12th Std.

INSTANT SUPPLEMENTARY EXAM. - JUNE 2023

PART - III

PHYSICS

(With Answers)

Reg. No.

Time Allowed : 3.00 Hours] [Maximum Marks : 70

Instructions : (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.
(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART - I

Note : (i) Answer **all** the questions. **(15 × 1 = 15)**
(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. The speed of light in an isotropic medium depends on, _____
(a) its density (b) its wavelength
(c) the nature of propagation
(d) the motion of the source w.r.t. medium

2. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly:
(a) 1.0 Am^2 (b) 1.2 Am^2
(c) 0.5 Am^2 (d) 0.8 Am^2

3. Two wires of A and B with circular cross section are made up of the same material with equal lengths. If $R_A = 3R_B$, then what is the ratio of radius of wire A to that of B?
(a) 3 (b) $\sqrt{3}$ (c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{3}$

4. Which of the following electromagnetic radiations is used for viewing objects through fog?
(a) Microwave (b) Gamma rays
(c) X-rays (d) Infrared

5. Emission of electrons by the absorption of heat energy is called _____ emission.
(a) photoelectric (b) field
(c) thermionic (d) secondary

6. In a series RL circuit, the resistance and inductive reactance are the same, then the phase difference between the voltage and the current in the circuit is:
(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{6}$ (c) $\frac{\pi}{2}$ (d) Zero

7. If the nuclear radius of ^{27}Al is 3.6 Fermi, the approximate nuclear radius of ^{64}Cu in Fermi is:
(a) 2.4 (b) 1.2 (c) 4.8 (d) 3.6

8. The barrier potential of a silicon diode is approximately:
(a) 0.7 V (b) 0.3 V
(c) 2.0 V (d) 2.2 V

9. An electric dipole is placed at an alignment angle of 30° with an electric field of $2 \times 10^5 NC^{-1}$. It experiences a torque equal to 8 Nm. The charge on the dipole if the dipole length is 1 cm is :
(a) 4 mC (b) 8 mC
(c) 5 mC (d) 7 mC

10. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is :
(a) 30° (b) 45° (c) 60° (d) 90°

11. Light transmitted by Nicol Prism is :
(a) partially polarised (b) unpolarised
(c) plane polarised
(d) elliptically polarised

12. The verticle component of Earth's Magnetic field at a place is equal to the horizontal component. The value of angle of dip at this place is :
(a) 30° (b) 45° (c) 60° (d) 90°

13. The materials used in Robotics are :
    (a) Aluminium and Silver
    (b) Silver and Gold
    (c) Copper and Gold
    (d) Steel and Aluminium

14. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV is:
    (a) 4125 Å (b) 3750 Å
    (c) 6000 Å (d) 2062.5 Å

15. The principle based on which a solar cell operates is :
    (a) Diffusion
    (b) Recombination
    (c) Photovoltaic action
    (d) Carrier flow

PART - II

Note : Answer **any six** questions. Question No. **24** is **Compulsory.** **(6 × 2 = 12)**

16. What is photoelectric effect?

17. State Fleming's left hand rule.

18. Find the polarizing angle for glass of refractive index 1.5.

19. State Lenz's law.

20. What is the reason for reddish appearance of sky during sunset and sunrise?

21. Define Capacitance.

22. Distinguish between intrinsic and extrinsic semiconductors.

23. Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it.

24. The radians of the 5^{th} orbit of hydrogen atom is 13.25 Å. Calculate the de broglie wavelength of the electron orbiting in the 5^{th} orbit.

PART - III

Note : Answer **any six** questions. Question No. **33** is **Compulsory.** **(6 × 3 = 18)**

25. State and explain the principle of potentiometer.

26. Find the ratio of the intensities of light with wavelength 500 nm and 300 nm which undergo Rayleigh scattering.

27. Explain the various energy losses in a transformer.

28. State and prove Brewster's law.

29. Calculate the electric flux through the rectangle of side 5 cm and 10 cm kept in the region of a uniform electric field 100 NC^{-1}. The angle θ is 60°. If θ becomes zero, what is the electric flux?

30. Explain the alpha decay process with example.

31. Write down Maxwell equations in integral form.

32. List out the advantages and limitations of frequency modulation.

33. A coil of a tangent galvanometer of diameter 0.24m has 100 turns. If the horizontal component of Earth's Magnetic field is 25×10^{-6} T then, calculate the current which gives a deflection of 60°.

PART - IV

Note: Answer **all** the questions **(5 × 5 = 25)**

34. (a) What is absorption spectrum? Explain its types. **(OR)**
    (b) Obtain the law of radioactive decay.

35. (a) Obtain the conditions for bridge balance in Wheatstone's bridge.
    (OR)
    (b) Obtain the equation for bandwidth in Young's double slit experiment.

36. (a) Explain in detail the principle, construction and working of a Van de Graff generator.

(OR)

(b) What is dispersion? Obtain the equation for dispersive power of a Medium.

37. (a) (i) State Ampere's circuital law.

(ii) Find the magnetic field due to a long, straight conductor using Ampere's circuital law.

(OR)

(b) State and Prove De Morgan's first and second theorems.

38. (a) Explain the working of a single-phase AC generator with necessary diagram.

(OR)

(b) (i) List out the characteristics of photons. (any two)

(ii) Calculate the momentum of an electron with kinetic energy 2 eV.

ANSWERS

PART - I

1. (b) its wavelength
2. (b) 1.2 Am^2
3. (c) $\frac{1}{\sqrt{3}}$
4. (d) Infrared
5. (c) thermionic
6. (a) $\frac{\pi}{4}$
7. (c) 4.8
8. (a) 0.7 V
9. (b) 8 mC
10. (a) 30°
11. (c) plane polarised
12. (b) 45°
13. (d) Steel and Aluminium
14. (b) 3750 Å
15. (c) Photovoltaic action

PART - II

16. The ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength (or frequency) is called photoelectric effect.

17. Stretch out forefinger, the middle finger and the thumb of the left hand such that they are in three mutually perpendicular directions. If the forefinger points in the direction of magnetic field, the middle finger in the direction of the electric current, then thumb will point in the direction of the force experienced by the conductor.

18. Brewster's law, $\tan i_p = n$

For glass, $\tan i_p = 1.5$;

$i_p = \tan^{-1} 1.5$

$i_p = 56.3°$

For water, $\tan i_p = 1.33$;

$i_p = \tan^{-1} 1.33$

$i_p = 53.1°$

19. Lenz's law states that the direction of the induced current is such that it always opposes the cause responsible for its production.

20. **(i)** During sunrise and sunset, the light from sun travels a greater distance through the atmosphere.

(ii) Hence, the blue light which has shorter wavelength is scattered away and the red light which has longer wavelength and less -scattered manages to reach our eye.

21. **(i)** The capacitance C of a capacitor is defined as ratio of the magnitude of charge on either of the conductor plates to the potential difference existing between them.

$$C = \frac{Q}{V}$$

(ii) The SI unit of capacitance is coulomb per volt or farad.

22.

Intrinsic semiconductor	Extrinsic semiconductor
A pure form of Silicon or Germanium without impurity	The semiconductor with trivalent or pentavalent impurities.
The number of electrons in the conduction band is equal to the number of holes in the valence band	The number of electrons in the conduction band is not equal to the number of holes in the valence band.
Eg. : Pure silicon and Pure Germanium	**Eg. :** *n*-type and *p*-type semiconductor.

23. **Solution :**

$I = 32\ A,\ \ t = 1\ s$

Charge of an electron, $e = 1.6 \times 10^{-19}$ C

The number of electrons flowing per second, n =?

$$I = \frac{q}{t} = \frac{ne}{t}$$

$$n = \frac{It}{e}$$

$$n = \frac{32 \times 1}{1.6 \times 10^{-19} C}$$

$$n = 20 \times 10^{19} = 2 \times 10^{20} \text{ electrons}$$

24. **Solution:**

$2\pi r = n\lambda$

$2 \times 3.14 \times 13.25 Å = 5 \times \lambda$

$\therefore \lambda = 16.64$ Å

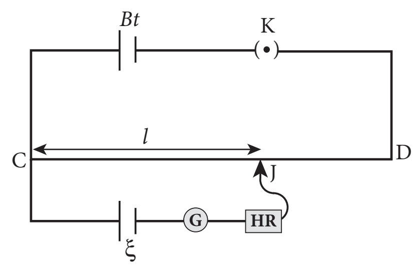
PART - III

25. The emf of the cell is directly proportional to the balancing length.

$\varepsilon = Irl$ where I→current; r→resistance per unit length of the wire.

(i) The principle of the potentiometer is illustrated in figure. A steady current is maintained across the wire CD by a battery Bt. The battery, key and the potentiometer wire connected in series form the primary circuit.

(ii) The positive terminal of a primary cell of emf ε is connected to the point C and negative terminal is connected to the jockey through a galvanometer G and a high resistance HR. This forms the secondary circuit.



Potentiometer

(iii) Let the contact be made at any point J on the wire by jockey. If the potential difference across CJ is equal to the emf of the cell ε, then no current will flow through the galvanometer and it will show zero deflection.

(iv) CJ is the balancing length *l*. The potential difference across CJ is equal to I*rl* where I is the current flowing through the wire and *r* is the resistance per unit length of the wire.

Hence $\varepsilon = Irl$

26. According to Rayleigh $I \propto \frac{1}{\lambda^4}$

Intensity of light I_1 for wavelength $\lambda_1 = 500$ nm

Intensity of light I_2 for wavelength $\lambda_2 = 300$ nm

$$I_1 \propto \frac{1}{\lambda_1^4} \; ; I_2 \propto \frac{1}{\lambda_2^4}$$

$$\frac{I_1}{I_2} = \frac{\lambda_2{}^4}{\lambda_1{}^4} = \left(\frac{\lambda_2}{\lambda_1}\right)^4$$

$$= \left(\frac{300\times10^{-9}}{500\times10^{-9}}\right)^4 = \left(\frac{3}{5}\right)^4$$

$$= \frac{3\times3\times3\times3}{5\times5\times5\times5} = \frac{9\times9}{25\times25} = \frac{81}{625}$$

$I_1 : I_2 = 81:625$

Ratio of the intensities = **81:625**

27. **Energy losses in transformers :**

Transformer do not have any moving parts so that its efficiency is much higher than that of rotating machines like generators and motors. But there are many factors which lead to energy in a transformer.

(i) **Core loss or Iron loss**

1. This loss takes place in transformer core. Hysteresis loss and eddy current loss are known as core loss or Iron loss. When transformer core is magnetized and demagnetized repeatedly by the alternating voltage applied across primary coil, hysteresis takes place due to which some energy is lost in the form of heat.
2. Alternating magnetic flux in the core induces eddy currents in it. Therefore there is energy loss due to the flow of eddy current, called eddy current loss which is minimized by using very thin laminations of transformer core.

(ii) **Copper loss**

Transformer windings have electrical resistance. When an electric current flows through them, some amount of energy is dissipated due to Joule heating. This energy loss is called copper loss which is minimized by using wires of larger diameter.

(iii) **Flux leakage**

Flux leakage happens when the magnetic lines of primary coil are not completely linked with secondary coil. Energy loss due to this flux leakage is minimized by winding coils one over the other.

28. The British Physicist, Sir. David Brewster found that at the polarising angle, the reflected and the refracted rays are perpendicular to each other. Suppose i_p is the polarising angle and r_p is the angle of refraction, we can write

$$r_p = 90° - i_p \qquad ...(1)$$

From Snell's law, the refractive index n of the medium with respect to air is,

$$\frac{\sin i_p}{\sin r_p} = n \qquad ...(2)$$

Substituting equation (1) in (2), we get,

$$\frac{\sin i_p}{\sin(90^\circ - i_p)} = \frac{\sin i_p}{\cos i_p} = n$$

$$\tan i_p = n$$

This equation is known as Brewster's law. Brewster's law states that the tangent of the polarising angle for a transparent medium is equal to its refractive index. The polarising angle is known as Brewster's angle which dependes on the nature of the refracting medium.

29. The electric flux through the rectangular area

$$\theta = 60°$$

$$\Phi_E = \vec{E}.\vec{A} = EA\cos\theta$$

$$\Phi_E = 100 \times 5 \times 10 \times 10^{-4} \times \cos 60°$$

$$\Phi_E = 5000 \times 10^{-4} \times \frac{1}{2} = 2500 \times 10^{-4}$$

$$\Phi_E = 0.25\ Nm^2C^{-1}$$

30. **(i)** When an unstable nucleus decay by emitting an α-particle (^4_2He nucleus), it loses two protons and two neutrons. As a result, its atomic number Z decreases by 2, and the mass number decreases by 4. We write the alpha decay process symbolically in the following way

$$^A_ZX \rightarrow ^{A-4}_{Z-2}Y + ^4_2He$$

(ii) Here X is called the **parent nucleus** and Y is called the **daughter nucleus**.

Ex : Decay of Uranium $^{238}_{92}U$ to thorium $^{234}_{90}Th$ with the emission of ^4_2He nucleus (α-particle)

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^4_2He$$

(iii) The total mass of the daughter nucleus and ^4_2He nucleus is always less than that of the parent nucleus. The difference in mass ($\Delta m = m_X - m_Y - m_\alpha$) is released as energy called **disintegration energy** Q and is given by $Q = (m_X - m_Y - m_\alpha)c^2$

(iv) In alpha decay process, the disintegration energy is certainly positive (Q > 0). In fact, the disintegration energy Q is also the net kinetic energy gained in the decay process or if the parent nucleus is at rest, Q is the total kinetic energy of daughter nucleus and the ^4_2He nucleus.

(v) Suppose Q < 0, then the decay process cannot occur spontaneously and energy must be supplied to induce the decay.

31. Maxwell's equations explain the behaviour of charges, currents and properties of electric and magnetic fields.

(i) First equation :

Gauss's law relates the net electric flux to net electric charge enclosed in a surface. Mathematically, it is expressed as

$$\oint_s \vec{E}.d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

(Gauss's law for electricity)

(ii) Second equation.

This law is similar to Gauss's law for electricity. So this law can also be called as Gauss's law for magnetism. The surface integral of magnetic field over a closed surface is zero. Mathematically,

$$\oint_s \vec{B}.d\vec{A} = 0$$

(Gauss's law for magnetism)

(iii) Third equation :

It is Faraday's law of electromagnetic induction. This law relates electric field with the changing magnetic flux which is mathematically written as

$$\oint_l \vec{E}.\vec{dl} = -\frac{d}{dt}(\phi_B) \quad \textbf{(Faraday's law)}$$

(iv) Fourth equation :

It is modified Ampere's circuital law. This is also known as Ampere – Maxwell law. This law relates the magnetic field around any closed path to the conduction current and displacement current through that path.

$$\oint_l \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0\varepsilon_0 \frac{d}{dt}\oint_s \vec{E}.\vec{dA}$$

(Ampere - Marwell's law)

32. **Advantages of FM:**

(i) In FM, there is a Large decrease in noise. It leads to an increases in signal-noise ratio.

(ii) The operating range is quite large.

(iii) The transmission efficiency is very high as all the transmitted power is useful.

(iv) FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio.

Limitations of FM :

(i) FM requires a much wider channel.

(ii) FM transmitters and receivers are more complex and costly.

(iii) In FM reception, less area is covered compared to AM.

33. **Solution :**

The diameter of the coil is 0.24 m. Therefore, radius of the coil is 0.12 m.

Number of turns is 100 turns.

Earth's magnetic field is 25×10^{-6} T

Deflection is $\theta = 60^\circ \Rightarrow \tan 60^\circ = \sqrt{3} = 1.732$

$$I = \frac{2RB_H}{\mu_0 N} \tan\theta$$

$$= \frac{2 \times 0.12 \times 25 \times 10^{-6}}{4 \times 10^{-7} \times 3.14 \times 100} \times 1.732$$

$$= 0.82 \times 10^{-1} \text{ A}$$

$$I = 0.082 \text{ A}$$

PART - IV

34. (a)

When light is allowed to pass through an absorbing substance then the spectrum obtained is known as absorption spectrum. It is the characteristic of absorbing substance.

(a) Continuous absorption spectrum :

When we pass white light through a blue glass plate, it absorbs all the colours except blue and gives continuous absorption spectrum.

line absorption spectra

(b) Line absorption spectrum :

(i) When light from the incandescent lamp is passed through cold gas, the spectrum is thus obtained through the dispersion.

(ii) Light from the carbon arc is made to pass through sodium vapour, a continuous spectrum of carbon arc with two dark lines in the yellow region are obtained.

(c) Band absorption spectrum :

(i) When the white light is passed through the iodine vapour, dark bands on continuous bright background is obtained.

(ii) White light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.

(OR)

(b) **Radioactive law of disintegration :**

(i) At any instant *t*, the number of decays per unit time, called rate of decay $\left(\frac{dN}{dt}\right)$ is proportional to the number of nuclei (*N*) at the same instant.

$$-\frac{dN}{dt} \propto N$$

The negative sign in the equation implies that N is decreasing with time.

(ii) By introducing a proportionality constant, the relation can be written as

$$\frac{dN}{dt} = -\lambda N \qquad ...(1)$$

(iii) Here proportionality constant λ is called decay constant which is different for different radioactive sample.

By rewriting the equation (1), we get

$dN = -\lambda N dt$ ...(2)

(iv) Here dN represents the number of nuclei decaying in the time interval *dt*.

(v) Let us assume that at time $t = 0$ s, the number of nuclei present in the radioactive sample be N_0. By integrating the equation (2), we can calculate the number of undecayed nuclei N present at any time *t*.

From equation (2), we get

$$\frac{dN}{N} = -\lambda dt \quad ...(3)$$

$$\int_{N_0}^{N} \frac{dN}{N} = -\int_0^t \lambda dt$$

$$[\ln N]_{N_0}^{N} = -\lambda t$$

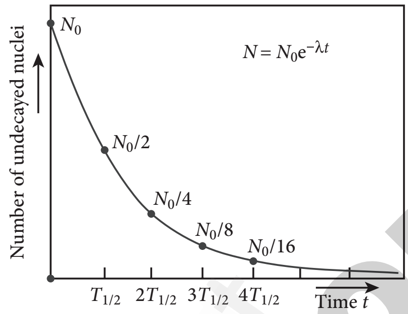
$$\ln\left[\frac{N}{N_0}\right] = -\lambda t$$

Taking exponentials on both sides, we get

$$N = N_0 e^{-\lambda t} \quad ...(4)$$

[Note : $e^{\ln x} = e^y \Rightarrow x = e^y$]

(vi) Equation (4) is called the law of radioactive decay. Here *N* denotes the number of undecayed nuclei present at any time *t* and N_0 denotes the number of nuclei present initially time $t = 0$. Note that the number of atoms is decreasing exponentially over the length of time. This implies that the time taken for all the radioactive nuclei to decay will be infinite.



Law of radioactive decay

(vii) We can also define another useful quantity called activity (R) or decay rate which is the number of nuclei decayed per second and it is denoted as $R = \left|\frac{dN}{dt}\right|$. Note that activity R is a positive quantity.

From equation (4), we get

$$R = \left|\frac{dN}{dt}\right| = \lambda N_0 e^{-\lambda t} \quad ...(5)$$

$$R = R_0 e^{-\lambda t}. \quad ...(6)$$

where $R_0 = \lambda N_0$

(viii) The equation (6) is also equivalent to radioactive law of decay. Here R_0 is the activity of the sample at *t=0* and *R* is the activity of the sample at any time *t*. From equation (6), activity also shows exponential decay behavior. The activity *R* also can be expressed in terms of number of undecayed atoms present at any time *t*. From equation (6), since $N = N_0 e^{-\lambda t}$, we write $R = \lambda N$ ...(7)

(ix) Equation (7) implies that the activity at any time t is equal to the product of decay constant and number of undecayed nuclei present at that time *t*. Since *N* decreases with time, *R* also decreases.

(x) The SI unit of activity R is Becquerel and one Becquerel (Bq) is equal to one decay per second. There is also another standard unit for the activity called Curie(Ci).

1 Curie = 1 Ci

$= 3.7 \times 10^{10}$ decays per second

$1 \text{ Ci} = 3.7 \times 10^{10}$ Bq.

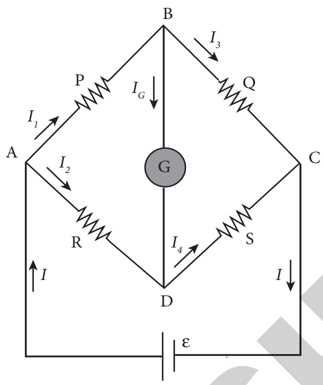
35. (a) An important application of Kirchhoff 's rule is Wheatstone's bridge. It is used to compare resistances and in determining the unkonwn resistance in electrical network.

(i) The bridge consists of four resistances P, Q, R and S connected as shown in Figure. A galvanometer G is connected between the points B and D. The battery is connected between the points A and C. The current through the galvanometer is I_G and its resistance is G.

(ii) Applying Kirchhoff's current rule to junction B and D respectively.

$$I_1 - I_G - I_3 = 0 \quad ...(1)$$

$$I_2 + I_G - I_4 = 0 \quad ...(2)$$



Wheatstone's bridge

(iii) Applying Kirchhoff's voltage rule to loop ABDA,

$$I_1P + I_GG - I_2R = 0 \quad ...(3)$$

Applying Kirchhoff's voltage rule to loop ABCDA,

$$I_1P + I_3Q - I_4S - I_2R = 0 \quad ...(4)$$

(iv) When the points B and D are at the same potential, the bridge is said to be balanced. No current flows through galvanometer ($I_G = 0$). Substituting $I_G = 0$ in equation (1), (2) and (2), we get

$$I_1 = I_3 \quad ...(5)$$

$$I_2 = I_4 \quad ...(6)$$

$$I_1P = I_2R \quad ...(7)$$

Using equation (7) in equation (4), we get

$$I_3Q = I_4S \quad ...(8)$$

Dividing equation (8) by equation (7), we get

$$\frac{P}{Q} = \frac{R}{S} \quad ...(9)$$

This is the bridge balance condition. Under this condition galvanometer shows null deflection.

(OR)

(b) **Condition for bright fringe (or) maxima :**

(i) The condition for the point P to have a constructive interference (or) be a bright fringe is, Path difference, $\delta = n\lambda$

where, $n = 0, 1, 2, \ldots$

$$\therefore \frac{dy}{D} = n\lambda.$$

$$y = n\frac{\lambda D}{d} \text{ (or) } y_n = n\frac{\lambda D}{d}$$

(ii) This is the condition for the point P to have a bright fringe. The distance y_n is the distance of the n^{th} bright fringe from the point O.

Condition for dark fringe (or) minima :

(i) The condition for the destructive interference or the point P to be have a dark fringe is,

Path difference, $\delta = (2n - 1)\frac{\lambda}{2}$

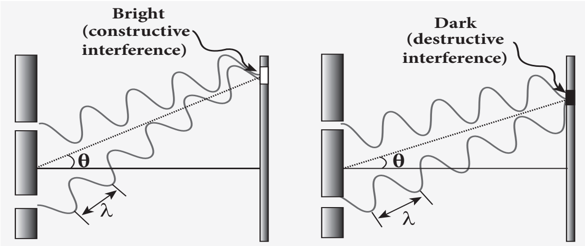
where, $n = 1, 2, 3, \ldots$

$$\therefore \frac{dy}{D} = (2n - 1)\frac{\lambda}{2}$$

$$y = \frac{(2n-1)}{2}\frac{\lambda D}{d} \text{ (or) } y_n = \frac{(2n-1)}{2}\frac{\lambda D}{d}$$

(ii) This is the condition for the point P to have a dark fringe. The distance y_n is the distance of the n^{th} dark fringe from the point O.

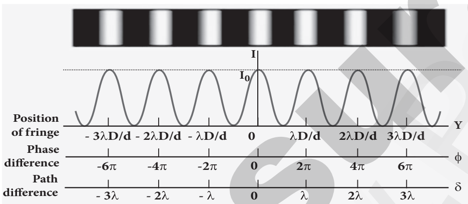
(iii) The formation of bright and dark fringes is shown in Figure.



Formation of bright and dark fringes

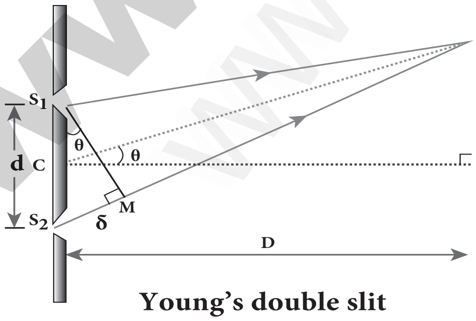
(iv) This shows that on the screen, alternate bright and dark fringes are seen on either side of the central bright fringe.

(v) The central bright is referred as 0^{th} bright followed by 1^{st} dark and 1^{st} bright and then 2^{nd} dark and 2^{nd} bright and so on, on either side of O successively as shown in Figure.



Interference fringe pattern (need to make it vertical)

Equation for bandwidth :



Young's double slit arrangement to find path difference

(i) The bandwidth (β) is defined as the distance between any two consecutive bright or dark fringes.

(ii) The distance between $(n+1)^{th}$ and n^{th} consecutive bright fringes from O is given by

$$\beta = y_{(n+1)} - y_n = \left((n+1)\frac{\lambda D}{d}\right) - \left(n\frac{\lambda D}{d}\right)$$

$$\beta = \frac{\lambda D}{d}$$

(iii) Similarly, the distance between $(n+1)^{th}$ and n^{th} consecutive dark fringes from O is given by,

$$\beta = y_{(n+1)} - y_n = \left(\frac{(2(n+1)-1)}{2}\frac{\lambda D}{d}\right) - \left(\frac{(2n-1)}{2}\frac{\lambda D}{d}\right)$$

$$\beta = \frac{\lambda D}{d}$$

36. (a) It is a machine which produces large electrostatic potential difference of the order of 10^7 V.

Principle:

Electrostatic induction and action at points.

Construction:

(i) A large hollow spherical conductor is fixed on the insulating stand as shown in the figure.

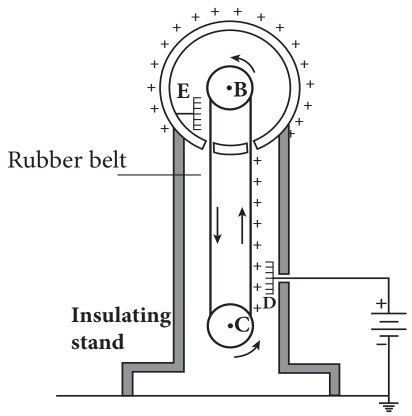
(ii) A pulley B is mounted at the centre of the hollow sphere and another pulley C is fixed at the bottom.

(iii) A belt made up of insulating materials like silk or rubber runs over both pulleys. The pulley C is driven continuously by the electric motor.

(iv) Two comb shaped metallic conductors E and D are fixed near the pulleys.

(v) The comb D is maintained at a positive potential of the order of 10^4 volt.

(vi) The upper comb E is connected to the inner side of the hollow metal sphere.



Working:

(i) Because of the high electric field near the comb D, the air gets ionized.

(ii) The negative charges in air move towards the needles and positive charges are repelled towards the belt due to action of points.

(iii) The +ve charges stuck to the belt moves up end and reaches near the comb E.

(iv) E acquires negative charge and the sphere acquires positive charge due to electrostatic induction.

(v) The acquired +ve charge is distributed on the outer surface of the sphere.

(vi) Thus the machine, continuously transfers the positive charge to the sphere.

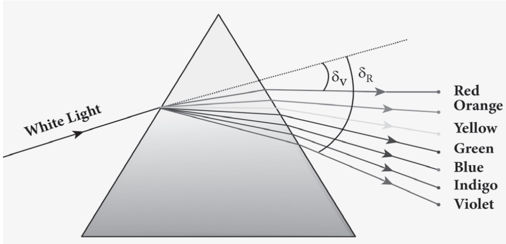
(vii) The leakage of charges from the sphere can be reduced by enclosing it in a gas filled steel chamber at a very high pressure.

(viii) The high voltage can be used to accelerate positive ions for the purpose of nuclear disintegrations and other applications.

(OR)

(b) (i) Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its spectrum.

(ii) Consider a beam of white light passing through a prism. It gets dispersed into its constituent colours.



Angle of deviation for different colours

(iii) If the angle of prism is small of the order of 10°, the prism is said to be a small angle prism.

(iv) When rays of light pass through such prisms, the angle of deviation also becomes small.

(v) Let If A be the angle of a small angle prism and δ be its angle of minimum deviation, then the prism formula becomes.

$$n = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

For small angles of A and δ_m,

$$\sin\left(\frac{A+\delta}{2}\right) \approx \left(\frac{A+\delta}{2}\right)$$

$$\sin\left(\frac{A}{2}\right) \approx \left(\frac{A}{2}\right)$$

$$\therefore n = \frac{\left(\frac{A+\delta}{2}\right)}{\left(\frac{A}{2}\right)} = \frac{A+\delta}{A} = 1 + \frac{\delta}{A}$$

Further simplifying, $\frac{\delta}{A} = n - 1$

$$\delta = (n - 1)A$$

(vi) When white light enters the prism, the deviation is different for different colours. Thus, the refractive index is also different for different colours.

For Violet colour, $\delta_V = (n_V - 1)A$

For Red colour, $\delta_R = (n_R - 1)A$

(vii) As, angle of minimum deviation for violet colour δ_V is greater than angle of deviation for red colour δ_R, the refractive index for violet colour n_V is greater than the refractive index for red colour n_R.

Subtracting δ_R from δ_V we get,

$$\delta_V - \delta_R = (n_V - n_R)A$$

(viii) The angular separation between the two extreme colours (violet and red) in the spectrum $(\delta_V - \delta_R)$ is called the angular dispersion.

(ix) If we take δ is the angle of minimum deviation for any mean colour (green or yellow) and n the corresponding refractive index. Then,

$$\delta = (n - 1)A$$

(x) Dispersive power (ω) is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any middle colour.

Dispersive power (ω),

$$\omega = \frac{\text{angular dispersion}}{\text{middle deviation}} = \frac{\delta_V - \delta_R}{\delta}$$

Substituting $(\delta_V - \delta_R)$ and (δ),

$$\omega = \frac{(n_V - n_R)}{(n-1)}$$

37. (a)

(i) **Ampere's law:** The line integral of magnetic field over a closed loop is μ_0 times net current enclosed by the loop.

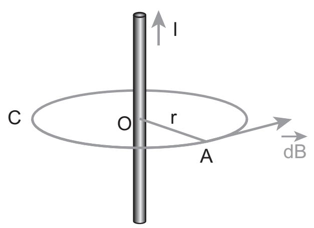
$$\oint_C \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

(ii) Consider a straight conductor carrying I.

B $\rightarrow$ magnetic field

$dl \rightarrow$ line element along the tangent to circular loop

I $\rightarrow$ current flowing through the conductor



Ampèrian loop for current carrying straight wire

From Ampere's law

$$\oint_C \vec{B}.\vec{dl} = \mu_0 I$$

$$\oint_C B dl = \mu_0 I$$

$$B\oint_C \vec{dl} = \mu_0 I$$

For a circular loop, the circumference is $2\pi r$,

$$B\int_0^{2\pi r} dl = \mu_0 I$$

$$\vec{B}.2\pi r = \mu_0 I$$

If B is uniform = $B = \dfrac{\mu_0 I}{2\pi r}$

In vector form, the magnetic field is $\vec{B} = \dfrac{\mu_0 I}{2\pi r}\hat{n}$

where $\hat{n}$ is the unit vector along the tangent to the Amperian loop. This perfectly agrees with the result obtained from Biot savart law as given in equation $\vec{B} = \dfrac{\mu_0 I}{2\pi r}\hat{n}$.

(OR)

(b) **De morgan's First theorem :**

Statement : The first theorem states that the complement of the sum of two logical inputs is equal to the product of its complements.

Proof

The Boolean equation for NOR gate is $Y = \overline{A + B}$

The Boolean equation for a bubbled AND gate is $Y = \overline{A}.\overline{B}$.

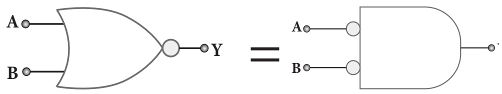
Both cases generate same outputs for same inputs. It can be verified using the following truth table.

A	B	A+ B	$\overline{A+B}$	$\overline{A}$	$\overline{B}$	$\overline{A}.\overline{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

From the above truth table, we can conclude $\overline{A + B} = \overline{A}.\overline{B}$.

Thus De Morgan's first theorem is proved. Hence, a NOR gate is equal to a bubbled AND gate.

The corresponding logic circuit diagram is shown in Figure



NOR gate equals bubbled AND gate

De morgan's second theorem :

Statement

The second theorem states that the complement of the product of two inputs is equal to the sum of its complements.

Proof

The Boolean equation for NAND gate is $Y = \overline{A.B}$

The Boolean equation for bubbled OR gate is $Y = \overline{A} + \overline{B}$

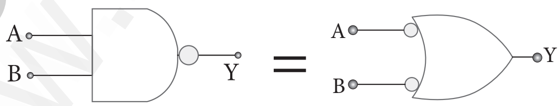
A and B are the inputs and Y is the output. The above two equations produces the same output for the same inputs. It can be verified by using the truth table

A	B	A.B	$\overline{A.B}$	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

From the above truth table we can conclude $\overline{A.B} = \overline{A} + \overline{B}$.

Thus De Morgan's second theorem is proved. Hence, a NAND gate is equal to a bubbled OR gate.

The corresponding logic circuit diagram is shown in Figure.



NAND gate equals bubbled OR gate

38. (a) **Single phase AC generator**

(i) The armature conductors are connected in series to form a single circuit which generates single phase alternating emf. So it is called single phase alternator.

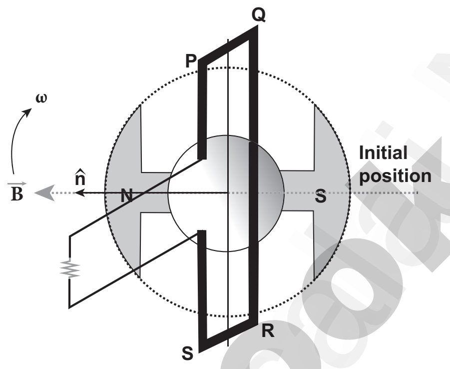
(ii) In the simplified version of AC generator, a single-turn rectangular loop PQRS is mounted on the stator. The field winding is fixed inside the stator and it can be rotated about an axis, perpendicular to the plane of the paper.

Working :

(i) The loop PQRS is stationary and is also perpendicular to the plane of the paper. When field windings are excited, magnetic field is produced around it.

(ii) Let the field magnet be rotated in clockwise direction. Assume that initial position of the field magnet is horizontal. At that instant, the direction of magnetic field is perpendicular to the plane of the loop PQRS.

(iii) The induced emf is zero.



The loop PQRS and field magnet in its initial position

This is represented by origin O in the graph drawn between induced emf and time angle.

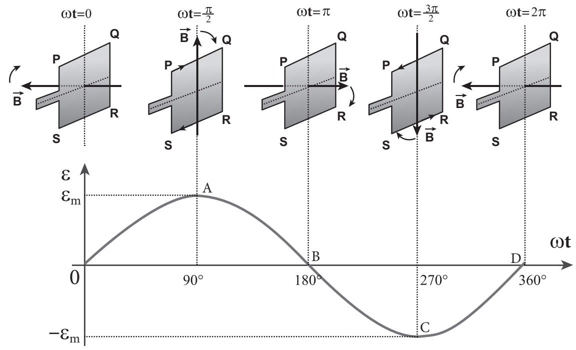
(iv) When field magnet rotates through 90°, magnetic field becomes parallel to PQRS. The induced emfs across PQ and RS would become maximum.

(v) Since they are connected in series, emfs are added up and the direction of total induced emf is given by Fleming's right hand rule.

(vi) For the rotation of 180° from the initial position, the field is again perpendicular to PQRS and the induced emf becomes zero. This is represented by point B.

(vii) The field magnet becomes again parallel to PQRS for 270° rotation of field magnet. The induced emf is maximum but the direction is reversed. Thus the current flows along SRQP. This is represented by point C.

(viii) On completion of 360°, the induced emf becomes zero and is represented by the point D. From the graph, it is clear that emf induced in PQRS is alternating in nature. Therefore, when field magnet completes one rotation, induced emf in PQRS finishes one cycle.



Variation of induced emf with respect of time angle

(OR)

(b) (i)

According to particle nature of light, photons are the basic constituents of any radiation and possess the following characteristic properties.

(i) The photons of light of frequency ν and wavelength λ will have energy, given by

$$E = h\nu = \frac{hc}{\lambda}$$

(ii) The energy of a photon is determined by the frequency of the radiation and not by its intensity and the intensity has no relation with the energy of the individual photons in the beam.

(iii) The photons travel with the velocity of light and its momentum is given by

$$p = \frac{h}{\lambda} = \frac{h\nu}{c}$$

(iv) Since photons are electrically neutral, they are unaffected by electric and magnetic fields.

(v) When a photon interacts with matter (photon-electron collision), the total energy, total linear momentum and angular momentum are conserved. Since photon may be absorbed or a new photon may be produced in such interactions, the number of photons may not be conserved.

(ii) ***Solution :*** Relatron between momentum and Kinetic energy is $P^2 = 2\,mK$

$$= 2 \times (9.11 \times 10^{-31}) \times (2) \times (1.6 \times 10^{-19})$$

$\left[\begin{array}{l}\text{Mass of electron} \\ = 9.11 \times 10^{-31}\,kg\end{array}\right]$

$$P^2 = 58.304 \times 10^{-50}$$

$$\therefore P = \sqrt{58.304 \times 10^{-50}}$$

$$P = 7.63 \times 10^{-25}\ \text{kg ms}^{-1}$$

★ ★ ★