OCTOBER – 2016

[Time : 3 hours] **PHYSICS [XII] (With key)** [Marks : 150]

PART - I

Note : (i) Answer **all** the questions.

(ii) Choose and write the **correct** answer. **[30 × 1 = 30]**

1. In hydrogen atom, which of the following transitions produces spectral line of maximum wavelength?

   (*a*) 2→1 (*b*) 4→1

   (*c*) 6→5 (*d*) 5→2

2. In holography, which of the following are recorded on the photographic film?

   (*a*) amplitude and frequency

   (*b*) phase and frequency

   (*c*) phase and amplitude

   (*d*) amplitude, phase and frequency

3. The unit of grating element is:

   (*a*) no unit (*b*) metre

   (*c*) metre^{-1} (*d*) degree

4. The ratio of nuclear density to the density of mercury is about:

   (*a*) 1.3×10^{10} (*b*) 1.3

   (*c*) 1.3×10^{13} (*d*) 1.3×10^{4}

5. The maximum carrier swing allowed in frequency modulation is :

   (*a*) 455 kHz (*b*) 10.7 MHz

   (*c*) 75 kHz (*d*) 150 kHz

6. Len'z law is in accordance with the law of:

   (*a*) Conservation of charges

   (*b*) Conservation of flux

   (*c*) Conservation of momentum

   (*d*) Conservation of energy

7. The part of the AC generator that passes the current from the coil to the external circuit is:

   (*a*) field magnet (*b*) split rings

   (*c*) slip rings (*d*) brushes

8. Two point charges +4q and +q are placed 30 cm apart. At what point on the line joining them the electric field is zero ?

   (*a*) 15 cm from the charge +q

   (*b*) 7.5 cm from the charge +q

   (*c*) 20 cm from the charge +4q

   (*d*) 5 cm from the charge +q

9. The purpose of dividing each frame into two fields so as to transmit 50 views of the picture per second is :

   (*a*) to avoid flicker in the picture

   (*b*) the fact that handling of higher frequencies is easier

   (*c*) that 50 Hz is the power line frequency in India

   (*d*) to avoid unwanted noises in the signals

10. The Logic gate for which the output is '1', only when both the inputs are '0' is :

    (*a*) OR (*b*) NAND

    (*c*) EXOR (*d*) NOR

11. The instantaneous current in an AC circuit containing a pure inductor is $i = I_0 \sin\omega t$. The instantaneous emf is:

    (*a*) $e = E_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

    (*b*) $e = E_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

    (*c*) $e = E_0 \sin(\omega t - \pi)$

    (*d*) $e = E_0 \sin(\omega t + \pi)$

12. According to Bohr's postulates, which of the following quantities take discrete values?
    (*a*) Kinetic energy
    (*b*) Potential energy
    (*c*) Angular momentum
    (*d*) Momentum

13. The first excitation potential energy or the minimum energy required to excite the hydrogen atom from ground state:
    (*a*) 13.6 eV (*b*) 10.2 eV
    (*c*) 3.4 eV (*d*) 1.89 eV

14. Positive rays of the same element produce two different traces in a Bainbridge mass spectrometer. The positive ions have :
    (*a*) same mass with different velocity
    (*b*) same mass with same velocity
    (*c*) different mass with same velocity
    (*d*) different mass with different velocity

15. According to relativity, the length of a rod in motion:
    (*a*) is same as its rest length
    (*b*) is more than its rest length
    (*c*) is less than its rest length
    (*d*) may be more or less than or equal to rest length depending on the speed of the rod

16. The decay constant of a free neutron is:
    (*a*) 0.013 minute^{-1}
    (*b*) 0.053 minute^{-1}
    (*c*) 3 minutes
    (*d*) 0.069 minute^{-1}

17. In the nuclear reaction
    $_{80}Hg^{198} + X \rightarrow {}_{79}Au^{198} + {}_{1}H^{1}$, X stands for :
    (*a*) proton (*b*) electron
    (*c*) neutron (*d*) deutron

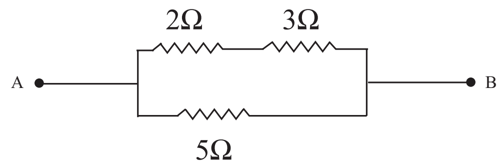
18. In an electromagnetic wave:
    (*a*) power is equally transferred along the electric and magnetic fields.
    (*b*) power is transmitted in a direction perpendicular to both the fields.
    (*c*) power is transmitted along electric field.
    (*d*) power is transmitted along magnetic field.

19. An oscillator is :
    (*a*) an amplifier with feedback
    (*b*) converter of a.c. to d.c. energy
    (*c*) nothing but an amplifier
    (*d*) an amplifier without feedback

20. The electrostatic force between two point charges kept at a distance 'd' apart, in a medium $\varepsilon_r = 6$, is 0.3 N. The force between them at the same separation in vacuum is:
    (*a*) 20 N (*b*) 0.5 N
    (*c*) 1.8 N (*d*) 2 N

21. In Raman effect, wavelength of incident light is 5890 Å. The wavelength of stokes and antistokes lines are respectively:
    (*a*) 5885 Å and 5880 Å
    (*b*) 5895 Å and 5900 Å
    (*c*) 5885 Å and 5895 Å
    (*d*) 5895 Å and 5885 Å

22. The effective resistance between points A and B in the given network is:



    (*a*) 2.5 Ω (*b*) 10 Ω
    (*c*) 0.4 Ω (*d*) 11 Ω

23. In the forward bias characteristic curve, a diode appears as:
    (*a*) a high resistance (*b*) a capacitor
    (*c*) an OFF switch (*d*) an ON switch

24. A dipole is placed in a uniform electric field, with its axis parallel to the field, it experiences :
    (*a*) only a net force
    (*b*) only a torque
    (*c*) both a net force and torque
    (*d*) neither a net force nor a torque

25. In RLC series AC circuit at resonance:
    (a) Resistance is zero
    (b) Net reactance is zero
    (c) impedance is maximum
    (d) voltage leads the current by a phase angle $\frac{\pi}{2}$

26. Which one of the following is not an electromagnetic wave ?
    (*a*) X - rays
    (*b*) γ - rays
    (*c*) Ultra Violet rays (UV rays)
    (*d*) β - rays

27. In a thermocouple, when the temperature of cold junction is increased (but less than neutral temperature) the temperature of inversion:
    (*a*) increases
    (*b*) decreases
    (*c*) does not change
    (*d*) first increases and then decreases

28. The work done in moving 6 μC charge between two points is 1.2×10^{-5} J. Find the potential difference between two points:
    (a) 6 V *(b)* 2 V
    (*c*) 12 V (*d*) 72 V

29. Joule's law of heating is:
    (*a*) $H = \frac{I^2}{R}t$ (*b*) $H = V^2Rt$
    (*c*) $H = VIt$ (*d*) $H = IR^2t$

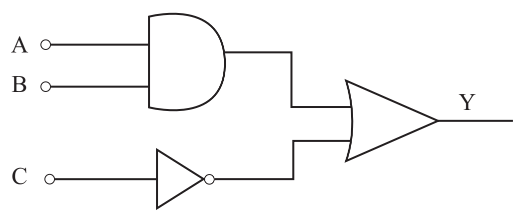
30. The momentum of the electron having wavelength 2 Å is:
    (*a*) 3.3×10^{24} kgms^{-1}
    (*b*) 6.6×10^{24} kgms^{-1}
    (*c*) 3.3×10^{-24} kgms^{-1}
    (*d*) 6.6×10^{-24} kgms^{-1}

Part - II

Note : Answer **any fifteen** questions.

[15 × 3 = 45]

31. What are the applications of capacitors?
32. An infinite line charge produces a field of 9×10^4 NC^{-1} at a distance of 2 cm. Calculate the linear charge density.
33. Define current density ? Give its unit.
34. The resistance of a platinum wire at 0°C is 4Ω. What will be the resistance of the wire at 100° C if the temperature coefficient of resistance of platinum is 0.0038/°C?
35. Distinguish between primary cell and secondary cell.
36. State tangent law.
37. What is electromagnetic induction?
38. Calculate the power loss in the form of heat when a power of 11, 000 W is transmitted at 220 V.
39. What are emission and absorption spectra ?
40. Why the centre of Newton's rings is dark ?
41. Write any three uses of Laser in medical field.
42. A Coolidge tube operates at 24,800 V. What is the maximum frequency of X-radiation emitted from Coolidge tube ?
43. Write three uses of electron microscope.
44. Write any three properties of β rays
45. What is mass defect ?
46. What is Light Emitting Diode (LED)? Give its symbol.
47. Give the Barkhausen conditions for oscillation.
48. Define bandwidth of an amplifier.
49. What is the Boolean expression for the logic diagram shown in figure. Evaluate its output if A = 1, B = 1, C = 1.



50. Write any three merits of satellite communication.

Part - III

Note : (i) Answer to question no. **59** is **compulsorily.**

(ii) Answer **any six** of the remaining **11** questions. **[7 × 5 = 35]**

(iii) Draw diagrams wherever necessary.

51. Define electric potential at a point. Obtain an expression for electric potential at a point due to a point charge.
52. State and verify Faraday's second law of electrolysis through an experiment.
53. State and explain kirchhoff's voltage law for electrical networks.
54. Two parallel wires each of length 5 m are placed at a distance of 10 cm apart in air. They carry equal currents along the same direction and experience a mutually attractive force of 3.6×10^{-4} N. Find the current through the conductors.
55. Obtain an expression for the coefficient of mutual induction between two long solenoids.
56. In Young's double slit experiment, the intensity ratio of two coherent sources is 81 : 1. Calculate the ratio between maximum and minimum intensities.
57. Explain the spectral series of hydrogen atom (diagram is **not** necessary).
58. Write any five applications of photoelectric cell.
59. The time interval measured by an observer at rest is 2.5×10^{-8} s. What is the time interval as measured by an observer moving with a velocity V = 0.73C?

(OR)

A metallic surface when illuminated with light of wavelength 3333 Å emits electrons with energies upto 0.6 eV. Calculate the work function of the metal.

60. Explain the binding energy curve (graph is not necessary).
61. Explain the pin-out configuration of an operational amplifier with the diagram.
62. What are the advantages and disadvantages of Frequency Modulation ?

Part - IV

Note : (i) Answer **any four** questions in detail.

(ii) Draw diagrams wherever necessary. **[4 × 10 = 40]**

63. State Gauss' law. Using this, derive an expression for electric field due to an infinitely long straight charged wire with uniform charge density.
64. Derive an expression for the force on a current carrying conductor placed in a magnetic field. Find the magnitude of the force.
65. Obtain an expression for the current in an AC circuit containing a pure inductance only. Find the phase relationship between voltage and current. Draw the necessary graph.
66. On the basis of wave theory explain total internal reflection. Write the conditions for total internal reflection to take place.
67. Describe J.J. Thomson's method for determining the specific charge of an electron.
68. What is a nuclear reactor? Explain the functions of (i) moderator (ii) control rods and (iii) neutron reflector. Mention two uses of a nuclear reactor (diagram **not** necessary).
69. With a neat circuit diagram, explain the working of a single stage CE amplifier. Draw the frequency response curve.
70. With the help of a block diagram, explain the function of superheterodyne AM receiver.

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Answers

Part - I

1. (*c*)	2. (*c*)	3. (*b*)	4. (*c*)	5. (*d*)
6. (*d*)	7. (*d*)	8. (*c*)	9. (*b*)	10. (*d*)
11. (*a*)	12. (*c*)	13. (*b*)	14. (*c*)	15. (*c*)
16. (*b*)	17. (*c*)	18. (*b*)	19. (*a*)	20. (*c*)
21. (*c*)	22. (*a*)	23. (*d*)	24. (*d*)	25. (*b*)
26. (*d*)	27. (*a*)	28. (*b*)	29.(*c*)	30. (*c*)

PART - II

31. i) Capacitors are used in the ignition system of automobiles engines to eliminate sparking.
ii) They are used to reduce voltage fluctuations in power supplies and to increase efficiency of power transmission.
iii) They are used to generated electromagnetic oscillations and in tuning the radio circuits.

32. $E = \dfrac{\lambda}{2\pi\varepsilon_o}$; $\lambda = E \times 2\pi\varepsilon_o$

$$= 9 \times 10^4 \times \frac{1}{18 \times 10^9} \times 2 \times 10^{-2}$$

$$\left(\because 2\pi\varepsilon_o = \frac{1}{18 \times 10^9}\right)$$

$$\lambda = \boxed{10^{-7} \text{C m}^{-1}}$$

33. Current density at a point is defined as the quantity of charge possing per unit time through unit area, taken perpendicular to be direction of flow of charge at that point. $J = I/A$. Its unit is Am^{-2}

34. **Given data :**

$R_o = 4\Omega$; $\propto = 0.0038/°C$; $t = 100°C$; $R_6 = ?$

Solution:

$$R_t = R_o(1 + \alpha t)$$

$$R_t = 4(1 + 0.0038 \times 100)$$

$$= 4(1 + 0.38) = 4 \times 1.38$$

$$\boxed{R_t = 5.52\,\Omega}$$

35. Primary Cell:
The cells from which the electric energy is derived by irreversible chemical action are called primary cells. ***e.g.,*** Lechlanche cell, Daniel cell, dry cell.
Secondary Cell:
Secondary cells are the cells from which electric energy is derived by reversible chemical actions. These can be recharged electrically. ***e.g.*** Lead acid, accumulator.

36. A magnetic needle suspended at a point where there are two crossed magnetic fields at right angle to each other will come to rest in the direction of resultant of these two fields.

37. The phenomenon of producing an induced emf due to the changes in magnetic flux associated with a closed circuit is known as electromagnetic induction.

38. Power loss $= I^2R$

$$P = VI$$

$$I = \frac{P}{V} = \frac{11,000}{220} = 50 \text{ A}$$

$\therefore$ Power loss $= 50^2R = 2500$ R W

39. Emission Spectra: When the light emitted directly from a source is examined with spectrometer, the spectra obtained is called emission spectrum. It is of 3 types: 1. Continuous spectrum; 2. Line spectrum and 3. Band spectrum.
Absorption Spectra: When the light emitted from a source is made to pass through an absorbing material and then examined with a spectrometer, the obtained spectrum is called absorption spectrum. It is of 3 types: 1. Continuous absorption spectrum; 2. Line absorption spectrum and 3. Band absorption spectrum.

40. Newton's ring is dark: The thickness of the air film at the point of contact of lens L with glass plate is zero. Hence there is no path difference between the interfering waves. So it should apper bright.
But the wave reflected from the denser glass plate has suffered a phase change of π while the wave reflected at the spherical surface of the lens has not suffered any phase change. Hence the centre of the Newtons ring is dark.

41. i) In medicine, micro surgery has become possible due to narrow angular spread of the laser beam.
ii) The laser beams are used in endoscopy.
iii) It can also be used for the treatment of human and animal cancer.

42. $\gamma_{max} = \frac{eV}{R} = \frac{1.6\times10^{-19}\times24,800}{6.626\times10^{-34}}$

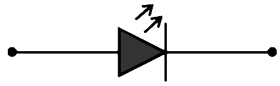
$= 5988.5 \times 10^{15}$ Hz

43. The electron microscope is used in
- i) The study of structure of textile fibres, surface of metals, composition of paints etc.
- ii) In medicine and biology it is used to study virus and bacteria.
- iii) In physics, it has been used in the investigation of atomic structure and structure of crystals.

44. Properties of β – rays:
- i) β–particles carry one unit of negative charge and mass equal to that of electron. Therefore, they are nothing but electrons.
- ii) The β – particles emitted from a source have velocities over the range of 0.3 c to 0.99 c, where c is the velocity of light.
- iii) They are deflected by electric and magnetic fields.

45. Mass defect is the difference of mass between the total mass of the nucleons constituting the nucleus and the actual mass of the nucleus.
$\Delta m = (Zm_p + Nm_n) - m$. (m = mass of stable nucleus).

46. Light Emitting Diode (LED):
A light emitting diode (LED) is a forward biased PN junction diode, which emits visible light when energized.
When a junction diode is forward biased, electrons from N-side and holes from P-side move towards the depletion region and recombination takes place. When an electron in the conduction band recombines with a hole in the valence band, energy is released, in the form of light.



47. The gain of the amplifier with positive feed back = $A_f = \frac{A}{1 - A\beta}$
- i) Loop gain $A\beta = 1$ and
- ii) The net phase shift round the loop is 0° or integral multiple of 2π.

48. Bandwidth is defined as the frequency interval between lower cut off and upper cut off frequencies.
$BW = f_U - f_L$.

49. i) Output of AND gate = AB

Output of NOT gate = $\overline{C}$

Output of OR gate = AB + $\overline{C}$

ii) If A = 1, B = 1 and C = 1

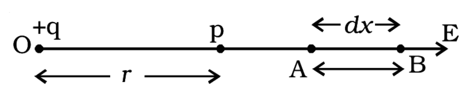
then Y = 1.1 + $\overline{1}$ = 1 + 0 = 1

50. Merits
- i) Mobile communication can be easily established by satellite communication.
- ii) Satellite communication is economical compared with terrestrial communication particularly where long distances are involved.
- iii) Compared to the optical fiber communication, satellite communication has the advantages that, quality of transmitted signal and location of sending and receiving stations are independent of distance.

Part - III

51. The electric potential in an electric field at a point is defined as the amount of work done in moving a unit positive charge from infinity to that point against the electric forces.

Let +q be an isolated point charge situated in air at O.P is a point at a distance r from +q. Consider two points A and B at distances x and x + dx from the point O figure.



Electric potential due to a point charge

The potential difference between A and B is,
$dv = -E\ dx$

The force experienced by a unit positive charge placed at A is

$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x^2}$

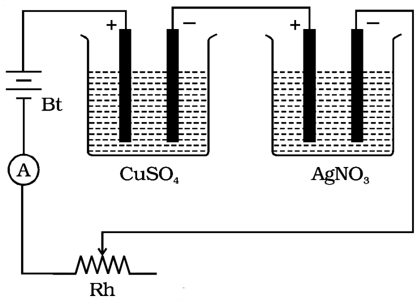
$\therefore\ dv = -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}\cdot dx$

The negative sign indicates that the work is done against the electric force.

The electric potential at the point P due to the charge +q is the total work done in moving a unit positive charge from infinity to that point.

$V = \int_{\infty}^{r}\frac{q}{4\pi\varepsilon_0}\cdot dx = \frac{q}{4\pi\varepsilon_0 r}$

52. **Second Law :** The mass of a substance liberated at an electrode by a given amount of charge is proportional to the chemical equivalent of the substance. If E is the chemical equivalent of a substance, from the second law m∝E.



Verification of Faraday's second law

Verification of Faraday's Second law of electrolysis: Two electrolytic cells containing different electrolytes, $CuSO_4$ solution and $AgNO_3$ solution are connected in series with a battery, a rheostat and an ammeter. Copper electrodes are inserted in $CuSO_4$ and silver electrodes are inserted in $AgNO_3$.

The cathodes are cleaned, dried, weighed and then inserted in the respective cells. The current is passed for some time. Then the cathodes are taken out, washed, dried and weighed. Hence the masses of copper and silver deposited are found as m_1 and m_2.

It is found that $\frac{m_1}{m_2} = \frac{E_1}{E_2}$, where E_1 and E_2 are the chemical equivalents of copper and silver respectively.

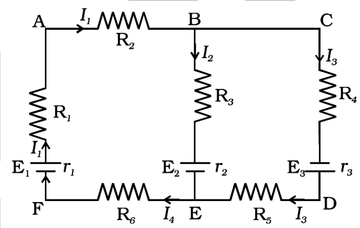
$m \propto E$

Thus, the second law is verified.

53. **Kirchoff's Second law (Voltage law):** Kirchoff's voltage law states that the algebraic sum of the products of resistance and current in each part of any closed circuit is equal to the algebraic sum of the emf's in that closed circuit. This law is a consequence of conservation of energy.

In applying Kirchoff's laws to electrical networks, the direction of current flow may be assumed either clockwise or anticlockwise.

However, in the application of Kirchoff's second law, we follow that the current in clockwise direction is taken as positive and the current in anticlockwise direction is taken as negative.



Kirchoff's laws

Let us consider the electric circuit given in Figure 2.

Considering the closed loop ABCDEFA,

$I_1R_2 + I_3R_4 + I_3r_3 + I_3R_5 + I_4R_6 + I_1r_1 + I_1R_1 = E_1 + E_3$

Both cells E_1 and E_3 send currents in clock wise direction. For the closed loop ABEFA

$I_1R_2 + I_2R_3 + I_2r_2 + I_4R_6 + I_1r_1 + I_1R_1 = E_1 - E_2$

Negative sign in E_2 indicates that it sends current in the anticlockwise direction.

54. **Given data :**

$I_1 = I_2 = I$; $I = 5m$, $a = 10^{-1}$ m.

$F = 3.6 \times 10^{-4}$ N, I = ?

Solution:

$F = \frac{\mu_0 I_1 I_2 l}{2\pi a}$; $F = \frac{2\times10^{-7} I^2 l}{a}$

$\therefore\ I^2 = \frac{F.a}{2\times10^{-7} l} = \frac{3.6\times10^{-4}\times10^{-1}}{2\times10^{-7}\times5} = 36$

$\therefore$ **I = 6 A**

55.

Mutual induction between two long solenoids

S_1 and S_2 are two long solenoids each length l. The solenoid S_2 is wound closely over the solenoid S_1 figure.

N_1 and N_2 are the number of turns in the solenoids S_1 and S_2 respectively. Both the solenoids are considered to have the same area of cross section A as they are closely wound together. I_1 is the current flowing through the solenoid S_1. The magnetic field B_1 produced at any point inside the solenoid S_1 due to the current I_1 is

$$B_1 = \mu_o \frac{N_l}{l} I_1 \quad \text{..... (1)}$$

The magnetic flux linked with each turn of S_2 is equal to B_1A.

Total magnetic flux linked with solenoid S_2 having N_2 turns is

$$\phi_2 = B_1 A N_2$$

Substituting for B_1 from equation (1)

$$\phi_2 = \left(\mu_o \frac{N_1}{l} I_1\right) A \; N_2$$

$$\phi_2 = \frac{\mu_o N_1 N_2 A I_1}{l} \quad \text{..... (2)}$$

But $\phi_2 = MI_1$ ..... (3)

where M is the coefficient of mutual induction between S_1 and S_2.

From equations (2) and (3),

$$MI_1 = \frac{\mu_o N_1 N_2 A I_1}{l} \quad ; \quad M = \frac{\mu_o N_1 N_2 A}{l}$$

If the core is filled with a magnetic material of permeability μ.

$$M = \frac{\mu_o N_1 N_2}{l}$$

56. **Given data :**

$$\frac{I_1}{I_2} = \frac{81}{1} \quad ; \quad \frac{I_{max}}{I_{min}} = ?$$

Solution:

$$\therefore \quad \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{81}{1}$$

$$\frac{a_1}{a_2} = \frac{9}{1} \Rightarrow a_1 = 9a_2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(9a_2 + a_2)^2}{(9a_2 - a_2)^2} = \frac{(10a_2)^2}{(8a_2)^2} = \frac{100}{64}$$

$$\frac{I_{max}}{I_{min}} = \frac{25}{16}$$

$I_{max} : I_{min} = 25 : 16$

57. 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.

Here, $n_1 = 1$, $n_2 = 2, 3, 4$ ...

The wave number of the Lyman series is given by, $\bar{\nu} = R\left(1 - \frac{1}{n_2^2}\right)$

ii) Balmer sereis: 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,

$$\bar{\nu} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{4} - \frac{1}{n_2^2}\right)$$

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) Paschen series: 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

$$\bar{\nu} = R\left(\frac{1}{3^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{9} - \frac{1}{n_2^2}\right)$$

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,

$$\bar{\nu} = R\left(\frac{1}{4^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{16} - \frac{1}{n_2^2}\right)$$

v) Pfund series: 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,

$$\bar{\nu} = R\left(\frac{1}{5^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{25} - \frac{1}{n_2^2}\right)$$

58. i) Photoelectric cells are used for reproducing sound in cinematography.

ii) They are used for controlling the temperature of furnaces.

iii) Photoelectric cells are used for automatic switching on and off the street lights.

iv) Photoelectric cells are used in the study of temperature and spectra of stars.

v) Photoelectric cells are also used in obtaining electrical energy from sunlight during space travel.

59. **Given data :**

$t_0 = 2.5 \times 10^{-8}$ s ; v = 0.73 c ; $t = ?$

Solution:

$$t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{2.5\times10^{-8}}{\sqrt{1-\frac{(0.73c)^2}{c^2}}} = \frac{2.5\times10^{-8}}{\sqrt{1-0.73\times0.73}}$$

$$t = \frac{2.5\times10^{-8}}{\sqrt{1-0.5329}} = \frac{2.5\times10^{-8}}{\sqrt{0.4671}} = \frac{2.5\times10^{-8}}{0.6834}$$

$$\boxed{t = 3.658\times10^{-8}\,\text{s}}$$

(OR)

Given data :

l = 3333 Å ; K.E. = 0.6 eV ; W = ?

Solution:

Work function, $W = h\nu -$ kinetic energy

or $W = \frac{hc}{\lambda} -$ K.E.

$$= \left(\frac{6.626\times10^{-34}\times3\times10^{8}}{3333\times10^{-10}}\right) - (0.6\times1.6\times10^{-19})$$

$$= (5.96\times10^{-19}) - (0.96\times10^{-19})$$

$$W = 5\times10^{-19}\text{ J.}$$

$$W = \frac{5\times10^{-19}}{1.6\times10^{-19}}\text{ eV}$$

$$\boxed{W = 3.125\text{eV}}$$

60. The binding energy per nucleon is

$$\frac{BE}{A} = \frac{\text{Binding energy of the nucleus}}{\text{Total number of nucleons}}$$

It is found that the binding energy per nucleon varies from element to element. A graph is plotted with the mass number A of the nucleus along the X-axis and binding energy per nucleon along the Y-axis (figure).

Explanation of binding energy curve

i) The binding energy per nucleon increases sharply with mass number A upto 20. It increases slowly after A = 20. For A<20, there exists recurrence of peaks corresponding to those nuclei, whose mass numbers are multiples of four and they contain not only equal but also even number of protons and neutrons.

Example: $_2He^4$, $_4Be^8$, $_6C^{12}$, $_8O^{16}$, and $_{10}Ne^{20}$. The curve becomes almost flat for mass number between 40 and 120. Beyond 120, it decreases slowly as A increases.

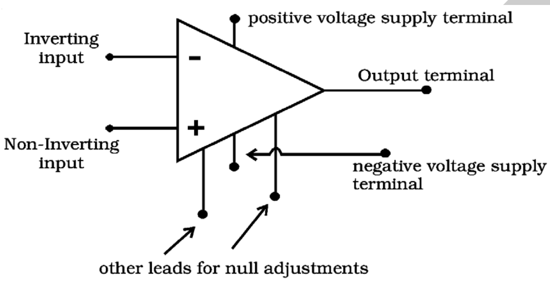
ii) The binding energy per nucleon reaches a maximum of 8.8 MeV at A = 56, corresponding to the iron nucleus ($_{26}Fe^{56}$). Hence, iron nucleus is the most stable.

iii) The average binding energy per nucleon is about 8.5 MeV for nuclei having mass number ranging between 40 and 120. These elements are comparatively more stable and non radioactive.

iv) For higher mass numbers the curve drops slowly and the BE/A is about 7.6 MeV for uranium. Hence, they are unstable and radioactive.

v) The lesser amount of binding energy for lighter and heavier nuclei explains nuclear fusion and fission respectively. A large amount of energy will be liberated if lighter nuclei are fused to form heavier one (fusion) or if heavier nuclei are split into lighter ones (fission).

61. Circuit symbol and pin-out configuration of an OP-AMP: The OP-AMP is represented by a triangular symbol as shown in Figure. It has two input terminals and one output terminal. The terminal with *negative sign* is called as the inverting input and the terminal with *positive sign* is called as the non-inverting input. The input terminals are at the base of the triangle. The output terminal is shown at the apex of the triangle.



Symbol for OP-AMP

The widely used very popular type OP-AMP IC 741, which is available in DIP. Referring to the top view of the dual-in-package, the pin configuration of IC 741 can be described (Figure) as follows. The top pin on the left side of the notch indicates Pin 1. The pin number 2 is inverting input terminal and 3 is non-inverting input terminal. Pin 6 is the output terminal. A d.c. voltage or a.c. signal placed on the inverting input will be 180° out of phase at the output. A d.c. voltage or a.c. signal placed on the non-inverting input will be inphase at the output. Pins 7 and 4 are the power supply terminals. Terminals 1 and 5 are used for null adjustment. Null adjustment pins are used to null the output voltage when equal voltages are applied to the input terminals for perfect balance. Pin 8 indicates no connection.

62. Advantages:

(i) It gives noiseless reception. Noise is a form of amplitude variation and a FM receiver will reject such noise signals.

(ii) The operating range is quite large.

(iii) The efficiency of transmission is very high.

Disadvantages:

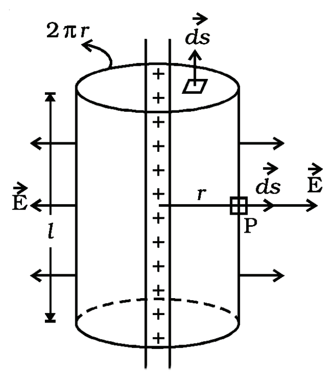
i) A much wider channel is required by FM.

ii) FM transmitting and receiving equipments tends to be more complex.

Part - IV

63. Gauss law: The total flux of the electric field E over any closed surface is equal to $1/\varepsilon_o$ times the net charge enclosed by the surfce.
Field due to an infinite long straight charged wire:

Electric field due to an infinite long straight charged wire: Consider an uniformly charged wire of infinite length having a constant linear charge density λ (charge per unit length). Let P be a point at a distance *r* from the wire (figure) and E be the electric field at the point P. A cylinder of length *l*, radius *r*, closed at each end by plane caps normal to the axis is chosen as Gaussian surface. Consider a very small area *ds* on the Gaussian surface.



Infinitely long straight charged wire

By symmetry, the magnitude of the electric field will be the same at all points on the curved surface of the cylinder and directed radially outward. $\vec{E}$ and $\vec{ds}$ are along the same direction.

The electric flux (ϕ) through curved surface

$= \oint E\, ds \cos\theta$

$= \phi \oint E\, ds$ $\quad$ [$\because \theta = 0; \cos\theta = 1$]

$= E\,(2\pi rl)$ $\quad$ ($\because$ The surface area of the curved part is $2\pi rl$)

Since $\vec{E}$ and $\vec{ds}$ are right angles to each other, the electric flux through the plane caps = 0.

$\therefore$ Total flux through the Gaussian surface, $\phi = E\, 2\pi rl$

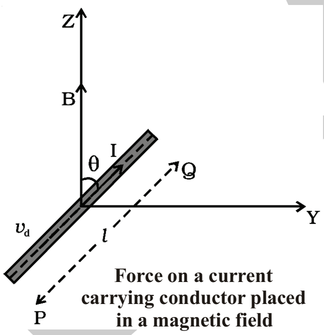
The net charge enclosed by Gaussian surface is, $q = \lambda l$

$\therefore$ By Gauss's law,

$$E\,(2\pi rl) = \frac{\lambda l}{\varepsilon_o} \quad \text{or} \quad E = \frac{\lambda}{2\pi\varepsilon_o}$$

The direction of electric field E is radially outward, if line charge is positive and inward, if the line charge is negative.

64.



Force on a current carrying conductor placed in a magnetic field

Force on a current carrying conductor placed in a magnetic field: Consider a conductor PQ a length l and area of cross section A. The conductor is placed in a uniform magnetic field of induction B making an angle θ with the field [Figure]. A current I flows along PQ. Hence, the electrons are drifted along QP with drift velocity v_d. If n is the number of free electrons per unit volume in the conductor, then the current is

$I = nAv_d e$

Multiplying both sides by the length l of the conductor,

$\therefore\ Il = nAv_d el$.

Therefore the current element,

$\vec{Il} = -\, nA\, \vec{v_d}\, el$ $\quad$ ..... (1)

The negative sing in the equation indicates that the direction of current is opposite to the direction of the drift velocity of the electrons.

Since the electrons move under the influence of magnetic field, the magnetic lorentz force on a moving electron.

$\vec{f} = -e\left(\vec{v_d} \times \vec{B}\right)$ $\quad$ ..... (2)

The negative sign indicates that the charge of the electron is negative.

The number of free electrons in the conductor

$N = nAl$ $\quad$ ..... (3)

The magnetic lorentz forces on all the moving free electrons

$\vec{F} = \vec{N} f$

Substituting equations (2) and (3) in the above equation

$\vec{F} = nAl\left(-e\left(\vec{v_d} \times \vec{B}\right)\right)$

$\vec{F} = -\, nAl\, e\, \vec{v_d} \times \vec{B}$ $\quad$ ..... (4)

Substituting equation (1) in equation (4)

$\vec{F} = \vec{Il} \times \vec{B}$

This total force on all the moving free electrons is the force on the current carrying conductor placed in the magnetic field.

Magnitude of the force

The magnitude of the force is $F = BIl \sin\theta$

i) If the conductor is placed along the direction of the magnetic field, θ = 0°. Therefore force F = 0.

ii) If the conductor is placed perpendicular to the magnetic field, θ = 90°, F = BIl. Therefore the conductor experiences maximum force.

Direction of force: The direction of the force on a current carrying conductor placed in a magnetic field is given by Fleming's Left Hand Rule.

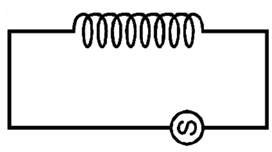
65. Circuit with an inductor: An alternating source of emf is applied to a pure inductor of inductance L. The inductor has a negligible resistance and is wound on a laminated iron core. Due to an alternating emf that is applied to the inductive coil, a self induced emf is generated which opposes the applied voltage. (e.g) Choke coil.

The instantaneous value of applied emf is given by:

$e = E_o \sin \omega t$ .... (1)

Induced emf $e' = -L \cdot \frac{di}{dt}$

where L is the self inductance of the coil. In an ideal inductor circuit induced emf is equal and opposite to the applied voltage.



(a)

Therefore $e = -e'$

$$E_o \sin \omega t = -\left(-L\frac{di}{dt}\right)$$

$$\therefore E_o \sin \omega t = L\frac{di}{dt}$$

$$di = \frac{E_o}{L} \sin \omega t \, dt$$

Integrating both the sides,

$$i = \frac{E_o}{L}\int \sin \omega t \; dt$$

$$= \frac{E_o}{L}\left[-\frac{\cos \omega t}{\omega}\right]$$

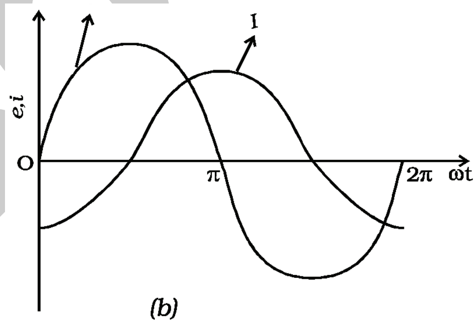
$$= -\frac{E_o \cos \omega t}{\omega L}$$

$$i = \frac{E_o}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$i = I_o \cdot \sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{........ (2)}$$

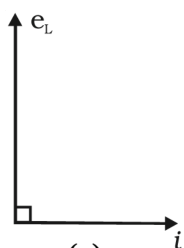
where $I_0 = \frac{E_o}{\omega L}$. Here, ωL is the resistance offered by the coil. It is called inductive reactance. Its unit to ohm.

From equations (1) and (2) it is clear that in an a.c. circuit containing a pure inductor the current i lags behind the voltage *e* by the phase angle of π/2. Conversely the voltage across L leads the current by the phase angle of π/2. This fact is presented graphically in Figure (b).



(b)

Pure inductive circuit



(c)

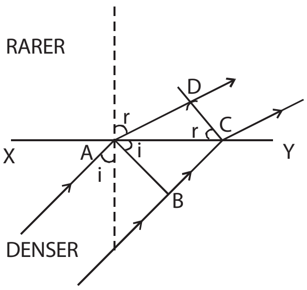
Phasor diagram

Figure (c) represents the phasor diagram of a.c. circuit containing only L.

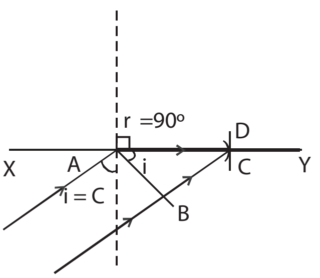
66. Total Internal Reflection by Wave Theory: Let XY be a plane surface which separates a rarer medium (air) and a denser medium. Let the velocity of the wavefront in these media be C_a and C_m respectively.

A plane wavefront AB passes from denser medium to rarer medium. It is incident on the surface with angle of incidence i. Let r be the angle of refraction.

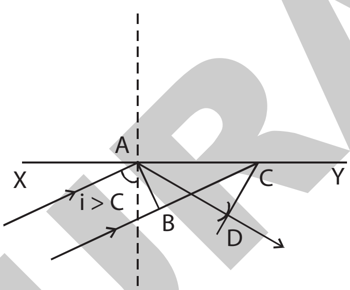
$$\frac{\sin i}{\sin r} = \frac{(BC/AC)}{(AD/AC)} = \frac{BC}{AD} = \frac{c_m t}{c_a t} = \frac{c_m}{c_a}$$



(a)



(b)



(c)

Total Internal reflection

Since $\frac{c_m}{c_a} < 1$, i is less than r. This means that the refracted wavefront is deflected away from the surface XY.

In right angled triangle ADC, there are three possibilities:

(i) AD < AC (ii) AD = AC and (iii) AD > AC

(i) **AD < AC:** For small values of i. BC will be small and so AD > BC but less than AC [Figure (a)]

$\sin r = \frac{AD}{AC}$, which is less than unity

i.e., $r < 90°$

For each value of i, for which $r < 90°$, a refracted wavefront is possible.

(ii) **AD = AC:** As i increases r also increases. When AD = AC, $\sin r = 1$ (or) $r = 90°$. i.e., a refracted wavefront is just possible [Figure(b)]. Now the refracted ray grazes the surface of separation of the two media. The angle of incidence at which the angle of refraction is 90° is called the critical angle C.

(iii) AD > AC: When AD > AC, $\sin r > 1$. This is not possible [Figure (c)]. Therefore no refracted wave front is possible, when the angle of incidence increases beyond the critical angle. The incident wavefront is totally reflected into the denser medium itself. This is called total internal reflection.

Hence for total internal reflection to take place (i) light must travel from a denser medium to a rarer medium and (ii) the angle of incidence inside the denser medium must be greater than the critical angle. i.e. $i > C$.

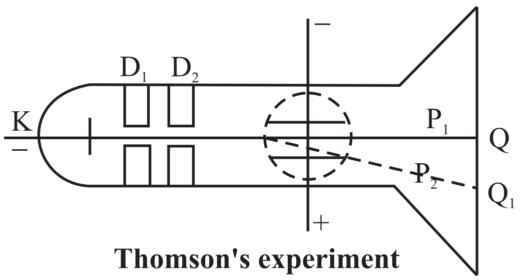
67. The specific charge is defined as the charge per unit mass of the particle.

Principle: The fact that the cathode rays (electrons) are deflected by electric and magnetic fields is made use of in this method.

Experimental arrangement:

A highly evacuated discharge tube used in this experiment is as shown in figure. Cathode rays are produced by the discharge between the cathode and the anodes D_1 and D_2. A thin pencil of cathode ray comes out through fine pin holes in the anode discs. The cathode rays then pass between two parallel metal plates P_1 and P_2 and strike the flat face of the tube.

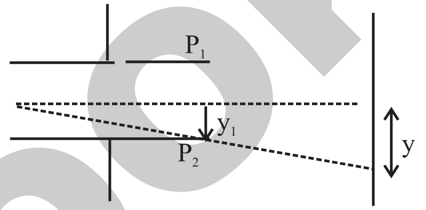
This face is coated with suitable fluorescent material. A spot of light is produced at Q. But when a potential difference V is applied between P_1 and P_2, the beam is deflected to point Q_1. By the use of a pair of coils, uniform magnetic field is produced perpendicular to the plane of the paper and outwards through out the region between P_1 and P_2.



Thomson's experiment

Theory

1. **Determination of V:** With a given electric intensity between the plates P_1 and P_2 the magnetic induction B is adjusted until the beam strikes the screen at the original position Q. Then the downward force Ee due to the electric field is balanced by the force Bev due to magnetic induction where e is the charge of the cathode ray particle and v is the velocity of the cathode rays.
   $Ee = Bev$
   $$v = \frac{E}{B} \quad ..... (1)$$
2. **Determination of e/m:** Now the magnetic induction is switched off. The deflection $QQ_1 = y$ caused by the electric field alone is measured. At the instant when the cathode rays enter the region between the plates P_1 and P_2, initial velocity in the downward direction u = 0.
   Acceleration along the downward direction $a = \frac{Ee}{m}$, where m is the mass of each cathode ray particle.
   Time for which the electron moves in the electric field $t = \frac{l}{v}$ where l is the length of either of the plates and v is the velocity of the electron.
   The deflection produced on the cathode rays along the downward direction in the electric field is given by
   $$y_1 = \frac{1}{2}\left(\frac{Ee}{m}\right)\left(\frac{l}{v}\right)^2 \quad ..... (2)$$
   Substituting for v from equation (1) in equation (2) we get
   $$y_1 = \frac{1}{2}\left(\frac{Ee}{m}\right)\left(\frac{l^2}{E^2}\right)B^2 = \frac{1}{2}\frac{e}{m}\frac{l^2B^2}{E}$$



Path of an electron in the electric field

The displacement of the spot of light on the screen is given by figure. $y = K y_1$, where K is a constant determined by the geometry of the discharge tube. Substituting for y_1 we get,
$$y = K\frac{1}{2}\frac{e}{m}\frac{l^2B^2}{E} \quad ..... (3)$$
$$\frac{e}{m} = \frac{2yE}{Kl^2B^2} \quad ..... (4)$$
By substituting the known values in the above relation e/m of an electron can be calculated. The value of e/m calculated using this experiment was found to be 1.7592×10^{11} C kg^{-1}.

68. A nuclear reactor is a device in which the nuclear fission reaction takes place in a self sustained and controlled manner.
(i) ***Moderator:*** The function of a moderator is to slow down fast neutrons produced in the fission process having an average energy of about 2 MeV to thermal neutrons with an average energy of about 0.025 eV, which are in thermal equilibrium with the moderator. Ordinary water and heavy water are the commonly used moderators. A good moderator slows down neutrons by elastic collisions and

it does not remove them by absorption. The moderator is present in the space between the fuel rods in a channel. Graphite is also used as a moderator in some countries.

In fast breeder reactors, the fission chain reaction is sustained by fast neutrons and hence no moderator is required.

(ii) ***Control rods:*** The control rods are used to control the chain reaction. They are very good absorbers of neutrons. The commonly used control rods are made up of elements like boron or cadmium. The control rods are inserted into the core and they pass through the space in between the fuel tubes and through the moderator. By pushing them in or pulling out, the reaction rate can be controlled. In our country, all the power reactors use boron carbide (B4C), a ceramic material as control rod.

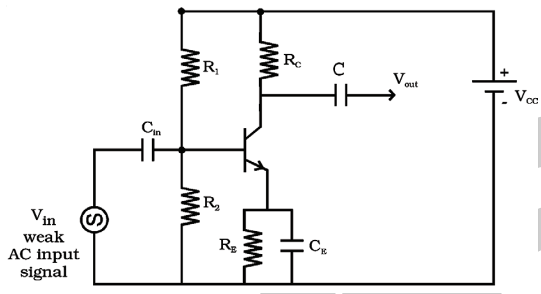
(iii) ***Neutron reflectors:*** Neutron reflectors prevent the leakage of neutrons to a large extent, by reflecting them back. In pressurised heavy water reactors the moderator itself acts as the reflector.

In the fast breeder reactors, the reactor core is surrounded by depleted uranium (uranium which contains less than 0.7% of $_{92}U^{235}$) or thorium ($_{90}Th^{232}$) which acts as neutron reflector. Neutrons escaping from the reactor core convert these materials into Pu^{239} or U^{233} respectively.

Uses of reactors:

1) Nuclear reactors are mostly aimed at power production, because of the large amount of energy evolved with fission.
2) Nuclear reactors are useful to produce radio-isotopes.
3) Nuclear reactor acts as a source of neutrons, hence used in the scientific research.

69. Single Stage CE Amplifier: Figure shows a single stage CE amplifier. The different circuit elements and their functions are described as follows.



Single Stage CE amplifier

i) **Biasing Circuit:** The resistances R_1, R_2 and R_E form the biasing and stabilization circuit.

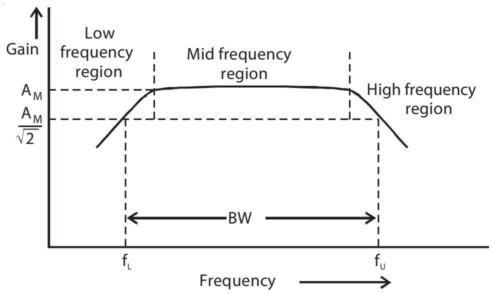
ii) **Input Capacitance C_{in}:** This is used to couple the signal to the base of the transistor. If this is not used. The signal source resistance will come across R_2 and thus change the bias. The capacitor C_{in} allows only a.c. signal to flow.

iii) **Emitter Bypass Capacitor C_E**: This is connected in parallel with R_E to provide a low reactance path to the amplified a.c. signal. If it is not used, then amplified a.c. signal flowing through R_E will cause a voltage drop across if, thereby shifting the ouput voltage.

iv) **Coupling Capacitor C:** This is used to couple the amplified signal to the output device. This capacitor C allows only a.c. signal to flow.

Working: When weak input a.c. signal is applied to the base of the transistor, a small base current flows. Due to transistor action, a much larger a.c. current flows through collector load R_C, a large voltage appears across R_C and hence at the output. Therefore, a weak signal applied to the base appears in amplified form in the collector circuit. Voltage gain (A_v) of the amplifier is the ratio of the amplified output voltage to the input voltage.

Frequency response and bandwidth: The voltage gain (A_v) of the amplifier for different input frequencies can be determined. A graph can be drawn by taking frequency (*f*) along X-axis and voltage gain (A_v) along Y-axis. The frequency response curve obtained will be of the form as shown in Figure. It can be seen that the gain decreases at very low and very high frequencies, but it remains constant over a wide range of mid-frequency region.



Frequency response curve

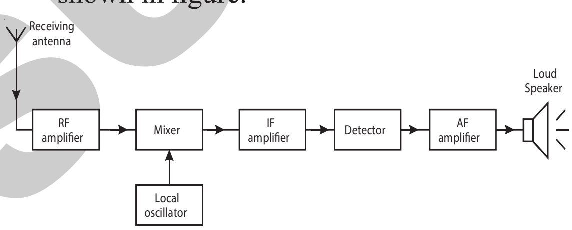
Lower cut-off frequency (f_L) is defined as the frequency in the low frequency range at which the gain of the amplifier is $\frac{1}{\sqrt{2}}$ times the mid frequency gain (A_M). Upper cut-off frequency (f_U) is defined as the frequency in the high frequency range at which the gain of the amplifier is $\frac{1}{\sqrt{2}}$ times the mid frequency gain (A_M).

Bandwidth is defined as the frequency interval between lower cut off and upper cut off frequencies.

$BW = f_U - f_L$.

70. Superhetrodyne AM Receiver: The shortcomings of straight radio receiver were overcome by the invention of superhetrodyne receiver. All the modern receivers utilise the superhetrodyne circuit.

The functional block diagram of AM receiving system of superhetrodyne type is shown in figure.



Superhet AM receiver

i) RF Amplifier: The RF amplifier uses a tuned parallel circuit. The radiowaves from various broadcasting stations are intercepted by the receiving antenna and are coupled to this stage. This stage selects the desired radiowave and enhances the strength of the wave to the desired level.

ii) Mixer and Local Oscillator: The amplified output of RF amplifier is fed to the mixer stage, where it is combined with the output of a local oscillator. The two frequencies beat together and produce an intermediate frequency (IF). The intermediate frequency is the difference between oscillator frequency and radio frequency. The output of this section is always equal to the intermediate frequency 455 kHz.

For example, if 600 kHz station is tuned, then local oscillator will produce a frequency of 1055 kHz and consequently the output from the mixer will have frequency of 455 kHz. By achieving this fixed intermediate frequency, the amplifier circuit in such receivers can be made to operate with maximum stability, selectivity and sensitivity.

iii) IF Amplifier: The output of the mixer circuit is fed to the tuned IF amplifier. This amplifier is tuned to one frequency (i.e., 455 KHz) and is amplified.

iv) Detector: The output from the IF amplifier is coupled with input of a detector. The audio signals are extracted from the IF output. Usually a diode detector circuit is used because of its low distortion and excellent audio fidelity (reproducing ability).

v) AF Amplifier: The detected AF signal is usually weak and so it is further amplified by the AF amplifier. Then, the output signal from the amplifier is fed to the loud speaker, which converts the audio signal into sound waves corresponding to the original sound at the broadcasting station.

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