CHAPTER-1
INTRODUCTION

1.1 General Introduction

1.1.1 A Brief History of Science

Science is attainment to give a logical, rather than religious or miraculous explication of environmental sequence. Members of society belong to various regions all over world starts to progress science at time to time emphatically. At the beginning, most of the people, considered the schedule along with accurately equitable way, to confirm the duration of time in 6 second. They had drawn the path of motion of planets, moon as well as sun. Further, these people followed ‘placeable method’ for decade number at that time, while Roman people used a new notation at that time for each new power of decade. First European attainments were made to give rational description of working of the environment that start with Greeks early in the year. Pythagoras and his supporter make devotion; to study the number system belongs to a religious alliance. They believed that, world should be similar to the entire number system divided into definite number of components. They introduced complex number system like root two, which cannot be written as a ratio of complete number. This has been dangerous menace to above system, so the past tells about the murder of Pythagorean who published mystery rational number system.

The Greeks Leucippus, Democritus as well as Epicurus kept ahead the assumption, in which the materials are consisting of very tiney particles. This dissimilar substance is being prepared by dissimilar association of the tiney particles. Aristarchus Samos was the first, who offered that, the earth revolve within 360 days about the sun, instead of the natural clarification that, the sun revolve about earth. Further, he also calculated the corresponding areas of the earth, sun as well as moon. Though, it was not essentialy think by the Greeks for examination of such hypothesis preliminary. After this, almost of them were seeing that, a self-accordant clarification of the universe is based on a little numeral of a thoughtful rule.

Aristotle has got credit because, he provided almost all-inclusive clarification. According to him, there exist four earthly components like blaze, liquid, aura, as well as earth and everyone has their normal position established by its mass. He found that,
there are three layers in which land-water layer, water-air layes, air-blaze layer one above each other respectively. Above sequence makes natural perceptive. Frozen masses submerged under liquid; if gas delivered inside liquid the gas burbles to the facade; and flames leap outward in the process of burning. Now, moon is very small in the sky by showing its visibility as compared to other stars, and they were constitution of fifth element, which is without weight. According to Aristotle's, motion of any object is considered with respect to other moving object. Otherwise, it is at rest. Hence, it was said by Aristotle that, a vacancy is not possible so this explanation of pointers motion was again interiorly accordant.

The natural science, which exhibit allied and arranged watch of the nature, progressed with the raise of Greek people. Greek life style and scientific thought was first grown-up the Ionian seashore of Asia little about the sixth century and after the Aegean islands and the Greek community in southern Italy. One of the epoch-making episodes was that, Greeks established association, such as the association, the gallery. Plato (427-347 B.C.) founded the academy on the boundary of Athens, while Aristotle (384-322 B.C.) established the gallery in Athens in 334 B.C. This association was powerfulness to be contemplated as the first standard of the research organization of latest times. Elementary, person lived on the greenery and berries, and the animals and fish that they handled to grab. As the centuries passed out, clusters of killers launch forming settlements and very little settlements bit by bit expand into communities as well as cities. Category of worker was necessary in any grand town, with an classified into community framework, and further forward looking of the worker category resulted in some human becoming specific in brain games, such as contemplate about the center of the infinity or underlying canon of the corporal earth. Some people were trained in forward applied science, which might have conduct to foundation of institutions. Thus, the organization of the educational institution of the Lyceum might be concerned as a natural source of the advanced nation of ancient Greek towns. Number of important accomplishment was created by Greek thinkers; ancient Greek body of knowledge never belongs to a self-maintaining company. It may be the grand heritage that, Greek outlook left-hand to experience the various pattern of coherent and objective think of human beings, such as to made hypothesis, to infer and to prove. Additionally, the
Greeks viewed us that, how to explore for a single opinion of everything in the cosmos is characteristic of civilian. Aristotle was the greatest Greek philosopher, who explained a large range of natural phenomena and theorized that, all the thought should happen in accordance with general principles. He accepted the abstraction of Empedocles, that whole substance was created by four primary elements.

The Greeks were taken more achievement to explicate the orbitory motion of the stars, the planets, and the moon as well as the sun. This orbitory motion played very important character in progression of advanced technology. The asteroids are at very large distance from earth, so that, their relative revolution can’t be detected apart from some generation of periodicity. Hence, somebody on the surface of earth observed that, the asteroids are supposed to be finding stationary in earth’s globe. This globe revolving with fixed velocity around the earth and the speed of the earth is slightly greater than once in period of day and night. It comes back to original place at a given interval of period at single day in each year. In the same way, the sun as well as the moon comes to recline on same spheres that revolve around the earth only for one time per day also occurs in a single time per every twenty seven days. It is difficult to the observers on the surface of the earth; to observe the motion of the planets. As we know that, the orbital distance of the planets with respect to the sun as well as period of revolution on orbit is continuously increases as planets moves away from the sun. For an instance, Venus which is very close to the earth as well as having very bright planetary neighbours, exhibits 225 days short period as compared to the period of the earth for one year. From this, it is clear that, yearly journey made by Venus through the night-sky as seen from earth surface. The Greek peoples explained above movement with the help of gadgets discovered by Eudoxus, which one was the first Greek, used large-scale examination for invent arithmetical representation.

As the planet having periodic motion, Eudoxus developed a system of spheres, and this system was carried out by every planet in which earth sphere is at the centre but axis of rotation with large sphere is fixed. The above description of the circle which is in perfect geometrical form is fixed by the Greek. Apollonius recommend that, every plane were connected to little sphere with respect to large sphere which is rolled on the central surface of the earth and this rolling is greater as compared to per day revolution.
of the earth. The sphere which is large may be considered for the daily planetary motion, while a small sphere perform retrograde motion. The reliable observations described mathematically increases accurately. This description was planned by Hipparchus, who deliberates conclusion which was reported by Babylonians as well as Greek peoples.

Further, Precession of the equinox invented by Hipparchus, considered that, the sun is 20 seconds more return to the position covered at equinox in every year, which the sun does returns to the stars whose position is fixed among them. Hipparchus attempted the position and brightness of more than 1000 stars for the satisfaction of desired perfect data. During the same period, Ptolemy, who monitored the Alexandria in Egypt- the arrangement of epicycles and eccentrics needed 80 circles to illustrate periodicities aware by the heaven? Most of the contribution made by Aristotle in the field of science related to biology. In his contribution, he categorized near about the species of 540 animals. In this classification, he carried out careful dissection of minimum fifty various animals.

For all time, Archimedes was the most brilliant researcher among the 3 greatest persons during the period 287 B.C. to 212 B.C. Archimedes discovered the new screw for embossed liquid, which establish rule of buoyancy of a mass in water. Further he computed perfect significance of $\pi$, between other activities.

In the course of European science, Archimedes focused on Aristotle’s attitude, which was intrested towards the role of women. Generalzation of Animals proposed by Archimedes, he cleared that, male is somewhat better and more heavenly as compared to women, regarding the principle of acivities to produce gear. Also in the ordinary course of nature, female serves the matter, which we should look upon her state of deformity.

**The Dark Ages:** At the end of Roman, there was starting of Dark Age. The discovery plough as well as disc of water was done at the time of Dark Age. During the time of Greek kindom, the information related to science was migrated into Egypt without ending the learning in dark ages. The human living in these areas not only converted above information in Arabic language but also supported to it. Scientists of Arabs in their colleges discovered most important phenomena of light called refraction. In this
time most of Indian technical data was interpreted in to Arebian, further which was used in India in the form of algebra as well as character. During this period, peoples of Arabs were transported some paper of art to west which was produced in china. During this time Arab people has preserved all these data into their words, which we are using presently.

**The middle era:**

The academician work in Europe in the course of the dark ages (from gravitate of Rome to the starting of the central era, or medieval time about one thousand one hundred) had been troubled with the cheating of church manuscripts. It should study first in the cathedral college. These colleges grow in to the first institutions, with colleges in Cambridge and Oxford. In Oxford, there were number of colleges in which work of progress in physics was carried out. In Oxford, scientist William has found the reason behind the rotation of body. Further Aristotle declared that, any object performing rotational motion was not necessary to have connection with other moving body in order to stop its rotation. But rotation of body depends upon energy stored in the body. Above concept of Aristotle provides support to the present advanced theory of thrust. This canon gives good philosophical theory, that other gears are parallel, which was the beginning of some new appropriation. That was significant because it supplied an objective means for selecting between two assumptions. Several of the ahead of time scientific inventions were prepared in east but some circumstance of latest physics is basically present in west. Hence at that time, the phenomena of universe such as balance description as one of future that was predicted cosmologically.

**Rebirth of Science:**

Greek and Arab were discovered education, for all peoples which in turn has produced intelligence as well as good educations in Europe. This work result into providation of much more fresh education which can be further expanded. In Germany, scientist Durer discovered painting, which was considered as the starting of arts. Further in Italy, Michelangelo developed education in order to built up better living of their sculpture through education which was responsible for generation of orchestral tunes. In Wittenberge cathedral, scientist Martin has written ninety five theses in which he described the redevelopment of objector. In 1492, Columbus was coming towards
America at the same time European has done number of invention. During this time, unfortunately, there was also the termination of much more human educations which were take place in Europe. Further they quietly trusted that non-Christian life style was worthless.

However, in the time of the rebirth Aquinas consolidation of Greek people, as well as personally Aristotelian, attitude along Catholic religion ultimately produces lot of difficulties to the church. Further scientist Copernicus advised motion of the earth as well as motion of all satellites that they are moving about the sun, instead of doing the opposite motion. According to Aristotle, as well as many of canonical declarations, it was assumed that, the earth being at rest position instead of doing motion. If earth was moving and it was at the center of universe, otherwise paradise was not beyond the sphere of the asterisks. The approximation of earth in motion was so rotatory that, Copernicus did not ready to publish his data until he was on bed (1543). Under Galileo, rebirth has seen the beginning of advanced science. Galileo has done important contribution in defining the role of scientist. According to Galileo, purpose of scientist was that, they do not only explicate the existence of matters in the universe but also represent them properly. Galileo has given verbal explanation of phenomena which occurs in nature with the help of mathematics. Further he also confirmed such phenomena experimentally in order to see the given description about the phenomena of nature is right. This was the second major contribution of Galileo in terms of various phenomena occurring in the nature. Above description produces more difference as explained by Aristotle in his qualitative skill. But some of them were approved with realism. In universe, every body has their proper place, because they are made due to the earth matter. But using Galileo’s description one can explain mathematically that, how long time body was remains in motion and then stop. They confirm by doing experiment and finally told that, the given description was right.

This idea of Galileo was applied in the mechanics for the body which was falling, further which was constructed with the help of impulse theory. Galileo had made prediction that, all bodies having equal masses take same rate of time to fall. Therefore, distance covered by the falling body was balanced and it is equal to the square of the slip away period of coming down. The reason behind this is that, in open, targets moves
very fastly in downward direction. Galileo has measured the magnitude by rolling down a body on smooth surface. Even though, in absence of watch in that period for perfect measurements that Galileo has recorded. Stillman Drake was the student of Galileo, and he famed that a human can keep period while vocal with accuracy of about 0.01 sec. Galileo is best known for his backing to Copernicus representation of the cosmic arrangement. When Galileo find out the innovation of the telescope, further he prepared and makes one telescope for itself. This is the first telescope workable for astronomical examinations. He observed that, the Jupiter had moons, and it is tiny pattern of the solar arrangement with in it. Moon and Venus, both have equivalent states because they were inside Copernicus arrangement. Therefore moon has similar structure that of earth because mountains were present on the moon. After his support to the Copernicus theory, he was arrested in his house even although he denied when front with the dead punishment. During this time, he developed mechanics up to the extent at which he commit why planetoid can not drop in to sunshine.

Francis Bacon (1561-1626) has given more philosophic bottom for advanced scientific technique. His big job is issued in 1605 and 1620, were much important in providing the access to science ahead the 200 years. Bacon had a confidence that, the kindness of man could be increased by science. This confidence in people development, that kindness is rolling forwards to some supreme state of gladness in which battle, exhaustness and penury will be stamp out. Part of this eye sight was his trust justified in the birth history of making, in the good of human to controlling universe. This goodness of authority around the remaining of universe also ran a guiding canon of body of knowledge and modern innovation for most of the duration since Bacon. Bacon’s sense was normally technical, subjective and preliminary. Bacon removed a deduced hypothesis such as concept of the integrity of circular rotation used by the Greeks. France scientist Rene Descartes offered various accesses in evolution of body knowledge. Descartes trusted that, the normal canon ruling character was achieved by the union of clean argument and trigonometrically logic (“I think, therefore I exist”). He stated logical access that includes some question in his topics which can be organized with proper reason, a skill which is calm used in body of knowledge at same day. It is called as mechanism, because its normal appropriation is that, we can lowest a marvel
to a cluster of free elements. This access has control scientific accurate discovery through the last 300 years, and has confirm highly profitable in a region in which the sections are longer free. Holism the reverse of mechanism, simulate that few wonders, at lowest, can sole be accepted as united gross, and so can’t be busted down in to free sections.

Descartes really believed that, God had made and cut up the method at starting, and it had moving ever, since inside the rules of mother-nature outside more agencies. The one divergence to a gadget was the heart of a man, which is godly and apart from the automated body. As we know that, animal does not have a brain, so they work as a machine and they does not feel the pain. During that time, there were Cartesian supporters who would cut out animals to display how the gadget created by mother-nature could mimic distress. Therefore, from many years, the world can be treated as a gadget, and was built-up by Newton’s mechanics. In 1812, Laplace had made the statement that, if informations for a given point realize all the strength, which active Mother Nature and the corresponding place of whole thought. Formation is sufficiently large, such that it can analyse these data. Biggest masses of cosmos and masses of minimal molecule must be evaluated using single formula [51, 54, 59, 61and 62].

1.1.2 Development of Physics

There are difference between basic and social sciences, and both are related to nature, which the physical properties of the matters, as comes out through human experiences. As we know that, the study of various types of energy and matter are done under subject of science called physics. Composition of material, its structure and interaction between particles of matter, energy associated with matter and momentum associated with material are also studied in physics. In other way, one can say that, physics is the subject of science related with the nature and it do the study of properties of matter like inertia, elasticity and energy of matter. Studies of motion of heavy bodies in medium and through space with time are subject of physics.

Physics includes subjects such as mechanics; heat, light, statistical physics, thermodynamics, radioactivity, nuclear reaction, and other radiation. Physics also includes oscillations and waves, special theory relativity, semiconductor materials, solar cell, different form of energies, structure of matter, Doppler Effect, sound wave,
electromagnetism and atomic structure. Starting of subject physics is not definite, but it was assumed that, the birth of physics was from the belly of mythos and illusion, and the technological cosmos vision exponentially comes-out from cabala. The collection of knowledge with the help of experiments and through the observations becomes Physics as a large subject. In physic, only listing of human experience is not sufficient but also it believed on experimental observations and results.

Generally, in physics the accurate results can be obtained by repeating the experiments number of times that means, symmetrical systems behave symmetrically, which makes rechecking of results easy. Scientific assumption need to be devised so as to provide him self to re-examine or even to be invalidated. In number of cases, only single projection demand is confirmed inaccurate to confound assumption.

In physics, phenomenon is normally experimental and a truth is normally the effect of people analysis. Speculative details are the register of people attention and the phenomenon are phrase of how we recognize the applicable corporal event. The perception and interpretation of physical event depends upon person to person, so that it is noted that, everyone contributes the understanding of physical events with the help of learning. Any physical quantity can be signified with its measurement by some proper method. From many years, human mind is in puzzling situation; Aristotle has tried to understand the behavior of animal and after that, the scientist Descartes had proposed the model of function of the human brain. Further, with help of hydraulically state, as well as brain function, we can understand, perceive and describe the physical laws. This happen because human brain is combination of tremendous amount of nerve cell called as ‘neuron’. Hence, the scientist all over the world explained some basic concept and some scientist try to explain the idea of rational through that forward formation of new physical laws.

Further, the study of activity of human brain provides few good expectations, which solve the difficult problem of body mind to decide the progress of physics is so difficult to and it likely to put in a black box. Now a day, human being used different instruments and home appliances, which are produced by science. But we are known about that; it is common to all animal that uses the application of physics. In night bats fly and position of obstacle and their feed using ultrasonic waves, some bats emits
ultrasonic wave with different frequency to find their feed accurately. It is similar to the concept of frequency modulation used in broadcasting. Some bats used the principle of Doppler Effect in order to find the distance between it and its feed. Some moths has ability to capture supersonic wave coming from bats and passes towards the bats, so as to disturb them and they run out from the bats. There is number such examples, in which animals uses science. It is well known that, animal have ability to adjust them with nature to survive their life. We also known that, human being is familiar with physics, so that small babies look towards a body in motion or when different sound is produced, they do face towards sound. Small children’s are more sensitive to what is happening in their surrounding medium and they try to learn from that.

Small children learn language totally by listening other people’s conversation independently. When some toys placed in front of children, they try to pick up the toys; children repeat to pick up toy again and again, as result their arm is capable to hold the toys. When, we hold body of large mass or toy of large mass without shape, the child hold the toy and trying to stand up. From his, child understanding that, large toy is heavier than the small toy. Hence, it is one type of conclusion drawn by physicist depending upon observation made from child.

We can say that, people have used number of physical process and other processes in their life. Human being required two thousand kilo calories which was taken from carbohydrates, protein etc. to perform their work. This amount of energy of similar to the electric energy used by hundred volts bulb, since all biological activity in the nature obeys the law of conservation of work. All animals follow the conservation law in their life. Therefore, the learning of science is type of invention and creation, especially; we can say that, in our body number of processes is taking to perform various activity of the body. Hence, it is essential that, each person should learn the science in their whole life. The working of human brain is carried out with the help of nervous system, in which each cell produces electrical signal with exchange of sodium, chlorine and potassium ion. When nerve cell is at rest position, it produces resting potential which is negative milli volt, but the cell is stimulated by external energy, immediately it produces action potential due to exchange of ions. This action potential (electrical signal) is responsible to carry the information in our body. The transportation
of message from brain to other parts or from other body parts to brain is done with help of electrical signal. Thus, this is the invention of electricity [77, 82, 81, 92, and 94].

1.1.3 Branches of Physics

The main aim of physics is to design and carry on the experiments. The other purpose of physics is to study the motion of object and which quantity is responsible to accelerate the object, to investigate energy required to do the motion of object, and identify various types of energies like kinetic energy, potential energy and gravitational energy. The other focus of physics is to study elastic properties of materials. To understand the gravitational forces, this is responsible for holding earth, moon and sun in rotational motion. Another purpose of physics is to study the oscillation of a body and waves generated by body and sound produced from it.

The application of thermal (internal) energy is studied under physics. The other goal of physics is to study the nature of light, and its propagation in the form of transverse wave, similarly, the sound is travel in the form of longitudinal wave. It also studies the Doppler Effect in sound as well as in light.

There are various branches of physics and their sub-branches under which subject physics was studied. The different branches are mechanics, mathematical physics, classical electrodynamics, quantum mechanics, thermodynamics, condensed matter physics, nuclear physics, light and optics, atomic physics, modern physics, thermal physics, biophysics, astrophysics, electronics and sound waves.

1. Classical Mechanics: This subject deals with the study of the motion laws given by Newtons, energy as well as work, various conservation laws; such as conservation of energy, conservation of momentum, conservation of mass etc. It also study the elastic properties of material, consisting various modulus related to materials, the phenomenon of surface tension, viscosity of liquids, planetary motion (Kepler’s law) and motion of object in central force field. It also studies the elastic and inelastic collisions between large bodies or masses. Especially, this subject provides theoretical framework to development equations of motion for bodies that are under the influence of forces.

2. Mathematical Physics: Mathematical physics provides analytical tools required for theory. Mathematics is the language that nature speaks. It provides the sensible basis and total tool cabinet essential for the smooth utilization in physics. It involves the
study of differential equations apply to solve the various equations such as heat equation, Laplace equation, equation of wave motion, Schrodinger equation that are used in quantum mechanics.

3. **Classical Electrodynamics**: Classical electrodynamics is the branch of physics which deals with the study of electric field, magnetic field and electromagnetism. In this, the origin of electric field is the stationary charge similarly when charge is in uniform motion it produces magnetic field. Now, when we studies electric field and magnetic field together, then this is known as ‘electromagnetism’. From the designing of communication antennas to the making of electrical circuits, the field has wide applicability.

4. **Quantum Mechanics**: Under this subject, the study of motion of smallest scale of energy level of atom and bodies, such as light particle photon and up to the sub atomic level and other particles that make of the universe has been done. Also, it studies black body radiation, which obeys Stefan’s law. It study the motion of microscopic particle in potential well, square well potential, perturbation theory, spectra of hydrogen atom, Bohr atomic model, phenomenon of photoelectric effect, uncertainty principle, Schrodinger time dependent and time independent equation, to find the molecular structure. This subject also describes the calculation of wave function associated with particle moving in space.

5. **Heat and Thermodynamics**: It is a core branch, which provides a consideration without practical to study the motion of many particle systems. The motion of single particle is studied in quantum physics rather than the multi particle motion, because there are many variables, which makes calculation difficult. Thermodynamics is predecessor of statistical mechanics. It describes the macroscopic properties of particles in bulk. The principles of this statistical science found applications in finance and economics. The basic theory finds applications in almost any situation where you are thinking about aggregates of particles. This course involves the study of equation of state, critical constant, basic concepts of thermodynamic such as entropy, enthalpy, thermodynamic equilibrium, adiabatic relations and heat transfer mechanism.

6. **Condensed Matter Physics**: This course explains all phenomen comes in material existing in condensed form, which contains metals, semiconductors, and all
types of materials that exist as congregations of matter. The instruments made from semiconductor material are used in information technology, due to this, research progress in this subject. It explains all physical processes in majority material like Ferromagnetism, super fluidity, and super-conductivity.

7. **Nuclear Physics**: This course describes total phenomena, which take place at the bottom level of nucleus of atom. It involves the study of basic properties of nucleus, such as nucleus composition, charge on nucleus, size, and density, volume of nucleus, magnetic moment and electric quadruple moment. It explains topics like radioactivity, particle accelerator and detector, concept of elementary particles, Quarks model of nucleus, nuclear fission and fusion reactions, nuclear energy and different types of nuclear power reactor. Using nuclear energy, the nuclear weapons like, atom bomb, hydrogen bombs were created. Electrical energy is made available to mankind using nuclear energy with help of nuclear reactors which is totally clean energy. Research regarding the building maintenance, and deployment of nuclear reactors forms a major part of research, besides the development of nuclear fusion reactors, that provide completely clean energy at very low cost.

8. **Astronomy and Astrophysics**: Astronomy means the study of various stars and planets present in the universe and study was made on the basis of theory is called astrophysics. Physics has single goal to explain each phenomena which occur in nature. From the explanation of what powers stars, the cataloging of galaxies across the universe using terrestrial and space-based telescope, to the search for extra terrestrial planets, the field encompasses a diverse range of interesting subjects.

9. **Light and Optics**: Thomas Young put forward the dual nature of light. He said that, light has particle nature as well as wave nature. Sound travels through the medium in the form of waves and it were carried by air, and same argument was made Thomas Young for light. He produced interference pattern using double slit experiment, which gives a proof of wave nature of light. Using interference patterns, he measured the wavelength of light. Further, scientist Augustin Fresnel proved that every optical phenomenon was explained with the help of wave theory. This subject involves the study of reflection, refraction, diffraction and polarization phenomena of light [108, 112, 110, 152, and 123].
10. **Modern Physics - Relativity:** In the year 1905, Einstein proposed special theory of relativity. This theory is based upon two basic postulates. The first postulate is the principle of equivalence in which the laws of physics are the same in all inertial frames that is all inertial frames are equivalent. This postulate implies that, mechanics laws as well as electricity and magnetism are invariant under all transformations. This brings a degree of unity between the two and also states that, the absolute inertial frame does not exist. The second postulate was about the speed of light which has constant value also called universal constant. Velocity of light is independent on relative motion between the inertial frames, source as well as observer. Further, this theory predicted that, velocity and mass of an object depends on each other, so that, it is transformed into energy according to the relation $E = mc^2$; when the given mass is moving with a velocity equal to the velocity of light. In the year eighteen eighty seven, Michelson and Morley measured the velocity of the earth in the ether medium by calculating the path difference between two light waves moving perpendicular to each other. Thus we can understand, this is due to negative result, as it is impossible to calculate velocity of earth relative with ether. Therefore, effect of ether is undetectable.

11. **Thermal Physics:** Thomas discovered engine running on steam, which has produced more interest in the science for the study of heat that led to them significant to the industrial advancement, which started in England. Sadi Carnot laid to the proper investigations of engines operating on heat. Working of water wheel is compared with working of a heat engine, in which heat flows from a greater to a less temperature. Joule developed relation between work and heat by rotating a paddle wheel under water. Joules proposed first law of thermodynamic on the basis of exchange of energy, and can be stated as heat supplied to the system plus work done on the system must be equal to the change in energy of system. Further, Clausius indicated that, in any suddenly occurring natural process, the entropy of the system always raised. Hence, he proposed thermodynamics second law. Thus, thermodynamics laws form basis of thermal physics [166, 234, 251, and 308].

12. **Bio-Physics:** This course involves the study of biological problems occurring in the body, such as function of brain, working of heart, function of eye, function of kidney,
function of liver, function of intestine, function of nerve cell etc., which generates electrical signal and many other functions related to human body using physics.

13. **Electronics**: Basically electronics can be classified into two branches, analog and digital electronics. In analog system, quantities are changing continuously, while in digital electronic quantities are changing in steps. The term digital implies a system of counting using discrete units. A digital computer means its ability to use logical functions to perform various operations. This subject contains the study of various instruments that were made from semiconductor materials. It also studies the working of transistor, amplifiers and logic gates.

14. **Sound**: Physics includes many subjects; from that main subject is sound. Sound plays most significant role in the modern world. Sound waves have large number of applications in various fields depending upon their types.

15. **Laser**: Laser means light amplification by stimulated emission of radiation. Laser action takes place by stimulated process in three levels as well as four level pumping schemes. This includes types of lasers, such as solid state laser, semiconductor laser, gas laser and laser cavities. It examines the development of population inversion in low density material as well as in three or four level systems of high density materials. Laser has many applications namely in military, medical field, in agricultural field, in surgery, laser printers and in number of industries etc.

16. **Solid State Physics**: Solid state physics has great importance during the last few decades because of many far reaching discoveries in this field. It provides knowledge of the electronic structure of solids especially metal, semiconductors and dielectrics, which helps to prepares materials of desired properties. In this course, the structure of crystal and bonding among atoms or molecules is studied. Electrical properties of metal, magnetic and dielectric properties of material, study if semiconductors, superconductivity and study of nano materials are done under this subject.

1.2 **Basic Theory of Waves**

A wave is oscillatory disturbance produced at one point and it is transmitted to the other point by the way of vibration in which energy is transferred through the medium or vacuum. There are three types of waves:
1. Mechanical waves: These waves are well known to us, because we can produce them regularly; the simple examples are ripple waves, sound waves produced by vibrating body and wave produced at the time of earthquake. These waves consisting of two main features that are given by Newton's laws and they can be present only in the material medium like water, air and rock. When these wave passes through the medium, due to its disturbance medium get deformed.

2. Electromagnetic waves: We are less known about these waves, but we use them constantly. These waves are produced due to the superposition of time varying electric field and magnetic field and both fields are mutually perpendicular to each other. The examples are short and long radio waves, IR radiations, UV radiations microwaves radiations, and gamma radiation etc.; we know that, no material medium is necessary for the propagation of E.M. waves and they are produced by vibration of electrical charges. In similar way, earth gravitational field generates gravitational waves due to the oscillation or displacement in gravitational field. E.M. radiation is the energy, which propagated through vacuum or through a material medium. Scientist Maxwell was found the presence of E.M. waves and in the year eighteen sixty four he put forward the theory of E.M. waves, saying that sun light, black body radiation and other types of energy have the same nature as that of E.M. waves.

Further, Maxwell made noticeable observation that, when electric charge is in motion, it produces electric and magnetic field that are linked with each other and travel in the space in the form of E.M. waves. Heat energy reaches us in the form of infrared radiation which is a type of electromagnetic radiation. The entire universe occurs in the form of EM radiation. Modern communication devices and medical equipment’s are depends upon each other. We know that, life of all living things on the earth depends upon E.M. waves coming from the sun. The eyes of many animals including those of humans are sensitive to E.M. radiations- called light, which containing the visible portion of electromagnetic spectrum. Green plants are sensitive to the higher intensity of E.M. radiation, which is responsible for the growth of plant done through photosynthesis process.

Our daily life is depend upon electromagnetic radiation produced by man, food is warmed in microwave ovens, airplanes are directed by radar waves, television, radio
and cellphones uses electromagnetic waves transferred from broadcasting stations, and heater gives out infrared waves which warms us. Ultraviolet radiation cannot be seen by eye, but its effect causes pain from sunburn, U.V. radiations are harmful to our life. Similarly x-rays are useful in medicine, with the help of x-ray physician notice the internal parts of the body and internal structure of crystalline solids and Gamma radiation, which given out from nuclear reactions and radioactive disintegration have high energy so they are harmful to living system. Before Maxwell, in 1820 Oersted discovered that a current carrying conductor produces magnetic field around it and Michael Faraday showed that a varying magnetic field induces an e.m.f in coil. In 1887, scientist Hertz has given experimental proof of the validation by creating the first man-made E.M.radiations with their properties. The Faraday-Maxwell-Hertz theory of electromagnetic radiation tells that no material medium was essential for the transmission of electric and magnetic field radiation [148].

E.M. radiation has properties similar to the other types of waves like reflection, refraction, diffraction, interference and polarization. The main characteristics of electromagnetic waves are frequency with which it changes over time and its wavelength. Electromagnetic radiation, behaves some time particle-like properties in addition to those related with wave motion. The energy of electromagnetic waves is the product of frequency and integer h, in which h is called Planck's constant. Visible light and other forms of electromagnetic radiation are nothing but as a stream of photons, having energy which is directly proportional to frequency.

Electromagnetic spectrum consists of wide range of frequencies or wavelengths, and orderly distributed according to their wavelengths or frequencies in the form of separate groups and different properties. Since the range of electromagnetic spectrum is quite large, it is expressed in logarithmic or exponential scale. As stated in Maxwell’s theory, electromagnetic radiations travel through the space with the velocity equal to the velocity of light and they are differing by frequency. It is not easy to decide higher limit to the frequency spectrum of the electromagnetic radiations.

3. Matter waves: These waves are commonly used in modern technology. Matter waves are related with negatively charged particle, positively charged particle, other
elementary particles and even atoms and molecules. Because matter is made from these particle and waves associated with these particle are called matter waves. 

**Mechanical waves consists water waves, sound waves and seismic waves:**

i. Water waves: As wave advances through water, alternate compressions and rarefactions of the water are formed along the direction of propagation. There is continuous variation of pressure and volume of water along the direction of propagation. Therefore differential equation of wave motion of longitudinal wave is developed in terms of variation in pressure and volume of fluid.

ii. Sound waves: We are familiar with sound of different types. Now a day’s, modern civilization has provided number of sources of sound but people living in city want to go away from them. The railway, two and four wheeler motor vehicles, aeroplane, industries radio etc. produces too much large sound; that the person, who wants a peaceful life. However, they have a need to produce sound proof buildings or want to move away from the city. But sounds are so much interesting. We speak to each other by producing different types of sound from our throat and mouth. Sound has physical nature, which is most important, that is how sound is generated, how it travels through the medium from one place to other place and how it produces sensation to our ear. The refraction or bending of sound takes place due to the wind so that wave front bends towards the region of lower velocity. Velocity of sound falls with fall in temperature and it will bend towards the region of lower temperature. In the day time, lower layers of atmosphere are at larger temperature, this cause effect on the direction of propagation of sound and it is same to that of wind blowing in the opposite direction that is wave front bends in upward direction. In the night time, the lower regions of atmosphere are at very lower temperature as a results wind is blowing in the same direction as that of propagation of sound that is it bends in downward direction. Thus in former case sound is heard over short distance and in later case sound is heard over long distance.

Sound wave is one form of energy that travels in the mode of waves which are progressive and longitudinal. The sound is due to vibrations of some material body acting as a source. Due to vibrations, compressions and rarefactions are produced alternately and they travel in the medium. Depending upon the frequency range, the sound waves can be classified in to three categories-
a) Audible waves: These are the sound waves having their frequency in between 20 Hz to 20 KHz and can be heard by the human ears. These waves are produced by vibrating bodies such as vocal cords, air column, stretched strings and stretched membrane.

b) Infrasonic waves: These are the waves having frequency lower than the audible limit (below 20Hz). These waves are produced by large vibrating bodies, such as vibrations produced during earthquake and vibrations of pendulum.

c) Ultrasonic waves: These are the waves of frequency higher than 20KHz. Human ear is not sensitive to these waves, but animal like dogs, birds and bats are sensitive to these waves.

Sound energy progresses in atmospheric pressure and travel at a great distance. Sound is the physical phenomenon that encourages the sense of hearing. Sound is generated by vibrating bodies in the form of waves producing compression and rarefaction in the air. Sound waves have some important characteristics and properties. The sound waves have characteristics such as frequency or wavelength, intensity, pitch, loudness, quality or timber and velocity. At typical temperature and pressure, wavelengths of sound waves lies between 17m to 17mm. further, sound wave intensity is that quantity of energy crossing per unit area around a point in one second. Intensity of sound wave depends upon amplitude of sounding body, surface area of sounding body, density of medium and motion of air. Pitch is a sensation which determines the shrillness of the sound. Pitch depends upon the frequency but does not depend upon loudness or quality. Loudness is the sensation which determines the degree of sound power produced in the ear. Loudness depends upon the intensity of sound, and related by the relation

\[ \text{Loudness} \propto \log I \]

Similar to the intensity, loudness also depends upon amplitude, surface area of vibrating body, motion of the medium and frequency of the source. Quality of sound allows us to differentiate two sounds of the equal pitch and loudness created by two different sources. The sound is measured in unit decibel (dB). Medium through which wave propagates, decide speed of sound, and it is important property of the material. The first important exertion for the measurement of the speed of the sound was taken
by Isaac Newton. He observed that the speed of sound in specific substance was identical to the square root of the pressure divided by its density.

Further, French mathematician Laplace modified the formula by inferring that the phenomenon of the sound moving is not isothermal, as assumed by Newton, but it was adiabatic. Then he added factor to the equation as gamma and multiple by, and obtained correct equation. Therefore, the final equation is called Newton-Laplace equation. In given equation, \( K \) is the bulk modulus of elasticity of medium, \( C \) is calledspeed of sound and \( \rho \) is called density. Therefore the speed of sound is directly proportional to square root of the bulk modulus of medium and oppositely dependent on the square root of density of medium. Speed of sound varies with environmental conditions, for example, the velocity of sound changes with change in temperature of gases. When the temperature of air is 20 degree and it is at sea level, the speed of sound is nearly 343 meter per second. In renewed water for same temperature the speed of sound is about 1500 meter per second and in iron the speed of sound is around \( 5 \times 10^3 \) m/sec. Sound velocity being somewhat sensitive, due to a second order non-harmonic effect to the sound amplitude and result in non-linear propagation effect. Thus was no production of harmonic and mixed tones in original sound.

iii. Seismic Waves: Seismology is another division that studies seismic waves originated from earthquake. Seismic waves are given out when energy stored in the earth crust released suddenly. The disturbance produce at any place inside the earth end waves through the body of the earth these waves are called as seismic waves. When these waves emerge out and reach the place they shake the surrounding area and gives rise to an earthquake.

The place within the earth where the disturbance begins is known as focus. The place above the focus on the surface of earth is known as epicenter. This point is the center of tremors on the earth and the waves of earth quake are most active at this point. There are four type of waves originated from the earth quake namely, Primary or pressure waves, shear waves, Rayleigh or R-wave and lateral or L-wave.

1. Pressure wave or P-waves: This wave are originated from the focus and travel through the body of the earth at the high speed, these waves are the first to reach on the earth surface. This waves has longitudinal nature and can be transmitted through
both solid and liquid material in the earth's interior, the velocity of pressure waves is given by formula

\[ V_p = \frac{\sqrt{\frac{k+4}{3\eta}}}{\rho} \]

Where \( K \) is modulus of elasticity, \( \eta \) is the inflexibility modulus and \( \rho \) is density of upper shell of earth. Velocity of these waves through upper crust of earth is 5.6 km/s.

2. Shear waves or S-waves: These waves possess transverse nature. These waves travel only through solid material within earth. Velocity of S-waves is less than pressure waves. Velocity of s-waves is given by formula,

\[ V_s = \frac{\eta}{\sqrt{\rho}} \]

These waves are more violent than the pressure waves.

3. Rayleigh Waves or R-waves: These waves originate from the epicenter and travels through the surface region of the earth in a homogeneous medium, the velocity of this wave have been constant. Since the earth has heterogeneous medium, consequently this waves get dispersed and travels with different velocities.

4. Lateral waves or L-waves: These waves also originate from the epicenter and having transverse nature. Hence these waves cause main shock on an earth quake and are responsible for the most of the destruction of human life and properties. The instrument use to record earth quakes and other movements of earth crust is called seismograph. The intensity of seismic waves that is earth quake is measured in scale called Richter scale invented by Charles F. Richter.

iv. Standing Waves: These waves are produced due to interference. When two waves of same amplitude and wavelength travels through space, comes together at some points and move from each other in opposite directions to other points, produces alternative constructive and destructive interference pattern. Standing waves are set up in the strings of musical instruments when plucked.

v. Bow Waves: If any aircraft travels at the speed of sound, it was assumed that this crash-up of sound waves ahead of the airplane forced a sound obstacle and goes faster than the speed of sound; it is essential to plane to collapse the sound barrier. At this
time over lapping wave peaks interrupt the movement of air over the wings, so that making it more problematic to manage the craft.

An air craft with sufficient power easily travels faster than the speed of sound which is called Supersonic. When the bug swims faster than wave speed, it produces a wave pattern which overtakes the waves it creates. The wave super imposed at the corner and creates a V shape, called a bow wave, which seems to be dragging behind the bug. Speed boat moving through the water produces bow waves whose nature is not oscillatory. It is a disturbance formed by the overlapping of number of circular waves.

f) Shock Waves: A boat moving with high speed through the water produces two dimensional bow waves and supersonic aircraft produces a three dimensional shock wave. Bow wave is generated due to the coinciding of circles that form a V shape and shock wave is created by coinciding spheres that forms a cone. Shock wave is the combination of two pinecones in which a higher pressure is cone produced near the bow of the supersonic aircraft and minimum pressure cone at the end of craft. Among these cones, the air pressure increases suddenly to overhead of atmospheric pressure, after that it goes down atmospheric pressure earlier suddenly coming back to ordinary outside the internal tail cone. These higher pressure quickly followed by under pressure strengthens the sonic boom. When anybody is moving with a speed greater than the speed of sound it will produce sound.

When supersonic bullet passes above the head it generates a crack, called as little sonic boom. When moving bullet is larger in size it disturbs large amount of air in its path and crack produced is more boom like. When a lion breaks crack in circus the cracking sound is nothing but a sonic boom generated by the tip of the whip when it moves with a speed which is above to the sound velocity. But in this case, a bullet and the whip are not sources of sound, but when they are moving at supersonic velocities, they create their individual sound generating shock waves.

Wave is produced due to the vibration in which energy is transfer from one place to another place. Frequency is the number of oscillation per second. In wave motion energy is transferred from one point to other point, in which there is no actual displacement of particles of the medium. The term wave means a transport of disturbances that are generally not considered as a motion of the medium. In case of
wave motion, the energy of oscillation is going away from the source in the form of disturbance in the nearby medium. When a particle moves through space, it carries energy and momentum with it. Whenever particle goes, the energy goes with it; this is one way of transport of energy in which there is actual displacement of particles of the medium from one place to another place. The way of transport of energy is that the particle of medium vibrates about their mean position and energy is transferred from one particle to other particle. This process of transfer of energy from particle to particle continues and the disturbance carried forward, hence oscillatory disturbance travel through a medium by the way of vibration. This is called wave motion. For example waves over a stretched string, light waves, sound waves, and seismic wave’s etc. waves are given by a wave equation which shows how the disruption passes over time. The equation varies in accordance with type of wave. The activities of particles in quantum mechanics are explained by waves, gravitational waves also move in the space, which are generated due to the oscillation or displacement in gravitational fields. The explanation of waves is thoroughly related to their physical source for every precise occurrence of a wave process. The sound waves are associated with a mechanical wave and different from E.M. wave. Therefore the concept like mass, momentum, inertia, and elasticity must be valuable in explaining acoustic wave processes. This difference in origin of the sound wave and electromagnetic wave presents definite wave features specific to the properties of the medium. Other properties, however, even though frequently explained in terms of source must be widespread to all waves. Due to above reasons, wave theory signifies a specific section of physics that is related with the properties of wave methods autonomously of their physical basis. In case of audile waves, the disruption that is traveling in space can be present in the medium if the medium is neither extremely stiff nor extremely pliable. If every part that makes the medium were strictly bound with medium, then all parts vibrate together without lake of time in the transmission of the vibration and therefore there is absence of wave motion. In other way, when total parts were not dependent on each other and then there is no any type of transmission of the vibration and result in to absence of wave motion. Inside the wave, the period of a vibration is dissimilar for neighboring points in the space because the vibration takes different times to reach these points.
If we assume the oscillation of material medium which consist of ‘sound’ in its largest view, we have a similar state of matters. Sound is form of energy produced during mechanical vibration and it is propagated through a medium which causes motion of particles of medium. The occurrence of propagation is not a simple it gives the relationship among the parameters of the sound wave and the medium. In the frequency spectrum higher limit of frequency of sound is fixed. Propagation of sound in any medium is meaningful only when wavelength of wave is equal to the distance between two molecules called intermolecular distance. We know that speed of sound is in the range of thousands cm/sec and distance between molecules is in the range of few A\(^0\) that is \(10^{-8}\) centimeter, and then the acoustic spectrum contains higher frequency range which is fixed around \((10^{12})\) vibration per second [97].

1.2.1 Properties of Waves

Waves show simple performances below a number of typical situations. There are different physical properties of waves such as, reflection, refraction, interference, transmission, absorption, diffraction, polarization and dispersion.

1. Reflection: It is the basic property of wave and perform valuable role in a number of phenomena like production of echoes, rolling of thunder reverberation effect musical tone heard near the ear. When wave incident on surface of material, it get reflected by changing its direction, in this case both angle of incident and angle of reflection is equal that made to the line normal to the surface. Reflections of sound wave have applications in horns, trumpets and sound boards. Due to the reflection of sound waves stationary waves are produced in wire and in pipes.

2. Refraction: Refraction phenomena take place when wave travels from one medium to another medium, in which, there is change in velocity of sound wave. In other word, there is change in dimension of the phase velocity. Refractive index of material is given in terms of refraction of wave through medium and incident of wave on the medium means that it is the ratio of angle of incident to the angle of refraction called as Snell’s law. We listens sound of lightning in rainy season when it is not far from us, but we are not able to listens sound of lightning if it is very long distance from us due to
the refraction. The sound has lower speed at higher heights and turns away from the land. The contradictory always happen in a winter day or in a night day in which sheet of air close to the land is colder than sheet of air far from land, and in this case speed of sound closer to the land is decreased. The greatest velocity of the sound waves result in to the complete bending of the sound towards the land, so that we can listens sound over long distances. It is well known that velocity of sound changes with temperature and in water temperature varies with distance so that refraction also takes place in water. This carriage a difficulty for surface containers that rebound ultrasonic waves of the lower level of the ocean to map the feature of base of sea. Refraction of sound cause benefit to submarines that help to given out detection. Due to the thermal inclines and sheets of water at various temperatures, the refraction of sound left space or dark spots in the water. This cannot be seen by submarines. The number of times of reflections and refractions of ultrasonic waves can be used in seeing various parts in the body without using X-ray. When sound of greater frequency sound pass in the body, it gets reflected largely from outer edge of an body part rather than it's inter side, and we get the idea of the image of body part. When ultrasonic waves trike on object which in motion, then there is small change in frequency of reflected sound. This principle is used in Doppler Effect with help of which, we can observe beating heart of a fetus three months after conception. Thus, bending of sound waves occurs when it passes from one medium to other medium and it depends on the relative velocity of sound wave in the two media.

3. Interference: Interference is the important phenomena, occur with a wave. Waves, that interferes to each other by the principle of superposition to produce interference pattern. When waves are in phase or they have same starting phase, called as coherent property produces interference patterns. We can observe interference phenomena in sound, if we consider that two sources of sound generates sound wave of same frequency and we are at the same distance from the source, we heard louder sound because the sound from two sources add together. In this case the antinodes and nodes of two sounds are in phase. However, if distance between listener and sound source increases at this time difference in path becomes equal to the half the wave length that produces rarefaction from one source whose place is taken by compression
produced by other source. This is called destructive interference where intensity of sound is less.

4. Transmission: We are familiar with that generally waves travels in a straight line through same medium. There are different types of medium such as bounded medium, linear medium in which there are addition of amplitudes of various waves at any specific place in the certain medium i.e. medium which is uniform throughout. An anisotropic material is one in which some physical properties changes more than one direction while in case of isotropic material all properties remain same in all directions.

5. Absorption: Sound is absorbed by different materials up to different extents. When sound wave incident on material, it get absorbed by the material. Different materials have different absorption power, depending upon the nature of material. Sound passes totally through an open window and no part of sound returns so open window can be considered as perfect sound absorber. The absorption of sound in any substance can be expressed that the substance absorbs half or one third of sound equal to the open window of the same area. The fraction is called absorption coefficient and it is the ratio of energy absorbed by absorber at any time to the energy that given out through an open window having same area at same time. Electrons in an atom perform vibration motion with its natural frequency; however when a wave with same natural frequency as that of electrons incident on an atom, then the electrons will absorbs the energy of wave and convert it in to vibration motion. In general, the coefficient of absorption changes with frequency, it is higher when frequency is more.

6. Diffraction: Sound wave obeys diffraction similar to the light waves. When sound wave incident on the corner of an obstacle they get bends or bending of sound wave from the edge of an obstacle or spreading of sound after emerging from a slit. A diffraction phenomenon in light as well as in sound occurs under condition when the size of the obstacle or slit is equal to the wavelength of the wave. The public observation shows that the quality of sound listen around edge of an obstacle is different from that the quality of sound heard directly. This change in quality of sound is due to the elimination of upper harmonics of high pitch around the edge of an obstacle.
7. **Polarization**: Sound waves are longitudinal in nature so they could not obey polarization. Especially polarization phenomena are used to check transverse nature of wave.

8. **Dispersion**: Dispersion of wave means spreading of wave after passing through the medium. It is the ability of material to disperse wave after emerging through material. Dispersion occurs in light when white light pass through a glass prism that produce spectrum consisting of several colors.

9. **Total internal reflection**: Sound wave undergoes total internal reflection similar as that of light waves. This is because when sound waves moving in the medium where they has lower speed and meet the surface of other medium where they has higher speed at an angle greater than the critical angle. When sound waves pass in to steel from air, refracted wave bends away from the normal. It moves in the direction of surface of steel when angle of refraction is ninety degree or \( \sin r = 1 \), and \( \sin i \) is thirty degree and thirty nine minute called critical angle. Further if the sound meet surface of steel from air with incidence angle higher than critical angle, the wave undergoes total internal reflection. This is why intensity of sound decreases when it travels through pipe or speaking tube.

### 1.3 Ultrasonic Waves

Linear acoustics deals with the variation of local pressure, density and temperature produced by a sound wave, which is negligible in comparison with the equilibrium value of the same quantities. In other words, it is generally concerned with small amplitude phenomena, which can be described to a better guess in terms of linear differential equations. Amplitude of the acoustic wave decreases when it propagates through the bulk materials. Generally, weakening denotes entire damage of amplitude of sound wave in the direction of propagation way due to total mechanism, which is accountable to losses such as absorption, scattering and diffraction. On the other hand, the absorption mentions total spending of amplitude of audio wave, which causes in increase in temperature of the medium through which wave propagates and is related with relaxation concept.

Scattering and diffraction causes the flow of wave energy in the opposite direction instead of its original direction of propagation. Attenuation produces an
exponential decrease in the wave amplitude. Relaxation also occurs in liquids, which is either the thermal relaxation or due to structural rearrangement of the molecules. At very high frequencies, the liquid have many properties of solid like shear, elastic module and longitudinal stiffness of the order of the values found for polymer materials. The high frequency ultrasonic wave is used to measure the shear rigidity and compressibility of the non-crystalline liquid lattice and compare these properties of the values found in normal solids. Ultrasonic absorption data serve as a useful means of determining the volume viscosity of liquids and the relationship between shear volume and viscous process [280].

The propagation of sound waves based on Hooke’s law in which the pressure at any point in the body is a linear function of the strain at that point. Wave propagation in materials always exhibits an amplitude loss resulting from the conversion of acoustic energy into other forms. As the energy of sound wave is introduced into the transmission medium it increases, non-linearity in the transmission. The propagation of sound waves having high amplitudes is accompanied by a series of non-linear effects that depend on the displacement amplitude of the wave. The presence of these non-linear terms significantly changes the propagation pattern of the sound wave and also its absorption. Non-linearity produces cavitations in liquids, generates harmonics and increases the propagation velocities.

Ultrasonic has been with living beings from prehistoric days, though human beings had limited themselves to the primary sense of sound and hearing in the audible range. It was known almost two hundred years ago that dog could hear sound at frequencies well above the audible limits and hence the Galton Whistle began to be used as a practical device. The clear recognition that bats uses ultrasound for their location. The use of ultrasound means that of locating underwater objects started at the time of First World War is the beginning of the modern phase of the subject. Also, it has been recognized that, underwater animals like whales and dolphins have been using similar technique in nature. The increasing observation of the refraction phenomena in gases and later in liquids towards the twenties and the observation of the diffraction of light by ultrasonic wave in the mid thirties, greatly increase the interest in physical ultrasonic. The production and finding of ultrasonic waves over increased limit of
number of cycles per second enabled a whole range of new phenomenon to be studied. The thermal phonons can be studied using ultrasonic techniques and other application in solid state studies and in material science have made the subject to be an active interest.

‘Ultrasonic’ is a Latin word “ultra” means outside, and “sonic” is called sound. This word is used to demonstrate sound waves, which oscillate extra speedily so that human ear can perceive it. Ultrasound was well-defined by the American Organization, as the sound whose frequencies are higher and above 20 KHz. The wave length of ultrasonic waves has the value equal to 1.9 centimeter or below it in the air. Sound waves move in the form of concentric empty spheres, in which compacted molecules of air forms the sphere. In this case due to the enlargement of air molecules, there is increase in distance between the spheres and waves of sound travel through it. Therefore, sound waves consist of number of alternative compressions and rarefactions through the air medium, even though sound waves also propagate through other medium like liquid gas and material medium. Very fast change in pressure generates sound waves. Anybody oscillating about their mean position creates periodic sound waves. An implosive and volatile pressure change generates sound beats. The other source of sound wave is Vortex shedding.

The velocity of sound wave is mainly depends on the medium and its nature through which it travels. Generally velocity of sound in gases, liquids and solids is in the order of gases < liquids < solids [288], pitch is important characteristic of sound so that its frequency is related with pitch. If pitch is higher, frequency of sound is higher and vice-versa. Audible frequency for human ear are in the range of 20 Hz to 20 KHz. Frequencies of sound wave below 20 Hz are called infrasonic waves, frequency above 20 KHz are called ultrasonic waves and speed greater than 750 miles per hour is called supersonic waves, therefore human ear is not sensitive to these waves. Animals like dogs, birds and bats are sensitive to these waves. Ultrasonic waves are related to very high frequencies, which has shorter wavelength and allow better resolution in imaging technologies. The sound waves having frequency less than audible range is known as infrasonic waves.
These waves are produced by large vibrating bodies such as vibrations generated during earthquake and vibration of pendulum. The sound frequency between 18 to 20 Hz is the minimum audible range of human being. During propagation of sound wave, its frequency remains constant. The wavelength is the reciprocal of frequency i.e. inversely proportional to frequency ($\lambda = 1/f$). Sounds having frequency between the limit of 20 KHz to 100 KHz are generally used in the communication and direction finding by bats, dolphins and few other kinds [70]. In medical applications, ultrasound having higher frequency greater than 1MHz is used. These sounds are generated with the help of transducer. Hence transducers are used for generation and monitoring of ultrasonic waves in gases, liquids and solids.

Ultrasonic instruments are widely used for sonar system and in medical applications like sonograms and lithotripsy. In solids, they are being used for non-destructive testing of structures. In number of medical investigative applications, echo time method and Doppler shift method are used, in which reflected sounds waves are used for measurement of the distance of internal body parts and their arrangements in the body. One of them is echocardiogram, in which activity of heart such as speed and direction of blood flow, action of heart valve is produced in the form of electrical pulses and can be seen on the screen of cathode ray oscilloscope.

Sound wave propagates in the form of longitudinal waves. During propagation, there is vibration of medium particles in the direction of wave propagation. This cause in the production of alternative rarefactions as well as compressions of the medium particles. Wavelength of sound wave is measure of distance between two rarefactions or two compressions. Sound waves having larger wavelengths can go above little objects and it is similar to that ocean waves go above little objects. Sound waves having
small wavelength, have a tendency of diffraction or scattering by an object whose size is comparable to the wavelength of wave [85].

1.3.1 Production of Ultrasonic Waves

Ultrasonic waves cannot be produced by the ordinary method i.e. by using mechanical vibrations. This is because of the comparatively low natural frequencies of the moving parts. Therefore, other methods are used for the production of ultrasonic waves. The method chosen depends upon the power output necessary and the frequency range needed. A device which produces ultrasonic waves is called ultrasonic transducer. In other words, transducer converts sound energy into electrical energy. The examples of electro-acoustic devices are loudspeakers, microphones, hydrophones and sonar projectors. Above devices transforms pressure of sound wave into electrical signal. The broadly used transfer device principles are electromagnetism, electrostatics and piezoelectricity.

Quartz crystals cut in various directions are used from many years as transducers. Ferroelectric material began to be developed in the past few decades. Ferroelectric ceramics have non-Centro-symmetric unit cells, which are randomly oriented below the Curie temperature, but it can be permanently aligned by the application of a large polarizing field. While performing investigations directly on solids, piezoelectric transducers are the best choice because the audio reactance of the piezoelectric materials has same order of magnitude as that of the solid. Barium titanate and lead zirconate titanate are known as polycrystalline ceramic materials that are frequently used for ultrasonic transducers because these transducers have a good broad band frequency capability for both generating and receiving sound. However, deposited thin film transducers have more advantages over quartz transducers for continuous ultrasonic waves.
The finding of piezo-electricity produced noteworthy awareness in the European scientific public. Before First World War and continuous effort of thirty years, result into invention of piezo-electricity. It is found that; piezo-electricity plays an important role in scientific activity. In piezo-electricity there is alternate conversion of mechanical energy and electrical energy. Similarly proper use of thermodynamics to explain various features of piezo-electricity as well as dissimilar nature of crystal had been studied. Paul Langevin and his colleagues first used the piezo-electric materials during First World War, so they were credited to their work, and they constructed an ultrasonic submarine detector. Term piezoelectricity describes the generation of an electrical polarization in substance by the application of a mechanical stress conversely, a change in shape of a substance when an electric field is applied.

Piezoelectricity occurs only in a substance in which centre of symmetry is absent. They constructed transducer by using thin crystal of quartz made from mosaic. The crystal is pasted among plates of steel and arranged in such manner that, it forms compound system and capable to generate resonance frequency up to 50 KHz. They used this instrument to transfer a greater frequency signal through the water in order to measure the deepness of water with help of coming back echo. For vacuum tube oscillator, stable frequency device were constructed with help of quartz crystals. When especially quartz crystal possessing property of piezo-electricity is compressed by applying pressure, opposite charges are developed on the surface of the crystal and it get electrically charged there by producing flow of electrons called electric current. When applied pressure is large, higher electric current is produced. If the crystal is abruptly over extended instead of being compressed, the current flow in opposite direction itself. Alternating current was produced due to the alternate squeezing and elongating the crystal. When alternating electric current is applied across the surface of crystal and natural frequency of crystal becomes equal to frequency of alternate electric current, as a result alternating current causes contraction and expansion in the crystal. This alternating current across crystal generates ultrasonic waves.

The production of ultrasonic wave from electromagnetic source is possible in many solids over frequencies from KHz to GHz. It was discovered in 1967 that, electromagnetic radiation can excite acoustic resonance in single crystal of Bi$^{24}$ and Al$^{25}$.
at liquid helium temperatures without making any contact to the samples and with apparently strong coupling to the conduction electrons in the crystal. Ultrasonic waves are also produced by using modulated light. When modulated sunlight is incident upon a metal plate, the resultant alternating thermal effects caused an audible signal to be emitted at the frequency of modulation.

The concentration of waves along direction of ultrasonic wave depends upon the way how crystal is cut. In other word, waves are focused perpendicularly to the direction of propagation. In case of longitudinal waves; molecules of medium perform back and forth motion when these waves travel in the same direction. Sometime, wave also exhibits transverse nature, in which medium particles execute vibration in perpendicular direction to the wave propagation. Ultrasonic waves may be propagates in the form of surface waves. In surface waves, it is observed that, atoms of neighboring medium execute up and down motion; also they execute increasing and shrinking motion. We know that, in greatest applications, ultrasonic waves are produced by using a device called transducer. Main part of transducer is quartz crystal, which transforms electrical energy into mechanical energy (audiosignal). In transducer, the generated sound waves are reflected and they come back again to the transducer in the form of echoes and they are transformed back in electrical signals with help of same transducer.

The other method used to produce ultrasonic waves is Magnetostriction effect. In this method, size of nickel or iron rod is altered due to magnetization; this alteration in the dimension of element produces ultrasonic waves. Whistle or siren type generators are also used to produce ultrasonic waves. In this case, reflector is placed in resonant cavity and flow of gas or liquid is passed through it. Vibration of reflector produces ultrasonic vibrations that are characteristic of individual gas or liquid.

In medical field, ultrasonography instrument, piezoelectric transducers are used in order to generate ultrasonic waves. These transducers are constructed with help of particular type of ceramics. In these transducers, mechanical oscillations and electrical fields are interconnected through a self-property of the material. Mechanical and adaptable type whistle was invented by Francis Galton in 1983 called as Galton whistle. This whistle generates ultrasonic waves of lower frequency. Magnetostriction
method is used when frequencies up to 300 KHz are needed, while piezo-electric generators are used mostly for the frequencies above that [288, 70, and 85].

1.3.2 History of Piezo-Electric Effect

The first practical explanation of a linking between macroscopic piezo-electric marvels and crystallographic arrangement were published in the year 1880 by Pierre and Jacques curie. In their practical, they exposed crystals like topaz, tourmaline, cane sugar, Rochelle salt and quartz to mechanical stress and measured charges appearing on the surface of crystal. The curie brothers declared that, electrical effect occurs in the crystal due to the change in temperature as well as mechanical tension produced in crystal. Therefore, above principle can be used in order to find the cuts of crystal. Even though above principle is also used to decide practical purpose of crystal. The curie brothers defined that, crystals showing the direct piezoelectric effect, would also exhibit the reverse piezoelectric effect. This property was mathematically derived by using important thermodynamic principle by Lippmann in the year 1881. After that, Curie instantly defined the presence of the reverse effect. Further he continuously works on total effect of reversibility in piezo-electric crystal and acquire measurable evidence.

Centre of application of piezo-electricity in science has been recognized after taking efforts of communicating work among scientist of Europe during two years. Piezo-electric crystal is identified by its non-symmetric nature. On this basis, they studied reversible interchange between mechanical as well as electrical energy. Further they also studied composite relation between electrical, thermal and mechanical changing parameters on the basis of thermodynamic effects. In between 25 years, too much work has been done by this core in order to develop a multipurpose and total framework. They found out totally twenty natural crystal classes in which effects of piezo-electricity take place. They also defined total eighteen probable macroscopic piezoelectric constants associated with thermodynamic action of crystal.

The first thoughtful applications work on piezo-electric instruments was taken in between World War first. In 1917, Langevin P. and their collagenous started to develop perfect ultrasonic submarine detector. They constructed a transducer using thin crystal of quartz made from mosaic material and crystal is pasted between plates of steel. After that, these plates are mounted in housing suitable for submersion. Actually, during this
renewal succeeding World War-I, the large numbers of classic piezo-electric uses with which we people are well presently familiar. Such devices are microphones, accelerometers, ultrasonic transducers, phonograph pick-ups, and signal filters, had been considered and decreased in practice.

At the time of World War II, Japan and Soviet Union, and their seperated research groups were working on the improvement capacitor materials. As compared to common crystals, particular ceramic material posseses 100 times greater dielectric constants. Additionally, similar category material is prepared that shows same enhancements in piezoelectric properties. Barium titanate application research committee, also called co-operative association of competitions was established by number of Japanese industries and universities in 1965. In order to find new markets, solve different manufacturing problems and to overcome the technical challenges they appointed organizational precedent. Persistent had taken much more efforts in the materials research and he had developed new Piezo-ceramic materials. These materials are reasonable and they are without patent limitations. Using these materials, manufacturing industries in Japan rapidly produced many piezo ceramic crystals that can be used in signal filtering purpose. These newly produced piezo-electric ceramic filters have been used in various instruments such as radio, communication instruments, television as well as Piezo-electric lighters for natural gas equipment’s.

1.3.3 Piezoelectric Effect

There are certain materials that have capability to generate an electric charge when pressure is applied across it. In Greek, the word piezoelectric is called piezein. The meaning of piezein is to squeeze or to press, and the word has Greek meaning to push. One of the distinctive features of the piezoelectric effect is that, it possesses reversible property. The meaning of reversible is that, any materials showing the direct piezoelectric effect, they also show the opposite piezoelectric effect. When mechanical pressure is applied across piezoelectric material, it results in to a displacement of the positive and negative charge at the middle in the material takes place. This shifting of positive and negative charges inside material produces an external electric field. When this process is reversed or if charges are present on outer side of the material, this outer electric field either stretches or compresses the piezoelectric material.
It is well known that, piezoelectric effect plays an important role in many applications that includes the manufacturing of piezoelectric crystal and detection of ultrasonic waves. The piezoelectric material also used in production of large voltages, in the generation of high frequency up to mega hertz range, in the microbalances, in ultrafine concentrating of optical instruments. The base of many scientific equipmental techniques up to the atomic resolution level is the piezoelectric crystal. They are used in scanning electron microscope, transmission electron microscope, scanning tunneling microscope [64]. The piezoelectric effect further used in extraordinary applications as well as it can be used as the detonation source in cigarette lighters. In 1880 Jacques and Pierre Curie [27], showed that, when two opposite faces of a thin slice of certain crystals are subjected to distortion, the opposite charges are established on the surfaces of a slice. The magnitude of potential difference developed between two faces is proportional to the deformation produced. The polarities of the charges produced are reversed, if the direction of deformation is reversed. The deformation producing forces may be compression or tension. This phenomenon is known as ‘Piezoelectric Effect’. The crystals which exhibit this effect are quartz, SiO\textsubscript{2}, barium titanate, tourmaline, Rochelle salt etc. we study piezoelectric effect with a quartz crystal [26, 161]. After that for many years, piezo-electricity persisted in laboratory.

After the end of First World War, the first application of piezo-electric materials was used in the production of sonar device. This primary use of piezo-electric material in sonar device generated powerful international developing interest in devices that are made from piezo-electric material. New type of ferro-electric materials are revealed by assembly of research in Russia, Japan as well as US throughout Second World War that was made by the man. This newly invented ferroelectric material possesses piezoelectric constants, which were several times greater than usual piezo-electric materials. Even though quartz minerals are the first material, which is commercially used a piezo-electric material and up to this time it is used in sonar finding applications. The output of this research was used in the preparation of lead zirconate titanate and barium titanate. These two materials had very important and precise properties that appropriate for specific applications. In current years, due to the increasing environmental anxiety about the toxicity in devices containing large amount of lead and according to the
instruction given by RoHS and monitored in the European Union, it has become necessary to develop piezo-electric materials which are free from lead elements.

Natural quartz is a hexagonal prism shaped crystal. It has pyramids at both ends as shown in fig. 1.1(a). If three coordinate axes are fixed, the z-axis passes through end points of pyramid and called optic axis. The X-axis passes through the corners (called electrical axis) and the Y-axis passes through the mid points of opposite sides (called mechanical axis) as shown in fig. 1.1(b).

![Piezoelectric Quartz Crystal Diagram](image)

**Fig 1.1: Piezoelectric Quartz Crystal**

1. A thin plate cut perpendicular to X-axis is known as ‘X-cut plate’, whereas the onother which cut perpendicular to Y-axis is called ‘Y-cut plate’. If X-cut crystal plate is cut under pressure, the charge is developed as shown in figure 1.2. If it is cut under tension, the charge is also developed but the polarity is reversed. Thus, the mechanical strain in X-cut plate induces electric polarization. This is called ‘Direct Piezo Electric Effect’. (DPEE)
Fig. 1.2: X-Cut plate is under A) Compression, B) Tension

ii. If X-cut crystal plate is placed between two electrodes and connected to D.C. voltage, the mechanical deformation takes place along Y-axis and Z-axis; and deformation is proportional to the electric potential. This is shown in figure 1.3 and called as Inverse Piezo Electric Effect (IPEE) [235].

Fig. 1.3: X-Cut crystal plate placed between electrodes

iii. **Piezoelectric Ceramics**

Piezo-electric ceramic is made from perovskite crystals. Every one crystal is constitution of a little metal having four valence electrons situated underside of lattice of bigger divalent metal of charged particles and $O_2$. This is shown in figure 1.4. When fine powder of elements of metal oxide is mixed together with definite proportion, it formulates piezo-electric ceramic material. After that, prepared given mixture is heated sufficiently, so that uniform powder is formed. Then, this powder is mixed with a biological binder and they are converted into particular shapes like, discs, bars and plates. After that discs, bars and plates are heated for precise time under prearranged temperature. Due to this process, the particles of this powder sinter and the material turn in to dense crystalline structure.
Fig. 1.4: Piezoelectric ceramic crystalline structure, earlier and later polarization

The elements acquire desired shapes after they cooled. Beyond the “Curie temperature”, every perovskite crystal in high temperature condition shows simple cubic (SC) symmetrical structure without dipole moment as presented in figure 1.5. Though, at temperatures, which are less than the Curie temperature, every perovskite crystal possesses tetragonal symmetrical structure and they are related with dipole moment. Neighboring dipoles (consisting of two equal and opposite charges separated by finite distance) creates “domains”. These arrangements produce net dipole moment, which is associated with domain, this result in to the net polarization of material containing their domain. Figure 1.5(a) displays the direction of polarization between adjoining domains is without direction having no overall polarization.

Fig. 1.5: Pushing method; (a) random orientation of polar domains to former polarization (b) polarization due to high dc electric field (c) remainance of polarization after removal of electric field

Small volume of elements (domains) in the ceramic material is rearranged by placing the element under a very large D.C. electrostatic field. The temperature was kept slightly less than the Curie temperature as presented in figure 1.5(b). Thus, it is termed “poling process”.

When poling

- [Diagram of poling process]
treatment is completed, most of domains get arranged with the application of electric field and they get expanded relative to the domains those not aligned due to applied electric field. Thus expansion of element takes place along the direction of applied electric field. After removal of applied electric field, greatest dipoles are locked to their position into a configuration of close arrangement (Fig.1.5c). Hence, element shows a secular polarization, so they elongated permanently. In this case, the length of element rises slightly and it is within the micrometer range.

Fig.1.6: response of piezoelectric component to applied electric field

Behaviors of piezo-electric component of ceramic are described with help of number of pictures as presented by Fig 1.6. When element is mechanically compressed, there is change in dipole moment related with the element. This change in dipole moment generates potential difference. When Compression in the element is along the direction of polarization, and then potential difference produced in this situation has same polarity equal to pushing potential difference (Fig. 1.6b). When tension applied is parallel to the polarization direction, or when compression is tangential to the direction of polarization, this action produces potential difference having polarity which is contradictory to pushing potential difference (Fig. 1.6c). Therefore, from above discussion, we said that, with help of piezo ceramic component mechanical energy due to compression can be transformed into electrical energy.

If applied voltage across the ceramic component has same polarity and it is in the same direction of poling voltage, then ceramic component undergoes increase in length and its diameter would turn in to smaller size (Fig. 1.6d). When reverse polarity voltage is applied across the ceramic material, the shape of element changes and it became smaller and wider (Fig. 1.6e). If a device is placed under the action of alternating voltage, then there will be alternate expansion and contraction of the element due to the supplied voltage frequency. Ceramic component may be used as an actuator only when it works in above way. In this situation there is transformation of electrical energy in mechanical energy.

The other Ferro-electric material is the barium titanate, whose chemical formula is BaTiO₃. When we consider the structure of this material, we need to consider the temperature as compared to the Curie. Therefore, Curie temperature makes,
change in element from Ferro-electric to non-Ferro-electric material. The Curie temperature for barium titanate is approximately 393 kelvin. The figure (1.7) shows the basic structure of barium titanate when it is above the Curie temperature. The green spheres at the corners represent the barium atoms while the blue spheres on the surface are the oxygen atoms and red sphere in the middle represents the titanium atom. Consider the center symmetry of this structure, for every point located by \((x, y, z)\) there is a mirror image located at \((-x, -y, -z)\). The materials which have center symmetry are not Ferro-electric. However, at temperature below the Curie temperature the structure is shown (fig. 1.8) below.

![Fig. 1.7: Barium titanate above Curie temperature](image)

![Fig. 1.8: Barium titanate below the Curie temperature](image)

When titanium atom is above the center, the barium titanium material is now a Ferro-electric material. There is a naturally occurring dipole moment because of the off-set of atom which is at the center position. Electric dipole moment is a vector quantity which
measures the separation distance between opposite charges. The moment of electric dipole is directly depends on an electric field as shown in (fig. 1.9) orange color.

Fig. 1.9: Dipole-moment

If we focus on the dipole moment, we can understand the piezoelectric effect by taking a slice of the material with its dipole moment pointing up. If we compress this material by pushing from above and below, the material will get smaller in the vertical dimension and the result is that, the titanium atom gets closer to the center of the structure. Which means the dipole moment gets smaller and the electric field gets smaller. We can increase the electric field by elongating the dipole moment. This happens by pushing from the left and right sides, causing the titanium atom to get further away from the center.

Fig. 1.10: Dipole moment with no external force

Fig. 1.11: Top and bottom external force: dipole moment decreases.

Fig. 1.12: Left and right external force: dipole moment increases.
These types of forces on Ferro-electric materials cause changes in the electrostatic field. Whenever electrostatic field changes, the material changes its shape. This is called ‘transducer’, which converts mechanical energy to electric energy as well as being able to convert electrical energy into mechanical energy. This conversion is a primary characteristic of piezo-electric effect. Dehydrated bone of animal or human body shows few piezo-electric properties. Fukada had study on this and he observed that, these effects are not result of apatite crystals, but it occurs because of collagen. Collagen shows the polar single axis direction of molecular dipoles in its arrangement and can be treated as bio-electric. Hence, collagen is some type of dielectric material showing quasi-permanent space charge as well as dipolar charge.

When large numbers of molecules of collagen are placed under force, they get stressed in similar manner as displacing major number of the charge carrier from inside of specimen on surface of specimen. This results in to generation of potentials.

The piezo-electric effect was commonly acts as biological sensor. Pennsylvania University was published the use of piezo-electric effect as biological sensor. At that time they continued application of electrical potential and finally they found that, electrical potential would encourages re-absorption as well as progress of bone in vivo. There are other biological materials such as tendon, silk, wood, enamel, dentin, and viral proteins exhibiting piezoelectric properties.

Ceramic materials in which there are random orientations of the particles must acts as ferroelectric material and shows piezo-electric properties. The large scale piezo-electric effect is possible in rough polycrystalline without-ferroelectric piezoelectric materials. The group of ceramic material with perovskite, tungsten-bronze and other associated structures shows piezo-electric effect. A piezoelectric potential can be produced in nano-structured semiconductor material which have without central symmetrical structure. This is due to polarization of charges below applied force per unit area and change in dimension. The zinc blend and wurtzite structures possess same this property. As compared to quartz crystal Polyvinylidene Di-fluoride shows more piezoelectric property which is many times higher than quartz. Under the action of electric field molecules of polymers attract and repel to each other. A powerful shear piezoelectric effect was perceived in self-built phenylalanine peptide nano-tubes.
1.3.4 Applications of Piezo-electric Effect

Piezoelectric materials have some important properties so can be used in various fields, which are discussed as follows:

a) High Voltage and Power Sources
Piezo-electric material is used in cigarette lighter. In cigarette lighter when button is pressed, a hammer loaded with spring which strike on a piezo-electric crystal. Due to this, high voltage is produced there by causing flow of electric current across a small spark gap. This sparking heat a gas and ignition take place. Piezo-electric materials are also used in gas burners.

A piezoelectric transformer is one in which multiple ac voltage is generated. Regular transformer works on a principle of mutual inductance, in which two coils are coupled together by magnetic field. The variation of voltage in one coil induces voltage in other coil due to the linkage of magnetic flux between the coils. In piezo-electric transformer, instead of magnetic coupling, acoustic coupling is used. This transformer consists of two short length bar of piezo-ceramic material, in which an input voltage is applied across a first bar. This voltage produces alternating stress in the bar due to opposite piezo-electric effect and whole bar set in to vibration. The vibration frequency is selected in such way that, it is similar to the resonant frequency of the block. Then a greater output voltage is produced across second bar by the piezoelectric effect. Piezo-electric transformer has some extra advantages as when it operated above its resonant then it can act as inductive load. Now a day, instead of conventional transformer, piezo-electric transformer is used in ac or dc inverters. Therefore these inverters are used to run cold cathode fluorescent lamps. Transformer made from piezo-electric material is a compact device of high voltage source.

b) Sensors

The piezoelectric sensor works on principle in which a physical quantity i.e. pressure is converted into a force, which is acting on two opposite surfaces of the sensing elements. The general application of sensor is that, it detects pressure variation in the form of sound. The common examples are piezo-electric microphones and piezo-electric pickups. Specifically, piezoelectric sensors are used in ultrasonic transducer having very large frequency for number of applications.
a) **Piezoelectric Motors**

Concerning motors made from piezo-electric material, in which the piezo-electric component obtains an electrical signal, after that it applies directional force on opposite ceramic disc in such way that, it move in the specified direction. The motion is being produced, if piezo-electric element travels in opposite direction as that of a static platform. Using piezoelectric technology, nano-motion has designed various series of motors. Nano-motion vehicles have capacity of driving both straight line and rotational stages.

b) **Mirror alignment**

Alignment of laser mirror has been done using piezo-electric materials. Piezoelectric material has capacity to displace a heavy mass above very small distance. This property of piezo-electric material can be employed in mirrors made from laser which are arranged electrically. Distance between mirrors is accurately monitored with help of piezo-electric element. Perfect optical setting of mirrors are done using laser beam with in laser cavity. Therefore this technique improves the output of beam.

c) **Quartz clocks**

In quartz clocks, crystal oscillator is used to generate the frequency that is made from quartz crystal. It transforms piezo-electricity to produce regularly time based electric pulses that can be used to mark time.

d) **Reductions of Vibrations and Noise**

If piezo-electric component is attached to the vibrating material, it reduces vibration of material. Bending of material takes place, when vibrations in material are in any one direction. Vibration reduction system attached to the vibrating material gives higher response to the bending. As a result, vibration reduction system feeds electric signal to piezo-electric component so it bend in opposite direction.

e) **Photovoltaic**

When photovoltaic cell consisting piezo-electric material is placed close to the source of noise then it improves the productivity of photovoltaic cell. This improvement in efficiency of photovoltaic cell is explained with the help of biological cell using nanotubes made from zinc oxide material. But it is observed that, electric power produced piezo-electric effect is very small.
f) Energy Harvesting

Now a day, cultivating of kinetic energy through walking of walkers is in developing process. In this case, piezo electric floorings have been created, and this work was started in Japan at the two railway stations. Many electronic display systems and automatic ticket gates are operated on light produced from foot traffic in which piezo-electric materials are used. We know that, in London, familiar night club is developed on the basis of piezoelectric technology. They designed special energy cultivating piezo-electric tiles from which power is generated and this electric power is used for the lightning and to run the sound systems. This piezo-electric tiles works on low frequency, so that, power production is also low. The power generation is depends upon surface area crossing per unit time by the number of people. Israel has mounted piezo-electric materials below the traffic road and electric energy produced is used to run road lights, billboards and signs.

g) Engine Knock Sensors

Now a day, engine maker companies are continuously facing the problem, which occurs during the controlling of engine parameters. Under the incorrect situations, gasoline engine is susceptible to an unwanted phenomenon called detonation. The time, to which detonation arises, the fuel blasts rather than burning smoothly and result in to damaging the engine. The efficiency of engine can be increased by developing the best control system using piezo-electric elements. As soon as when detonation is started in the engine piezo-electric knock sensor sense the detonation before it becomes dangerous

h) Optical Adjustment

Number of telescopes mounted on the surface of earth is affected by distortion caused by atmosphere. In similar way spaceship is subject to vibration and movement. Hence it is necessary to adjust real-time with the help of control system.

i) Piezoelectric Relays

Now a day, relays and switches are made from Piezo electric elements. Either strip actuators or stack actuators are used to open and closed electrical contact. Such components are maintenance free and long life. The actuator made from piezo-electric material operates fast with precise control that is not possible in electromagnetic relay.
j) **Piezoelectric Printers**

There are two types of printers namely dot matrix and inkjet printers, in which piezo-electric actuators are used. In dot matrix printer, piezo-electric actuator moves the head needle that poke through strip of ink tape in the reverse direction of paper in different pattern to create word. Now a day, laser printers are used instead of dot matrix printers. In Inkjet printer, piezoelectric actuators head act on small diaphragms or in other way change the geometry of inkwell as result ink droplets are forced out of an orifice onto paper. This is leading skills used in the printer up to this date.

k) **Piezoelectric speaker**

Piezo-electric elements are used in manufacturing of speakers in order to produce sufficiently sound from small electric appliance. Such speakers are usually low-cost and need a small power to generate comparatively higher sound. Thus, piezoelectric speaker are used in many devices as mention below.

- Mobile phones
- Head phone
- Small dolls
- Drone

l) **Piezoelectric Buzzers**

Piezoelectric speakers and piezo-electric buzzer are same, but one difference is that they are built with lower fidelity in order to generate a louder volume above narrow frequency range. Buzzers are used in a seemingly endless array of electronic device.

1.4 **Generation Methods of Ultrasonic Waves**

Different methods are used for production of ultrasonic waves and they are listed below:

i. Galton Whistle

ii. Piezoelectric Oscillator

iii. Magnetostriction Oscillator.

1.4.1 **Galton Whistle**

Ultrasonic waves are produced by adjustable whistle known as ‘Galton whistle’. This whistle is discovered by Galton. This whistle produces ultrasound of lower
frequency, which is audible to human ear and other animals. It consists of a small size organ pipe whose one face is closed to form air column ‘A’. The length of air column is adjusted by means of movable piston. The suitable position of piston ‘P’ can be adjusted by means of screw S₁. The open face of organ pipe ‘A’ is fitted with a flap ‘L’. The upper organ pipe ‘C’ also consists of piston, whose length is adjusted by means of screw S₂. The distance between the ends of pipe ‘A’ and pipe ‘C’ is adjusted by means of the screw S₂ as shown in figure 1.13.

Nozzle ‘N’ is fitted at the top end of pipe ‘C’, and a blast air is allowed to pass through nozzle. The blast air comes out from other end of pipe ‘C’ and it strikes on the flap ‘L’. This causes vibration of air column in the pipe and column of air is made to vibrate to the resonant frequency by adjusting the length of air column in pipe ‘A’. The resonant frequency varies with length and diameter of the pipe ‘A’.

\[
\lambda = 4(L + x)
\]

Fig. 1.13: Galton’s Whistle

If air column in pipe has length L and x is the end correction then the wavelength of resonating air column is

The number of vibration per second of sound is
\[ F = \frac{V}{\lambda} = \frac{V}{4(L+x)} \]

Using this whistle, frequencies of thirty thousand Hertz can be generated.

**1.4.2 Piezoelectric Oscillator**

This oscillator is based on the piezo-electric properties of quartz crystal. The two brothers, J. Curie and P. Curie discovered that, if first pair of opposite faces of quartz crystal is placed under pressure, then electric charges are developed on the second pair of opposite faces, which is perpendicular to first pair. Change in polarity of developed charges depends upon applied tension rather than pressure. This means that, when faces of quartz crystal are placed under tension, there is change in polarity of charges. It is found that, the electric charges developed are proportional to the degree of pressure. Oppositely, compression or extension occurs across the first pair of faces, when second pair of faces is subjected to electric field. This compression or expansion depends upon the direction of applied electric field. The potential difference between the faces is proportional to the amount of compression or extension.

If one pair of faces of quartz crystal is subjected to alternating electric field, there is alternate increase and decrease in thickness between another pair of faces. This results in production of mechanical vibration whose frequency is same as the frequency of the alternating electric field. When the frequency of vibrations is same as that of natural frequency of the crystal, resonance occurs and vibrations of large amplitude are setup in the quartz.

Piezo-electric oscillator consists of oscillatory circuit in which tuning is done with variable capacitor so as to provide voltage. Fig. 1.14 shows block diagram of oscillator, which consists of metel plates A and B. between these two metal plates, a small piece of quartz crystal is placed. This arrangement is similar to parallel plate capacitor and crystal serve as dielectric. Metal plates A and B are joined to the two terminal of primary of a transformer and then it is coupled to the oscillatory circuit of a transistor. When high voltage with help of H.T. battery is applied to the oscillatory circuit, the oscillator generates high frequency alternating e.m.f. having a frequency.
This high alternating voltage from coil $L_1$ is induced into the primary coil $L_3$ of transformer according to the principle of mutual inductance. After that, this high alternating voltage is applied across plates A and B. This alternating voltage produces inverse piezo-electric effect and quartz crystal undergoes alternative contraction and expansion. The crystal obeys mechanical vibrations, and it produces frequency which is given by formula

$$F = \frac{p}{2l} \sqrt{Y/\rho}$$  

In above formula, 'p' has integer values like 1, 2, 3, 4 and so on that is first, second, third over tones etc., 'p' and 'Y' are the density and Young's modulus respectively.

In piezo-electric oscillator coil $L_2$ and variable capacitor $C_1$ forms a tank circuit, which produces frequency. Occurrence of resonance in the circuit depends upon the value of capacitor. Therefore, value of capacitor is so adjusted for which alternating voltage frequency and natural frequency of crystal are equal. Under this condition, resonance setup in the circuit.

Using quartz crystal, ultrasound of frequencies 540 KHz can be generated. In order to generate higher frequencies, the plates A and B should be very thin and strong so that plates have capacity to withstand the strain.

The velocity of the quartz along x-direction is given by

$$V = \sqrt{(Y/\rho)}$$  

\[f = \frac{1}{2\pi \sqrt{L_1C_1}}\]  

\[f = \frac{1}{2\pi \sqrt{L_1C_1}}\]
For quartz, the Young’s modulus \( (Y) = 7.9 \times 10^{10} \text{N/m}^2 \) and \( \rho = 2650 \text{ kg/m}^3 \)

1) **Advantages:** Using piezo-electric oscillator, higher frequencies in the range of some Hertz to Mega Hertz can be obtained. There is no effect of humidity and temperature on the output of oscillator.

2) **Disadvantages:**
   Price of piezo-electric crystal is too much large. It is difficult to cut the quartz crystal in specific shape.

### 1.4.3 Magnetostriction Effect

Joule discovered that, when magnetic field is applied along the length of ferromagnetic rod such as nickel it undergoes change in its length. The increase in the value of magnetic field increases length of rod. This effect called 'Magnetostriction' or 'magnetic-strict ion'. The increase in length is very small and it is greater in nickel than in any other ferromagnetic material. The increase in length depends upon the magnetization intensity and it is independent upon the direction of applied magnetic field. Thus, if varying magnetic field parallel to the length of rod is applied, if every time the strength of magnetic field increases, there is increase in length of rod. This results in setting up vibrations in the rod with a frequency, which is twice that of the magnetic field. If a permanent steady magnetic field of suitable strength is applied by means of dc power source and changing alternating field is superimposed on it, the frequency of vibration set up in the rod will be the same as that of changing alternating field. Due to elastic properties and dimension of the rod, if the natural frequency of vibrations of rod is the same as that of frequency of alternating field, amplitude becomes large and resonance setup. In this situation rod vibrate with ultrasonic frequencies and pass out ultrasonic waves.

Change of length of the rod proportional to intensity of magnetization so long as the magnetic field is well above the magnetic saturation, i.e.

\[
\frac{\delta l}{\delta x} = kB
\]

For flux density below magnetic saturation, the change is proportional to square of flux density, i.e.
\[ \frac{\delta l}{\delta x} = kB^2 \]  \hspace{1cm} 1.5

Where, \( \frac{\delta l}{\delta x} \) is the change in length per unit length and \( k \) is the characteristic property of material, called magnetostrictive constant.

The value of ‘\( k \)’ is positive for the material which expands on magnetization (e.g. perm) and the value of \( k \) is negative for the materials which contract on magnetization (e.g. nickel, permendur and invar). If the rod with high \( k \) value (+ve or -ve) is subjected to rapidly varying magnetic field its length will change periodically with a given magnetic field. The change in length produces mechanical vibrations. This is used in construction of vibrating element for the production of ultrasonic waves. As the rod vibrates longitudinally, it can be treated as the vibrating rod free at both ends; and its natural frequency is given by

\[ n = \frac{N}{2l} \sqrt{\frac{Y}{\rho}} \]  \hspace{1cm} 1.6

In above formula, \( l \), \( Y \) and \( \rho \) are the length, Young modulus and density of rod material respectively. ‘\( N \)’ is the harmonic mode such as 1, 2, 3, and so on.

**1.4.4 Magnetostriction Oscillator**

The magnetostrictive oscillator was first designed by G.W. Pierie by using triode valve or transistor as an amplifier. It is found that, a little change in length of ferromagnetic rod like iron or nickel occurs due to the application of strong magnetic field along the length of rod. Such effect is known as ‘Magnetostriction effect’. The applied magnetic field causes change in length that depends on intensity of field. An alternating current fed to the coil wound on the rod of magnetic material (nickel) produces the change in magnetic field which sets the rod in to vibrations (length wise). The vibration per second of the rod is double the frequency of alternating current.

As shown in figure. 1.15, XY is the nickel rod clamped at the Centre and two coils \( L_1 \) and \( L_2 \) are wound around its two ends. The coil \( L_2 \) is in the plate- cathode circuit and coil \( L_1 \) is in the grid- cathode circuit, and is inductively coupled. The nickel rod gets magnetized by plate current in coil \( L_2 \). Any change in current across coil \( L_2 \) results in the change of magnetization of rod which causes a change in rod length. The change in
length produces change of flux linked with the grid coil $L_1$, there by inducing an e.m.f. is amplified and passed on to the plate circuit, so that the oscillations are maintained. The oscillator frequency ‘$F$’ is controlled by the variable capacitor ‘$C$’ and is given by

$$F = \frac{1}{2\pi \sqrt{LC}}$$

1.7

Where ‘$L$’ is the inductance of coil $L_2$ and ‘$C$’ is the capacitance of the condenser $C$ in the L-C circuit.

From the principle of Magnetostriction, we know that, the frequency of nickel rod will be twice the frequency of oscillator. It is possible to make the rod vibrate at the same frequency of oscillator by imposing on rod the polarizing magnetic field.

The polarizing field may be produced either by permanent magnet placed along the side of rod. The amplitude of the vibrations will be maximum at the resonance i.e. when $n = f$ (with polarizing field) or $2n = f$ (without polarizing field). As the natural frequency of rod falls in the range of ultrasonic; the above system is employed for generation of ultrasonic waves. By varying the length of rod, higher frequency oscillations of different frequencies can be obtained. A nickel rod of ten centimeter long gives out ultrasonic waves of frequency 25,000 cycles per second.

a) Advantages

Magnetostriction oscillator is easy to build and it is economical range. Without taking the risk of damaging of circuit, it generates higher power. The Magnetostriction oscillator possesses larger power handling capacity, higher Q factor and sharp resonance curve.
b) Disadvantages

Due to some limitations, the frequency above 3 Mega Hertz cannot be produced by this oscillator. The variation in temperature affects the frequency of vibration. Hysteresis and production of eddy currents results in to loss of energy. The bundle of fine insulated wires of nickel or a cylinder with alternating layers of nickel and with paraffin wax is used to avoid production of eddy currents in the rod to minimize loss of energy.

1.5 Detection of Ultrasonic Waves

We cannot directly detect the ultrasonic waves although some animals, especially, the bat can do so. However, the ultrasonic waves are detected using following few techniques [293, 153, and 36].

1.5.1 Piezo-Electric Detector

The quartz crystal is used for the detection of ultrasonic waves. This wave produces varying electric charges on the faces perpendicular to those which receive them. On the other hand, one couple of faces of quartz crystal when subjected to ultrasonic, opposite faces which are perpendicular to the previous one, varying electric charges is produced. Of course, the charges are very small. These charges are, therefore, amplified and then detected by some suitable means.

1.5.2 Kundt’s Tube Method

A Kundt’s tube with lycopodium powder or air free sand can be used to detect ultrasonic waves of relatively large wavelength as done for audible sound waves. Due to passing of ultrasonic waves heaps are formed at the nodes and it is driven off at the antinodal points.

1.5.3 Sensitive Flame Method

When the open end organ pipe is blown, the flame at the midpoint of the organ pipe produces fundamental tone that gives a band with teeth in the resolving mirror. This indicates the position of the node at that place. The flames at the ends of organ pipe would give bands in absence of teeth that shows there are antinodes at the two ends of the pipe. In other way, when a narrow sensitive flame is moved in organ pipe, where ultrasonic waves are present, the flame remains stationary at antinodes and flickers at nodes.
1.5.4 Thermal Detector Method

It consists of fine platinum wire, which is moved in the medium of ultrasonic waves, temperature of the medium changes due to the alternative compression and rarefaction. There is a change of temperature at nodes but at antinodes, there is no change in temperature. Therefore, the resistance of platinum wires changes at the nodes and remains constant at the antinodes. The change in the resistance of platinum wire corresponding with time could be noticed by using a sensitive bridge arrangement. The bridge will be in the balanced position, when the platinum wire is at antinodes.

1.5.5 Rotating Disc Method

It consists of horizontal cylindrical resonator tube. In this resonator, a circular rotating disc is suspended by means of quartz fiber. At starting the rotating disc is adjusted in such way that the surface of disc makes an angle of 45° to the axis of resonator tube. Mirror is attached to the fiber and light from lamp is made to incident on mirror so that reflected light from mirror is taken on the scale. When sound wave propagates through resonator tube, the disc gets deflected and torsional couple acts on the fiber. Due to the couple we measure deflection of spot on the scale. In this case, couple is proportional to the mean square of the velocity of wave. In this way one can detect the sound wave.

1.6 Properties of ultrasonic waves

a. An ultrasonic wave possesses high energy.
b. Velocity of ultrasonic waves is the function of its frequency.
c. Due to higher frequency they have small wavelength showing less diffraction. Due to high frequency they travel longer distance without loss of energy.
d. Intensity of ultrasonic waves is very high, so they produce disturbances when passes through liquids thereby forming bubbles in the liquids.
e. Due to the reflection property they produces stationary waves when propagates through liquids.
f. Similar to conventional sound waves, they obey the phenomena of light.
g. When ultrasonic waves propagate through liquids, they acts as diffraction grating known as acoustic grating.
h. After passing through material they generate extreme heat.

1.7 Applications of Ultrasonic Waves

a. Ultrasonic Interferometer

In this device, piezo-electric quartz crystal is subjected to produce mechanical vibrations, in which frequency of vibrations and frequency of ultrasonic waves are equal. Plane waves generated by the quartz crystal are sent out in the ultrasonic interferometer. These waves are reflected back from reflector which is placed in its path. Due to the superposition of the direct and reflected waves, stationary waves are formed between crystal and the reflector.

The velocity of ultrasonic waves in the medium placed between the crystal and reflector can be measured with usual method. This method is used for measuring the velocity of sound in liquids as well as for gases at different temperatures.

b. Echo Sounding

Ultrasonic sound waves are used for sound signaling, depth sounding, determining the position of ice bergs, submarines, etc. These applications make use of echo principle. The high frequency sound waves can be readily formed into a narrow beam and can be focused in any desired direction. Because of this, these waves can travel many kilometers in water before being absorbed. Ultrasonic waves of 50 kHz frequencies are generated by crystal vibrator. The moment the signal is sent from the transmitter, a deflection of the spot on the C.R.O. screen is observed. The beam travels to the receiver or obstacle and reflects back. When reflected beam returns, it is indicated by the deflection of the spot. The time interval between the two deflections could measure. If we know the speed of the ultrasonic waves and the time interval, the position of the receiver or obstacle can be determined. This is the principle underlined in the echo sounding [280, 288, and 70].

Piezo-electric crystal can be used for sending a beam of ultrasonic waves. These waves are reflected from aero-plane or submarine, and when anybody comes in its path, the reflected rays from that object can be detected with the help of quartz crystal which acts as receiver. Submerged submarine or aircraft may be located by this technique. Latest new device invented called sea-scanner, which sends out ultrasonic waves forward of a ship and on its two sides in the water as well as in downward
direction. Then echoes are received from fish, reefs etc. in radar type screen or in a loud speaker. From this, one can measure the distance between ship obstacles. Hence the device is important for navigation.

Making special arrangement of recording the lake of time between the emission of ultrasonic waves and reception of waves after reflection from the bottom of sea, the depth of sea can be found. The device is called fathometer in which transmitter and receiver are placed in water. In this instrument, the indicator is consists of metal stylus at the end of arm, which touches a paper coated with solution of potassium iodide and starch. It is rotating with a constant speed of 90 rotations per minute, which is on back side of metal plate. As soon as the stylus passes zero on the paper scale, immediately a pulse of ultrasonic waves is sent forth by the transmitter. After amplification, echo passes through the stylus and sensitized paper to the back metal plate liberating iodine. The brown spot is made on the paper which indicates the depth of sea.

c. Cleaning and Clearing
Cleaning of cloths is possible by using ultrasonic technology. The ultrasonic shake the dust particles form the cloths in to the detergent without damaging the cloths. Recently, an ultrasonic washing machine has been developed that washes the cloths within fifteen minutes which consumes less power.

d. Direction Signaling
The ultrasonic waves has smaller wavelength, using this property the ultrasonic waves can be focused into a sharp beam and used to send signal on proper direction.

e. Detection of flaws in metals
Defects in metals can be detected with the help of ultrasonic waves. We know that, flaws in the metal produces a change in the medium due to which reflection of ultrasonic waves takes place. Hence, when ultrasonic waves pass through a metal having some hole or crack inside it, an appreciable reflection occurs. The reflection also takes place at the back surface of the metal. The reflected pulses are picked up by receiver and are suitably amplified. These pulses are now applied to one set of plates of cathode ray oscillograph. The transmitted signal and reflected signal from the flaw and back surface of metal produce a peak each. The position of the second peak on time base of oscillograph will give distance of flaw [313].
f. Mullard soldering in iron
It is used for soldering of metals such as aluminium. In this, ultrasonic waves with an
addition to the electric current are used. The ultrasonic waves remove the film of oxide
formed and thus facilitate the soldering.

g. Formation of alloys
The beam ultrasonic wave is used to keep the compositions of alloys mixed uniformly
even as they have different densities. Therefore, using ultrasonics we obtain alloys of
uniform composition.

h. Ultrasonic mixing
Liquids like water and oil cannot be mixed to each other. But colloid solution of these
two liquids could be produced simultaneously by placing it into ultrasonic radiations.
Now-a-days, most of the emulsions like polishes, food products and pharmaceutical
preparations are prepared by using ultrasonic mixing.
The oily sludge of metals can be shacked using ultrasonic waves of frequency about
60,000 cycles per second. It can be used for removing greases, dust and metal filling in
cars, cameras and delicate instruments.

i. Cavitations and Implosion
When sound is propagated through elastic media like air and some solids,
continuous alteration take place in that medium. In case of in-elastic media like water
and some liquids, continuous alteration occurs as long as the amplitude of the sound is
comparatively small. When amplitude is increased, intense ultrasonic waves rupture a
liquid and produces cavities, when there is large dragging of particles at the time of
rarefaction because of negative pressure.

In a mixture of liquids, due to large pressure cavity collapses and breaks liquids
in to very tiny drops that are thrown aggressively into other liquid. This process results
in implosions. At the time of implosion shock waves are radiated from the places of the
collapse. It is observed that, the temperature about 10,000°F and pressure 10,000 PSI
are produced at the implosion sites of cavitations foams.

The formation and implosion of bubbles accounts for erosion and pitting of an
ultrasonic transducer kept in the liquid. The bubbles have two effects i) they produce a
dense cloud in front of transducer as well as delay propagation of ultrasonic waves, ii) frequent implosion of bubbles destroys the surface of the transducer causing pits.

Even though cavitations bubbles formed by ultrasonic vibrators in liquids hinder the wave propagation, it has some successful industrial application like ultrasonic cleaning, ultrasonic emulsification, etc.

j. Coagulation and Crystallization

The suspended particles of liquid, by ultrasonic, can be brought quite close to each other so that coagulation may takes place. The crystallization rate is also affected by ultrasonic. The size of crystal, when molten metal is put to crystallization can be made smaller and more uniform by the use of ultrasonic.

k. Ultrasonic in metallurgy

To irradiate molten metal’s which are in the process of cooling so as to refine the grain size and to prevent the formation of cores and to release trapped gases, the ultrasonic waves are used.
I. **Enemy of lower life**

Ultrasonic waves have been found to lame smaller animals such as frogs, fish and rats. It also used to damage bacteria. Yeast cells lose their rate of production when subjected to ultrasonic waves.

m. **Treatment of neuralgic pain**

Ultrasonic waves can be used to curie neuralgic and rheumatic pains. The ultrasonic wave produces smoothing massage on the affected parts. They are also used for relieving pain in arthritis. In this method, vibrating metal head of higher frequency is passed over the skin. The vibrating penetrates the tissues and the deep massage relieves the pain. The ultrasonic waves have been used to bring the contracted fingers to its original position.

n. **Detection of abnormal growth**

Irregular development in brain or fetus which could not be identified with the help of X-rays, but using ultrasonic technique it can be found out. The physical properties of materials can be studied by passing the ultrasonic waves through it [109, 193, and 303].

o. **Acoustic grating**

The variations in density of fluid layer to layer occurs when ultrasonic waves propagates through a fluids, as a result, fluid serve as a diffraction grating called ‘acoustic grating’. When light from monochromatic source is passed through fluid, it bends and produces diffraction pattern. Hence, according to condition of diffraction; we determine the velocity of ultrasonic waves. The condition is,

\[ d \sin \theta = n \lambda \]  \hspace{1cm} 1.8

In above relation, ‘n’ is the diffraction order, ‘\( \lambda \)’ is the wavelength of monochromatic and ‘d’ be separation distance between nodal or anti-nodal layers.

The value of grating element (d) is calculated using equation 1.8. With the calculated value of d, the wavelength is determined using relation

\[ d = \frac{\lambda}{2} \text{ or } \lambda = 2d \]  \hspace{1cm} 1.9

The velocity of ultrasonic wave and frequency at which resonance occurs are related by following equation

\[ V = f \lambda = 2fd \]  \hspace{1cm} 1.10

Where, V is velocity and f is frequency.
Using acoustic grating technique, velocity of ultrasonic waves in liquids as well as in gases can be determined at different temperatures. With these values the number of parameters like acoustic impedance (Z), adiabatic compressibility (β), free volume (Vf), available volume (Va), internal pressure (πi), as well as relaxation time (τ) can be calculated. In present work, all above mentioned parameters are measured using ultrasonic interferometer.

p. **Motion and flow measurement sensors**

Ultrasound is also used for opening the gate automatically, in which high frequency wave detector senses a human approach and open the door automatically. The flow of liquids trough pipes or open channels is calculated using ultrasonic flow meters. Ultrasonic flow meter determines the mean velocity of flowing liquid through pipe and channel.

q. **Ultrasound documentation**

Ultrasound documentation is also system of real time locating. RTLS are helpful for routinely tracking and to locate position of the subjects under observation. In this method fundamental nodes are incorporated with objects and detectors. After that, RTLS, send signal through ultrasonic wave in order to communicate their position to microphone detectors.

r. **Ultrasonic humidifier**

Ultrasonic humidifier is a unique type nebulizer that produces very fine spray, is famous humidifier. Working of humidifier is base on the principle that, metal plate oscillates with frequency equal to the frequency of ultrasonic wave. Due to which nebulization and even atomization of water takes place. In this technique, water is not converted in to vapor but forms smog at low temperature. Water in humidifier contains some calcium, minearls, bacteria and other impurities, which is nebulized by pressure created by ultrasonic waves. Impurities present in the water of humidifier causes sickness known as humidifier fever. Humidifier made from ultrasonic is always applicable for aeroponics, in which they are commonly used as foggers.

s. **Weapons**

Some military weapons are made using ultrasonic technique, such as riot control, misguiding of attackers.
t. **Sonogram**

In sonogram machine, with the help of ultrasonic waves a picture of movement of internal body parts are produced. Ultrasonic waves from Sonogram machine incident on a different organs and reflect from these organs. The machine is capable to measure the distance among waves to produce perfect picture, which can be seen on computer screen. This technique is comparatively economical and handy as compared with other technique. This technique is used to find the position of fetus and fetal movement and heart beat and also to determine the sex of the body.

u. **Medical applications**

Ultrasonic waves are non-invasive medical tool. Hence, ultrasonic waves has number of medical applications such as used in cancer treatment, neurosurgery, to clean tooth, cataract treatment, breaking of stone in kidney. In animal like horse, removing of tissue tendon injuries can be done using ultrasonic technique [63]. Ultrasound is used to estimate fat width and inner muscle fat in living animals. With help of ultrasonic technique breeding period in the cow and their husbandry can be increased.

Comparatively, large power ultrasound may be used to destroy kidney stone or tissue. It increases speed drugs to reach targeted area. Much research requires little particles which are obtained by ultrasonic technique. Similarly ultrasonic technique is used in the separation of cells and also in the measurement of elastic properties of tissue [230]. The ultrasonic waves may be used in removing polarization in an electric cell by stirring bubbles of hydrogen in order to avoid their deposition.

v. **Ultrasonic impact treatment**

Many properties of metals including physical and mechanical can be improved by UIT technique. Modification in particle as well as size of particle is decreased with help of ultrasonic treatment. UIT technique is powerful in addressing stress deterioration cracking, deterioration fatigue. UIT device rely on magnetostrictive transducers.
Ultrasonic waves with definite configurations create small ruptures of light in an exotic phenomenon called 'sonoluminescence'. In remote control device, ultrand is used in regulating the sound of television and to change the channels. [209].

w. Heating Effect

High intense heat is produced when ultrasonic waves pass through a material. Thus when ultrasonic beam of high intensity is passed through water at zero degrees centigrade with ice floating on its surface, water is boiled without melting the ice.

x. Mechanical Effect

A glass rod oscillating with frequency equal to the frequency of ultrasonic wave will be used to bore a hole in to metal or glass. This vibrating glass rod easily passes through glass or metal similar to hot knife. Different size and shape such as square, triangular, circular and elliptical holes can be bored using ultrasonic drill. The drill is used for preparing teeth for filling.

1.8 Statement of Problem

The ultrasonic velocity technique was used since last few years, which have created valuable interest in the study of nature of interaction among molecules in liquid and liquid solutions. Properties like ultrasonic velocities, viscosities and densities and change in above properties with respective to combination of solutions at different temperatures are used to prepare various engineering methods, chemical plants and in biological productions. The measurements of speed of ultrasonic wave, density of solution, and viscosity are used in food treatment process, various types of material testing, navigation purpose and glassware, cloths cleaning process. Above properties are also effectively used in fabric industry, leather industry as well as medicinal industry.

Now a day, measurements of speed of sound being used in synthetic technology to recognize synthetic solvent as well as polymer interactions between the various polymer solutions. The deviations in speed of sound, density as well as viscosity and their study were found very good qualitative and measurable way to bring out the knowledge about molecular or atomic arrangement and nature of forces present among molecules. The thermal and physical as well as thermodynamic properties of two liquid solutions are of very much important in gaining basic knowledge on inter as well as intra interactions among the molecules, internal arrangement of molecules, physical and-
chemical behavior of molecules. The study is also in confirming several liquid state
theories that is useful in finding the properties of liquid mixtures. Ultrasonic studies offer
prosperity information in case of the liquid state.

By passing ultrasonic waves through pure liquid and mixtures of liquid, their
properties can be studied. Significant and fundamental part is to obtain the informations
about the molecules, the solvent species and to determine the particular solvent
species. Also, for determining the interactions among them were shown by the number
of researches, which are accountable for large scale thermo-dynamic and thermo-acoustic properties in liquid solutions. Among various spectroscopic methods like X-ray
crystallography, chromatography, Nuclear Magnetic Resonance (NMR), Electron Spin
Resonance, Raman spectroscopy, neutron and light scattering, circular dichroism as
well as infra-red and determination of speed of ultrasonic waves were found to be
useful instrument, in the examination of atomic structure and thermo-dynamic
properties. These measurement techniques are also useful to study the interactions
among molecules of pure liquid and liquid solutions, as well as to study interactions
between ions in the solutions.

Structure association of bio-molecules is decided using ultrasonic speed
measurement technique. Speed of sound provides well knowledge in case of nature of
bonding among the molecule and creation of complexes at different temperatures
through molecular interactions. Ultrasonic velocity measurement method offers very fast
constructive techniques for characterizing material. Ultrasonic speed along with
viscosity and density gives good knowledge in case of interaction among the ions,
dipoles, formation of hydrogen bonding among the molecules, multi-polar as well as
existence of dispersive forces. Sound speed, viscosity as well as density provide
important information concerning the activities of liquid mixtures, due to complex
creation, interactions among dipoles and associated structural changes. These all
changes produce effect on compressibility of the binary liquid mixtures, which finally
results in to corresponding change in ultrasonic velocity. The various acoustical and
thermo-dynamic parameters help to understand the nature as well as strong-ness of
molecular interaction that present in liquid mixture. Molecular interaction produces the
structural changes in its arrangement as well as change in shape of molecules.
Therefore, chemical as well as physical properties of liquid mixtures are learned with ultrasonic technique due to its multipurpose property. This property gives much more information regarding the interaction between molecules of different binary as well as ternary liquid mixtures. Therefore, the basic properties of mixture and their additional properties are provided to be progressively useful in area of thermodynamic. Hence number of researchers are interested to work in this subject because thermodynamic and acoustic are the challenging area for many researchers.

It is very well know that, information about structure breaking and making effect of the liquid component is provided by thermo-dynamic and acoustic parameters of binary liquid solutions. In understanding the interactions among molecules of the binary liquid mixture, the computed parameters like molar sound velocity, relaxation time, free volume, adiabatic compressibility, intermolecular free length, pressure between molecules, Gibbs free energy, absorption coefficient as well as enthalpy would be helpful. Ultrasonic techniques have been effectively applied in order to study weak and strong interaction among molecules, that are exists in binary liquid mixtures. The results obtained in present work are helpful to describe the nature of molecular interactions among dimethyl sulphoxide with n-Alkanol. It is also interested to know how the ion with solvent interactions in aqueous as well as non-aqueous solvents are altered by mixing of fatty alcohols in large limit of composition as well as at various temperatures is main aim of present research work. According to our information, nobody has taken logical efforts in the study of ion-solvent interaction in the medium of aqueous and non-aqueous at different temperatures in binary solutions. Therefore, the present investigation reports ultrasonic velocity, density, viscosity and other derived thermo acoustic parameters for the following systems

i. Dimethyl sulphoxide + hexan-1-ol  
ii. Dimethyl sulphoxide + hepta-1-ol  
iii. Dimethyl sulphoxide + octan-1-ol  
iv. Dimethyl sulphoxide + nonan-1-ol  
v. Dimethyl sulphoxide + decan-1-ol

1.9 Research Objectives
1. To study the interactions among molecules, measuring the ultrasonic speed, density as well as viscosity of given five liquid systems.

2. To calculate the valuable typical parameters of liquid solutions evaluated from practical outcomes and verify the relation of adiabatic compressibility with the percentage composition of binary liquid mixtures.

3. Using practical results, various valuable thermodynamic and acoustic parameters will be evaluated, from which thermodynamic position of given mixture can be studied.

4. To verify the applicability of molar sound velocity.

5. To show the relation between deviation of these parameters with variation in combination of binary liquid systems.

6. To study interactions between molecules in terms of excess properties of evaluated parameters.

7. To study the effect of variation of temperature on molecular interaction.

1.10 Scope of research work

Now a day, ultrasonic technique for the measurement of speed sound is applied in order to study and understand the nature of interaction among molecules of pure and liquid solutions. Various ultrasonic parameters give out important information concerning with performance of liquid mixtures. In this situation, different interactions such as di-polar interactions, creation of complexes as well as associated changes in structural arrangement causes variation in compressibility of system. This variation in compressibility of liquid mixtures ultimately produces change in speed of ultrasonic wave propagating through liquid. Physical, thermal as well as chemical properties of binary liquid systems-liquid are thermodynamically much more valuable in order to study the theoretical concept of thermodynamic, acoustic as well as transport phenomena like energy, momentum, and heat. Thermo-dynamic and acoustic properties of liquid are totally depend on the composition of liquids. Hence, these properties being very helpful in understanding the type of interaction that taking place between molecules of component. It also useful in the study, that how much amount the pattern of molecular combination take place that result during intermolecular interaction.
Ultrasonic investigation of various parameters and its study is used in characterizing the different features of physical and chemical activities of liquid solutions. Velocity of ultrasonic waves, density and viscosity are the simple properties but are found to be important in marine engineering, pharmaceuticals and chemical technology. Acoustic parameters explain the various interactions between the liquid molecules.

1.11 Outline of Thesis

Chapter first includes a brief history of science in which a development of science was started in 36B.C. After that European made attempt to provide national explanation for the working of nature began with Greek in 600B.C. The Greek Leucippus (440B.C.) place the assumption in which he considered, the matter was made from very small atoms. Further, in 427-347B.C. Greek founded academy the lyceum and the museum, which is the initial example of scientific center of recent times. Aristotle was the greatest philosophers, who describe very large variety of natural assumption and told that the whole thing must take place according to fundamental principle. After that, Greek has taken more exertion to elucidate the motion of sun, moon as well as planets that has done a main part in progress of recent science. Archimedes in 287-212B.C. discovered Archimedean screw for lifting water from underground and proposed the principle of buoyancy of object in liquid, as well as evaluated perfect value of pie.

Dark Age was started after the end of Roman Empire around 400A.D. In this duration, major important inventions were made. Examples are discovery of plough and water wheel. Later on, Greek knowledge was converted in to Arabic and they 1st invented phenomena of refraction, named by Snell’s law. In the middle age, European scholar established first university with college in Cambridge and Oxford with William that investigate the cause of motion. In the period of 1530 Copernicus suggested in his theory that, earth and other planet revolved about sun. Renaissance also was seen the beginning of recent science below Galileo Galilei in 1564-1642.

Laplace was a great physicist, who had made important declaration that, “if intelligence for a given time, knows all the forces that manage nature and location of total objects which made it and if that cleverness is adequately infinite to topic and given data to analysis”. There is clear beginning of physics, but assumed that birth of physics
was from stomach of myth and magic. Up to wide range, physics can be considered as practical science which gathers knowledge that is received through observation and experiments. Physics is the vast and can be divided into number of branches such as mechanics, mathematical physics, classical physics, quantum physics, nuclear physics, light and optics, atomic physics, biophysics, astrophysics and sound.

This chapter also includes basic theory of waves and their different types. The waves are classified into three categories such as mechanical waves, electromagnetic waves and matter waves. Sound wave is one type of mechanical wave which is further classified into three types according to their frequency range. Among that ultrasonic waves that are used in research study. The ultrasonic waves have frequency above 20 KHz that are beyond the limit of a human audible range. In this chapter, researcher discussed the various methods of production of ultrasonic waves. The main source of production of ultrasonic wave is piezo-electric crystal called as piezo-electric effect. The ultrasonic waves are produces by using Galton whistle, piezo electric oscillator and Magnetostriction oscillator can be explain with diagram in details. This chapter includes the various techniques used for the detection of ultrasonic waves. For example, piezo-electric method, sensitive flame method, and thermal detector method Kundt’s tube method and so on.

Finally, chapter concluded with the properties of ultrasonic waves and their applications. Ultrasonic waves has many applications in various field, such as medical engineering, surgery, military, research laboratory, metallurgy, ultrasound identification, sensor devices, physical therapy and so on.

Chapter second contains the brief review of literature survey regarding the research topic. The literature review indicates that, ultrasonic studies were carried out in number of binary liquid solutions, so that this process gives very fast non-destructive technique for characterizing the material. From last few years, wide range of studies has been done on speed of ultrasonic waves in binary liquid solutions. Short review of the reported studies of ultrasonic velocity in pure liquids over the past few decade and binary liquid mixtures over the last 20 years was included in this chapter. Here, researcher discussed various theories regarding with pure liquid system and liquid mixture system. Many researchers used Eyring theory and Schaaff’s theory for the
study of liquid and liquid mixtures and ion-solvent interactions. Relation between molar volume and sound velocity was derived by the scientist Rao. Wada has developed connection between adiabatic compressibility with molar volume. The scientist Jacobson derived the relation between intermolecular free length and adiabatic compressibility which affect the force between molecules. Jacobson also derived the relation between surface tension and viscosity of liquids.

The detail investigation of intermolecular free length in solutions is done by Jacobson and he observed that, speed of sound as well as compressibility depends upon intermolecular free length. Concept of collision factor theory is used in the calculation of sound speed in clean liquid that was derived by Schaff’s. In binary solutions speed of sound is determined using the theory of collision factor which was further extended by Nutsch-Kuhnkiies. Marks calculated speed of sound in alcohols and connected it with chemical composition in alcohols. Nomoto’s derived the relation among molar sound velocity and molar volume for pure liquid. For binary liquid mixtures, adiabatic compressibility relation is derived by Vangeel and Dael Van W.Junjie derived the relation for calculation of ultrasonic velocity in liquid mixtures. Dack obtained internal pressure for the solvents dimethyl sulfoxide. In the given mixtures, existence of molecular interaction among molecules is due to experimentally calculated values of viscosity, density and sound speed. Corresponding change in above values, point out presence of molecular interaction among liquid molecules. Acoustic parameter also confirms the existence of interaction among molecules in given mixtures. It has been observed that, interaction among molecules in the ternary mixture were stronger than that of binary mixture and competitive mechanism established in hydrogen bond and dipole-dipole interactions among solute and solvent. For alkan-1-ol, it is observed that, going from propan-1-ol to dodecan-1-ol, the experimental values of internal pressure increases regularly with chain length. The result for methanol and ethanol must be treated carefully on account of known peculiarity of both alcohols.

Chapter III is the theoretical aspects which consist of theory related to the research work. The number of researchers has been studied acoustic and thermodynamic properties of solution containing alkanols. An alkanols also called spirits are carbon-based composites. In alkanols, one atom of hydrogen in aliphatic carbon
can be exchanged with a hydroxyl group. Therefore, alkanols molecule is the combination of two groups, that is alkyl group and hydroxyl group, which has petrolic smell. Hydroxyl group present in alcohols is responsible for chemical and physical properties of alcohols. The physical and chemical properties of alcohols are mainly due to the presence of hydroxyl group. This chapter also contains classification of alkanols with their chemical formulae. The physical properties such as boiling point, solubility, acidity and chemical properties of alkanols with other compounds are explained in details.

Formation of molecule is due to the bonding force among atoms. The nature of bonding force may be chemical or intermolecular. Here, researcher focused on intermolecular force between molecules. The strength of intermolecular force depends upon strength of covalent bond, that is when covalent bond is strong intermolecular force is weak and vice-versa. Also, there exists force between two charges according to Coulomb's law, dipole-dipole force among neutral polar molecules, water molecules form due to presence of intermolecular force and bonding is called hydrogen bonding. As compared to other compounds hydrogen atom is unique due to the reason that, it has only one electron called as valence electron. The other forces are charge dipole force, dipole-induced dipole force which present in non-polar molecules. In molecules, there are various types of interactions, such as ion-ion interaction, ion-dipole interaction, dipole-induced dipole interaction, induced dipole-induced dipole interaction, dipole-dipole interaction and so on.

This chapter deals with Jacobson free length theory, in which intermolecular free length is evaluated using sound velocity in liquid mixtures. The basic solvents used in research work are double distilled water as a reference solvent and dimethyl sulphoxide. Dimethyl sulphoxide is a colorless liquid in which polar and non-polar compound are soluble, as well as it is mixed in a large variety of carbon based solvents and also in water. Generally dimethyl sulphoxide is used in animal medicine as ointment for horses as well as in drug distribution. Additional chemicals such as one-hexanol, heptanol, octanol, nonanol and decanol are used in present work. Detail information of above alkanols with their chemical formula, method of preparation, physical properties, chemical properties and their uses are given in the chapter. Finally, chapter contains the
various formulae used in the research work for calculations. The various parameters related to the ultrasonic study of binary liquid mixtures are evaluated. These parameters are speed of ultrasonic sound, viscosity, density, distance between molecules, free volume, adiabatic compressibility, available volume, reduction time, audio effective resistance, internal pressure, absorption coefficient, Wada’s constant, Rao’s constant and Gibbs free energy etc. which are discussed in details.

Chapter IV is experimental technique, which is employed in the present research work. First researcher has given the introduction about experimental technique according to literature survey. This chapter also includes various methods such as sing around method, pulse technique method; pulse echo overlap method, optical diffraction method and ultrasonic interferometer method in order to measure speed of ultrasonic waves. The experimental arrangement and theory of above three methods are explained in details. Researcher has used ultrasonic interferometer method in present research work and hence it is discussed in detail.

Ultrasonic interferometer is very humble instrument with the help of which, one can obtain precise and reliable data. Using this data, we find the speed of ultrasonic wave in clean liquid and binary liquid solutions with high precision. In this method, the ultrasonic wave of known frequency is produced by the piezoelectric method. The velocity of ultrasonic wave is determined by the formula \( V = \nu \lambda \) in which, \( \lambda \) is the wavelength of ultrasonic wave and \( \nu \) is the number of waves per second of piezoelectric quartz crystal. Interferometer consists of quartz crystal, radio frequency oscillator, cell and measuring assembly. Quartz crystal is a silicon dioxide of trigonal class having three polar axes at 60° to each other. A transducer is a circular plate of diameter 1 cm, cut from X-axis of crystal coated with gold on both sides and acts as electrode. Radio frequency oscillator is a fixed frequency oscillator whose frequency is controlled by quartz crystal in the power amplifier of the circuit. Oscillator provides a voltage about 400 volts across the crystal which excites the X-cut crystal to producing the wave.

The cell is double walled cylindrical vessel made of stainless steel having capacity of 12ml liquid. An X-cut quartz crystal is fitted at its bottom at the center and for measuring purpose micrometer screw gauge is used, which has a least count of
Viscosity is the property of fluid by virtue of which a fluid possesses opposition to its flow. Temperature affects the viscosity of liquid and hence at low temperature viscosity is greater. The coefficient of viscosity (\(\eta\)) is described on the ground of the relative motion between different layers of fluid. The coefficient of viscosity is measured in unit poise and other units such as Pa S, Ns m\(^{-2}\), or Kg m\(^{-1}\)s\(^{-1}\).

In this chapter, different methods of viscosity measurement are discussed. Some of them are Poiseuilles method, Stoke’s falling sphere method, Ostwald’s viscometer, rising bubble method, oscillating method, ultrasonic method and rotating cylinder method. These all methods have some difficulties in accurate measurement of viscosity, but Ostwald’s viscometer is modest and easy device. Density of liquid is defined as ratio of mass to the volume of that liquid and measured in cubic centimeter or cubic meter. In this chapter, various methods of density measurement such as specific gravity bottle method, pyknometer method, mercury sinker method and hydrometer have been discussed. The chapter includes experimental setup for measurement of ultrasonic velocity, viscosity and density. The experimental setup consists of various instruments such as constant temperature bath, digital balance, ultrasonic interferometer, Ostwald’s viscometer and specific gravity bottle. Lastly, chapter contains calibration and measurement of specific gravity bottle, Ostwald’s viscometer and ultrasonic interferometer. Comparision of experimental measured values of viscosity and density for given temperatures has been done with literature values, which show good agreement. Ultrasonic velocity in distilled water is measured at above four temperatures and compared with literature values.

Chapter V is the result and discussion. In this chapter, we have used five bi-nary liquid systems over total concentrations for temperatures, 303.15, 308.15, 313.15 and 318.15 kelvin. The systems are dimethyl sulphoxide + hexan-1-ol, dimethyl sulphoxide + heptan-1-ol, dimethyl sulphoxide + octan-1-ol, dimethyl sulphoxide + nonan-1-ol and dimethyl sulphoxide + decan-1-ol. Using ultrasonic interferometer, speed of sound, density as well as viscosity of five binary liquid mixtures has been recorded for whole concentrations. Using experimentally observed values of sound speed, density and viscosity, the various sound parameters like relaxation time, acoustic effective resistance, molar sound velocity (R), and Wada constant has been evaluated for
various concentrations and temperatures. Similarly, various thermodynamic parameters namely adiabatic compressibility, intermolecular free length, internal pressure, free volume, available volume, Gibb’s energy, Enthalpy have been evaluated for the same concentrations and temperatures. Also excess values of all above parameters have been calculated. Using all above parameters, behavior and nature of interaction among molecules in liquid solution are discussed.

Chapter VI contains chapter wise summary and conclusion of present work containing five systems for whole concentration at four temperatures. This chapter also includes recommendations, future scope of the research work and limitations of research work.