Bonding in solids

- A crystal consists of atoms or molecules bound by interatomic forces or bonds.
- The interatomic forces are basically electrostatic in nature. These forces consist of both attractive and repulsive forces.
- Attractive forces are between negatively and positively charged particles and repulsive forces are between same kinds of particle
- The different types of bonds are due to the differences in electronic structure of the atoms. Depending on strength and directionality, bonds are divided into two types: (1) **primary** and (2) **secondary bonds**. Primary bonds are interatomic in nature whereas secondary bonds are intermolecular in nature.

Ionic , Covalent and Metallic **Hydrogen ,Van Der Wall's**

Ionic Bond

- An ionic bonding is the Attractive Force existing between positive ion and a negative ion when they are brought into close proximity or surrounding. Bond between Metal and non metal
- They are formed when atoms of different elements lose or gain their electrons in order to achieve stabilized outermost electronic configuration.
- Elements are classified as either electropositive or electronegative, depending upon when they tend to lose or gain electrons in order to achieve this stable outer shell electron configuration
- Ionic bonds are mainly formed in inorganic compound like NaCl and KOH etc., and never in pure elements
- They have high melting and boiling points. Ionic solids are good insulators of electricity in their solid state and good conductor of electricity in their molten state. Ionic solids are soluble in water and slightly soluble in organic solvents.

Let us consider the combination between the Sodium (metal) and Chlorine (non-metal) to form sodium chloride. The sodium has a single electron in its outer shell and this transfer to join the seven electrons in the outer shell of chlorine

Characteristics of Ionic bonds

(i) Ionic bonds are unidirectional.

(ii) They are generally crystalline in nature

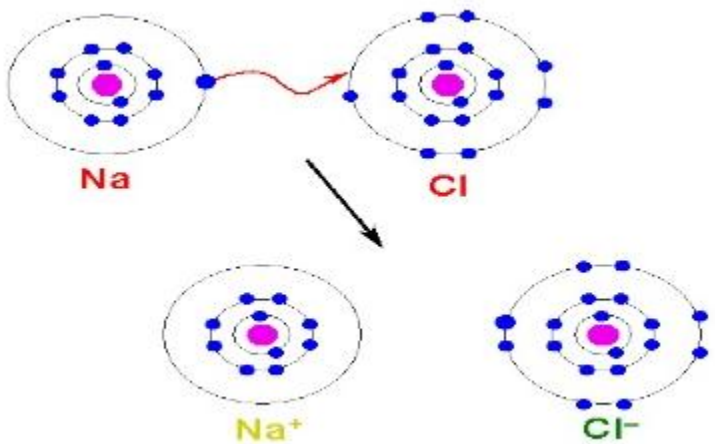
(iii) They are rigid.

(iv) They have high melting and also high boiling point because strong electrostatic forces bind them.

(v) They are generally non-conductors of electricity but their metals and solutions conduct electricity.

(vi) They are usually highly soluble in water and other polar solvents but insoluble in organic solvents.

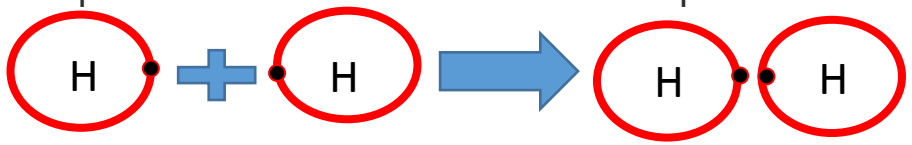
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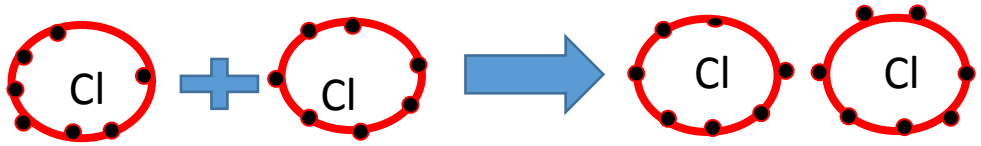


Covalent Bond

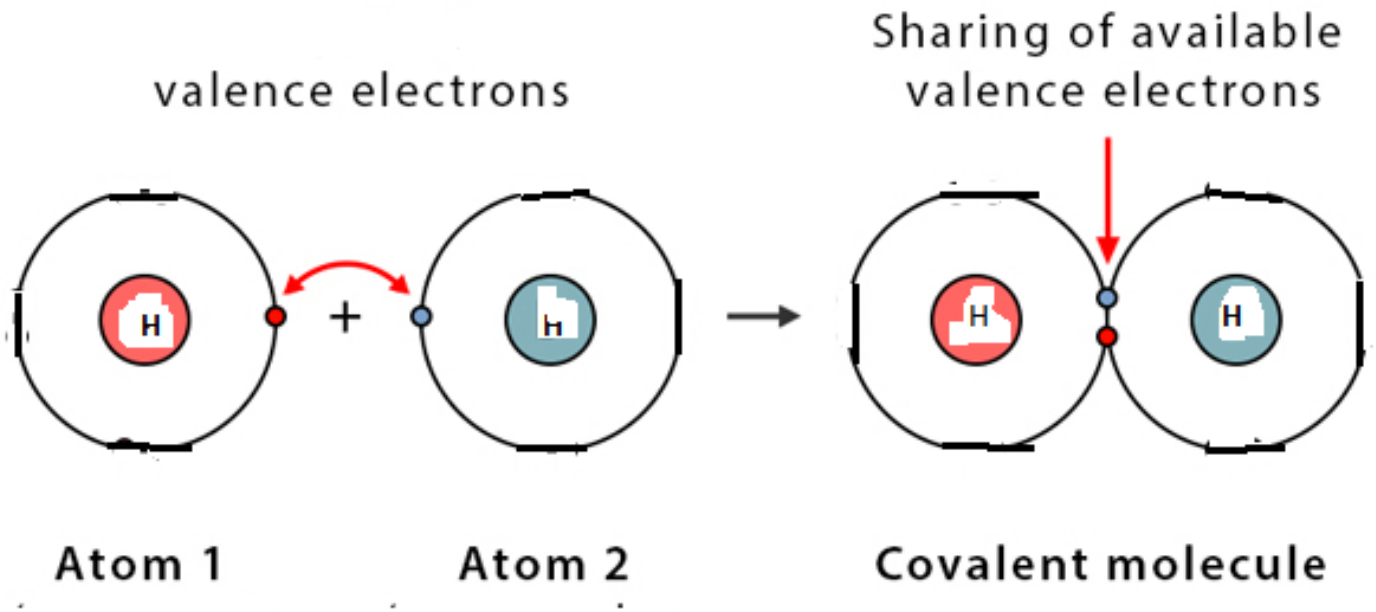
- Covalent bonds are the most important means of bonding in organic chemistry.
- A covalent bond is formed by equal sharing of electrons from both the participating atoms. The pair of electrons participating in this type of bonding is called shared pair or bonding pair. (Lewis concept) equal sharing of electrons between two atoms
- The covalent bonds are also termed as **molecular bonds.** Sharing of bonding pairs will ensure that the atoms achieve stability in their outer shell which is similar to the atoms of noble gases. **Octet rule is followed by the atom**
- The covalent bond is formed by sharing of electrons between atoms rather than by **transfer of electrons**. Only a few solids are held together by covalent bonds. Covalent bonding alone is not sufficient to build a solids.
- An excellent example of covalent bonding is found in the Chlorine molecule. Here the outer shell of each Chlorine atom possesses seven electrons. Each chlorine atom would like to gain an electron and thus form a stable **octet**. This can be done by sharing of two electrons between pairs of chlorine atoms thereby producing stable **diatomic molecules**

Double bonds share two pairs of electrons (like O_2 and triple bonds share three pairs of electrons (likeN_2. Bonds sharing more than one pair of electrons are called multiple covalent bonds.




Cl
Cl
Cl
Cl

Cl-Cl


valence electrons
Sharing of available valence electrons
H
H
H
H
Atom 1
Atom 2
Covalent molecule

- In this bonding a stable arrangement is achieved by sharing of electrons rather than transfer of electrons. Sometimes a covalent bond is also formed when two atoms of different non-metals share one or more pair of electrons in their outermost energy level. e.g.- Water molecule Bonding between two atoms of same element Bonding between two different nonmetals Covalent compounds are bad conductors of electricity.

Insoluble- in water Soluble- in organic solvents like BenzeneIt has been observed that in a metal atoms, the electrons in their outermost energy levels are loosely held by their nucleii. Thus a metal may be considered as a cluster of positive ions surrounded by a large number of free electrons, forming electron cloud. e.g.- all metals High thermal and electrical conductivity Low melting and boiling point temperature Have a bright lustre Metallic solids are malleable and ductile Covalently bonded atoms often produce an Electric dipole configuration with hydrogen atom as the positive end of the dipole. If bonds arise as a result of electrostatic attraction between atoms, it is known as hydrogen bonding. The hydrogen bonds are directional • Relatively strong bonding • These solids have low melting point • No valence electrons hence good insulators Soluble in both polar and non-polar solvents • They are transparent to light e.g. – water molecule, ammonic molecules •

Characteristics of Covalent Bond

(i) Covalent compounds are directional in nature.

(ii) They can be solids, liquids and gasses.

(iii) They are soft and have low melting and boiling points.

(iv) They are generally insulators electrically.

(v) They are soluble in non-polar solvents such as benzene and carbon tetrachloride and insoluble in water.

Metallic Bond

- **Metallic bonds nothing but it +Ve charge nucleus is embed in the A "sea" of free or, delocalized electrons.** Metallic bonds are the chemical bonds that hold atoms together in metals.
- This bond is also called **unsaturated covalent bond** A metallic bond is a type of chemical bond in which a 'cloud' of free moving valence electrons
- is bonded to the positively charged ions in a metal. It can be described as the sharing of free electrons among a lattice of positively charged metal ions. The structure of metallic bonds is entirely different from that of ionic and covalent bonds. These are formed when the valence electrons of metal atoms are shared by more than one neighboring atom **Example:** The metal atoms Na, Cu, Ag, Fe etc., are bound to each other in their crystals by metallic bond.
- Metallic bonds are formed when the charge is spread over a larger distance as compared to the size of single atoms in solids. for example, zinc and copper. and Fe
- They differ from covalent and ionic bonds because the electrons in metallic bonding are delocalized, that is, they are not shared between only two atoms. Instead, the electrons in metallic bonds float freely through the lattice of metal nucle

- Metals are characterized by bright, luster, high electrical and thermal conductivity malleability, ductility and high tensile strength. A metallic crystal consists of a very large number of atoms arranged in a regular pattern.
- Different models have been proposed to explain the nature of metallic bonding. Two most important modules are as follows
- In model, a metal is assumed to consist of a lattice of positive ion (or kernels) immersed in a sea of mobile valence electrons, which move freely within the boundaries of a crystal.
- A positive kernel consists of the nucleus of the atom together with its core on a kernel is, therefore, equal in magnitude to the total valence electronic charge per atom.
- The free electrons shield the positively charged ion cores from mutual electrostatic repulsive forces which they would otherwise exert upon one another. In a way, these free electrons act as ‘glue’ to hold the ion cores together.
- The forces that hold the atoms together in a metal as a result of the attraction between positive ions and surrounding freely mobile electrons are known as metallic bonds.

- They differ from covalent and ionic bonds because the electrons in metallic bonding are delocalized, that is, they are not shared between only two atoms. These , the electrons in metallic bonds float freely through the lattice of metal nuclei
- This type of bonding gives metals many unique material properties, including excellent thermal and electrical conductivity,

Electrical Conductivity

Electrical conductivity is a measure of the ability of a substance to allow a charge to move through it. Since the movement of electrons is not restricted in the electron sea, any electric current passed through the metal passes through it

When a potential difference is introduced to the metal, the delocalized electrons start moving towards the positive charge. This is the reason why metals are generally good conductors of electric current

.2. Thermal Conductivity

The thermal conductivity of a material is a measure of its ability to conduct/transfer heat. When one end of a metallic substance is heated, the kinetic energy of the electrons in that area increases. These electrons transfer their kinetic energies to other electrons in the sea via collisions.

The greater the mobility of the electrons, the quicker the transfer of kinetic energy. Due to metallic bonds, the delocalized electrons are highly mobile, and they transfer the heat through the metallic substance by colliding with other electrons.

3. Malleability and Ductility 4. Metallic Luster

When light is incident on a metallic surface, the energy of the photon is absorbed by the sea of electrons that constitute the metallic bond. The absorption of energy excites the electrons, increasing their energy levels. These excited electrons quickly return to their ground states, emitting light in the process. This emission of light due to the de-excitation of electrons attributes a shiny metallic lustre to the metal.

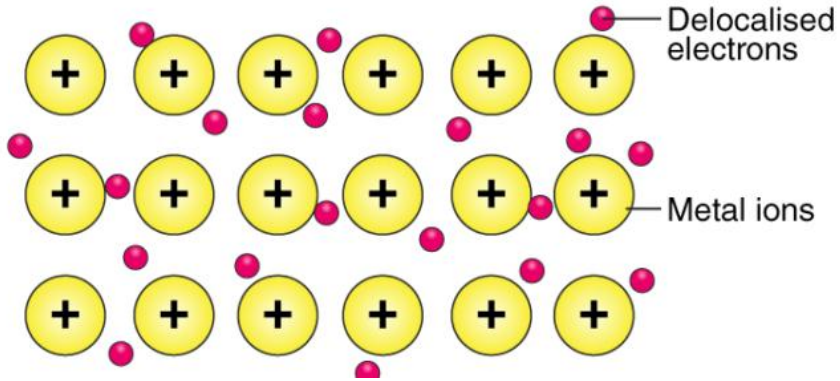
5. High Melting and Boiling Points

As a result of powerful metallic bonding, the attractive force between the metal atoms is quite strong. In order to overcome this force of attraction, a great deal of energy is required. This is the reason why metals tend to have high melting and boiling points. The exceptions to this include zinc, cadmium, and mercury (explained by their electron configurations, which end with ns^2).

The metallic bond can retain its strength even when the metal is in its melt state. For example, gallium melts at 29.76^{o}C but boils only at 2400^{o}C. Therefore, molten gallium is a non volatile liquid.

Metallic Bond

- Because metals are solid, their atoms are tightly packed in a regular arrangement. They are so close to each other so valence electrons can be easily moved away from their atom**.**
- **Therefore we have** A “sea” of free, delocalized electrons is formed surrounding a lattice of positively charged metal ions. These ions are held by strong attractive forces to mobile electrons; in this way, metallic bonds are formed as shown in Fig.

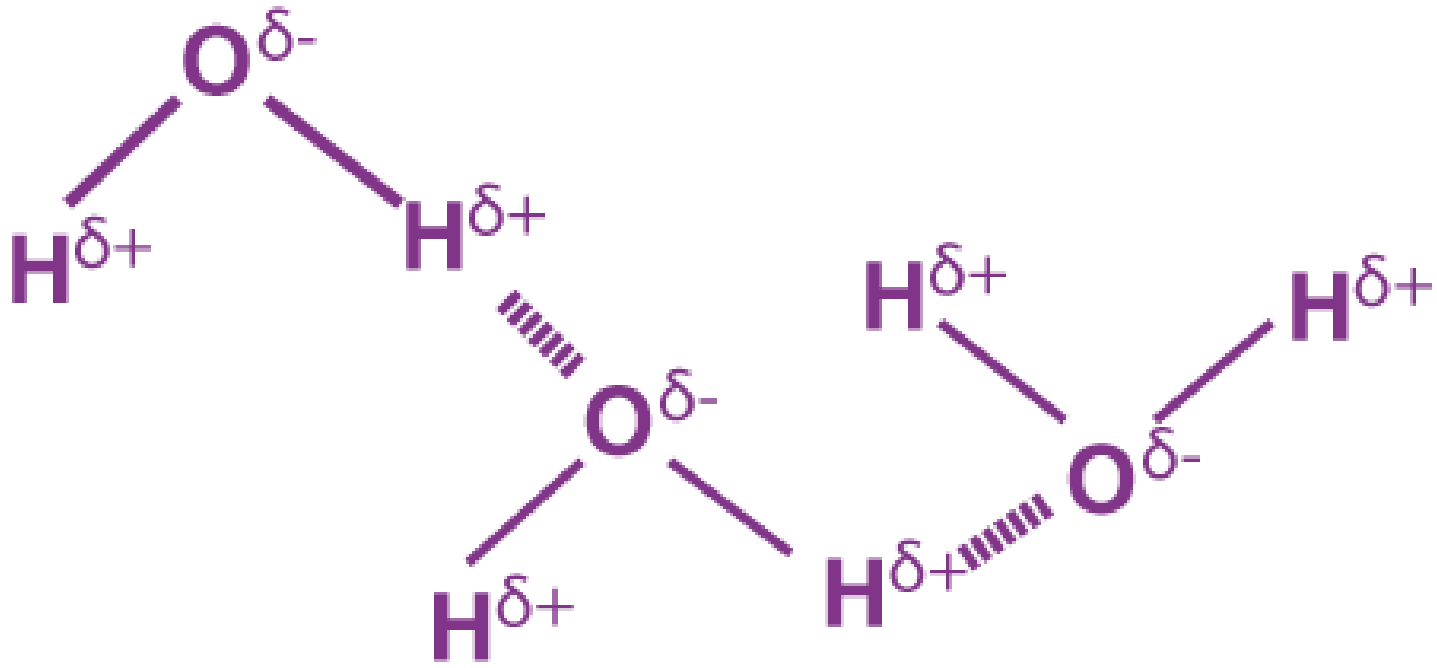


Thi. They are good conductors of electricity also.

he metal atoms Na, Cu, Ag, Fe etc., are bound to each other in their crystals by metallic bond

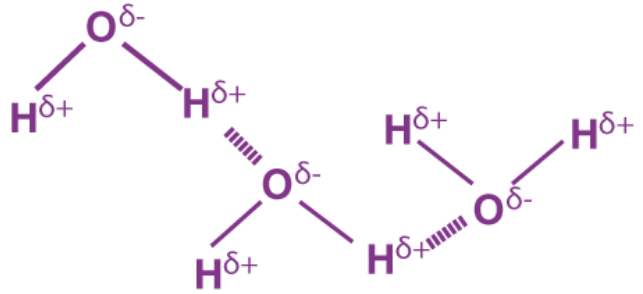
Hydrogen Bond

- Hydrogen bonding in which a special class of attractive intermolecular forces that arise due to the dipole-dipole interaction between a hydrogen atom that is bonded to a highly electronegative atom and another highly electronegative atom which lies in the vicinity of the hydrogen atom.



Hydrogen Bond

- For example, in water molecules (H_2O), hydrogen is covalently bonded to the more electronegative oxygen atom. Therefore, hydrogen bonding arises in water molecules due to the dipole-dipole interactions between the hydrogen atom of one water molecule and the oxygen atom of another H_2O molecule.
- the location of the bond pair of electrons in the O-H bond is very close to the oxygen nucleus (due to the large difference in the electro negativities of oxygen and hydrogen).
- Therefore, the oxygen atom develops a partial negative charge (-δ) and the hydrogen atom develops a partial positive charge (+δ).
- Now, hydrogen bonding can occur due to the electrostatic attraction between the hydrogen atom of one water molecule (with +δ charge) and the oxygen atom of another water molecule (with -δ charge).
- Thus, hydrogen bonds are a very special class of intermolecular attractive forces that arise only in compounds featuring hydrogen atoms bonded to a highly electronegative atom.
- Hydrogen bonds are mostly strong in comparison to normal dipole-dipole and dispersion forces. However, they are weak compared to true covalent or ionic bonds.



- In a molecule, when a hydrogen atom is linked to a highly electronegative atom, it attracts the shared pair of electrons more and so this end of the molecules becomes slightly negative while the other end becomes slightly positive.
- The negative end of one molecule attracts the positive end of the other and as a result, a weak bond is formed between them. This bond is called the **hydrogen bond.**
- As a result of hydrogen bonding, a hydrogen atom links the two electronegative atoms simultaneously, one by a covalent bond and the other by a hydrogen bond. The conditions for hydrogen bonding are:
- The molecule must contain a highly electronegative atom linked to the hydrogen atom. The higher the electronegativity more is the polarization of the molecule.
- The size of the electronegative atom should be small. The smaller the size, the greater is the electrostatic attraction.
-

Van der Waals Bond

- Van der Waals forces are weak intermolecular forces that are dependent on the distance between atoms or molecules. These forces arise from the interactions between uncharged atoms/molecules. the group of forces that fall under the category of '***weak chemical forces'***, Van der Waals forces are the weakest. And non-directional
- They are known to rapidly vanish when the distance between the interacting molecules increases.
- When the electron density around the nucleus of an atom undergoes a transient shift, it is common for Van der Waals forces arising. For example, when the electron density increases in one side of the nucleus, the resulting transient charge may attract or repel a neighboring atom. The nature of these forces is dependent on the distance between the atoms.
- Weak attraction force exists between the opposite ends of the dipole in the neighboring atoms.
- This force only inert gas atom to condenses at low temperature
- Magnitude of Van der Waals forces is weaker than hydrogen bond.
- They cant respond the electrical conductivity when external electrical field is applied.
- These solid are characteristic by low melting point , high thermal expansion coefficient.
- Due to the weak force they are soft and mechanically weak.
-

Van der Waals Bond

- According to the Van Der Waals forces definition, they are comparatively weaker electrostatic forces that attract uncharged or neutral molecules towards each other in almost all organic liquids, gasses, and solids.
- In solids, these forces hold each other having lower melting points, and are relatively softer than the ones held by ionic or metallic bonds.
- In comparison to most of the ionic and covalent bonds, these interactions do not arise from an electronic bond.
- The Van Der Waal forces include attractions within various atoms, resulting from influenced dipoles. However, they also involve a repulsive interaction within molecules, arising from the overlapping of more than two atomic electronic clouds situated closer to each other.
- .Some Van Der Waals forces examples are hydrogen bonding, dipole-dipole interactions, and dispersion forces.

Van der Waals Bond

- equation of Van Der Waal Bonds The Van Der Waals equation is a state that shows two properties of gases, such as the excluded volume of real gases and its attractive forces.
- It gets expressed as:(P+n2a/V2) (V-nb)= nRTWhere a = magnitude of attraction within molecules/ atoms And, b = excluded volume .
- Study the equation thoroughly, and find out some Van Der Waals equation examples. Properties of Van Der Waals The below pointers show some of the characteristics of Van Der Waals forces.
- They comprise relatively weaker, electric forces compared to ionic, metallic or covalent bonds. The interactions are addictive when a large number of molecules are present.
- These are still present when molecules get placed afar. The Van Der Waal force is omnipresent and responsible for the attraction of atoms and molecules within each other.
- They remain unaffected due to temperature changes except in situations of dipole-dipole interactions
- .Although they are present in most of the materials, yet their effects get overpowered by the primary bonds.

- **Types of Van Der Waals InteractionsInitially**, there were three types of Van Der Waals forces. These include: London Dispersion Forces:
- These bonds are the weakest attractive bonds, resulting from temporary and induced dipoles present in various atoms and molecules.
- They form when electrons present in two adjacent atoms occupy temporary positions. They are also known as dipole-induced dipole attraction.
- These forces are also responsible for the condensation of non-polar substances into liquids. They often freeze into solids when the temperature falls quickly.
- According to the Van Der Waals definition, these forces depend on the polarization ability of the molecules or atoms. The dispersion interactions are also present within two molecules, even the polar ones when they are extremely close to each other.
- The strength of the Waals forces depends on the number of electrons present in the molecule. Moreover, they occur due to the movement of the electrons.(Image will be uploaded soon)

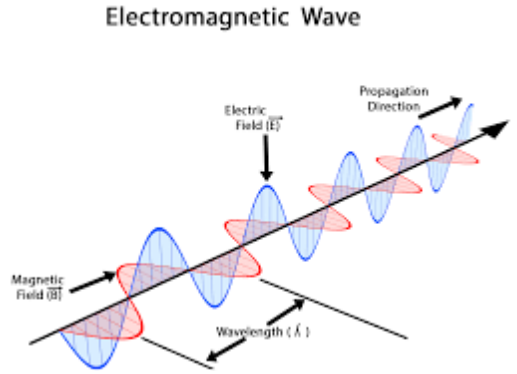
Electromagnetic Spectrum

➢Fundamentals of EM waves in the classical electrodynamics, can be showed with help of several experiments but classical understanding of EM waves is not sufficient.

➢Around 1900, Max Planck established the theory that EM radiation behaves not only as classical wave, but also as mass-less particle.

➢In 1904, Albert Einstein confirmed this theory with the discovery of the photo effect, which cannot be explained with classical explanatory approaches.

➢The energy of such a mass less 'light particle', a so-called photon, is directly correlated to its frequency:



Electromagnetic Spectrum




All electromagnetic waves travel at the same speed through empty space. That speed, called the **speed of light**, is about 300 million meters per second (3.0×10^8 m/s). Nothing else in the universe is known to travel this fast. The sun is about 150 million kilometers (93 million miles) from Earth, but it takes electromagnetic radiation only 8 minutes to reach Earth from the sun. If you could move that fast, you would be able to travel around Earth 7.5 times in just 1 second!

Wavelength and Frequency of Electromagnetic Waves

Although all electromagnetic waves travel at the same speed across space, they may differ in their wavelengths, frequencies, and energy levels.

Wavelength is the distance between corresponding points of adjacent waves Wavelengths of electromagnetic waves range from longer than a soccer field to shorter than the diameter of an atom.

Wave frequency is the number of waves that pass a fixed point in a given amount of time. Frequencies of electromagnetic waves range from thousands of waves per second to trillions of waves per second.

The energy of electromagnetic waves depends on their frequency. Low-frequency waves have little energy and are normally harmless. High-frequency waves have a lot of energy and are potentially very harmful.

Electromagnetic Spectrum





Basic Properties of Electromagnetic Waves

They both represent electromagnetic waves. These are waves that consist **of vibrating electric and magnetic fields.** They transmit energy through matter or across space.

Some electromagnetic waves are generally harmless. The light we use to see is a good example. Other electromagnetic waves can be very harmful and care must be taken to avoid too much exposure to them. X rays are a familiar example.

Property 1: Electromagnetic waves are transverse in nature.

2: They propagate by varying electric fields and magnetic fields, such that these two fields are at **right angles to each other** and at a right angle with the direction of propagation of the wave.

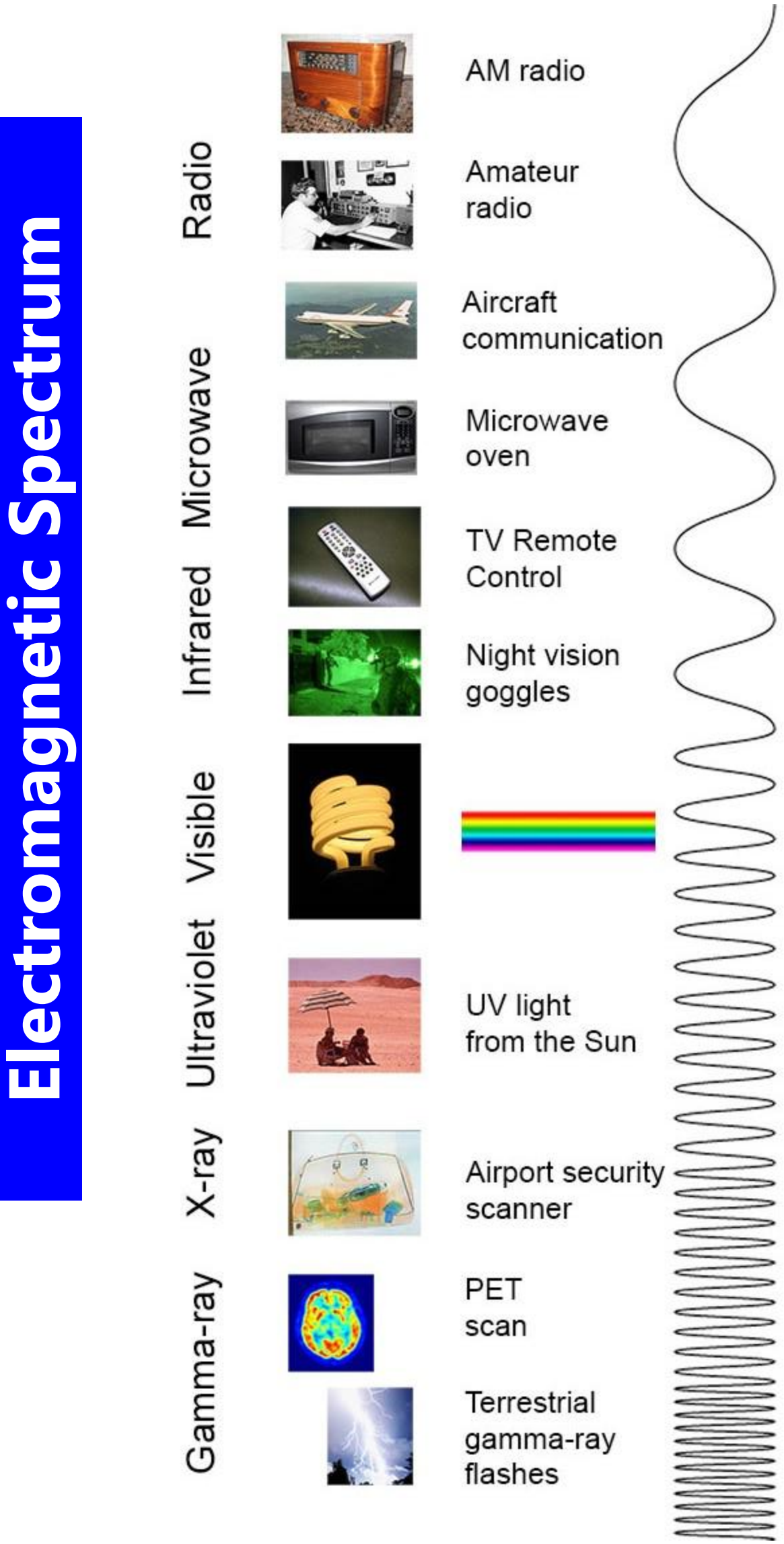
3: Electromagnetic waves travel with a constant velocity in vacuum. The speed of the waves is 3×10^8 m/s.

4: Electromagnetic waves are non-mechanical waves. They do not require any material medium for propagation

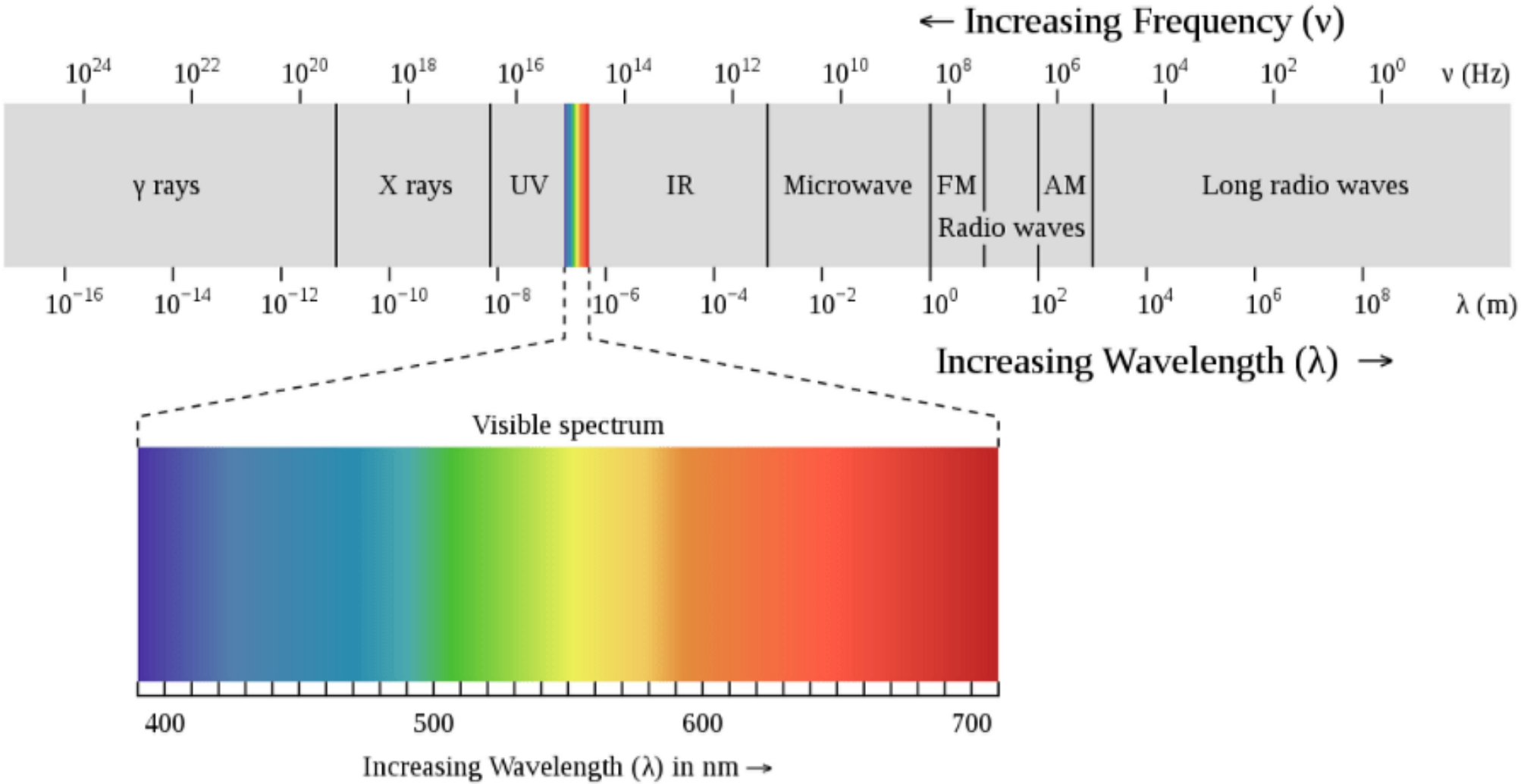
5: They obey the equation $c = f\lambda$. Here, f is the frequency is Hertz and λ is the wavelength meters. The product of wavelength and frequency is equal to a constant c, the speed of light which is equal to 3×10^8 m/s. From this relation between wavelength, frequency and speed of light we can understand that the electromagnetic waves will travel with the speed of light regardless of wavelength and frequency.

6: The oscillating electric field and magnetic field are in the same phase. The ratio of the amplitudes of the electric field and the magnetic field is equal to the velocity of the wave.

Electromagnetic Spectrum



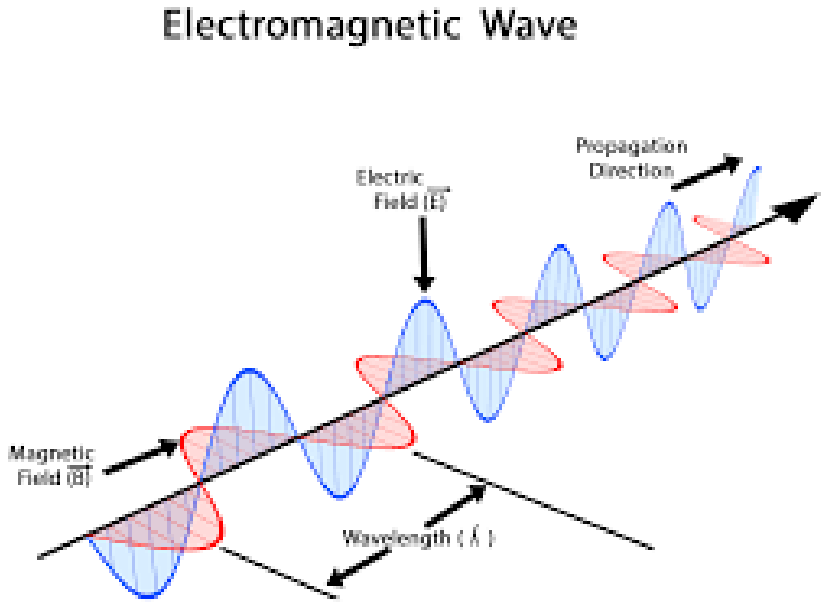
Electromagnetic Spectrum



Use of Electromagnetic Spectrum

EM waves traveling in space without obstruction approximate the behavior of plane waves. Electromagnetic waves have an electric (**E**) field component and a magnetic (**H**) field component that oscillate in phase and in directions perpendicular to each other.

For plane waves, also called transverse electromagnetic (TEM) waves, both **E** and **H** components are in transverse planes (perpendicular) to the traveling direction of the electromagnetic wave. In mathematical terms, an electromagnetic wave propagates in the direction of the cross-product of two vectors **E** × **H**. That is, assuming that the direction of the propagation of EM waves is in the z direction as illustrated in Fig. 1.2, the *x*-*z* plane contains the electric component **E** with the electric field components directed towards the *x*-axis, while the *y*-*z* plane contains the magnetic component **H** with magnetic field components directed towards the *y*-axis.



Use of Electromagnetic Spectrum

➢The behaviour of an electromagnetic wave in a substance depends on its frequency or wavelength. The differing behaviours of different groups in the electromagnetic spectrum make them suitable for a range of uses.

➢**Radio waves the** frequency range from 3×10^{5}Hz to 3×10^{9}Hz These waves are produced by oscillating electric circuits having an inductor and capacitor.

➢Radio waves are used for communication such as television and radio.

➢Radio waves are transmitted easily through air.

➢They do not cause damage if absorbed by the human body, and they can be reflected to change their direction. These properties make them ideal for communications.

R

Use of Electromagnetic Spectrum

Producing radio waves - Higher

Radio waves can be produced by oscillations in electrical circuits. When radio waves are absorbed by a conductor, they create an alternating current. This electrical current has the same frequency as the radio waves. The conductor could be, for example, an aerial on a radio. Information is coded into the wave before transmission, which can then be decoded when the wave is received. Television and radio systems use this principle to broadcast information.

Microwaves are the form of E.M radition with wave length ranging form one meter to one millimeter. and Frequency 300 MHz to 300 GHz.

Microwaves are used for cooking food(2450MHz) and for satellite communications. High frequency microwaves have frequencies which are easily absorbed by molecules in food. The internal energy of the molecules increases when they absorb microwaves, which causes heating. Microwaves pass easily through the atmosphere, so they can pass between stations on Earth and satellites in orbit. Microwaves are good examples of transmitting information for one place to another. Source produced by electronic ckt. With antennas that are typically around one meter or less in size produced by sp.vacume tube.

Use of Electromagnetic Spectrum

➢Infrared region lies between **visible** and **microwave** portion of the electromagnetic spectrum with wavelength ranging form 10-6 to8*10-4 meter

➢'Near' I.R closest in the wavelength of visible light' Far 'I.R. is closed to primary source of I.R in the form of heat.They strongly absorb by glass. Object which is very cold emits I.R.

➢When object is not quite enough to radiate visible light it will emit most of its energy in I.R for example charcoal may not give off light but does I.R radiation by which we feel as heat .more warmer is object more I.R radiations are emitted.

➢Infrared light is used by electrical heaters, cookers for cooking food, and by infrared cameras which detect people in the dark.

➢ Infrared light has frequencies which are absorbed by some chemical bonds. The internal energy of the bonds increases when they absorb infrared light, which causes heating. This makes infrared light useful for electrical heaters and for cooking food. All objects emit infrared light. The human eye cannot see this light, but infrared cameras can detect it. This 'thermal imaging' is useful for detecting people in the dark.

Use of Electromagnetic Spectrum

Visible light Visible light is the light we can see. electromagnetic spectrum with wavelength ranging form 740nm to 380nm anf frequency 4.05*1014Hz to about 7.8*1014Hz

Visible lightemits or reflected from object It is used in fibre optic communications, where coded pulses of light travel through glass fibres from a source to a receiver.

Ultraviolet radiation wavelength ranging form 4* 10-7m(400nm) to 6*10-10m (0.6nm)can pass through glass also quartz Ultraviolet radiation can kill bacteria that are present in water - this sterilizes the water and makes it safe to drink. Ultraviolet radiation is also good for the skin as it helps to make vitamin D. However, too much exposure to UV can cause skin problems.

Use of Electromagnetic Spectrum

Radio waves and microwaves

These two parts of the spectrum share a lot of similarities and uses. Their main uses concern wireless communication – in fact many things that people often assume use radio waves actually use microwaves (e.g. WiFi, radar, mobile phones, satellite communications At very high intensity, microwaves can also be used to heat things: This is what happens in a microwave oven

Infrared Infrared is emitted by warm objects and can be detected using special cameras (thermal imaging cameras). These can be used in industry, in research and also in medicine Many security cameras are capable of seeing slightly into the infrared part of the spectrum and this can be used to allow them to see in the dark: Infrared lights are used to illuminate an area without being seen, which is then detected using the camera Remote controls also have small infrared LEDs that can send invisible signals to an infrared receiver on a device such as a TV Infrared travels down fibre optic cables more efficiently than visible light, and so most fibre optic communication systems use infrared

What are X-Rays?

We can define X-Rays or X-radiation as a form of electromagnetic radiation. They are powerful waves of electromagnetic energy. Produced by high energy electronic transitions in heavier atoms. High penetrating power can ionize through which they pass. Most of them have a wavelength ranging from 0.01 to 10 nanometres, corresponding to frequencies in the range 30 petahertz to 30 exahertz and energies in the range 100 eV to 100 keV.

Who invented the X-Ray?

German physicist Wilhelm Röntgen is typically credited for the discovery of X-Rays in 1895 because he was the first to comprehensively study of X-ray.

How do X-Rays work?

They are produced when high-velocity electrons collide with the metal plates, thereby giving the energy as the X-Rays and themselves absorbed by the metal plate.

The X-Ray beam travels through the air and comes in contact with the body tissues, and produces an image on a metal film.

Soft tissue like organs and skin, cannot absorb the high-energy rays, and the beam passes through them.

Dense materials inside our bodies, like bones, absorb the radiation.

Properties of X-Rays

They have a shorter wavelength of the electromagnetic spectrum.

Requires high voltage to produce X-Rays.

They are used to capture the human skeleton defects.

They travel in a straight line and do not carry an electric charge with them.

They are capable of travelling in a vacuum.

Use of Electromagnetic Spectrum

Gamma rays Gamma rays are very dangerous and can be used to kill cells and living tissue If the gamma rays are carefully aimed at cancerous tissue they can be very effective at killing it Gamma rays can also be used to sterilise things by killing off the bacteria

German scientist **H. R. Hertz** in 1887 ,first of all gave a practical demonstration of the production of *Electromagnetic wave.* using an oscillatory circuit. ***Hertz Experiment*** was based on the fact that a vibrating electric charge radiates Electromagnetic waves. He produced Electromagnetic waves in the laboratory . Hertz used the arrangement shown in the figure for the production of Electromagnetic waves

Hertz Experiment

The arrangement consists of a two large metallic plates P_1 and P_2 connected to an Induction coil Two metallic spheres are also used in the arrangement. They are denoted as S_1 and S_2. These metallic spheres are connected to the metallic plates.

A small air gap separates these two metallic spheres. The metallic spheres behaves like a capacitor of capacitance C.

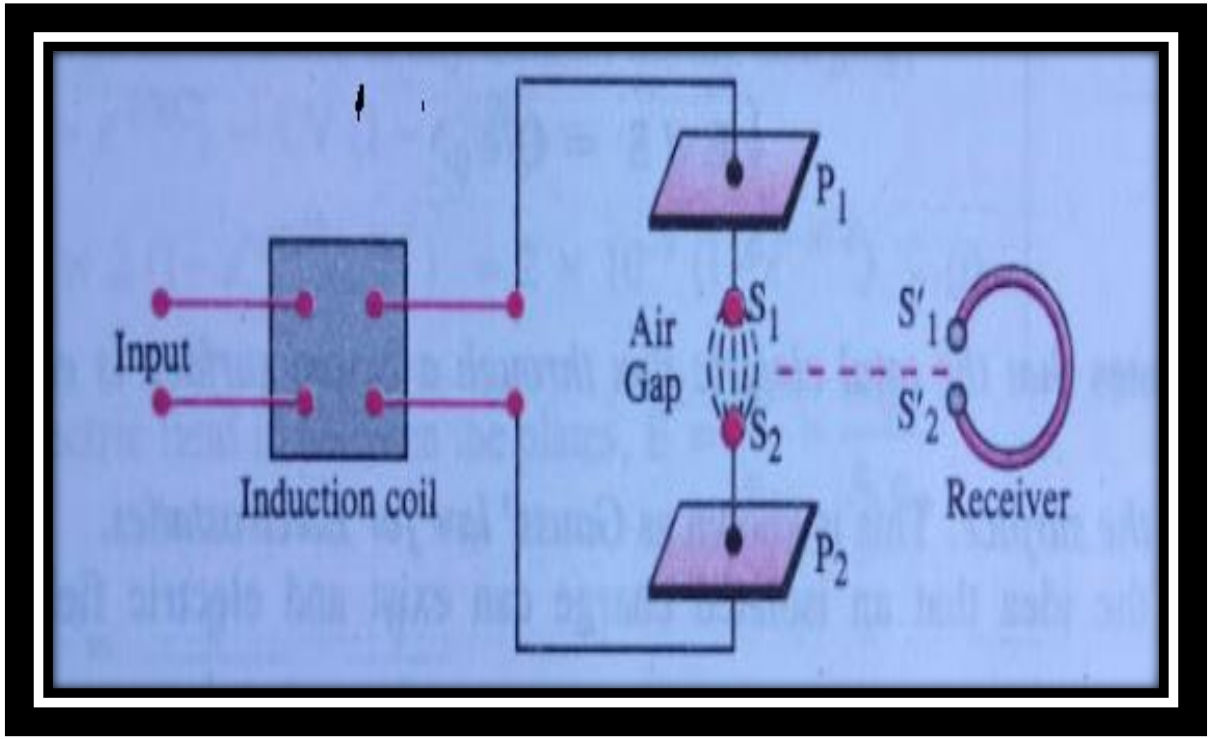
This circuit is know as transmitter.

Hertz used a single loop of wire to spheres S_1' and S_2' in the arrangement. away from the transmitter

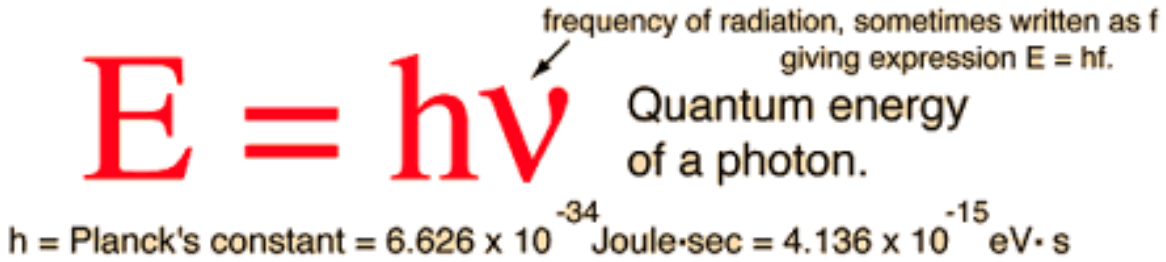
This circuit is know as receiver.

we can say that a transmitter is an L-C circuit.

The L-C circuit gives rise to Electromagnetic waves due to transfer of energy. The energy gets transferred from the electric field of the capacitor to the magnetic field of the inductor (i.e., Induction coil)



PLANCK HYPOTHESIS



➢Until the late 19th century, Newtonian physics dominated the scientific worldview. However, by the early 20th century, physicists discovered that the laws of classical mechanics do not apply at the atomic scale.t

➢The photoelectric effect could not be rationalized based on existing theories of light, as an increase in the intensity of light did not lead to the same outcome as an increase in the energy of the light.

➢Planck postulated that the energy of light is proportional to the frequency, and the constant that relates them is known as Planck's constant (h). His work led to Albert Einstein determining that light exists in discrete quanta of energy, or photons.

PLANCK HYPOTHESIS

- According to the Planck hypothesis, **all electromagnetic radiation is quantized and occurs in finite "bundles" of energy** which we call photons. ...
- The quantization implies that a photon of blue light of given frequency or wavelength will always have the same size quantum of energy.
- The quantum of energy for a photon is not Planck's constant **h** itself, but the product of **h** and the frequency.
- The quantization implies that a photon of blue light of given frequency or wavelength will always have the same size quantum of energy.
- For example, a photon of blue light of wavelength 450 nm will always have 2.76 eV of energy. It occurs in quantized chunks of 2.76 eV, and you can't have half a photon of blue light - it always occurs in precisely the same sized energy chunks.
- But the frequency available is continuous and has no upper or lower bound, so there is no finite lower limit or upper limit on the possible energy of a photon.
- On the upper side, there are practical limits because you have limited mechanisms for creating really high energy photons. Low energy photons abound, but when you get below radio frequencies, the photon energies are so tiny compared to room temperature thermal energy that you really never see them as distinct quantized entities - they are swamped in the background. Another way to say it is that in the low frequency limits, things just blend in with