

Class XII Session 2023-24
Subject - Physics
Sample Question Paper - 4

Time Allowed: 3 hours

Maximum Marks: 70

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. A half wave rectifier is being used to rectify an alternating voltage of frequency 50 Hz. The number of pulses of rectified current obtained in one second is [1]
 - a) 50 Hz
 - b) 200 Hz
 - c) 100 Hz
 - d) 25 Hz
2. A piece of copper and other of germanium are cooled from room temperature to 80 K, then [1]
 - a) resistance of copper will decrease
 - b) the resistance of copper will increase while that of germanium will decrease
 - c) resistance of each will increase
 - d) the resistance of copper will decrease while that of germanium will increase
3. Binoculars is preferred to a terrestrial telescope to observe a cricket match, because [1]
 - a) telescope has chromatic aberration
 - b) binoculars gives three dimensional view
 - c) telescope does not give erect image
 - d) binocular has shorter focal length
4. A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16K, the magnetisation will be [1]
 - a) 2 Am^{-1}
 - b) $\frac{2}{3} \text{ Am}^{-1}$

6 Am^{-1}

c) 2.4 Am^{-1}

d) $\frac{32}{3} \text{ Am}^{-1}$

5. Two capacitors of capacitances C_1 and C_2 are connected in parallel. If a charge Q is given to the combination, the ratio of the charge on the capacitor C_1 to the charge on C_2 will be [1]

a) $\sqrt{\frac{C_1}{C_2}}$

b) $\frac{C_2}{C_1}$

c) $\frac{C_1}{C_2}$

d) $\sqrt{\frac{C_2}{C_1}}$

6. The scale of a galvanometer of resistance 100Ω contains 25 divisions. It gives a deflection of one division on passing a current of $4 \times 10^{-4} \text{ A}$. The resistance in ohms to be added to it so that it may become a voltmeter of range 2.5 volt is [1]

a) 100

b) 250

c) 300

d) 150

7. A magnetic field of $2 \times 10^{-2} \text{ T}$ acts at right angles to a coil of area 100 cm^2 with 50 turns. The average emf induced in the coil is 0.1 V when it is removed from the field in the time t . The value of t is: [1]

a) 0.01 s

b) 1 s

c) 10 s

d) 0.1 s

8. The magnetic moment of a revolving electron around the nucleus varies with principal quantum number n as [1]

a) $\mu \propto n$

b) $\mu \propto \frac{1}{n^2}$

c) $\mu \propto n^2$

d) $\mu \propto \frac{1}{n}$

9. What happens to fringe width in the Young's double slit experiment, if it is performed in glycerine instead of air? [1]

a) The fringes shrink

b) The fringes disappear

c) The fringes remain unchanged

d) The fringes get enlarged

10. A point charge $+q$, is placed at a distance d from an isolated conducting plane. The field at a point P on the other side of the plane is [1]

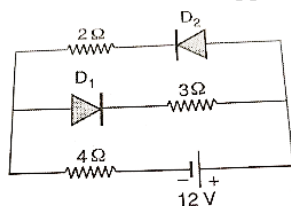
a) Directed radially away from the point charge.

b) Directed perpendicular to the plane but towards the plane.

c) Directed perpendicular to the plane and away from the plane.

d) Directed radially towards the point charge.

11. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit? [1]



a) 1.33 A

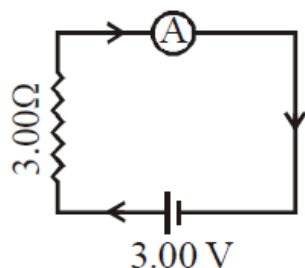
b) 1.71 A

c) 2.31 A

d) 2.0 A

12. A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass plate. The refractive index of the liquid is [1]

In the circuit (Fig.) the current is to be measured. What is the value of the current if the ammeter shown



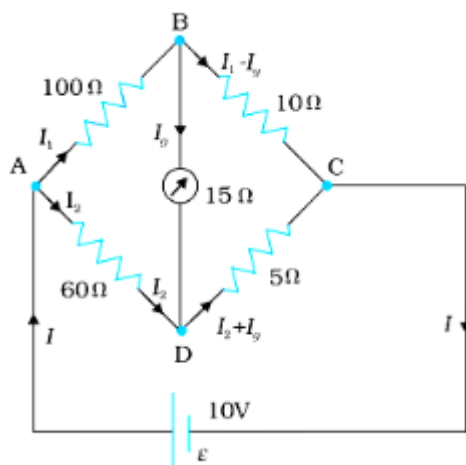
- a. is a galvanometer with a resistance $R_G = 60.00 \, \Omega$;
- b. is a galvanometer described in (a) but converted to an ammeter by a shunt resistance $r_s = 0.02 \, \Omega$;
- c. is an ideal ammeter with zero resistance?

Section C

22. The four arms of a Wheatstone bridge (Fig.) have the following resistances:

[3]

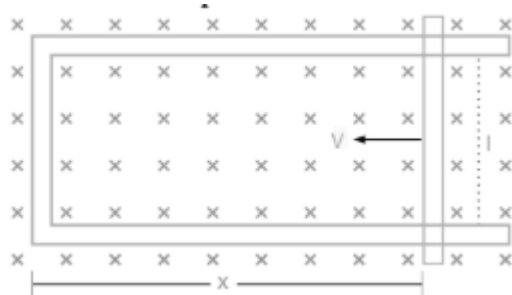
$AB = 100 \, \Omega$, $BC = 10 \, \Omega$, $CD = 5 \, \Omega$, and $DA = 60 \, \Omega$.



A galvanometer of $15 \, \Omega$ resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across AC.

23. Explain the formation of depletion layer and barrier potential in a p-n junction diode. [3]
24. a. A monoenergetic electron beam with the electron speed of $5.20 \times 10^6 \, \text{ms}^{-1}$ is subject to a magnetic field of $1.30 \times 10^{-4} \, \text{T}$ normal to the beam velocity. What is the radius of the circle traced by the beam, given e/m for electron equals $1.76 \times 10^{11} \, \text{C kg}^{-1}$? [3]
 b. Is the formula you employ in (a) valid for calculating the radius of the path of a 20 MeV electron beam? If not, in what way is it modified?
25. Heavy water is a suitable moderator in a nuclear reactor. Explain briefly why? [3]
26. Using Bohr's postulates of the atomic model, derive the expression for the radius of « 111 electron orbit. Hence obtain the expression for Bohr's radius. Show graphically the (nature of) variation of the radius of the orbit with the principal quantum number n . [3]
27. The angular width of a central maximum in the Fraunhofer diffraction pattern of a slit is measured. The slit is illuminated by the light of wavelength $6000 \, \text{\AA}$. When the slit is illuminated by the light of another wavelength, the angular width decreases by 30%. Calculate the wavelength of this light. The same decrease in the angular-width of the central maximum is obtained when the original apparatus is immersed in a liquid. Find the refractive index of the liquid. [3]
28. i. A rod of length l is moved horizontally with a uniform velocity v in a direction perpendicular to its length [3]

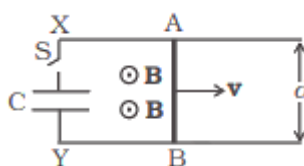
through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod.



- ii. How does one understand this motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor? Explain.

OR

Find the current in the sliding rod AB (resistance = R) for the arrangement shown in Figure. B is constant and is out of the paper. Parallel wires have no resistance. v is constant. Switch S is closed at time $t = 0$.



Section D

29. Read the text carefully and answer the questions:

[4]

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

- (i) Which wavelength of the Sun is used finally as electric energy?

radio waves, infrared waves, visible light, microwaves

- | | |
|----------------|-------------------|
| a) microwaves | b) visible light |
| c) radio waves | d) infrared waves |

- (ii) Which of the following electromagnetic radiations have the longest wavelength?

X-rays, γ -rays, microwaves, radiowaves

- | | |
|-------------------|---------------|
| a) γ -rays | b) microwaves |
| c) radiowaves | d) X-rays |

- (iii) Which one of the following is not electromagnetic in nature?

X-rays, gamma rays, cathode rays, infrared rays

- | | |
|---------------|------------------|
| a) gamma rays | b) infrared rays |
| c) X-rays | d) cathode rays |

OR

The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

- | | |
|-------------------------------------------------|-------------------------------------------------|
| a) gamma rays, ultraviolet, infrared, microwave | b) microwave, gamma rays, infrared, ultraviolet |
| c) microwave, infrared, ultraviolet, | d) infrared, microwave, ultraviolet, |

gamma rays

gamma rays.

(iv) Which of the following has minimum wavelength?

X-rays, ultraviolet rays, γ -rays, cosmic rays

a) X-rays

b) cosmic rays

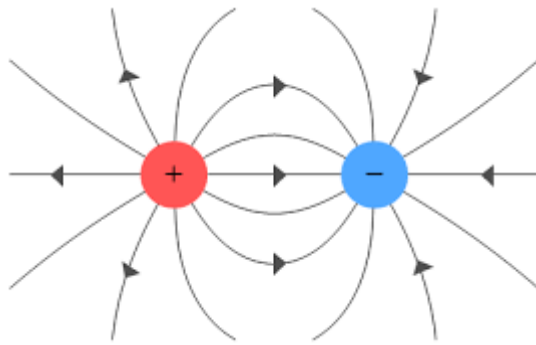
c) ultraviolet rays

d) γ -rays

30. Read the text carefully and answer the questions:

[4]

Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. There are two types of charges positive and negative charges. Also, like charges repel each other whereas unlike charges attract each other.



(i) Charge on a body which carries 200 excess electrons is:

a) $-3.2 \times 10^{-17} \text{ C}$

b) $-3.2 \times 10^{-18} \text{ C}$

c) $3.2 \times 10^{18} \text{ C}$

d) $3.2 \times 10^{-17} \text{ C}$

(ii) Charge on a body which carries 10 excess electrons is:

a) $1.6 \times 10^{-18} \text{ C}$

b) $1.6 \times 10^{-21} \text{ C}$

c) $2.6 \times 10^{-18} \text{ C}$

d) $-1.6 \times 10^{-18} \text{ C}$

(iii) Mass of electron is:

a) $1.6 \times 10^{-19} \text{ kg}$

b) $9.1 \times 10^{-31} \text{ g}$

c) $9.1 \times 10^{-31} \text{ kg}$

d) $1.6 \times 10^{-19} \text{ g}$

(iv) A body is positively charged, it implies that:

- there is only a positive charge in the body
- there is positive as well as negative charge in the body but the positive charge is more than negative charge
- there is equally positive and negative charge in the body but the positive charge lies in the outer regions
- the negative charge is displaced from its position

a) Option (iii)

b) Option (iv)

c) Option (ii)

d) Option (i)

OR

On rubbing, when one body gets positively charged and other negatively charged, the electrons transferred from positively charged body to negatively charged body are:

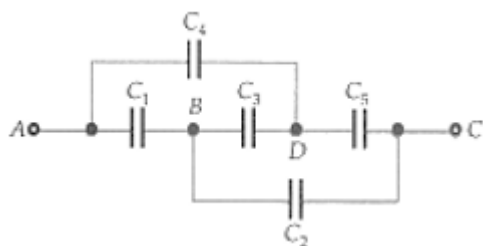
- a) both valence electrons and electrons of the inner shell b) none of these
- c) electrons of inner shells d) valence electrons only

Section E

31. a. Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision. [5]
- b. The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm. Calculate the focal length of the objective and the eyepiece.

OR

- i. Distinguish between unpolarised light and linearly polarised light. How does one get linearly polarised light with the help of a polaroid?
- ii. A narrow beam of unpolarised light of intensity I_0 is incident on a polaroid P_1 . The light transmitted by it is then incident on a second polaroid P_2 with its pass axis making an angle of 60° relative to the pass axis of P_1 . Find the intensity of the light transmitted by P_2 .
32. Five capacitors of capacitance $10\mu\text{F}$ each are connected with each other, as shown in Fig. Calculate the total capacitance between the points A and C. [5]



OR

- A parallel plate capacitor is charged to a potential difference V by a DC source. The capacitor is then disconnected from the source. If the distance between the plates is doubled, state with reason, how the following will change -
- i. Electric field between the plates?
- ii. Capacitance?
- iii. Energy stored in the capacitor?
33. i. With the help of a diagram, explain the principle and working of a device which produces current that reverses its direction after regular intervals of time. [5]
- ii. If a charged capacitor C is short-circuited through an inductor L , the charge and current in the circuit oscillate simple harmonically.
- a. In what form the capacitor and the inductor store energy?
- b. Write two reasons due to which the oscillations become damped.

OR

- i. Prove that current flowing through an ideal inductor connected across ac source lags the voltage in phase by $\frac{\pi}{2}$.
- ii. An inductor of self-inductance 100 mH, and a bulb are connected in series with ac source of rms voltage 10 V, 50 Hz. It is found that the effective voltage of the circuit leads the current in phase by $\frac{\pi}{4}$. Calculate the inductance of the inductor used and average power dissipated in the circuit if a current of 1 A flows in the circuit.

Solution

Section A

1. (a) 50 Hz

Explanation: For each complete cycle of input ac, we get one pulse in the output (that lasts for the positive half cycle of the input). Since, there is one pulse per input cycle, the pulse frequency is also 50 Hz.

2.

(d) the resistance of copper will decrease while that of germanium will increase

Explanation: When cooled from room temperature to 80 K, the resistance of copper (a metallic conductor) will decrease while that of germanium (a semiconductor) will increase.

3.

(b) binoculars gives three dimensional view

Explanation: As both eyes are used for viewing, binoculars project a 3D image and provide a better in depth perception and a broader field of vision i.e., binocular lens gives the proper three dimensional image.

4.

(b) $\frac{2}{3} \text{ Am}^{-1}$

Explanation: On increasing the temperature magnetic susceptibility of paramagnetic material decreases or vice versa . According to Curie law, we can deduce a formula for the relation between magnetic field induction, temperature and magnetisation.

$$\text{i.e., } I \text{ (magnetization)} \propto \frac{B(\text{ magnetic field induction })}{t(\text{ temperature in kelvin })} \Rightarrow \frac{I_2}{I_1} = \frac{B_2}{B_1} \times \frac{t_1}{t_2}$$

Let us suppose, here $I_1 = 8 \text{ Am}^{-1}$

$$B_1 = 0.6 \text{ T}, t_1 = 4 \text{ K}$$

$$B_2 = 0.2 \text{ T}, t_2 = 16 \text{ K}$$

$$\Rightarrow \frac{0.2}{0.6} \times \frac{4}{16} = \frac{I_2}{8}$$

$$\Rightarrow I_2 = 8 \times \frac{1}{12} = \frac{2}{3} \text{ Am}^{-1}$$

5.

(c) $\frac{C_1}{C_2}$

Explanation: As C_1 and C_2 are connected in parallel, so the potential $V = \frac{Q}{C_1 + C_2}$ will be same for both capacitors. thus, $Q_1 =$

$$\frac{QC_1}{C_1 + C_2} \text{ and } Q_2 = \frac{QC_2}{C_1 + C_2}$$

$$\therefore \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$$

6.

(d) 150

$$\text{Explanation: } R = \frac{V}{I_g} - G$$

$$V = 2.5 \text{ V} ; G = 100 \text{ Ohm} ; I_g = 0.01 \text{ A}$$

On solving we get,

$$R = 150 \text{ Ohm}$$

7.

(d) 0.1 s

$$\text{Explanation: } \varepsilon = -N \frac{d\phi}{dt} = -N \frac{0 - BA}{t} = \frac{NBA}{t}$$

$$\therefore t = \frac{NBA}{\varepsilon}$$

$$= \frac{50 \times 2 \times 10^{-2} \times 100 \times 10^{-4}}{0.1} \text{ s} = 0.1 \text{ s}$$

8.

(a) $\mu \propto n$

$$\text{Explanation: } L = n \cdot \frac{h}{2\pi} \text{ and } \mu = \frac{e}{2m} \cdot L$$

$$\therefore \mu = \frac{e}{2m} \cdot \frac{nh}{2\pi} \therefore \mu \propto n.$$

9. (a) The fringes shrink
Explanation: The fringes shrink
10.
 (c) Directed perpendicular to the plane and away from the plane.
Explanation: Let charge +q is placed to the left of isolated conducting plane AB vertical to plane of paper. Due to induction by +q charge, R.H.S. plane will acquire positive charge.
 So, line of forces will emerge perpendicularly, outward and parallel to each other.
11.
 (d) 2.0 A
Explanation: Diode D_1 is reverse biased, so it offers an infinite resistance. So no current flows in the branch of diode D_1 .
 Diode D_2 is forward biased, and offers no resistance in the circuit. So current in the branch.

$$I = \frac{V}{R_{eq}} = \frac{12}{2+4} = 2A$$
12.
 (d) 1.47
Explanation: the refractive index of liquid must be equal to refractive index of glass=1.47
13.
 (b) Both A and R are true but R is not the correct explanation of A.
Explanation: Both A and R are true but R is not the correct explanation of A.
 But a photoelectric effect can be explained only on the basis of the quantum nature of light.
14.
 (c) A is true but R is false.
Explanation: Electrostatic forces are conservative. Work done in moving a charge in a uniform electric field is path independent.
15.
 (b) Both A and R are true but R is not the correct explanation of A.
Explanation: Suppose the amplitude of waves from each slit is a. Therefore, intensity due to each slit - a^2 . When interference is destructive,
 the resultant amplitude = $a - a = 0$
 \therefore Minimum intensity = 0
 When interference is constructive the resultant amplitude
 $= a + a = 2a$
 Maximum intensity = $(2a)^2 = 4a^2$
 $= 4$ times the intensity due to each slit.
16.
 (b) Both A and R are true but R is not the correct explanation of A.
Explanation: Like a choke coil, a capacitor can reduce ac without consuming any power. Both A and R are true but R is not the correct explanation of A.

Section B

17. According to Faraday's law of electromagnetic induction, a time-varying magnetic field produces an induced emf. According to Maxwell, a time-varying electric field sets up a current and hence a magnetic field. Such a current is called displacement current. It follows that a time-varying electric field produces a magnetic field and vice-versa. Hence the behaviours of electric and magnetic fields are symmetrical.
18. Here $H = 1500 \text{ Am}^{-1}$, $\phi = 2.4 \times 10^{-5} \text{ Wb}$, $A = 0.5 \times 10^{-4} \text{ m}^2$
 Magnetic induction,

$$B = \frac{\phi}{A} = \frac{2.4 \times 10^{-5}}{0.5 \times 10^{-4}} = 0.48 \text{ Wbm}^{-2}$$
 Permeability,

$$\mu = \frac{B}{H} = \frac{0.48}{1500} = 3.2 \times 10^{-4} \text{ TmA}^{-1}$$
 As $\mu = \mu_0 (1 + \chi_m)$

∴ Susceptibility,

$$\chi_m = \frac{\mu}{\mu_0} - 1 = \frac{3.2 \times 10^{-4}}{4 \times 3.14 \times 10^{-7}} - 1$$

$$= 254.77 - 1 = 253.77$$

19. Here $n_e = 8 \times 10^{13} \text{ cm}^{-3}$, $n_h = 5 \times 10^{12} \text{ cm}^{-3}$, $\mu_e = 23,000 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$, $\mu_h = 100 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$

i. As $n_e > n_h$, the semiconductor must be n-type.

ii. Resistivity,

$$\rho = \frac{1}{e(n_e \mu_e + n_h \mu_h)}$$

$$= \frac{1}{1.6 \times 10^{-19} (8 \times 10^{13} \times 23 \times 10^3 + 5 \times 10^{12} \times 10^2)} \Omega \text{ cm}$$

$$= \frac{1}{1.6 \times 10^{-19} (184 \times 10^{16} + 5 \times 10^{14})} \Omega \text{ cm}$$

$$= \frac{1}{1.6 \times 10^{-5} \times 18405} \Omega \text{ cm} = 3.395 \Omega \text{ cm}$$

20. Here $K = 5 \text{ MeV} = 5 \times 1.6 \times 10^{-13} \text{ J}$, $\theta = 90^\circ$, $Z = 79$

Impact parameter

$$b = \frac{kZe^2 \cot \frac{\theta}{2}}{K}$$

$$= \frac{9 \times 10^9 \times 79 \times (1.6 \times 10^{-19})^2 \cot 45^\circ}{5 \times 1.6 \times 10^{-13}}$$

$$= 2.27 \times 10^{-14} \text{ m}$$

21. $N=100$ turns and radius= 0.20 cm .The plane of the coil is XY plane and the field point is on the Z-axis.

∴ The magnetic field on the axial point B = $\frac{\mu_0 I R^2 N}{2(R^2 + z^2)^{3/2}}$

$$= \frac{4\pi \times 10^{-7} \times \frac{2}{\pi} \times (0.2)^2 \times 100}{2[(0.2)^2 + (0.2\sqrt{3})^2]^{3/2}}$$

$$= \frac{8 \times 0.04 \times 10^{-7} \times 100}{2 \times 0.04 \times 8 \times 0.2}$$

$$= 25 \mu\text{T}$$

OR

a. Total resistance in the circuit is, $R_G = 60.00 \Omega$. Hence, $I = e/(r + g) = \frac{3}{63} = 0.048 \text{ A}$

b. The resistance of the galvanometer converted to an ammeter is, $\frac{R_G r_s}{R_G + r_s} = \frac{60 \Omega \times 0.02 \Omega}{(60 + 0.02) \Omega} = 0.02 \Omega$

The total resistance in the circuit is, $0.02 \Omega + 3 \Omega = 3.02 \Omega$. Hence, total current is given by $I = \frac{3}{3.02} = 0.99 \text{ A}$

c. For the ideal ammeter with zero resistance, $I = \frac{3}{3} = 1.00 \text{ A}$

Section C

22. Applying kirchoff law:

Considering the loop BADB, we have

$$100I_1 + 15I_g - 60I_2 = 0$$

$$\text{or } 20I_1 + 3I_g - 12I_2 = 0 \text{ [(a)]}$$

Considering the loop BCDB, we have

$$10(I_1 - I_g) - 15I_g - 5(I_2 + I_g) = 0$$

$$10I_1 - 30I_g - 5I_2 = 0$$

$$2I_1 - 6I_g - I_2 = 0 \text{ [(b)]}$$

Considering the loop ADCEA,

$$60I_2 + 5(I_2 + I_g) = 10$$

$$65I_2 + 5I_g = 10$$

$$13I_2 + I_g = 2 \text{ [(c)]}$$

Multiplying Eq. (b) by 10

$$20I_1 - 60I_g - 10I_2 = 0 \text{ [(d)]}$$

From Eqs. (d) and (a) we have

$$63I_g - 2I_2 = 0$$

$$I_2 = 31.5I_g \text{ [(e)]}$$

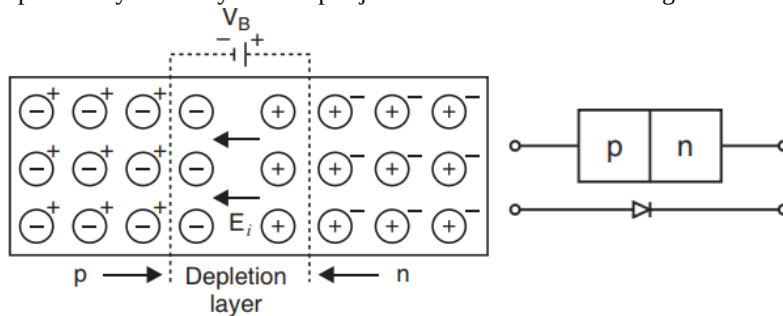
Substituting the value of I_2 into Eq. [(c)], we get

$$13(31.5I_g) + I_g = 2$$

$$410.5 I_g = 2$$

$$I_g = 4.87 \text{ mA.}$$

23. At the junction there is diffusion of charge carriers due to thermal agitation; so that some of electrons of n-region diffuse to p-region while some of holes of p-region diffuse into n-region. Some charge carriers combine with opposite charges to neutralise each other. Thus near the junction there is an excess of positively charged ions in n-region and an excess of negatively charged ions in p-region. This sets up a potential difference called potential barrier and hence an internal electric field E_i across the junctions. The field E_i is directed from n-region to p-region. This field stops the further diffusion of charge carriers. Thus the layers ($\approx 10^{-4}$ cm to 10^{-6} cm) on either side of the junction becomes free from mobile charge carriers and hence is called the depletion layer. The symbol of p-n junction diode is shown in Fig.



24. a. Here, $v = 5.20 \times 10^6 \text{ ms}^{-1}$, $B = 1.30 \times 10^{-4} \text{ T}$, $\frac{e}{m} = 1.76 \times 10^{11} \text{ Ckg}^{-1}$, $\theta = 90^\circ$

Force exerted by the magnetic field on the electron

$$F = e|\vec{v} \times \vec{B}| = evB \sin \theta = evB \quad (\because \sin 90^\circ = 1)$$

since, the normal magnetic field provides the centripetal force, this gives (condition For the electron to move in a circle)

$$\therefore evB = \frac{mv^2}{r} \text{ or } r = \frac{mv}{eB} = \frac{v}{(e/m)B} = \frac{5.20 \times 10^6}{1.76 \times 10^{11} \times 1.30 \times 10^{-4}} = 0.27 \text{ m} = 27.7 \text{ cm}$$

b. Energy,

$$E = 20 \text{ MeV} = 20 \times 1.6 \times 10^{-13} \text{ J} = \frac{1}{2}mv^2 \therefore v = \left(\frac{2 \times 20 \times 1.6 \times 10^{-13}}{9 \times 10^{-31}} \right)^{1/2} = 2.67 \times 10^9 \text{ m/s}$$

Which is greater than the velocity of light.

Therefore the formula $r = \frac{mv}{eB}$ is not valid for calculating the radius of the path of 20 MeV electron beam because electron with such high energy has a velocity in the relativistic domain (ie. comparable with the velocity of light, For this, we use relativistic formula as follows.

$$r = \frac{mv}{eB} = \left(\frac{m_0}{\sqrt{1-v^2/c^2}} \right) \frac{v}{eB}$$

25. In nuclear fission reactors, the neutrons must be slowed down to ensure an effective fission chain reaction occurs. This process of slowing neutrons down is known as moderation. The moderator is used in nuclear reactor to reduce the velocity of neutrons so that it can break the uranium nucleus. Heavy water which has heavy hydrogen is very suitable moderator. The moderator is most effective in slowing down the speed of neutrons when its nuclear mass is of the order of mass of neutron.

This is because if the nucleus is too heavy then neutron after collision with it returns back with the same speed. If the nucleus is too light then neutron will move forward with almost same speed. If their masses are of the same order (which is in case of heavy water) then they will exchange their speed and neutron will get the thermal speed of deuterons.

26. For a circular orbit of the electron, $\frac{mv^2}{r} = \frac{kZe \cdot e}{r^2} = \frac{kZe^2}{r^2}$

$$\text{or } mv^2 = \frac{kZe^2}{r}$$

$$\text{or } r = \frac{kZe^2}{mv^2} \dots\dots\dots(\text{i})$$

Using Bohr's quantization condition for angular momentum,

$$L = mvr = \frac{nh}{2\pi}$$

$$\text{or } r = \frac{nh}{2\pi mv} \dots\dots\dots(\text{ii})$$

From (i) and (ii),

$$\frac{kZe^2}{mv^2} = \frac{nh}{2\pi mv}$$

$$\text{or } v = \frac{2\pi kZe^2}{nh}$$

$$\therefore r = \frac{nh}{2\pi m} \cdot \frac{nh}{2\pi kZe^2}$$

$$= \frac{n^2 h^2}{4\pi^2 m k Z e^2}$$

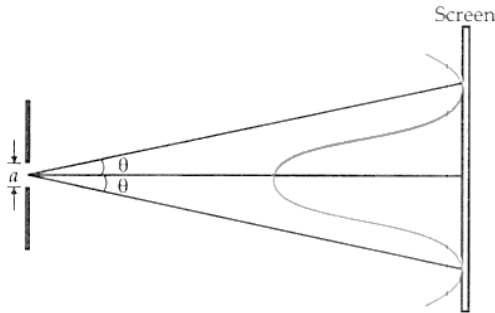
$$\text{Bohr's radius, } r_0 = \frac{h^2}{4\pi^2 m k e^2} [n = 1, Z = 1]$$

As $r \propto n^2$ the graph of r versus n is a parabola as shown in Fig.

27. In single slit diffraction, first minimum occurs at

$$a \sin \theta = \lambda \text{ or } \sin \theta = \frac{\lambda}{a}$$

$$\text{As } \lambda \ll a, \text{ so } \theta \simeq \sin \theta = \frac{\lambda}{a}$$



The angular width of the central maximum is

$$\phi = 2\theta = \frac{2\lambda}{a}$$

$$\therefore \frac{\phi_2}{\phi_1} = \frac{\lambda_2}{\lambda_1}$$

$$\text{or } \lambda_2 = \frac{\phi_2}{\phi_1} \cdot \lambda_1 = \frac{70}{100} \times 6000 = 4200 \text{ \AA} [\because \phi_2 = 70\% \text{ of } \phi_1]$$

When the apparatus is immersed in the liquid, the decrease in angular width is the same. This indicates that the wavelength of light in the liquid is also 4200 \AA.

$$\mu = \frac{\lambda}{\lambda_l} = \frac{6000}{4200} = 1.43$$

28. i. Suppose a rod of length 'l' moves with velocity v inward in the region having uniform magnetic field B .

Initial magnetic flux enclosed in the rectangular space is $\phi = |B|lx$

As the rod moves with velocity $-v = \frac{dx}{dt}$

Using Lenz's law,

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(Blx) = Bl \left(-\frac{dx}{dt} \right)$$

$$\therefore \varepsilon = Blv$$

ii. Suppose any arbitrary charge 'q' in the conductor of length 'l' moving inward in the field as shown in figure, the charge q also moves with velocity v in the magnetic field B .

The Lorentz force on the charge 'q' is $F = qvB$ and its direction is downwards.

So, work done in moving the charge 'q' along the conductor of length l

$$W = F.l$$

$$W = qvBl$$

Since emf is the work done per unit charge

$$\therefore \varepsilon = \frac{W}{q} = Blv$$

This equation gives emf induced across the rod.

OR

This is the similar problem as we discussed above. Here, a conductor of length d moves with speed v , perpendicular to the magnetic field B as shown in figure. Due to this a motional emf is induced across two ends of rod ($\varepsilon = vBd$). since, switch S is closed at time $t = 0$, capacitor is charged by this potential difference. Let $Q(t)$ be the charge on the capacitor and current flows from A to B . Now, the induced current

$$I = \frac{dQ}{dt} = \frac{Bvd}{R} - \frac{Q}{RC}$$

$$\frac{Q}{RC} + \frac{dQ}{dt} = \frac{Bvd}{R}$$

$$Q + RC \frac{dQ}{dt} = vBdC \text{ (Let } vBdC = A) \dots (1)$$

$$Q + RC \frac{dQ}{dt} = A$$

$$\frac{dQ}{A-Q} = \frac{1}{RC} dt$$

By integrating we have

$$\int_0^Q \frac{dQ}{A-Q} = \frac{1}{RC} \int_0^t dt = -[\ln(A-Q) - \ln A] = \frac{t}{RC}$$

$$\ln \frac{A-Q}{A} = -\frac{t}{RC}$$

$$\frac{A-Q}{A} = e^{-t/RC} \text{ (by taking exponential on both sides)}$$

$$Q = A(1 - e^{-t/RC})$$

Current in the rod is given by :-

$$I = \frac{dQ}{dt} = \frac{d}{dt} [A(1 - e^{-t/RC})]$$

$$= -A(e^{-t/RC}) \left(-\frac{1}{RC}\right) \text{ thus from 1st equation}$$

$$I = \frac{vBd}{R} e^{-t/RC}$$

Section D

29. Read the text carefully and answer the questions:

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths.

Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

- (i) **(d)** infrared waves

Explanation: Infrared rays can be converted into electric energy as in solar cell.

- (ii) **(c)** radiowaves

Explanation: Radiowaves have longest wavelength.

- (iii) **(d)** cathode rays

Explanation: Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

OR

- (c)** microwave, infrared, ultraviolet, gamma rays

Explanation: $\lambda_{\text{micro}} > \lambda_{\text{infra}} > \lambda_{\text{ultra}} > \lambda_{\text{gamma}}$

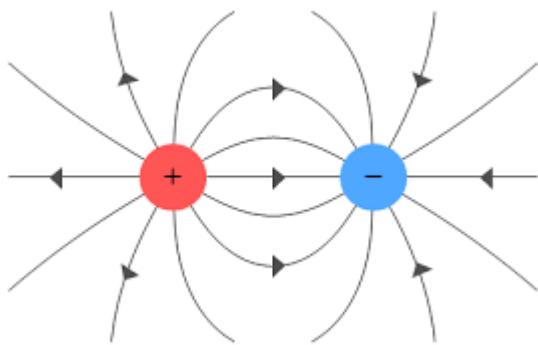
- (iv) **(d)** γ -rays

Explanation: γ -rays have minimum wavelength.

30. Read the text carefully and answer the questions:

Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field.

There are two types of charges positive and negative charges. Also, like charges repel each other whereas unlike charges attract each other.



- (i) **(a)** $-3.2 \times 10^{-17} \text{ C}$

Explanation: $-3.2 \times 10^{-17} \text{ C}$

- (ii) **(d)** $-1.6 \times 10^{-18} \text{ C}$

Explanation: $-1.6 \times 10^{-18} \text{ C}$

- (iii) **(c)** $9.1 \times 10^{-31} \text{ kg}$

Explanation: $9.1 \times 10^{-31} \text{ kg}$

- (iv) **(c)** Option (ii)

Explanation: there is positive as well as negative charge in the body but the positive charge is more than a negative charge

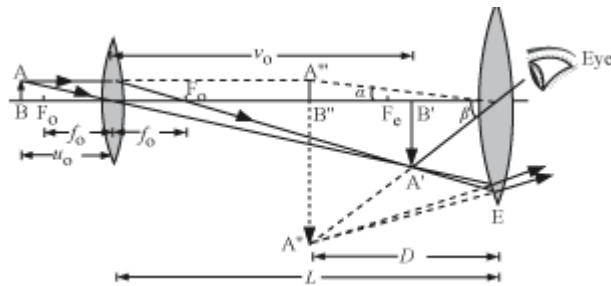
OR

(d) valence electrons only

Explanation: valence electrons only

Section E

31. a.



where AB = object, A'B' = image formed by objective, A''B'' = image formed by eyepiece

L is the separation between the eyepiece and the objective,

f_o is the focal length of the objective,

f_e is the focal length of the eyepiece,

D is the least distance for clear vision

b. For the least distance of clear vision, the total magnification is given by:

$$m = -\frac{L}{f_o} \left(1 + \frac{D}{f_e} \right) = m_o \cdot m_e \dots (i)$$

Also, the given magnification for the eyepiece:

$$m_e = 5 = \left(1 + \frac{D}{f_e} \right)$$

$$\Rightarrow 5 = 1 + \frac{20}{f_e}$$

$$\Rightarrow f_e = 5 \text{ cm}$$

Substituting the value of m and m_e in equation (i), we get:

$$m = m_o \cdot m_e$$

$$\Rightarrow m_o = \frac{m}{m_e} = \frac{20}{5} = 4$$

Now, we have:

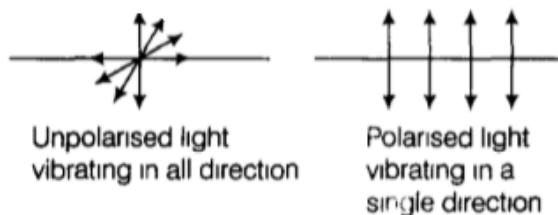
$$m_o = \frac{L}{|f_o|}$$

$$\Rightarrow f_o = \frac{14}{4} = 3.5 \text{ cm}$$

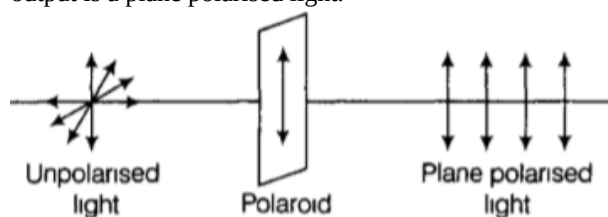
OR

i. In a beam of unpolarized light, the vibrations of light vectors are in all directions in a plane perpendicular to the direction of propagation.

In the linearly polarised light, the vibrations of light take place in a particular direction, perpendicular to the direction of wave motion.



Polaroid is a special crystalline solid which contains a special axis called the optic axis. When we make an unpolarised light to fall on a polaroid. Only vibration parallel to optic axis is allowed to pass through and all other vibration are cut. Thus, the output is a plane polarised light.



ii. Intensity coming out of a single polaroid is half of the incident intensity so, the intensity of transmitted light from polaroid P_1 , $I = \frac{I_0}{2}$

By using law of Malus,

the intensity of emergent light from polaroid P_2 is

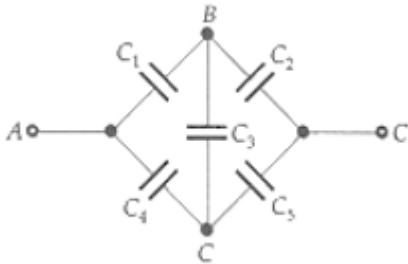
$$I' = I \cos^2 \theta$$

where, θ = angle between P_1 and P_2 .

Intensity of light after transmission from polaroid is

$$\begin{aligned} I' &= I \cos^2 \theta = \frac{I_0}{2} \times (\cos 60^\circ)^2 \\ &= \frac{I_0}{2} \times \left(\frac{1}{2}\right)^2 = \frac{I_0}{8} \end{aligned}$$

32. The given circuit can be redrawn in the form of a Wheatstone bridge as shown in Fig.

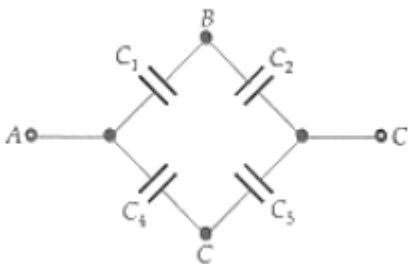


As $C_1 = C_2 = C_4 = C_5$

$$\text{Therefore, } \frac{C_1}{C_2} = \frac{C_4}{C_5}$$

Thus the given circuit is a balanced Wheatstone bridge. So the potential difference across the ends of the capacitor C_3 is zero.

Capacitance C_3 is ineffective. The given circuit reduces to the equivalent circuit shown in Fig.



Capacitors C_1 and C_2 form a series combination of equivalent capacitance C_6 given by

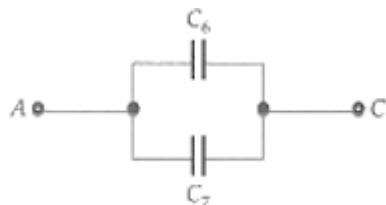
$$C_6 = \frac{C_1 \times C_2}{C_1 + C_2} = \frac{10 \times 10}{10 + 10} = 5 \mu\text{F}$$

Similarly, C_4 and C_5 form a series combination of equivalent capacitance C_7 given by

$$C_7 = \frac{C_4 \times C_5}{C_4 + C_5} = \frac{10 \times 10}{10 + 10} = 5 \mu\text{F}$$

As shown in Fig. (b), C_6 and C_7 form a parallel combination. Hence the equivalent capacitance of the network is given by

$$C = C_6 + C_7 = 5 + 5 = 10 \mu\text{F}$$



OR

After disconnection from battery and doubling the separation(d) between the two plates of the given capacitor,

i. Charge on capacitor remains same.

i.e, $CV = C'V'$ (where C , V , C' , V' are the initial capacitance, initial potential difference, final capacitance and final voltage respectively)

$$\Rightarrow CV = \left(\frac{C}{2}\right) V' \Rightarrow V' = 2V \text{ (since } C \propto \frac{1}{d}, \text{ that's why } C' = C/2)$$

Final electric field between the plates

$$E' = \frac{V'}{d'} = \frac{2V}{2d}$$

$$E' = \frac{V}{d} = E = \text{initial electric field}$$

Electric field between the two plates remains same.

ii. Capacitance reduces to half of original value as

$$C \propto \frac{1}{d} \Rightarrow C' = \frac{C}{2}$$

iii. Energy stored in the capacitor before disconnection from battery. Initial stored energy,

$$U_1 = \frac{q^2}{2C}$$

Now, energy stored in the capacitor when distance between the plates doubled is

$$U_2 = \frac{q^2}{2(C')} = \frac{q^2}{2 \times \left(\frac{C}{2}\right)} = \frac{q^2}{C}$$

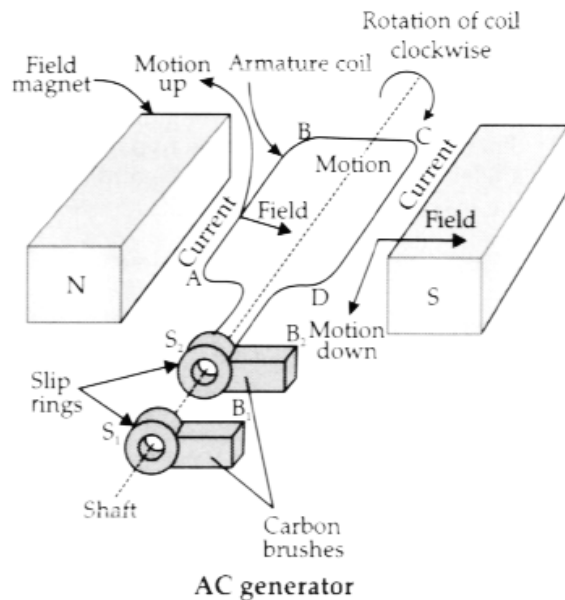
$$\Rightarrow U_2 = 2 \left(\frac{q^2}{2C} \right) = 2U_1 \quad \therefore U_2 = 2U_1$$

Hence, final energy stored in capacitor gets doubled to its initial value.

33. i. AC generator: it converts mechanical energy into the alternating form of electrical energy.

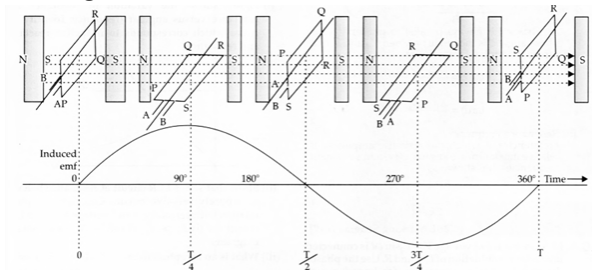
Basic elements of an AC generator:

- Rectangular coil: Also called as an armature
- Strong permanent magnets: The magnetic field is perpendicular to the axis of rotation of the coil.
- Slip rings
- Brushes



Principle: It is based on the principle of electromagnetic induction. That is, when a coil is rotated about an axis perpendicular to the direction of the uniform magnetic field, an induced emf is produced across it.

Working of AC Generator



ii.

- The capacitor stores energy in the form of an electric field and the inductor stores energy in the form of a magnetic field.
- Oscillation becomes damped due to :
 - The resistance of the circuit
 - Radiation in the form of EM waves

OR

i.



$$\text{Induced emf, } e = -L \frac{dI}{dt}$$

Hence, Net voltage in the circuit

$$= V - L \frac{dI}{dt}$$

According to Kirchhoff's Rule

$$V - L \frac{dI}{dt} = 0$$

$$V_m \sin \omega t = L \frac{dI}{dt}$$

$$dI = \frac{V_m}{L} \sin \omega t dt$$

$$I = -\frac{V_m}{\omega L} \cos \omega t$$

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

$$\therefore I = I_m \sin \left(\omega t - \frac{\pi}{2} \right)$$

Hence current lags by $\frac{\pi}{2}$

ii. $L = 100 \text{ mH}$ inductance of the inductor is given by $X_L = 2\pi\omega L$ and $X_L = R = 2\pi\omega L$

$$= 2 \times \frac{22}{7} \times 50 \times 100 \times 10^{-3} = 10\pi = 31.4\Omega \text{ also Average power dissipation,}$$

$$P = V_{\text{rms}} I_{\text{rms}} \cos \phi$$

$$= 10 \times 1 \times \cos \frac{\pi}{4}$$

$$= \frac{10}{\sqrt{2}} \text{ W}$$

$$= 5\sqrt{2} \text{ Watts or (7.05 W)}$$