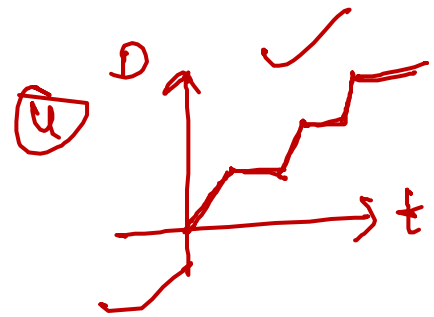
(+ve)
(-ve)
(0)









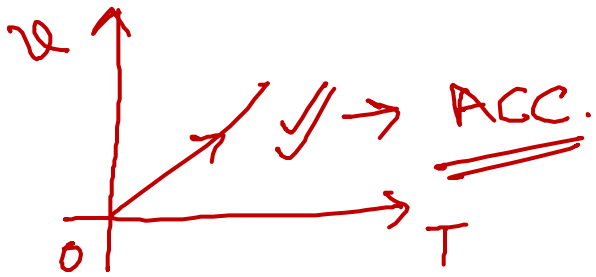


* Velocity - Time (वेग-समय):-

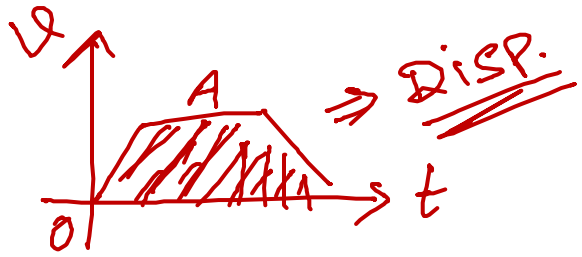
① Acceleration (त्वरण) ⇒ Slope (ढलान)

② Disp (विस्थापन) ↓

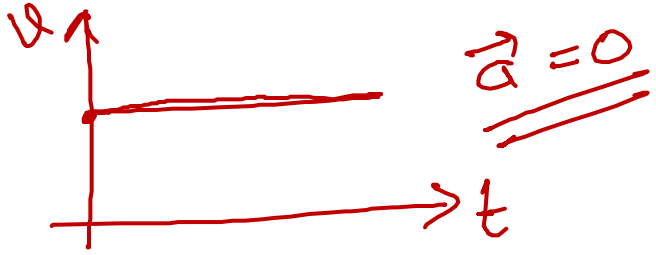
Area under curve

① 

// → Acc.

② 

⇒ Disp.

③ 

$\vec{a} = 0$

Kinematics Formula Summary

For 1-D motion with *constant* acceleration:

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

- $v_f = v_0 + at$
- $\bar{v} = (v_0 + v_f)/2$
- $\Delta x = v_0 t + \frac{1}{2} a t^2$
- $v_f^2 - v_0^2 = 2a\Delta x$

Projectile Motion (प्रक्षेप्य गति)

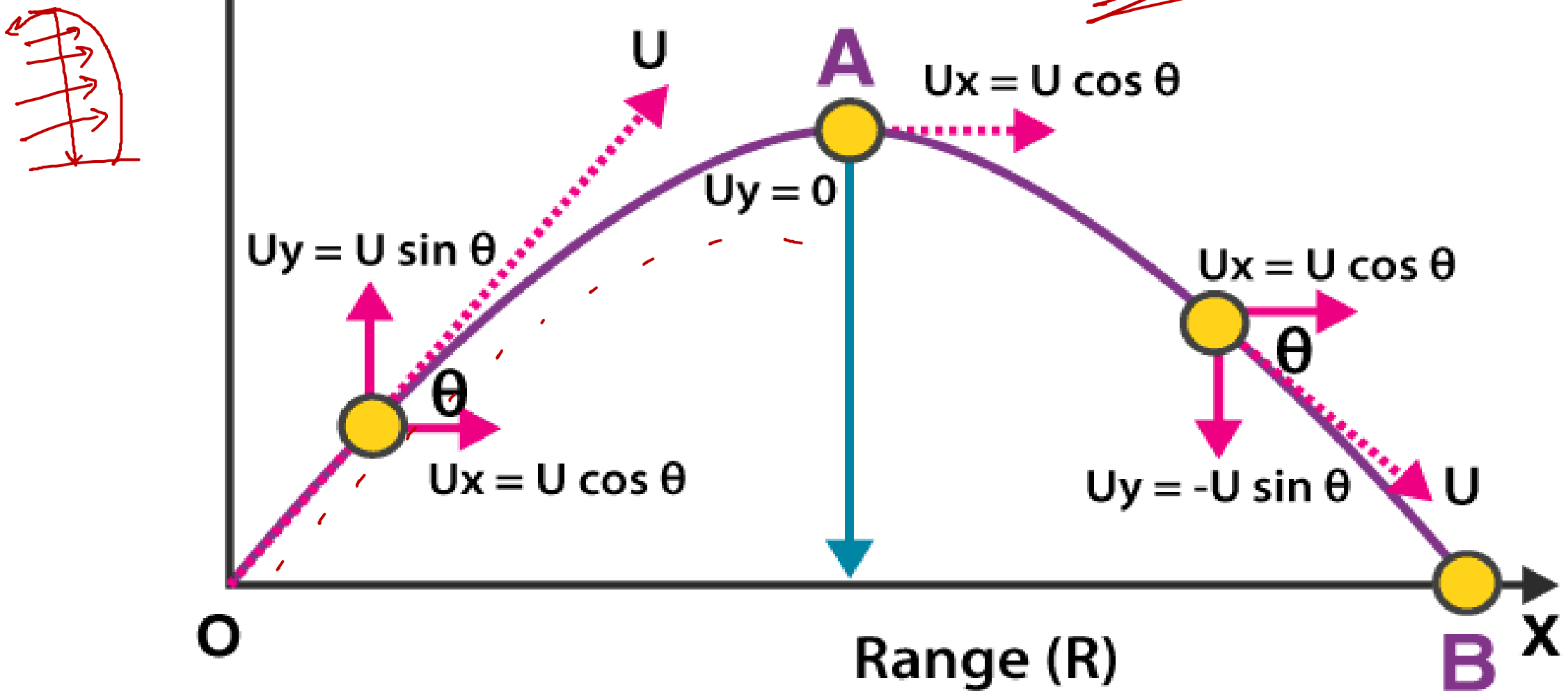
- **In a Projectile Motion, there are two simultaneous independent rectilinear motions:**

1. **Along the x-axis:** uniform velocity, responsible for the **horizontal** (forward) **motion** of the particle.

2. **Along y-axis:** uniform acceleration, responsible for the **vertical** (downwards) **motion** of the particle.

PROJECTILE MOTION

{ Path ⇒ Parabolic
परवलयाकार }



1. $v = u - gt$

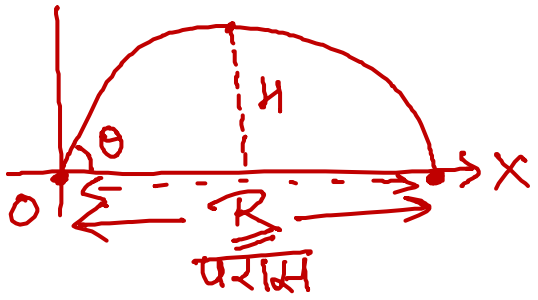
2. $s = ut - \frac{1}{2}gt^2$

3. $v^2 = u^2 - 2gs$

u = Initial velocity | g = Acceleration due to gravity

t = Time | s = Displacement | v = Final velocity

(1)



Time of Flight — उड्डयन काल , Hight — अं० , परास — R

$\Rightarrow$ Range (परास) :- $\Rightarrow \dfrac{u^2 \sin 2\theta}{g}$

$\sin 2\theta = \sin 90 = 1$

$2\theta = 90^\circ$

$\Rightarrow \theta = 45^\circ$

$$\boxed{R_{max} = \frac{u^2}{g}}$$

$\Rightarrow$ Hight अं. $\Rightarrow$ $\Rightarrow \dfrac{u^2 \sin^2\theta}{2g}$

$\theta = 90^\circ$

$$\boxed{H_{max} = \frac{u^2}{2g}}$$

$\Rightarrow T = \dfrac{2u\sin\theta}{g}$

$\theta = 90^\circ$

$T_{max} = \dfrac{2u}{g}$

0°

Cause of motion

$\Rightarrow 1N = 10^5$ Dyne

$\Rightarrow 1Dy = 10^{-5}N$

Newton's Laws of Motion

I. Law of Inertia

II. F=ma

III. Action-Reaction

Force (बल) :-

- The push or pull on an object with mass that causes it to change its velocity.
- द्रव्यमान के साथ किसी वस्तु पर धक्का या खिंचाव जिससे उसका वेग बदल जाता है।

Vector (सदिश)

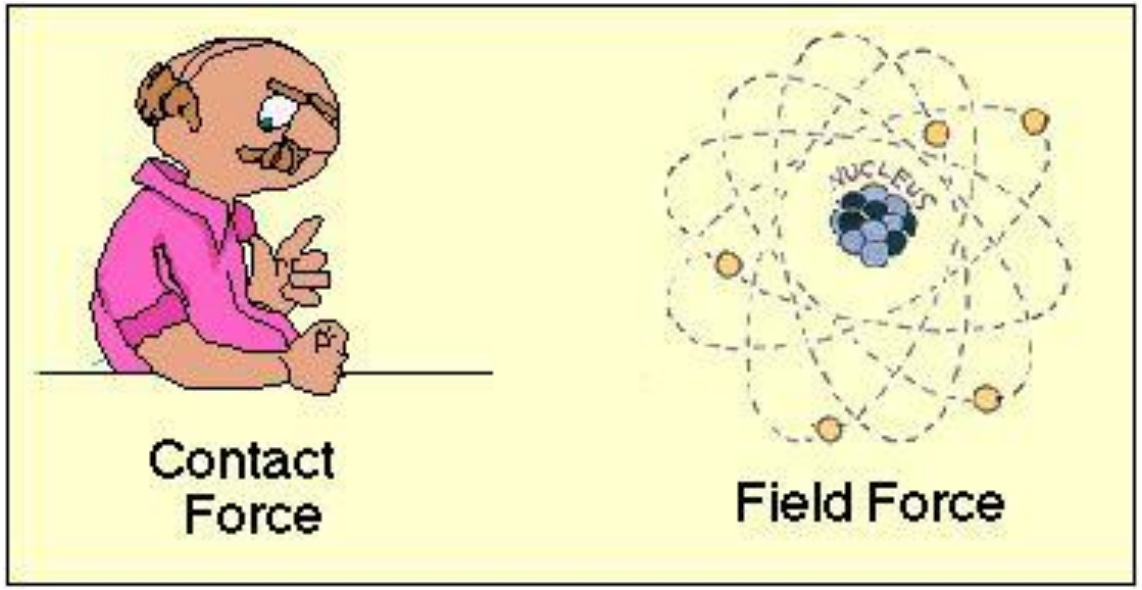
Common symbols:	$\vec{F}$, F $\quad \vec{F} = m\vec{a}$
SI unit:	Newton (SI)
In SI base units:	$kg \cdot m/s^2$
Other units: (CGS)	dyne, poundal, pound-force, kip, kilo pond
Derivations from other quantities:	F = m a
Dimension:	LMT^{-2} $\quad [MLT^{-2}]$

Four Forces Known in the Universe

- **Electromagnetic**- caused from electric and magnetic interactions
- **Strong Nuclear-** Responsible for holding nucleus together in the atom; strongest force; acts over the shortest distance
- **Gravitation**- weakest force; acts over the longest distance
- **Weak Nuclear-** Responsible for radioactivity in atoms

Types of Forces

- There are two main types of forces
  - Contact (संपर्क)
  - Field (असंपर्क)



Contact Forces

- Contact Force
  - Exists when an object from the external world touches a system and exerts a force on it

- Think About a Book on a Table

  - If you push it, you are exerting a contact force

  - If you put it down, no longer interacting… so no more force from you

  - But table is touching it- table is now exerting a force

Field Forces

- An object can move without something directly touching it

- What if you dropped the book?
  - It falls due to gravity

- Gravitational Force is a field force.
  - They affect movement without being in physical contact

- Can you think of other field forces?
  - Magnetic fields
  - Electric Forces
  - Nuclear Forces

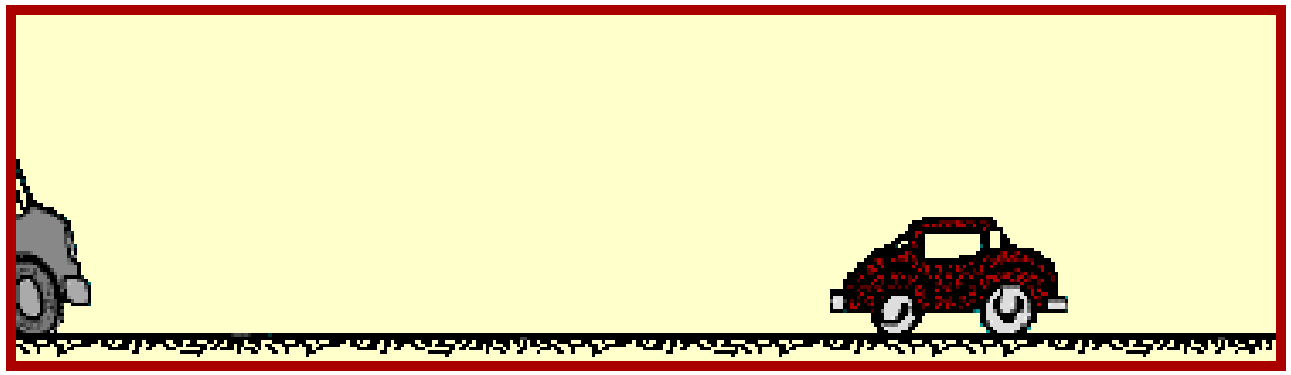
Two Types of Forces

- Example of Contact Forces
- Friction
- Tension

- Examples of Field Forces
- Gravitational
- Electric
- Magnetic
- Applied
- Spring

Force and mass

- Mass – measurement of how difficult it is to change the objects velocity
- Inertia – resistance to change in velocity
- So mass is a measurement of an object's inertia



Newton's Laws

① Rest

② motion

③ Direction

NEWTON'S LAWS OF MOTION

(जड़त्व का नियम)

- **Newton's first law (law of inertia) :** Newton's 1st law states that a body at rest or uniform motion will continue to be at rest or uniform motion until and unless a net external force acts on it.

वस्तु अपनी विरामावास्था या एक सीध में एकरूप गत्यावस्था में तब तक रहती है, जब तक बाह्य बल (external force) द्वारा उसकी विरामावस्था या गत्याव्स्था में कोई परिवर्तन न लाया जाए. वस्तु के विराम की अवस्था (Inertia) का बोध होता है. अतः इस नियम को विराम का नियम भी कहते हैं.

1st Law

- *Inertia is the tendency of an object to resist changes in its velocity: whether in motion or motionless.*

These pumpkins will not move unless acted on by an unbalanced force.

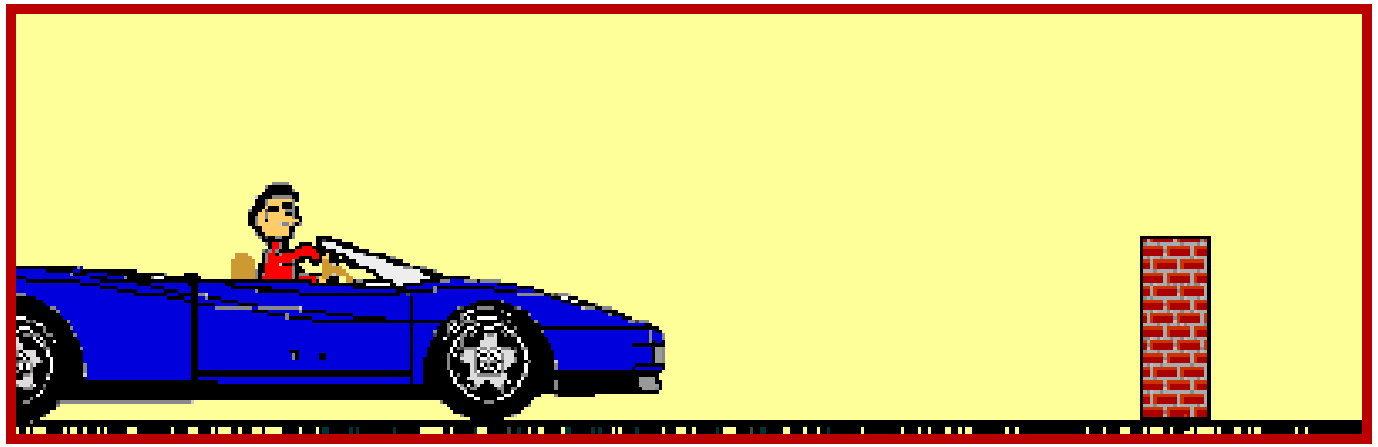
1st Law

- Once airborne, unless acted on by an unbalanced force (gravity and air – fluid friction), it would never stop!

1st Law

- Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.

Newtons's 1st Law and You



Don't let this be you. Wear seat belts.

Because of inertia, objects (including you) resist changes in their motion. When the car going 80 km/hour is stopped by the brick wall, your body keeps moving at 80 m/hour.

Newton's Second Law

Force equals mass times acceleration.

$$F = ma$$

Acceleration: a measurement of how quickly an object is changing speed.

MOMENTUM (संवेग):

$\vec{p} = m\vec{v}$

संवेग = द्रव्यमान × वेग

$\vec{p} \rightarrow$ kg-m/s $\Rightarrow [MLT^{-1}]$

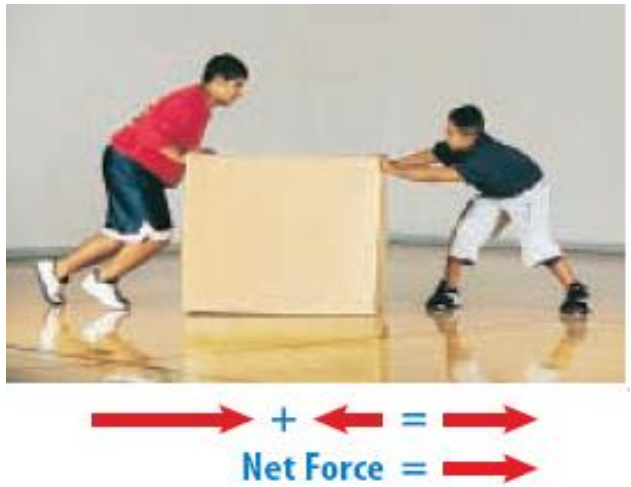
Acceleration

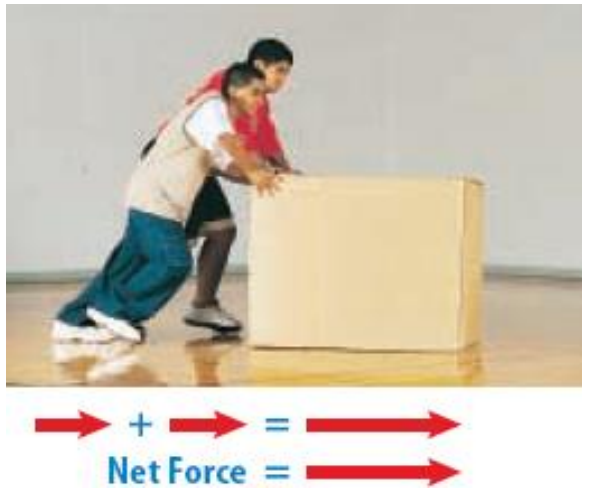
- An ***unbalanced force*** causes something to accelerate.
- A force can cause motion only if it is met with an ***unbalanced force***.
- Forces can be balanced or unbalanced.
- Depends on the **net force** acting on the object
- **Net force (F_{net}):** The sum total and direction of all forces acting on the object.
    - **Net forces: Always cause acceleration.**

Balanced Versus Unbalanced

Balanced forces cause no acceleration.

Balanced Versus Unbalanced





Unbalanced forces cause acceleration.

What does F = ma say?

F = ma basically means that the force of an object comes from its mass and its acceleration.

Force is measured in

Newtons (N) = mass (kg) x acceleration (m/s^2)

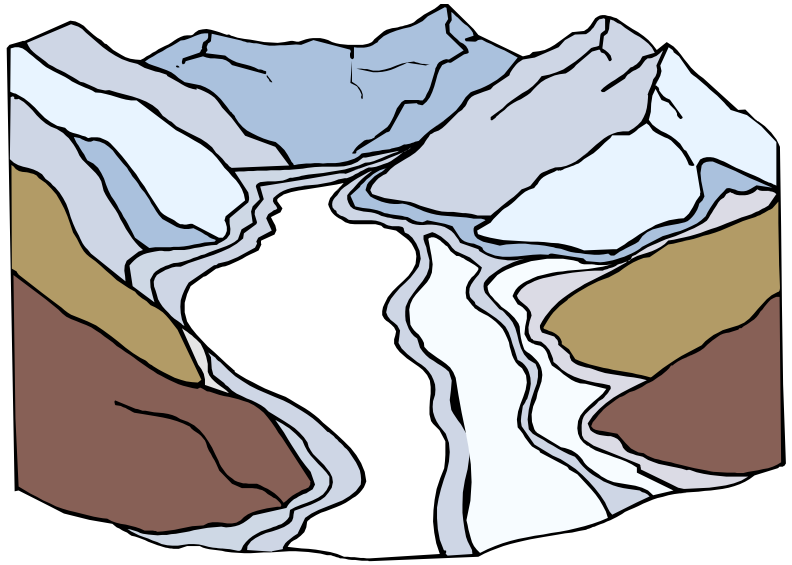
Or

kg m/s^2

$$1\ \text{Newton} = 1\ \text{kg} * \frac{\text{m}}{\text{s}^2}$$

High Mass

Something very massive (high mass) that's changing speed very slowly (low acceleration), like a glacier, can still have great force.



Low Mass

Something very small (low mass) that's changing speed very quickly (high acceleration), like a bullet, can still have a great force. Something very small changing speed very slowly will have a very weak force.

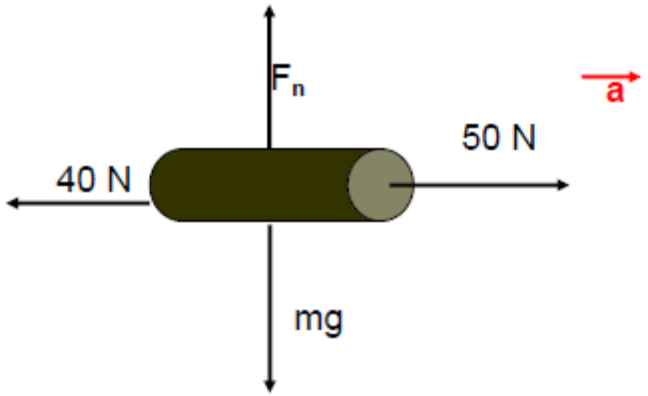
In Summary

- The acceleration of an object is directly proportional to the net force & inversely proportional to its mass.

- F = ma
- Force = Mass x Acceleration

Example

- A 50 N applied force drags an 8.16 kg log to the right across a horizontal surface. What is the acceleration of the log if the force of friction is 40.0 N?



$$F_{NET} = ma$$

$$F_a - F_f = ma$$

$$50 - 40 = 8.16a$$

$$10 = 8.16a$$

$$a = \text{1.23 m/s/s}$$

• Newton's 2nd law of motion :

Newton's 2nd law states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force.

वस्तु के संवेग (Momentum) में परिवर्तन की दर उस पर लगाये गये बल के अनुक्रमानुपाती (Directly proportional) होती है |

$\vec{F} \propto \frac{d\vec{p}}{dt}$

$\vec{F} \propto \frac{d}{dt}(m\vec{v})$

$\vec{F} \propto m\frac{d\vec{v}}{dt}$ ✓

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

$\vec{F} = Kma$

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

① $\vec{F} = m\vec{a}$ ✗

② $\vec{F} \propto m\vec{a}$ ✗

③ $\vec{F} = \frac{d\vec{p}}{dt}$ ✗

④ $\vec{F} \propto \frac{d\vec{p}}{dt}$ ✓✓

2nd Law

2nd Law (F = m x a)

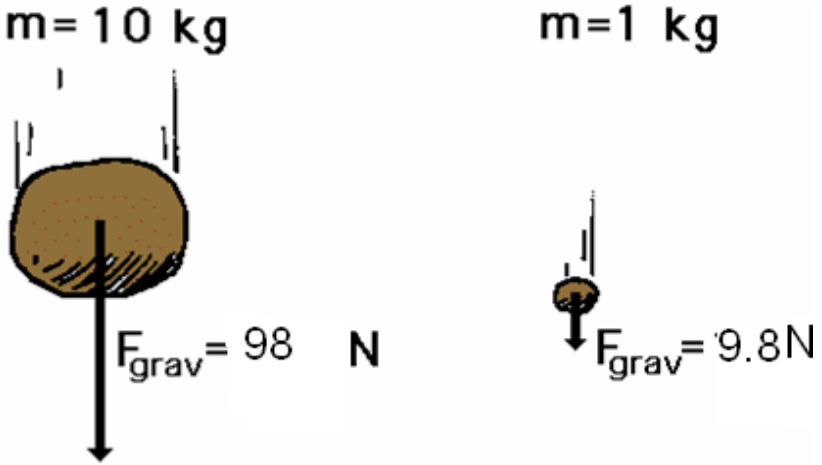
- How much force is needed to accelerate a 1400 kilogram car 2 meters per second/per second?
- Write the formula
- F = m x a
- Fill in given numbers and units
- F = 1400 kg x 2 meters per second/second
- Solve for the unknown
- 2800 kg-meters/second/second or **2800 N**

Net Force N	Mass Kilograms	Acceleration m/s/s
10	2	5 m/s/s
20	2	10 m/s/s
20		5 m/s/s
10	5	m/s/s
	1	10 m/s/s

If mass remains constant, doubling the acceleration, doubles the force. If force remains constant, doubling the mass, halves the acceleration.

Newton's 2nd Law proves that different masses accelerate to the earth at the same rate, but with different forces.

- We know that objects with different masses accelerate to the ground at the same rate.
- However, because of the 2nd Law we know that they don't hit the ground with the same force.



$a = \frac{F}{m}$ $\frac{98}{9.8}$

$a = \frac{98\ N}{10\ kg}$

$a = 9.8\ m/s^2$

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

$a = \frac{9.8\ N}{1\ kg}$

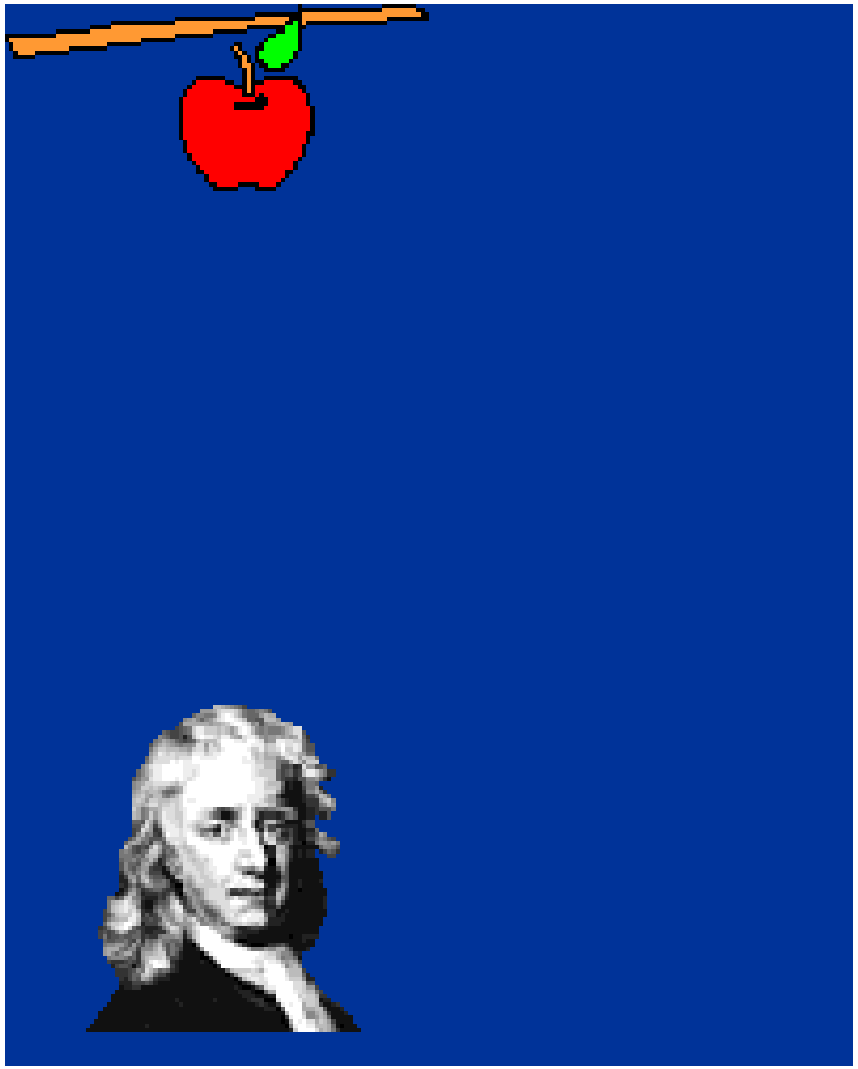
$a = 9.8\ m/s^2$

F = ma

98 N = 10 kg x 9.8 m/s/s

F = ma

9.8 N = 1 kg x 9.8 m/s/s



Check Your Understanding

- 1. What acceleration will result when a 12 N net force applied to a 3 kg object? A 6 kg object?
- 2. A net force of 16 N causes a mass to accelerate at a rate of 5 m/s^2. Determine the mass.
- 3. How much force is needed to accelerate a 66 kg skier 1 m/sec/sec?
- 4. What is the force on a 1000 kg elevator that is falling freely at 9.8 m/sec/sec?

Check Your Understanding

- 1. What acceleration will result when a 12 N net force applied to a 3 kg object?

  12 N = 3 kg x 4 m/s/s

- 2. A net force of 16 N causes a mass to accelerate at a rate of 5 m/s^2. Determine the mass.

  16 N = 3.2 kg x 5 m/s/s

- 3. How much force is needed to accelerate a 66 kg skier 1 m/sec/sec?

  66 kg-m/sec/sec or 66 N

- 4. What is the force on a 1000 kg elevator that is falling freely at 9.8 m/sec/sec?

  - **9800 kg-m/sec/sec or 9800 N**

Newton's Third Law

For every action there is an equal and opposite reaction.

• Newton's Third Law of Motion :

The Newton's 3rd law states that for every action there is an equal and opposite reaction.

प्रत्येक क्रिया (Action) की उसके बराबर तथा उसके विरुद्ध दिशा में प्रतिक्रिया (Reaction) होती है. इस

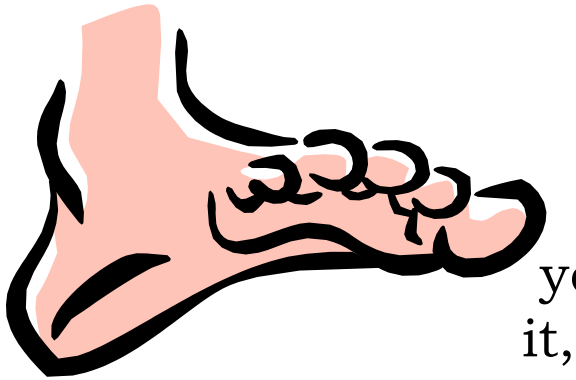
नियम को क्रिया-प्रतिक्रिया (Law of action and reaction) का नियम कहा जाता है.

What does this mean?

For every force acting on an object, there is an equal force acting in the opposite direction. Right now, gravity is pulling you *down* in your seat, but Newton's Third Law says your seat is pushing *up* against you with *equal force*. This is why you are not moving. There is a *balanced force* acting on you– gravity pulling down, your seat pushing up.

Think about it . . .

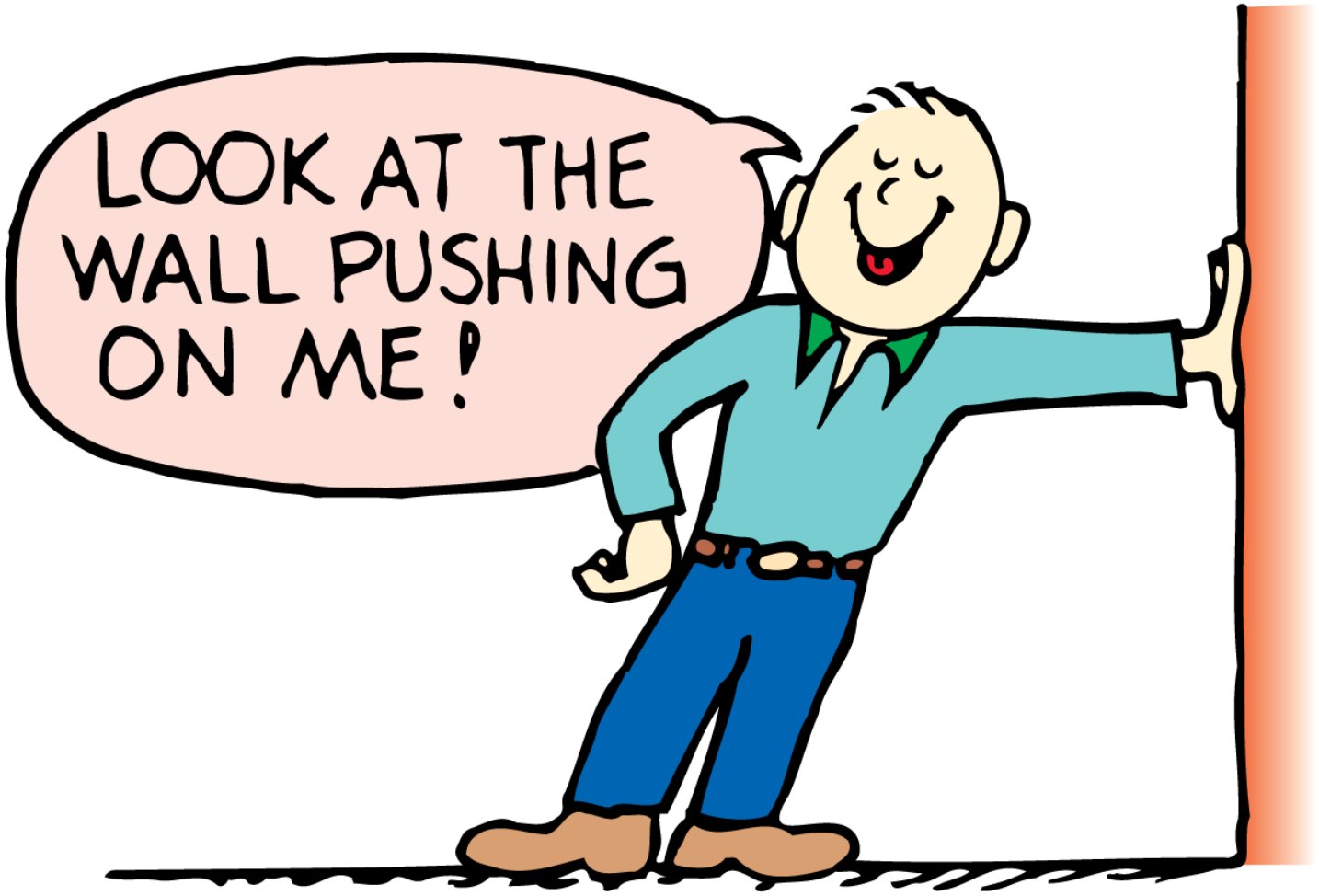
What happens if you are standing on a skateboard or a slippery floor and push against a wall? You slide in the opposite direction (away from the wall), because you pushed on the wall but the wall pushed back on you with equal and opposite force.



Why does it hurt so much when you stub your toe? When your toe exerts a force on a rock, the rock exerts an equal force back on your toe. The harder you hit your toe against it, the more force the rock exerts back on your toe (and the more your toe hurts).

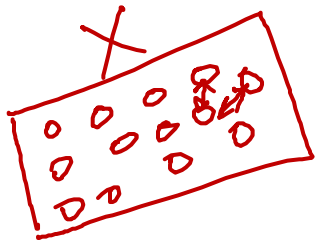
Forces and Interactions

When you push on the wall, the wall pushes on you.



Newton’s Third Law

When the girl jumps to shore, the boat moves backward.

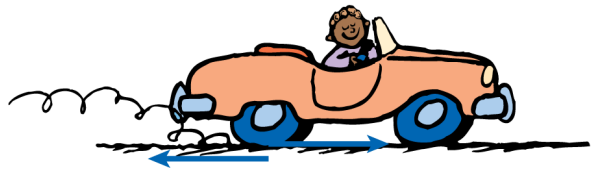


3rd Law

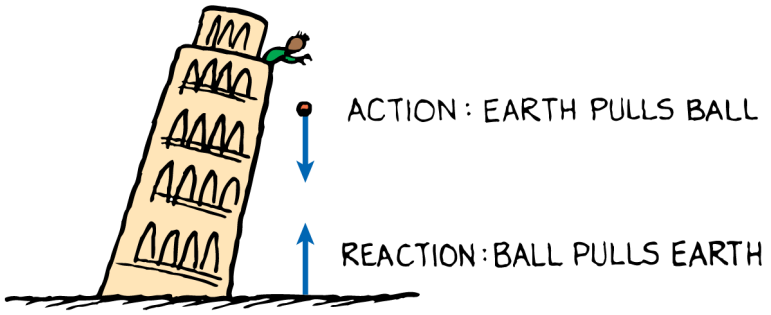
Flying gracefully through the air, birds depend on Newton's third law of motion. As the birds push down on the air with their wings, the air pushes their wings up and gives them lift.

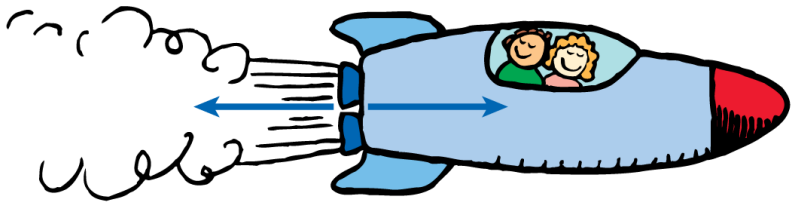
Identifying Action and Reaction Pairs

When action is *A exerts force on B*, the reaction is simply *B exerts force on A.*



ACTION : TIRE PUSHES ROAD REACTION : ROAD PUSHES TIRE

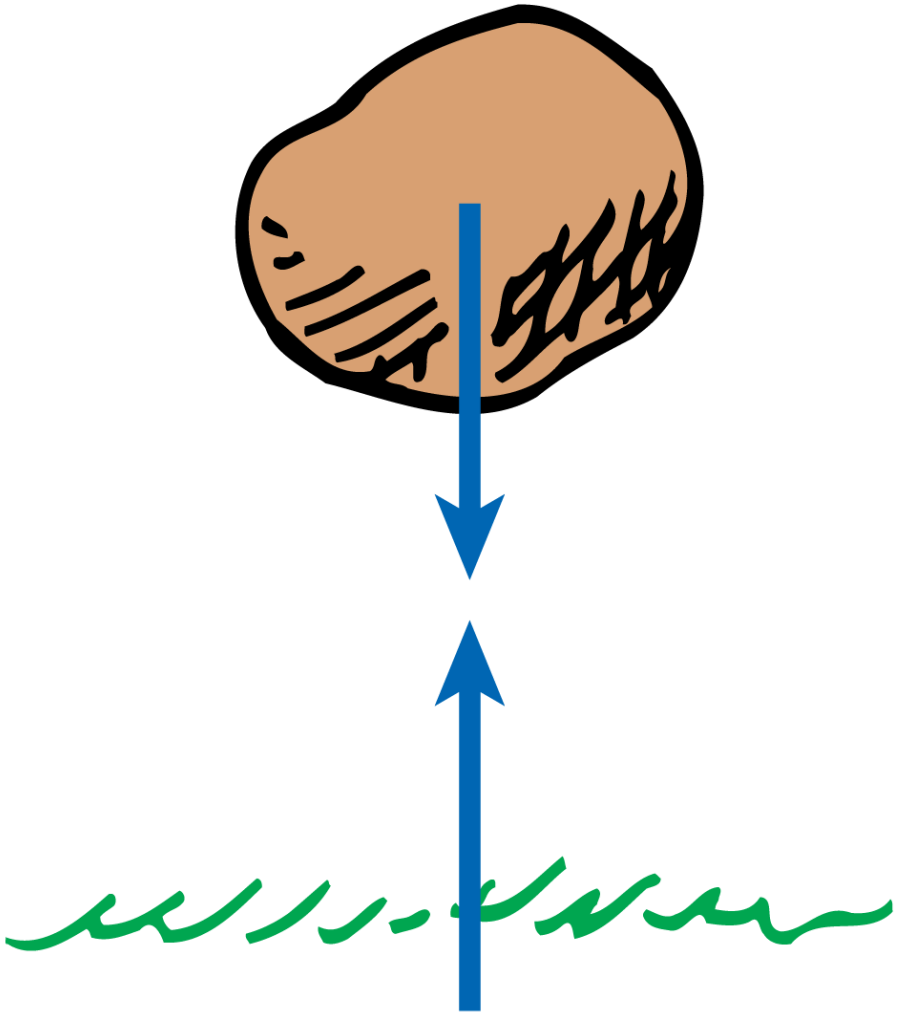




ACTION : ROCKET PUSHES GAS REACTION : GAS PUSHES ROCKET

Action and Reaction on Different Masses

Earth is pulled up by the boulder with just as much force as the boulder is pulled down by Earth.



Question

1. A force interaction requires at least a(n)
    a. single force.
    b. pair of forces.
    c. action force.
    d. reaction force.

Question

3. The force that directly propels a motor scooter along a highway is that provided by the
   a. engine.
   b. fuel.
   c. tires.
   d. road.

Question

- We know that Earth pulls on the moon. Does the moon also pull on Earth? If so, which pull is stronger?
- Asking which pull is stronger is like asking which distance is greater—between New York and San Francisco, or between San Francisco and New York. The distances either way are the same. It is the same with force pairs. Both Earth and moon pull on each other with equal and opposite forces.

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