CHAPTER 1

GRAVITATION

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MATH-SCIENCE DEARS

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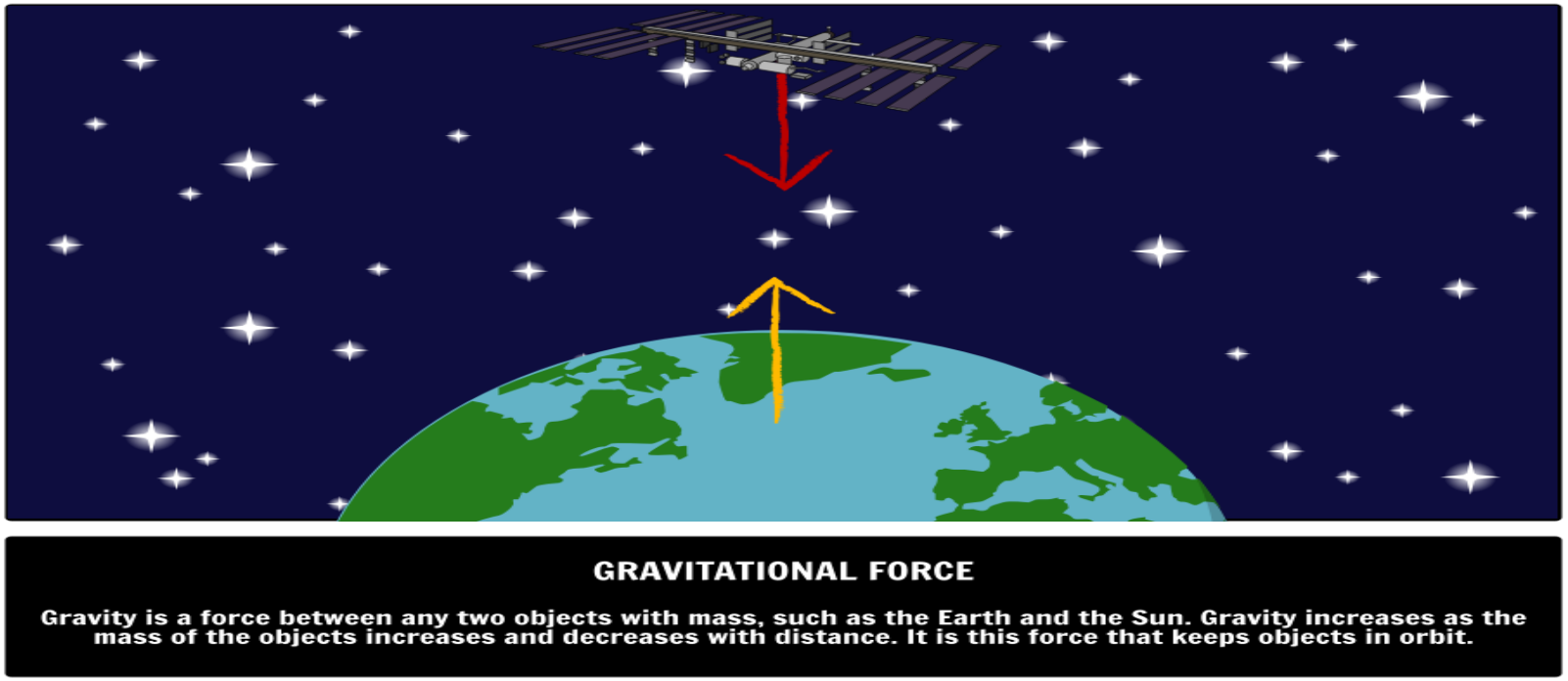
What Is Gravitation



Gravitation is the force of attraction between any two bodies.

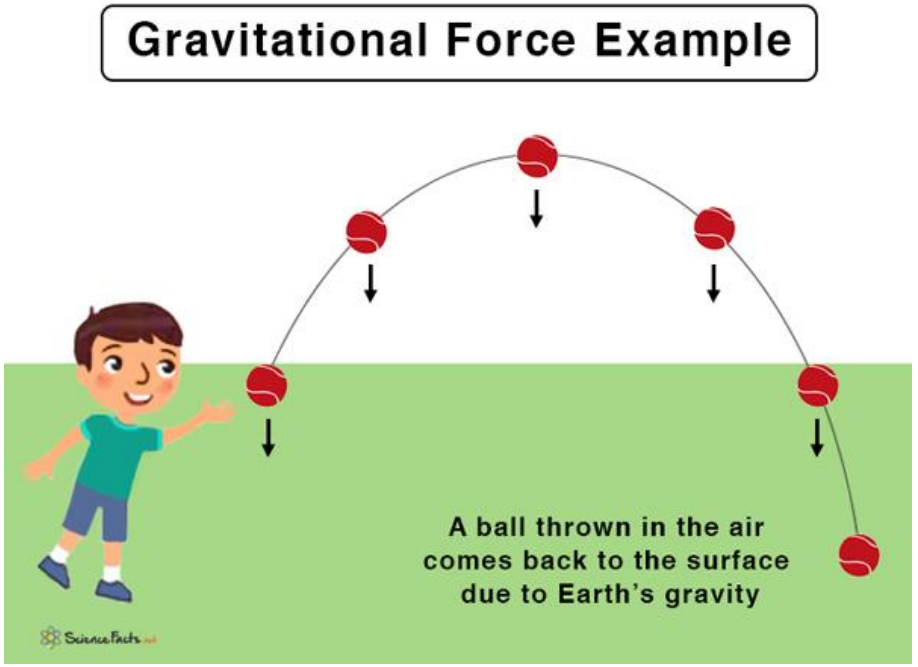
All the objects in the universe attract each other with a certain amount of force, but in most cases, the force is too weak to be observed due to the very large distance of separation.

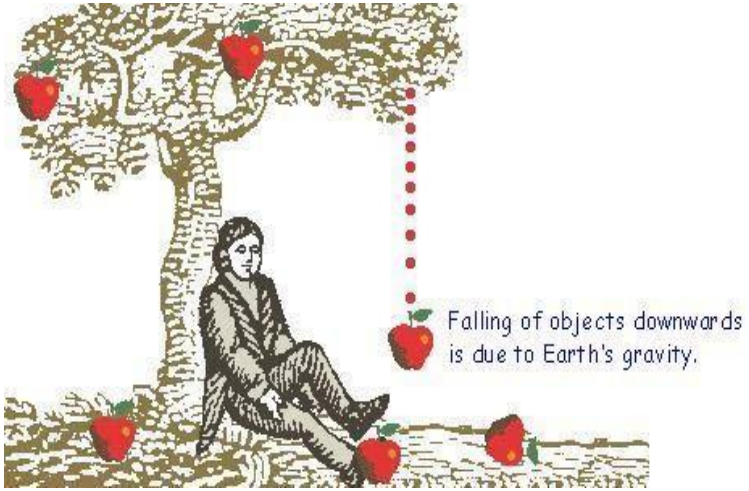
Some examples of gravity are:

The force that causes the ball to come down is known as gravity

Gravity keeps the planets in orbit around the sun.

Gravity is the force that causes a rock to roll downhill.




Falling of objects downwards
is due to Earth's gravity.

Newton's Observations

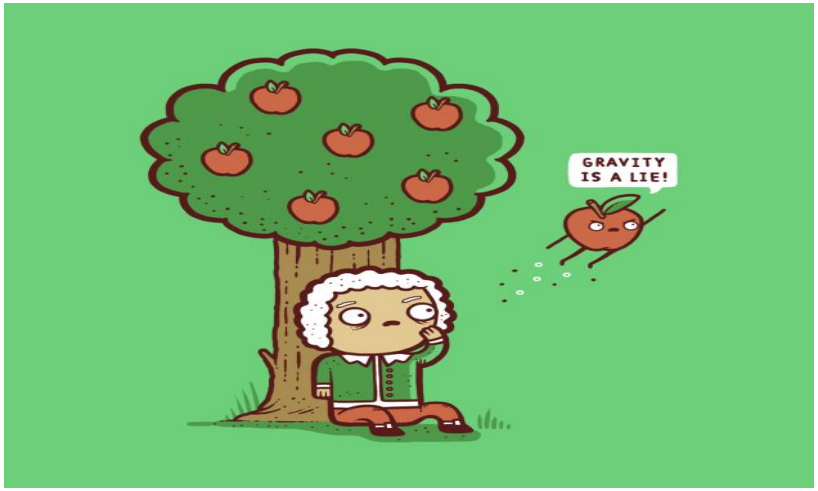


Fig. Gravitational Force of Earth

Why does Apple fall on Earth from a tree?

– Because the earth attracts it towards itself.

Can Apple attract the earth? -

Yes.

It also attracts the earth as per Newton's third law

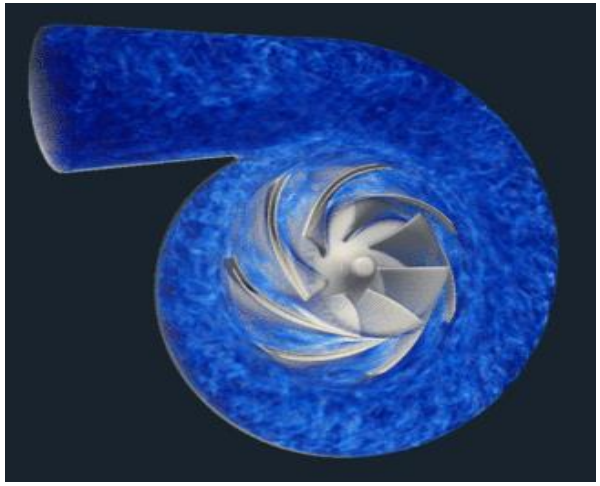
(every action has an equal and opposite reaction).

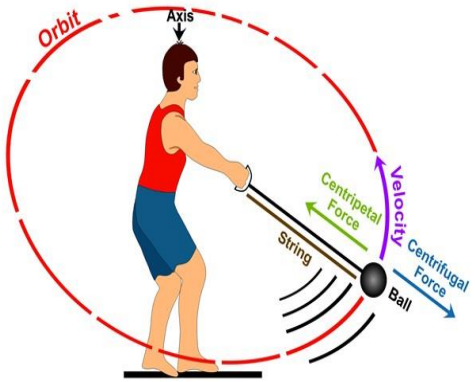
But the mass of the earth is much larger than Apple's mass thus the force applied by Apple appears negligible and Earth never moves towards it.

Newton thus suggested that all objects in this universe attract each other.

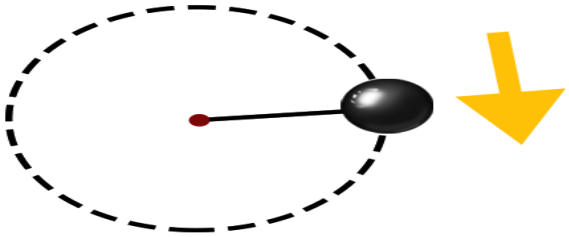
This force of attraction is called Gravitational Force.

What is the Centripetal Force?





The force that causes an object to move in a circle



centripetal force

- **A force acts on any object moving along a circle and it is directed towards the centre of the circle. This is called the Centripetal force.**

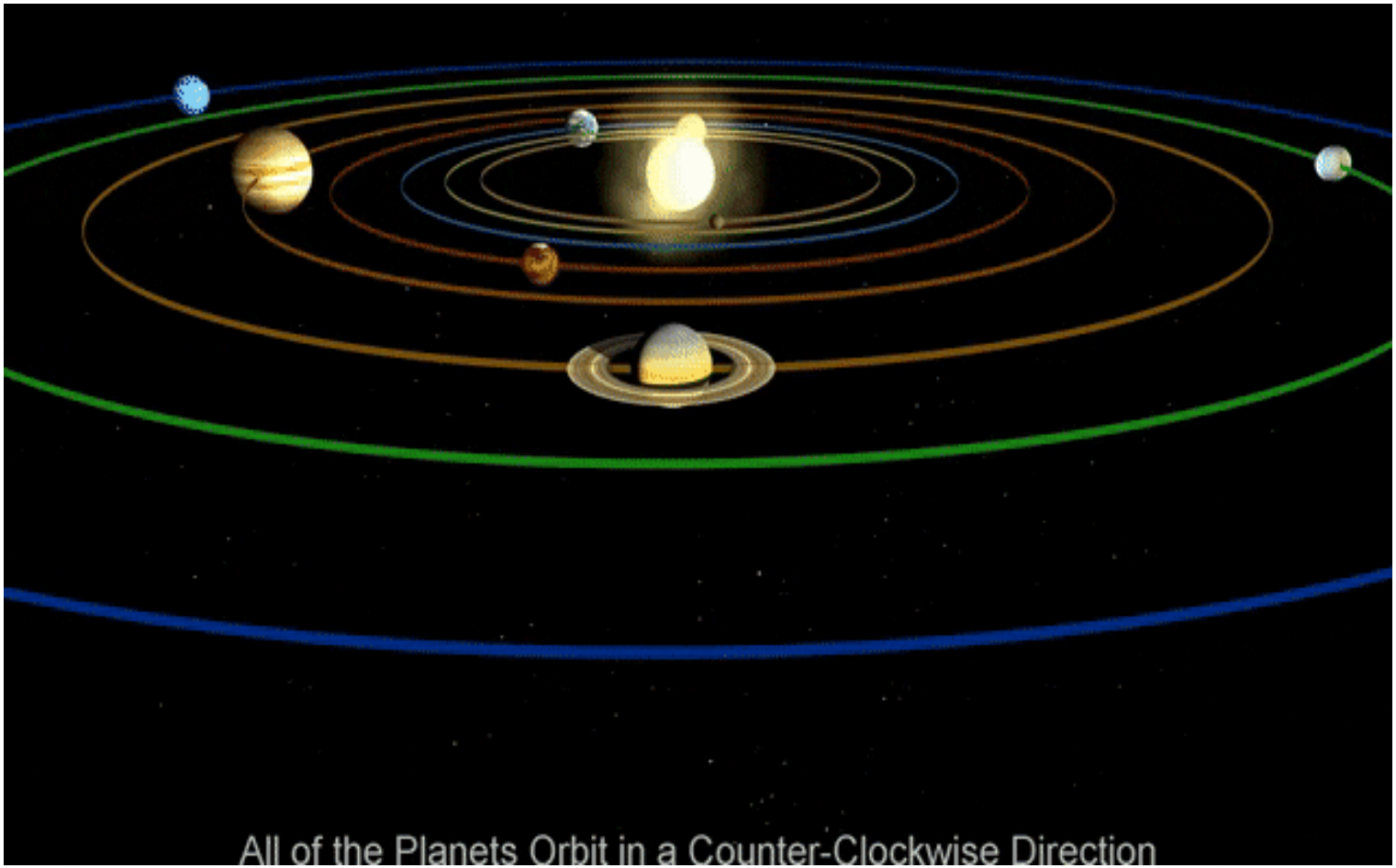
- **We know that an object in circular motion keeps on changing its direction.**

- **Due to this, the velocity of the object also changes.**

- **The centripetal force is exerted from the centre of the path.**

- **Without the Centripetal Force objects cannot move in circular paths, they would always travel straight.**

Johanes Kepler (1571-1630) was a German astronomer and Mathematician.
Kepler used the observations of Planetary positions made by Brahe to discover the laws of planetary motion.



Kepler's Three Law:

- **Kepler's Law of Orbits** –

The Planets move around the sun in elliptical orbits with the sun at one of the focii.

- **Kepler's Law of Areas** –

The line joining a planet to the Sun sweeps out equal areas in equal interval of time.

- **Kepler's Law of Periods** –

The square of its period of revolution around the sun is directly proportional to the cube of the mean distance of a planet from the sun.

Kepler's 1st Law of Orbits:

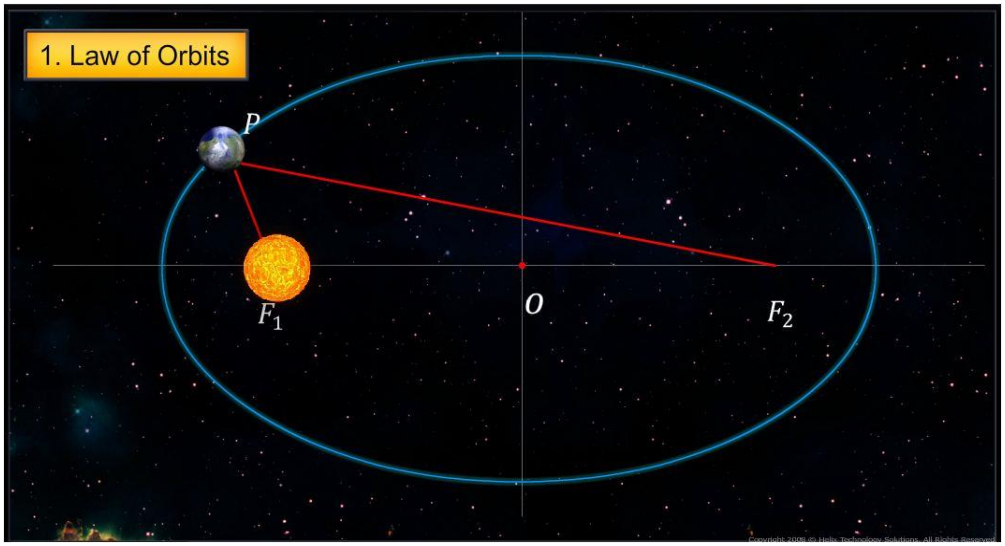
This law is popularly known as the law of orbits.

According to Kepler's first law,

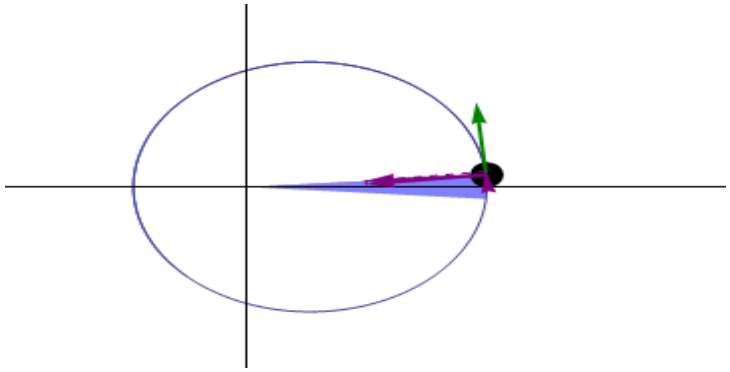
The orbit of a planet is an ELLIPSE with the SUN at one of the FOCI. The position of the SUN is indicated by S.

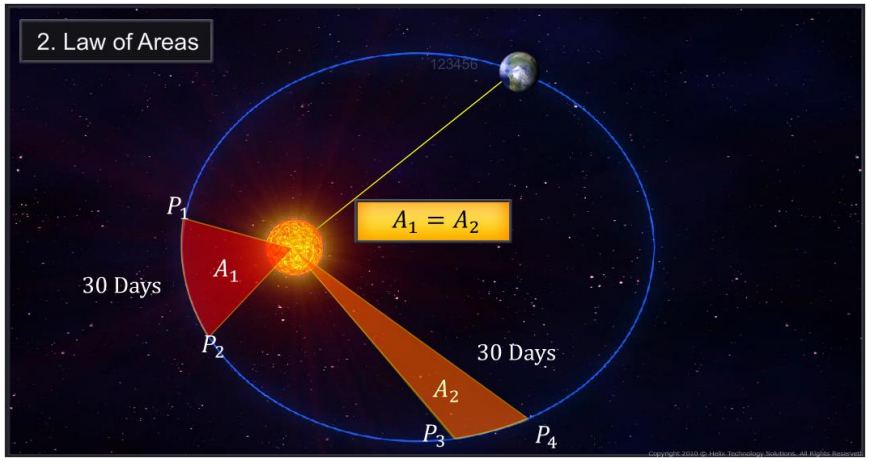
In an ellipse, we have two focus f_1 & f_2.

Sun is located at one of the foci of the ellipse.



Kepler's 2nd Law of Areas:





This law is known as the law of areas.

The line joining a planet to the Sun sweeps equal areas in equal interval of time.

In above figure, **the Sun is located at the focus and the planets revolve around the Sun.**

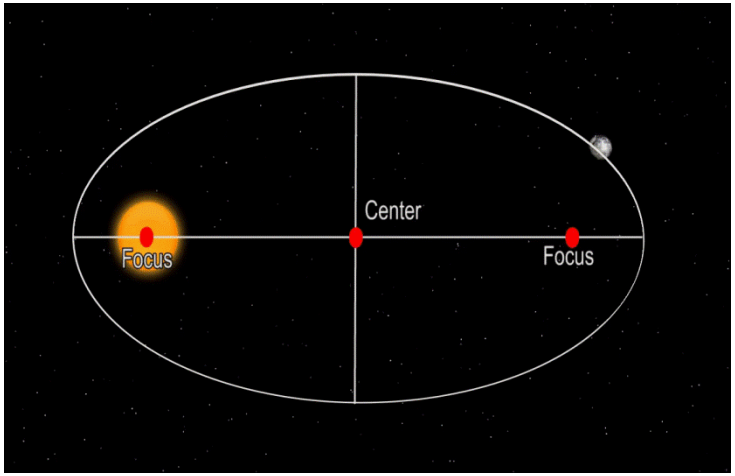
Assume that the planet starts revolving from point p1 and travels to p2 in a clockwise direction. So it revolves from point p1 to p2, as it moves the area swept from Is P1SP2.

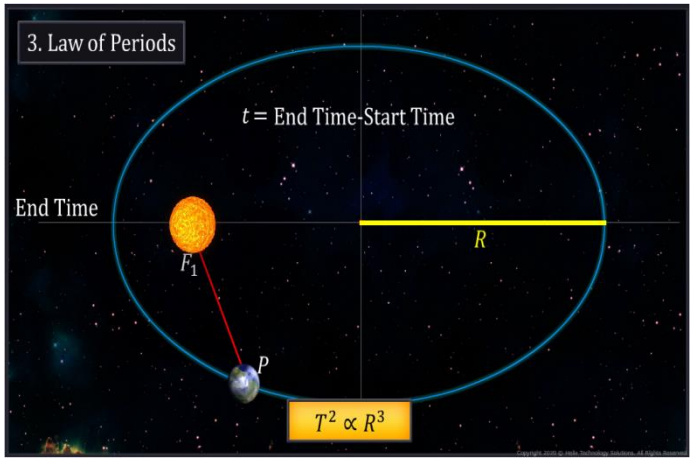
area P1SP2 = area P3SP4

As the area traveled by the planet from P1 to P2 and P3 to P4 is equal, therefore this law is known as the Law of Area. **When a planet is nearer to the Sun it moves fastest as compared to the planet far away from the Sun.**

Kepler's 3rd Law of Periods :

This law is known as the **law of Periods.**





The square of the time period of revolution around the sun is directly proportional to the cube of the mean distance of a planet from the sun.

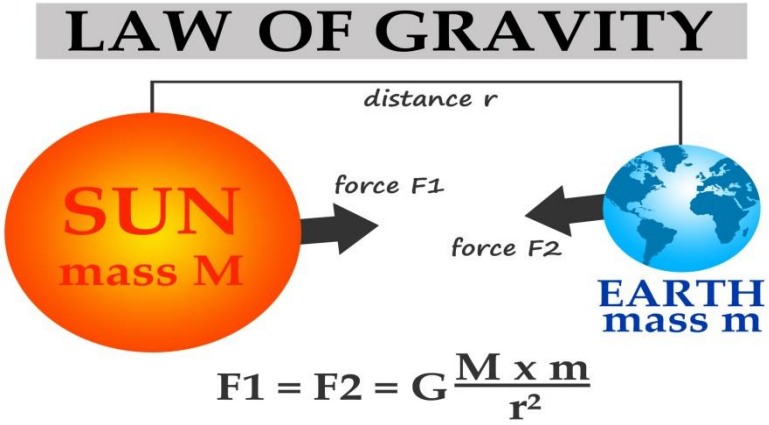
$T^2 \propto r^3$ $T^2 = K r^3$ $T^2 = K r^3$

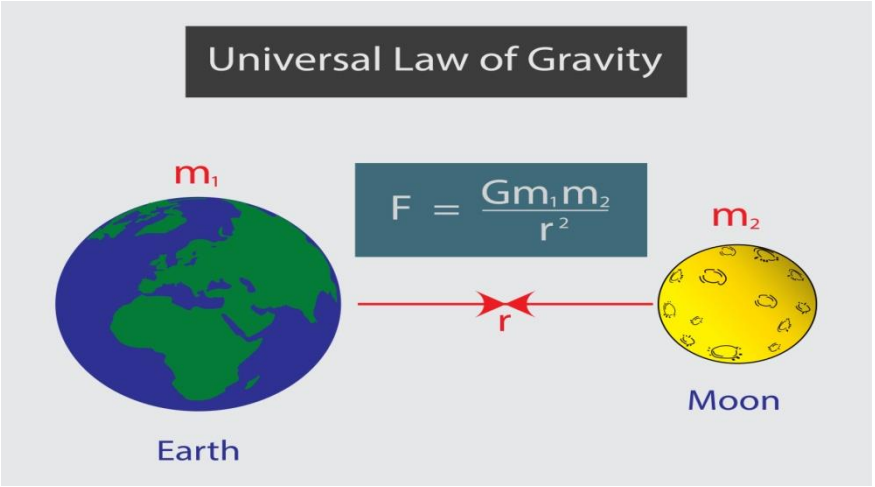
T = Time r = average

Universal Law of Gravitation by Newton

- According to the universal law of gravitation, every object attracts every other object with a force.
- This force is directly proportional to the product of their masses.
- This force is inversely proportional to the square of distances between them.

In figure, the force of attraction between two objects with masses m_1 and m_2 respectively that are 'd' distance apart.



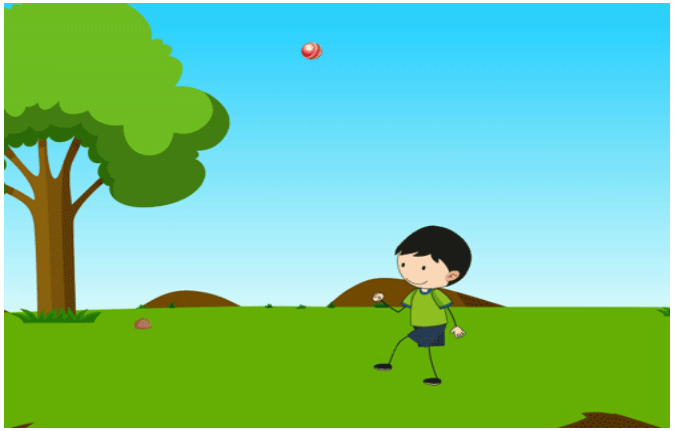


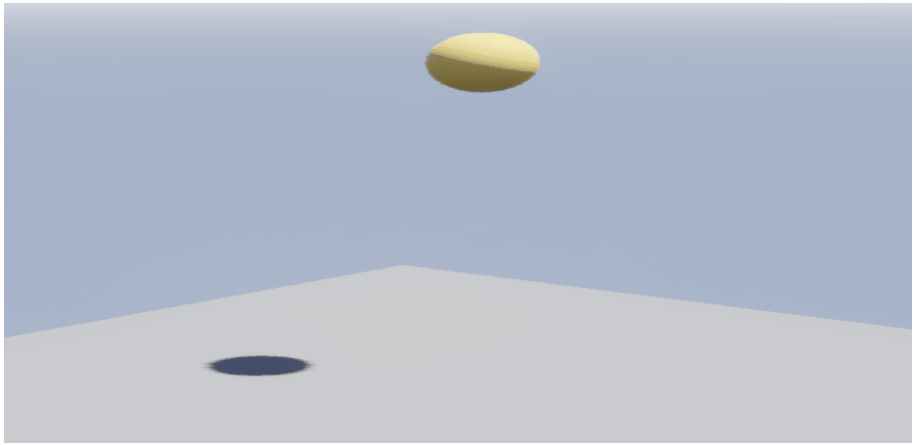
Value of G = 6.673×10^{-11} $Nm^2 kg^{-2}$

The proportionality constant G is also known as the **Universal Gravitational Constant**..

EARTHS GRAVITATIONAL ACCELERATION (g)

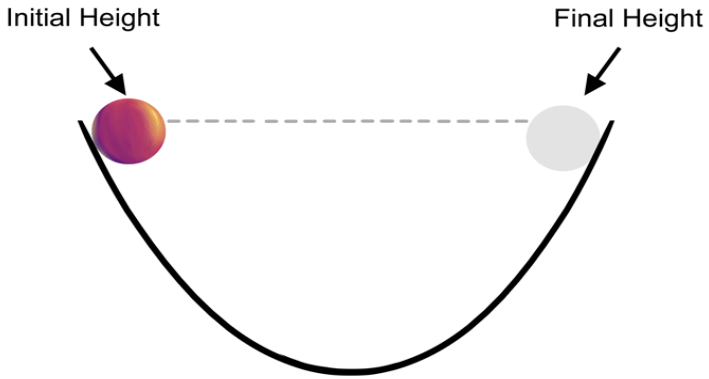
The earth exerts gravitational force on object near it.

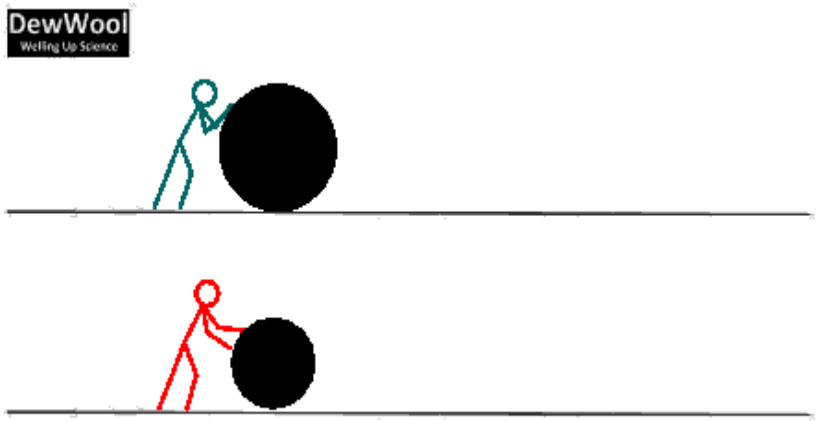


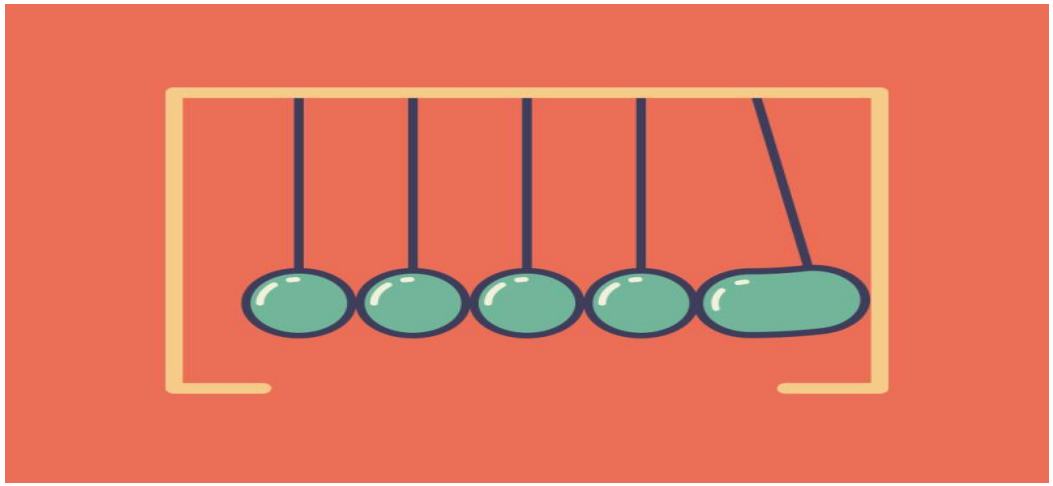


F = m a Newtons Second Law

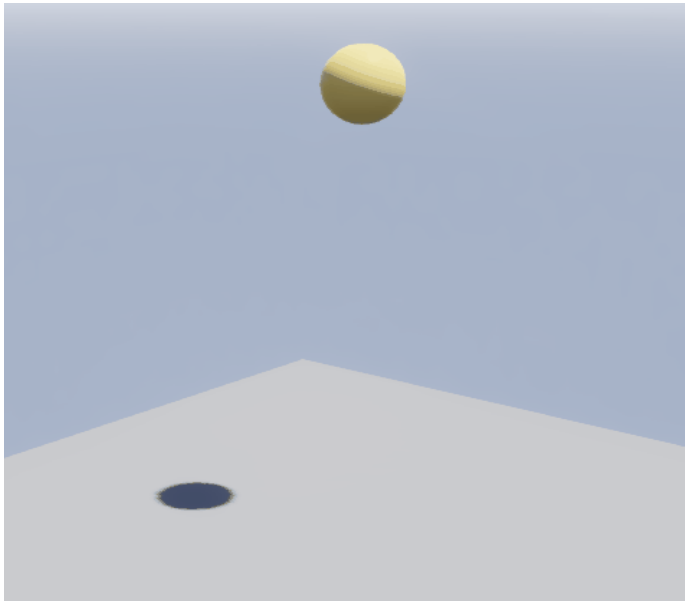
A force acting on a body results in its acceleration.

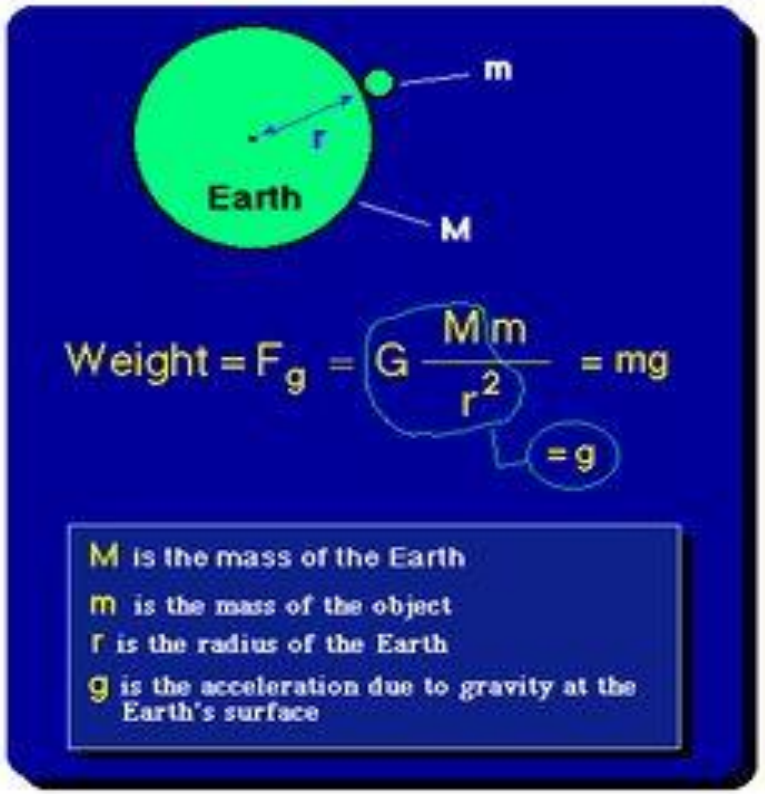






The gravitational force due to the Earth on a body results in its acceleration





Formula

$$g = \frac{GM}{r^2}$$

We know that

$F = G\frac{m_1 m_2}{r^2}$ Newtons law of Gravitation

$$F = G\frac{M\ m}{r^2} \quad \text{------(1)}$$

Also

F = m a

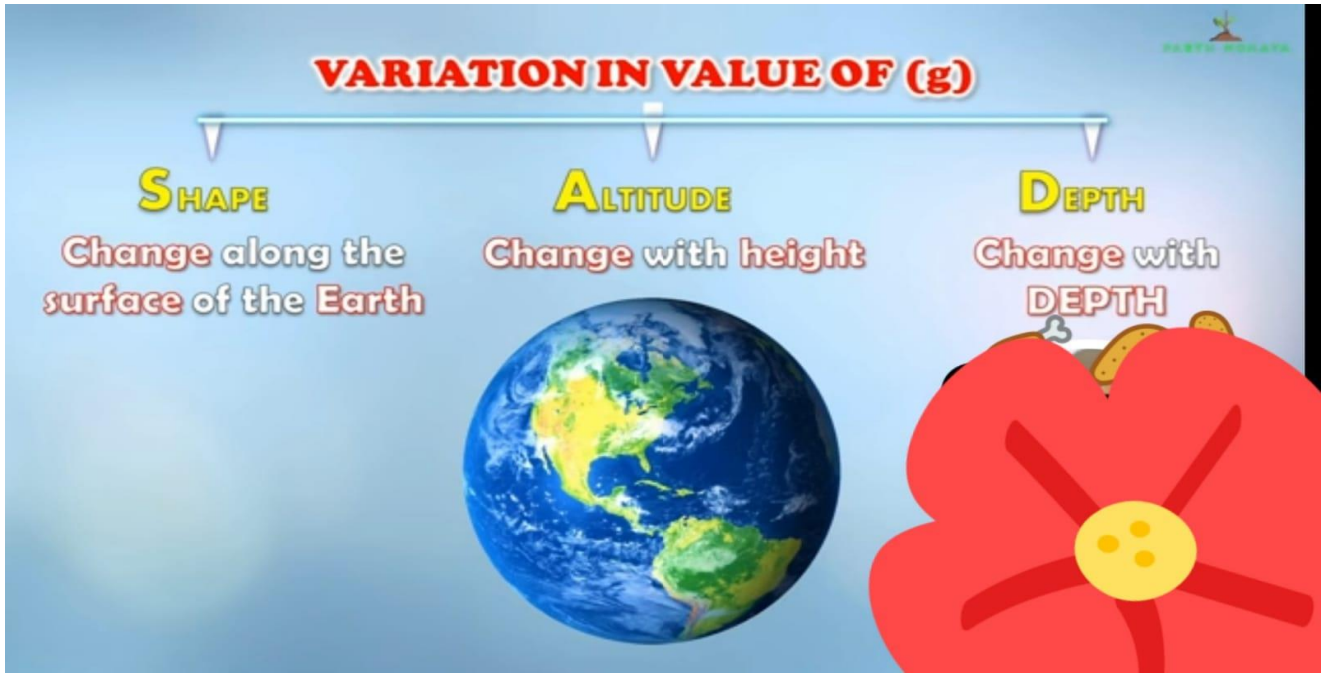
$F = m\ g$ --------- (ii)

Equating (i) & (ii)

$m\ g = G\frac{M\ m}{r^2}$

$$g = \frac{G\ M}{r^2}$$

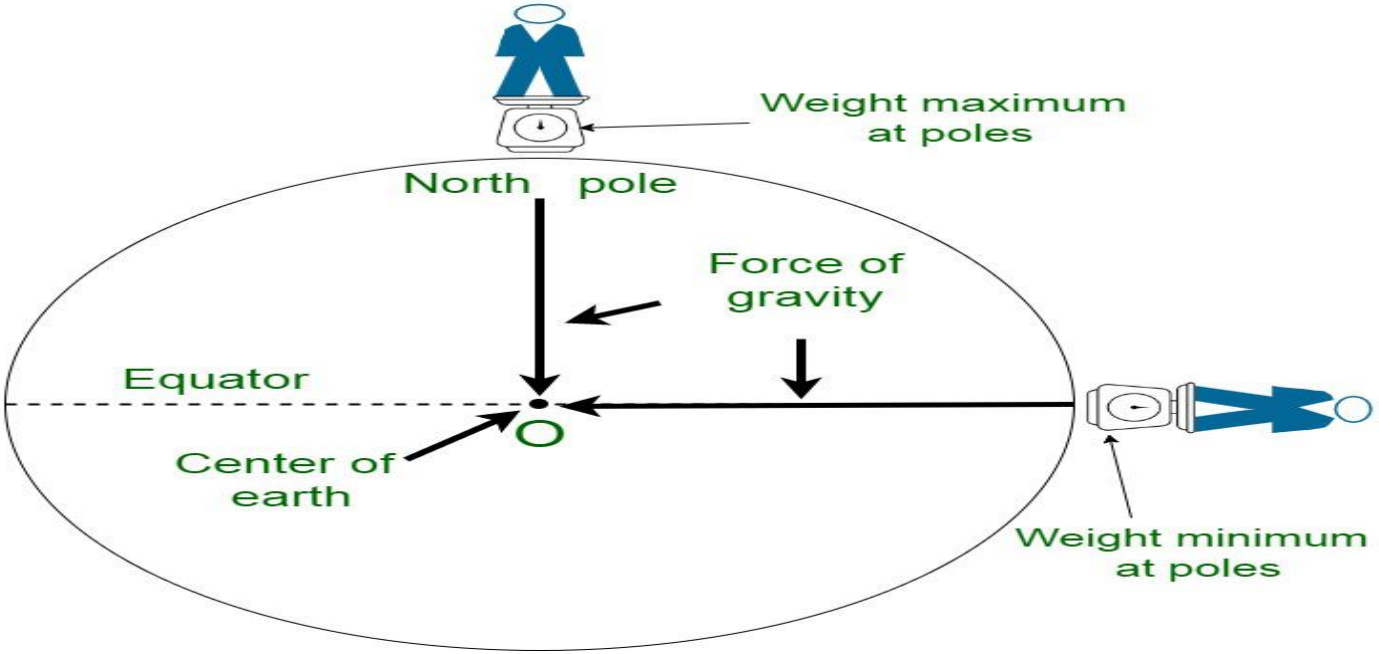
VARIATION IN VALUE OF g



a) Change along the surface of the earth

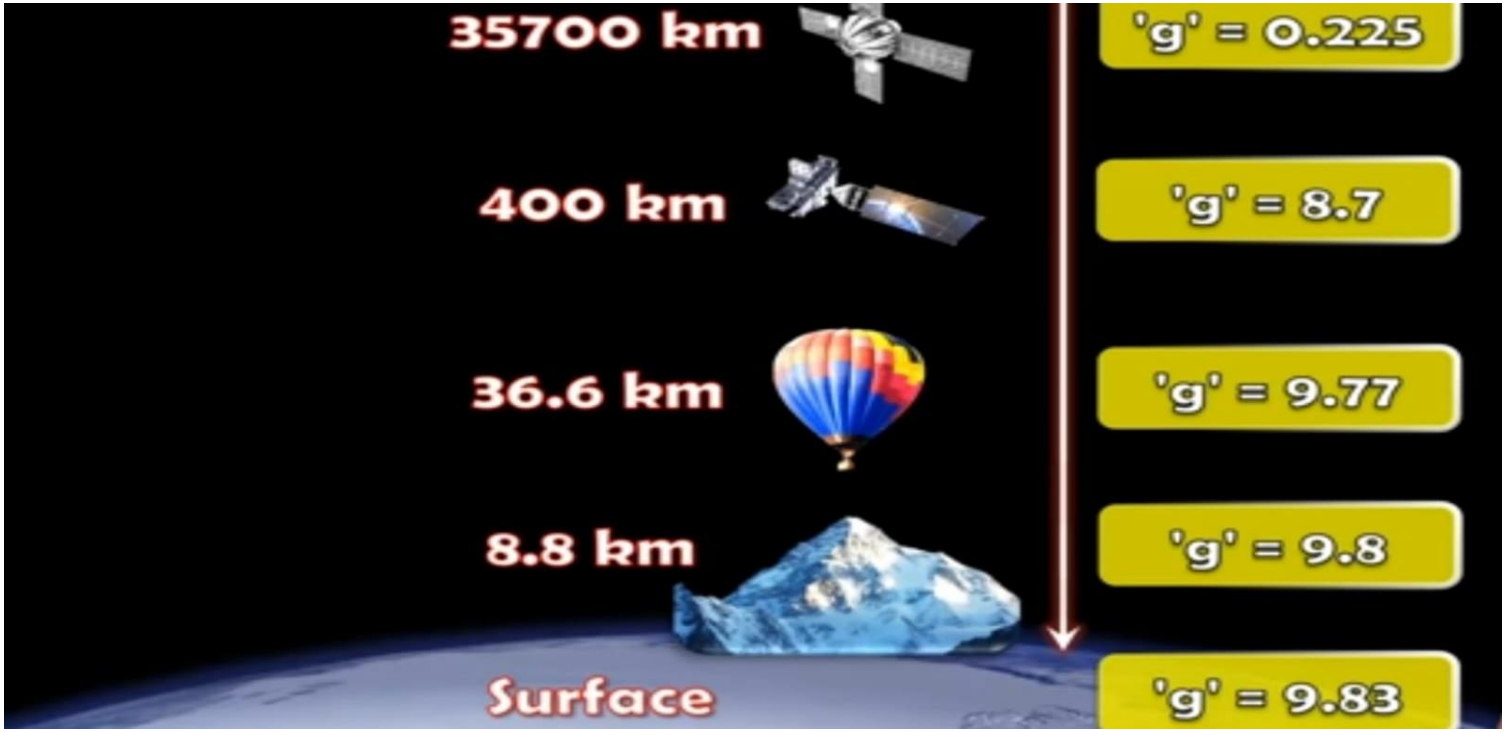
The variation of 'g' due to rotation of the earth.

The value of acceleration caused by gravity on the surface of Earth is around 9.8 m/s2. **But this value is not constant**. This value varies with change in the latitude from the Earth's surface. **The acceleration due to gravity (g) is large at the pole as compared to the equator.**



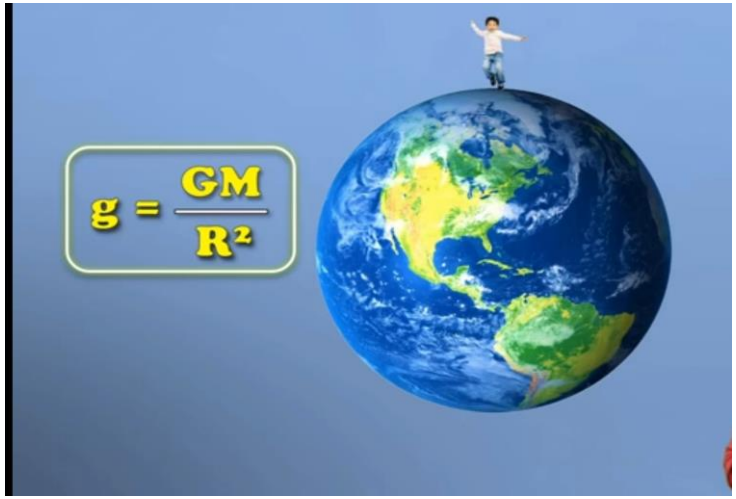
B. Change with height

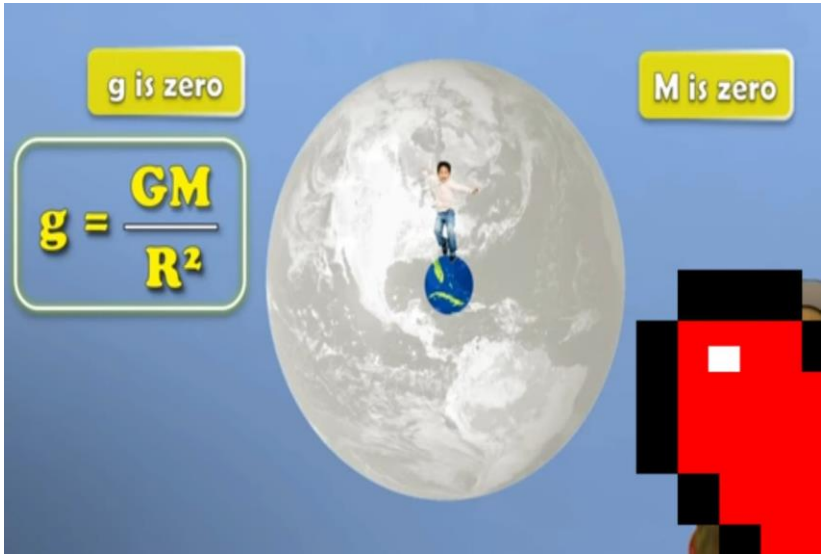
As we go above the earths surface the value of **r** increases and the value of **g** decreases.

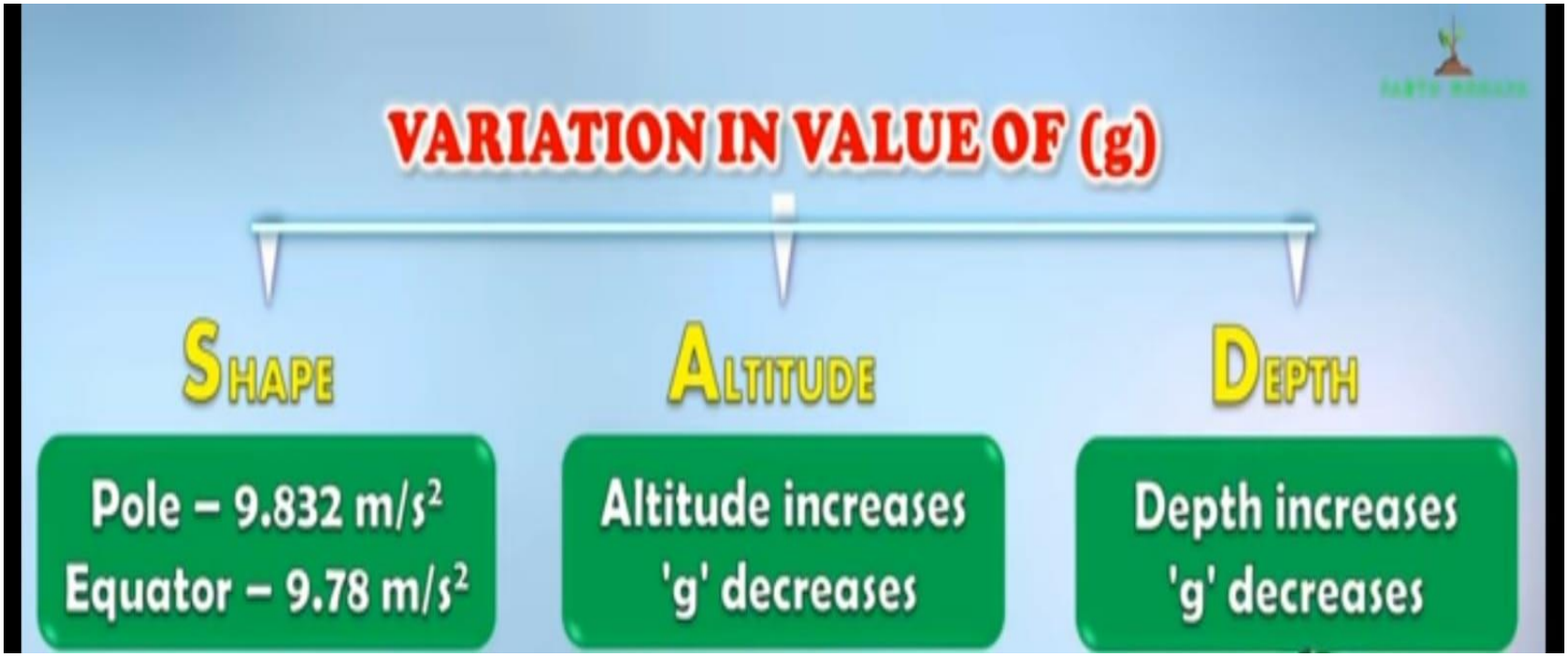


C. Change with depth

The value of g changes if we go inside the earth.







MASS AND WEIGHT

Mass is the amount present in the object.

Weight of an object is defined as the force with which the earth attracts the object.

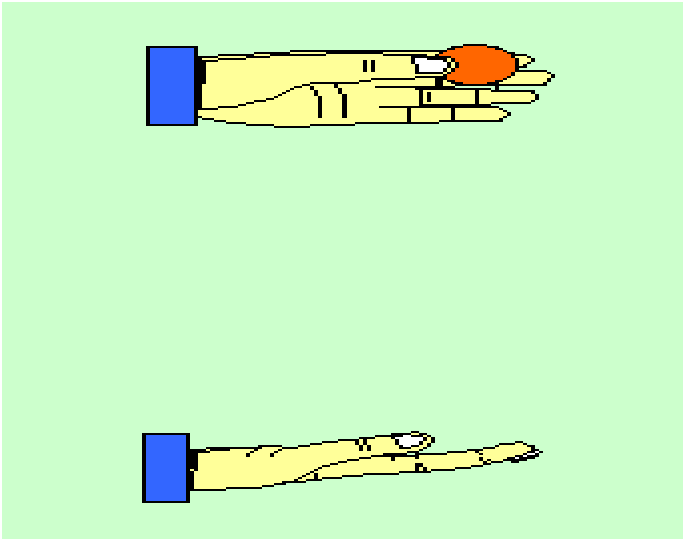
$$W = F = m\,g$$

Where w = Weight of the object

M = mass of the object g = acceleration due to gravity

Sr. No.	MASS	WEIGHT
1	The SI unit of mass is kg.	SI unit is Newton
2	Mass is a scalar quantity.	Weight is a vector quantity and its direction toward the centre of the earth
3	The value of mass is same everywhere.	The weight of an object changes from place to place.
4	mass is constant everywhere.	Weight can be zero based on the gravity acting upon it.

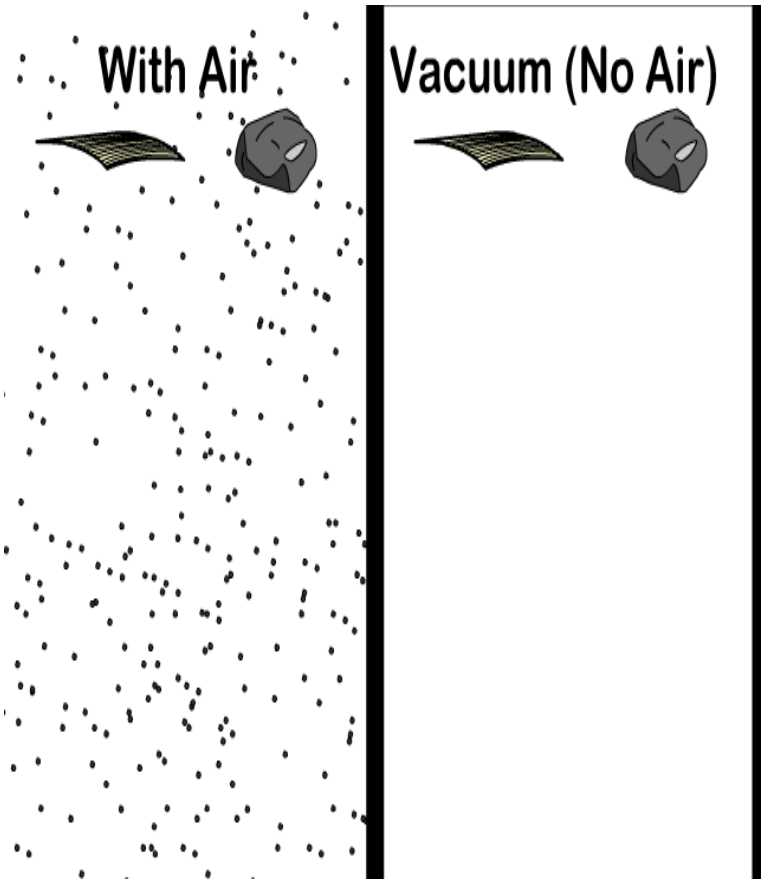
FREE FALL



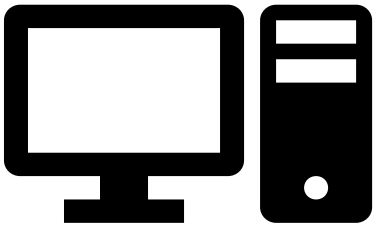
Definition. When a body moves exclusively under the influence of the Earth's gravity, it is said to be in freefall. The motion of the ball will be accelerated as a result of an external force acting on it. This free-fall acceleration is also known as acceleration due to gravity.

Examples of free fall

1. The ball is thrown in a projectile motion
2. A stone falling into an empty well
3. A spacecraft in continuous orbit



During the free fall the functional force due to air opposite the motion of the object and a buoyant force also acts on the object does true free fall is a possible only in vacuum



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