INTRODUCTION TO PHYSICS

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CHAPTER 1 UNITS

The Latin word for science is “scientia”, which means to know or to understand. Although there is no universally accepted definition of science, it is seen as a specific method for acquiring knowledge and understanding the world. Therefore, we may define science as an intellectual activity that systematically studies the structure and behavior of the physical and natural world through observation, testing, experimentation, and prediction. Many scientists would agree with Carl Sagan’s statement that “science is a way of thinking much more than it is a body of knowledge.” Science studies and investigates the natural world—from the smallest subatomic particles to large galaxies and the whole universe; from single celled organisms to the whole of ecology; from organs such as brain to emotion and consciousness. Based on the areas of specialty science can be classified into many branches. Biology studies living organisms, their structures and behaviors. Chemistry engages in the composition, structure, and properties of matter. Astronomy deals with celestial objects, their motions and positions, and their origin. Geology is the science that studies earth’s physical structure and substance, the soil and crust that constituted the earth, and so on.

The goal of science is to understand and explain the physical world. To that end, it employs a unique set of methods of inquiry that includes observation, measurement, theorizing, and experimentation. A more detailed account of science and its methods of inquiry can be found in *Introduction to Philosophy* by Samir Okasha, the Tibetan translation of which is used as the textbook for the philosophy of science class.

What then is physics and how is it different from other sciences? Physics is a branch of science that primarily studies matter and energy, and the interaction between the two. To put more simply, it is the science that studies matter and its motion through space and time along with related concepts such as speed, energy, force and so on. Because physics encompasses the study of the fundamental constituents of the universe, the basic structure of the matter, and the four fundamental forces, it is considered the most fundamental of all sciences.

What do Physics studies?

In general, we can say that physics studies the material objects. In particular, it studies mass, energy, force, particles and the interactions between them. Therefore, it encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. Its area of study also includes light and radiation, sound and color, planets and other celestial objects, galaxies and constellations. Different branches of science are classified based upon the primary areas of study. For example, chemistry studies the chemical compositions of material objects, their activities and interactions with each other, whereas biology is the study of organisms. We also have branches of science that focus on specific aspects of organisms such as their nervous system. Neuroscience, for example, is the study of nervous systems, brain, neurons and so on.

Although science has many branches, physics may be considered as the most fundamental of all because even the complicated and complex things that other sciences study could be broken down to more fundamental constituents such as atoms and subatomic particles, which are the fields of study of physics. Moreover, all the changes that we see in the universe are due to one or more of the four forces, which again are what physics studies.

Four Fundamental Forces

Given the importance of the four fundamental forces, we will go into some details about them. The four forces are the strong force, the weak force, the electromagnetic force and the gravitational force. All the forces that we see or experience are included in these four. The strong force is responsible for holding the protons and neutrons inside the nucleus. Color charge is the source of this force. The weak force is responsible for the interactions between the fermions and has very, very small range. The weak charge is the source of this force. The electromagnetic force is the force that we observe between electric charges, between magnets and between the electric charges and magnets. Its source is the electric charge. The gravitational force is the pulling force between objects of masses and its source is the mass.

Fundamental Force	Difference in strength of force	Range in meters	Source
Strong Force	1	10_{-15}	Color charge
Electromagnetic Force	10_{-2}	∞	Electric charge
Weak Force	10_{-7}	10_{-18}	Weak charge
Gravitational Force	10_{-39}	∞	Mass

For comparison’s sake, let us assume that the strength of the strong force is 1. The electromagnetic force would be just 1 percent of that, the weak force is merely 10^{-7th} of that and the gravitational force 10^{-39th}. Although strong force is the largest in strength, its range is only over the diameter of a nucleus of an atom. In this aspect the gravitational force has the largest range. This symbol ∞ represents infinity. As the table shows, the electromagnetic force and the gravitational force have infinite range.

As an aside, we would like to mention some similarities and differences between Buddhism and science. Although both rely on reasoning to establish the reality, they have different approaches to it. As mentioned before, science follows a set of methods in understanding the reality that includes making observations, developing hypotheses, experimentations, and theory building. In all these processes mathematics is used extensively, which is a big difference between science and Buddhism. Another major difference between the two is the kind of logic that they used. Science relies heavily on inductive reasoning, whereas in Buddhism any sound logic must necessarily be deductive in nature. In *Universe in a Single Atom* His Holiness the Dalai Lama writes, “One of the areas of reasoning where Buddhism and science differ lies in the role of deduction. What distinguishes science from Buddhism most in its application of reason is its highly developed use of profoundly complex mathematical reasoning.” Since mathematics is the language of physics, the two cannot be separated. Many experts agree that the development and the use of mathematics in physics is partly responsible for the great success that physics has enjoyed. As such, many modern biologists also attempts to present biological principles in mathematical form.

Fundamental Units

A unit of measurement is a definite magnitude of a physical quantity, defined and adopted by convention, that is used in understanding and describing physical phenomena. The phrase 'defined and adopted by convention', in the definition, is significant because it shows that joy and other emotions that are highly subjective cannot be measured using fundamental units.

The physics and other sciences seek to understand the world and its features and relationships for which there is a need to understand various quantities associated with it such as size, length, speed and so on. If we use units of measurement that are location or cultural dependent, but are not universal, then complications and difficulties would be created in communication and exchange of information. Even in our daily life we use measurements and quantities in our description of the world. For example in order to know whether a machine can lift a particular object, we need to know at least the mass of the object and the power of the machine.

Seven fundamental units are used to measure the seven basic quantities. The seven quantities are mass, length, time, temperature, electric current, amount of substance and the luminosity. Their units are kilogram, meter, second, kelvin, ampere, mole and candela respectively. Although there are other units used in different places to measure different quantities, the above seven are the SI units. The table below shows the units, their symbols and some conversion factors.

Quantity	Unit	Symbol
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminosity	Candela	cd

Two things that one needs to take note of are: 1) Although there are different systems of units, there is only one set of universal standard units, which are called the SI units; 2) The letters representing the units are case sensitive. The big 'A' is the symbol for Ampere and the small 'a' is the symbol for acceleration.

Three Essential Units

The three essential units are the units for mass, length, and time. Mass is understood as the amount of substance in an object. Its SI unit is kilogram (kg). However, pound and gram are also used to measure it. We write m = 10 kg to represent an object with mass 10 kilogram. The international prototype kilogram is stored at the International Bureau of Weights and Measures on the outskirts of Paris. (Figure 4)

Figure 4:

We can use any of the various units that are currently in use to measure the mass of an object. However, when masses are added to or subtracted from each other the units must be same because masses shown in different units cannot be summed or subtracted. For example masses measured in kg cannot be added to the ones that are measured in gram. What we need to do in such a case is to convert either the kilogram into grams or the grams to kilograms. Therefore, conversion of units become important in physics.

1 kg = 1000 g

1 g = 1000 mg

Meter (m) is the SI unit for measuring distance. We represent the length of a 10 meter long object as l = 10 m.

1 km = 1000 m

1 m = 100 cm

The duration between two events is called time and it could be measured in days, months, hours and minutes. But the international standard unit is the second. In the old days, the duration of second is calculated based on the duration of a day. However, today it is measured by an atomic clock. The second is represented by the symbol s.

1 hour = 60 minutes = 360 seconds

1 year = 365.25 days = $3x10^7$ seconds

Some examples of important lengths:

Object	Distance in meters
Closest star to Earth	4×10^{16}
Average distance between Sun and Earth	2×10^{11}
Average distance between Earth and Moon	4×10^{8}
Radius of Eearth	6×10^{6}
Average height of a satellite	2×10^{5}
Ant's body length	5×10^{-3}
Thickness of a human hair	1×10^{-4}
Size of a cell	1×10^{-5}
Diameter of a hydrogen atom	1×10^{-10}
Diameter of a proton	1×10^{-15}

Some examples of important masses:

Object	Mass in kilograms
Mass of the visible universe	1×10^{53}
Mass of the Milky Way	7×10^{41}
Mass of Sun	2×10^{30}
Mass of Earth	6×10^{24}
Mass of Moon	7×10^{22}
Mass of hydrogen atom	1×10^{-27}
Mass of electron	1×10^{-31}

Some examples of important times:

Object	Time in seconds
Age of Universe	5×10^{17}
Age of Earth	1×10^{17}
One Year	3×10^{7}
Average duration of a heartbeat	8×10^{-1}
Period of a radio wave	1×10^{-6}
Time for light to traverse a proton	3×10^{-24}

Conversion Table:

Quantity	Unit	Symbol	Conversion		
			From	to	Multiply by this
Length	Kilometer	km	Kilometer	Meter	1000
	Meter	m	Meter	Centimeter	100
	Centimeter	cm	Centimeter	Meter	0.01
	Millimeter	mm	Centimeter	Millimeter	10
Mass	Ton	t	Ton	Kilogram	1000
	Kilogram	kg	Kilogram	Gram	1000
	Gram	g	Gram	Kilogram	0.001
	Pound	lb	Pound	Kilogram	0.453
Time	Day	d	Day	Hour	24
	Hour	h	Hour	Second	3600
	Minute	m	Minute	Second	60
	Second	s	Day	Second	86400

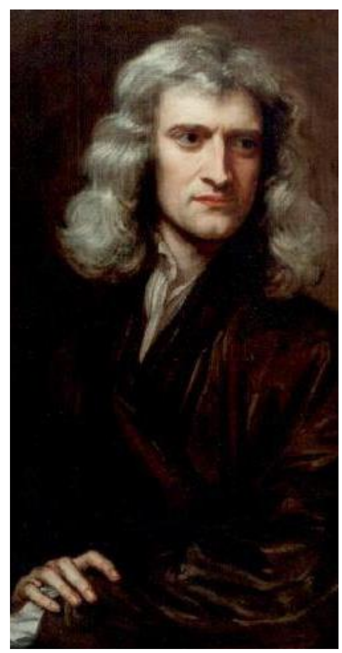
CHAPTER 2 MECHANICS

Mechanics is the branch of physics that deals with the motion of material objects and studies the laws governing these motions.

A Brief History

From almost 2000 years ago, the ancient Greeks had studied the natural world and had gained considerable knowledge about it. They had also studied motion and had formulated various hypotheses, most of which were not correct. Aristotle, for instance, classified motion into natural motions and violent motions and this view was widely accepted in the western world until 16^{th} century. Although Aristotle was successful in proving the earth as spherical, he believed in the geocentric model of the universe. In the 16th century, Copernicus proposed a new idea, in which he claimed the Sun, not the Earth, as the center of the universe.

Galileo, using telescopes that he invented, observed the sky and was able to show that the heliocentric model was in fact correct. Several decades later Newton expanded on the works of Galileo and made important discoveries about the laws of motions that laid a strong foundation for the study of mechanics. Although Galileo was considered the father of modern science, it was Newton who pioneered the study of mechanics.

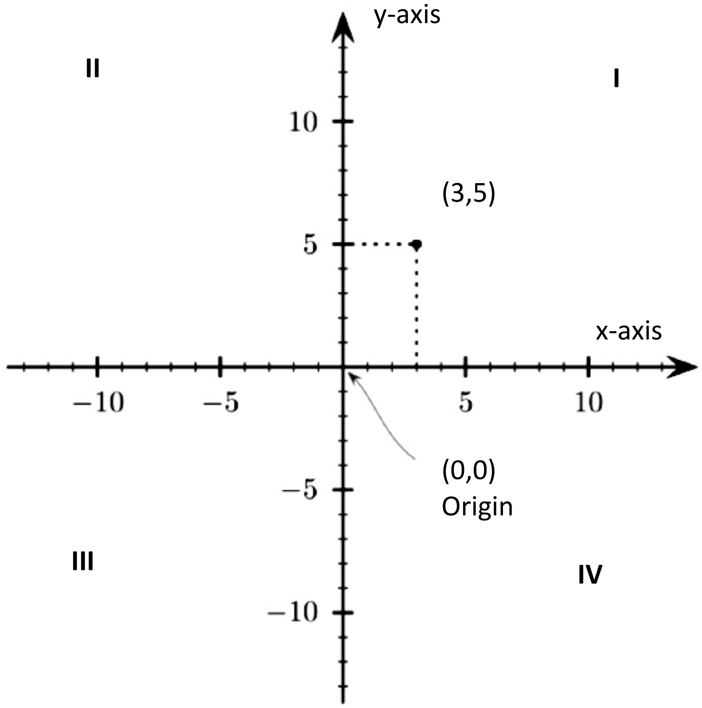


Isaac Newton

Newton was born in Lincolnshire, England on 25 December 1642. He studied at Trinity College, Cambridge and later became a professor of mathematics and physics at the same institution. He developed the theory of gravitation and using it he was able to resolve many problems associated with planetary motions. He was not only an imminent physicist but also a great mathematician. He developed theories on optics. But his most famous contributions are the three laws of motion and the universal law of gravitation.

Few Concepts to Know Before Delving into the Laws of Motion

Motion is a change in position of an object with time. There are many ways to define position but in physics Cartesian coordinates are used to define position of an object. To identify the position of an object in a 2-dimensional plane, we first draw a horizontal line that is perpendicular to a vertical line. We randomly label the horizontal line as x-axis and the vertical line as y-axis. We consider the intersecting point as the origin of the coordinate plane. We then divide the horizontal and the vertical lines into many equal parts. Using this system we can represent the positions of any objects and talk about the change in position of an object as well.



Speed is defined as the rate of change of the position of an object. In order to get the rate of change of something or the rate of doing work, we need to divide the change by the time it takes for the change to happen. As change in position is measured using the unit of distance, we divide length by time to get the speed. Thus, mathematically,

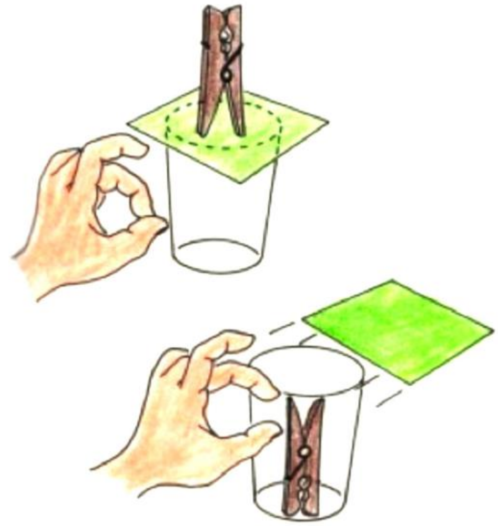
Speed = distance/time

Velocity is another concept that's associated with motion. It is similar to speed but it is not exactly the same. The main difference between speed and velocity is that velocity shows not only the magnitude but also the direction of the motion. It is also defined as the rate of change of displacement. As such, we can write:

V = displacement/time

The unit of velocity is m/s. Displacement is the shortest distance from the initial to the final position of an object. It is measured in meters. It is a vector quantity and therefore has direction. Just as speed and velocity are different, displacement is different from distance. For example, when an object travels around a 100-meter long circular path, the distance covered is 100 meters but the displacement is zero because the initial position and the final position are the same.

Newton's First Law of Motion



The First Law states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force. In other words, unless an external force acts, an object in rest will continue to remain in rest and an object in motion will continue to be in that motion without changing its velocity. This tendency of an object to resist change in its motion is called inertia. We have all experience inertia. When you are in a car and the car starts moving you feel a backward push. Similarly, when the car stops suddenly you feel a push forward. These are effects of inertia. When the car initially starts to move your body, which is in a state of rest wants to stay in that state because of inertia. The resistance of body to change its state is experienced by you as a push backward. (Figure 7)

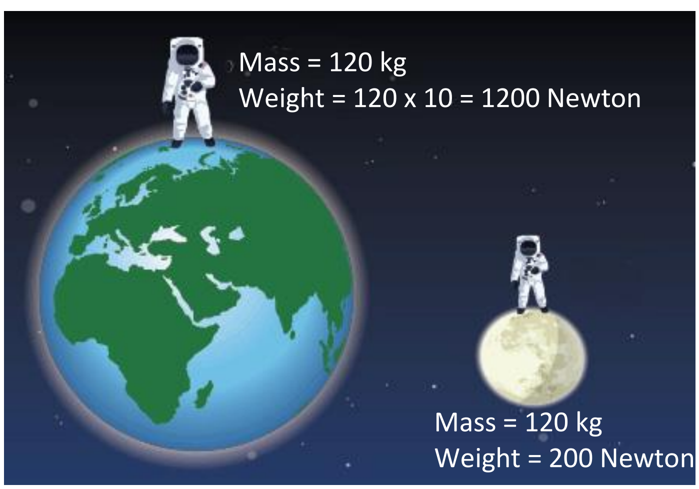
Newton's Second Law of Motion

The Second Law states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, and inversely proportional to the mass of the object.

The force is given by the product of the mass and the acceleration. Mathematically, F= ma, where F is force, m is mass and a is acceleration. The unit of force is $kg.m/s^2$, which is called Newton (N).

Acceleration

Acceleration is the rate of change of velocity. It shows the change that velocity undergoes in each second. We experience acceleration in our daily life. For example, in taking a ride in a car, it is initially in a state of rest. It then changes its velocity and moves. The velocity may increase for a while after which it may move in a uniform velocity. Occasionally, its velocity will decrease and finally it will come to a stop. When the car's velocity increases or decreases, it is undergoing acceleration. Since acceleration is the rate of change of velocity, its unit is also the unit of velocity divided by the unit of time: $(m/s)/s = m/s^2$.



Difference between Mass and Weight

As mentioned before mass is the amount of substance contained in an object and its unit is kilogram. Weight on the other hand is the gravitational pull that an object with mass experiences in the presence of gravity. It is the measure of gravitational force between the object and the earth. Therefore, its unit is same as the unit for force, which is Newton. When we say that a person has 60 kg, we are talking about the mass of his body since kg is the unit for mass. A person with 60 kg mass has a body weight of about 600 Newton.

If a body with some mass is not close to another massive body such as the Earth or the Moon, then that object will have mass but not any weight. This shows that any object with mass will have the same mass wherever the object is placed. However, depending on the location of the object, it can have different weights. For example, a person on the Moon will have only one sixth of the body weight that it has on the Earth. (Figure 8)

Gravity

Gravity is the attractive force between objects having masses. For example, the force that is responsible for the apple falling to the ground and the force that keeps the Earth revolving around the Sun. Gravity was discovered by Isaac Newton. It is said that Newton was inspired by an apple falling on his head while he was sitting under an apple tree to investigate why things fall to the Earth. He understood that objects having masses would attract each other and it is this force that was responsible for things falling to the Earth.

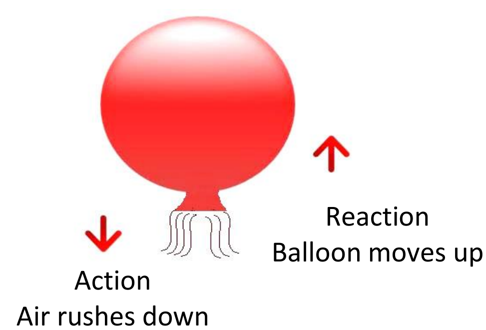
Although the story about apple hitting Newton's head may be nothing more than a story, there could be some element of truth in it. We can subject the fall of the apple to this analysis: The apple that was initially at rest starts to fall and begins to accelerate. According to the second law of motion, a force is required for acceleration to occur. If we call this force gravitational force, then the acceleration it produces is the acceleration due to gravity. Since the apple at the top of the tree would start falling if it is separated from the branch, it means that the gravitational pull extends at least to the top of the tree. It was Newton's brilliance that he thought the gravitation pull might reach the Moon and that it was this pull that's causing the Moon to rotate around the Earth.

It could be through this kind of reasoning that Newton was able to reach the conclusion that any two masses in the universe will attract each other and that the force of attraction is directly proportional to the production of the two masses and inversely proportional to the square of the distance between them. In mathematical representation, the gravitational force $F_g = G(m_1m_2)/r^2$

where F_g is the gravitation force, m_1 and m_2 are the two masses and r is the distance between the two masses. G is the universal gravitational constant. You will see many such equations in physics, which will be described in greater detail in subsequent years. The motion of many of the planetary objects could be explained using this law of gravitation.

Newton's Third Law of Motion

The Third Law states that for every action, there is an equal and opposite reaction. (Figure 9)



Energy

Energy is the ability to do work. It comes in two basic forms: kinetic energy and potential energy. Kinetic energy is the energy of motion. For example the energy that a flying bullet has to crush the target object. Potential energy is the energy that an object has due to its position in a force field. For example, a book resting on a table has some stored energy which can produce sound when the book falls to the ground. This is a potential energy.

One of the most important laws of classical physics is the law of the conversation of energy. This law states that energy can neither be created nor destroyed; rather, it transforms from one form to another. For instance, chemical energy can transform into heat energy or potential energy can transform into kinetic energy. This law was initially discovered in connection with thermodynamics.

Momentum

Momentum can be defined as "degree of motion." It depends on the mass of the object and the velocity of the object. More precisely momentum is defined as the product of mass and the velocity of the object. Therefore, the more massive the object is the greater its momentum is. Similarly, the higher velocity the object the greater its momentum.

Momentum = mass x velocity

The unit of momentum is kg.m/s.

Work

In physics work is understood as the displacement caused when a force acts upon an object. Therefore, the product of the force and distance is equal to the work done.

$w = F \times d$

The unit of work is N.m or $kg.m^2/s^2$. This is also called Joule.

Power

Power is the rate of doing work. Its formula is

$p = w/t$

The unit of power is J/s. This is also called Watt.

CHAPTER 3 MATTER

Matter is anything that has mass. Examples of matter include mountain, a table, house, which are all macroscopic, and elements such as gold, silver and copper, and particles such as protons, neutrons, and electrons as well.

Composition of Matter

In general subatomic particles such as quarks also have mass and as such they are considered as matter. However, in the present context matter refers to anything that is composed of atoms. Every macroscopic objects in the universe is constituted by atoms. Atom is a Greek word and it means "uncuttable" or "indivisible".

The view that the material world is composed of atoms existed in early Greece in the 5th century BCE. The Greeks, in their study of the nature of things, considered what would happen to a rock if it is continually broken into smaller and smaller pieces. They reasoned that there would come a time when the tiny pieces cannot be broken down further. That smallest piece is an atom, an indivisible particle that cannot be divided further. However, Aristotle did not accept this view. He instead proposed the four elements—earth, water, fire and air—as the fundamental constituents of matter. This view was accepted by the Western world for the next 2000 years because it seemed reasonable as all the matters that are visible to us were either solid, liquid, gas or fire.

In 19th century, John Dalton, an English chemist, physicist, and meteorologist, did pioneering work in the development of modern atomic theory. The theory states that all matters are composed of extremely small and indivisible particles called atoms. Although at the time atoms were believed to be the smallest particles, the development of science later showed that there are subatomic particles such as electrons, protons, neutrons and quarks. At present quarks and electrons are considered as the smallest particles but the search for more fundamental particles are still on.

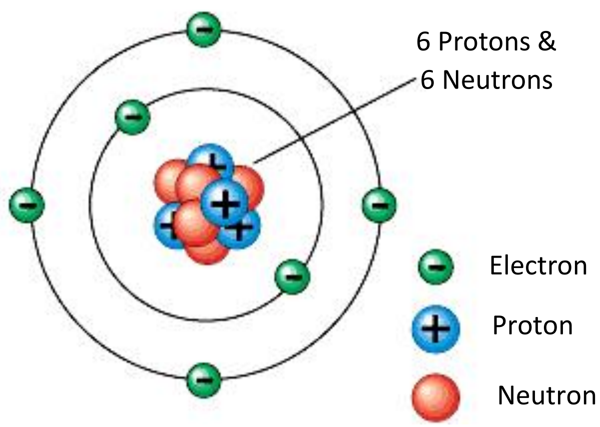
Atoms have many remarkable features. One they are very, very tiny. It is very hard to imagine the size of an atom. But we can use an analogy to help us. If suppose we could enlarge an apple to the size of the Earth, then atoms in it would be about the size of an apple. Atoms exist in extremely large numbers. For example, there are 10^{21} atoms in a drop of water. This number is larger than the number of drops in all the water on the planet. Atoms are always in motion. Atoms in solid bodies vibrate in their locations and the atoms in liquid move from places to places. For example, if we pour a cup of pigment in the ocean, it will spread all over the surface of the ocean. Atoms in gas are moving with even higher speed. Atoms do not age. For example, many of the atoms in our body are almost as old as the universe.

The air that we breathe in goes to our lungs and except for a small proportion are all absorbed by the body and become part of the body. These are later released by the body in various ways. We can almost say that the atoms that consisted our body are stuff that we have borrowed. These are constantly exchanged with other persons through respiration, perspiration and other processes.

Structure and Constituents of Atom

Atoms are composed by three subatomic particles: protons, neutrons and electrons. The table below shows some of the characteristics of these particles:

In general the structure of atom consists of two parts: a nucleus and electrons that surround the nucleus. Nucleus lies at the center of the atom and are composed of protons and neutrons. The number of protons in the nucleus of the atom determines what type of element the atom is. (Figure 10) For example, hydrogen, the smallest atom, has only one proton in its nucleus and oxygen has 8 protons, gold has 79 and uranium, the heaviest atom found naturally, has 92 protons. Nucleus has another constituent. It is called neutron. The presence or the number of neutrons in a nucleus does not affect the element type. Except for the lightest hydrogen atoms, all other atoms have one or more neutrons in them.



What then are the differences between proton, neutron and electron? They have different electric charges. Protons are positively charged, electrons are negatively charged and the neutrons have no charge. Electron has been translated by some as the "negative particle" because of its negative charge. The three particles have different masses. Electrons have much smaller masses. In fact, it's mass is approximately 1/2000th times that of proton and neutron. In terms of composition of the particles, protons and neutrons are composed of quarks. But so far scientists have not discovered any constituent particles for electrons.

particle	Symbol	Sign	Charge	Mass
Proton	p	+	$1.6x10^{-19}$C	1x 10^{-27} kg
Neutron	n	0	0	1x 10^{-27} kg
Electron	e	-	$-1.6x10^{-19}$C	1x 10^{-31} kg

How then do the atoms come together to form macroscopic objects? As mentioned earlier the number of protons in the atom determines the type of element it is. For example, an atom with 79 protons in its nucleus is a gold atom. Metals such as gold, silver, copper and iron are formed by bonding of many elements of the same kind. For example, a golden Buddha statue is made of gold elements and the copper wire in the electric wire is made of pure copper elements. However, most of the things that we see are made up of two or more elements. For example, brass is made up of copper and zinc and water is made up of hydrogen and oxygen. So far humans have discovered 118 elements of which 98 occur naturally and others have been created in laboratories. Based on their similar property and behavior, different elements have been classified into various groups, which is shown in the table below. Figure 11.

ནག་པོ། མཁྲེགས་གཟུགས་ཡིན།
སྔོན་པོ། གཤེར་གཟུགས་ཡིན།
དམར་པོ། རླངས་གཟུགས་ཡིན།
སྐྱ་ཐལ། རང་བྱུང་དུ་མི་རྙེད།

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 196.56655	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Uut (277)	114 Uuq (277)	115 Uup (277)	116 Uuh (277)		118 Uuo (277)

57 La 138.9055	58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04
89 Ac 232.0381	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

Molecule

Molecules are group of two or more atoms held together by chemical bond. For example, two hydrogen atoms and an oxygen atom are bound together to form water molecule. Trillions of water molecules come together to form a water droplet. Not all molecules are as simple as water molecules. For example, a DNA molecule that holds the code of life is a highly complex molecule. As mentioned in *Introduction to Biology* subatomic particles come together to form atoms, atoms combine to form molecules, molecules combine to form organelles, organelles combine to form cells, cells combine to form tissues, tissues combine to form organs and so on.

There are two ways in which atoms can combine to form larger particles. One way is to fuse the nuclei of atoms in what is known as fusion reaction. The product of such fusion reaction is the formation of new elements. The other way is for atoms to share their electrons with other atoms in what is called chemical reactions. The product of such reaction is the formation of molecules.

An interesting question to pose here is where did all the matter come from originally? Einstein's equation (E=mc2) says that matter can be converted to energy and vice versa. Based on this scientists claim that all the matter that exists in the universe may have come from energy that was present at the time of Big Bang. E=mc2 is perhaps the most well-known equation in the world. It was originally published by Albert Einstein in 1905. E is energy, m is mass and c is the velocity of light. The energy and mass that were earlier considered as two separate entities were unified by Einstein.

Three Phases of Matter

Almost all of the macroscopic objects exist in three phases or three forms—solid, liquid and gas. A solid is a substance that has a fixed volume and a fixed shape. A liquid has a fixed volume but does not have a fixed shape. A gas has no fixed volume or shape. One substance can take the form of all three. For example, ice is a solid form of water, water is in liquid form and the water vapor is in gas form. If we look at the atomic arrangements of the three states, atoms in solids are bonded fairly firmly together. In liquids, the atoms are more randomly arranged and a little bit further apart. Gases have much more randomly arranged atoms than either liquids or solids. Figure 12.

Density

Density is the amount of mass contained in a given volume or mass per unit volume. An object with large volume but small mass will have a small density. On the other hand, an object that has small volume but a large mass will have a large density. Cotton and sponge are objects of small density whereas iron and lead have large density. The symbol for density is the Greek letter rho and the formula for it is:

$$\rho = m/V$$

CHAPTER 4 HEAT

Heat is a form of energy that is transferred from one object to another when there is a temperature difference between the two. We are all very familiar with heat. We can feel hot and cold objects. We also know what is meant when someone says one object is hotter than the other.

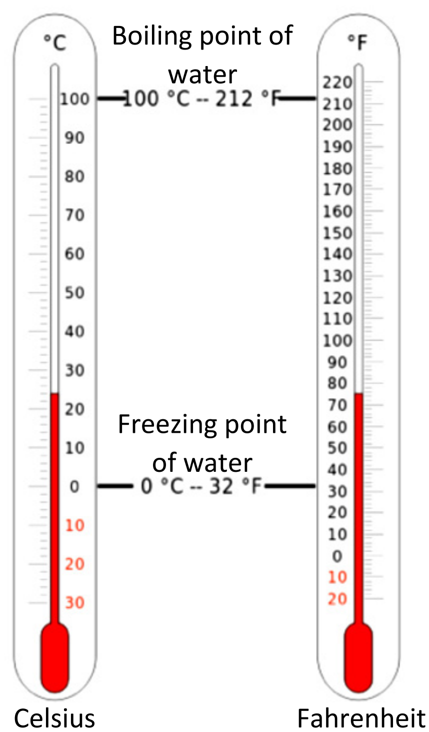
Temperature is a measure of the heat in an object.

When two objects of different temperatures come in contact with each other, heat flows from the hot object to the cold object until an equilibrium is reached. Once the temperatures of the two objects become equal, the flowing of heat from one object to the other stops. When a third object is brought in contact with either one of them and an equilibrium is reached, then all three objects are said to be in thermal equilibrium. This phenomenon is known as the Zeroth Law of Thermodynamics.

Unit of Heat

Heat is a form of energy and as such its unit has to be a unit of energy. Thus, the SI unit of heat is joule.

Heat is an important concept in physics because heat can change many of the properties of matter. For example, the speed of sound is affected by the rise in temperature of the medium. Similarly, the rise in the temperature of water increases the volume and as such decreases its density. An iron bar that appears to be invariable to our naked eyes undergoes change with the increase in its temperature.



There are three widely accepted units of temperature—namely Kelvin, Celcius and Fahrenheit. Different units are used in different places. In India and Europe, for example, the degree Celsius is used widely, whereas in the US Fahrenheit system is used. In the degree Celsius system, water boils at 100 degrees Celsius and freezes at 0 degree Celsius. On the other hand, on the Fahrenheit system these changing of the states of water occur at 212 F and 22 F respectively. Irrespective of what unit we use, the temperature that they represent is the same. Therefore, we need a way to convert from one system of unit to the other. We use the following equation to convert between Kelvin and degree Celsius:

$T_c = T_k - 273.15$, where T_c is the temperature measured in degree Celsius and T_k is the temperature measured in Kelvin. The following equation can be used to convert between degree Celsius and Fahrenheit:

$T_F = 9/5\ T_c + 32$

$T_c = 5/9\ (T_F – 32)$

The Celsius system was created based on the boiling point and the freezing point of water. And the Fahrenheit system is based on the freezing point of a particular salt and the normal human body temperature. Therefore, these are randomly scaled units and it also became possible to have negative temperatures. The Kelvin scale, developed by Lord Kelvin, is the absolute scale. It starts with zero as the lowest point and there isn't an upper limit to it. The zero as measured in this scale is called the absolute zero, which in degree Celsius is -273.15 C. The current scientific theories propose that absolute zero as the lowest possible temperature. Using the current available technologies scientists have been able to lower the temperature to almost absolute zero.

Methods of Heat Transfer

There are three ways of transferring heat: conduction, convection and radiation. Conduction is the transfer of heat between objects that are in physical contact. Transference of heat from fire to an aluminum pot when heating some water is an example of conduction. (Figure 14) The transfer of heat between an object and its environment, through fluid motion is called convection. For example, the spreading of heat through vapor or smoke. Radiation is the transfer of heat by means of electromagnetic waves. The transfer of heat energy from Sun to Earth is through radiation. This type of heat transfer does not require any media, neither does it require the two objects to be in touch with each other.

Laws of Thermodynamics

The first law of thermodynamics states that the initial energy of a system plus heat flow into the system is equal to the final energy of the system plus the external work done by the system. Mathematically,

$$E_i + Q_{into} = E_f + W$$

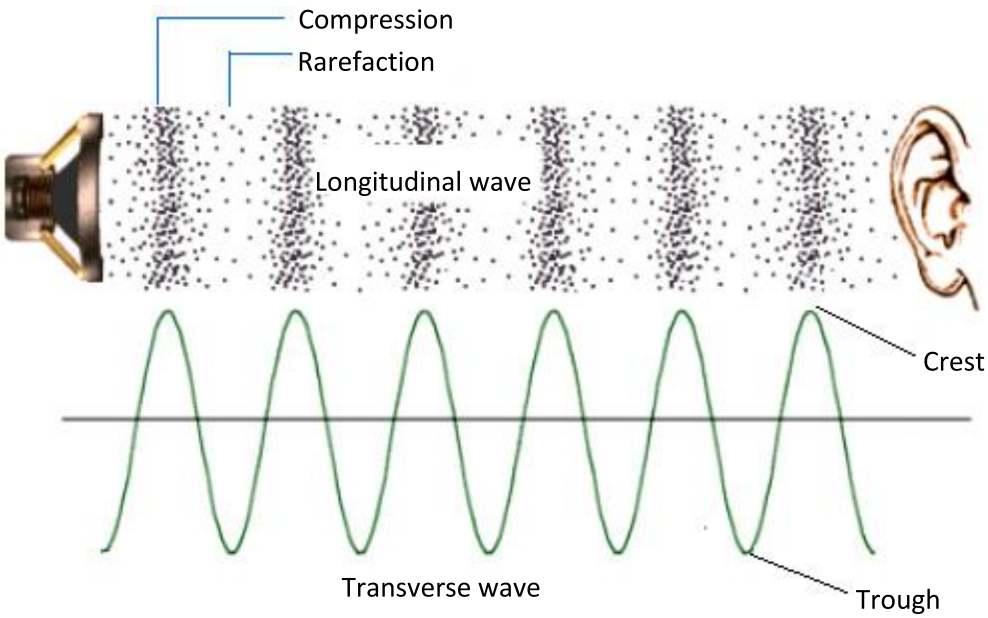
where E_i is the initial internal energy of the system, Q_{into} is the heat energy given to the system, E_f is the final internal energy of the system and W is the work done by the system. This law is equivalent to the law of the conservation of energy.

The second law of thermodynamics states that heat of itself never flows from a cold object to a hot object. In other words, the entropy of an isolated system will never decrease. Here entropy means the amount of disorder in a system. This law states that an isolated system will always move from an ordered state to a more disordered state.

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero.

CHAPTER 5 SOUND AND WAVES

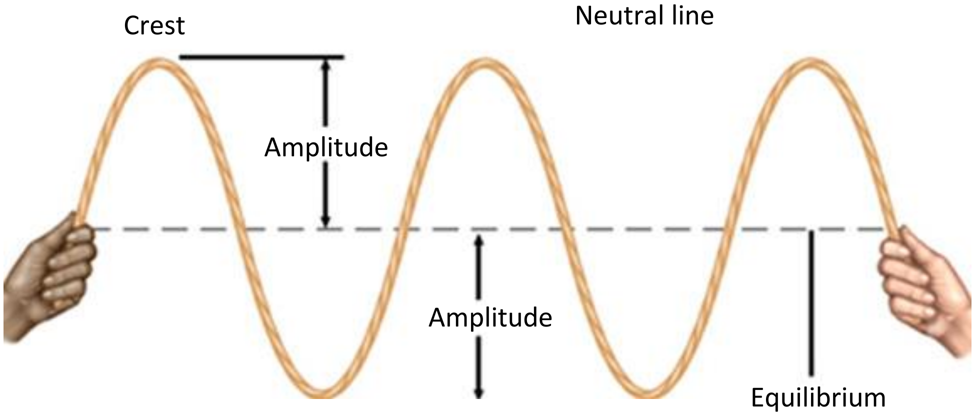
In general, anything that moves back and forth, side to side or up and down is in vibrational motion. For example, the motion of a moving pendulum. Wave is understood as the propagation of disturbance. Some waves, such as sound, require medium to travel and others, like light, don't. Based on the direction of movement of the individual particles of the medium relative to the direction that the waves travel, waves are categorized into two main types: transverse waves and longitudinal waves. As shown in the figure below, a transverse wave is a wave in which particles of the medium move in a direction perpendicular to the direction that the wave moves and a longitudinal wave is a wave in which particles of the medium move in a direction parallel to the direction that the wave moves. (Figure 15)



What then oscillates and what travels in a wave? It is the particles of the medium that oscillates and the energy that travels in a wave. For example, in a water wave, it is the water molecules that oscillate up and down and the energy that travels with the wave.

Wave Description

There are several features of wave that we are interested in. One of them is frequency. Frequency is the number of waves passing a point in a second. Its unit is hertz. Amplitude refers to the distance from the midpoint to the crest or trough of the wave. Wavelength of a wave is the distance from the top of one crest to the top the next crest. The unit of wavelength is meter. The period of a wave or vibration is the time for one complete vibration. Since we are measuring the duration of a wave, the unit is second. (Figure 16)



Sound

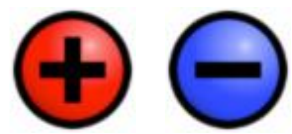
In general, all sounds originate from vibration of something. The human vocal sound comes from the vibration of the vocal cords. The rapid vibration of the cord causes a disturbance in the air that travels as a sound. Depending on the thickness of the vocal cords, sounds of different pitches are produced. Thick cords produce sounds of low pitch and think cords produce higher pitch. Women and small children have cords that are short and thin as such they have high pitched voice.

Sound is a longitudinal wave that travel through the air or another medium and can be heard when it reaches a person's or animal's ear. Sound needs a medium to travel and the conditions such as the density, temperature and so on affect the speed of the sound. For example, sound travels faster in a solid medium than in the air. It is because in solid medium the atoms are closely packed and the energy that travels as sound propagates much faster. Similarly, sound travels faster in hot air than in a cold air. Since moon does not have atmosphere on it one may shout as much as one wants on the moon but no sound will ever be produced.

Human ears can hear sounds of frequency ranging from 20 hz to 20000 hz. Those are audible sounds. Sounds having frequencies that are beyond that range are called inaudible sounds. They are inaudible to human ears. However, there are animals who could hear sounds of higher or lower frequencies. For instance, bats can hear sounds with frequency greater than 20000 hz.

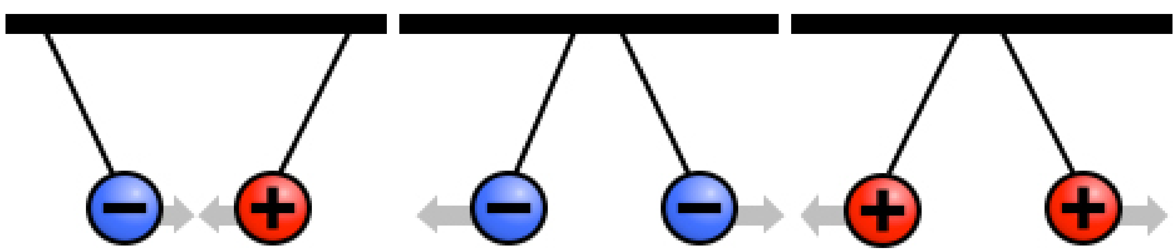
CHAPTER 6 ELECTROMAGNETISM

Electric Charge



Electric charge is the physical property of matter that causes it to experience an electric force. There are two types of electric charges: positive and negative. Of the three constituents of atom, protons are said to have positive charge and electrons are said to have negative charge. Neutrons, as we mentioned earlier, are neutral and hence have no charge. As shown in the figure, + sign represents positive charge and – sign represents negative charge. (Figure 17) Generally, e is used to symbolize charge and it is the fundamental unit of charge. Charge is considered as a fundamental and innate property just like mass. Every charge that we observe in nature are multiples of e and could be represented by this equation: $Q = \pm Ne$, where Q is the total charge, N is integer, and e is the fundamental charge. This symbol ± means either positive or negative.

The unit of charge is Coulomb. The fundamental charge e has 1.60×10^{-19} Coulombs. How then do the electric charges interact with each other? Well, like charges when come close together will repel each other and unlike charges attract each other. This is known as the Law of Charge. (Figure 18) Another fundamental law associated with the electric charges is the Law of Conservation of Charge. This law states that that electric charge can neither be created nor destroyed. The net quantity of electric charge, the amount of positive charge plus the amount of negative charge in the universe, is always conserved.



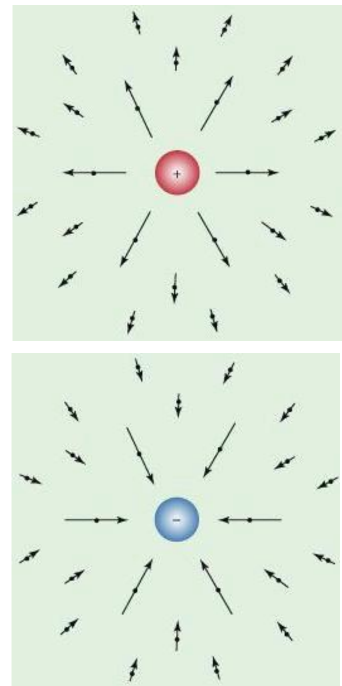
If all the ordinary things are made up of charged particles such as electrons and protons, then why don't they experience electric force from other objects? That is because most of the ordinary objects have equal number of positive and negative charges and they cancel each other's electric effect.

Electric Force

Electric force is a force that is produced by electric charge. Charles Augustin de Coulomb, a French physicist, studied the interactions between charges and discovered that the force between charges are directly proportional to the amount of charges and inversely proportional to the square of the distance between them. The more charge each charged object has stronger the force between them, and farther away the two charged objects are from each other the weaker the force between them. This is known as Coulomb's Law and is represented mathematically as:

$F = kq_1q_2/r^2$, where F is electric force, k is the Coulomb constant, q_1 and q_2 are the amount of charges in the two objects, and r^2 is the square of the distance between them.

Electric Field



Electric field could be understood as the area surrounding an electric charge wherein the effects of the charge could be felt. It is represented pictorially as arrows surrounding a charge as shown in Figure 19. Each arrow represents the strength and the direction of the field at that point. The length of the arrow indicates the strength of the field. Thus, the arrows closest to the charge (in the figure on right) are longest, indicating the strongest field and those that lie farther away are shorter, showing weaker field. How then do we find the strength and the direction of the electric field? It is done by placing a positive test charge in the field and measuring the force experienced by the test charge. When placed within the electric field, the test charge will either move toward or away from the source charge indicating either attractive or repulsive force. This idea was formally proposed by the English physicist Michael Faraday and it helped in resolving a difficult problem in early physics, which is known as action at a distance problem. This is the problem of explaining how two charges that are not in contact can exert force on each other.

Electric Current

Electric current is the rate of flow of electric charge past a given point. It is represented mathematically as I = q/t, where I is the current, q is charge and t is time. It is measured in Coulombs/second, which is named Amperes, by an instrument called ammeter. Although we are familiar with current flowing through an object such as a copper wire, current does not need a medium. For example, the motion of electrons through an empty space is also a current. Similarly, the lighting during a thunderstorm is also a stream of electric current. Although current can be produced by a flow of positive charge particles but the current that flows in usual copper wiring is mainly the flow of electrons. Different materials have different electron configurations and as such there are variations in how different materials conduct electricity. The materials that permit electrons to flow freely from particle to particle are called conductors and those that impede the free flow of electrons from particle to particle are called insulators. Most metals are examples of conductors and stone, plastic, wood are examples of insulators. Thus, we see electric wires are made up of metals such as copper. We also see electric wires covered in plastic to prevent electrocution.

Ohm's Law

The force that pushes charges through a wire is an electromotive force. It is generally defined as the electrical potential for a source in a circuit and is measured in Volts (V). Most materials tend to offer some hindrance to the flow of charge and this property is called resistance (R). It is measured in Ohms. An object that offers large resistance does not allow much current to pass through it. Ohm's Law shows that the electric potential difference between two points on a circuit (ΔV) is equivalent to the product of the current between those two points (I) and the total resistance of all electrical devices present between those two points (R). Mathematically, it is expressed as:

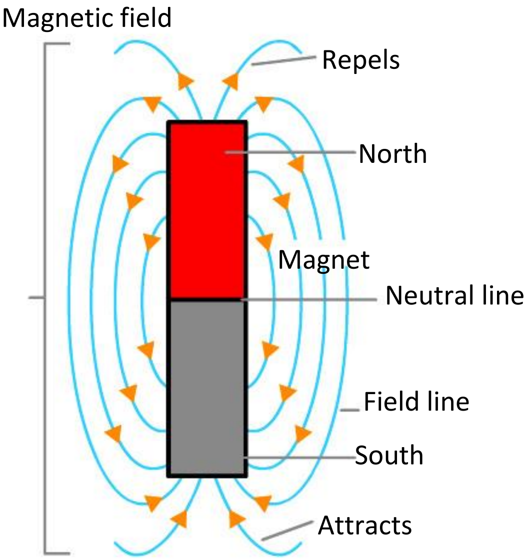
$$\Delta V = I.R$$

This relation was first discovered by Georg Simon Ohm, a German physicist.

Magnetism

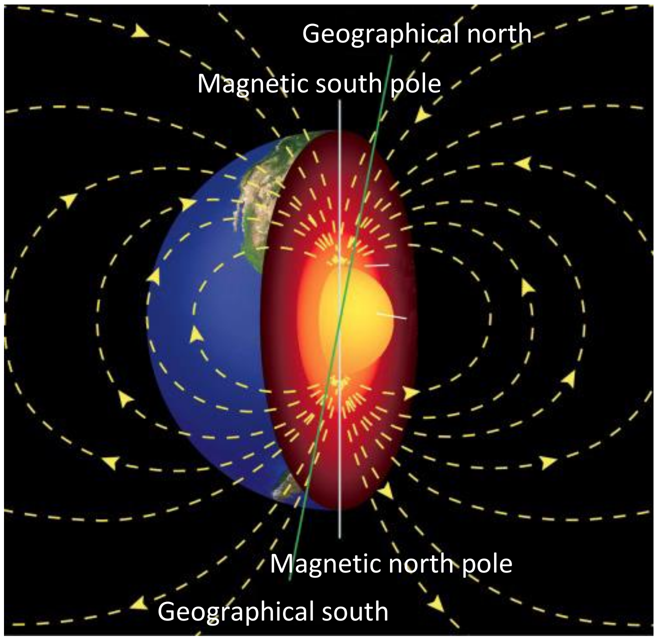
Most of us have seen magnets and we have even played with some. If you tie a string at the center of a bar magnet and let it hang, it will turn and point to the North-South direction. Thus, the magnet acts like a compass and indicates North and South. The end that points to the North is called magnet's north pole and the other is called the south pole.

Similar to the behavior of electric charge, like poles repel and unlike poles attract. One important difference between electric charges and magnetic poles is that poles are always found in pairs, while single electric charges can be isolated. Therefore, no matter how small you break a magnet into, each piece will always have two poles. The source of magnetism lies in the basic building block of all matter...the atom.



Magnetic Field

Earlier we mentioned that an electric charge is surrounded by electric field. When the charge moves it creates another field which is called magnetic field. A charge in motion is surrounded by both electric field and magnetic field. As the motion of electric charge produces magnetic field, the faster the motion stronger the field will be.
The magnetic north pole points to the geographical north pole and the magnetic south pole points to the geographical south. Earth acts like a huge magnet with its magnetic poles lying contra to the geographical poles. This property of the Earth allowed the sailors to navigate using compass. (Figure 21) The reason why the Earth behaves like a huge magnet is not known but it is obvious that it affects all the magnets. The magnetic property of the Earth is not a unique feature of this planet. These days scientists study the magnetic phenomenon of the Sun. Magnetic field is represented mathematically as $B = F/qv$, where F is the magnetic force, q is the charge, v is the velocity of the charge.



Magnetic Force
When a charge moves in the magnetic field it experiences a force that is given by $F = qvB$, where F is the force, q is the charge, v is the velocity and B is the magnetic field. This equation shows that the force experienced by a charge moving in a magnetic field is proportional to the charge, its velocity and the magnetic field.

Relationship between Electricity and Magnetism
For a long time people thought that electricity and magnetism were two completely separate phenomena. In 1820, the Danish physicist Hans Christian Oersted discovered that electric currents create magnetic field. When current is sent through a coil of wire, the coil becomes a magnet with its two magnetic poles and it functions as a magnet. This type of magnets are now called electromagnets. Then in 1831, the English physicist Michael Faraday discovered that when a magnet was inserted through a coil of wire it created current in the wire. A change in the magnetic flux through a coil of wire could induce current in the wire. This phenomenon is now called Faraday's law. These two discoveries showed a very close relationship between electricity and magnetism. In fact, it is believed that the source of both electricity and magnetism is the electric charge. Electricity and magnetism have been unified as a single phenomenon and it is well described by the electromagnetic theory.

CHAPTER 7 LIGHT & COLORS

Light is one of the most important things that we need for our survival. We know about things using light. For example, the eyes need light to see. We need light to survive. The nutrition that our body need come from plants and trees. The vegetation grows by taking energy from sun. The Sun is one of the most important sources of energy on this planet.

What then is light? It is an electromagnetic wave that are fluctuations of electric and magnetic fields. As a wave, we can talk about its frequency, wavelength and velocity. Light is composed of waves of different frequencies. We can use a prism to separate waves of different frequencies. The spectrograph below shows electromagnetic radiations of different frequencies. At the higher end of the frequency, we have gamma rays and at the lower end of the frequency we have radio waves. The light coming from sun has waves of all these frequencies. Of all these waves, human eyes can see only a small portion of light that lies in the middle of the spectrum. Those are the seven colors that we see in a rainbow.

Light travels very fast. In fact, light traveling in vacuum is the fastest moving thing in the universe. Scientists have not discovered anything faster than light traveling in vacuum. According to physical laws there is nothing that is faster than light. Maxwell's law shows that the speed of light in a vacuum is constant. Therefore, irrespective of who measures it, the velocity of light will always be same.

What then is the speed of light? The speed of light is roughly $3x10^8$ m/s. Usually, the symbol v is used to represent the velocity of an object. However, for light, the symbol c is used instead because it is a universal constant. C is an abbreviation of the Latin word *celeritas,* which means swift. The equation for the velocity of light is

$c = f\lambda$, where f is frequency, λ is wavelength of the light.

Even though the velocity of light is really high, it is not infinite. So it takes light certain amount of time to travel from place to place. For example, it takes 8 minutes and 18 seconds for light from Sun to reach Earth. A light reflected off Moon takes about 1.3 seconds to reach Earth. The light from the star that is closes to the solar system takes about 4 years to reach Earth.

One unique feature of light is that it does not require a medium to travel. Unlike sound and water waves, light can traverse in vacuum.

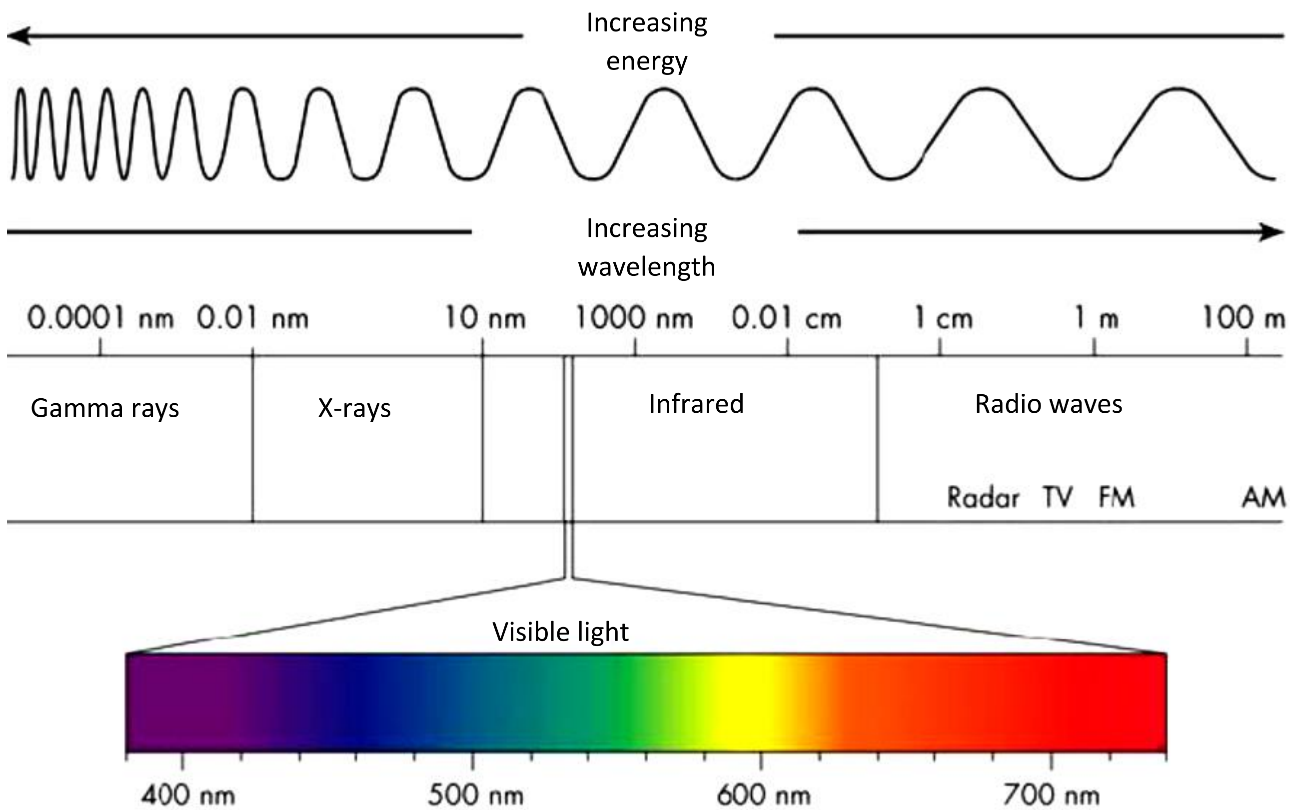
Dual Nature of Light

Although we say that light is a wave and it displays wave characteristics, it does display particle nature as well. We call the light that displays particle nature as photon and it is not considered a wave. Therefore, light is seen as having dual nature. As a wave, light has wavelength and frequency and it interferes with each other. As a particle, which is called a photon, it has momentum and it can push electrons off a surface of metal when light is shone on it. As a particle light has speed, which is same as c, and it can give off its momentum. However, a photon does not have mass.

Color

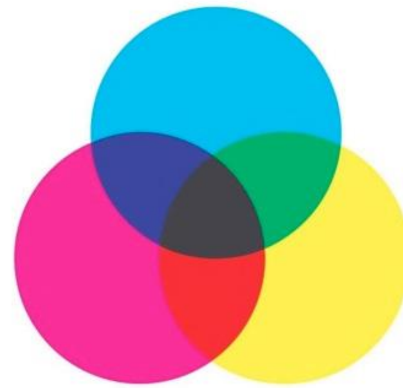
Color of an object and how it is perceived depends on several things: 1) the light that falls on the object, 2) the ability of the object to reflect and absorb light and, 3) the sense faculty of the observing person. To see a flower as red, the light that shines on the flower must have red light in it and the flower must be able to reflect red light and absorb the rest. Thus, an object that appears to us as red can appear to an insect something else. In talking about colors, there can be two types: color of light and color of pigment.

Light, as we mentioned earlier, is an electromagnetic wave and the differing colors of light is based primarily on the frequencies of the light. Human eyes can see lights of wavelengths ranging from 400 nm to 700 nm. So the visible light lies in that spectrum. Nanometer is a very small unit of distance. It is equal to 10^{-9} m. (Figure 22)



Of the seven colors in the visible light, red has the longest wavelength, followed by orange, yellow, green, blue and violet, in decreasing length. We can see the seven colors quite distinctly in a rainbow, that too in that order with red in the outermost ring.

There are two theories of color mixing: Additive color mixing and Subtractive color mixing. Color mixing with light is called Additive Color Mixing. In this theory red, green and blue were considered the primary colors because combination of two or three of these colors in varying amount allows for the production of other colors. For example, mixing of red and green produces yellow and combination of all three, in the right circumstances, produces even white.



Color mixing with pigment is called Subtractive Color Mixing. In order to be visible an object must give off light. The object might be an actual light source or a reflective light source. Objects that do not produce light are colored by a "color subtraction" process. When "white" light strikes the object some colors are absorbed and others are reflected. Figure 23.

Properties of Light

Although light is considered a wave, its rays travel in straight line. We can perform a simple experiment to test this by looking through a straight pipe and a curved pipe. When light travels from one medium to another medium, say from air to glass or water, it exhibits interesting changes. Some of the light is reflected and some passes through the second medium and is refracted.

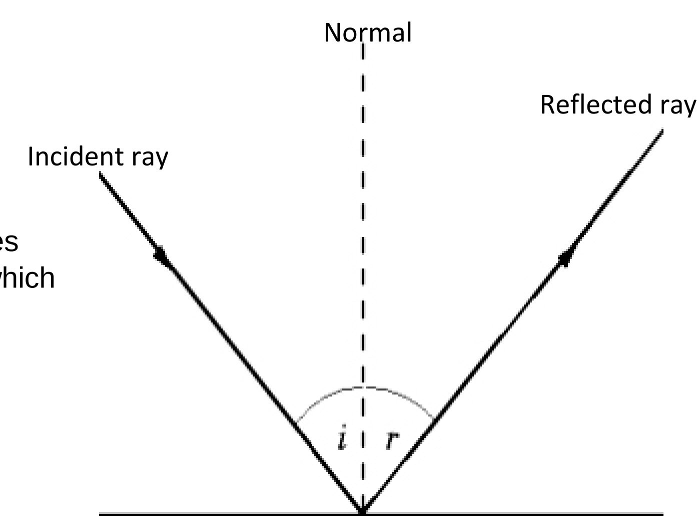
Reflection

Reflection is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated. For a smooth surface, reflected light rays travel in the same direction. This is called specular reflection. For a rough surface, reflected light rays scatter in all directions. This is called diffuse reflection.

Law of Reflection

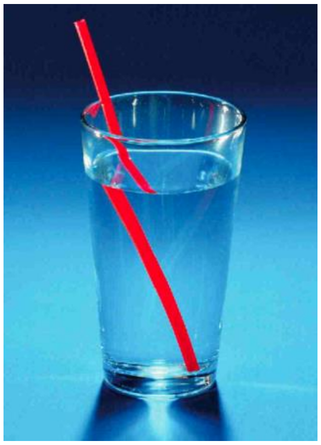
The laws of reflection are as follows:

a) The incident ray, the reflected ray and the normal to the reflection surface at the point of the incidence lie in the same plane.
b) The angle which the incident ray makes with the normal is equal to the angle which the reflected ray makes to the same normal. (Figure 24)



Refraction

Refraction is the change in direction of propagation of a wave due to a change in its transmission medium. For example, when we look at a straw in a glass of water, the straw appears to be bent. (Figure 25) You may have experienced the illusion, created by refraction effects, of the actual depth of a coin when you attempted to pick up the coin from a glass of water. The coin appears to be much closer to the surface than it actually is. The refraction occurs because light is traveling from a medium with higher density, which is water, to a medium with lower density that is air.



The refractive index or index of refraction (n) of a material is defined as:

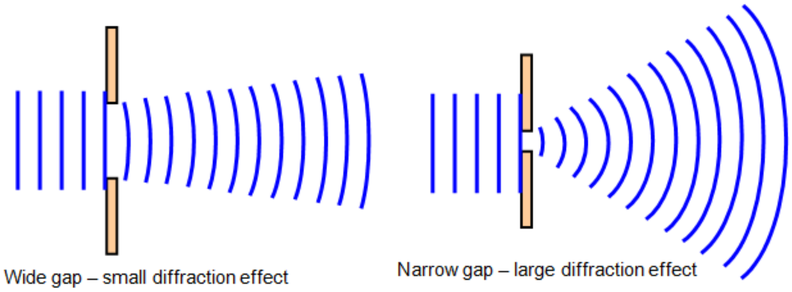
$$n = c/v,$$

where c is the speed of light in vacuum and v is the speed of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times faster in a vacuum than it does in water.

Even though optics also studies the behavior of light in other media such as lenses we will not go into these details.

Diffraction

Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye.

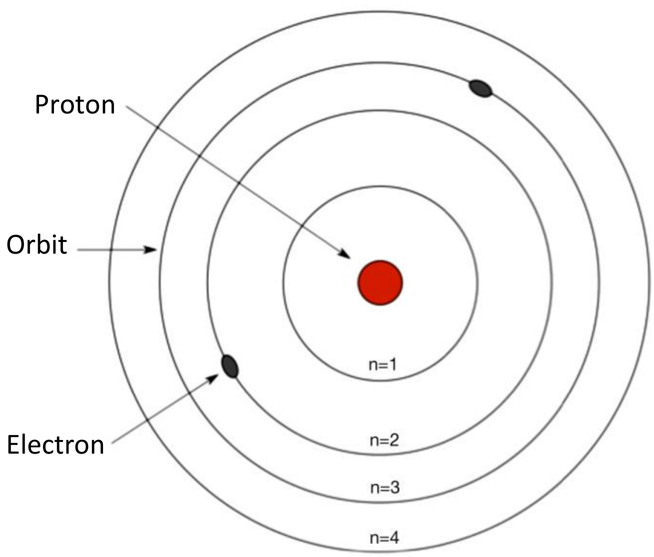


CHAPTER 8 ATOMS AND RADIATION

Bohr's Atomic Structure

In 1913, the Danish physicist Niels Bohr proposed a new atomic theory for the hydrogen atom based on quantum theory. Prior to this, scientists had already discovered electron and proton, which they knew were constituents of atom. Various atomic models had been proposed to explain the fundamental unit of matter.

The Bohr model shows the atom as a small, positively charged nucleus at the center surrounded by orbiting electrons. Because of its rough resemblance to the solar system, the model is also called the planetary model of an atom. Just like the Sun is at the center and the planets are orbiting around it because of gravitational force, the nucleus lies at the center of the atom with electrons moving around it because of the electrical force. This model also shows that the number of protons in the nucleus is equal to the number of electrons orbiting around it.



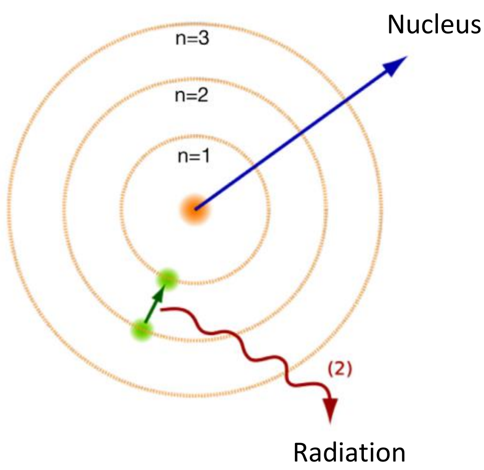
Energy Levels

Bohr's atomic structure has three main ideas:

1) Electrons assume only specific orbits around the nucleus. These orbits are stable and called "stationary" orbits. Each orbit has an energy associated with it and the electrons must have that specific energy to occupy the orbit. These orbits are sometimes referred to as energy levels.

2) The amount of energy associated with the orbit depends on the size of the orbit. The smaller or the orbit closest to the nucleus has an energy E1, the next closest E2 and so on.

3) Light is emitted when an electron jumps from a higher orbit to a lower orbit and absorbed when it jumps from a lower to higher orbit. When electron moves from one orbit to another, it must either absorb or give off the exact difference in energy between the two orbits. It can neither take nor radiate any random amount of energy.



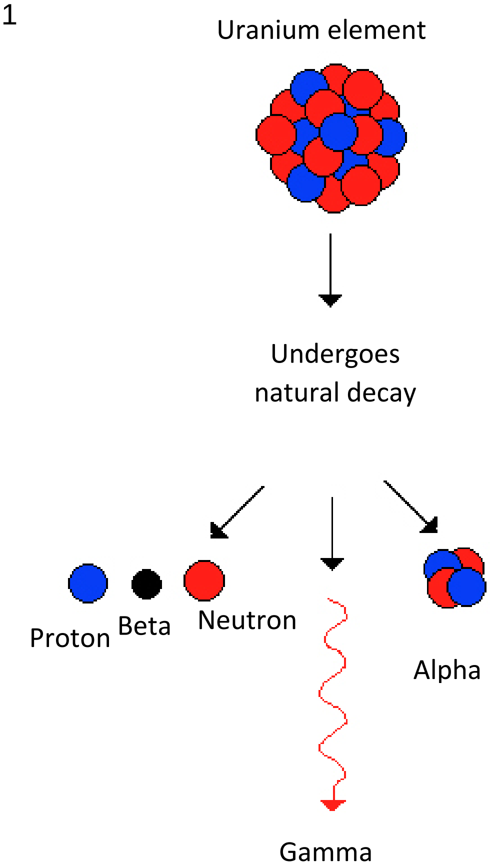
Some Useful Terms

The atomic number (represented by symbol Z) is the number of protons found in the nucleus of an atom of that element. For example, the atomic number of hydrogen is 1 and that of carbon is 6. The mass number (represented by symbol A) of atom is the sum of the number of protons and neutrons in the nucleus of that atom. For example, the mass number of carbon-12 is 12 because it has 6 protons and 6 neutrons in its nucleus. Oxygen-16 has 8 protons and 8 neutrons in its nucleus so its mass number is 16. Atomic mass unit (amu) is the total mass of an atom, which consists of the mass of the nucleus plus that of the electrons. It is defined to be 1/12 of the mass of an atom of carbon-12, or 1.660538921 $\times 10^{-24}$ gram.

Radioactivity

Radioactivity refers to the particles and radiation which are emitted from nuclei as a result of nuclear decay. Usually, radioactivity occurs in the heavier elements. Materials made up of these elements are called radioactive materials. However, it can also occur in various isotopes of lighter elements as well. Isotopes are those elements that have same number of protons but different number of neutrons. For example, carbon has several isotopes. Those are carbon-12, carbon-13 and carbon-14. Carbon-12 has equal number of protons and neutrons as such it is a stable element. Most of the carbon atoms in the universe are stable.

However, there are small amount of carbons whose nucleus has 7, 8 or even 10 neutrons. These are isotopes of carbon atom and are unstable. When carbon-14 undergoes decay it emits particles and in the process changes into nitrogen. Some of the well-known radioactive elements are carbon-14, uranium-238 and plutonium-239.

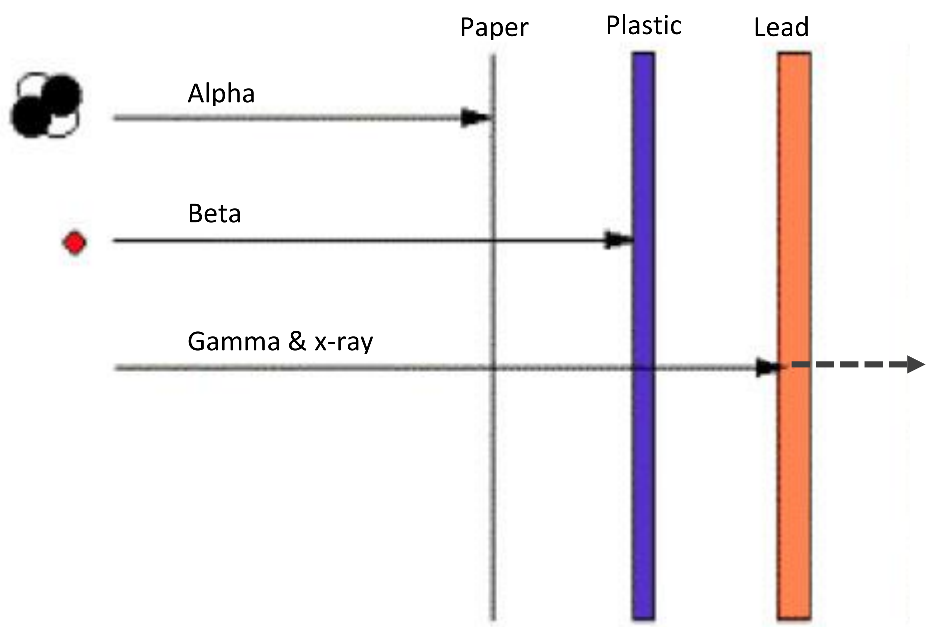


Radioactive decays occur both naturally as well as artificially. Decays occur at different rates for different elements. The time required for half the atoms of a radioactive isotope of an element to decay is called half-life of the element. For example, carbon-14 has a half-life of 5730 years. So if we have 1 kg of carbon-14, half of that amount would have decayed in 5730 years.

Benefits and Harms of Radiation

The radioactivity has many practical uses. It has been used very widely to date ancient objects. This is also used extensively in medical field in treating cancer and other diseases and also in various diagnostic tools. However, radiation could be very harmful for our bodies. Radiations can have adverse effect at the molecular and cellular levels. It can cause cancer by affecting DNA. If we learn how to handle these materials properly then we can reap the benefits without having to suffer the negative effects.

Figure 30

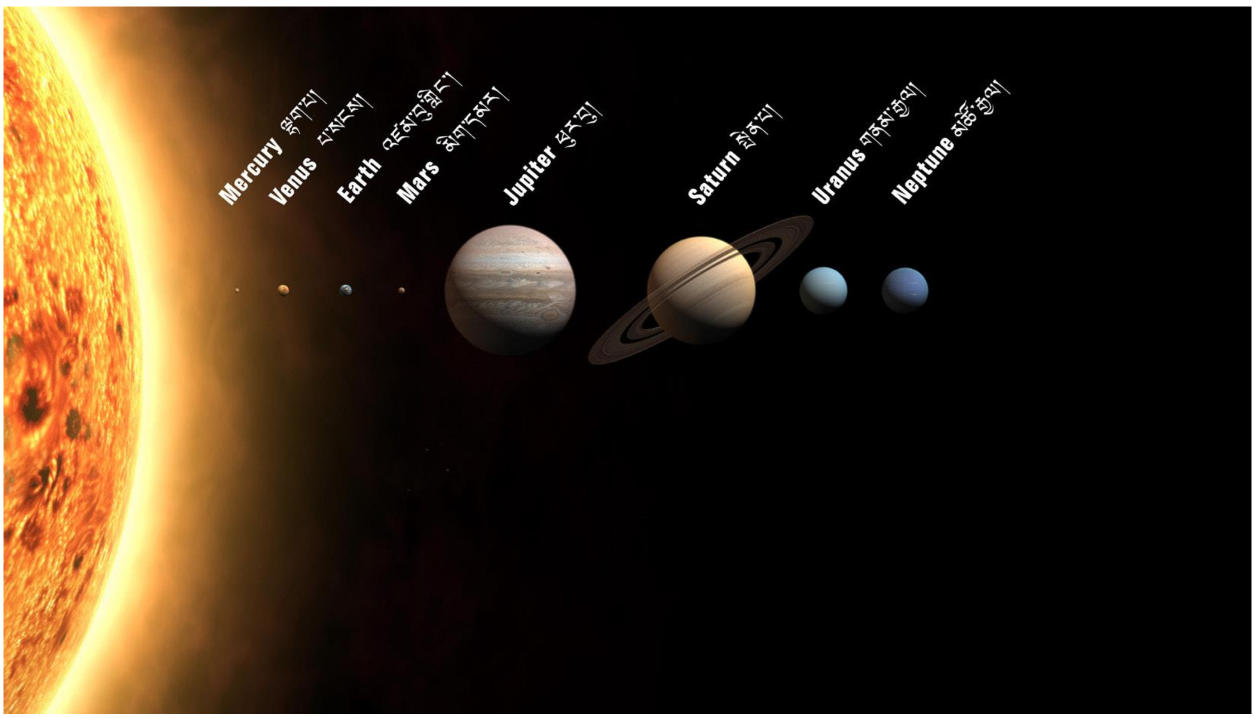


CHAPTER 9 UNIVERSE

Universe is a huge topic for a brief introductory chapter. In this chapter we will discuss two important things: the solar system and the evolution of the universe.

Solar System

Solar system is composed of 8 planets, the Sun, and other objects that orbit the Sun. The eight planets are Mercury, Venus, Mars, Earth, Jupiter, Saturn, Uranus and Neptune. (Figure 31) Pluto was known as the smallest planet in the solar system and the ninth planet from the sun. Because of its small size the International Astronomical Union decided to call Pluto a “dwarf planet”. The table below shows the size for the eight planets and their distances from Sun.



The first four planets are relatively close to Sun and as such these are considered as inner planets and the four giant planets are called outer planets. The inner planets are closer to the Sun and are smaller and rockier and denser. The outer planets are further away, larger and made up mostly of gases such as hydrogen and helium. Of the eight planets, the smallest is Mercury and the largest one is Jupiter. Jupiter is 300 times more massive than Earth.

Like Earth some planets have moons and some don’t. Mercury and Venus, for example, have no moons and Jupiter has 63 known moons. In the region between the inner planets and outer planets lies the asteroid belt which contains so many asteroids of varying sizes that orbit Sun.

The mean distance between Sun and Earth is about 150 million kilometers. This distance is considered a unit of distance and is called Astronomical Unit (AU). This unit of distance is used by the scientists to measure distances between the planets and other heavenly objects of the solar system. For example, the outermost planet of the solar system is 30.1 AU from the Sun, which is roughly 4.5×10^9 km away from the Sun.

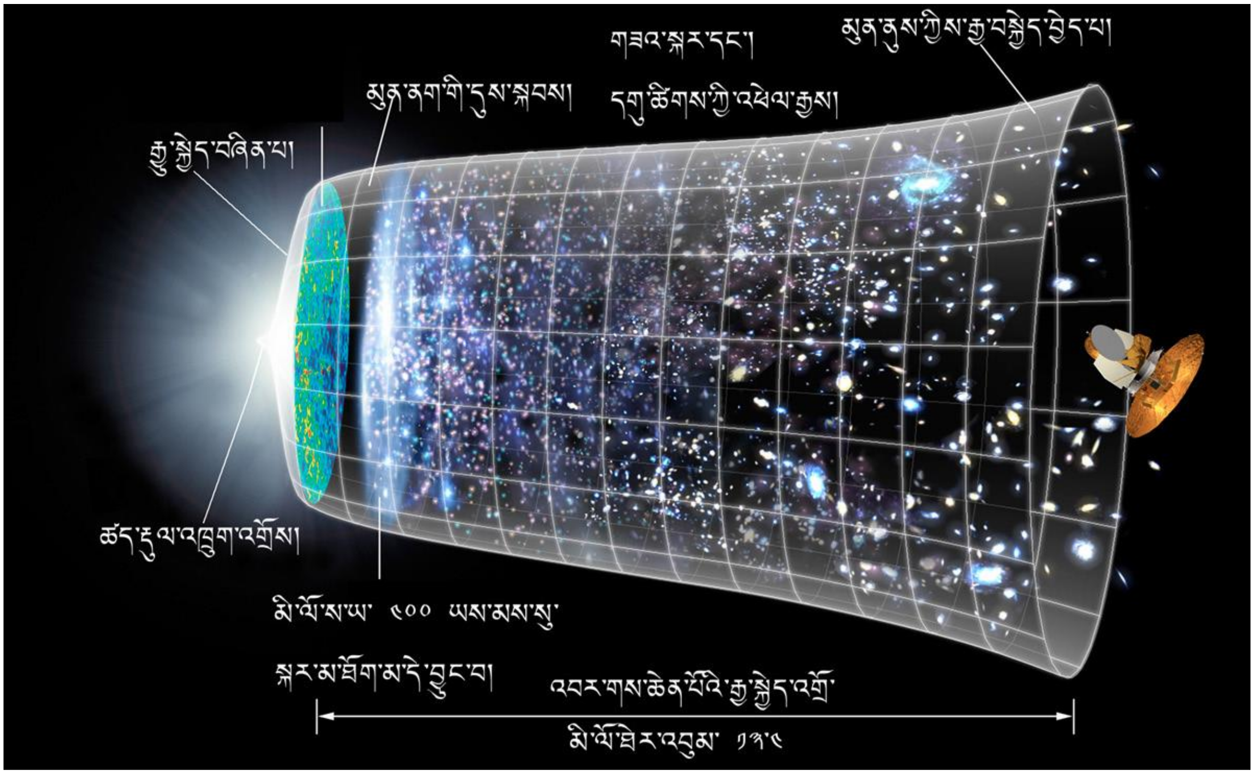
Planets	Distance from Sun	Radius
Mercury	57,910,000 km	4,800 km
	0.387 A.U.	
Venus	108,200,000 km	12,100 km
	0.723 A.U.	
Earth	149,600,000 km	12,750 km
	1.000 A.U.	
Mars	227,940,000 km	6,800 km
	1.524 A.U.	
Jupiter	778,330,000 km	142,800 km
	5.203 A.U.	
Saturn	1,424,600,000 km	120,660 km
	9.523 A.U.	
Uranus	2,873,550,000 km	51,800 km
	19.208 A.U.	
Neptune	4,501,000,000 km	49,500 km
	30.087 A.U.	
Pluto	5,945,900,000 km	3,300 km
(not a planet)	39.746 A.U.	

Universe

The universe is made up of stars, galaxies, planets and many other objects. What is the difference between these objects and how do we differentiate between stars and planets? There are many differences between stars and planets but some of the main differences are:

1) Stars are much more massive than planets
2) Stars have light of their own, whereas planets don't
3) Stars are much higher temperature than the planets, even though many planets have molten cores.

Because of their large masses, stars exert immense gravitational pull on each other and other objects with mass. This gravitation pull keeps the stars together is huge clusters called galaxies. There are countless numbers of galaxies in the universe. And we are on the Milky Way galaxy. If we look at the stars on a clear, moonless night, we can see the Milky Way as a dim glowing band arching across the night sky. Astronomers estimate that there are 100 billion to 200 billion galaxies in the universe, each of which has hundreds of billions of stars. (Figure 32)



When we measure the distances between stars, and between galaxies, then the Astronomical Unit too is too small. We have to rely on a new unit called light year, which is the distance covered by light in one year. One light year is equal to 9.5 $x10^{12}$ km. Proxima Centauri, the star that is closest to Sun, is about 4 light years away.

Big Bang

The most popular theory of our universe's origin states that the universe originated from the big bang some 13.7 billion years ago. This theory was born of the observation that other galaxies are moving away from our own at great speed, in all directions, as if they had all been propelled by an ancient explosive force. In 1927, Edwin Hubble, an American astronomer, while studying the galaxies using a powerful telescope discovered that the universe was expanding. The farther away the galaxies are, the faster they recede from each other. The statement that there is a direct correlation between the distance to a galaxy and its recessional velocity as determined by the red shift is known as Hubble's Law.

If the universe is expanding, then it means that if we move back in time the universe would get smaller and smaller. If we moved back to 13.7 billion years ago, then everything in the universe should be a single point in space. That point is extremely dense and bound by immense gravitational force. Some yet unknown factor caused this to explode and expand, thus creating this universe. This explanation is called the Big Bang Theory.

Hubble Space Telescope is one of the most powerful telescopes and it is orbiting the Earth. It is used by the astronomers to look deep into the space and find new objects. Most of the images of the deep space that are being published in newspapers and journals these days are from Hubble Telescope.

Some Interesting Features of the Universe

There are approximately 10^{11} galaxies in the universe and each galaxy contains roughly 10^{11} stars. So in total there are 10^{22} stars in our universe. Despite this many stars, less than 5% of the universe is composed by normal matters and energy that we are familiar with. It turns out that roughly 68.3% of the universe is dark energy. And about 26.8 % is dark matter according to latest findings and calculations. Dark matter and dark energy, as indicated by the names, are invisible to us. Their existence is just theorized based on the increasing rate of the acceleration of the universe.