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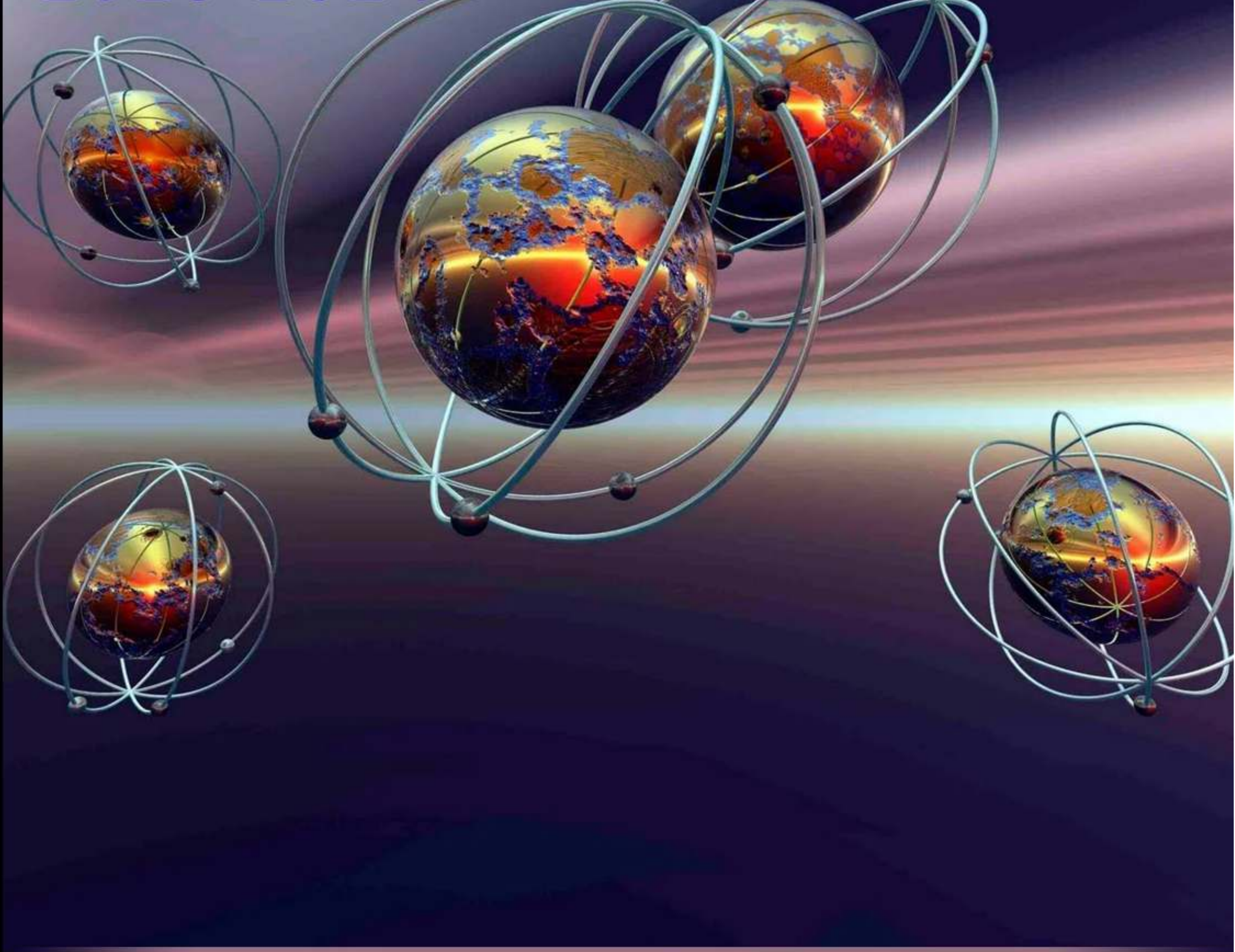

UNIT-5
Atomic and Nuclear Physics

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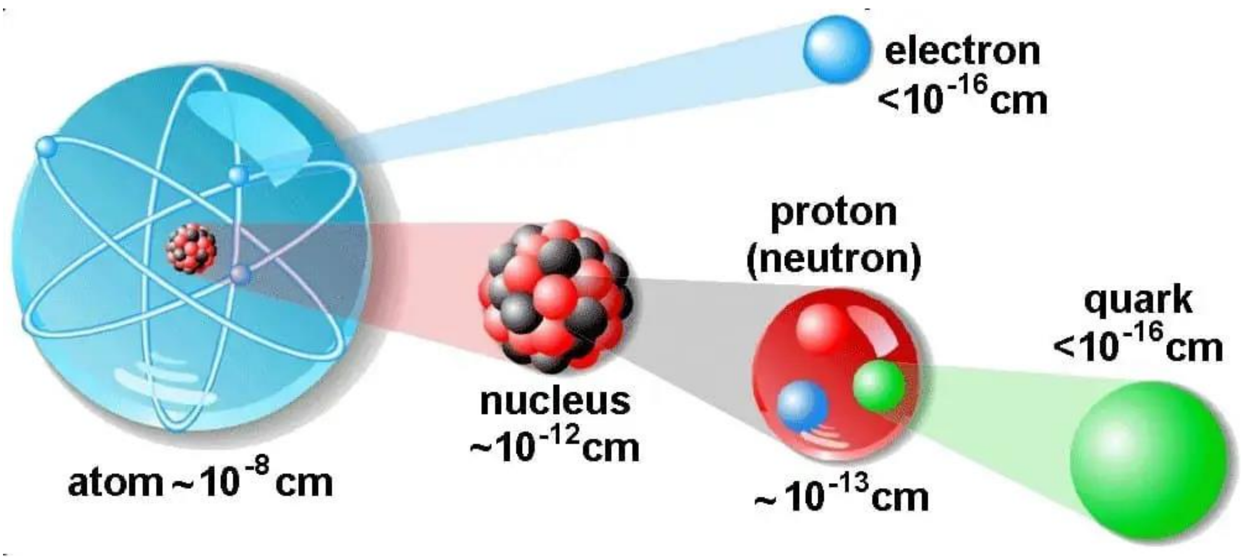
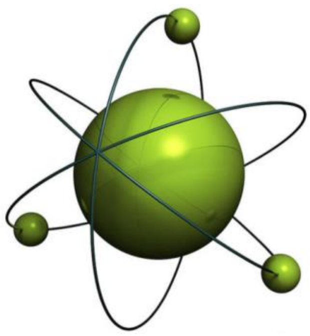
UNIT 5 – ATOMIC & NUCLEAR PHYSICS





COMPETITIVE EXAM

For

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UNIT 5– ATOMIC &NUCLEAR PHYSICS

5.1. Bohr Atom Model

Atom Models:

- There has been a variety of atomic models throughout history of atomic physics, that refers mainly to a period from the beginning of 19th century to the first half of 20th century, when a final model of atom which is being used nowadays was invented. The basic atom models are,
  - Dalton´s Billiard Ball Model,
  - J.J Thomson's "plum pudding" model
  - Rutherford's Planetary model
  - Bohr's Atomic model
  - Sommerfeld Relativistic atom model
  - Vector Atom model

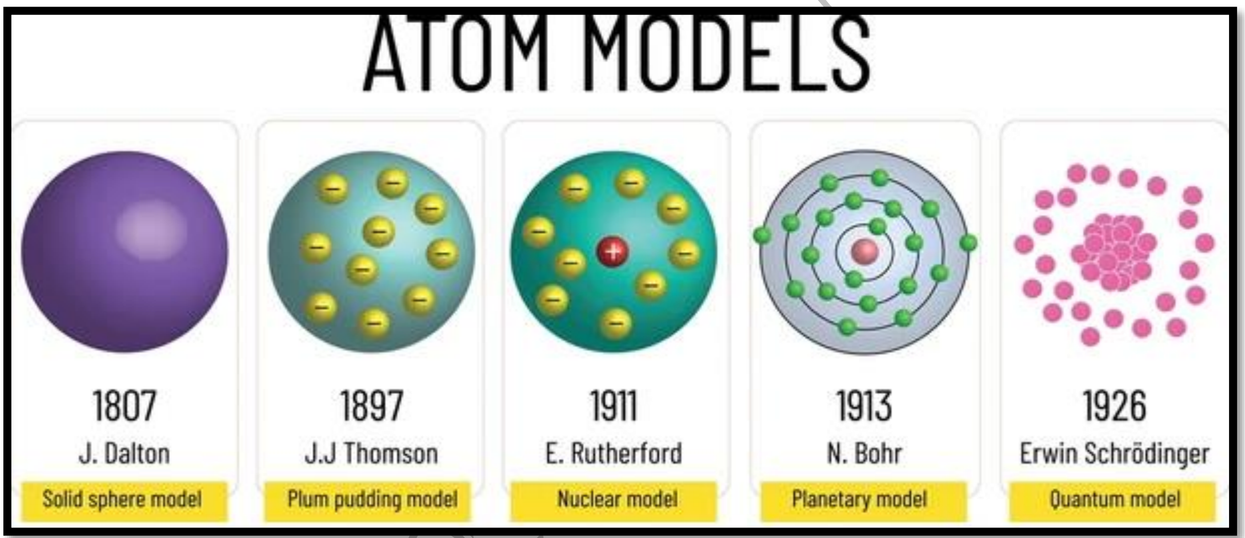
John Dalton's Atomic Model:

- John Dalton was an English scientist, who came up with an idea that all matter is composed of very small things. It was the first complete attempt to describe all matter in terms of particles. He called these particles atoms and formed an atomic theory. In this theory he claims that:
  - All matter is made of atoms. Atoms are indivisible and indestructible
  - All atoms of a given element are identical in mass and properties
  - Compounds are formed by a combination of two or more different kinds of atoms
  - A chemical reaction is a rearrangement of atoms

- Parts of his theory had to be modified based on the discovery of subatomic particles and isotopes. We now also know that atoms are not indivisible, because they are made up of neutrons, electrons and protons.

J.J. Thomson's Plum Pudding Model:

- After discovery of an electron in 1897, people realized that atoms are made up of even smaller particles. In 1904 J. J. Thomson proposed his famous "plum pudding model". In this model, atoms were known to consist of negatively charged electrons, however the atomic nucleus had not been discovered yet. Thomson knew that atom had an overall neutral charge. He thought that there must be something to counterbalance the negative charge of an electron. He came up with an idea that negative particles are floating within a soup of diffuse positive charge. His model is often called the plum pudding model, because of his similarity to a popular English dessert.

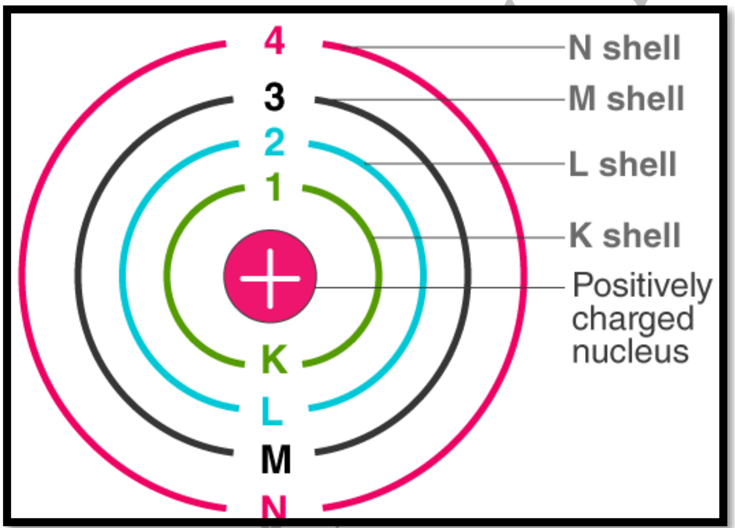


Rutherford's Planetary Model :

- Rutherford overturned Thomson's model in 1911 with his well-known gold foil experiment in which he demonstrated that the atom has a tiny and heavy nucleus. Rutherford designed an experiment to use the alpha particles emitted by a radioactive element as probes to the unseen world of atomic structure. If Thomson was correct, the beam would go straight through the gold foil. Most of the beams went through the foil, but a few were deflected.
- Rutherford presented his own physical model for subatomic structure, as an interpretation for the unexpected experimental results. In it, the atom is made up of a central charge surrounded by a cloud of orbiting electrons. Rutherford only committed himself to a small central region of very high positive or negative charge in the atom.

Bohr's Atom Model:

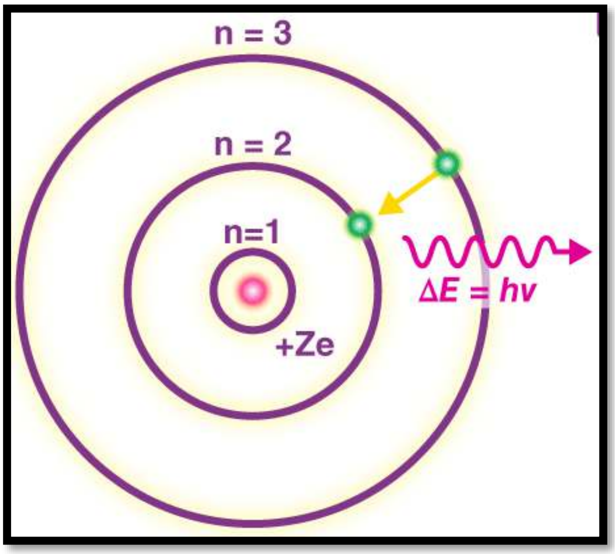
- Bohr model of the atom was proposed by Neil Bohr in 1915. Bohr theory Applicable to modified the atomic structure model by explaining that electrons move in fixed orbitals (shells) and not anywhere in between and he also explained that each orbit (shell) has a fixed energy level. Rutherford basically explained the nucleus of an atom and Bohr modified that model into electrons and their energy levels.



- Bohr's model consists of a small nucleus (positively charged) surrounded by negative electrons moving around the nucleus in orbits. Bohr found that an electron located away from the nucleus has more energy, and electrons close to the nucleus have less energy.

Postulates of Bohr's Model of an Atom:

- In an atom, electrons (negatively charged) revolve around the positively charged nucleus in a definite circular path called orbits or shells.
- Each orbit or shell has a fixed energy and these circular orbits are known as orbital shells.
- The energy levels are represented by an integer (n=1, 2, 3…) known as the quantum number. This range of quantum number starts from nucleus side with n=1 having the lowest energy level. The orbits n=1, 2, 3, 4… are assigned as K, L, M, N…. shells and when an electron attains the lowest energy level, it is said to be in the ground state.



- The electrons in an atom move from a lower energy level to a higher energy level by gaining the required energy and an electron moves from a higher energy level to lower energy level by losing energy.

Limitations of Bohr's Model of an Atom:

- Bohr's model of an atom failed to explain the Zeeman Effect (effect of magnetic field on the spectra of atoms).
- It also failed to explain the Stark effect (effect of electric field on the spectra of atoms).
- It violates the Heisenberg Uncertainty Principle.
- It could not explain the spectra obtained from larger atoms.
- It does not explain fine structure of spectral lines.

Exercise Questions: I

1.Who was the first to discover that electrons revolve around the nucleus?

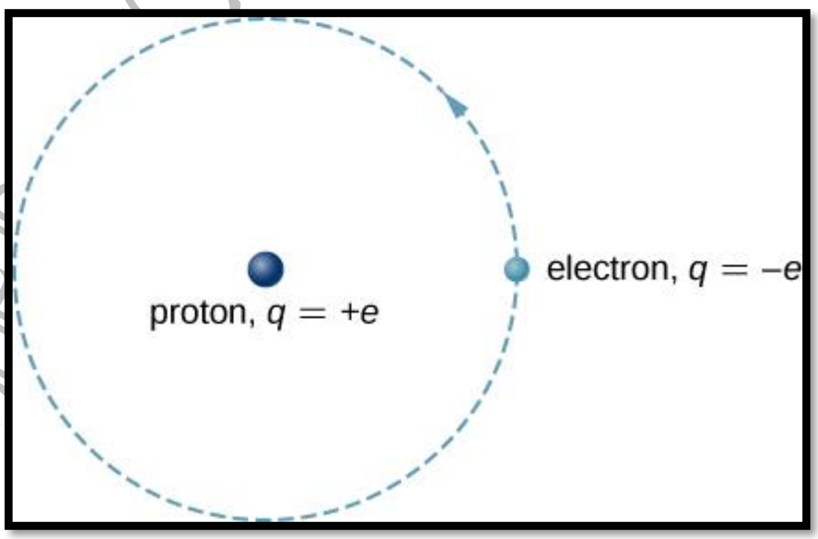
A) Dalton B) Rutherford C) Bohr D) Thomson

2.Electrons revolving in an orbit have fixed

A) Thickness B)Shape C)Angular momentum D) Route

5.2. Hydrogen Atom:

❖ The hydrogen atom is the simplest atom in nature and, therefore, a good starting point to study atoms and atomic structure. The hydrogen atom consists of a single negatively charged electron that moves about a positively charged proton. In Bohr's model, the electron is pulled around the proton in a perfectly circular orbit by an attractive Coulomb force. The proton is approximately 1800 times more massive than the electron, so the proton moves very little in response to the force on the proton by the electron. (This is analogous to the Earth-Sun system, where the Sun moves very little in response to the force exerted on it by Earth.) An explanation of this effect using Newton's laws is given in Photons and Matter Waves.



- With the assumption of a fixed proton, we focus on the motion of the electron.
- In the electric field of the proton, the potential energy of the electron is

$$U(r) = -ke^2 / r,$$

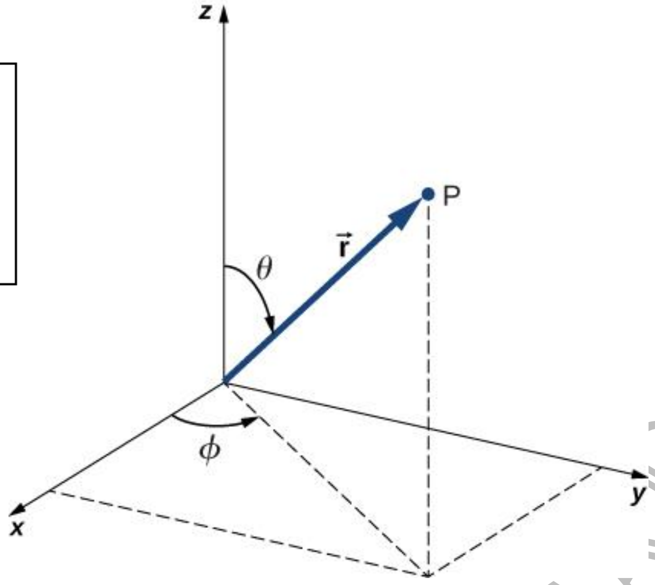
Where $k = 1/4\pi \in_0$

- and r is the distance between the electron and the proton. As we saw earlier, the force on an object is equal to the negative of the gradient (or slope) of the potential energy function. For the special case of a hydrogen atom, the force between the electron and proton is an attractive Coulomb force.
- Notice that the potential energy function $U(r)$ does not vary in time. As a result, **Schrödinger's equation** of the hydrogen atom reduces to two simpler equations: one that depends only on space (**x**, **y**, **z**) and another that depends only on time (**t**). (The separation of a wave function into space- and time-dependent parts for time-independent potential energy functions is discussed in Quantum Mechanics.) We are most interested in the space-dependent equation:

$$-\frac{h}{2m_e}\left(\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}\right)-k\frac{e^2}{r}\psi = E\psi$$

- where $\psi = \psi(x,y,z)$ is the three-dimensional wave function of the electron, m_e is the mass of the electron, and *E* is the total energy of the electron. Recall that the total wave function $\psi(x,y,z,t)$, is the product of the space-dependent wave function $\psi = \psi(x,y,z)$ and the time-dependent wave function $\varphi = \varphi(t)$
- In addition to being time-independent, $U(r)$ is also spherically symmetrical. This suggests that we may solve Schrödinger's equation more easily if we express it in terms of the spherical coordinates (r,θ,ϕ) instead of rectangular coordinates (x,y,z). A spherical coordinate system is shown in below Figure 8.2.2. In spherical coordinates, the variable *r* is the radial coordinate, θ is the polar angle (relative to the vertical **z**-axis), and ϕ is the azimuthal angle (relative to the **x**-axis). The relationship between spherical and rectangular coordinates is

$$x = rsin\theta\, cos\phi,\ y = rsin\theta sin\phi,,\ z = rcos\theta$$



5.3. Spectra of Hydrogen Atom and Hydrogen like Atoms:

- Whenever an electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference in energies of the two levels is emitted as a radiation of particular wavelength. It is called a spectral line. As the wavelength of the spectral line depends upon the two orbits (energy levels) between which the transition of electron takes place, various spectral lines are obtained. The different wavelengths constitute spectral series which are the characteristic of the atoms emitting them. The following are the spectral series of hydrogen atom.

(i) Lyman Series:

- When the electron jumps from any of the outer orbits to the first orbit, the spectral lines emitted are in the ultraviolet region of the spectrum and they are said to form a series called Lyman series (Fig).

  Here, $n_1 = 1,\ n_2 = 2,3,4\ etc$

  The wave number of the Lyman series is given by,

  $$v = R\left(1 - \left(1/n_2^2\right)\right)$$

(ii) Balmer Series:

- When the electron jumps from any of the outer orbits to the second orbit, we get a spectral series called the Balmer series. All the lines of this series in hydrogen have their wavelength in the visible region. Here $n_1 = 2, n_2 = 3,4,5$

  The wave number of the Balmer series is,

  $$v = R\left(1/2^2 - 1/n_2^2\right) = R\left(1/4 - 1/n_2^2\right)$$

- The first line in this series $(n_2 = 3)$, is called the H_{α^-} line, the second $(n_2 = 4)$, the H_{β^-} line and so on.

(iii) PaschenSeries:

- This series consists of all wavelengths which are emitted when the electron jumps from outer most orbits to the third orbit. Here $n_2 = 4,5,6$ and $n_1 = 3$. This series is in the infrared region with the wave number given by

$$v = R\left(1/3^2 - 1/n_2^{\,2}\right) = R\left(1/9 - 1/n_2^{\,2}\right)$$

(iv) Brackett Series:

- The series obtained by the transition of the electron from $n_2 = 5, 6...\ to\ n_1 = 4$ is called Brackett series. The wavelengths of these lines are in the infrared region. The wave number is,

$$v = R\left(1/4^2 - 1/n_2^{\,2}\right) = R\left(1/16 - 1/n_2^{\,2}\right)$$

(v) PfundSeries:

- The lines of the series are obtained when the electron jumps from any state $n_2 = 6,7...\ to\ n_1 = 5$. This series also lies in the infrared region. The wave number is,

$$v = R\left(1/5^2 - 1/n_2^{\,2}\right) = R\left(1/25 - 1/n_2^{\,2}\right)$$

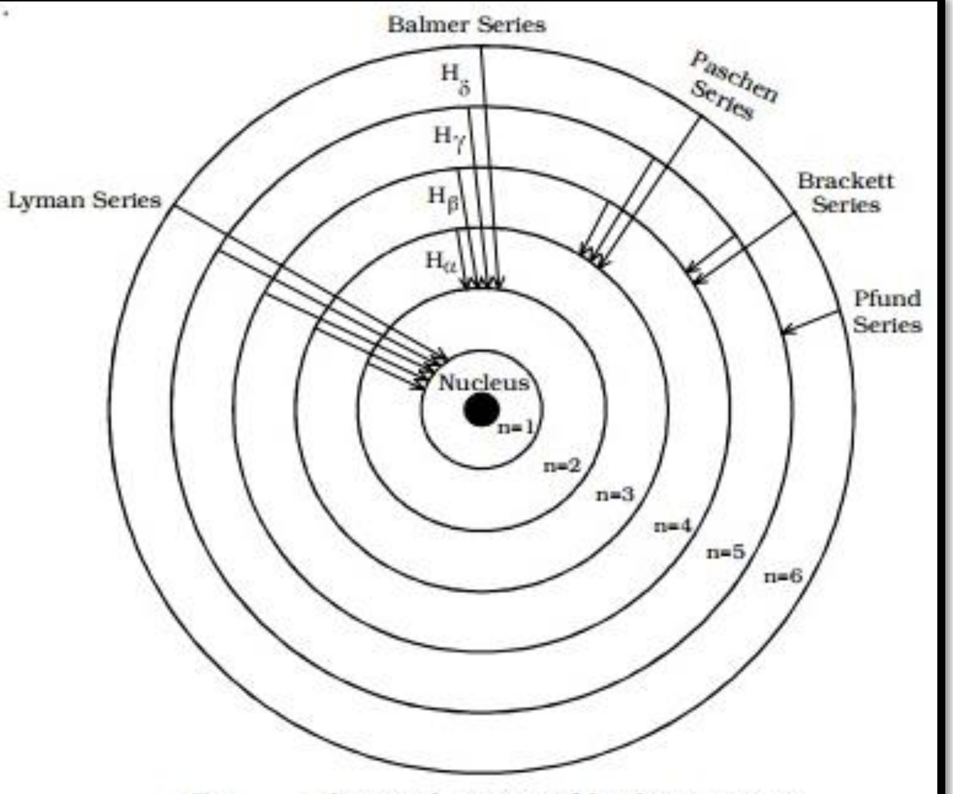


Fig Spectral series of hydrogen atom

Energy Level Diagram:

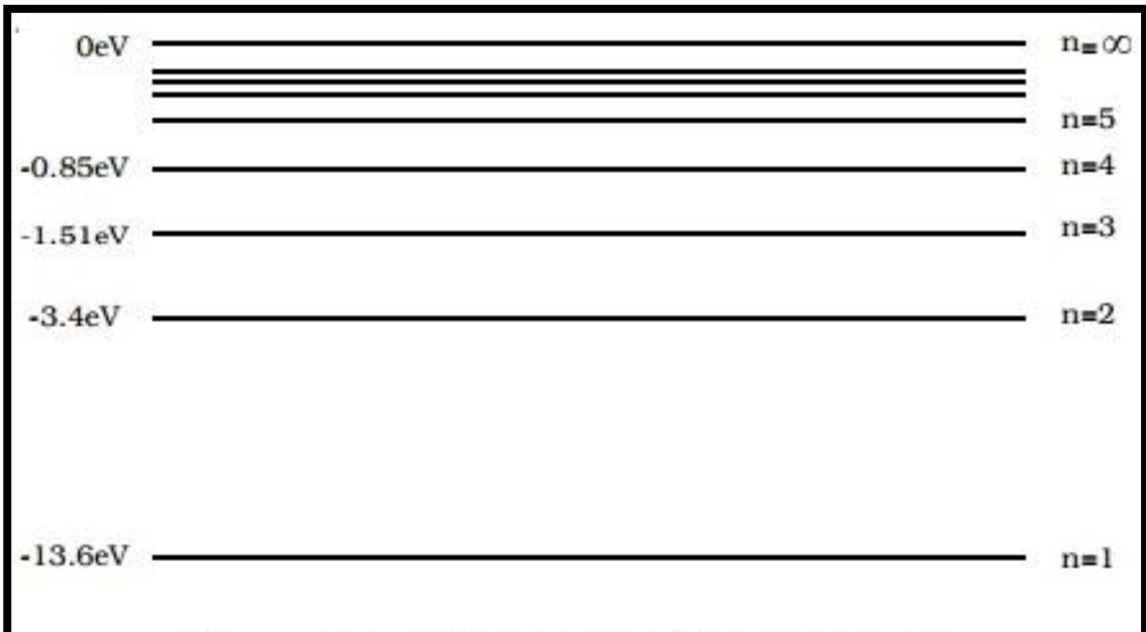


Fig Energy level diagram for hydrogen atom

- The energy of the electron in the n[th] orbit of the hydrogen atom is given by,

  $En = -13.6 / n^2 \ eV$

- Energy associated with the first orbit of the hydrogen atom is,

  $E_1 = -13.6 / 1^2 = -13.6 \ eV$

- It is called ground state energy of the hydrogen atom. Energy associated with the second orbit is given by,

  $E_2 = -13.6 / 2^2 = -3.4 \ eV$

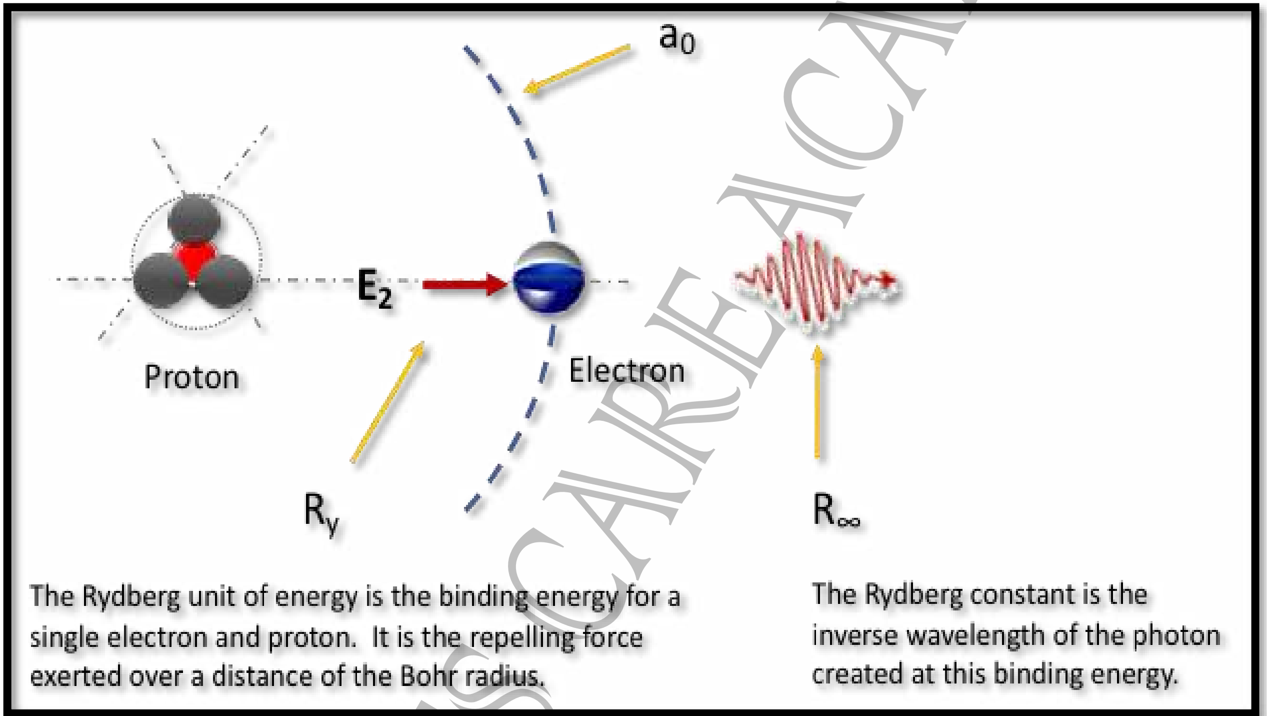
- It is called energy of first excited state of the hydrogen atom. The energy of second, third, fourth, excited states of the hydrogen atom are, $E_3 = -1.51 \ eV$, $E_4 = -0.85 \ eV$, $E_5 = -0.54 eV$ ...

  when $n = \infty$, $E_{inf} = -13.6 / inf^2 = 0$

- Therefore, it is seen from the above values, that, the energy associated with a state becomes less negative and approaches closer and closer to the maximum value zero corresponding to $n = \infty$.
- Taking these energies on a linear scale, horizontal lines are drawn which represent energy levels of the hydrogen atom (Fig). This diagram is known as energy level diagram.

5.4. Rydberg's Constant:

- The value of the Rydberg constant R_∞ is **10,973,731.56816 per metre**. When used in this form in the mathematical description of series of spectral lines, the result is the number of waves per unit length, or the wavenumbers. Multiplication by the speed of light yields the frequencies of the spectral lines.
- The Rydberg constant is used **to calculate the wavelengths in the hydrogen spectrum** – energy which is absorbed or emitted in the form of photons as electrons move between shells in the hydrogen atom.



- Hydrogen atoms inside a discharge lamp emit a series of lines in the visible part of the spectrum. This series was named after the Swiss teacher Johann Balmar and called the Balmer series. In 1885, Balmar found a way to describe the wavelengths of these lines by a trial and error method.

$$1/\lambda = R(1/4 - 1/n)$$

- Here n are integers starting from 3, 4, 5 and go till infinity. R is the rydberg constant. This article will look closely into rydberg or R constant, a unit of rydberg constant, and also discuss the rydberg constant derivation.

Rydberg Constant and its Importance:

- The Rydberg constant holds high importance in atomic physics as it is connected to fundamental atomic constants, i.e. e, h, c, and m_e. The constant can be derived with a high level of accuracy. The Rydberg constant first came into existence in 1890 when Swedish physicist Johannes Rydberg analyzed several spectra. Rydberg found that many of the Balmer line series could be explained by the equation:

$$n = n_0 - N_0 / (m + m')^2$$

- where m is a natural number, m' and n0 are quantum defects specific for a particular series. N_0 is the Rydberg constant. Rydberg is used as a unit of energy.

Speed of Light:

- It is the speed of light waves that propagate through different materials. In a vacuum, the speed of light is given as 3*108 meters per second. The speed of light is the fundamental concept of nature. In a famous equation $E = mc^2$, the speed of light (c) serves as constant linking energy (E) and mass of the particles.
- In terms of speed of light, the Rydberg constant (R) is given as Rhc, where h is Planck's constant and c is the speed of light. The dimensional formula of Rhc is equal to the dimensional formula for energy.

Explanation of Rydberg Constant

- When an electron changes its position from one atomic orbit to another, there is a change in the electron's energy. If the electron shifts from a higher energy state to a lower energy state, then a photon of light gets created. If the electron goes from a low energy state to a higher one, the atom absorbs a photon of light. A distinct spectral fingerprint characterizes every element.
- R_∞ or R_H denotes the rydberg constant, and it is a wavenumber associated with the atomic spectrum of each element. The value of rydberg constant in cm ranges from $109{,}678\ cm^{-1}$ to $109{,}737\ cm^{-1}$. The first value of the constant is the value of the rydberg constant for hydrogen, and the last value is for the heaviest element. The value of the rydberg constant is based on the fact that the nucleus of an atom that is emitting light is exceedingly huger than the single orbiting electron.

Dimensional Formula of Rydberg Constant:

- The Rydberg formula is expressed as a mathematical formula that denotes the wavelength of light emitted by an electron that moves between energy levels within an atom. Findings of Rydberg, along with Bohr's atomic model, give in below formula:

$$1/\lambda = RZ^2\left(1/n_1^{\,2} - 1/n_2^{\,2}\right)$$

5.43. Multiple Choice Questions (Important)

1. The minimum energy required by the electrons to escape from the orbit is known a _

A) potential energy B) kinetic energy

C) binding energy D) gravitational potential energy

2.The binding energy required for removing an electron from first Bohr's orbit is_____

A) -13.6 eV B) 13.6 eV C) -27.6 eV D) 27.6 eV

3.Binding energy of an electron is ________________________

A) directly proportional to n B) directly proportional to n^2

C) inversely proportional to n D) inversely proportional to n^2

4.As the binding energy of the nucleus increases the energy required to separate the nucleons

A) increases B) decreases

C) constant D) neither decreases nor increases

5.Which of the following is the main result of nuclear fission?

A) Helium B) Strontium C) Krypton D) Barium

6.Who measured the size of the nucleus first?

A) Bohr B) Einstein

C) Rutherford D) Geiger and Marsden

7.When a radioactive substance emits an α-particle, its position in the periodic table is lowered by which of the following?

A) One place B) Two places C) Three places D) Four places

8.Which is a non-central force?

A) Electrostatic force B) Nuclear force

C) Gravitational force D) Spring force

9.Which of the following substances cannot be emitted by radioactive substances during their decay?

A) Protons B) Neutrinos C) Helium nuclei D) Electrons

10. What is the reaction responsible for the production of light energy from the sun?

A) Fusion B) Fission C) Nuclear D) Emission

11. In a nuclear reaction, there is the conservation of which of the following?

A) Mass only
B) Energy only
C) Momentum only
D) Mass, energy, and momentum

12.Which of the following is used as a moderator in a nuclear reactor?

A) Cadmium B) Plutonium C) Uranium D) Heavy water

13. In nuclear reactors, what are the controlling rods made of?

A) Cadmium B) Graphite C) Stainless steel D) Plutonium

14. The operation of a nuclear reactor is said to be critical if the multiplication factor (k)has a value of what?

A) 1 B) 0 C) 1.5 D) 2.1

15. In which of the following process are Neutrons emitted?

A) Inverse beta Decay
B) Nuclear fission
C) Spontaneous Fission
D) Nuclear fusion

16.Atoms of different chemical elements that have the same number of nucleons are calledas?

A) Isobars B) Isotones C) Isomers D) Isotopes

17. Most of the energy released in fission process is in process of __________

A) Kinetic Energy B) Thermal Energy C) Light Energy D) Heat Energy

18.Fusion reactions are called __________

A) Thermonuclear
B) Thermoduric
C) Thermo Uric
D) Compound reactions

19. What is the most attractive part of nuclear energy?

A) Supports countries development

B) Causes no pollution

C) Has high efficiency of energy production

D) Is available in abundance

20.The atom as a whole is electrically charged.

A) True B) False

90. Fission occurs because the average binding energy per nucleon for the fission fragments is higher than that for the original nucleus. The change in binding energy per nucleon is approximately

A) 0.20 MeV B) 1.0 MeV C) 7.0 MeV D) 28 MeV

91. The conservation law violated by the reaction $p \rightarrow \pi_0 + e^+$ is the conservation of

A) charge. B) energy

C) linear momentum. D) lepton number and baryon number.

92.The fact that the binding energy per nucleon is roughly a constant over most of the range of stable nuclei is a consequence of the fact that the nuclear force

A) short range B) long range C) weak D) strong

93. The interaction that describes the forces among nucleons that hold nuclei together is

A) the strong nuclear interaction. B) the electromagnetic interaction.

C) the weak nuclear interaction. D) the gravitational interaction.

94.Which of the following is used to detect fission reaction:

A) Mass spectrograph B) Microscope

C) Through penetration D) Thermometer

95. Which of the following is correct during fusion of hydrogen into helium:

A) Mass is increased B) Mass is reduced

C) Energy is absorbed D) Energy is released

96.The density of atom is uniform, Who proposed this law?

A)Rutherfords model B)Bohrs model

C)J.J.Thomson model D) None of these

97.The mass will ___________________, when the energy is released from a system.

A) Increases B) Decreases C) Constant D) Zero

98. If the internal energy of a nucleus is high, then it is radioactive.

A) True B) False

99. A nucleus at rest splits into two nuclear parts having radii in the ratio of 1:3. Find the ratio of their velocities.

A) 1:9 B) 3:1 C) 1:27 D) 27:1

100. Which of the following has the highest neutron ratio?

A) ${}_8O^{16}$ B) ${}_2He^4$ C) ${}_{26}Fe^{56}$ D) ${}_{92}U^{235}$

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UNIT 5

ATOMIC & NUCLEAR PHYSICS

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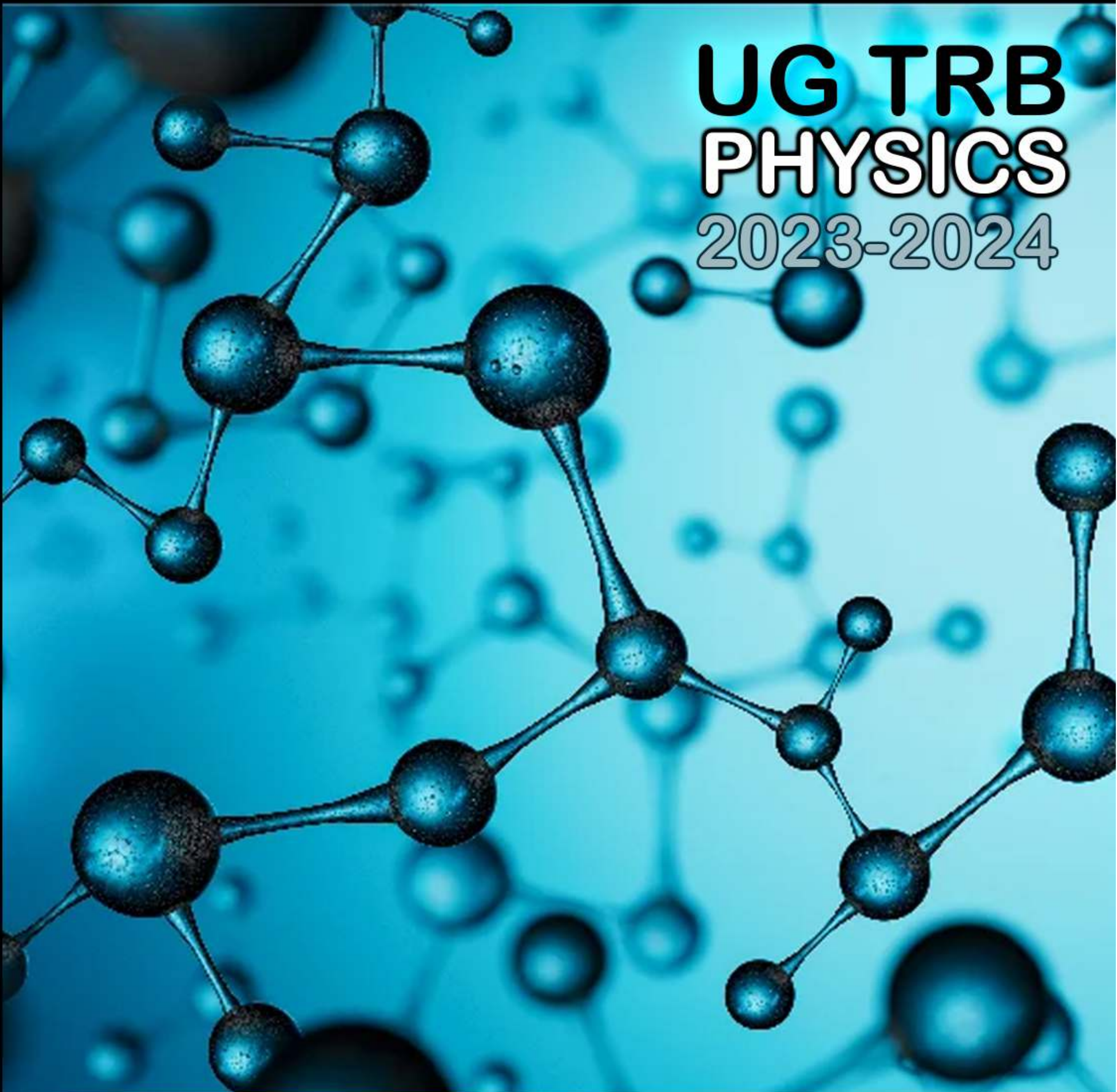

UG TRB PHYSICS 2023-2024

UNIT-7

Solid State Physics

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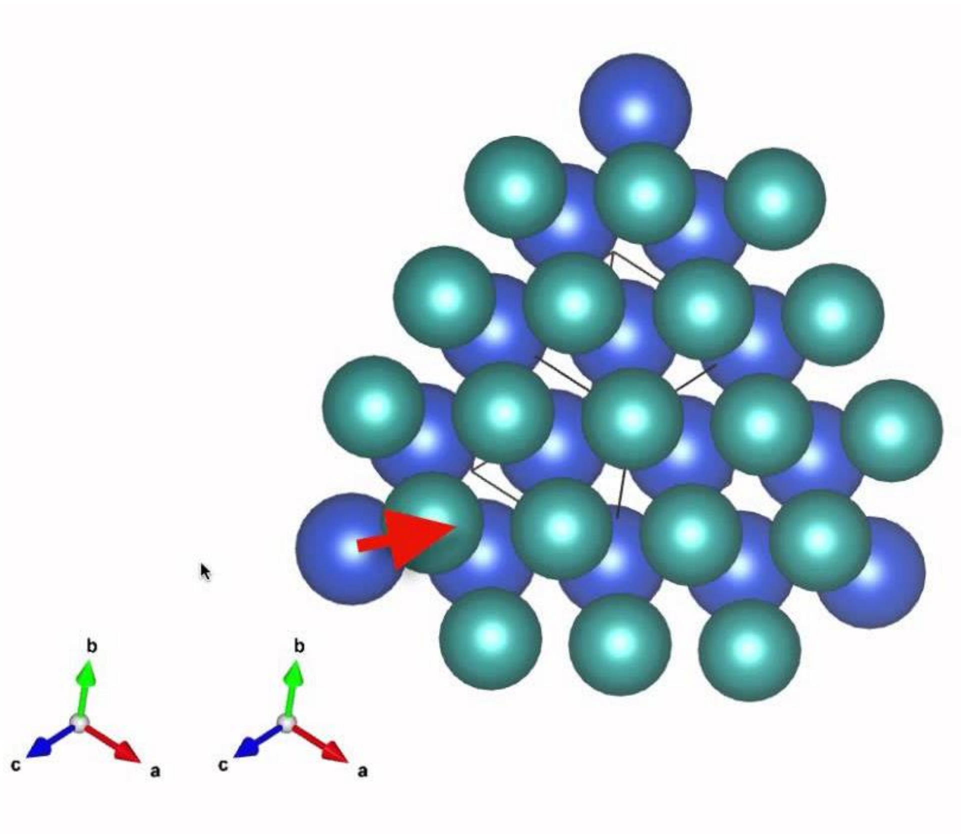
UNIT 7 – SOLID STATE PHYSICS



COMPETITIVE EXAM

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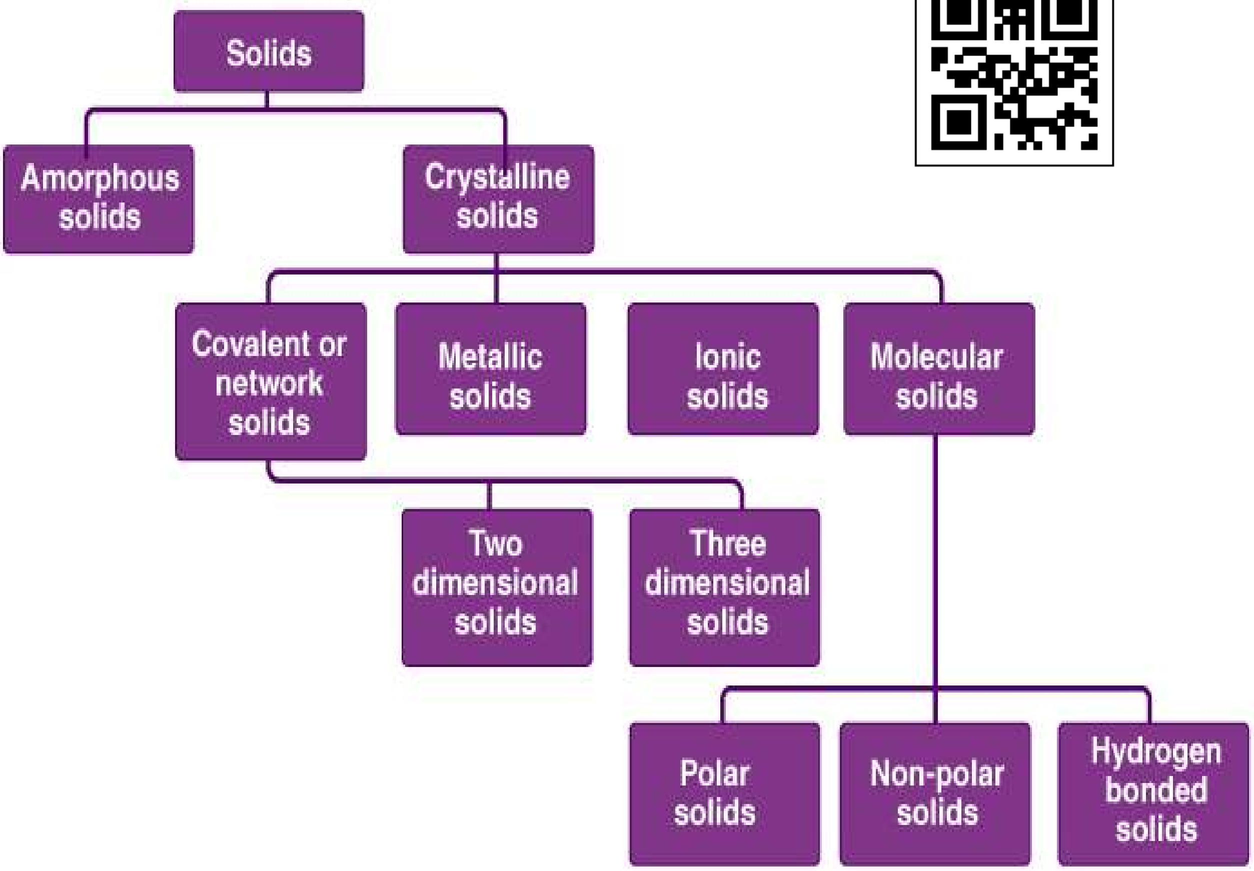
UG TRB PHYSICS – 2023-24

UNIT 7– SOLID STATE PHYSICS

7.1. Classification of Solids:

❖ The constituents of the solids are arranged in two different ways. This means that they either tend to form a regular and repetitive 3D structure which is known as a crystal lattice, which produces a crystalline solid, or they tend to aggregate without any specific order and produce an amorphous solid. There is a vast difference between crystalline and amorphous solids and here, we will learn about the comparison of amorphous vs. Crystalline.



The solid-state has the following distinguishing characteristics:

- They are distinguished by their mass, volume, and shape.
- The intermolecular distances are short.
- The intermolecular forces are extremely powerful.
- Atoms, molecules, and ions (constituent particles) have fixed positions in space and can only oscillate around their mean positions.
- They are rigid and inflexible.

Based on the arrangement of constituent particles, solids are classified into two types:

- Crystalline solid
- Amorphous Solid

7.1.1. Crystalline Solids:

- Crystalline solids consist of particles that are arranged in a three-dimensional manner. The intermolecular forces between them are equal. They are anisotropic and have a well-defined melting point as well. They are referred to as the true solids. Examples of crystalline solids are diamond, benzoic acid, etc. The application of diamond includes the making of beautiful jewellery, cutting of glass, etc.

7.1.2. Amorphous Solids:

- Amorphous refers to being shapeless. Amorphous solids have an irregular arrangement of solid particles. The intermolecular forces between them are not equal. Also, the distance between every two particles tends to vary. They do not possess a defined geometric shape. Amorphous solids are also known as supercooled liquids and are isotropic. Examples of amorphous solids include glass, naphthalene, etc

Applications of Glass are as Follows.

- It is widely used for the construction of buildings.
- It is also used in the packaging of cosmetics such as cosmetics boxes and the packing of food items such as in making food jars.

To better understand the difference between amorphous solids and crystalline solids better, let us take a look at the table given below. It showcases the crystalline and amorphous differences in detail.

7.1.3. Difference between Crystalline Solid and Amorphous Solid:

Let us look at the difference between crystalline and amorphous solids in detail

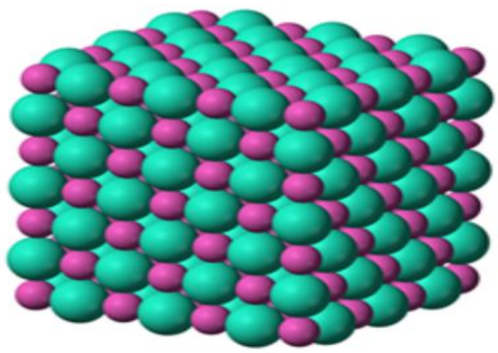
Difference between Crystalline and Amorphous

CRYSTALLINE SOLIDS	AMORPHOUS SOLIDS
Atoms are arranged in regular 3 dimension	They do not have regular arrangement
Sharp melting point	No particular melting point
Anisotropic	Isotropic
True solid	Pseudo solid
Symmetrical	Unsymmetrical
More rigid	Less rigid
Long range order	Short range order
Example: Potassium nitrate, copper	Example: Cellophane, polyvinyl chloride

7.2. What is Crystal Structure?

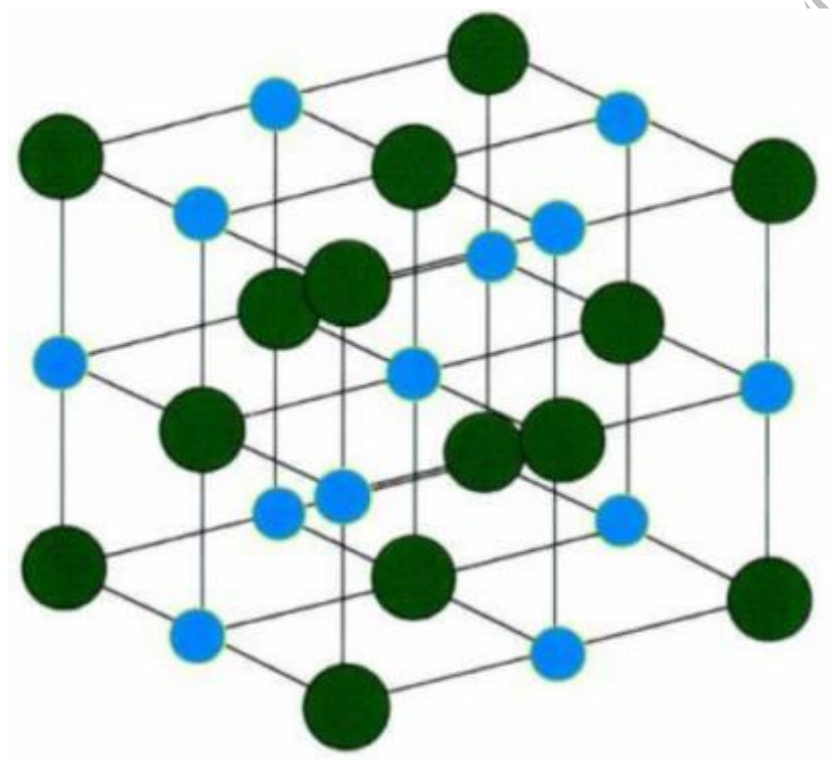
- A crystal structure is made of atoms. A crystal lattice is made of points. A crystal system is a set of axes. In other words, the structure is an *ordered array of atoms, ions or molecules*.
- Crystal Structure is obtained by attaching atoms, groups of atoms or molecules. This structure occurs from the intrinsic nature of the constituent particles to produce symmetric patterns. A small group of a repeating pattern of the atomic structure is known as the unit cell of the structure.A unit cell is the building block of the crystal structure and it also explains in detail the entire crystal structure and symmetry with the atom positions along with its principal axes.The length, edges of principal axes and the angle between the unit cells are called lattice constants or lattice parameters.

7.3. Unit Cell:



- Crystals use x-rays, which excite signals from the atom. The signals given by these atoms have different strengths, and they usually depend upon the electron density distribution in closed shells. The signals released by the atoms varies. Lighter the atoms, weaker is their signals. The mutual arrangement of atoms is also known as crystal structures. Crystal structures are derived from the physical density and chemical formulas of solids.

- ❖ Unit cell can be defined as the smallest part of a component of the crystal. A group of atoms, ions or molecules, which are arranged together in a pure manner to build the crystal. The unit cells are structured in three-dimensional space, which describes the bulk arrangement of atoms of the crystal.
- ❖ Unit Cell is the smallest part (portion) of a crystal lattice. It is the simplest repeating unit in a crystal structure. The entire lattice is generated by the repetition of the unit cell in different directions.

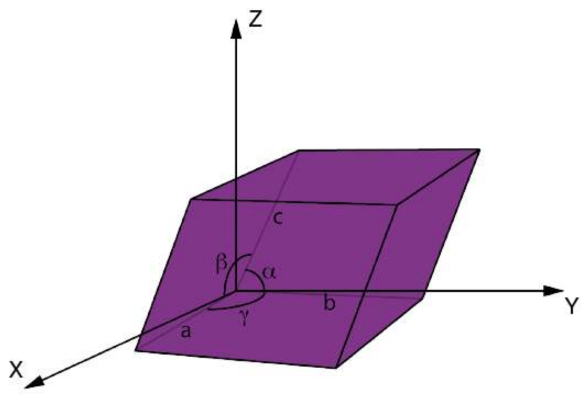


The sodium chloride crystal structure. Each atom has six nearest neighbours, with octahedral geometry. This arrangement is known as *cubic close packed* (ccp).

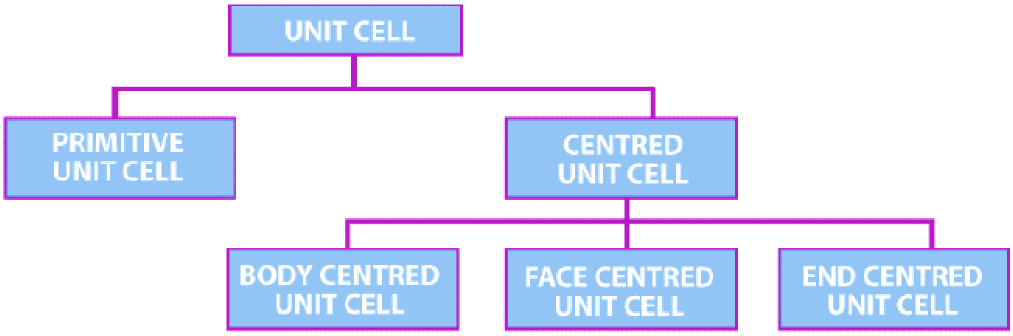
Light blue = Na^+
Dark green = Cl^-

7.3.1. Parameters of a Unit Cell:

- ❖ There are six parameters of a unit cell. These are the 3 edges which are a, b, c and the angles between the edges which are α, β, γ. The edges of a unit cell may be or may not be perpendicular to each other.



7.3.2. Types of Unit Cell:



7.3.2.1. Primitive Unit Cells:

- When the constituent particles occupy only the corner positions, it is known as Primitive Unit Cells.

7.3.2.2. Centered Unit Cells:

- When the constituent particles occupy other positions in addition to those at corners, it is known as Centred Unit Cell. There are 3 types of Centred Unit Cells:
  - Body Centred: When the constituent particle at the centre of the body, it is known as Body Centred Unit cell.
  - Face Centred: When the constituent particle present at the centre of each face, it is known as Face Centred Unit cell.
  - End Centred: When the constituent particle present at the centre of two opposite faces, it is known as an End Centred Unit cell.

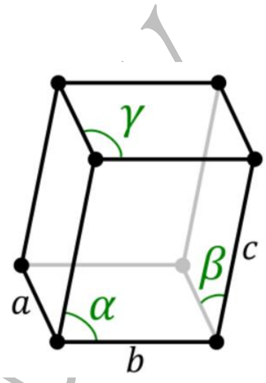
7.4. Crystal System:

- A Crystal System refers to one of the many classes of crystals, space groups, and lattices. In crystallography terms, lattice system and crystal, the system are associated with each other with a slight difference. Based on their point groups crystals and space groups are divided into seven crystal systems.
- The Seven Crystal Systems is an approach for classification depending upon their lattice and atomic structure. The atomic lattice is a series of atoms that are organized in a symmetrical pattern. With the help of the lattice, it is possible to determine the appearance and physical properties of the stone. It is possible to identify which crystal system they belong to. In a Cubic System crystals are said to represent the element earth. They are Seven Crystal Systems and are stated below with illustrated examples.

7.4.1. The Seven Crystal Systems

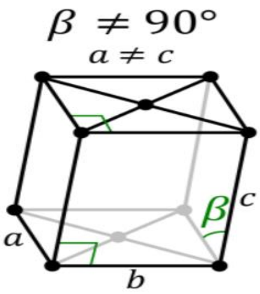
1. Triclinic System:

➢ It is the most unsymmetrical crystal system. All three axes are inclined towards each other, and they are of the same length. Based on the three inclined angles the various forms of crystals are in the paired faces. Some standard Triclinic Systems include Labradorite, Amazonite, Kyanite, Rhodonite, Aventurine Feldspar, and Turquoise.



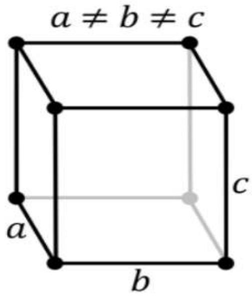
2. Monoclinic System:

➢ It comprises three axes where two are at right angles to each other, and the third axis is inclined. All three axes are of different length. Based on the inner structure the monoclinic system includes Basal pinacoids and prisms with inclined end faces. Some examples include Diopside, Petalite, Kunzite, Gypsum, Hiddenite, Howlite, Vivianite and more.



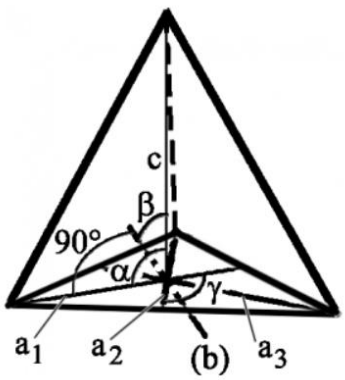
3. Orthorhombic System:

➢ It comprises three axes and is at right angles to each other. There are different lengths. Based on their Rhombic structure the orthorhombic system includes various crystal shapes namely pyramids, double pyramids, rhombic pyramids, and pinacoids. Some common orthorhombic crystals include Topaz, Tanzanite, Iolite, Zoisite, Danburite and more.



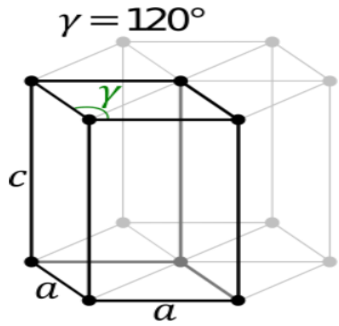
4. Trigonal System:

➢ Angles and axis in a trigonal system are similar to Hexagonal Systems. At the base of a hexagonal system (ross-section of a prism), there will be six sides. In the trigonal system (base cross-section) there will be three sides. Crystal shapes in a trigonal system include three-sided pyramids, Scalenohedral and Rhombohedra. Some typical examples include Ruby, Quartz, Calcite, Agate, Jasper, Tiger's Eyes and more.



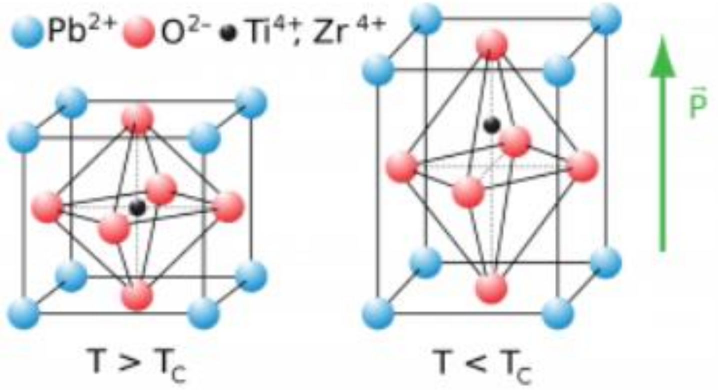
5. Hexagonal System:

- It comprises four axes. The three a1, a2 and a3 axes are all contained within a single plane (called the basal plane) and are at 120°. They intersect each other at an angle of sixty degrees. The fourth axis intersects other axes at right angles. Crystal shapes of hexagonal systems include Double Pyramids, Double-Sided Pyramids, and Four-Sided Pyramids. Example: Beryl, Cancrinite, Apatite, Sugilite, etc.



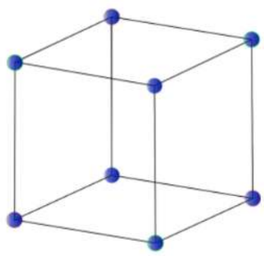
6.Tetragonal Systems:

- It consists of three axes. The main axis varies in length; it can either be short or long. The two-axis lie in the same plane and are of the same length. Based on the rectangular inner structure the shapes of crystal in tetragonal include double and eight-sided pyramids, four-sided prism, trapezohedrons, and pyrite.



7. Cubic System:

- Cubic system is the most symmetrical one out of the seven crystal system. All three angles intersect at right angles and are of equal length. Crystal shapes of a cubic system based on inner structure (square) include octahedron, cube, and Hexaciscoherdron. Example: Silver, Garnet, Gold, and Diamond.

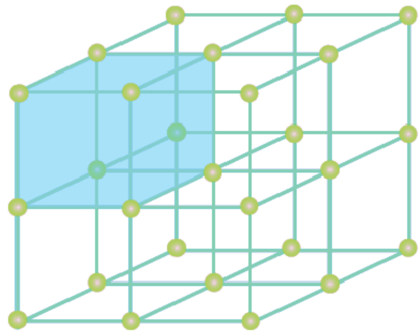


7.5. Crystal Lattices and Unit Cells:

- The 'crystal lattice' is the pattern formed by the points and used to represent the positions of these repeating structural elements. The periodic structure of an ideal crystal is most easily described by a lattice. The crystal lattice is the array of points at the corners of all the unit cells in the crystal structure.

7.5.1. What is Crystal Lattice?

- The crystal lattice is the symmetrical three-dimensional structural arrangements of atoms, ions or molecules (constituent particle) inside a crystalline solid as points.It can be defined as the geometrical arrangement of the atoms, ions or molecules of the crystalline solid as points in space.



7.5.2. Characteristics of Crystal Lattice:

- In a crystal lattice, each atom, molecule or ions (constituent particle) is represented by a single point.
- These points are called lattice site or lattice point.
- Lattice sites or points are together joined by a straight line in a crystal lattice.
- When we connect these straight lines we can get a three-dimensional view of the structure. This 3D arrangement is called Crystal Lattice also known as **Bravais Lattices.**

7.6. Bravais lattice:

- There are 14 types of three-dimensional lattices are present in crystals. These types are known as Bravais lattice. These lattices are named after the French physicist Auguste Bravais.
- Bravais Lattice indicates the 14 different 3-dimensional arrangements into which atoms can be arranged in crystals. The smallest group of symmetrically arranged atoms that can be repeated in an array to make up the entire crystal is called a unit cell. The most fundamental classification is known as the Bravais lattice. In other words, a Bravais lattice is an array of discrete points with an arrangement and orientation that look exactly the same from any of the discrete points, that is the lattice points are indistinguishable from one another.

7.6.1. 2D Bravais Lattices:

There are five basic 2D Bravais lattices.

1. Square, $a = b, \theta = 90°$

2. Hexagonal, $a = b, \theta = 120°$

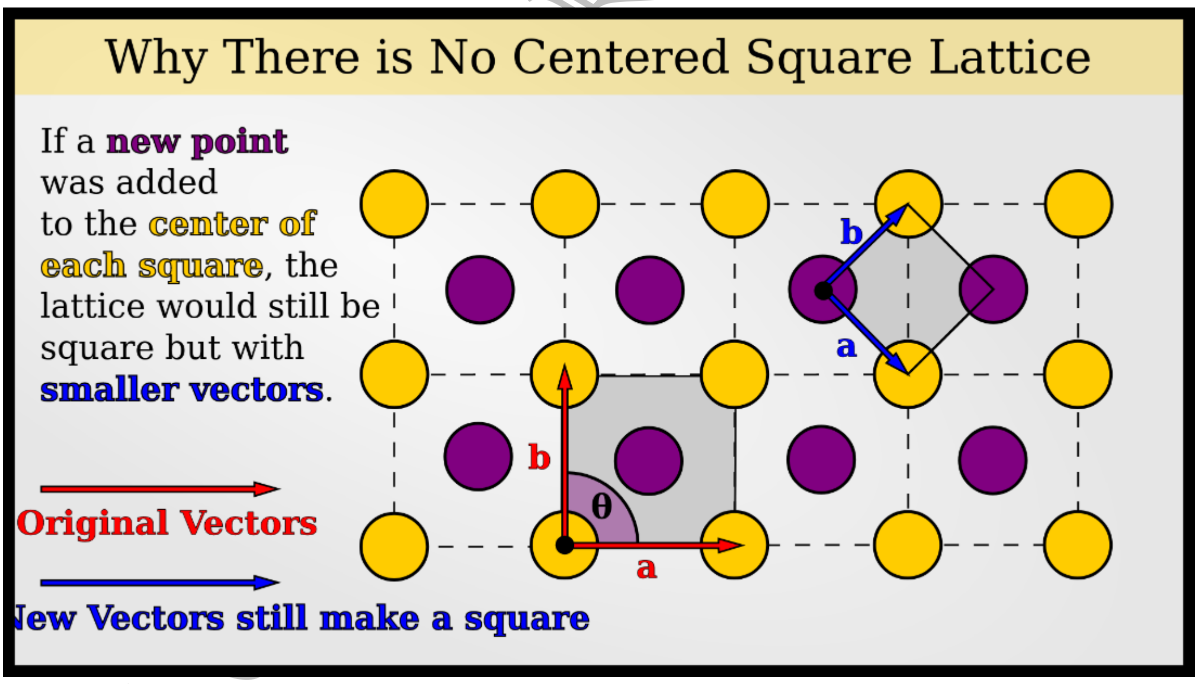
3. Rectangular, $a \neq b, \theta = 90°$

4. Centered Rectangular

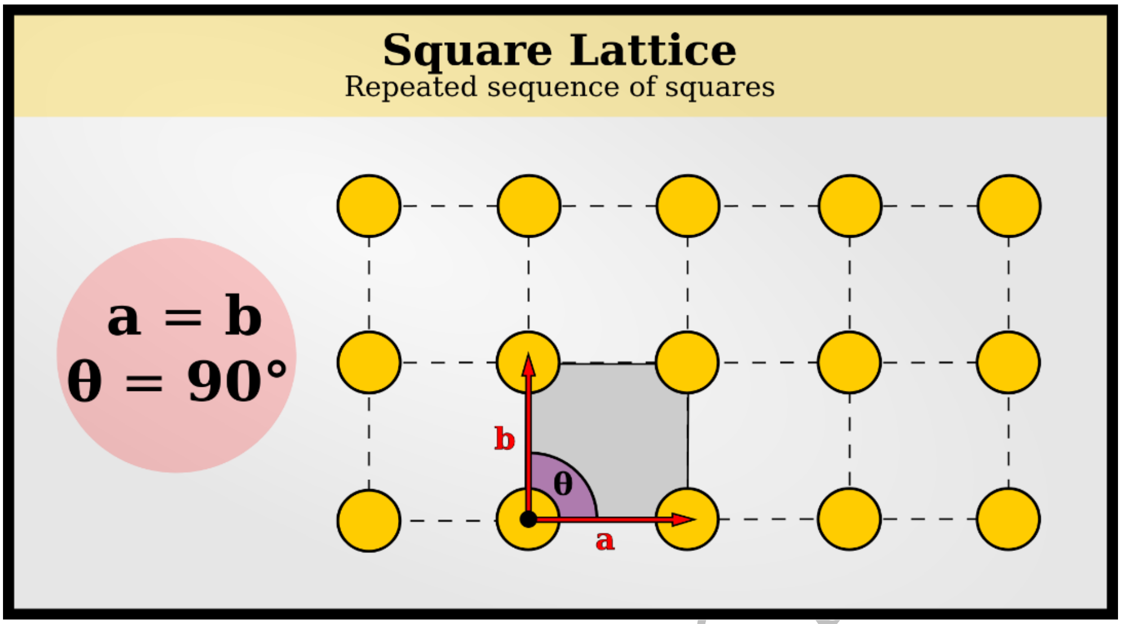
   - **Note:** the primitive cell is like hexagonal or square but less symmetry
   - **Note:** only centered, not face body or base

5. Rhomboidal, $a \neq b, \theta \neq 90°$

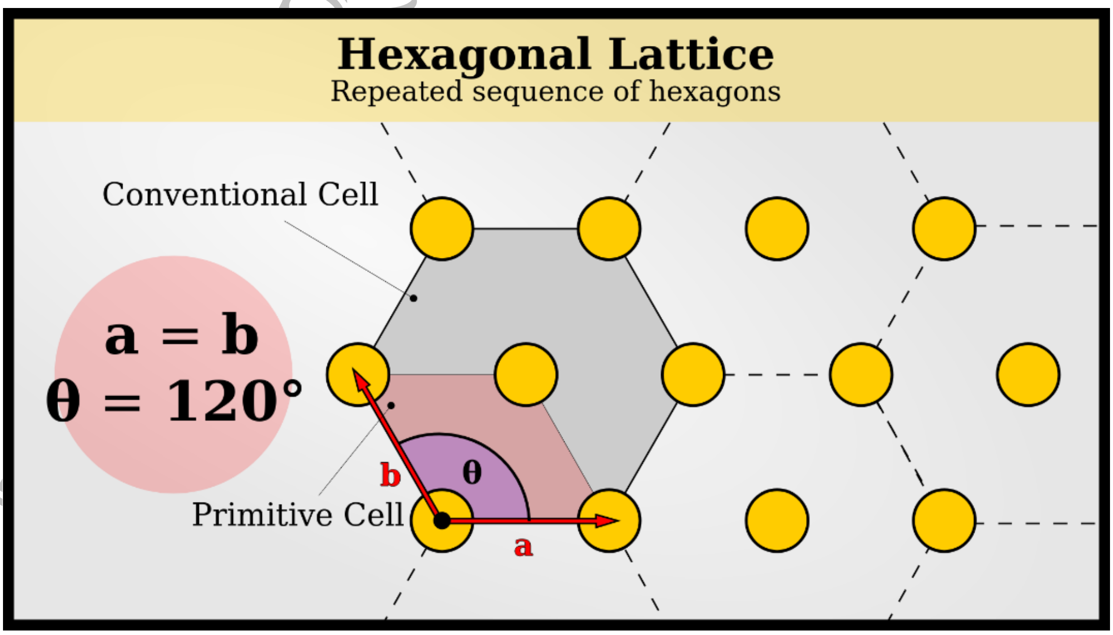
- If you tried to think of another pattern that fully covered a 2D space, such as centered square or off-centered rectangular, it could be reduced to one of these 5 2D lattices. A mathematician might like to prove this, but as an engineer I accept that the proof has already been performed. But I encourage you to think of a few examples of more complex arrangements, and consider which basic lattice you have. For example, you may notice that there is a centered-rectangular lattice, but not a **Centered-Square Lattice**. That's because if you added a centered atom to the **square lattice**, it would actually still be a square lattice, but smaller.



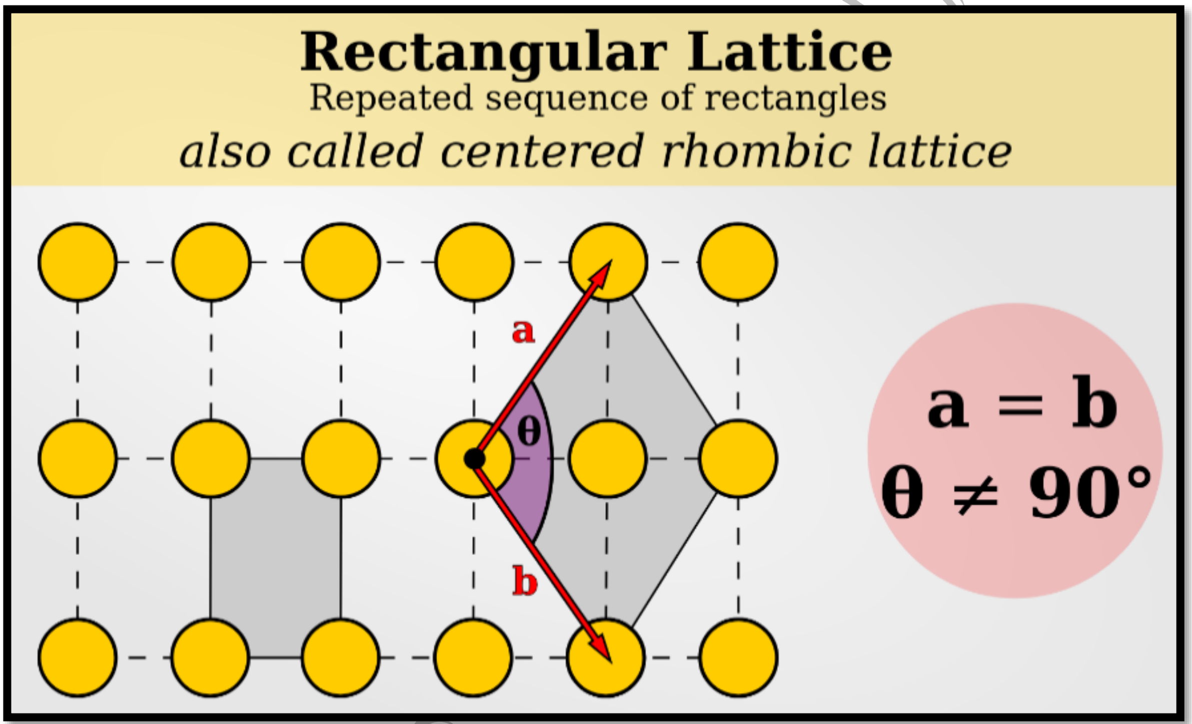
- On the other hand, adding a centered atom to rectangular means that the new crystal has a parallelogram-shaped lattice with a=b and $\theta \neq 90°$.Similarly, adding a centered atom to *this* lattice would give you back a rectangular lattice. Because rectangles have higher symmetry I prefer to describe them as rectangular and centered-rectangular lattices.

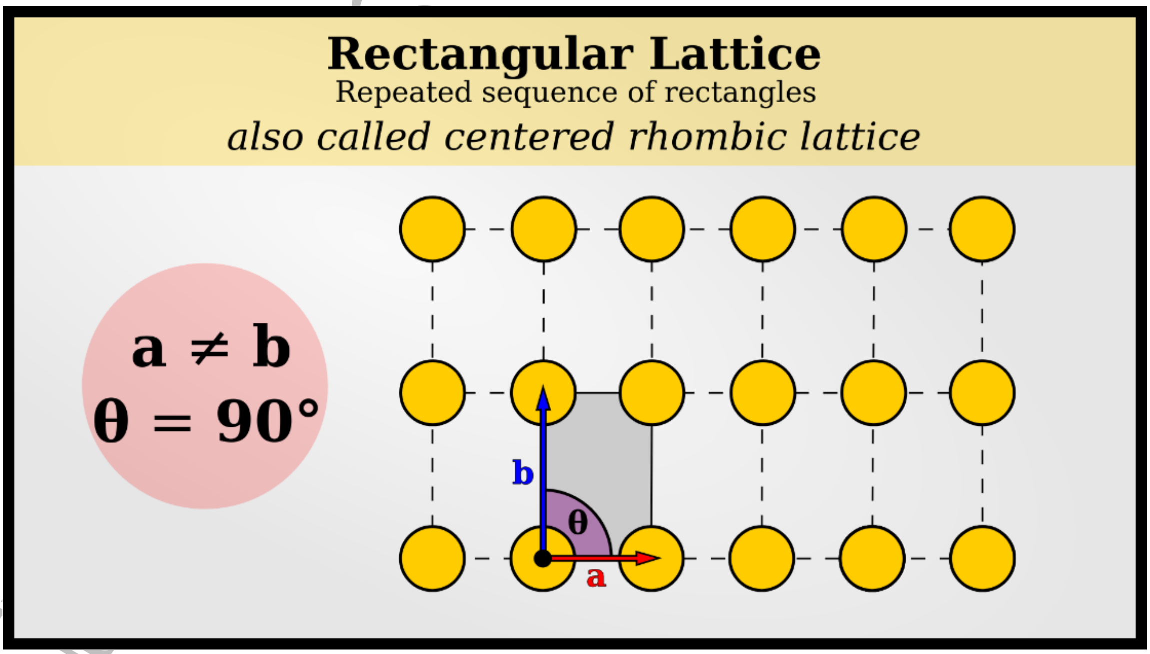


- I bring up the 2D lattices because I want to give you an opportunity to play with them in your head. Once we get to complicated 3D lattices, which matter because of crystallography, you'll probably just have to take my word that these are all 14 possible lattices.
- The **square 2D Bravais lattice** completely tiles a space with squares. The vectors a and b are equal to each other and are at right angles.
- **The hexagona**l 2D Bravais lattice might also be described as rhombic. You may like to think of them as triangular, although it actually requires 2 triangles (one up, the other down) to maintain translational symmetry.This lattice tiles a space with hexagons or rhombuses (I prefer "hexagonal" because it indicates higher symmetry). The vectors a and b are equal to each other and at an angle of 120.



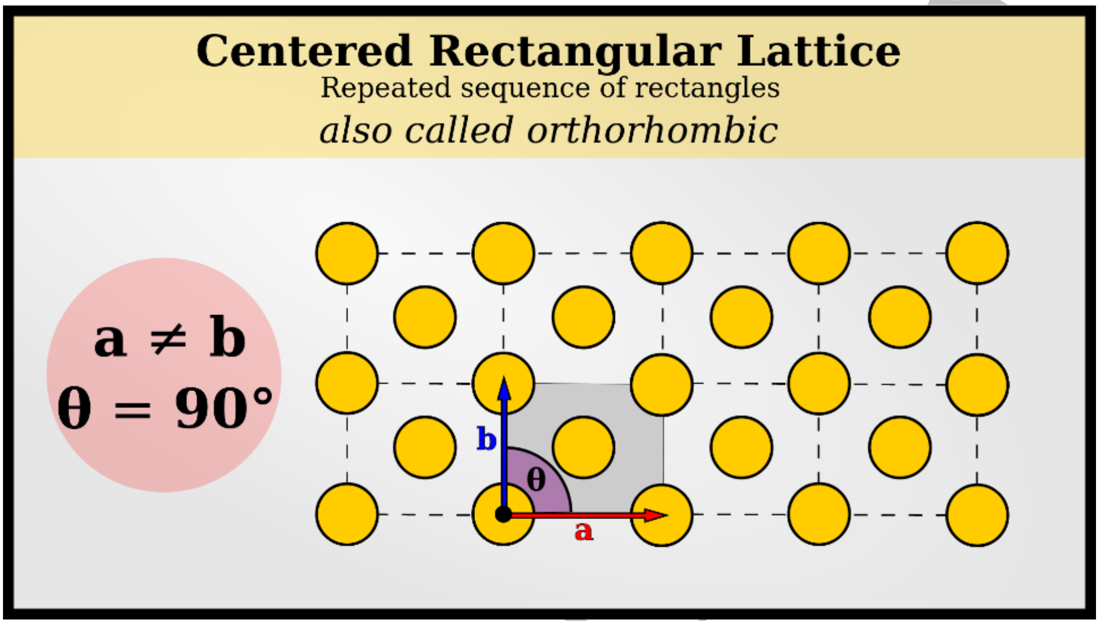
- (In principle, the hexagonal Bravais lattice is a subset of the centered-rectangular lattice, but it gets a special name because the perfect $120°$ angle has higher symmetry and makes hexagons).
- The **Rectangular 2D Bravais lattice**tiles a space with rectangles. The vectors a and b are a at right angles but have different magnitudes.
- Notice that another way to imagine this lattice is if you had a and b with the same length, but not at right angles, with another lattice point in the center.



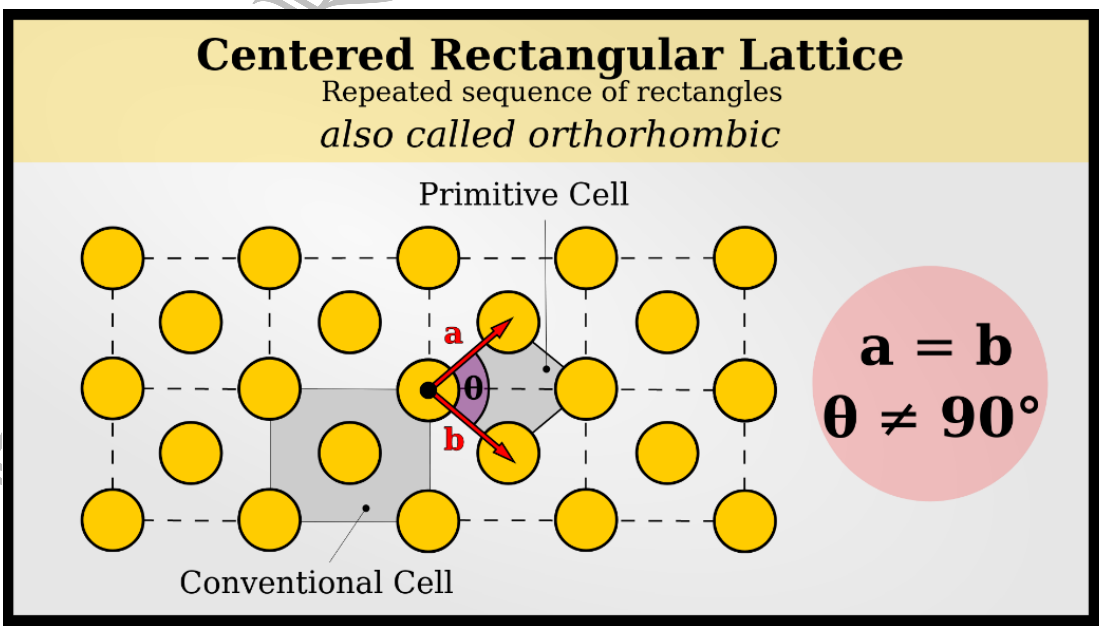


- I mention this just to help you think of the relationships between lattices, and how easily two seemingly-different lattices might end up being identical.

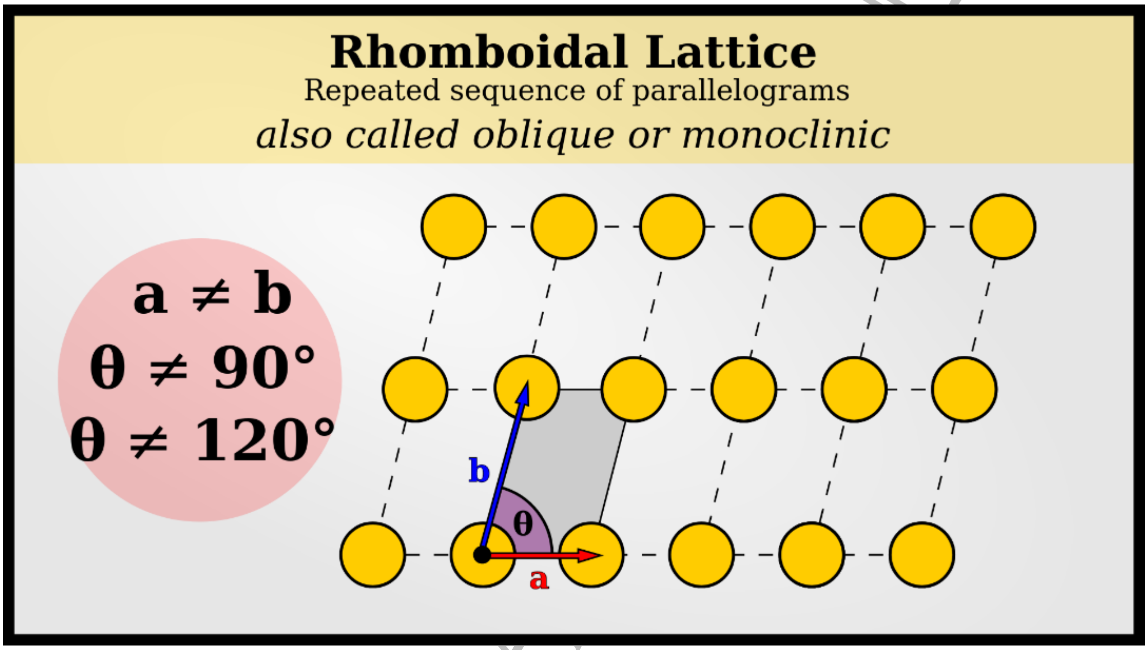
- The **Centered-Rectangular 2D Bravais lattice**tiles a space with rectangles that have an extra lattice point in the center. The vectors a and b are at right angles and have different lengths; one extra point is at the center.



- You may realize that it's possible to make a different lattice without requiring an atom in the center.
- This lattice has vectors a and b of the same length, at non-90° angles.
- From one perspective, this lattice is simpler than the original one I showed you, because the unit cell has less area and lattice points inside. Since this one is the simplest possible lattice, we call it the **primitive lattice**.
- However, this depiction of the primitive lattice does not show the full symmetry, so we tend to use the non-primitive, centered-rectangular depiction instead.



- The **rhomboidal 2D Bravais lattice**tiles a space with rhomboids. This lattice has vectors a and b of different lengths at non-90° angles.
- This lattice is actually called "oblique" in most places I looked, but I thought it would make more sense if I actually called it by the proper shape. Rhomboids are parallelograms with non-90° angles and 2 different side lengths. There is no such 2D shape as "oblique."



7.6.2. 3D Bravais Lattices:

- Now we get into the Bravais lattices which are useful to materials science. There are 14 3D Bravais lattices. Remember that the Bravais lattices come by considering **translational symmetry**. Other symmetries, like reflection or inversion, are captured in point groups and space groups, not Bravais lattices.
- I'll provide a short description of each lattice, and list some common materials with that structure. For a more in-depth look at each kind of lattice, I have written a dedicated article for each one. You can find those linked at the top or bottom of this article.
- Each lattice is a polyhedron with 6 faces, 12 edges, and 8 vertices. We can describe these polyhedrons using 3 vectors which correspond to 3 of the 12 edges (because of the 4-sided nature of the polygon, there will be 3 sets of 4 matching edges. That's why we only need to describe 3 different vectors, as long as they come from 3 different edge sets).The cube is the highest-symmetry lattice shape. All 12 edges are the same length and they all have the same angle to each other (90°), which can be represented as 3 vectors of identical length, at 90° to each other.

7.17. Multiple Choice Questions (Important):

1. Prompt emission of X-ray by an atom ionised by a higher energy X-ray is a type of which of the following phenomena?

   A) Luminescence B) Fluorescence

   C) Phosphorescence D) Spontaneous emission

2. The measurement of intensity of fluorescent X-rays provide a simple and ____________ way of _____________ analysis.

   A) Destructive, quantitative B) Non-destructive, quantitative

   C) Destructive, qualitative D) Non-destructive, qualitative

3. The energy of the emitted X-rays depends upon the _________ of the atom and their intensity depends upon the __________

   A) Atomic number, amount of sample

   B) Mass number, amount of sample

   C) Mass number, concentration of atoms

   D) Atomic number, concentration of atoms

4. Which of the following is Mosely's equation if 'C' is the speed of light, 'a' is proportionality constant, 'σ' is a constant which depends on electronic transition series, 'Z' is the atomic number and 'λ'is the wavelength?

   A) $C\lambda = a(Z-\sigma)^2$ B) $C/\lambda = a(Z-\sigma)^2$

   C) $C(Z-\sigma)^2 = a\lambda$ D) $C(Z-\sigma)^2 = a/\lambda$

5. In X-ray fluorescence spectrometer, the relationship between the excitation intensity and the intensity of fluorescence does not depend on which of the following?

   A) Spectrum of the incident radiation B) Angle of radiance

   C) Molecular weight D) Incident angle

6. Absorption meter is _______and ______ of the chemical state of the element concerned.

   A) Non-destructive, independent B) Destructive, independent

   C) Non-destructive, dependent D) Destructive, dependent

7. X-ray absorption meters have which of the following major disadvantages?

A) Low accuracy B) Low range C) Low sensitivity D) It is destructive

8. In absorption meter, which of the following is placed between the cell and the X-ray tube?

A) Collimator B) Filter C) Chopper D) Attenuator

9. In absorption meter, which of the following is placed between the chopper and the reference cell?

A) Collimator B) Filter

C) Photomultiplier tube D) Attenuator

10. In absorption meter, the two halves of the X-ray beam are allowed to fall on which of the following components?

A) Collimator B) Filter

C) Photomultiplier tube D) Attenuator

11. The photomultiplier tube used is absorption meter is coated with which of the following materials?

A) Sodium B) Potassium C) Phosphorous D) Chlorine

12. In absorption meter, which of the following is adjusted until the absorption of two X-ray beams are brought into balance?

A) Collimator B) Filter

C)Photomultiplier tube D) Attenuator

13. In absorption meter, the change in thickness of aluminium required for different samples is a function of the difference in which of the following parameters?

A) Amount B) Concentration C) Colour D) Composition.

14. Photographs made with X rays are known as ___________

A) X-graphs B) Gamma-graphs C) Radiographs D) Scanned Photos

15. X-rays are used with computer in __________

A) CT Scan B) CAT Scan C) CA Scan D) AT Scan

16. Which of the following disease can be detected by X-Ray?

A) Bladder infection B) Pneumonia C) Diarrhea D) Fever

90. Stacking sequence in hexagonal close packed (HCP) structure is?

A) AAAAA B) ABABAB C) ABCABC D) AABBAA

91. Stacking sequence in face centered cubic (FCC) close packed structure is?

A) AAAAA B) ABABAB C) ABCABC D) AABBAA

92. For pane (1 1 1) of FCC having a lattice parameter 'a', planar atomic density is given by?

A)$2.31/a^2$ B)$2.31/a^3$ C)$1.31/a^2$ D)$1.31/a^3$

93. For pane (1 1 1) of BCC having a lattice parameter 'a', planar atomic density is given by?

A)$1.07/a^2$ B)$0.58/a^2$ C)$2.07/a^2$ D)$0.78/a^2$

94. For pane (1 0 0) of BCC having a lattice parameter 'a', planar atomic density is given by?

A)$\frac{1}{a^3}$ B)$\frac{2}{a^2}$ C)$\frac{3}{a^4}$ D)$\frac{1}{a^2}$

95. For pane (1 1 0) of BCC having a lattice parameter 'a', planar atomic density is given by?

A)$\frac{3.690}{a^2}$ B)$\frac{2.312}{a^2}$ C)$\frac{1.414}{a^2}$ D)$\frac{0.580}{a^2}$

96. For pane (1 1 0) of SC having a lattice parameter 'a', planar atomic density is given by?

A)$\frac{0.580}{a^2}$ B)$\frac{0.707}{a^2}$ C)$\frac{0.707}{a^3}$ D)$\frac{0.508}{a^3}$

97. For pane (1 1 1) of SC having a lattice parameter 'a', planar atomic density is given by?

A)$\frac{0.58}{a^2}$ B)$\frac{0.78}{a^3}$ C)$\frac{0.68}{a^2}$ D)$\frac{0.88}{a^2}$

98. Which of the following equation describes Bragg's law of diffraction? (Assume that all symbols have their usual meaning.)

A)$2d\ sin\theta = \lambda$ B)$2d = n\lambda$ C)$2d = n\lambda\ sin\theta$ D)$2dsin\theta = n\lambda$

99. Miller indices for Octahedral plane in cubic crystal

A)(100) B)(110) C)(111) D) None

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UG TRB – 2023-24

PHYSICS

UNIT 7

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UG TRB PHYSICS 2023-2024

UNIT-8

Optics and Spectroscopy

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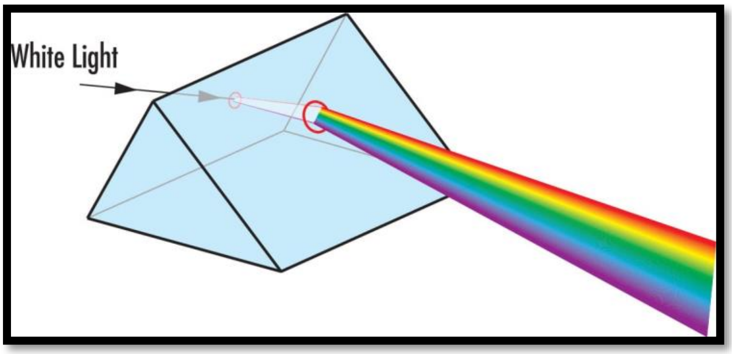
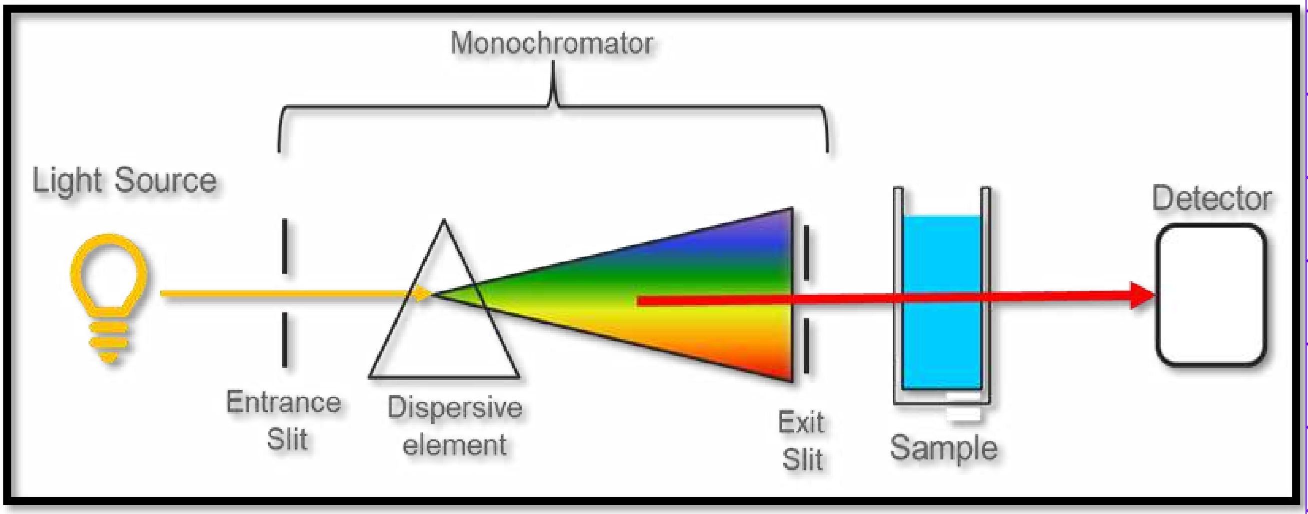
PHYSICS

UNIT 8 - OPTICS AND SPECTROSCOPY





COMPETITIVE EXAM

For

UG TRB – 2023-24

UG TRB – PHYSICS – 2023-24

UNIT 8 - OPTICS AND SPECTROSCOPY

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UG TRB PHYSICS – 2023-24

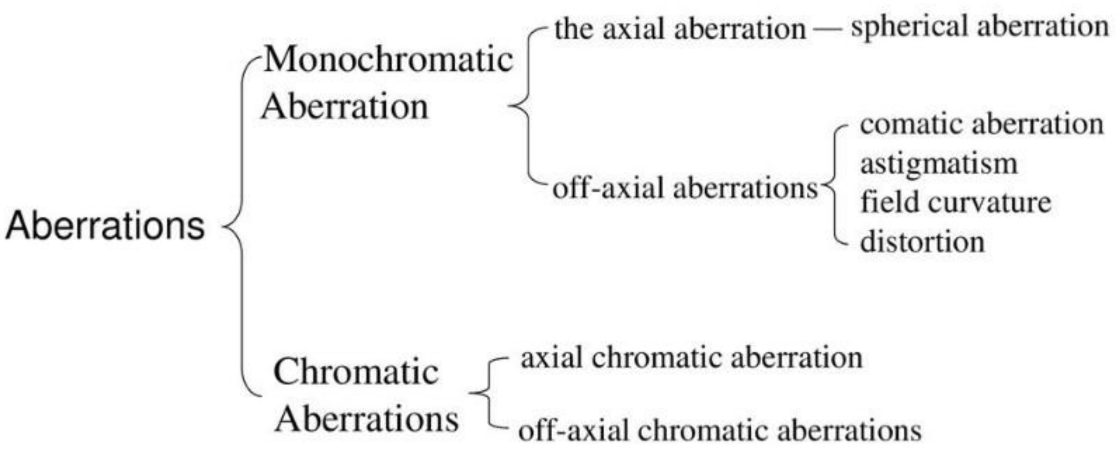
UNIT 8 - OPTICS AND SPECTROSCOPY

8.1. DEFECTS OF IMAGES FORMED BY LENSES:

- The defects in images formed by lenses are called aberrations. Images formed by a lens are defective because of the following reasons.
  1) Lens maker's formula is derived on the assumptions that incident rays are paraxial and aperture of the lens is small.
  2) Object may be extended and need not have point size always.
  3) Due to dispersion, the focal length of the lens changes with color.
  4) Refractive index of the lens changes with wavelength of the incident light.

8.2. ABERRATION:

- Aberrations are of two types
  1) Monochromatic aberrations
  2) Chromatic aberrations



8.2.1. Spherical and Chromatic Aberration in a Lens:

- According to geometric optics, the image of a point object formed in a lens is a point image. In reality, the image of a point object is not a point image, but it is spread in to a region in space both along and perpendicular to the axis of the lens. The deviation of an optical image in size, shape and position formed by a lens is known as aberration of an optical image.
- The aberration of an image is not due to any defect in the construction of the lens, but it is due to the reasons mentioned below:

  (1) The phenomenon of refraction in the lens and

  (2) Variation of refractive index of the material of a lens with the wavelength of light.

8.2.2. Monochromatic Aberration:

- The aberration of optical image even when monochromatic light is used is known as **monochromatic aberration.**
- There are five different types of monochromatic aberrations. They are,

  (1) Spherical aberration

  (2) Coma

  (3) Astigmatism

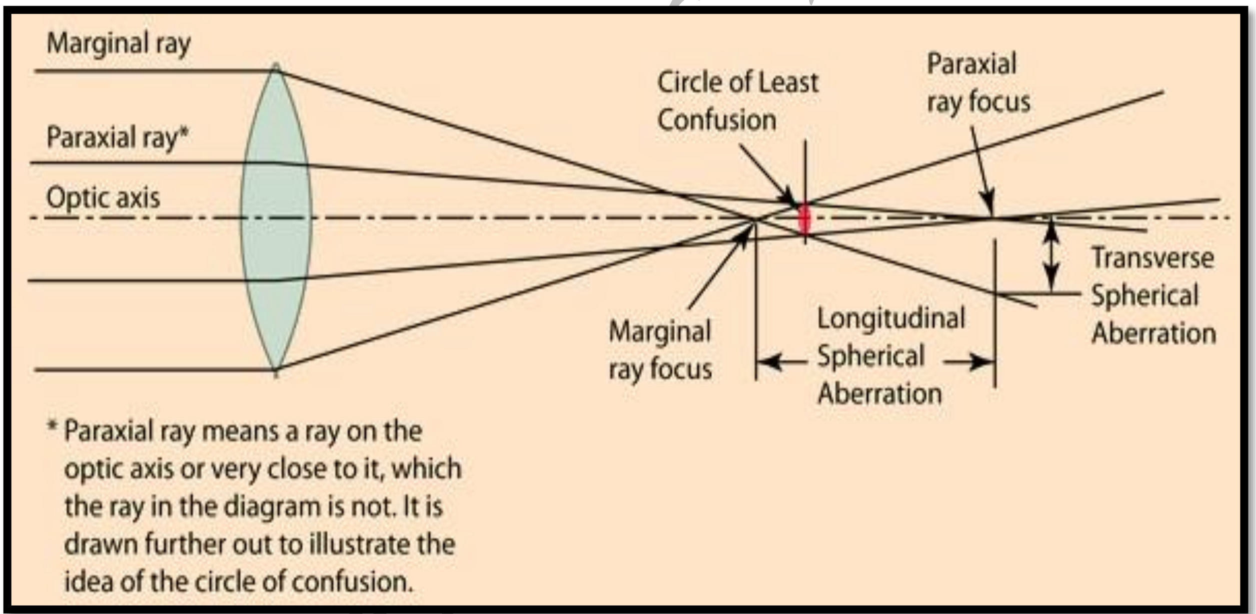
  (4) Curvature of the field and

  (5) Distortion

- When the concept of principal focal length is used, the presumption is that all parallel rays focus at the same distance, which is of course true only if there are no aberrations. The use of the lens equation likewise presumes an ideal lens, and that equation is practically true only for the rays close to the optic axis, the so-called paraxial rays. For a lens with spherical aberration, the best approximation to use for the focal length is the distance at which the difference between the paraxial and marginal rays is the smallest. It is not perfect, but the departure from perfect focus forms what is called the "circle of least confusion". Spherical aberration is one of the reasons why a smaller aperture (larger f-number) on a camera lens will give a sharper image and greater depth of field since the difference between the paraxial and marginal rays is less.

8.2.3. Spherical Aberration and its Minimization:

- The rays of light from the distant object after passing through the lens at the margin of the lens[known as marginal rays] converge at a point I_m close to the lens. Similarly, the rays of light passing through a region close to the axis [known as paraxial rays] converge at a point I_p, away from the lens. This results in an image that spreads into a region from I_m to I_p along the axis and from A to B perpendicular to the axis. This defect of the image due to the rays passing through different section of the lens, even with monochromatic light, is known as **spherical aberration of the lens.** The spread of the image along the axis, [dx] is known as longitudinal spherical aberration.
- The image formed at AB is a circle with least diameter and at this position the best image is formed. This circle is called the **circle of least confusion**. The radius of the circle of least confusion measures lateral spherical aberration

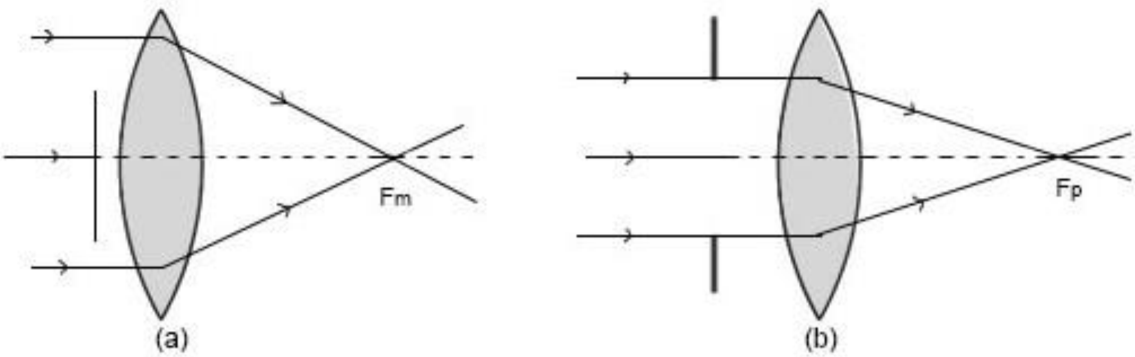


- Monochromatic aberration is also called as spherical aberration. The failure of paraxial and marginal rays to form a common image for pointed object in front of a lens on the principal axis is called spherical aberration.
- Spherical aberration is the blurriness at the edge of an image. Using a spherical lens on a camera **causes light near the edge of the lens (farther from the optical axis) to converge closer to the lens. "Positive" spherical aberration** means peripheral rays are bent too much**."Negative" spherical aberration** means peripheral rays are not bent enough.

8.3. METHODS OF REDUCING SPHERICAL ABERRATION:

(1) By using stops:

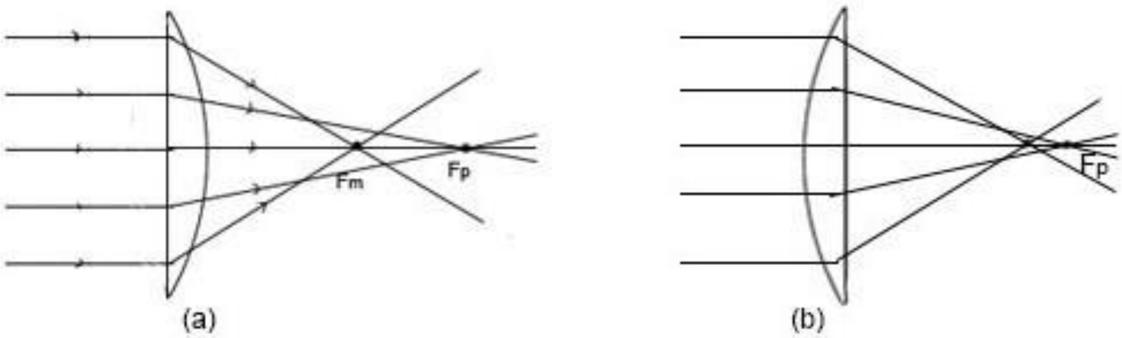
In this case, the stops used will either allow the paraxial rays or marginal rays. Usually the stop is used to avoid the marginal rays. This brings paraxial and marginal images close to one another thereby reducing the spherical aberration.



Reduction of spherical aberration by using stops in different positions.

(2)By the use of Plano-convex lens:

In a lens, the deviation produced by the lens is minimum,when the deviation is shared equally between the two surfaces of the lens. This is achieved in aPlano-convex lens by arranging convex side facing the incident or emergent rays whichever aremore parallel to the axis as shown in the following figure.



Reduction of spherical aberration by using plano - convex lens in different positions.

(3) By the use of crossed lenses:

It is theoretically known that the lenses have minimum spherical aberration when the parallel rays fall of the lens having their radii of curvature r1 and r2 bearing a ratio, which satisfies the following condition.

$$\frac{r_1}{r_2}=\frac{\mu(2\mu-1)-4}{\mu(2\mu+1)}.....(1)$$

In the above equation, μ is the refractive index of the material of the lens. For a lens of μ = 1.5, the

$$\frac{r_1}{r_2} = -\frac{1}{6}$$

A lens having its radii of curvature satisfying this condition is known as a crossed lens.

(4)By using two Plano-convex lenses separated by a suitable distance:

Math When the two plano-convex lenses are separated at a suitable distance, the total deviation is divided equally between the two lenses and the total deviation is minimum. This reduces the spherical aberration to minimum. The necessary condition is derived as follows

With reference of figure (4) , we can write,

$\angle BAK = \angle BF_2O_2 = \delta,$ Also $\angle F_1BF_2 = \angle BF_2F_1 = \delta,$ so that

$F_1F_2 = F_1B = F_1O_2$ or $O_2F_1 = \frac{1}{2}F_2O_2F_2$.

Since F_2 is the virtual object of the real image F_1 and using the lens formula for the second lens,

We can write the equation

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f^2} \ldots(2)$$

In this equation $u = f_1 - d \;\&\; v = \frac{f_1 - d}{2} \ldots(3)$

Substituting for 'u' and 'v' and simplifying , we get

$$\frac{2}{f_1 - d} - \frac{1}{f_1 - d} = \frac{1}{f_1} \Rightarrow \frac{1}{f_1 - d} = \frac{1}{f_2} = \frac{1}{f_1 - d} = \frac{1}{f_1} \Rightarrow f_2 = f_1 - d$$

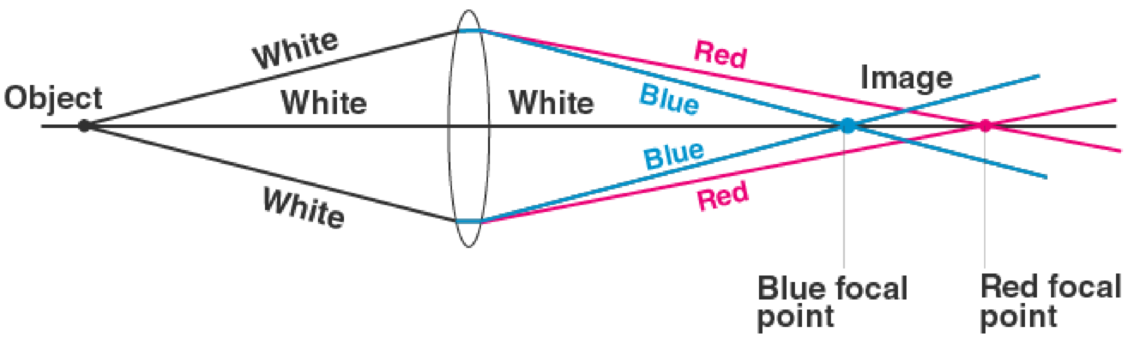
Equation (4) gives the condition for minimum spherical aberration.

5) By using suitable concave and convex lenses in contact:

Since spherical aberration produced by convex lens is positive and that produced by a concave lens is negative, a suitable combination of convex and concave lens will minimize the spherical aberration.

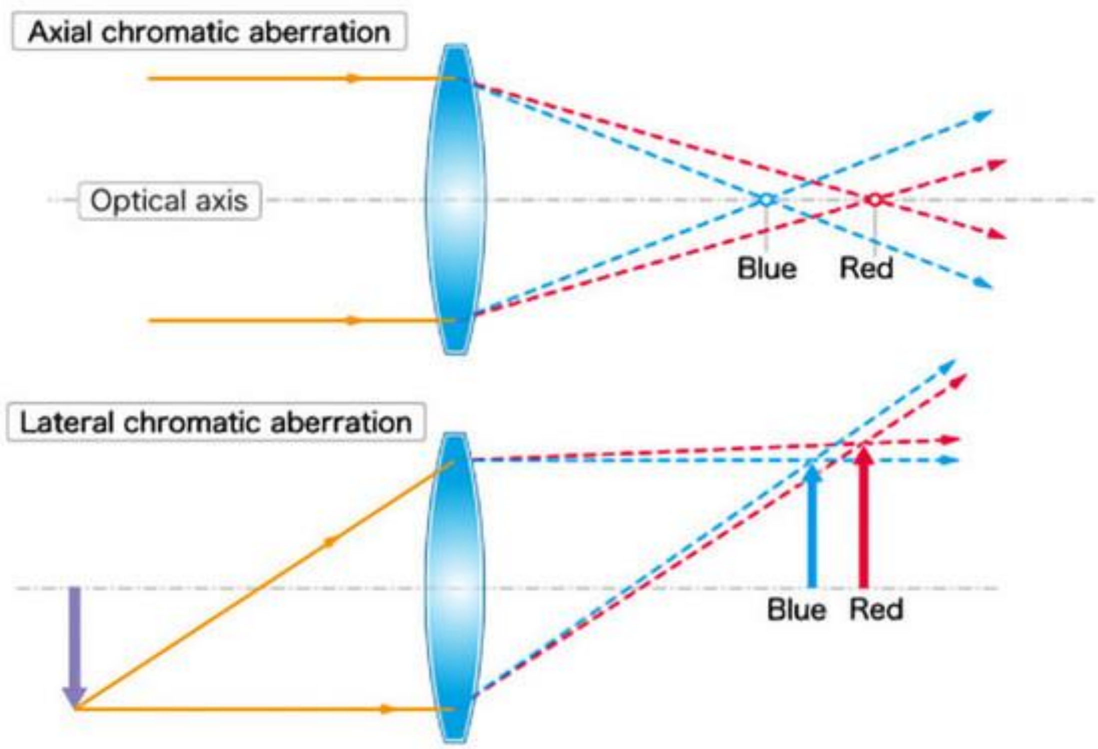
8.4. CHROMATIC ABERRATION:

- Aberration of optical images formed in a lens due to the variation of refractive index with the wavelength of light is known as chromatic aberration.
- **Chromatic aberrations** (present when using **more than one wavelength** of light) and monochromatic aberrations (present with a **single wavelength** of light).Monochromatic aberrations are **aberrations that occur in quasimonochromatic light**.



Chromatic Aberration

8.4.1. Longitudinal or Axial Chromatic Aberration:



- When a parallel beam of white light is passed through a lens, blue rays are brought to focus at a point near the lens and red rays are brought to focus at a point away from the lens and other coloured foci are formed in between them. Thus, the image spread over a distance 'x' from blue focus to red focus and this distance x = fr – fb, is called the **longitudinal or Axial ChromaticAberration.** An equation for axial chromatic aberration is derived as follows

- The focal length of a lens is given by,

$$\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]...(1)$$

or $$\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=\frac{1}{f(\mu-1)}...(2)$$

- similarly, the focal length for the blue and red rays is given by ,

$$\frac{1}{f_b}=(\mu_b-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=\frac{(\mu_b-1)}{(\mu-1)f}...(3)$$

- Also

$$\frac{1}{f_r}=(\mu_r-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=\frac{(\mu_r-1)}{(\mu-1)f}...(4)$$

- Subtracting equation (4) from equation (3), we get,

$$\frac{1}{f_b}-\frac{1}{f_r}=\frac{(\mu_b-1-\mu_r+1)}{(\mu-1)f}\Rightarrow\frac{f_r-f_b}{f_rf_b}=\frac{(\mu_b-\mu_r)}{(\mu-1)f}...(5)$$

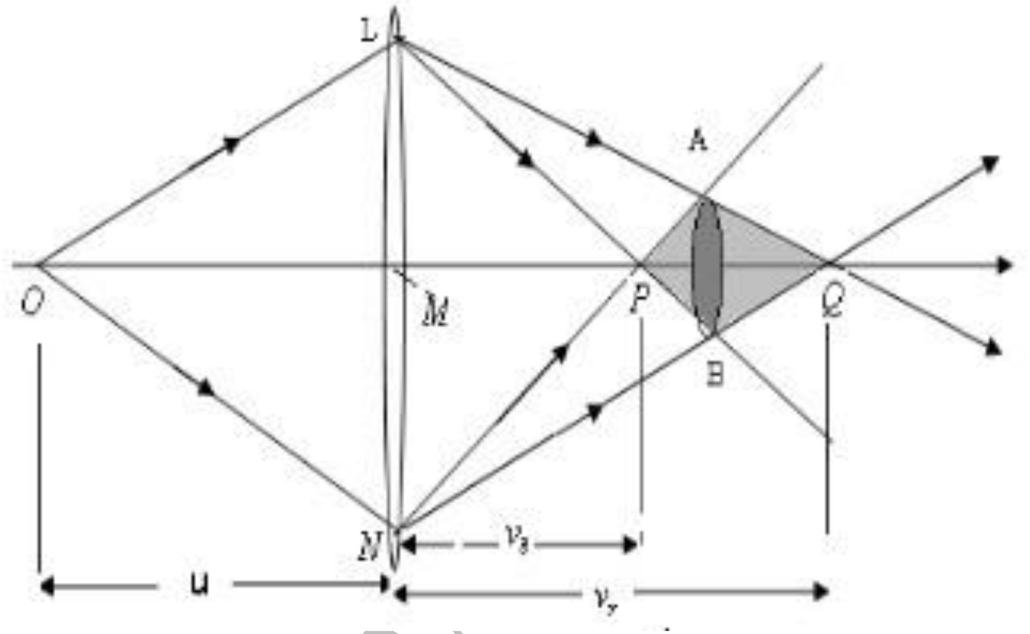
- Taking $f_rf_b=f^2$ (where f is the mean focal length), we can write equation (5) as

$$\frac{f_r-f_b}{f_2}=\frac{(\mu_b-\mu_r)}{(\mu-1)f}\Rightarrow f_r-f_b=\left[\frac{(\mu_b-\mu_r)}{(\mu-1)}\right]f=\omega\times f$$

- Thus $f_r-f_b=\omega f...(6)$
- In equation (6) 'ω' is the dispersive power of the material of the lens and f is the focal length of the mean ray. Therefore, axial chromatic aberration is equal to the product of the dispersive power of the material of the lens and the focal length of the lens. As and f are constant for a lens, a single lens cannot be used to minimize axial chromatic aberration. As a concave lens forms virtual focus, the focal length of the lens for mean ray is negative and hence a suitable combination of a convex and a concave lens can minimize axial chromatic aberration.

8.4.2. Circle of Least Confusion, a Measure of lateral Chromatic Aberration:

- Let a point object illuminated by white light is situated on the axis at a distance "u" from the lens and the blue and red images are formed on the axis at positions P and Q such that the coloured images spread from P to Q. A screen placed at AB has an image with least lateral chromatic aberration. The diameter of the circle of least confusion gives a measure of lateral chromatic aberration and equation for is calculated as follows.



Let 'u' be the object distance and 'v_r' and 'v_b' denote the image distance for red and blue images. If f_r and f_b represent the focal lengths for the red and blue rays of light, then

$$\frac{1}{v_b}-\frac{1}{u}=\frac{1}{f_b}...(1)$$

And $$\frac{1}{v_r}-\frac{1}{u}=\frac{1}{f_r}...(2)$$

- Subtracting equation (2) from (1), we get

$$\frac{1}{v_b}-\frac{1}{v_r}=\frac{1}{f_b}-\frac{1}{f_r}\Rightarrow\frac{v_r-v_b}{v_r v_b}=\frac{f_r-f_b}{f_r f_b}$$

- Taking $v_r v_b = v^2$ and $f_r f_b = f^2$ (where f is the mean focal length),

$$\frac{v_r-v_b}{v^2}=\frac{f_r-f_b}{f^2}=\frac{wf}{f^2}=\frac{w}{f}$$ (Because , $f_r - f_b = w\ f$)

- Therefore $v_r - v_b = \frac{wv^2}{f}$ ....(3)

- From similar triangles LQN and AQB we can write, $\frac{CQ}{AB} = \frac{MQ}{LN}$ ....(4)

- Also,from similar triangles LPN and APB we can write, $\frac{CQ}{AB} = \frac{MP}{LN}$ ....(5)

- Adding equations (4) and (5), we get,

$$\frac{PC+CQ}{AB} = \frac{MQ+MP}{LN} \Rightarrow \frac{PQ}{AB} = \frac{MQ+MP}{LN} \quad ....(6)$$

- Methods

But , $PQ = v_r - v_b; AB = d,$ in the diameter of the circle of least confusion and $LN = D$ is the diameter of the lens aperture and $MQ + MP = v_r + v_b = 2v$ approximately. Substituting theses values in equation (6),we get

$$= \frac{v_r - v_b}{d} = \frac{2v}{D} \Rightarrow D \times \left[\frac{(v_r - v_b)}{2v} \right] = d$$

- Using equation (3), we can write ,

$$d = D \times \left[\frac{1}{2v} \right] \frac{wv^2}{f} = \frac{1}{2}.Dw.\frac{v}{f} \quad ....(7)$$

- For a parallel beam of incident light, and hence equation (7) reduces to the from ,

$$d = \frac{1}{2}.Dw.\frac{f}{f} = \frac{1}{2}D.w \quad ....(8)$$

- Thus, the lateral chromatic aberration on the diameter of the lens aperture and the dispersive power of the material, but it is independent of the focal length of the lens.

8.5. METHODS OF MINIMIZING CHROMATIC ABERRATION:

8.5.1. Condition for achromatism of two lenses placed in contact:

- Let a convex lens C made of crown glass and a concave lens F made of flint glass in contact act as achromatic combination. Let μ_b, μ, μ_r and μ_b', μ', μ_r' represent the refractive indices for blue, yellow and red rays of light of the two materials of the lenses. Let f_b, f, f_r and $f_b^{'}, f^{'}, f_r^{'}$ are corresponding focal lengths of the two lenses and ω and ω' are the dispersive powers for crown and flint glass respectively. Let R_1 and R_2 be the radii of curvature of the Crown glass lens and let $R_1^{'}$ and $R_2^{'}$ be the radii of curvature of the Flint glass lens.

- Then using lens maker's formulae, we can write for the Crown glass lens

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \Rightarrow \left[\frac{1}{R_1} - \frac{1}{R_2}\right] = \frac{1}{(\mu - 1) f} \ldots(1) \text{ (for yellow ray)}$$

$$\frac{1}{f_r} = (\mu_r - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \Rightarrow \frac{1}{f_r} = \frac{(\mu_r - 1)}{(\mu - 1) f} \ldots(2) \text{ (for red ray)}$$

also $$\frac{1}{f_b} = (\mu_b - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \Rightarrow \frac{1}{f_b} = \frac{(\mu_b - 1)}{(\mu - 1) f} \ldots(3) \text{ (for blue ray)}$$

- In the same way, for the flint concave lens, we can write

$$\frac{1}{f'} = (\mu' - 1)\left[\frac{1}{R_1^{'}} - \frac{1}{R_2^{'}}\right] \Rightarrow \left[\frac{1}{R_1^{'}} - \frac{1}{R_2^{'}}\right] = \frac{1}{(\mu^{'} - 1) f^{'}} \ldots(4) \text{ (for yellow ray)}$$

$$\frac{1}{f_r^{'}} = (\mu_r - 1)\left[\frac{1}{R_1^{'}} - \frac{1}{R_2^{'}}\right] \Rightarrow \frac{1}{f_r^{'}} = \frac{(\mu_r^{'} - 1)}{(\mu^{'} - 1) f^{'}} \ldots(5) \text{ (for red ray)}$$

$$\frac{1}{f_b^{'}} = (\mu_b - 1)\left[\frac{1}{R_1^{'}} - \frac{1}{R_2^{'}}\right] \Rightarrow \frac{1}{f_b^{'}} = \frac{(\mu_b^{'} - 1)}{(\mu^{'} - 1) f^{'}} \ldots(6) \text{ (for blue ray)}$$

- If F_b and F_r denote the focal length of the combination for blue and red rays of flight , then , we can write,

$$\frac{1}{F_r} = \frac{1}{f_r} + \frac{1}{f_r} = \frac{(\mu_r - 1)}{(\mu - 1) f} + \frac{(\mu_r^{'} - 1)}{(\mu' - 1) f'} \ldots(7)$$

Similarly, $$\frac{1}{F_b} = \frac{1}{f_b} + \frac{1}{f_b} = \frac{(\mu_b - 1)}{(\mu - 1) f} + \frac{(\mu_b' - 1)}{(\mu^{'} - 1) f'} \ldots(8)$$

- For the combination to be achromatic, the focal length F_b and F_r must be equal, thus

$$F_r = F_b \text{ or } \frac{1}{F_b} = \frac{1}{F_r} \Rightarrow \frac{(\mu_r - 1)}{(\mu - 1) f} + \frac{(\mu_r - 1)}{(\mu - 1) f} = \frac{(\mu_b - 1)}{(\mu - 1) f} + \frac{(\mu_b - 1)}{(\mu - 1) f}$$

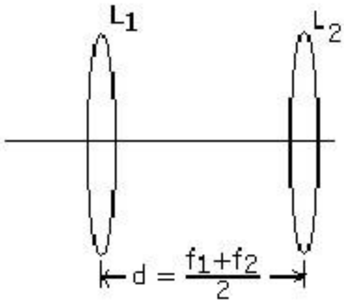
$$\Rightarrow \frac{(\mu_b-\mu_r)}{(\mu-1)f}-\frac{(\mu_r-1)}{(\mu-1)f}+\frac{(\mu_b^{'}-\mu_r)}{(\mu-1)f}-\frac{(\mu_r^{'}-1)}{(\mu-1)f^{'}}=0 \Rightarrow \frac{(\mu_b-\mu_r)}{(\mu-1)f}+\frac{(\mu_b^{'}-\mu_r')}{(\mu-1)f^{'}}=0$$

Using $\frac{(\mu_b-\mu_r)}{(\mu-1)}=\omega$ and $\frac{(\mu_b'-\mu_r')}{(\mu'-1)}=\omega'$, we get $\frac{\omega}{f}+\frac{\omega'}{f'}=0$ or

$$\frac{\omega}{f}=-\frac{\omega'}{f'} \Rightarrow \boxed{f=-f\frac{\omega}{\omega}} ...(9)$$

- Since ω and ω' are positive quantities, f' is negative if f is positive. Thus if crown glass is used to make convex lens, then flint glass lens must be concave. The ratio of the dispersive powers of the material of the lenses must be equal to the ratio of the focal lengths of the two lenses.

8.5.2. Condition for achromatism of two thin lenses separated by finite distance:



- Let f_1 and f_2 be the two convex lenses separated by a distance 'd' such that they act as achromatic combination. Let the two lenses are made of the same material and let μ, μ_b and μ_r denote the refractive indices for the mean ray, blue rays and red rays respectively.
- Let $f_r, f_r^{'}$ and $f_b, f_b^{'}$ are the focal lengths of the two lenses for red and blue rays of light. Then, the equivalent focal length of the two lenses for mean ray, red ray and blue ray are respectively given by the following equations.

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2}....(1)$$ (for mean ray)

$$\frac{1}{F_r}=\frac{1}{f_r}+\frac{1}{f_r^{'}}-\frac{d}{f_r f_r^{'}}....(2)$$ (for red rays)

$$\frac{1}{F_b}=\frac{1}{f_b}+\frac{1}{f_b^{'}}-\frac{d}{f_b f_b^{'}}....(3)$$ (for blue rays)

- In the above F, F_r and F_b are the combined focal length for the mean rays, red rays and blue rays.

But $\frac{1}{f_r} = \frac{(\mu_r - 1)}{(\mu - 1) f_1'} \; \frac{1}{f_r'} = \frac{(\mu_r - 1)}{(\mu - 1) f_2}$ & $\frac{1}{f_b} = \frac{(\mu_b - 1)}{(\mu - 1) f_1'} \; \frac{1}{f_b'} = \frac{(\mu_b - 1)}{(\mu - 1) f_2} \ldots.(4)$

- using equation (4) in equation (2) and (3) , we get

$$\frac{1}{F_r} = \frac{(\mu_r - 1)}{(\mu - 1) f_1} + \frac{(\mu_r - 1)}{(\mu - 1) f_2} - \frac{(\mu_r - 1)^2}{(\mu - 1)^2} \times \frac{d}{f_1 f_2} \ldots.(5)$$

and $\frac{1}{F_b} = \frac{(\mu_b - 1)}{(\mu - 1) f_1} + \frac{(\mu_b - 1)}{(\mu - 1) f_2} - \frac{(\mu_b - 1)^2}{(\mu - 1)^2} \times \frac{d}{f_1 f_2} \ldots.(6)$

- for the combination to be achromatic $F_r = F_b$; or $\frac{1}{F_r} = \frac{1}{F_b}$

- The material of the lenses must be equal to the ratio of the focal lengths of the two lenses.

- Using equation (5) and (6), we can write,

$$\frac{(\mu_r - 1)}{(\mu - 1) f_1} + \frac{(\mu_r - 1)}{(\mu - 1) f_2} - \frac{(\mu_r - 1)^2}{(\mu - 1) 2} \frac{d}{f_1 f_2} = \frac{(\mu_b - 1)}{(\mu - 1) f_1} + \frac{(\mu_b - 1)}{(\mu - 1) f_2} - \frac{(\mu_b - 1)^2}{(\mu - 1)^2} \times \frac{d}{f_1 f_2}$$

$$\frac{(\mu_r - 1)}{(\mu - 1)} \left[\frac{1}{f_1} + \frac{1}{f_2} \right] - \frac{(\mu_r - 1)^2}{(\mu - 1)^2} \frac{d}{f_1 f_2} = \frac{(\mu_b - 1)}{(\mu - 1)} \left[\frac{1}{f_1} + \frac{1}{f_2} \right] - \frac{(\mu_b - 1)^2}{(\mu - 1)^2} \times \frac{d}{f_1 f_2}$$

- Re arranging, the above equation, we get

$$\frac{(\mu_b - \mu_r)}{(\mu - 1)} \left[\frac{1}{f_1} + \frac{1}{f_2} \right] = \frac{d}{(\mu - 1)^2 f_1 f_2} \left((\mu_b - 1)^2 - (\mu_r - 1)^2 \right) = \frac{d}{(\mu - 1)^2 f_1 f_2} (\mu_b - \mu_r) [\mu_b + \mu_r - 2]$$

$$= \frac{d}{(\mu - 1)^2 f_1 f_2} (\mu_b - \mu_r) 2 [\mu - 2] \quad \text{(taking } \mu_b + \mu_r = 2\mu \text{)}$$

$$\frac{(\mu_b - \mu_r)}{(\mu - 1)} \left[\frac{1}{f_1} + \frac{1}{f_2} \right] = \frac{d}{(\mu - 1)^2 f_1 f_2} (\mu_b - \mu_r) 2 [\mu - 1] = \frac{2d (\mu_b - 1)}{(\mu - 1) f_1 f_2}$$

Thus, we get $\frac{1}{f_1} + \frac{1}{f_2} = \frac{2d}{f_1 f_2}$ or $\frac{f_1 + f_2}{f_1 f_2} = \frac{2d}{f_1 f_2} \quad \Rightarrow d = \frac{f_1 + f_2}{2}$

Equation (7) gives the condition for the two thin convex lenses separated by a distance for them to act as achromatic combination of lenses.

8.34. MULTIPLE QUESTION ANSWER

1. Which among the following is the property of light?

   A) Diffraction B) Reflection

   C) Total internal reflection D) All the options

2. Dispersion can be observed through___________________

   A) Wood B) Wall C) Paper D) Prism

3. What are the types of images formed?

   A) Real B) Virtual

   C) Neither real nor virtual D) Both real and virtual

4. Light has the properties of

   A) Wave B) Particle

   C) Neither wave nor particle D) Both wave and particle

5. Formation of images by mirrors is studied by:

   A) Geometrical optics

   B) Physical optics

   C) Neither Physical optics nor Geometrical optics

   D) None of the options

6. The bending of light when it passes from one medium to another is called_____

   A) Diffraction B) Reflection

   C) Total internal reflection D)

7. Refraction is used in devices like

   A) Cameras B) Projectors

   C) Telescopes D) All the above options

8. For the sustained interference of light, the necessary condition is that the two sources should

   A) Have constant phase difference B) Be narrow

   C) Be close to each other D) Of same amplitude

9. Coherent sources are those sources for which

A) Phase difference remain constant

B) Frequency remains constant

C) Both phase difference and frequency remain constant

D) None of these

10. Interference of light is evidence that:

A) The speed of light is very large B) light is a transverse wave

C) light is electromagnetic in character D) Light is a wave phenomenon

11. In Newton's Ring experiments, the diameter of bright rings is proportionalto

A) Square root of Odd Natural numbers B) Natural Number

C) Even Natural Number D) Square root of natural number

12. Extended source is needed in

A) Young's double slit experiment B) Bi prism Experiment

C) Newton's Ring Experiment D) None of them

13. The phenomenon of diffraction can be understood using

A) Huygens principle B) Fraunhofer

C) Uncertainty principle D) Fresnel

14. What is the name of the process whereby waves travel around corners and obstacles in their paths?

A) Reflection B) Refraction C) Interference D) Diffraction

15. In Fraunhofer diffraction, the incident wave front should be _________________

A) elliptical B) Plane C) Spherical D) Cylindrical

16. The wave nature of light is demonstrated by which of the following?

A) The photoelectric effect B) Color

C) The speed of light D) Diffraction

17. In Fresnel diffraction ________________________

A) source of light is kept at infinite distance from the aperture

B) source of light is kept at finite distance from the aperture

113. In Young's double slit experiment if the slit widths are in the ratio 1:9, the ratio of the intensity at minima to that at maxima will be:

A) 1 B) $\frac{1}{9}$ C) $\frac{1}{4}$ D) $\frac{1}{3}$

114. In interference with two coherent sources, the fringe width varies:

A) directly as wavelength

B) inversely as wavelength

C) directly as the separation between slits

D) inversely as the distance between the slits and screen

115. The sources of light are said to be coherent if the waves produced by them have the same:

A) wavelength

B) amplitude

C) wavelength and a constant phase difference

D) amplitude and the same wavelength

116. When light suffers reflection at the interface between water and glass, the change of phase in the reflected wave is

A) zero B) π C) $\frac{\pi}{2}$ D) 2π

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UNIT 8

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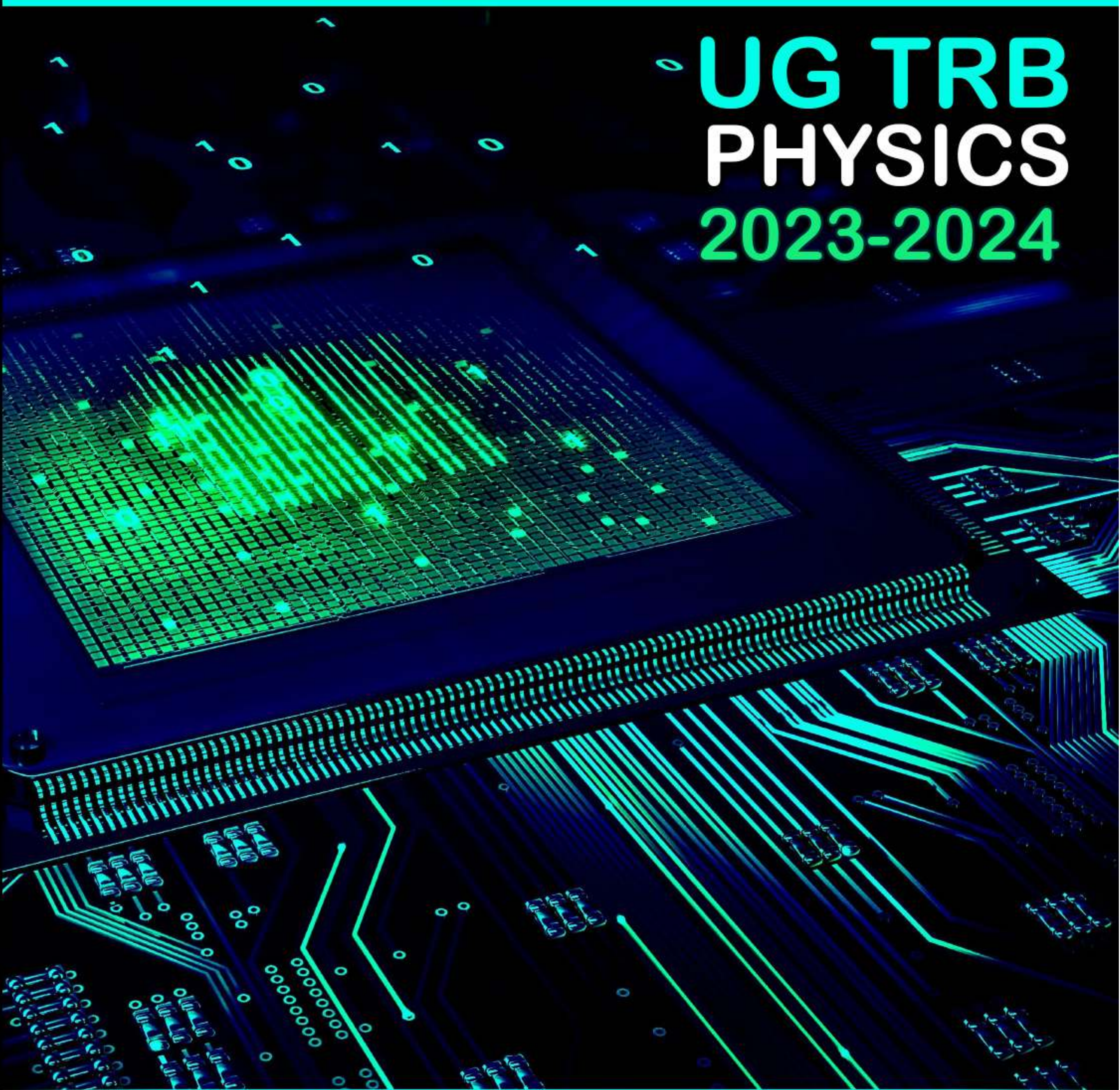

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UNIT-9

Electrical circuits and Electronics

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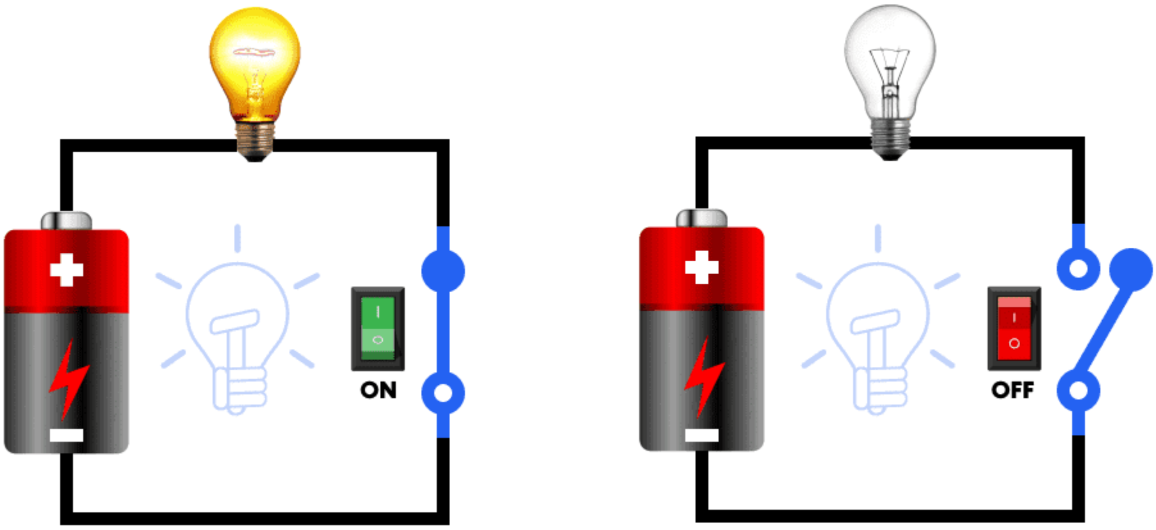
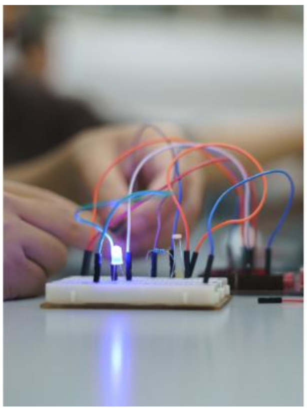
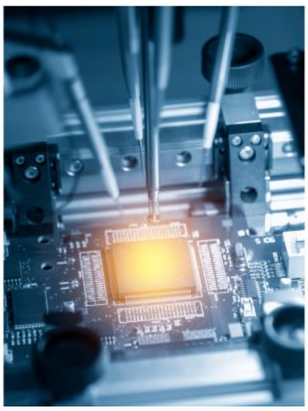
UNIT 9 – ELECTRICAL CIRCUITS & ELECTRONICS







COMPETITIVE EXAM
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UG TRB PHYSICS – 2023-24

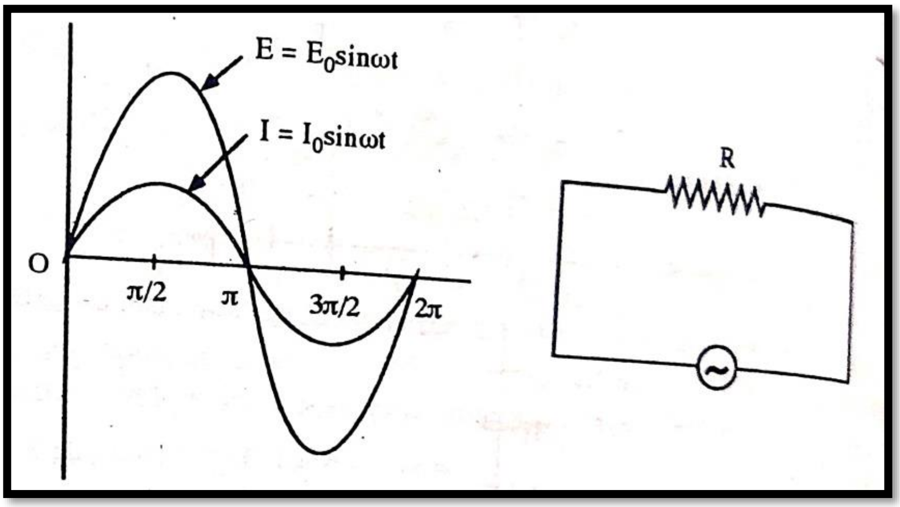
UNIT 9

ELECTRICAL CIRCUITS & ELECTRONICS

9.1. AC Circuits with R, L and C:

9.1.1. AC circuits Containing Only Resistance:

- When the circuit is non-inductive and contains a resistance R the current at any instant $I = E/R$.



- Suppose, the EMF at any instant $E = E_0 sin\omega t$

$$I = \frac{E_0 \sin\omega t}{R}$$

When,

$$\omega t = \frac{\pi}{2}, Sin\omega t = 1$$

$$I = \frac{E_0}{R} = I_0 I = I_0 sin\omega t$$

- Thus, the current is represented by a sine wave in phase with the EMF.

9.1.2. AC Circuits Containing Only Inductance:

- When an AC circuit contains only an inductance the current at any instant

$I = I_0 sin\omega t$ and $\boldsymbol{E = L\, dI/dt}$

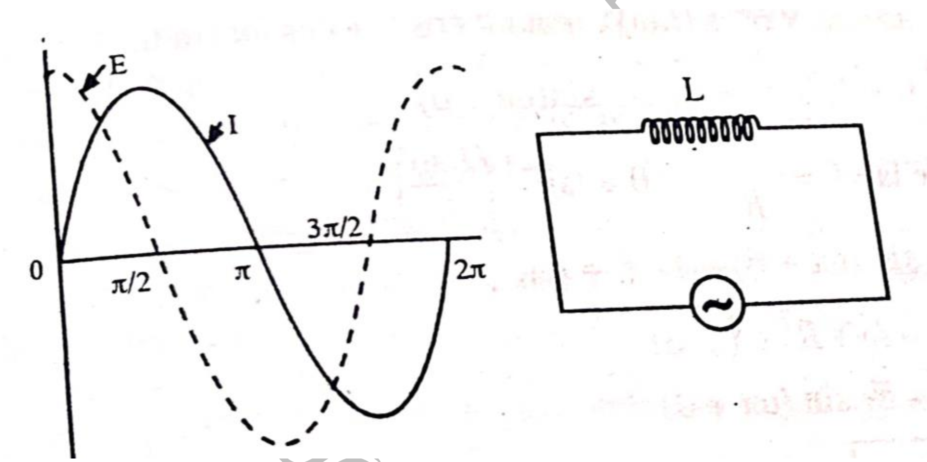
$$\boldsymbol{E = L\frac{d(I_0 sin\omega t)}{dt} = L\omega I_0 cos\omega t}$$

When $cos\omega t = 1, E = E_0$

$E_0 = L\omega I_0, \quad I_0 = \frac{E_0}{L\omega}$

$E = E_0 cos\omega t = E_0 sin(\omega t + \pi/2)$

i.e., EMF is ahead of current by $\pi/2$ or it is said that the current lags behind the EMF by $\pi/2$.



When $\omega t = 0, I = 0, E = E_0$

When $\omega t = \pi/2, I = I_0, E = E_0$

When $\omega t = \pi, I = I_0, E = -E_0$

When $\omega t = 3\pi/2, I = -I_0, E = 0$

When $\omega t = 2\pi, I = 0, E = E_0$

$L\omega$ is known as inductive reactance and has the same effect in AC circuits as resistance R in DC circuits.

Note:

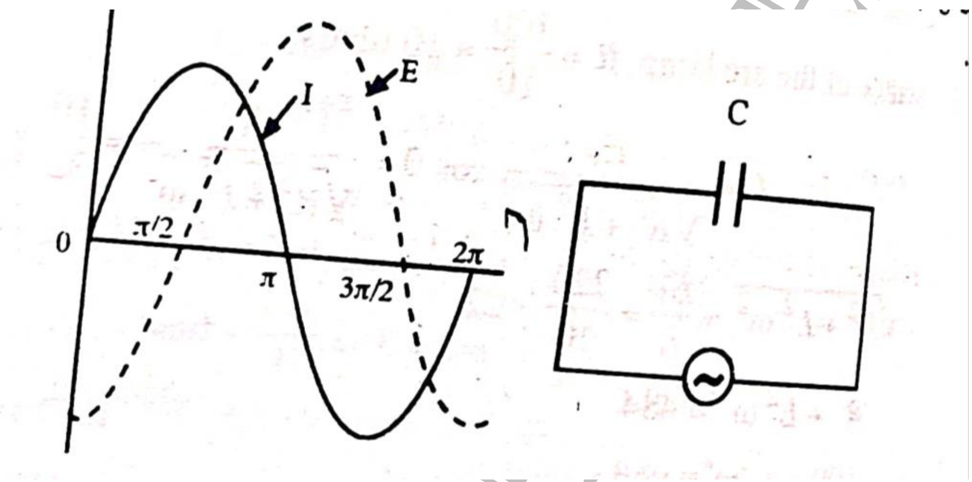
- In a circuit containing only inductance, the EMF is ahead of the current by $\pi/2$. Using operator j, $E_0 = j[L\omega\, I_0]$
- The inductive reactance $= L\omega$.

9.1.3. AC Circuits Containing Only Capacitance:

- Consider a condenser of capacity C joined to an AC source. The current at any instant

  $I = I_0 sin\omega t$

- The PD across the condenser at any instant $E = \frac{Q}{C}$



- The current at any instant $I = \frac{dQ}{dt}$

  $dQ = Idt$

  $Q = \int dQ = \int I\ dt = \int I_0 \sin\omega t dt$

  $E = \frac{\int I_0 \sin \omega t\ dt}{C}$

  $E = -\frac{I_0\, coscos\, \omega\, t}{C\omega} = \frac{I_0\, sin(\,\omega t - \frac{\pi}{2})}{C\omega}$

- When $sin\ (\omega t - \pi/2) = 1,\ \ E = E_0\frac{I_0}{C\omega}$

  $E = E_0 sin\ (\omega t - \pi/2)$

- Therefore the EMF lags behind the current by $\pi/2$ or the current is a head of EMF by $\pi/2$.

- Moreover, $E_0 = \frac{I_0}{C\omega}, I_0 = \frac{E_0}{\frac{1}{C\omega}}$

  $\frac{1}{C\omega}$ is known as capacitative reactance.

- As ω=2πf, capacitative reactance $= \frac{1}{2\pi f C}$

Note:

- In a circuit containing only a capacitor, the EMF lags behind the current by $\pi/2$. Using operator j.

$$E_0 = -j\left[\frac{I_0}{c\omega}\right] = I_0 = \left[\frac{-j}{c\omega}\right]$$

- The capacitative reactance $= \frac{1}{C\omega}$
- It is necessary to distinguish between the two kinds of reactance.Inductive reactance is represented by X_L and capacitative reactance by X_C.

1) $X_L = 2\pi f L$ and $X_C = \frac{1}{2\pi f C}$

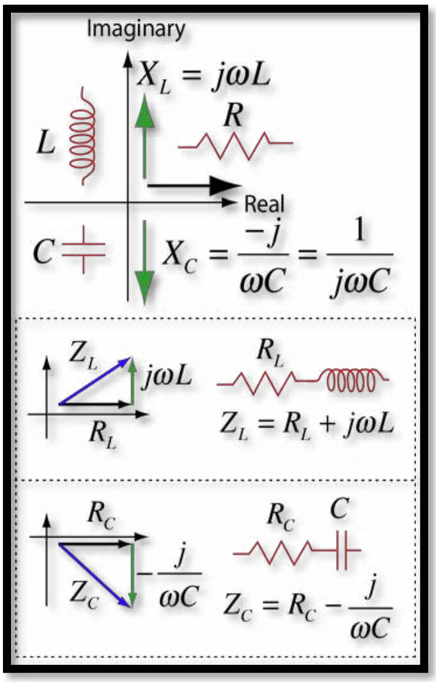
Two points should be noted

(i) Inductive reactance, X_L is directly proportional to both inductance and frequency.

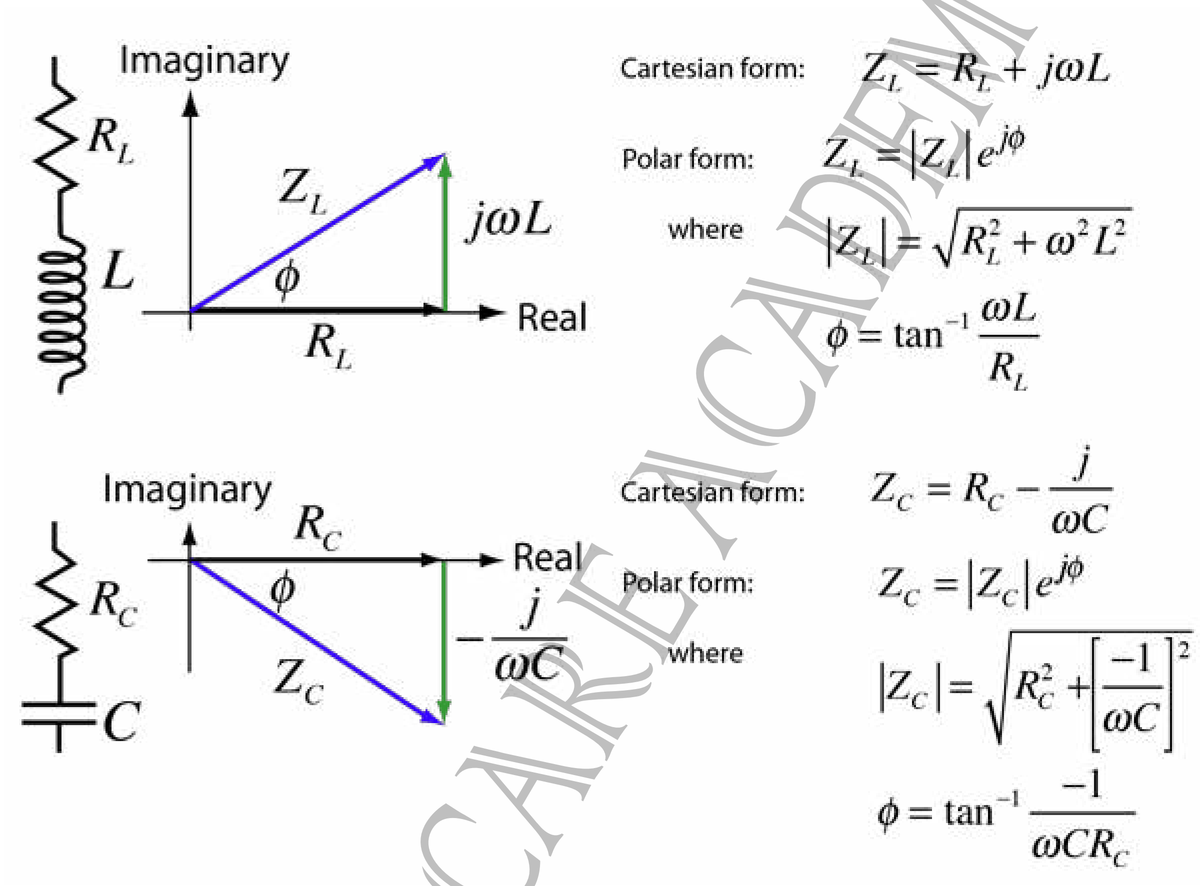
(ii) Capacitative reactance X_C is inversely proportional to both capacitance and frequency.

2) Relative to the same current, the PD across an inductance is ahead of the current by $\frac{\pi}{2}$, whereas the PD across a capacitance lags behind the current by $\frac{\pi}{2}$. Due th this reason, the phase difference between the two PDs is π and X_L is taken as +ve and X_C is taken as –ve.

9.2. Complex Impedance and Phase Diagram:



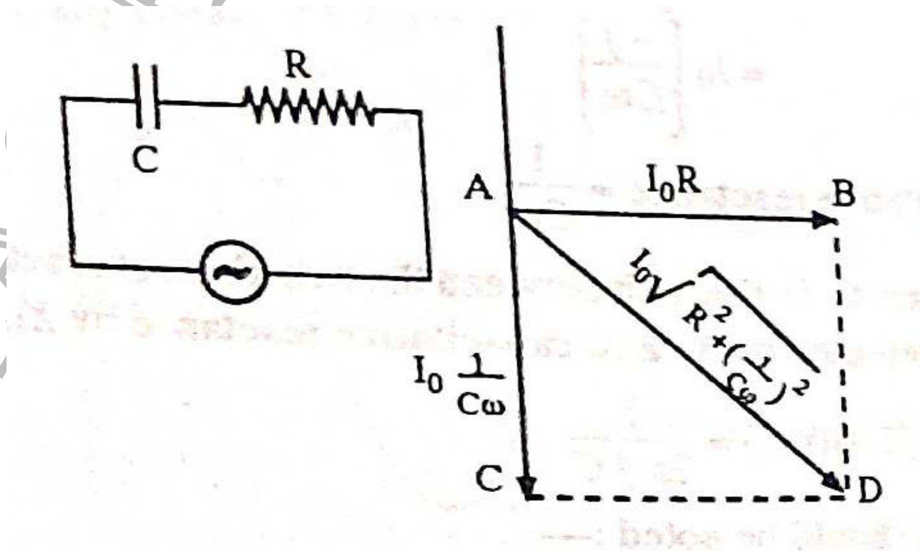
- Using complex impedance is an important technique for handling multi-component AC circuits. If a complex plane is used with resistance along the real axis then the reactances of the capacitor and inductor are treated as imaginary numbers. For series combinations of components such as RL and RC combinations, the component values are added as if they were components of a vector. Shown here is the cartesian form of the complex impedance. They can also be written in polar form. Impedances in this form can be used as building blocks for calculating the impedances of combination circuits like the RLC parallel circuit. This depicts the phasor diagrams and complex impedance expressions for RL and RC circuits in polar form. They can also be expressed in Cartesian form.



9.3. R-L and R-C circuits:

AC circuit containing resistance and capacitance:

- Consider an AC circuit containing a resistance R ands a capacitance C joined in series let the current at any instant be given by ,



$I = I_0 sin\omega t$ _______(1)

E.M.F at any instant , $E = RI + Q/C$

But ,

$Q = \int I_0 sin\omega t \; dt$

$E = RI_0 \sin \omega t + \frac{\int I_0 sin\omega t \; dt}{C}$

$E = RI_0 \, sin \, \omega \, t - \frac{I_0}{C} cos \quad \omega t$

$$E = I_0 \sqrt{R^2 + (\frac{1}{C\omega})^2} \times \left(sin\omega t \frac{R}{\sqrt{R^2 + (\frac{1}{C\omega})^2}} - cos\omega t \frac{\frac{1}{C\omega}}{\sqrt{R^2 + (\frac{1}{C\omega})^2}} \right)$$

Taking, $\frac{R}{\sqrt{R^2+\left(\frac{1}{C\omega}\right)^2}} = cos\,\theta$

$\frac{R}{\sqrt{R^2+\left(\frac{1}{C\omega}\right)^2}} = cos\,\theta$ and $\frac{\frac{1}{C\omega}}{\sqrt{R^2+\left(\frac{1}{C\omega}\right)^2}} = sin\theta$ and $tan\,\theta = \frac{\frac{1}{C\omega}}{R}$

$E = I_0 \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2} \, (sin\,\omega\, cos\,\theta - cos\,\omega\, t\, sin\,\theta)$

$= I_0 \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2} \, sin(\omega t - \theta)$

When $sin(\omega t - \theta) = 1$

$E = E_0 = I_0 \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$

$E = E_0 \, sin(\omega t - \theta)$

Therefore , the E.M.F lags behind the current by θ

$\theta = tan^{-1} \frac{\frac{1}{C\omega}}{R}$

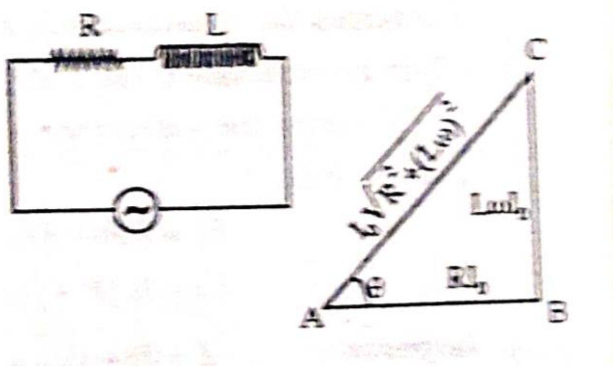
Also ,$E_{0=} I_0 \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$

$$I_0 = E_0 / \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$$

The impedance of the circuit,$Z = \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$

Ac Circuit Containing Resistance and Inductance :

- When an AC circuit contains a resistance R and an inductance L in series , the current at any instant t,



$$I = I_0 sin\omega t$$

EMF at any instant , $e = RI + L\, dI/dt$

$$E = R\, sin\omega t + L\frac{d(I_0 sin\omega t)}{dt}$$

$$= Rl_0 sin\omega t + L\omega l_0\, cos\omega t$$

$$= I_0[Rsin\omega t + L\omega cos\omega t]$$

$$= I_0\, [Rsin\omega t + L\omega cos\omega t]$$

$$= I_0\sqrt{R^2 + (L\omega)^2}\left[\frac{R}{\sqrt{R^2+(L\omega)^2}} sin\omega t + \frac{L\omega}{\sqrt{R^2+(L\omega)^2}} cos\omega t\right]$$

Taking $\frac{R}{\sqrt{R^2+(L\omega)^2}} = cos\theta$, and $\frac{L\omega}{\sqrt{R^2+(L\omega)^2}} = sin\theta$

$$E = I_0\sqrt{R^2 + (L\omega)^2}[cos\theta\, sin\omega t + sin\theta\, cos\omega t]$$

$$E = I_0\sqrt{R^2 + (L\omega)^2}\, sin(\omega t + \theta)$$

$$E = I_0\sqrt{R^2 + (L\omega)^2}\, \sin(\omega t + \theta\ )$$

Where $tan\theta = L\omega/R, or\theta = tan^{(-1)}(L\omega/R)$

When $sin(\omega t + \theta) = 1, E = E_0$

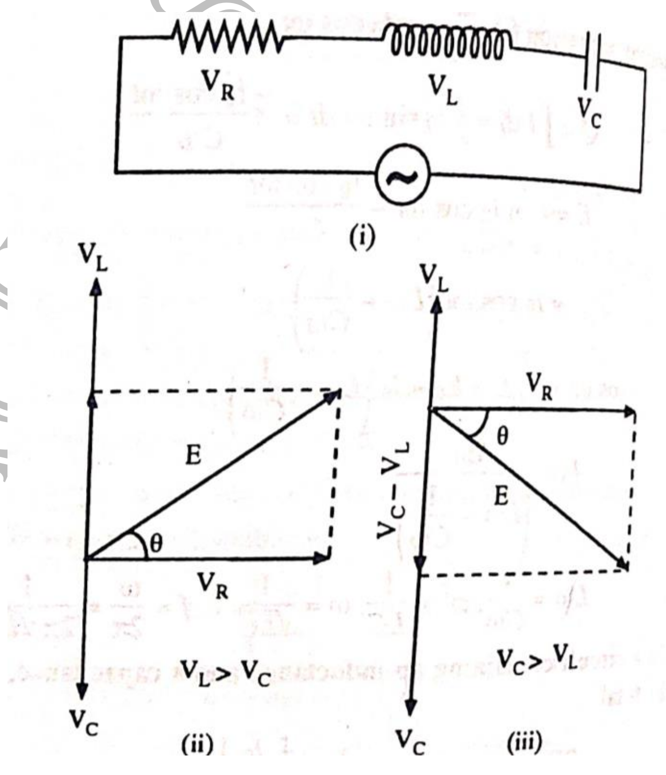
$$E_0 = I_0\sqrt{R^2 + (L\omega)^2}$$

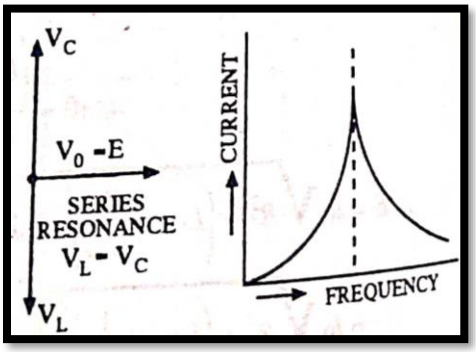
$$E = E_0 \, sin(\omega t + \theta)$$

- $\sqrt{R^2 + (L\omega)^2}$ is called as impedance of the circuit and has the same meaning of resistance in a DC circuit . thus impedence is also called as the effective resistence of an AC circuit as $\omega = 2\pi f$, where f is the frequency impedance $= \sqrt{R^2 + (L2\pi f)^2}$ from the equation (i) and (iii) it is clear the EMF is ahead of current by θ where $\theta = tan^{-1}(L\omega/R)$or the current lags behind the EMF by an angle θ .
- The impedance can also be calculate from the impedance triangle . taken AB representing RI_0 and BC representing $L\omega I_0$the PD
- RI_0 is I phase with the current where as $L\omega I_0$ is ahead of the current by $\frac{\pi}{2}$.
- The total PD equal to$I_0\sqrt{R^2 + (L\omega)^2}$ is represented by AC . therefore w, impedance $= \sqrt{R^2 + (L\omega)^2} = \sqrt{R^2 + (L2\pi f)^2}$.

<u>9.4. Series and Parallel Resonant- LCR circuits</u>:

LRC Circuit (series resonance circuit)





- Consider, a circuit containing an inductance L,a capacitor C and a resistance R joined series . this series circuit is connected to an AC supply given by

$$E = E_0 e^{jwt}$$

- The total impedance of the circuit is given by

$$Z = R + j(L\omega - 1/c\omega)$$

- The current I at any instant is

$$I = E/Z$$

$$I = E_0 e^{jwt}/R + j(L\omega - 1/c\omega)$$

$$I = E_0 e^{jwt}/\sqrt{R^2 + j(L\omega - 1/c\omega)^2}$$

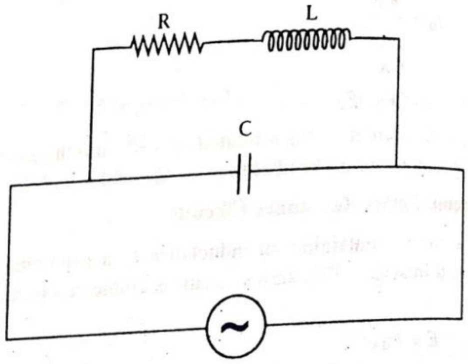
$$I = \frac{E_0 e^{jwt}}{\sqrt{R^2 + (L\omega - 1/c\omega)^2}} < \tan^{-1}\frac{L\omega - 1/c\omega}{R}$$

$$tan\delta = \frac{L\omega - 1/c\omega}{R}$$

$$I_0 = E_0/\sqrt{R^2 + (L\omega - 1/c\omega)^2}$$

Parallel Resonance Circuit (Reject tor Circuit):

- In parallel circuit , capacitor C is connected in parallel to the series combination of resistance R and inductance L . the combination is connected across the AC source.



$$Z_1 = R + jL\omega$$

$$Z_2 = \frac{1}{jL\omega}$$

- Z_1 andZ_2 are in parallel

$$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$\frac{1}{Z} = \frac{1}{R + jL\omega} + \frac{1}{\frac{1}{jC\omega}}$$

$$Y = \frac{1}{R + jL\omega} + jC\omega$$

$$Y = \frac{R - jL\omega}{R^2 + (jL\omega)^2} + jC\omega$$

$$Y = \frac{R}{R^2 + (L\omega)^2} + j\left[C\omega - \frac{L\omega}{R^2 + (L\omega)^2}\right]$$

$$Z = \frac{1}{Y} = \frac{1}{\frac{R}{R^2+(jL\omega)^2} + j\left[C\omega - \frac{L\omega}{R^2+(jL\omega)^2}\right]}$$

- Current :

$$I = \frac{E}{Z} = EY$$

$$I = E\left[\frac{R}{R^2 + (jL\omega)^2} + j\left[C\omega - \frac{L\omega}{R^2 + (jL\omega)^2}\right]\right]$$

9.5. Sharpness of Resonance Q factor:

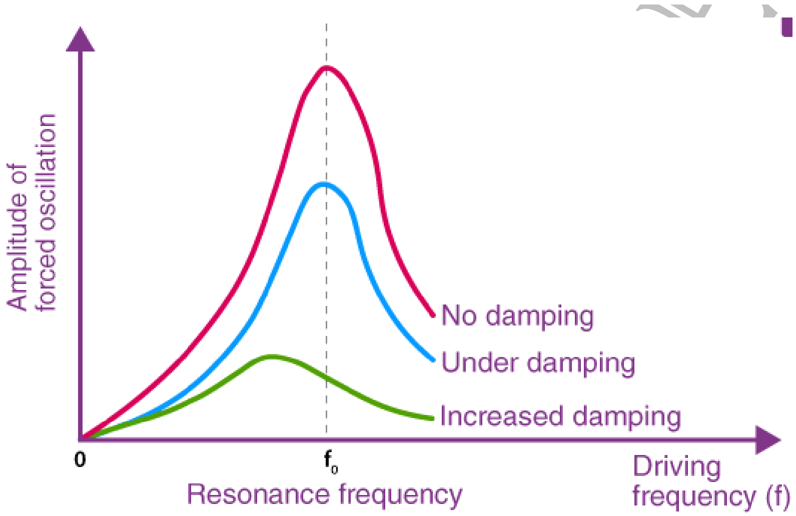
- Resonance is defined as the tendency of a system to vibrate with an increase in amplitude at the excitation of frequencies. Resonance frequency or resonant frequency is the maximum frequency at which the amplitude is relatively maximum. The Q factor is used to define the sharpness of the resonance.

What is Sharpness of Resonance?

- The sharpness of resonance is defined using the Q factor which explains how fast energy decay in an oscillating system. The sharpness of resonance depends upon:

- **Damping**: Effect due to which there is a reduction in amplitude of vibrations.
- **Amplitude**: Maximum displacement of a point on a vibrating body which is measured from its equilibrium position.

- The sharpness of resonance increases or decreases with an increase or decrease in damping and as the amplitude increases, the sharpness of resonance decreases.



What is Q Factor?

- Q factor or quality factor is a dimensionless parameter that is used to describe the underdamped resonator and characterizes the bandwidth and centre frequency of the resonator.
- The mathematical representation is:

$$Q = E_{stored}/E_{lost\ per\ cycle}$$

- The Q factor of an RF resonant circuit is given as:

$$\boldsymbol{Q = F_0/F_{3dB}}$$

What is Q Factor of Coil?

- Q factor for a coil is defined for a given frequency as the ratio of inductance L to the resistance R of a coil.

$$Q = \omega L/R$$

What is Q Factor of RLC Circuit?

- Q factor in a series circuit is:

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\omega_0 L}{R}$$

9.17. Multiple Choice Questions:

1. Addition of trivalent impurity to a semiconductor creates many _____________

A) holes
B) free electrons
C) valence electrons
D) bound electrons

2. A hole in a semiconductor is defined as _____________

A) a free electron
B) the incomplete part of an electron pair bond
C) a free proton
D) a free neutron

3. The impurity level in an extrinsic semiconductor is about _____________of pure semiconductor.

A)10 atoms for 10^8 atoms
B) 1 atom for 10^8 atoms
C) 1 atom for 10^4 atoms
D) 1 atom for 100 atoms

4. As the doping to a pure semiconductor increases, the bulk resistance of the semiconductor _____________

A) remains the same
B) increases
C) decreases
D) none of the above

5. A hole and electron in close proximity would tend to _____________

A) repel each other
B) attract each other
C) have no effect on each other
D) none of the above

6. In a semiconductor, current conduction is due _____________

A) only to holes
B) only to free electrons
C) to holes and free electrons
D) none of the above

7. The random motion of holes and free electrons due to thermal agitation is called ___

A) diffusion
B) pressure
C) ionisation
D) none of the above

8. When the temperature of an extrinsic semiconductor is increased, the pronounced effect is on _____________

A) junction capacitance B) minority carriers

C) majority carriers D) none of the above

9. With forward bias to a pn junction, the width of depletion layer _____________

A) decreases B) increases C) remains the same D) none of the above

10. The leakage current in a pn junction is of the order of _____________

A) A B) mA C) kA D) µA

11. In an intrinsic semiconductor, the number of free electrons _____________

A) equals the number of holes B) is greater than the number of holes

C) is less than the number of holes D) none of the above

12. At room temperature, an intrinsic semiconductor has _____________

A) many holes only B) a few free electrons and holes

C) many free electrons only D) no holes or free electrons

13. At absolute temperature, an intrinsic semiconductor has _____________

A) a few free electrons B) many holes

C) many free electrons D) no holes or free electrons

14. At room temperature, an intrinsic silicon crystal acts approximately as __________

A) a battery B) a conductor

C) an insulator D) a piece of copper wire.

15. A light emitting diode is _________

A) Heavily doped B) Lightly doped

C) Intrinsic semiconductor D) Zener diode

16. Which of the following is not a characteristic of LED?

A) Fast action B) High Warm-up time

C) Low operational voltage D) Long life

17. Which of the following materials can be used to produce infrared LED?

A) Si B) GaAs C) CdS D) PbS

97. The frequency of Colpitts oscillator is expressed as __________

(Where L is inductance and C is the effective capacitance)

A) $1/(4\pi\sqrt{LC})$

B) $1/(2\pi\sqrt{LC})$

C) $1/(3\pi\sqrt{LC})$

D) $\sqrt{3}/(2\pi\sqrt{LC})$

98. How many capacitors are there in the tank circuit of Colpitts oscillator?

A) 1

B) 2

C) 3

D) 0

99. Active element used in Colpitts oscillator is _________

A) Cell

B) Voltage regulator

C) Diode

D) Transistor

100. Colpitts oscillator provides more performance than Hartley oscillator because of its ________ elements.

A) Capacitive

B) Resistive

C) Inductive

D) Active

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PHYSICS

UNIT 9

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UNIT-10

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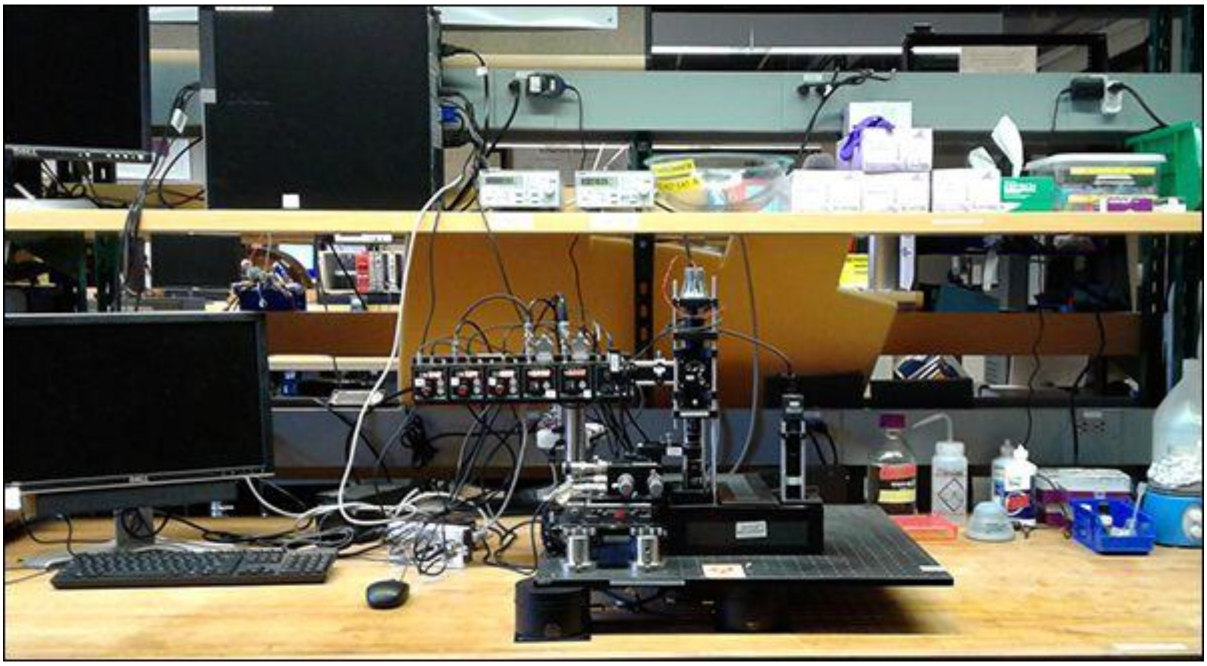
PHYSICS

UNIT 10

EXPERIMENTAL PHYSICS



COMPETITIVE EXAM

For

UG TRB – 2023-24

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UG TRB PHYSICS – 2023-24

UNIT 10

EXPERIMENTAL PHYSICS

10.1. Errors and Approximation:

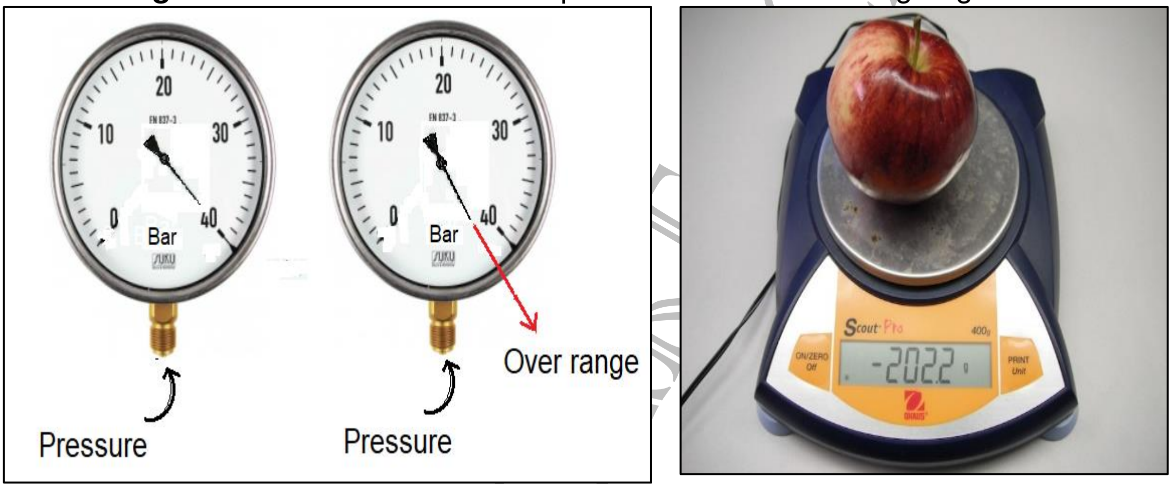
10.1.1 Errors:

- Errors are difference between the measured value and expected value calculated.
- When a single measurement is compared to another single measurement of the same experiment, the values are usually not identical.
- Errors are not always happened by the mistakes.
- It causes results that are inaccurate or misleading and can misrepresent nature.
- A precise experiment also has some small error.
- Errors cannot be completely ignored, but it can be reduced by being aware of common sources of errors and by using thoughtful and careful methods.
- All the scientific measurements suffer from uncertainty which results from unavoidable errors.
- All of these errors can be either random or systematic depending on how they affect the results.
- To find the true values of the experiments, we attempt to find this ideal quantity to the best of our ability with the time and resources available.
- The main strategy in dealing with these errors is to minimize them, but at the same time be honest about them and report truthfully.
- Common sources of error include instrumental, environmental procedural and human.

10.1.1.1 Instrumental Error:

- It happens when the instruments (apparatus) are being used are inaccurate, such as a balance that does not work. Instrumental errors can be classified as,
    i. Shortcoming of instruments: Friction in bearing of various moving parts, irregular spring tension.
    ii. Misuse of instruments: A good instrument is not properly used leads to giving abnormal readings.
    iii. Loading instruments: When the input given to instrument is exceeded the limit, the instruments may affect with the overloading and it leads to show error in next measurements.

Figure: Instrumental errors on pressure meter and weighing balance.



Example: A tape may be too long or an angle measuring instrument may be out of adjustment.

10.1.1.2 Environmental Errors:

- These errors are happening when some external factors in the environment such as an uncommon event, leads to the error.
- Ambient parameters such as temperature, pressure, humidity, dust, external magnetic and electrostatic fields, and frequency sensitivity of the instrument.
- These errors can be avoided by providing air conditioning, cleaning the instruments, housing the instruments in a proper protecting cover.
- The effects of electromagnetic or effects of the external field can be avoided by providing magnetic of electrostatic shields or screens.

Example: If you trying to measure the mass of some object on a scale, and your lab is windy, windy may cause the scale to read incorrectly.

10.1.1.3 Procedural Errors:

- These errors occur when the experimenter does not follow the proper methodological procedures during the measurements.
- There is no solution but can delete the measurements and redo the experiments carefully followed by the proper instructions.
- All the measurement should be done by the procedures which was developed by the manufacturer/professional users.

10.1.1.4 Human Errors:

- These errors due to carelessness or to the limitations of human ability.
- Two types of human error are transcriptional and estimation errors.

Transcriptional errors occur when the data is recorded or written down incorrectly.

***Example*:** The measured reading value is copied incorrectly or when a number is skipped when typing the data into a computer from data sheet.

Estimation errors can occur when reading the measurements on some instruments.

***Example*:** When reading a ruler, you may read the length of a pencil as being 10.3 cm, while other person read it as 10.4 cm.

10.1.2 Approximation:

- Approximation is an estimation value based on prior and reasoning.
- On many scenarios, physicist, engineers and other researchers need to make approximations or guesstimates for a particular quantity.
- The scientific theory predictions can differ from the actual measuring due to there are factors in the real situation that are not included in the theory.
- It is most often applied to numerical problems, also frequently applied in mathematical functions, shapes and physical laws.
- Many approximation numbers are based on formulae in which the input quantities are known only to a limited accuracy.
- The reason for the necessity of approximation is that real systems in nature are far too complex for physics to analyze them exactly in every detail.
- In general, a macroscopic system such as lengths, mass and time scales will need a large number of variables to describe it fully, even if we ignore for the moment its microscopic constitution.

- The sign of approximately $(\approx)$ was introduced by Alfred Greenhill a British mathematician.
- The drawback of the approximation is that is reduces accuracy of measurements. This can cause severe problems in sensitive experimental.

***Example (1)*:** Physicist often approximate the shape of the Earth as sphere even though more accurate representation are possible, because many physical properties such as gravity are much easier to calculate for a sphere than other shapes.

***Example (2)*:** If our aim of the experiment is finding the motion of the rocket as a whole, we need to know some particular mechanical variables such as original mass, the rate of mass depletion, the exhaust velocity relative to the rocket and gravitational acceleration.

Questions:

1) Temperature causes _____ of error.

A) Instrumental B) Procedural C) Environmental D) Human

2) Zero error is a type of ______ error.

A) Systematic B) Instrumental C) Random D) Human

3) The best method to deal the error is _____.

A) Ignoring B) Minimizing C) Repeat the experiment D) Accepting

4) If the length of the object is measured by two observers as 7.86 cm and 8.24. 1.2cm of length already broken in scale. What is the approximate length of the object?

A) 9.2 cm B) 9.3 cm C) 8.1 cm D) 8.7 cm

5) The difference between ________ is known as error of measurement.

A) True value and measurement B) Precision and True value

C) Measured value and Precision D) None of the above

6) Poor calibration of the instrument leads to _____.

A) Systematic error B) Random error C) Gross error D) Precision error

7) Which one of the following is not a systematic error type?

A) Gross error B) Environmental error

C) Observational error D) Instrumental error

8) Careless handling of instruments leads to ___.

A) Gross error B) Systematic error C) Environmental error D) Random error

9) The deviation between the measured quantity's actual value and the value displayed by the instrument under various conditions is known as ____.

A) Dynamic error B) Static error C) Absolute error D) Zero error

10) In a measuring systems random errors caused by ___.

A) Unpredictable effects B) Poor cabling setup

C) Calibration effects D) Environmental changes

10.2. Types of Errors:

There are two types of errors in experimental measurements.

1. Random errors
2. Systematic errors

- Random error varies changeable from one to another measurements while the systematic error has same values for every measurement.
- Random errors are unavoidable, but cluster around the true value.
- Systematic error can often be avoided by calibrating instruments.

10.2.1 Random Errors:

- Random error affects the last significant digit of a measurement.
- It refers to random fluctuations in the measured data due to limitations of instruments, environmental factors, slight variations in procedures and effects of something changing in the surrounding between measurements. Such as,
  - When weighing yourself on a scale, your position angle will be slightly different each time.
  - When taking a volume reading in a flask, you may read the value from a different angle each time.
  - Measuring the mass of a sample on an analytical balance may produce different values as air currents affects the balance or as water enters and leaves the specimen.
  - Measuring your height is affected by minor posture changes.
  - Measuring wind velocity depends on the height and time at which a measurement is taken. Multiple readings must be taken and averaged because gusts and changes in direction affect the value.

- Readings must be estimated when they fall between marks on a scale or when the thickness of a measurement marking is taken into account.

- For the reason that random error always occurs and cannot be predicted, its important to take multiple data points and average them to get a sense of the amount of variation and estimate the corrected value.

10.2.2 Systematic Errors:

- Systematic error is predictable and either constant or else proportional to the measurement. These errors primarily influence a measurements accuracy.
- It refers to reproducible fluctuations consistently in same direction due to an Equipments being wrongly calibrated, an equipment with zero error.
- Systematic errors cannot be detected or reduced by taking more measurements.
- Typical causes of systematic error include observational error, imperfect instrument calibration and environmental interface. Such as,
  - Forgetting to tare or zero a balance produces mass measurement that are always off by the same amount. An error caused by not setting an instrument to zero prior to its use is known as offset error.
  - Not reading the curve at eye level for a volume measurement will always result in an inaccurate reading. The value will be consistently low or high, depending on whether the reading is taken from above or below the mark.
  - Measuring length with a metal ruler will give a different result at a cold temperature than at a hot temperature, due to thermal expansion of the material.
  - An improperly calibrated thermometer may give accurate readings within a certain temperature range, but become inaccurate at higher or lower temperatures.
  - Measured distance is different using a new cloth measuring tape versus an older, stretched one. Proportional errors of this type are called scale factor errors.
  - Drift occurs when successive readings become consistently lower or higher over time. Electronic equipment tends to be susceptible to drift. Many other instruments are affected by (usually positive) drift, as the device warms up.
  - Once its cause is identified, systematic error may be reduced to an extent. Systematic error can be minimized by routinely calibrating equipment, using controls in experiments, warming up instruments prior to taking readings, and comparing values against standards.

- While random errors can be minimized by increasing sample size and averaging data, it's harder to compensate for systematic error. The best way to avoid systematic error is to be familiar with the limitations of instruments and experienced with their correct use.

Questions:

1) Systematic errors can be fixed by _____.

A) Calibrating
B) Repeated readings
C) Changing the scales
D) Changing of inputs

2) Metal ruler my gives the different results due to ____.

A) Thermal expansion
B) Conductivity nature
C) Zero error
D) None of the above

3) Random errors can be fixed by _____.

A) Multiple data’s
B) Calibration
C) Changing the instruments
D) Changing of inputs

4) An error caused by not setting an instrument to zero prior to its use is known as __.

A) Offset error
B) Random error
C) Environment error
D) Zero error

5) Random errors can be assessed ____.

A) Statistically
B) Empirically
C) Experimentally
D) By sensitivity analysis

6) When an instrument is not properly aligned with the direction of the desired measurement, an error occurs that is referred to as___.

A) Alignment error
B) Characteristic error
C) Environment error
D) Reading error

7) The discrepancy between a quantity's true value and its measured value is referred to as____.

A) Static correction
B) Change over
C) Dynamics correction
D) None of the above

8) The error which occurs due to carelessness of the operator is known as ___.

A) Observational error
B) Random error
C) Systematic error
D) Instrumental error

9) The parallax errors happened due to ___.

A) Error in reading of an operator
B) Static error of the instrument
C) Dynamic error of the instrument
D) Environmental conditions

10) Errors result from circumstances outside of the measuring device is known as ___.

A) Environmental error
B) Random error
C) Observational error
D) Systematic error

10.3. Absolute, Relative and Percentage of Errors

10.3.1. Absolute Error:

- The magnitude of the difference between the true value of the quantity and the individual measurement value is called the absolute error of the measurement. That is the absolute value of the deviation is *a* known as absolute error.
- The absolute error $|\Delta a|$ is always will be positive.

$$|\Delta a_1| = |\Delta a_{mean} - a_1|,$$

$$|\Delta a_2| = |\Delta a_{mean} - a_2|,$$

$$|\Delta a_n| = |\Delta a_{mean} - a_n|$$

10.3.1.1 Mean Absolute Error

- The arithmetic mean of all the absolute errors is taken as the final or mean absolute error of the value of the physical quantity (*a*).
- Mean absolute error is represented by Δa_{mean}.

$$\Delta a_{mean} = \frac{(|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \ldots.. + |\Delta a_n|)}{n}$$

$$\Delta a_{mean} = \frac{\sum_{t=1}^{n} |\Delta a_i|}{n}$$

- If only a single measurement of the physical quantity *a* is done by someone else, it is expected to be in the range,

$a_{mean} \pm \Delta a_{mean}$

i.e. $a = a_{mean} \pm \Delta a_{mean}$

the result is expected to be in the range

$a_{mean} + \Delta a_{mean} \leq a \leq a_{mean} - \Delta a_{mean}$

10.3.2 Relative and Percentage Error:

- The relative error is the ratio of the mean absolute error Δa_{mean} to the mean value a_{mean} of the quantity measured.

$$Relative\ error = \frac{\Delta a_{mean}}{a_{mean}}$$

- When the relative error is expressed in percent, it is called the percentage error (δa).
- Thus, Percentage error is,

$$\delta a = \frac{\Delta a_{mean} df\ \times 100\%}{a_{mean}}$$

Problems:

1. Calculate absolute error when the actual value is 22.13 and the measured value is 24.09.
2. Calculate the absolute and relative errors of the approximation 122.67 to the value 116.66.

Questions:

1) An analogue indicating device with a 0–2.5 V range displays a voltage of 1.46 V even though the voltage has a true value of 1.5 V. The proportional error is___.

A) -2.66 % B) -26.6 % C) -0.4 % D) -4.0 %

2) The sample size of 100 with a mean age of 34.25 from a population with a standard deviation of 10 and the 95% confidence interval of the average age of accidents in any city during the previous year are ___.

A) [32.29, 36.21] B) [32.29, 36.58] C) [32.605, 35.895] D) [31.92, 36.58]

3) While a metre reads 125 V, the actual voltage is 125.5 V. Find the instrument's static error ___.

A) 0.5 V B) 125 V C) 125/0.5 V D) 0.5/125 V

4) The discrepancy between a quantity's indicated value and true value is ___.

A) Absolute error B) Gross error C) Dynamic error D) Relative error

5) Improper zero adjustment is a type of ___.

A) Instrument error B) Random error C) Operator error D) None of the above

6) The span of a zero-centered voltmeter with a scale from – 5 V to + 5 V is ____.

A) 10 V B) 5 V C) 0 V D) -5 V

7) When an instrument's absolute static error is 2.5 V and its true value is 125 V, relative static error ___.

A) 2 % B) 4 % C) 5 % D) 10 %

8) Determine the relative error when the capacitor's true value is 201.4 F and its measured value is 204.3 F.

A) 1.43 % B) 1.23 % C) 1.68 % D) 1.94 %

9) When a capacitor's measured value is 195.5 F and its true value is 200 F, what is the relative static error?

A) 2.25 % B) 2.30 % C) 4.5 % D) 22.5 %

10) When a resistor's measured value is 105 and its true value is 100, what is the relative static error?

A) 5 % B) 10 % C) 2.5 % D) 6.25 %

10.4. Significant Figures:

- As significant figures are given in the form of digits, it is also called as significant numbers.
- The number of significant digits is found by counting all values from the first non-zero digit from the left side.
- These are important and reliable to display the quantity of a length, volume, mass, etc.
- Arithmetic operations such as addition, subtraction, multiplication and division are used when the significant number calculation.
- When the number of significant numbers increases, the accuracy will be increases.
- Significant figures are defined as the number of digits which is required to give the precise result of any experiment or a calculation.
- Significant figures are number of digits which is known reliably and also number which is uncertain.

10.4.1. Rules for the Significant Figures:

- Some of the rules are used to determine the significant figures, such as
  - ➢ All non-zero digits are significant figures.
  - ➢ Zeros which lie between to non-zero digits are also significant numbers.

- A trailing zero or final zero in the decimal portion only are significant.
- All zeros after decimal but before a non – zero digit is not considered a significant figure. E.g.,0.00465 has only 3 three significant figures.
- When the given number does not contain a decimal point, then the final zeroes are ambiguous and they are not considered as significant figures. E.g., 94000 has two significant figures. But when the number which is obtained on the basis of actual (real) measurement, then all zeroes which are to the right of the last non zero digit are also considered as significant figures. E.g., 9080 has four significant figures.
- When a decimal is present at the end of a whole number, then all zeros which are at the right end just before the decimal are considered as significant figures. E.g., 42200. Has five significant figures.
- When the number contains both an integral part as well as a decimal part, then all zeros in the number are considered as significant figures. E.g., 25.34 has four significant figures.

Example: When a period of oscillation of a simple pendulum is determined as 3.25 seconds. Then the digits 3 and 2 are reliable and certain, and the digit 5 is uncertain. Therefore, the calculated value has three significant figures.

10.4.2. Rules for rounding Significant Figures:

- A number is rounded to the needed number of significant digits by leaving one or more digits to the right. If the first digit on the left is less than the number 5, then the last digit must remain constant. If the first digit is more than the number 5, then the last digit of the significant figure is rounded up. If the remaining digit is exactly equal to the number 5, then the retained number is rounded up or down to get an even number. If more than one digit remains, round as a whole rather than one digit.
  - When the digit after the last significant digit is more than the number 5, then the last digit of the significant figure (or significant digit) is raised by one (1).
  - When the digit after the last significant digit is less than the number five (5)), then the last digit of the significant figure (or significant digit) is left without making any changes.
  - When the digit after the last significant digit is equal to the number five (5), then the last digit of the significant figure (or significant digit) is not altered when the number is even and is increased by 1 when it is odd.

10.5. Advantages of Average:

- It is most widely applied measure because it can be calculated very easily and can be understood without any complication.
- The result of average is always fixed as it is defined by rigid formula.
- Averages can be used for further study especially for algebraic calculation and statistical analysis.
- It is less affected by sampling fluctuations.
- It doesn't require the arrangements of data values and dividing data like other measurements of central tendencies.
- Completely based on observation; it represents the data not the terms positions.
- The average of a collected data is obtained by adding all the values and dividing the sum by total number of values that are added.

  Average $\bar{X} = \frac{X1+X2+X3+\ldots+Xn}{n}$

  - Arithmetic mean is simple to understand and easy to calculate.
  - It is rigidly defined.
  - It is suitable for further algebraic treatment.
  - It is least affected fluctuation of sampling.
  - It takes into account all the values in the series.

- If a variate X takes values $x_1, x_2, x_3, \ldots x_n$ with corresponding frequencies $f_1, f_2, f_3, \ldots f_n$ respectively, then the arithmetic average of these values is,

$$\bar{X} = \frac{f_1x_1 + f_2x_2 + \ldots + f_nx_n}{f_1 + f_2 + \ldots + f_n}$$

$$\bar{X} = \frac{\sum_{i=1}^{n} f_i x_i}{N}$$

$$N = \sum_{i=1}^{n} f_i = f_1 + f_2 + \ldots + f_n$$

Example Problem:

Find out the average of the given distribution.

x:	4	6	9	10	15
f:	5	10	10	7	8

Solution:

x_i	4	6	9	10	15
f_i	5	10	10	7	8
$x_i f_i$	20	60	90	70	120

$N = \Sigma f_i = 40$

$\Sigma f_i x_i = 360$

Therefore,

$$\bar{X} = \frac{360}{40} = 9$$

Questions:

1) The average of data set is obtained by ___ all the data values and _____ the sum by total number of the values.

A) Adding, Dividing
B) Subtracting, Dividing
C) Adding, Multiplication
D) Subtracting, Multiplication

2) The average of the set {12, -24, 25, -19}is___.

A) 2.5
B) -2.5
C) 3
D) -3

3) The average of 6, 9, 11, 12, x, 20 is 11. Find x.

A) 6
B) 8
C) 9
D) 7

4) Find the average of the following distribution.

x	10	30	50	70	89
f	7	8	10	15	10

A) 55
B) 54
C) 65
D) 64

5) Find the missing frequencies in the following frequency distribution if it is known that the mean of the distribution is 1.46.

x	0	1	2	3	4	5	Total
f	46	?	?	25	10	5	200

A) 76 & 38
B) 78 & 36
C) 66 & 48
D) 37 & 75

10.33. Multiple Choice Questions (Important)

1. Errors that occur during measurement of the quantities are of

A) 2 types B) 3 types C) 4 types D) 5 types

2. Systematic error occurred due to the poor calibration of the instrument that can be corrected by

A) Taking several readings B) replacing instruments

C) Taking mean of values D) taking median of values

3. Error that occurs due to equally affected measurements is called

A) random error B) systematic error

C) frequent error D) precision

4. Error that occurs during the measurement of quantities is

A) random error B) systematic error

C) frequent error D) both A and B

5. What is the reason for the occurrence of systematic in an instrument?

A) No use for a long-time B) High use

C) Manufacturing fault D) Delivery fault

6. How are systematic errors removed usually for an instrument?

A) By-replacing it B) By re- calibrating it

C) By using a repairing service D) By not using it for some time

7. If the error in the measurement of the radius of a sphere is 2%, then the error in the determination of the volume of the sphere will be

A) 4% B) 6% C) 8% D) 2%

8. The mean length of an object is 5 cm. Which of the following measurements is most accurate?

A) 4.9 cm B) 4.805 cm C) 5.25 cm D) 5.4 cm

9. Columun A	Columun B
i) Length	1) Burette
ii) Volume	2) Vernier callipers
iii) Diameter of a thin wire	3) Screw gauge
iv) Mass	4) Common balance

A) i) 2); ii) 1); iii) 3); iv) 4)

B) i) 4); ii) 2); iii) 3); iv) 1)

C) i) 3); ii) 2); iii) 4); iv) 1)

D) i) 4); ii) 2); iii) 1); iv) 3)

10. The magnitude of the difference between the individual measurement and true value of the quantity is called

A) Absolute error B) Percentage error C) Relative error D) None of these

11. systematic errors can be

A) negative only B) positive only

C) either positive or negative D) none of these

12. The_______ is a measure of how closed the measured value is to the true value of quantity

A) Accuracy B) Precision C) Error D) none of these

13. If Z =A^3, then $\frac{\Delta Z}{Z}$ = ______

A) $\frac{\Delta A^3}{A}$ B) $3\left(\frac{\Delta A}{A}\right)$ C) $\left(\frac{\Delta A}{A}\right)^3$ D) $\left(\frac{\Delta A}{A}\right)^{\frac{1}{3}}$

14. If X= a-b, then the maximum percentage error in the measurement of X will be

A) $\left(\frac{\Delta a}{a-b}+\frac{\Delta b}{a-b}\right)\times 100\ \%$ B) $\left(\frac{\Delta a}{a}+\frac{\Delta b}{b}\right)\times 100\ \%$

C) $\left(\frac{\Delta a}{a-b}-\frac{\Delta b}{a-b}\right)\times 100\ \%$ D) $\left(\frac{\Delta a}{a}-\frac{\Delta b}{b}\right)\times 100\ \%$

15. The most suitable instrument for measuring the size of an atom is:

A) Electron microscope B) Vernier calliper

C) optical microscope D) screw gauge

16. The method used to measure the distance of a planet from the earth is:

A) Parallax method B) Archimedes method

C) Newtons method D)Galileos method

17. which of the following is caused by careless handling?

A) Systematic error B) Gross error

C) Random error D) None of these

C) Taking average value of resistances determined using (B)

D) Both (B) and (C)

92. The best instrument for accurate measurement of EMF of a cell is

A) Potentiometer B) Metre bridge

C) Voltmeter D) Ammeter and Voltmeter

93. Basically a potentiometer is a device for

A) Comparing two voltages B) Measuring a current

C) Comparing two currents D) Measuring a voltage

94. In order to achieve high accuracy, the slide wire of a potentiometer should be

A) As long as possible B) As short as possible

C) Neither too small not too large D) Very thick

95. A series LCR circuit (R = 30 ohm, X_L = 40 ohm, X_C = 80 ohm) is connected to an AC source of 200 V and 50 Hz. The power dissipated in the circuit is :

A) 480 W B) 240 W C) 48 W D) 24 W

96. The Power factor of a Series LCR circuit at resonance is

A) 0.707 B) 0.50 C) 0.00 D) 1.00

97. Calculate the quality factor Q for an RLC circuit having R= 10 ohm, C= 30 Mf, and L= 27 mH.

A) 3 B) 6 C) 9 D) 15

98. What is a recirculating register?

A) Serial out connected to serial in B) All Q outputs connected together

C) A register that can be used over again D) Parallel out connected to Parallel in

99. In a 4-bit Johnson counter sequence, there are a total of how many states or bit patterns?

A) 1 B) 3 C) 4 D) 8

100. How much storage capacity does each stage in a shift register represent?

A) One bit B) Two bits C) Four bits D) Eight bits

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PHYSICS

UNIT 10

EXPERIMENTAL PHYSICS