Collect information about high and low tides from geography books. Observe the timing of high and low tides at one place when you go for a picnic to be a beach. Take pictures and hold an exhibition.

Earth' gravitational force

Will the velocity of a stone thrown vertically upwards remain constant or will it change with time? How will it change? Why doesn't the stone move up all the time? Why does it fall down after reaching a certain height? What does its maximum height depend on ?

The earth attracts every object near it towards itself because of the gravitational force. The centre of mass of the earth is situated at its centre, so the gravitational force on any object due to the earth is always directed towards the centre of the earth. Because of this force, an object falls vertically downwards on the earth.

Similarly, when we throw a stone vertically upwards, this force tries to pull it down and reduces its velocity. Due to this constant downward pull, the velocity becomes zero after a while. The pull continues to be exerted and the stone starts moving vertically downward towards the centre of the earth under its influence.

Solved Examples

Example 1: Calculate the gravitational force due to the earth on Mahendra in the earlier example.

Given: Mass of the earth = $m_1 = 6 \times 10^{24}$ kg

Radius of the earth = $R = 6.4 \times 10^6$ m

Mahendra's mass = $m_2 = 75$ kg

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

Using the force law, the gravitational force on Mahendra due to earth is given by

This force is 1.83×10^9 times larger than the gravitational force between Mahendra and Virat.

$$F = \frac{G\, m_1 m_2}{R^2}$$

$$F = \frac{6.67 \times 10^{-11} \times 75 \times 6 \times 10^{24}}{(6.4 \times 10^6)^2} \text{ N} = 733 \text{ N}$$

Example 2: Starting from rest, what will be Mahendra's velocity after one second if he is falling down due to the gravitational force of the earth?

Given: u = 0, F = 733 N,

Mahendra's mass = m = 75 kg

time t = 1 s

Mahendra's acceleration

$$a = \frac{F}{m} = \frac{733}{75} \text{ m/s}^2$$

According to Newton's first equation of motion,

$v = u + a\,t$

Mahendra's velocity after 1 second

$v = 0 + 9.77 \times 1$ m/s

$v = 9.77$ m/s

This is 1.83×10^9 times Mahendra's velocity in example 2, on page 6.

Use your brain power !

According to Newton's law of gravitation, every object attracts every other object.

Thus, if the earth attracts an apple towards itself, the apple also attracts the earth towards itself with the same force. Why then does the apple fall towards the earth, but the earth does not move towards the apple?

The gravitational force due to the earth also acts on the moon because of which it revolves around the earth. Similar situation exists for the artificial satellites orbiting the earth. The moon and the artificial satellites orbit the earth. The earth attracts them towards itself but unlike the falling apple, they do not fall on the earth, why? This is because of the velocity of the moon and the satellites along their orbits. If this velocity was not there, they would have fallen on the earth.

Earth's gravitational acceleration

The earth exerts gravitational force on objects near it. According to Newton's second law of motion, a force acting on a body results in its acceleration. Thus, the gravitational force due to the earth on a body results in its acceleration. This is called acceleration due to gravity and is denoted by 'g'. Acceleration is a vector. As the gravitational force on any object due to the earth is directed towards the centre of the earth, the direction of the acceleration due to gravity is also directed towards the centre of the earth i.e. vertically downwards.

Think about it

1. What would happen if there were no gravity?
2. What would happen if the value of G was twice as large?

Value of g on the surface of the earth

We can calculate the value of g by using Newton's universal law of gravitation for an object of mass m situated at a distance r from the centre of the earth. The law of gravitation gives

$$F = \frac{G\,M\,m}{r^2} \quad \text{............. (3)}$$

M is the mass of the earth.

$$F = m\,g \quad \text{................... (4)}$$

From (3) and (4), $mg = \frac{G\,M\,m}{r^2}$

$$g = \frac{G\,M}{r^2} \quad \text{............ (5)}$$

If the object is situated on the surface of the earth, r = R = Radius of the earth. Thus, the value of g on the surface of the earth is.

$$g = \frac{G\,M}{R^2} \quad \text{......... (6)}$$

The unit of g in SI units is m/s^2. The mass and radius of the earth are 6×10^{24} kg and 6.4×10^6 m, respectively. Using these in (6)

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6)^2} = 9.77\ m/s^2 \quad \text{......................... (7)}$$

This acceleration depends only on the mass M and radius R of the earth and so the acceleration due to gravity at a given point on the earth is the same for all objects. It does not depend on the properties of the object.

Can you tell?

What would be the value of g on the surface of the earth if its mass was twice as large and its radius half of what it is now?

Variation in value of g

A. Change along the surface of the earth : Will the value of g be the same everywhere on the surface of the earth? The answer is no. The reason is that the shape of the earth is not exactly spherical and so the distance of a point on the surface of the earth from its centre differs somewhat from place to place. Due to its rotation, the earth bulges at the equator and is flatter at the poles. Its radius is largest at the equator and smallest at the poles. The value of g is thus highest (9.832 m/s^2) at the poles and decreases slowly with decreasing latitude. It is lowest (9.78 m/s^2) at the equator.

B. Change with height : As we go above the earth's surface, the value of r in equation (5) increases and the value of g decreases. However, the decrease is rather small for heights which are small in comparison to the earth's radius. For example, remember that the radius of the earth is 6400 km. If an aeroplane is flying at a height 10 km above the surface of the earth, its distance from the earth's surface changes from 6400 km to 6410 km and the change in the value of g due to it is negligible. On the other hand, when we consider an artificial satellite orbiting the earth, we have to take into account the change in the value of g due to the large change in the distance of the satellite from the centre of the earth. Some typical heights and the values of g at these heights are given in the following table.

Place	Height (km)	g (m/s^2)
Surface of the earth (average)	0	9.8
Mount Everest	8.8	9.8
Maximum height reached by man-made balloon	36.6	9.77
Height of a typical weather satellite	400	8.7
Height of communication satellite	35700	0.225

1.7 Table showing change of g with height above the earth's surface

C. Change with depth : The value of g also changes if we go inside the earth. The value of r in equation (5) decreases and one would think that the value of g should increase as per the formula. However, the part of the earth which contributes towards the gravitational force felt by the object also decreases. Which means that the value of M to be used in equation (5) also decreases. As a combined result of change in r and M, the value of g decreases as we go deep inside the earth.

Think about it

1. Will the direction of the gravitational force change as we go inside the earth?
2. What will be the value of g at the centre of the earth?

Every planet and satellite has different mass and radius. Hence, according to equation (6), the values of g on their surfaces are different. On the moon it is about $1/6^{th}$ of the value on the earth. As a result, using the same amount of force, we can jump 6 times higher on the moon as compared to that on the earth.

Mass and Weight

Mass : Mass is the amount of matter present in the object. The SI unit of mass is kg. Mass is a scalar quantity. Its value is same everywhere. Its value does not change even when we go to another planet. According to Newton's first law, it is the measure of the inertia of an object. Higher the mass, higher is the inertia.

Weight : The weight of an object is defined as the force with which the earth attracts the object. The force (F) on an object of mass m on the surface of the earth can be written using equation (4)

$$\therefore \text{Weight, } W = F = m\,g \quad .... \quad \left(g = \frac{G\,M}{R^2} \right)$$

Weight being a force, its SI unit is Newton. Also, the weight, being a force, is a vector quantity and its direction is towards the centre of the earth. As the value of g is not same everywhere, the weight of an object changes from place to place, though its mass is constant everywhere.

Colloquially we use weight for both mass and weight and measure the weight in kilograms which is the unit of mass. But in scientific language when we say that Rajeev's weight is 75 kg, we are talking about Rajeev's mass. What we mean is that Rajeev's weight is equal to the gravitational force on 75 kg mass. As Rajeev's mass is 75 kg, his weight on earth is F = mg = 75 x 9.8 = 735 N. The weight of 1 kg mass is 1 x 9.8 = 9.8 N. Our weighing machines tell us the mass. The two scale balances in shops compare two weights i.e. two masses.

Use your brain power !

1. Will your weight remain constant as you go above the surface of the earth?
2. Suppose you are standing on a tall ladder. If your distance from the centre of the earth is 2R, what will be your weight?

Solved Examples

Example 1: If a person weighs 750 N on earth, how much would be his weight on the Moon given that moon's mass is $\frac{1}{81}$ of that of the earth and its radius is $\frac{1}{3.7}$ of that of the earth ?

Given: Weight on earth = 750 N,

Ratio of mass of the earth (M_E) to mass of the moon (M_M) = $\frac{M_E}{M_M} = 81$

Ratio of radius of earth (R_E) to radius of moon (R_M) = $\frac{R_E}{R_M} = 3.7$

Let the mass of the person be m kg

Weight on the earth = m g = 750 = $\frac{m\,G\,M_E}{R_E^{\,2}}$ $\quad\therefore\, m = \frac{750\,R_E^{\,2}}{(G\,M_E)}$ .... (i)

Weight on Moon $= \frac{m\,G\,M_M}{R_M^{\,2}}$ using (i)

$$= \frac{750\,R_E^{\,2}}{(G\,M_E)} \times \frac{G\,M_M}{R_M^{\,2}} = 750\,\frac{R_E^{\,2}}{R_M^{\,2}} \times \frac{M_M}{M_E} = 750 \times (3.7)^2 \times \frac{1}{81} = 126.8 \text{ N}$$

The weight on the moon is nearly 1/6th of the weight on the earth. We can write the weight on moon as mg_m (g_m is the acceleration due to gravity on the moon). Thus g_m is 1/6th of the g on the earth.

Do you know ?

Gravitational waves

Waves are created on the surface of water when we drop a stone into it. Similarly you must have seen the waves generated on a string when both its ends are held in hand and it is shaken. Light is also a type of wave called the electromagnetic wave. Gamma rays, X-rays, ultraviolet rays, infrared rays, microwave and radio waves are all different types of electromagnetic waves. Astronomical objects emit these waves and we receive them using our instruments. All our knowledge about the universe has been obtained through these waves.

Gravitational waves are a very different type of waves. They have been called the waves on the fabric of space-time. Einstein predicted their existence in 1916. These waves are very weak and it is very difficult to detect them. Scientists have constructed extremely sensitive instruments to detect the gravitational waves emitted by astronomical sources. Among these, LIGO (Laser Interferometric Gravitational Wave Observatory) is the prominent one. Exactly after hundred years of their prediction, scientists detected these waves coming from an astronomical source. Indian scientists have contributed significantly in this discovery. This discovery has opened a new path to obtain information about the Universe.

Free fall

Try this

Take a small stone. Hold it in your hand. Which forces are acting on the stone? Now release the stone. What do you observe? What are the forces acting on the stone after you release it?

We know that the force of gravity due to the earth acts on each and every object. When we were holding the stone in our hand, the stone was experiencing this force, but it was balanced by a force that we were applying on it in the opposite direction. As a result, the stone remained at rest. Once we release the stone from our hands, the only force that acts on it is the gravitational force of the earth and the stone falls down under its influence. Whenever an object moves under the influence of the force of gravity alone, it is said to be falling freely. Thus the released stone is in a free fall. In free fall, the initial velocity of the object is zero and goes on increasing due to the acceleration due to gravity of the earth. During free fall, the frictional force due to air opposes the motion of the object and a buoyant force also acts on the object. Thus, true free fall is possible only in vacuum.

For a freely falling object, the velocity on reaching the earth and the time taken for it can be calculated by using Newton's equations of motion. For free fall, the initial velocity $u = 0$ and the acceleration $a = g$. Thus we can write the equations as

$$v = g\,t$$

$$s = \frac{1}{2} g\, t^2$$

$$v^2 = 2\, g\, s$$

For calculating the motion of an object thrown upwards, acceleration is negative, i.e. in a direction opposite to the velocity and is taken to be $-g$. The magnitude of g is the same but the velocity of the object decreases because of this -ve acceleration.

The moon and the artificial satellites are moving only under the influence of the gravitational field of the earth. Thus they are in free fall.

Do you know ?

The value of g is the same for all objects at a given place on the earth. Thus, any two objects, irrespective of their masses or any other properties, when dropped from the same height and falling freely will reach the earth at the same time. Galileo is said to have performed an experiment around 1590 in the Italian city of Pisa. He dropped two spheres of different masses from the leaning tower of Pisa to demonstrate that both spheres reached the ground at the same time.

When we drop a feather and a heavy stone at the same time from a height, they do not reach the earth at the same time. The feather experiences a buoyant force and a frictional force due to air and therefore floats and reaches the ground slowly, later than the heavy stone. The buoyant and frictional forces on the stone are much less than the weight of the stone and does not affect the speed of the stone much. Recently, scientists performed this experiment in vacuum and showed that the feather and stone indeed reach the earth at the same time.

https://www.youtube.com/watch?v=eRNC5kcvINA

Solved Examples

Example 1. An iron ball of mass 3 kg is released from a height of 125 m and falls freely to the ground. Assuming that the value of g is 10 m/s^2, calculate

(i) time taken by the ball to reach the ground

(ii) velocity of the ball on reaching the ground

(iii) the height of the ball at half the time it takes to reach the ground.

Given: m = 3 kg, distance travelled by the ball s = 125 m, initial velocity of the ball = u = o and acceleration a = g = 10 m/s^2.

(i) Newton's second equation of motion gives

$$s = u\,t + \frac{1}{2} a\,t^2$$

$$\therefore\ 125 = 0\,t + \frac{1}{2} \times 10 \times t^2 = 5\,t^2$$

$$t^2 = \frac{125}{5} = 25 \qquad ,\ t = 5\ s$$

The ball takes 5 seconds to reach the ground.

(ii) According to Newton's first equation of motion final velocity = v = u + a t

$= 0 + 10 \times 5$

$= 50\ m/s$

The velocity of the ball on reaching the ground is 50 m/s

(iii) Half time $= t = \frac{5}{2} = 2.5\ s$

Ball's height at this time = s

According to Newton's second equation

$$s = u\,t + \frac{1}{2} a\,t^2$$

$$s = 0 + \frac{1}{2} 10 \times (2.5)^2 = 31.25\ m.$$

Thus the height of the ball at half time
= 125-31.25 = 93.75 m

Example 2. A tennis ball is thrown up and reaches a height of 4.05 m before coming down. What was its initial velocity? How much total time will it take to come down? Assume g = 10 m/s^2

Given: For the upward motion of the ball,
the final velocity of the ball = v = 0
Distance travelled by the ball = 4.05 m
acceleration a= - g = -10 m/s^2

Using Newton's third equation of motion

$$v^2 = u^2 + 2\,a\,s$$

$$0 = u^2 + 2\,(-10) \times 4.05$$

$$\therefore\ u^2 = 81$$

u = 9 m/s The initial velocity of the ball is 9 m/s

Now let us consider the downward motion of the ball. Suppose the ball takes t seconds to come down. Now the initial velocity of the ball is zero, u = 0. Distance travelled by the ball on reaching the ground = 4.05 m. As the velocity and acceleration are in the same direction,

a = g=10 m/s

According to Newton's second equation of motion

$$s = u\,t + \frac{1}{2} a\,t^2$$

$$4.05 = 0 + \frac{1}{2} 10\,t^2$$

$$t^2 = \frac{4.05}{5} = 0.81\ , \qquad t = 0.9\ s$$

The ball will take 0.9 s to reach the ground. It will take the same time to go up. Thus, the total time taken = 2 x 0.9 = 1.8 s

Use your brain power !

According to Newton's law of gravitation, earth's gravitational force is higher on an object of larger mass. Why doesn't that object fall down with higher velocity as compared to an object with lower mass?

Gravitational potential energy

We have studied potential energy in last standard. The energy stored in an object because of its position or state is called potential energy. This energy is relative and increases as we go to greater heights from the surface of the earth. We had assumed that the potential energy of an object of mass m, at a height h from the ground is mgh and on the ground it is zero. When h is small compared to the radius R of the earth, we can assume g to be constant and can use the above formula (mgh). But for large values of h, the value of g decreases with increase in h. For an object at infinite distance from the earth, the value of g is zero and earth's gravitational force does not act on the object. So it is more appropriate to assume the value of potential energy to be zero there. Thus, for smaller distances, i.e. heights, the potential energy is less than zero, i.e. it is negative.

When an object is at a height h from the surface of the earth, its potential energy is $-\frac{GMm}{R+h}$

here, M and R are earth's mass and radius respectively.

Escape velocity

We have seen than when a ball is thrown upwards, its velocity decreases because of the gravitation of the earth. The velocity becomes zero after reaching a certain height and after that the ball starts falling down. Its maximum height depends on its initial velocity. According to Newton's third equation of motion is

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

v = the final velocity of the ball = 0 and a = - g

$\therefore\ 0 = u^2 + 2(-g)s$ and maximum height of the ball $= s = -\frac{u^2}{2g}$

Thus, higher the initial velocity u, the larger is the height reached by the ball.
The reason for this is that the higher the initial velocity, the ball will oppose the gravity of the earth more and larger will be the height to which it can reach.
We have seen above that the value of g keeps decreasing as we go higher above the surface of the earth. Thus, the force pulling the ball downward, decreases as the ball goes up. If we keep increasing the initial velocity of the ball, it will reach larger and larger heights and above a particular value of initial velocity of the ball, the ball is able to overcome the downward pull by the earth and can escape the earth forever and will not fall back on the earth. This velocity is called escape velocity. We can determine its value by using the law of conservation of energy as follows.

An object going vertically upwards from the surface of the earth, having an initial velocity equal to the escape velocity, escapes the gravitational force of the earth. The force of gravity, being inversely proportional to the square of the distance, becomes zero only at infinite distance from the earth. This means that for the object to be free from the gravity of the earth, it has to reach infinite distance from the earth. i.e. the object will come to rest at infinite distance and will stay there.

For an object of mass m

on the surface of earth

A. Kinetic energy = $\frac{1}{2} mv^2_{esc}$

B. Potential energy = $-\frac{GMm}{R}$

C. Total energy = E_1 = Kinetic energy + Potential energy

$= \frac{1}{2} mv^2_{esc} - \frac{GMm}{R}$

at infinite distance from the earth

A. Kinetic energy = 0

B. Potential energy $= -\frac{GMm}{\infty} = 0$

C. Total energy = E_2 = Kinetic energy + potential energy = 0

From the principle of conservation of energy

$E_1 = E_2$

$$\frac{1}{2} m v^2_{esc} - \frac{GMm}{R} = 0$$

$$v^2_{esc} = \frac{2\,GM}{R}$$

$$v_{esc} = \sqrt{\frac{2\,GM}{R}}$$

$$= \sqrt{2\,g\,R}$$

$$= \sqrt{(2 \times 9.8 \times 6.4 \times 10^6)} = 11.2 \text{ km/s}$$

The spacecrafts which are sent to the moon or other planets have to have their initial velocity larger than the escape velocity so that they can overcome earth's gravitational attraction and can travel to these objects.

Solved Examples

Example 1. Calculate the escape velocity on the surface of the moon given the mass and radius of the moon to be 7.34×10^{22} kg and 1.74×10^6 m respectively.

Given: $G = 6.67 \times 10^{-11}$ N m^2/kg^2, mass of the moon = M = 7.34×10^{22} kg and radius of the moon = R= 1.74×10^6 m.

Escape velocity = $v_{esc} = \sqrt{\frac{2\,GM}{R}}$

$$\sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 7.34 \times 10^{22}}{1.74 \times 10^6}}$$

= 2.37 km/s

Escape velocity on the moon 2.37 km/s.

Do you know ?

Weightlessness in space

Space travellers as well as objects in the spacecraft appear to be floating. Why does this happen? Though the spacecraft is at a height from the surface of the earth, the value of g there is not zero. In the space station the value of g is only 11% less than its value on the surface of the earth. Thus, the height of a spacecraft is not the reason for their weightlessness. Their weightlessness is caused by their being in the state of free fall. Though the spacecraft is not falling on the earth because of its velocity along the orbit, the only force acting on it is the gravitational force of the earth and therefore it is in a free fall. As the velocity of free fall does not depend on the properties of an object, the velocity of free fall is the same for the spacecraft, the travelers and the objects in the craft. Thus, if a traveller releases an object from her hand, it will remain stationary with respect to her and will appear to be weightless.

Exercise

1. Study the entries in the following table and rewrite them putting the connected items in a single row.

I	II	III
Mass	m/s^2	Zero at the centre
Weight	kg	Measure of inertia
Acceleration due to gravity	Nm^2/kg^2	Same in the entire universe
Gravitational constant	N	Depends on height

2. Answer the following questions.

a. What is the difference between mass and weight of an object. Will the mass and weight of an object on the earth be same as their values on Mars? Why?

b What are (i) free fall, (ii) acceleration due to gravity (iii) escape velocity (iv) centripetal force ?

c. Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?

d. A stone thrown vertically upwards with initial velocity u reaches a height 'h' before coming down. Show that the time taken to go up is same as the time taken to come down.

e. If the value of g suddenly becomes twice its value, it will become two times more difficult to pull a heavy object along the floor. Why?

3. Explain why the value of g is zero at the centre of the earth.

4. Let the period of revolution of a planet at a distance R from a star be T. Prove that if it was at a distance of 2R from the star, its period of revolution will be $\sqrt{8}$ T.

5. Solve the following examples.

a. An object takes 5 s to reach the ground from a height of 5 m on a planet. What is the value of g on the planet?

Ans: 0.4 m/s^2

b. The radius of planet A is half the radius of planet B. If the mass of A is M_A, what must be the mass of B so that the value of g on B is half that of its value on A?

Ans: 2 M_A

c. The mass and weight of an object on earth are 5 kg and 49 N respectively. What will be their values on the moon? Assume that the acceleration due to gravity on the moon is 1/6th of that on the earth.

Ans: 5 kg and 8.17 N

d. An object thrown vertically upwards reaches a height of 500 m. What was its initial velocity? How long will the object take to come back to the earth? Assume g = 10 m/s^2

Ans: 100 m/s and 20 s

e. A ball falls off a table and reaches the ground in 1 s. Assuming g = 10 m/s^2, calculate its speed on reaching the ground and the height of the table.

Ans. 10 m/s and 5 m

f. The masses of the earth and moon are 6 x 10^{24} kg and 7.4x10^{22} kg, respectively. The distance between them is 3.84 x 10^5 km. Calculate the gravitational force of attraction between the two?

Use G = 6.7 x 10^{-11} N m^2 kg^{-2}

Ans: 2 x 10^{20} N

g. The mass of the earth is 6 x 10^{24} kg. The distance between the earth and the Sun is 1.5x 10^{11} m. If the gravitational force between the two is 3.5 x 10^{22} N, what is the mass of the Sun?

Use G = 6.7 x 10^{-11} N m^2 kg^{-2}

Ans: 1.96 x 10^{30} kg

Project:

Take weights of five of your friends. Find out what their weights will be on the moon and the Mars.

HZ7YSF

2.Periodic Classification of Elements

- **Elements and their classification**
- **Newlands Law of Octaves**
- **Modern Periodic Table**
- **Dobereiner's Triads**
- **Mendeleev's Periodic Table**

Can you recall?

1. What are the types of matter?
2. What are the types of elements?
3. What are the smallest particles of matter called?
4. What is the difference between the molecules of elements and compounds?

Classification of elements

We have learnt in the previous standards that all the atoms of an element are of only one type. Today 118 elements are known to the scientific world. However, around year 1800 only about 30 elements were known. More number of elements were discovered in the course of time. More and more information about the properties of these elements was gathered. To ease the study of such a large number of elements, scientists started studying the pattern if any, in the vast information about them. You know that in the initial classification elements were classified into the groups of metals and nonmetals. Later on another class of elements called metalloids was noticed. As the knowledge about elements and their properties went on increasing different scientists started trying out different methods of classification.

Dobereiner's Triads

In the year 1817 a German scientist Dobereiner suggested that properties of elements are related to their atomic masses. He made groups of three elements each, having similar chemical properties and called them triads. He arranged the three elements in a triad in an increasing order of atomic mass and showed that the atomic mass of the middle element was approximately equal to the mean of the atomic masses of the other two elements. However, all the known elements could not be classified into the Dobereiner's triads.

Sr. No.	Triad	Element -1 Actual atomic mass(a)	Element - 2		Element - 3 Actual atomic mass (c)
			Mean = $\frac{a+c}{2}$	Actual atomic mass	
1	Li, Na, K	Lithium (Li) 6.9	Sodium $\frac{6.9 + 39.1}{2} = 23.0$	(Na) 23.0	Potassium (K) 39.1
2	Ca, Sr, Ba	Calcium (Ca) 40.1	Strontium $\frac{40.1 + 137.3}{2} = 88.7$	(Sr) 87.6	Barium (Ba) 137.3
3	Cl, Br, I	Chlorine (Cl) 35.5	Bromine $\frac{35.5 + 126.9}{2} = 81.2$	(Br) 79.9	Iodine (I) 126.9

2.1 Dobereiner's Triads

Can you tell?

Identify Dobereiner's triads from the following groups of elements having similar chemical properties.

1. Mg (24.3), Ca (40.1), Sr (87.6)
2. S (32.1), Se (79.0), Te (127.6)
3. Be (9.0), Mg (24.3), Ca (40.1)

Newlands' Law of Octaves

The English scientist John Newlands correlated the atomic masses of elements to their properties in a different way. In the year 1866 Newlands arranged the elements known at that time in an increasing order of their atomic masses. It started with the lightest element hydrogen and ended up with thorium. He found that every eighth element had properties similar to those of the first. For example, sodium is the eighth element from lithium and both have similar properties. Also, magnesium shows similarity to beryllium and chlorine shows similarity with fluorine. Newlands compared this similarity with the octaves in music. He called the similarity observed in the eighth and the first element as the **Law of octaves.**

Do you know ?

In the Indian music system there are seven main notes, namely, Sa, Re, Ga, Ma, Pa, Dha, Ni, and their collection is called 'Saptak'. The frequency of the notes goes on increasing from 'Sa' to 'Ni'. Then comes, the 'Sa' of the upper 'Saptak' at the double the frequency of the original 'Sa'. It means that notes repeat after completion of one 'Saptak'. The seven notes in the western music are Do, Re, Mi, Fa, So, La, Ti.

The note 'Do' having double the original frequency comes again at the eighth place. This is the octave of western notes. Music is created by the variety in the use of these notes.

Musical Note	Do (Sa)	Re (Re)	Mi (Ga)	Fa (Ma)	So (Pa)	La (Dha)	Ti (Ni)
Elements	H F Cl Co &Ni Br	Li Na K Cu Rb	Be Mg Ca Zn Sr	B Al Cr Y Ce & La	C Si Ti In Zr	N P Mn As	O S Fe Se

2.2 Newlands' Octaves

Many limitation were found in Newlands' octaves. This law was found to be applicable only up to calcium. Newlands fitted all the known elements in a table of 7 X 8 that is 56 boxes. Newlands placed two elements each in some boxes to accommodate all the known elements in the table. For example, Co and Ni, Ce and La. Moreover, he placed some elements with different properties under the same note in the octave. For example, Newlands placed the metals Co and Ni under the note 'Do' along with halogens, while Fe, having similarity with Co and Ni, away from them along with the nonmetals O and S under the note 'Ti'. Also, Newlands' octaves did not have provision to accommodate the newly discovered elements. The properties of the new elements discovered later on did not fit in the Newlands' law of octaves.

Mendeleev's Periodic table

The Russian scientist Dmitri Mendeleev developed the periodic table of elements during the period 1869 to 1872 A.D. Mendeleev's periodic table is the most important step in the classification of elements. Mendeleev considered the fundamental property of elements, namely, the atomic mass, as standard and arranged 63 elements known at that time in an increasing order of their atomic masses. Then he transformed this into the periodic table of elements in accordance with the physical and chemical properties of these elements.

Mendeleev organized the periodic table on the basis of the chemical and physical properties of the elements. These were the molecular formulae of hydrides and oxides of the elements, melting points, boiling points and densities of the elements and their hydrides and oxides. Mendeleev found that the elements with similar physical and chemical properties repeat after a definite interval. **On the basis of this finding Mendeleev stated the following periodic law.**

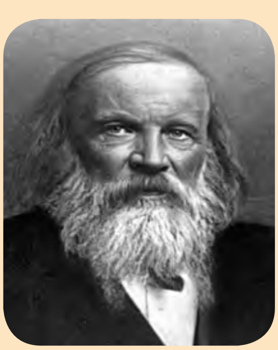
Properties of elements are periodic function of their atomic masses.

The vertical columns in the Mendeleev's periodic table are called groups while the horizontal rows are called periods.

Series ↓	Group I - R^2O	Group II - RO	Group III - R^2O^3	Group IV RH^4 RO^2	Group V RH^3 R^2O^5	Group VI RH^2 RO^3	Group VII RH R^2O^7	Group VIII - RO^4
1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl= 35.5	
4	K=39	Ca=40	- = 44	Ti= 48	V=51	Cr= 52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	-=68	-=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	-=100	Ru=104,Rh=104 Pd=106,Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	-	-	-	----
9	(-)	-	-	-	-	-	-	
10	-	-	?Er=178	?La=180	Ta=182	W=184	-	Os=195, Ir=197 Pt=198, Au=199
11	(Au=199)	Hg=200	Ti=204	Pb=207	Bi= 208	-	-	
12	-	-	-	Th=231	-	U=240	-	---

2.3 Mendeleev's Periodic Table

(The general molecular formulae of compounds shown as R^2O, R^2O^3, etc. in the upper part of Mendeleev's periodic table, are written as R_2O, R_2O_3,etc. in the present system.)



Dmitri Mendeleev

Introduction to scientist

Dmitri Mendeleev (1834-1907) was a professor in the St. Petersburg University. He made separate card for every known element showing its atomic mass. He arranged the cards in accordance with the atomic masses and properties of the elements which resulted in the invention of the periodic table of elements.

Think about it

1. There are some vacant places in the Mendeleev's periodic table. In some of these places the atomic masses are seen to be predicted. Enlist three of these predicted atomic masses along with their group and period.
2. Due to uncertainty in the names of some of the elements, a question mark is indicated before the symbol in the Mendeleev's periodic table. What are such symbols?

Merits of Mendeleev's periodic table

Science is progressive. There is a freedom in science to revise the old inference by using more advanced means and methods of doing experiments. These characteristics of science are clearly seen in the Mendeleev's periodic table.

While applying the law that the properties of elements are a periodic function of their atomic masses, to all the known elements, Mendeleev arranged the elements with a thought that the information available till then was not final but it could change. As a result of this, Mendeleev's periodic table demonstrates the following merits.

1. Atomic masses of some elements were revised so as to give them proper place in the periodic table in accordance with their properties. For example, the previously determined atomic mass of beryllium, 14.09, was changed to the correct value 9.4, and beryllium was placed before boron.
2. Mendeleev kept vacant places in the periodic table for elements not discovered till then. Three of these unknown elements were given the names eka-boron, eka-aluminum and eka-silicon from the known neighbours and their atomic masses were indicated as 44, 68 and 72, respectively. Not only this but their properties were also predicted. Later on these elements were discovered and named as scandium (Sc), gallium (Ga) and germanium (Ge) respectively. The properties of these elements matched well with those predicted by Mendeleev. See table 2.4. Due to this success all were convinced about the importance of Mendeleev's periodic table and this method of classification of elements was accepted immediately.

Property	eka- aluminum(E) (Mendeleev's prediction)	Gallium (Ga)(actual)
1. Atomic mass	68	69.7
2. Density (g/cm^3)	5.9	5.94
3. Melting point(^{0}C)	Low	30.2
4. Formula of chloride	ECl_3	$GaCl_3$
5. Formula of oxide	E_2O_3	Ga_2O_3
6. Nature of oxide	Amphoteric oxide	Amphoteric oxide

2.4 Actual and predicted properties of gallium.

3. There was no place reserved for noble gases in Mendeleev's original periodic table. However, when noble gases such as helium, neon and argon were discovered towards the end of nineteenth century, Mendeleev created the ' zero' group without disturbing the original periodic table in which the noble gases were fitted very well.

Use your brain power !

Chlorine has two isotopes,viz, C1-35 and C1-37. Their atomic masses are 35 and 37 respectively. Their chemical properties are same. Where should these be placed in Mendeleev's periodic table? In different places or in the same place?

Demerits of Mendeleev's periodic table

1. The whole number atomic mass of the elements cobalt (Co) and nickel (Ni) is the same. Therefore there was an ambiguity regarding their sequence in Mendeleev's periodic table.
2. Isotopes were discovered long time after Mendeleev put forth the periodic table. As isotopes have the same chemical properties but different atomic masses, a challenge was posed in placing them in Mendeleev's periodic table.
3. When elements are arranged in an increasing order of atomic masses, the rise in atomic mass does not appear to be uniform. It was not possible, therefore, to predict how many elements could be discovered between two heavy elements.
4. Position of hydrogen : Hydrogen shows similarity with halogens (group VII). For example, the molecular formula of hydrogen is H_2 while the molecular formulae of fluorine and chlorine are F_2 and Cl_2, respectively. In the same way, there is a similarity in the chemical properties of hydrogen and alkali metals (group I). There is a similarity in the molecular formulae of the compounds of hydrogen alkali metals (Na, K, etc.) formed with chlorine and oxygen. On considering the above properties it can not be decided whether the correct position of hydrogen is in the group of alkali metals (group I) or in the group of halogens (group VII).

Compounds of H	Compounds of Na
HCl H_2O H_2S	NaCl Na_2O Na_2S

2.5 Similarity in hydrogen and alkali metals

Element (Molecular formula)	Compounds with metals	Compounds with nonmetals
H_2 Cl_2	NaH NaCl	CH_4 CCl_4

2.6 : Similarity in hydrogen and halogens

Use your brain power !

1. Write the molecular formulae of oxides of the following elements by referring to the Mendeleev's periodic table. Na, Si, Ca, C, Rb, P, Ba, Cl, Sn.
2. Write the molecular formulae of the compounds of the following elements with hydrogen by referring to the Mendeleev's periodic table. C, S, Br, As, F, O, N, Cl

Modern Periodic Law

The scientific world did not know anything about the interior of the atom when Mendeleev put forth the periodic table. After the discovery of electron, scientists started exploring the relation between the electron number of an atom and the atomic number. The atomic number in Mendeleev's periodic table only indicated the serial number of the element.

In 1913 A.D. the English scientist Henry Moseley demonstrated, with the help of the experiments done using X-ray tube, that the atomic number (Z) of an element corresponds to the positive charge on the nucleus or the number of the protons in the nucleus of the atom of that element. This revealed that 'atomic number' is a more fundamental property of an element than its atomic mass. Accordingly the statement of the modern periodic law was stated as follows:

Properties of elements are a periodic function of their atomic numbers.