Solved Paper 2023
Physics
Class-XII

Time : 3 Hours **Max. Marks : 70**

General Instructions :

Read the Following Instructions very carefully and follow them :

*(i) This question paper contains **35** questions. **All** questions are compulsory.*

*(ii) Question paper is divided into **FIVE** Sections— Section **A, B, C, D** and **E**.*

*(iii) **In section — A:** question number **1** to **18** are Multiple Choice (MCQ) type questions carrying **1** mark each.*

*(iv) **In section — B:** question number **19** to **25** are Short Answer-1 (SA-1) type questions carrying **2** marks each.*

*(v) **In section — C:** question number **26** to **30** are Short Answer-2 (SA-2) type questions carrying 3 marks each.*

*(vi) **In section — D:** question number **31** to **33** are Long Answer (LA) type questions carrying **5** marks each.*

*(vii) **In section — E:** question number **34** and **35** are case-based questions carrying **4** marks each.*

*(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section—**B**, 2 questions in Section — **C**, 3 questions in Section — **D** and 2 questions in Section—**E**.*

(ix) Use of calculators is NOT allowed.

$$c = 3 \times 10^8 \text{ m/s}$$
$$h = 6.63 \times 10^{-34} \text{ Js}$$
$$e = 1.6 \times 10^{-19} \text{ C}$$
$$\mu_o = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$
$$\varepsilon_o = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$
$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

Mass of electron $= 9.1 \times 10^{-31}$ kg

Mass of Neutron $= 1.675 \times 10^{-27}$ kg

Mass of Proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

Delhi Set-1 **55/5/1**

SECTION - A

1. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3} Nm, the magnitude of either charge of the dipole, is

(A) 4 μC **(B)** 7μC

(C) 8 mC **(D)** 2 mC

Ans. Option (A) is correct.

Explanation:

$$\theta = 30°$$
$$E = 2 \times 10^5 \text{ N/C}$$

$$\tau = 8 \times 10^{-3}\text{ Nm}$$
$$l = 2\text{ cm} = 2 \times 10^{-2}\text{ m}$$
$$\tau = pE\sin\theta \quad [p = ql]$$
$$\therefore \quad \tau = qlE\sin\theta$$
Or, $$q = \frac{\tau}{lE\sin\theta}$$
Or, $$q = \frac{8\times10^{-3}}{2\times10^{-2}\times2\times10^{5}\times\sin 30°}$$
$$\therefore \quad q = 4\mu C$$

2. Two long parallel wires kept 2 m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is

(A) 4.5×10^{-7} Nm^{-1}, attractive
(B) 4.5×10^{-7} N/m, repulsive
(C) 9×10^{-7} N/m, repulsive
(D) 9×10^{-7} N/m, attractive **1**

Ans. Option (D) is correct

Explanation:
$$i_1 = i_2 = 3\text{A}$$
$$r = 2\text{m}$$
$$F/l = \frac{\mu_0}{2\pi}\times\frac{i_2 i_2}{r}$$
$$\left[\frac{\mu_0}{2\pi} = 2\times10^{-7} N_A^{-2}\right]$$
Or, $$F/l = 2\times10^{-7}\times\frac{3\times3}{2}$$
$$\therefore \quad F/l = 9 \times 10^{-7}\text{ N}$$
Force per unit length $= 9.0 \times 10^{-7}$ N/m

Since, the currents are in same direction so there would be an attractive force between them.

3. Which of the following has its permeability less than that of free space?

(A) Copper **(B)** Aluminium
(C) Copper chloride **(D)** Nickel **1**

Ans. Option (A) is correct

Explanation: $\mu_r < 1$ for diamagnetic substance. Copper is diamagnetic substance.

4. A square shaped coil of side 10 cm, having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is

(A) 0.1 V **(B)** 0.5 V
(C) 0.75 V **(D)** 1.0 V **1**

Ans. Option (D) is correct.

Explanation:
$$N = 100$$
$$A = \frac{1}{10}\times\frac{1}{10}\text{m}^2$$
$$\frac{dB}{dt} = 1.0\text{ Ts}^{-1}$$
$$\text{emf} = \text{NA}\frac{dB}{dt}$$
$$\therefore \quad \text{emf} = 100\times\frac{1}{10}\times\frac{1}{10}\times1$$
$$= 1\text{ V}$$

5. Which one of the following electromagnetic radiation has the least wavelength?

(A) Gamma rays **(B)** Microwaves
(C) Visible light **(D)** X-rays **1**

Ans. Option (A) is correct.

Explanation: Wavelength of Gamma rays < 10^{-3} nm
Wavelength of Microwave: 1 mm – 0.1m
Wavelength of Visible light: 400nm – 700 nm
Wavelength of X-Rays: 10^{-3} nm – 1 nm

6. In a Young's double-slit experiment, the screen is moved away from the plane of the slits. What will be its effect on the following?

(i) Angular separation of the fringes.
(ii) Fringe-width.

(A) Both (i) and (ii) remain constant.
(B) (i) remains constant, but (ii) decreases.
(C) (i) remains constant, but (ii) increases.
(D) Both (i) and (ii) increase. **1**

Ans. Option (C) is correct.

Explanation: Angular separation is independent of distance of screen from slits.
Fringe width is proportional to the distance of screen from slits.

7. The energy of a photon of wavelength λ is

(A) $hc\lambda$ **(B)** hc/λ
(C) λ/hc **(D)** $\lambda h/c$ **1**

Ans. Option (B) is correct.

Explanation: Energy of photon,
$$E = h\nu$$
But $$\nu = \frac{c}{\lambda}$$
So, $$E = \frac{hc}{\lambda}$$

8. The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is

(A) $\frac{64}{125}$ **(B)** $\frac{4}{5}$
(C) $\frac{5}{4}$ **(D)** 1 **1**

Ans. Option (D) is correct.

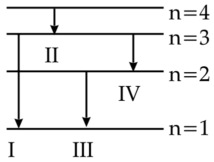
Explanation: Nuclear density is independent of mass number.

9. During the formation of a *p-n* junction:

(A) diffusion current keeps increasing.
(B) drift current remains constant.
(C) both the diffusion current and drift current remain constant.
(D) diffusion current remains almost constant but drift current increases till both currents become equal. **1**

Ans. Option (D) is correct.

10. The diagram shows four energy level of an electron in Bohr model of hydrogen atom. Identify the transition in which the emitted photon will have the highest energy.

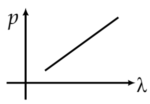


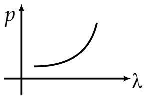
(A) I **(B)** II
(C) III **(D)** IV **1**

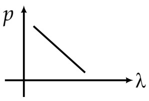
Ans. Option (A) is correct.

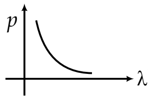
Explanation: Difference of energy level is highest in transition I.

11. Which of the following graphs correctly represents the variation of a particle momentum with its associated de-Broglie wavelength?

(A) 

(B) 

(C) 

(D) 

1

Ans. Option (D) is correct.

Explanation: $\lambda \propto \frac{1}{p}$

12. The capacitors, each of 4 μF are to be connected in such a way that the effective capacitance of the combination is 6 μF. This can be achieved by connecting

(A) All three in parallel
(B) All three in series
(C) Two of them connected in series and the combination in parallel to the third.
(D) Two of them connected in parallel and the combination in series to the third. **1**

Ans. Option (C) is correct.

Explanation: When two 4μF capacitors are joined in series, the equivalent capacitance becomes 2μF.

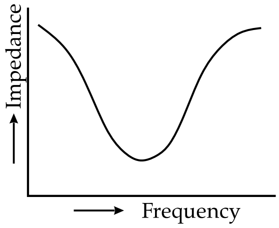
When this combination is joined in parallel with another 4μF capacitor, the effective capacitance becomes 6μF.

13. Which of the following statements about a series LCR circuit connected to an ac source is correct?

(A) If the frequency of the source is increased, the impedance of the circuit first decreases and then increases.
(B) If the net reactance (X_L - X_C) of circuit becomes equal to its resistance, then the current leads the voltage by 45°.
(C) At resonance, the voltage drop across the inductor is more than that across the capacitor.
(D) At resonance, the voltage drop across the capacitor is more than that across the inductor. **1**

Ans. Option (A) is correct.

Explanation: Frequency vs. impedance graph of a series LCR circuit connected to an ac source is shown below:



It is clear from the graph that the impedance first decreases and then increases with increase of frequency.

14. According to Huygens principle, the amplitude of secondary wavelets is

(A) equal in both the forward and the backward directions.
(B) maximum in the forward direction and zero in the backward direction.
(C) large in the forward direction and small in the backward direction.
(D) **s**mall in the forward direction and large in the backward direction. **1**

Ans. Option (B) is correct.

Explanation: Voiget and Kirchhoff mathematically proved that amplitude of secondary wavelets is proportional to $\frac{1}{2}(1+\cos\theta)$. In backward direction, $\theta = \pi$. Hence, amplitude is zero in backward direction.

15. The radius of the nth orbit in Bohr model of hydrogen atom is proportional

(A) n^2 **(B)** $\frac{1}{n^2}$
(C) n **(D)** $\frac{1}{n}$ **1**

Ans. Option (A) is correct.

Explanation: $r_n \propto n^2/Z$

Note: In question number 16 to 18 two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(A) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A).
(B) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).
(C) Assertion (A) is true and Reason (R) is false.
(D) Assertion (A) is false and Reason (R) is also false.

16. Assertion (A): The resistance of an intrinsic semiconductor decreases with increase in its temperature.

Reason (R): The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature. **1**

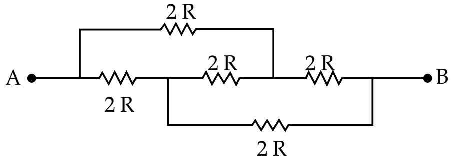
Ans. Option (A) is correct.

Explanation: In semiconductors, as temperature increases, thermally generated electron and hole pair increases and the resistance decreases.

Hence, assertion and reason both are correct and the reason explains the assertion.

17. Assertion (A): The equivalent resistance between points A and B in the given network is 2R.

Reason (R): All the resistors are connected in parallel **1**



Ans. Option (C) is correct.

Explanation: The given resistance network represents in the bridge balance condition, so the equivalent resistance between A and B will be 2R, Hence assertion (A) is correct but Reason (R) is false because all resistances are not in parallel.

18. Assertion (A): The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.

Reason (R): The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$. **1**

Ans. Option (C) is correct.

Explanation: $\tau = NBIA\sin\theta$

θ is the angle between the area vector and the direction of magnetic field.

If the plane of loop is perpendicular to the electric field, then the angle between the area vector and the direction electric field is 0^0. Hence, $\tau = 0$.

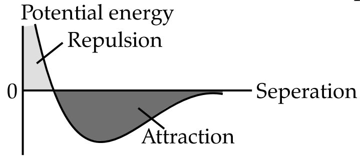
So, the assertion is true.

The torque is the cross product of the magnetic moment of the loop and the magnetic field. Hence the reason is false.

SECTION - B

19. Draw a graph showing the variation of potential energy of a pair of nucleons as a function of their separation. Indicate the region in which the nuclear force is (a) attractive and (b) repulsive. **2**

Ans. Graph showing variation of potential energy of a pair of nucleons as a function of their seperation:



20. (a) How will the De Broglie wavelength associated with an electron be affected when the (i) velocity of the electron decreases ? and (ii) accelerating potential is increased? Justify your answer. **2**

OR

(b) How would the stopping potential for a given photosensitive surface change if (i) the frequency of the incident radiation were increased? and (ii) the intensity of incident radiation were decreased? Justify your answer. **2**

Ans. (a) (i) From De Broglie equation $\lambda = \dfrac{h}{mv}$

As velocity (v) decreases, the wavelength (λ) increases.

(ii) $$\lambda = \frac{h}{\sqrt{2meV}}$$

As accelerating potential (V) increases, wavelength (λ) decreases.

OR

(b) (i) From Einstein's photoelectric equation,

$$hv = \phi_0 + \text{KE}$$

$\text{KE} = eV_s$, where V_S is the stopping potential.

(i) Stopping potential depends on the frequency of the incident radiation. If frequency increases KE increases (Since, ϕ_0 remains constant). Hence, stopping potential increases.

(ii) There is no intensity term in Einstein's equation. Hence, stopping potential is independent of intensity of incident radiation.

21. Identify the electromagnetic wave whose wavelengths range is from about

(a) 10^{-12} m to about 10^{-8} m.

(b) 10^{-3} m to about 10^{-1} m.

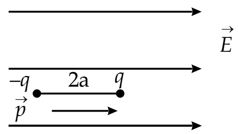
Write one use of each. **2**

Ans. (a) X-Ray. Used as diagnostic tool in medical science.

(b) Microwave. Use in radar system.

22. Depict the orientation of an electric dipole in (a) stable and (b) unstable equilibrium in an external uniform electric field. Write the potential energy of the dipole in each case. **2**

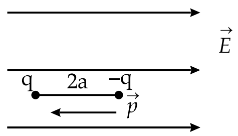
Ans. (a) Stable equilibrium: When angle between $\vec{p}$ and $\vec{E}$ is 0^0.



Potential energy of dipole = $-p\text{E}\cos\theta$

In this case $\theta = 0^0$, so Potential energy = $-p\text{E}$

(b) Unstable equilibrium: When angle between $\vec{p}$ and $\vec{\text{E}}$ is 180^0.



Potential energy of dipole = $-p\text{E}\cos\theta$

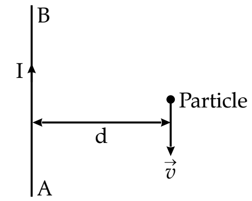
In this case $\theta = 180^0$, so Potential energy = $p\text{E}$

23. (a) Write the expression for the Lorentz force on a particle of charge q moving with a velocity $\vec{v}$ in a magnetic field $\vec{\text{B}}$. When is the magnitude of this force maximum? Show that no work is done by this

force on the particle during its motion from a point $\vec{r_1}$ to point $\vec{r_2}$. **2**

OR

(b) A long straight wire AB carries a current I. A particle (mass m and charge q) moves with a velocity $\vec{v}$, parallel to the wire, at a distance d from it as shown in the figure. Obtain the expression for the force experienced by the particle and mention its directions. **2**



Ans. (a) Expression for Lorentz force:

$$\vec{F} = q(\vec{v} \times \vec{B})$$

The force is maximum when the angle between $\vec{v}$ and $\vec{B}$ is 90^0.

Here, $\vec{F}$ is perpendicular to $\vec{v}$. So, no work is done by this force on the particle during its motion

OR

(b) Magnetic field produced by the current carrying from a point $\vec{r_1}$ to point $\vec{r_2}$ wire, $B = \frac{\mu_0 I}{2\pi d}$

The direction of field is ⊗

Force acting on the particle $= q(\vec{v} \times \vec{B})$

Here, $\theta = 90°$

So, Force $= qvB = \frac{\mu_0}{2\pi}\frac{qv}{d}I$

Its direction is towards right. Repulsive.

24. The potential difference applied across a given conductor is doubled. How will this affect (i) the mobility of electrons and (ii) the current density in the conductor? Justify your answers. **2**

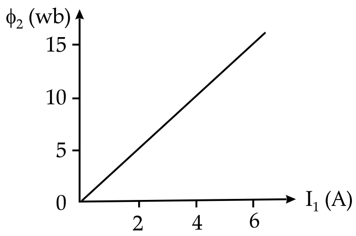
Ans. (i) Mobility ∝ 1/Potential difference

So, if potential difference is doubled, mobility will be halved.

(ii) Current density ∝ Potential difference

So, if potential difference is doubled, current density will also be double.

25. Two coils C_1 and C_2 are placed close to each other. The magnetic flux ϕ_2 linked with the coil C_2 varies with the current I_1 flowing in coil C_1, as shown in the figure. Find



(i) the mutual inductance of the arrangement, and

(ii) the rate of change of current $\left(\frac{dI_1}{dt}\right)$ that will induce an emf of 100 V in coil C_2. **2**

Ans. (i) Since, $N_2\phi_2 = MI_1$

From graph, $\phi_2 = 10$Wb corresponding to $I_1 = 4$A and $\phi_2 = 10$Wb

$\therefore \quad N_2 \times 10 = M \times 4$

Considering $N_2 = 1$

$$M = \frac{10}{4} = 2.5\text{H}$$

(ii) Again, $N_2\phi_2 = MI_1$

Or, $\frac{d}{dt}(N_2\phi_2) = \frac{d}{dt}(MI_1)$

Or, $N_2\frac{d\phi_2}{dt} = M\frac{dI_1}{dt}$

Considering $N_2 = 1$

$$\varepsilon = M\frac{dI_1}{dt}$$

or, $100 = 2.5 \times \frac{dI_1}{dt}$

$\therefore \quad \frac{dI_1}{dt} = 40$ A/s

SECTION - C

26. (a) A plane wave-front propagating in a medium of refractive index 'μ_1' is incident on a plane surface making an angle of incidence (i). It enters into a medium of refractive index μ_2 ($\mu_2 > \mu_1$).

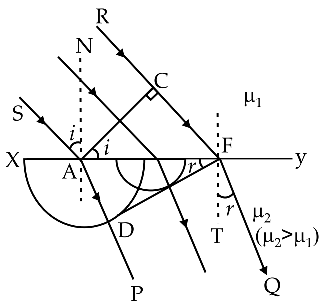
Use Huygen's construction of secondary wavelets to trace the retracted wave-front. Hence, verify Snell's law of refraction. **3**

OR

(b) Using Huygen's construction, show how a plane wave is reflected from a surface. Hence, verify the law of reflection. **3**

Ans. (a) A plane wavefront AC is incident on the plane of separation XY of two media of refractive indices μ_1 and μ_2 ($\mu_2 > \mu_1$) making an angle i. This is known as angle of incidence.

When the wavefront touches the point A, the point becomes a source of secondary wavelets. Thus, when the whole waveform passes through the XY plane, each point of AF becomes the source of secondary wavelets.



When point C of the wavefront in medium 1 traverses CF distance by that time (t) the wavelet from point A traverses AD distance. If v_1 and v_2 are the speeds of light in medium 1 and 2 respectively, then $AD = v_2t$ and $CF = v_1t$.

Refracted wavefront DF which is obtained by drawing a tangent to the arc having radius v_2t and centre A. The angle made by the tangent with the plane XY is r. This is known as angle of refraction.

The perpendiculars drawn on wavefront AC are the incident rays. The perpendiculars drawn on wavefront DF are the refracted rays.

AN and TF are the perpendiculars drawn on XY, the plane of separation of the two media.

$\angle CAF = \angle i = 90° - \angle NAC = 90° - (90° - \angle SAN)$

$\therefore \quad \angle SAN = \angle i$

Similarly, $\quad \angle QFT = \angle r$

In ΔACF,

$$\sin i = \frac{CF}{AF} = \frac{v_1t}{AF}$$

In ΔADF,

$$\sin r = \frac{AD}{AF} = \frac{v_2t}{AF}$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c_1t}{c_2t} = \frac{c_1}{c_2} = {}_1\mu_2$$

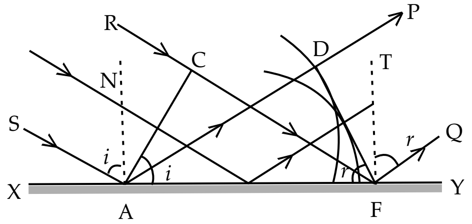
This is Snell's law.

OR

(b) A plane wavefront AC is incident on a plane reflector XY making an angle i. This is known as angle of incidence.

Each and every point of the wavefront when touches the reflector becomes a source of secondary wavelets. When the wavefront touches the point A, the point becomes a source of secondary wavelets. Thus, when the whole waveform touches the XY plane, each point of AF becomes the source of secondary wavelets. When point C of the wavefront in medium 1 traverses CF distance by that time (t) the wavelet from point A traverses AD distance. If v_1 is the speeds of light in medium then $AD = v_1t$ and $CF = v_1t$.

Reflected wavefront DF which is obtained by drawing a tangent to the arc having radius v_1t and centre A. The angle made by the tangent with the plane XY is r. This is known as angle of refraction.



The perpendiculars drawn on wavefront AC are the incident rays. The perpendiculars drawn on wavefront DF are the reflected rays.

AN and TF are the perpendiculars drawn on XY, the plane reflector.

$$\angle CAF = \angle i = 90° - \angle NAC = 90° - (90° - \angle SAN)$$

$\therefore \quad \angle SAN = \angle i$

Similarly, $\quad \angle QFT = \angle r$

In ΔACF and ΔAFD

$$\angle ACF = \angle ADF = 90°$$
$$CF = AD$$

AF is the common side

So, the triangles are congruent.

$$\angle CAF = \angle AFD$$

$\therefore \quad \angle i = \angle r$

This is law of reflection.

27. An alternating voltage of 220 V is applied across a device X. A current of 0.22 A flows in the circuit and it lags behind the applied voltage in phase by π/2 radian. When the same voltage is applied across another device Y, the current in the circuit remains the same and it is in phase with the applied voltage.

(i) Name the devices X and Y and,

(ii) Calculate the current flowing in the circuit when the same voltage is applied across the series combination of X and Y. **3**

Ans. (i) Since, current lags behind the voltage, X is an inductor.

Since, current and voltage remain in phase, Y is a resistor.

(ii) Since, $\quad X_L = \frac{V}{I} = \frac{220}{0.22}$

$= 1000\Omega$

And, $\quad R = \frac{220}{0.22}$

$= 1000\Omega$

$$Z = \sqrt{R^2 + X_L^2}$$
$$= \sqrt{(1000)^2 + (1000)^2}$$
$$= 1000\sqrt{2}\Omega$$

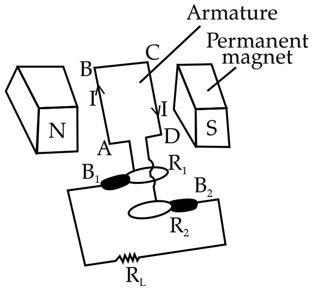
So, the required current $= \frac{220}{Z} = \frac{220}{1000\sqrt{2}} = 0.155\text{A}$

28. State the basic principle behind the working of an ac generator. Briefly describe its working and obtain the expression for the instantaneous value of emf induced. **3**

Ans. Basic principle of working of AC generator:

Basic principle of working of AC generator is electromagnetic induction. A copper coil known a armature is rotated in a strong magnetic field and emf is induced in the coil according to the Faraday's laws of electromagnetic induction and the direction of induced emf is determined by Fleming's right hand rule.

Working of ac generator:



Main components of ac generator are:

(i) Armature, (ii) Field magnet, (iii) slip ring (iv) Brush

Armature (ABCD) is a copper coil wound on a soft iron core. The armature is rotated by a turbine.

The armature is placed in between poles of a strong permanent magnet (NS) known as field magnet.

Two ends of armature coil are connected to the slip rings(R_1 and R_2) . Carbon brushes (B_1 and B_2) kept just in firm contact with the rings. External circuit is connected with the brushes.

When armature rotates in the magnetic field induced emf is generated which is supplied to the external circuit through the brushes.

Expression of instantaneous emf induced:

If the armature has N number of turns, then magnetic flux through the coil is

$$\phi = N(\vec{B}.\vec{A})$$

$$= NBA\cos\theta$$

If ω is the angular velocity, then emf induced

$$\varepsilon = -\frac{d\phi}{dt}$$

$$= \text{NBA}\omega\sin\omega t$$

$$\therefore \quad \varepsilon = \varepsilon_0\sin\omega t \quad (\text{where NBA}\omega = \varepsilon_0)$$

29. (a) Briefly describe how the current sensitivity of a moving coil galvanometer can be increased.

(b) A galvanometer shows full scale deflection for current I_g. A resistance R_1 is required to convert it into a voltmeter of range (0 – V) and a resistance R_2 to convert it into a voltmeter of range (0 – 2V). Find the resistance of the galvanometer. **3**

Ans. (a) Current sensitivity of galvanometer:

Current sensitivity of galvanometer = $\theta/I = NBA/c$

So, to increase the current sensitivity:

(i) Permanent magnet should be strong so that B is high.

(ii) N and A should be high.

(iii) Value of c must be low.

(b) To convert into a voltmeter of range (0 – V),

$$V = I_g(R_g + R_1) \qquad ...(i)$$

To convert into a voltmeter of range (0 – 2V),

$$2V = I_g(R_g + R_2) \qquad ...(ii)$$

Dividing equation (i) by (ii)

$$\frac{V}{2V} = (R_g + R_1)/ (R_g + R_2)$$

Or, $$\frac{1}{2} = (R_g + R_1)/ (R_g + R_2)$$

$$\therefore \quad R_g = R_2 - 2R_1$$

30. (a) (i) Differentiate between 'distance of closest approach' and 'impact parameter'.

(ii) Determine the distance of closest approach when an alpha particle of kinetic energy 3.95 MeV approaches a nucleus of Z = 79, stops and reverses its directions. **3**

OR

(b) (i) State three postulates of Bohr's theory of hydrogen atom.

(ii) Find the angular momentum of an electron revolving in the second orbit in Bohr's hydrogen atom. **3**

Ans. (a) (i) Difference between "distance of closest approach" and "impact parameter":

Distance of closest approach	Impact Parameter
Distance of closest approach is the distance of a charged particle from the centre of the nucleus where the total kinetic energy of the charged particle gets converted into potential energy.	Impact parameter is the perpendicular distance between the path of projected charged particles and centre of the nucleus.
$r = \dfrac{Ze^2}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$	$b = \dfrac{Ze^2\cot(\theta/2)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$

(ii) Distance of closest approach = $r = \dfrac{Qq}{4\pi\varepsilon_0 E}$

$$Q = 79e = 79 \times 1.6 \times 10^{-19}\text{C}$$
$$q = 2e = 2 \times 1.6 \times 10^{-19}\text{C}$$
$$E = 3.95 \text{ MeV}$$
$$= 3.95 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$\therefore r = (9 \times 10^9)\frac{(79\times1.6\times10^{-19})\times(2\times1.6\times10^{-19})}{3.95\times10^6\times1.6\times10^{-19}}$$

$$= 576 \times 10^{-16} \text{ m}$$
$$= 5.76 \times 10^{-14} \text{ m}$$

OR

(b) (i) Postulates of Bohr's theory:

Postulate 1: In an atom electrons are revolving around the nucleus in definite circular orbits. These orbits are called 'stationary orbits' and each orbit or shell possesses fixed energy. While revolving in these orbits electrons do not emit any radiation.

Postulate 2: Electrons can move only those permissible orbits where the angular momenta of electrons are integral multiples of $\frac{h}{2\pi}$ where h is the Planck's constant.

Postulate 3: Transition of electrons may occur from one stationary orbit to another. During such transition energy may be emitted or absorbed following the relation $E_i - E_f = h\nu$ (where $E_i \sim E_f$ is the difference of energies of the two stable orbits).

(ii) Angular momentum of electron revolving in 2nd orbit in Bohr's Hydrogen atom:

Angular momentum $= \frac{nh}{2\pi}$

Here, $n = 2$,

$\therefore$ Angular momentum $= 2\times\frac{h}{2\pi} = \frac{h}{\pi}$

SECTION - D

31. (a) (i) Explain how free electrons in a metal at constant temperature attain an average velocity under the action of an electric field. Hence obtain an expression for it. 3

(ii) Consider two conducting wires A and B of the same diameter but made of different materials joined in series across a battery. The number density of electrons in A is 1.5 times that in B. Find the ratio of drift velocity of electrons in wire A to that in wire. B. 2

OR

(b) (i) A cell emf of (E) and internal resistance (r) is connected across a variable load resistance (R). Draw plots showing the variation of terminal voltage V with (i) R and (ii) the current (I) in the load. 2

(ii) Three cells, each of emf E but internal resistances 2r, 3r and 6r are connected in parallel across a resistor R.

Obtain expressions for (i) current flowing in the circuit, and (ii) the terminal potential difference across the equivalent cell. 3

Ans. (a) (i) In absence of any electric field, the free electrons in metals move haphazardly in all possible directions and hence, develop no net flow of current. When an electric field is applied, a force acts on the electrons and the electrons now tend to move in the direction of the force.

When electron collides with lattice, its velocity becomes instantaneously zero and then again it starts moving in a specific direction due to the applied electric field.

If the average time between two collisions (relaxation time) is τ, then

$$l = \frac{1}{2}a\tau^2$$

Where l = average drift distance

a = acceleration $= \frac{Ee}{m}$

E = electric field intensity

e = charge of electron

m = mass of electron

$$\therefore \quad l = \frac{1}{2}\frac{Ee}{m}\tau^2$$

$$\text{Drift velocity} = \frac{l}{\tau} = v_d = \frac{1}{2}\frac{Ee}{m}\tau$$

$\frac{e\tau}{2m}$ = K, a constant , which depends on the nature of the material and the temperature.

$$\therefore \quad v_d = K \times E$$

Thus, free electrons in a metal at constant temperature under the action of an electric field attain a constant average velocity.

(b) Since, the wires are joined in series current flowing through then will be same.

Let the current in both A and B be I.

Diameter being same, there areas of cross section are also same. Let it be A.

So, in wire A

$$I = n_A e A v_{dA}$$

In wire B,

$$I = n_B e A v_{dB}$$

Taking the ratio,

$$1 = \frac{n_A}{n_B}\times\frac{v_{dA}}{v_{dB}}$$

Or, $$1 = 1.5\times\frac{v_{dA}}{v_{dB}}$$

$$\therefore \quad \frac{v_{dA}}{v_{dB}} = \frac{1}{1.5} = 2:3$$

OR

(b) (i) Terminal voltage vs. load resistance graph:

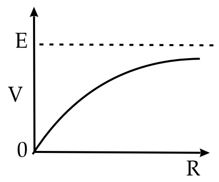
$$V = E - ir$$

And $$i = \frac{E}{R+r}$$

$$\therefore \quad V = E - \frac{Er}{R+r}$$

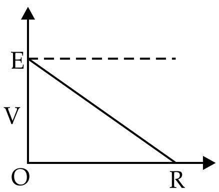
Or, $$V = E\frac{1-r}{r+R}$$

$$\therefore \quad V = \frac{ER}{(r+R)}$$

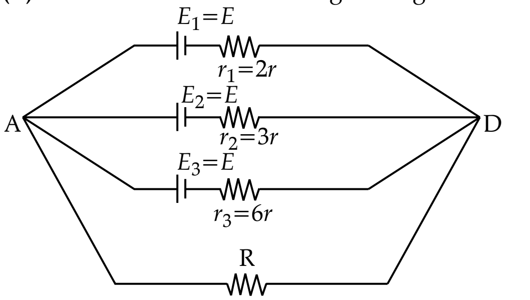


Terminal voltage vs. current graph:

$$V = E - ir$$



(ii) Three cells combination diagram is given below,



Current through cells (i) $= \dfrac{E_{eq}}{r_{eq}} = \dfrac{E_1}{r_1}+\dfrac{E_2}{r_2}+\dfrac{E_3}{r_3}$ ...(i)

And $\quad \dfrac{1}{r_{eq}} = \dfrac{1}{r_1}+\dfrac{1}{r_2}+\dfrac{1}{r_3}$

Or, $\quad \dfrac{1}{r_{eq}} = \dfrac{1}{2r}+\dfrac{1}{3r}+\dfrac{1}{6r}$

$\therefore$ Equivalent resistance of internal resistance

$$r_{eq} = r$$

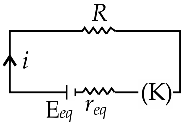
Putting in equation (i),

$$i = \frac{E_{eq}}{r} = \frac{E}{2r}+\frac{E}{3r}+\frac{E}{6r}$$

$$i = \frac{6E}{6r} = \frac{E}{r}$$

$\therefore \quad E_{eq} = E$

So, the equivalent circuit is,



(i) Current flowing through the circuit $= i = \dfrac{E}{(R+r)}$

(ii) Terminal potential difference, $V = iR$

Or, $\quad V = \left(\dfrac{E}{R+r}\right)R$

$\therefore \quad V = \dfrac{ER}{r+R}$

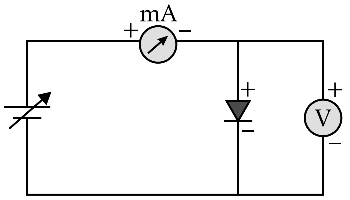
32. (a) Draw the circuit arrangement for studying V-I characteristics of a *p-n* junction diode in (i) forward biasing and (ii) reverse biasing. Draw the typical V-I characteristics of a silicon diode. Describe briefly the following terms: (i) minority carrier injection in forward biasing and (ii) breakdown voltage in reverse biasing. **5**

OR

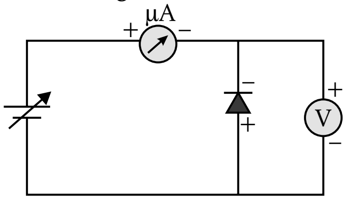
(b) Name two important processes involved in the formation of a p-n junction diode. With the help of a circuit diagram, explain the working of junction diode as a full wave rectifier. Draw its input and output waveforms. State the characteristic property of a junction diode that makes it suitable for rectification. **5**

Ans. (a) Circuit diagram to study the V-I Characteristics of *p-n* junction diode in

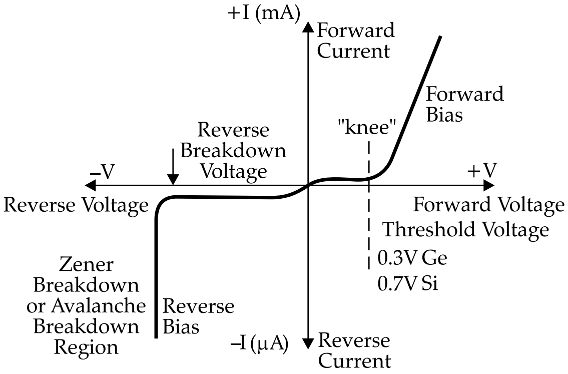
(i) Forward biasing:



(ii) Reverse biasing:



***V–I* Characteristics of Diode**



(i) Minority carrier injection in forward bias:

In forward biased p-n junction, electrons from n-region diffuse into p-region where they are minority carriers. Holes are injected from p-side to n-side where they are minority carriers. This process is known as 'minority carrier injection'.

(ii) Breakdown voltage in reverse bias:

In reverse biased p-n junction, only minority carriers can cross the junction. Hence, a very small amount of current flows in reverse direction which is known as reverse saturation current. If the reverse voltage is increased to a very large value, a large reverse current flows through the diode due to zener diode breakdown. The voltage at which this happens is known as breakdown voltage.

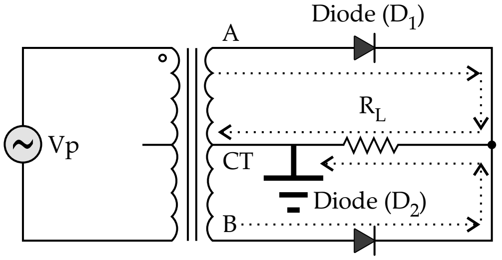
OR

(b) Two processes involved in formation of p-n junction:

(i) Diffusion

(ii) Drift

Full wave rectifier:



Centre-tapped transformer

A centre-tapped transformer and two *p-n* junction diodes are used for a full weave rectifier.

Input of the transformer is connected to the ac supply.

In secondary there are three terminals – A, B and CT.

For positive half cycle, A is positive, B is negative. For the negative half cycle, A is negative, B is positive. CT is always at zero potential. It is always grounded.

Anode of one diode (D_1) is connected to A and anode of other diode (D_2) is connected to B.

Cathodes of both the diodes are joined together and ultimately connected to CT through a load resistance (R_L).

When positive half cycle appears, A is at positive and B is at negative potential. So, diode D_1 is forward biased and hence, it conducts.

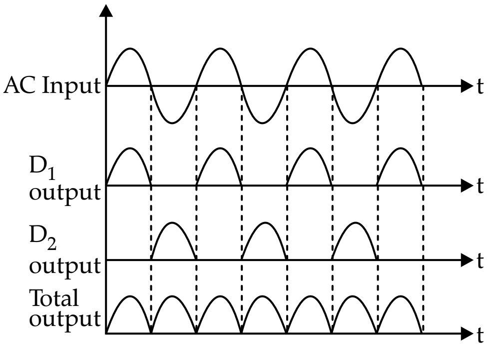
When negative half cycle appears, B is at positive and A is at negative potential. So, diode D_2 is forward biased and hence, it conducts.

The process repeats.

For both the half cycles current flowing through the load resistance is unidirectional. Hence, a DC voltage appears across it.

Thus, a full wave rectifier works.

Input and output wave forms:



Characteristic property of junction diode that makes it suitable for rectification:

An ideal *p-n* junction diode exhibits zero resistance when forward biased and infinite resistance when reversed biased.

33. (a) (i) Draw a ray diagram to show the working of a compound microscope. Obtain the expression for the total magnification for the final image to be formed at the near point. **3**

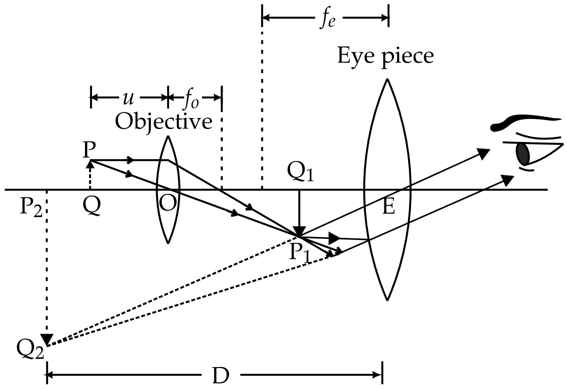
(ii) In a compound microscope an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye-piece has a focal length of 5 cm and the final image is formed at the near point, find the magnifying power of the microscope. **2**

OR

(b) (i) Draw a ray diagram for the formation of image of an object by an astronomical telescope, in normal adjustment. Obtain the expression for its magnifying power.

(ii) The magnifying power of an astronomical telescope in normal adjustment is 2.9 and the objective and the eyepiece are separated by a distance of 150 cm. Find the focal lengths of the two lenses. **5**

Ans. (a) (i) Ray diagram of compound microscope:



In a compound microscope there are two lenses – objective (O) and Eyepiece (E).

Object PQ is placed in front of the objective at a distance more than the focal length of the objective.

An inverted, magnified, real image P_1Q_1 is formed in front of eyepiece within the optical centre and the focus of the eyepiece. This acts as the object of the eyepiece. An (erect with respect to P_1Q_1, inverted with respect to PQ), magnified, virtual image P_2Q_2 is formed at a distance D (minimum distance of distinct vision) from the eyepiece.

Magnification:

For objective:

Object distance = u

Image distance = v

$$\text{Magnification} = m_o = \frac{v}{u} = \frac{P_1Q_1}{PQ}$$

Applying the lens formula,

$$\frac{1}{v} - \frac{1}{-u} = \frac{1}{f_0}$$

Or, $$1 + \frac{v}{u} = \frac{v}{f_0}$$

Or, $$\frac{v}{u} = \frac{v}{f_0} - 1$$

For eyepiece:

$$\text{Magnification} = m_e = 1 + \frac{D}{f_e}$$

Magnification of the combination of objective and eyepiece = $m = m_O \times m_e$

Or, $$m = \frac{v}{u} \times \left(1 + \frac{D}{fe}\right)$$

Or, $$m = \left(\frac{v}{f_0} - 1\right)\left(1 + \frac{D}{fe}\right)$$

P_1Q_1 image is formed very close to the eyepiece, hence v can be approximated as the distance between the two lenses i.e., the length of the tube(L).

$$\therefore \quad m = \left(\frac{L}{f_0} - 1\right)\left(1 + \frac{D}{f_e}\right)$$

Since, $f_e << D$ and $f_0 << L$, hence the above expression may be approximated as,

$$m = \frac{L}{f_0} \times \frac{D}{f_e}$$

(ii) Given, $u = 1.5$ cm, $f_0 = 1.25$ cm, $f_e = 5$ cm, $D = 25$ cm

Here, all alphabets are in their usual meanings

Applying lens formula for objective lens,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_0}$$

Or, $$\frac{1}{v} - \frac{1}{-1.5} = \frac{1}{1.25}$$

$$\therefore \quad v = 7.5 \text{ cm}$$

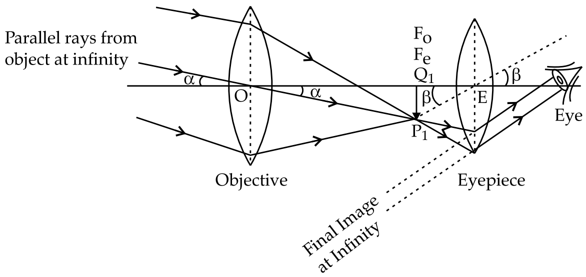
$$\text{Magnification} = m = \frac{v}{u} \times \left(1 + \frac{D}{f_e}\right)$$

Or, $$m = \frac{7.5}{-1.5} \times \left(1 + \frac{25}{5}\right)$$

$$\therefore \quad m = -30$$

OR

(b) (i) Astronomical telescope in normal adjustment:



In an astronomical telescope there are two lenses – objective (O) and Eyepiece (E).

The two lenses are so placed during focussing that the foci of the lenses meet at a point.

Objective is directed towards the object at infinity.

Parallel rays coming from the object meet at the focus of the objective and forms an inverted, real image P_1Q_1 in front of eyepiece. This point is the focus of eyepiece too.

This acts as the object of the eyepiece. An (inverted with respect to P_1Q_1, erect with respect to original object), highly magnified, real image is formed at infinity.

Magnification $= m$

$$= \frac{\text{Angle subtended at eye by the final image}}{\text{Angle subtended at eye by the object}}$$

Or, $m =$

$$\frac{\text{Angle subtended at eyepiece by the final image}}{\text{Angle subtended at objective by the object}}$$

Or, $$m = \frac{\beta}{\alpha}$$

Or, $$m = \frac{\angle Q_1EP_1}{\angle Q_1OP_1}$$

Or, $$m = \frac{\tan\angle Q_1EP_1}{\tan\angle Q_1OP_1}$$

[α and β being very small, $\tan\alpha = \alpha$ and $\tan\beta = \beta$]

Or, $$m = \frac{\frac{Q_1P_1}{Q_1E}}{\frac{Q_1P_1}{Q_1O}}$$

Or, $$m = \frac{Q_1O}{Q_1E}$$

$$\therefore \quad m = \frac{f_o}{f_e}$$

(ii) Since, $$m = \frac{f_o}{f_e}$$

Or, $$2.9 = \frac{f_o}{f_e}$$

$$\therefore \quad f_o = 2.9 f_e$$

Also, $$f_o + f_e = 150$$

Or, $$2.9 f_e + f_e = 150$$

$$\therefore \quad f_e = \frac{150}{3.9}$$

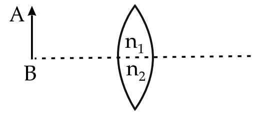
$$= 38.46 \text{ cm}$$

$$f_O = 2.9 f_e$$
$$= 2.9 \times 38.46$$
$$= 111.54 \text{ cm}$$

SECTION - E

34. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Considering image formation by a single spherical surface successively at the two surfaces of a lens, lens maker's formula is obtained. It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature. This formula helps us obtain a relation between u, v and f for a lens. Lenses form images of objects and they are used in a number of optical devices, for example microscopes and telescopes. **4**

(i) An object AB is kept in front of a composite convex lens, as shown in figure. Will the lens produce one image? If not, explain.



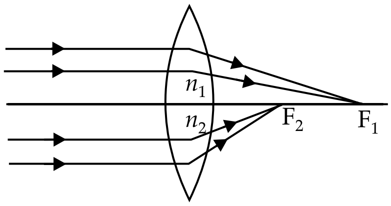
(ii) A real image of an object formed by a convex lens is observed on a screen. If the screen is removed, will the image still be formed? Explain.

(iii) A double convex lens is made of glass of refractive index 1.55 with both faces of the same radius of curvature. Find the radius of curvature required if focal length is 20 cm.

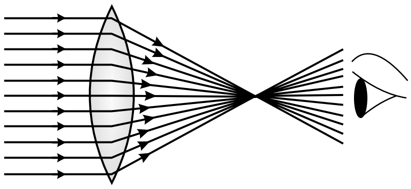
OR

(iii) Two convex lenses A and B of focal lengths 15 cm and 10 cm respectively are placed coaxially '*d*' distance apart. A point object is kept at a distance of 30 cm in front of lens A. Find the value of '*d*' so that the rays emerging from lens B are parallel to its principal axis.

Ans. (i) No, the lens will not produce one image. It will produce two images. Refractive index upper and lower section of the lens being different there will be two foci and hence, two images will be formed.



(ii) If the screen is removed, the image will be still formed and it can be seen by looking through the lens through the specific cone of light.



(iii) Using lens maker's formula

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

Or, $$\frac{1}{20} = (1.55-1)\left(\frac{2}{r}\right)$$

$\therefore$ $$r = 22 \text{ cm}$$

OR

The equivalent focal length of two lenses separated by a distance d be f

$$\frac{1}{f} = \frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2}$$

Or, $$\frac{1}{f} = \frac{1}{15}+\frac{1}{10}-\frac{d}{15\times10}$$

Or, $$\frac{1}{f} = \frac{1}{6}-\frac{d}{150}$$

When a point object is kept distance 30 cm from this lens combination, the rays emerge as parallel to the principal axis. So, focal length of the combination is 30 cm.

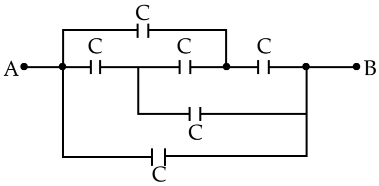
$\therefore$ $$\frac{1}{30} = \frac{1}{6}-\frac{d}{150}$$

Or, $$\frac{d}{150} = \frac{1}{6}-\frac{1}{30}$$

$\therefore$ $$d = 20 \text{ cm}$$

35. A capacitor is a system of two conductors separated by an insulator. The two conductors have equal and opposite charges with a potential difference between them. The capacitance of a capacitor depends on the geometrical configuration (shape, size and separation) of the system and also on the nature of the insulator separating the two conductors. They are used to store charges. Like resistors, capacitors can be arranged in series or parallel or a combination of both to obtain desired value of capacitance. **4**

(i) Find the equivalent capacitance between points A and B in the given diagram.

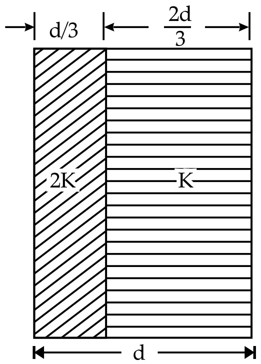


(ii) A dielectric slab is inserted between the plates of a parallel plate capacitor. The electric field between the plates decreases. Explain.

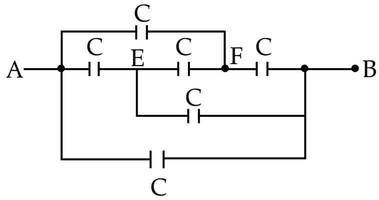
(iii) A capacitor A of capacitance C, having charge Q is connected across another uncharged capacitor B of capacitance 2C. Find an expression for (a) the potential difference across the combination and (b) the charge lost by capacitor A.

OR

(iii) Two slabs of dielectric constants 2K and K fill the space between the plates of a parallel plate capacitor of plate area A and plate separation *d* as shown in figure. Find an expression for capacitance of the system.

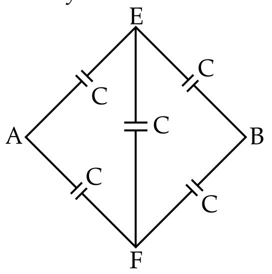


Ans. (i) The given combination:



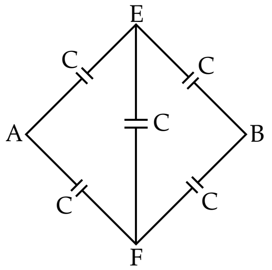
Initially the capacitor between A and B is not considered.

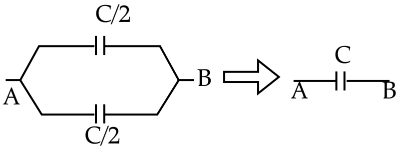
So, the circuit may be redrawn as



This is like a balanced Wheatstone bridge. So, the capacitor between E and F may not be considered.

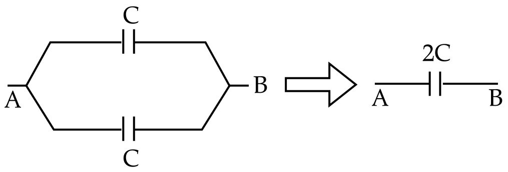
So, the circuit is further modified as





The capacitance between A and B is C.

Now capacitor between A and B (left out initially) is considered.



So, the equivalent capacitance between A and B is 2C.

(ii) When a dielectric is placed between charged plates of a capacitor, the polarization of dielectric produces an electric field opposing the field produced by the charges on the plate. Thus, the resultant electric field between the plates decreases.

(iii) Both capacitors will attain a common potential, V_C.

(a)
$$V_C = \frac{\text{Total charge}}{\text{Total capacitance}}$$
$$= \frac{Q}{C+2C} = \frac{Q}{3C}$$

(b) Final charge on capacitor A
$$= Q_A = CV_C$$
$$= \frac{CQ}{3C} = \frac{Q}{3}$$

So, charge lost by capacitor A
$$= Q - \frac{Q}{3} = \frac{2Q}{3}$$

OR

By placing the dielectric slab, it behaves like two capacitors in series

$$C_1 = \frac{K_1\varepsilon_0 A}{d/3} = \frac{6K\varepsilon_0 A}{d}$$
$$C_2 = \frac{K_2\varepsilon_0 A}{2d/3} = \frac{3K\varepsilon_0 A}{2d}$$
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Or,
$$\frac{1}{C_{eq}} = \frac{d}{6K\varepsilon_0 A} + \frac{2d}{3K\varepsilon_0 A}$$

Or,
$$\frac{1}{C_{eq}} = \frac{5d}{6K\varepsilon_0 A}$$

$\therefore$
$$C_{eq} = \frac{6K\varepsilon_0 A}{5d}$$

Delhi Set-2 — 55/5/2

Note: Except these, all other questions are from Delhi Set-1

SECTION - A

1. A charge Q is placed at the centre of a cube. The electric flux through one if its face is

(A) $\frac{Q}{\varepsilon_0}$ **(B)** $\frac{Q}{6\varepsilon_0}$

(C) $\frac{Q}{8\varepsilon_0}$ **(D)** $\frac{Q}{3\varepsilon_0}$ **1**

Ans. Option (B) is correct.

Explanation: According to Gauss'Law total electrical flux $= \frac{Q}{\varepsilon_0}$

So, electric flux through each face $= \frac{Q}{6\varepsilon_0}$

5. Choose the correct option related to wavelengths (λ) of different parts of electromagnetic spectrum.

(A) $\lambda_{x\text{-rays}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{\text{visible}}$

(B) $\lambda_{\text{visible}} > \lambda_{x\text{-rays}} > \lambda_{\text{radio waves}} > \lambda_{\text{micro waves}}$

(C) $\lambda_{\text{radio waves}} > \lambda_{\text{micro waves}} > \lambda_{\text{visible}} > \lambda_{x\text{-rays}}$

(D) $\lambda_{\text{visible}} < \lambda_{\text{micro waves}} < \lambda_{\text{radio waves}} < \lambda_{x\text{-rays}}$ **1**

Ans. Option (C) is correct

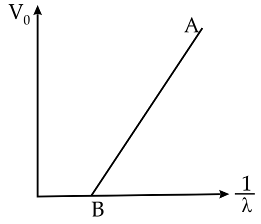
Explanation: Wavelength of radio wave > 0.1 m

Wavelength of microwave: 1 mm – 0.1m

Wavelength of visible light: 400nm – 700nm

Wavelength of X-rays: 10^{-3} nm – 1 nm

11. Figure shows a plot of stopping potential (V_0) versus $\frac{1}{\lambda}$, is the wavelength of the radiation causing photoelectric emission from a surface. The slope of the line is equal to



(A) ϕ_0 (B) $\frac{h}{e}$

(C) $\frac{hc}{e}$ (D) $\frac{h^2c}{e^2}$ **1**

Ans. Option (C) is correct.

Explanation: From Einstein's equation,

$$eV_0 = h\nu - h\nu_0$$

or, $$V_0 = \frac{h\nu}{e} - \frac{h\nu_0}{e} \qquad \left[\because \nu = \frac{h}{c}\right]$$

or, $$V_0 = \frac{hc}{\lambda e} - \frac{hc}{\lambda_0 e}$$

So, the slope of V_0 vs. $1/\lambda$ graph is hc/e.

13. An ideal inductor is connected across an AC source of voltage. The current in the circuit.

(A) is ahead of the voltage in phase by π

(B) lags voltage in phase by π

(C) is ahead of voltage in phase by $\pi/2$

(D) lags voltage in phase by $\pi/2$. **1**

Ans. Option (D) is correct.

Explanation: For a pure inductor AC circuit,

if $V = V_0 \sin\omega t$

the current $i = i_0 \sin(\omega t - 90^0)$

Note: In question number 16, two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(A) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A).

(B) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).

(C) Assertion (A) is true and Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

16. Assertion (A): In insulators, the forbidden gap is very large.

Reason (R): The valence electrons in an atom of an insulator are very tightly bound to the nucleus.

Ans. Option (A) is correct.

Explanation: In insulators forbidden band gap is more than 3eV which is large enough. So, the assertion is true.

Since, the electrons are very tightly bound to nucleus they cannot easily jump to the conduction band. This explains why the forbidden band gap is so large.

So, the reason is also true and it explains the assertion.

SECTION - B

21. Identify the electromagnetic radiation and write its wavelength range which is used to kill germs in water purifier. Name the two sources of these radiations. **2**

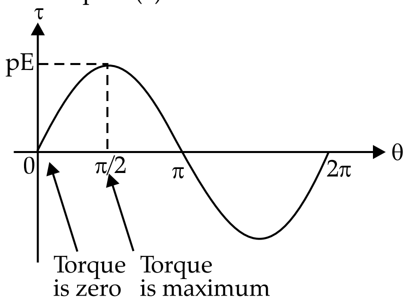
Ans. The electromagnetic radiation which is used to kill germs in water purifier: Ultraviolet rays.

Wavelength range of ultraviolet radiation: 1 nm – 400 nm

Sources of ultraviolet radiation: Sunlight, electric arcs.

22. An electric dipole of dipole moment ($\vec{p}$) is kept in a uniform electric field $\vec{E}$. Show graphically the variation of torque acting on the dipole (τ) with its orientation (θ) in the field. Find the orientation in which torque is (i) zero and (ii) maximum. **2**

Ans. Graphical variation of torque (τ) with the orientation of electric dipole (θ) in the electric field:



(i) At $\theta = 0°$, torque is zero.

(ii) At $\theta = 90°$, torque is maximum.

24. A potential difference (V) is applied across a conductor of length 'L' and cross-sectional area 'A'.

How will the drift velocity of electrons and the current density be affected if another identical conductor of the same material were connected in series with the first conductor ? Justify your answers. **2**

Ans. Since, $$R = P\frac{L}{A}$$

$$I = \frac{V}{R} = \frac{V}{\frac{\rho L}{A}} = \frac{VA}{\rho L}$$

$$I = neAV_d = \frac{VA}{\rho L}$$

when another conductor is joint in series

$$\text{Effective Resistance} = R + R = \frac{2\rho L}{A}$$

$$\text{Effective current} = \frac{V}{2R} = \frac{V}{\frac{2\rho L}{A}} = \frac{VA}{2\rho L}$$

Now $\dfrac{VA}{2\rho L} = neAV_{d'}$

or, $\dfrac{1}{2}\left(\dfrac{VA}{\rho La}\right) = neAV_{d'}$

or, $\dfrac{1}{2}\times neAV_d = neAV_{d'}$

or, $V_d = 2V'_d$

Drift velocity in second case will be half of the initial drift velocity

Current density = $J = neV_d$

Initially current density = $J = neV_d$

When another conductor injured in series

current density $J' = neV_{d'}$

$$\frac{J}{J'} = \frac{V_d}{V_d'} = \frac{2Vd'}{V_d'} = 2$$

$\therefore$ $J = 2J'$

Current density in second case will be half of the initial current density.

SECTION - C

27. A current of 1A flows through a coil when it is connected across a DC battery of 100 V. If DC battery is replaced by an AC source of 100 V and angular frequency 100 rad s^{-1}, the current reduces to 0.5 A. Find

(i) impedance of the circuit.

(ii) self-inductance of coil.

(iii) phase difference between the voltage and the current. **3**

Ans. (i) Impedance of the circuit = $Z = \dfrac{100}{0.5} = 200\Omega$

(ii) Resistance $= R = \dfrac{100}{1} = 100\Omega$

Impedance $= Z = \sqrt{(\omega L)^2 + R^2}$

Or, $200 = \sqrt{(\omega L)^2 + 100^2}$

Or, $200^2 = (\omega L)^2 + 100^2$

Or, $\sqrt{200^2 - 100^2} = \omega L$

Or, $173.2 = 100 \times L$

$\therefore$ $L = 1.732\text{H}$

(iii) Since, $\tan\theta = \dfrac{\omega L}{R}$

Or, $\tan\theta = \dfrac{173.2}{100} = 1.732$

Or, $\theta = \tan^{-1}1.732$

$\therefore$ $\theta = 60°$

28. The primary coil having N_p turns of an ideal transformer is supplied with an alternating voltage V_p. Obtain an expression for the voltage V_s induced in its secondary coil having N_s turns. Mention two main sources of power loss in real transformers. **3**

Ans. Expression of voltage V_S induced in secondary coil of a transformer:

Let V_P be the applied alternating emf in the primary coil of a transformer.

Alternating current produced in the primary = I_1.

Induced emf in the primary will be equal to the applied emf for ideal transformer.

So, $V_P = N_P \dfrac{N\phi}{dt}$

(where N_P = number of turns in primary, $\dfrac{d\phi}{dt}$ = rate of change of flux)

Since there is no loss of flux in an ideal transformer,

Induced emf in secondary = $E_S = N_S \dfrac{d\phi}{dt}$

$\therefore$ Taking the ratio,

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} = n$$

(where n = turns ratio or transformer ratio)

Sources of power loss:

(i) Hysteresis loss: Hysteresis loss is due to reversal of magnetization in the transformer core. This loss depends upon the volume and grade of the iron, frequency of magnetic reversals and value of flux density

(ii) Copper loss is due to ohmic resistance of the transformer windings. Copper loss for the primary winding is $I_1^2R_1$ and for secondary winding is $I_2^2R_2$. Where, I_1 and I_2 are current in primary and secondary winding respectively, R_1 and R_2 are the resistances of primary and secondary winding respectively.

30. (a) (i) Write the limitations of Rutherford's model of atom.

(ii) The wavelength of the second line of the Balmer series in the hydrogen spectrum is 4861 Å. Calculate the wavelength of the first line of the same series. **3**

OR

(b) (i) Increase in the intensity of the radiation causing photo-electric emission from a surface, does not affect the maximum K.E. of the photo electrons. Explain.

(ii) The photon emitted during the de-excitation from the first excited level to the ground state of hydrogen atom is used to irradiate a photo cathode in which stopping potential is 5 V. Calculate the work function of the cathode used. **3**

Ans. (a) (i) Limitations of Rutherford 's model of atom:

- Rutherford's model failed to explain the stability of atoms.

  Charged particle that is moving in a circular path undergoes an acceleration and radiates energy. Thus, the revolving electron losses energy and finally falls into the nucleus. But this is not the reality. Atoms are stable enough.

- Atom exhibits line spectrum. Rutherford's model failed to explain this. According to Rutherford, if electron continuously emits energy then there should be continuous band spectrum. But that is not the reality.

(ii) For Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

For 2nd line, $n = 4$

$$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$\text{Or,} \quad \frac{1}{4861} = \frac{3R}{16}$$

$$\therefore \quad R = \frac{16}{3 \times 4861}$$

For 1st line, $n = 3$

$$\therefore \quad \frac{1}{\lambda'} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\text{Or,} \quad \frac{1}{\lambda'} = \frac{5R}{36}$$

$$\text{Or,} \quad 1/\lambda' = \frac{5 \times 16}{36 \times 3 \times 4861}$$

$$\text{Or,} \quad \lambda' = \frac{36 \times 3 \times 4861}{5 \times 16}$$

$$\therefore \quad \lambda' = 6562.35 \text{Å}$$

OR

(b) (i) From Einstein's photoelectric equation.

$$h\nu = \phi_0 + KE_{max}$$

So, KE energy of photoelectron depends on the frequency of incident radiation and the work function of the substance. There is no intensity term in the equation. Hence, the KE is independent of the intensity of the radiation.

(ii) From Einstein's photoelectric equation,

$$eV_s = h\nu - \phi_0$$

and

$$h\nu = E_2 - E_1$$

$$= -\frac{13.6}{2^2} - \left(-\frac{13.6}{1^2}\right)$$

$$= 10.2 \text{ eV}$$

Putting the Einstein's equation,

$$5\text{eV} = 10.2\text{eV} - \phi_0$$

$$\therefore \quad \phi_0 = 5.2 \text{ eV}$$

Delhi Set-3 55/5/3

Note: Except these, all other questions are from Delhi Set-1 & 2

SECTION - A

2. Two horizontal thin long parallel wires, separated by a distance r carry current I each in the opposite directions. The net magnetic field at a point midway between them, will be

(A) zero

(B) $\left(\frac{\mu_0 I}{2\pi r}\right)$ vertically downward

(C) $\left(\frac{2\mu_0 I}{r}\right)$ vertically upward

(D) $\left(\frac{\mu_0 I}{\pi r}\right)$ vertically downward **1**

Ans. Option (D) is correct.

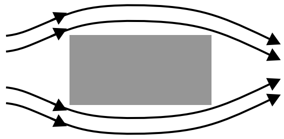
Explanation: Magnetic field due to both the wires is

$$\frac{\mu_0 I}{4\pi\left(\frac{r}{2}\right)} = \frac{\mu_0 I}{2\pi r}$$

So, total field is $2 \times \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{\mu_0}{\pi}\frac{I}{r}$

The direction will be vertically downward.

3. Which of the following cannot modify an external magnetic filed as shown in the figure ?



(A) Nickel **(B)** Silicon

(C) Sodium Chloride **(D)** Copper **1**

Ans. Option (A) is correct.

Explanation: Nickel is a ferromagnetic substance. Ferromagnetic substance does not modify external magnetic field as shown.

7. E, c and v represent the energy, velocity and frequency of a photon. Which of the following represents its wavelength ?

(A) $\frac{h\nu}{c^2}$ **(B)** $h\nu$

(C) $\frac{hc}{E}$ **(D)** $\frac{h\nu}{c}$ **1**

Ans. Option (C) is correct.

Explanation: $E = h\nu$

$$\text{Or,} \quad E = \frac{hc}{\lambda}$$

$$\therefore \quad \lambda = \frac{hc}{E}$$

9. The energy required by an electron to jump the forbidden band in silicon at room temperature is about.

(A) 0.01 eV **(B)** 0.05 eV

(C) 0.7 eV **(D)** 1.1 eV **1**

Ans. Option (D) is correct.

13. What is the ratio of inductive and capacitive reactance in an ac circuit ?

(A) $\omega^2 LC$ **(B)** LC^2

(C) $\frac{LC}{\omega^2}$ **(D)** $\omega^2 L$ **1**

Ans. Option (A) is correct.

Explanation: Inductive reactant $X_L = \omega L$

Capacitive reactant $X_C = \frac{1}{\omega C}$

$$\therefore \quad \frac{X_L}{X_C} = \omega^2 LC$$

14. In an interference experiment, third bright fringe is obtained at a point on the screen with a light of 700 nm. What should be the wavelength of the light source in order to obtain the fifth bright fringe at the same point ?

(A) 420 nm **(B)** 750 nm

(C) 630 nm **(D)** 500 nm **1**

Ans. Option (A) is correct.

Explanation: Since, $y_n = \frac{n\lambda D}{d}$

For 3rd bright fringe,

$$y_3 = \frac{3\times 700D}{d} = \frac{2100D}{d}$$

For 5th bright fringe,

$$y_5 = 5\lambda'\frac{D}{d}$$

Since $y_5 = y_3$

$$5\lambda'\frac{D}{d} = 2100\frac{D}{d}$$

$$\therefore \quad \lambda' = \frac{2100}{5} = 420 \text{ nm}$$

Note: In question number 17, two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

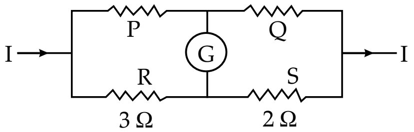
(A) Both Assertion (A) and Reason (R) are true and (R) is the correct explanation of (A).

(B) Both Assertion (A) and Reason (R) are true and (R) is NOT the correct explanation of (A).

(C) Assertion (A) is true and Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

17. Assertion (A): The given figure does not show a balanced Wheatstone bridge.



Reason (R): For a balanced bridge small current should flow though the galvanometer. **1**

Ans. Option (A) is correct.

Explanation: Balance condition of Wheatstone bridge is $\frac{P}{Q} = \frac{R}{S}$

In the given circuit, $\frac{P}{Q} \neq \frac{R}{S}$.

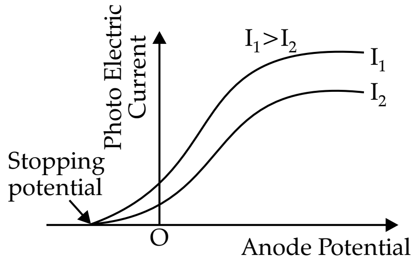
So, the assertion is true.

Since, the given bridge is not in balanced condition, so current will flow in the galvanometer.

SECTION - B

19. Plot a graph showing the variation of photo electric current, as a function of anode potential for two light beams having the same frequency but different intensities I_1 and I_2 ($I_1 > I_2$). Mention its important features. **2**

Ans. Variation of photoelectric current as a function of anode potential:



Important features:

(i) As intensity increases, saturation current increases.

(ii) Stopping potential is independent of the intensity of light.

21. How are electromagnetic waves produced ? Write their two characteristics. **2**

Ans. Accelerated charged particles produce electromagnetic waves.

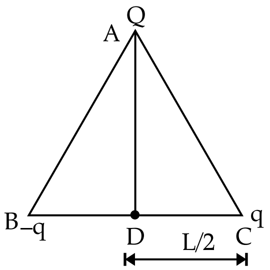
Characteristics of electromagnetic waves:

(i) Electromagnetic waves are transverse in nature.

(ii) All electromagnetic waves travel through vacuum with a speed 3 x 10^8 m/s.

(iii) In electromagnetic waves the oscillations of $\vec{E}$ and $\vec{B}$ are perpendicular to each other and also perpendicular to the direction of propagation of the wave.

22. Three points charges Q, q and – q are kept at the vertices of an equilateral triangle of side L as shown in figure. What is



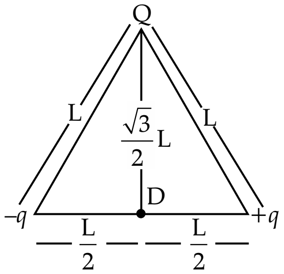
(i) the electrostatic potential energy of the arrangement ? and

(ii) the potential at point D ? **2**

Ans. Potential energy of the system $= U = \dfrac{1}{4\pi\varepsilon_0}$

$$\left[\frac{(+q)(-q)}{L}+\frac{(+q)Q}{L}+\frac{(-q)Q}{L}\right] = \frac{-1}{4\pi\varepsilon_0}\frac{q^2}{L}$$

Potential at D:

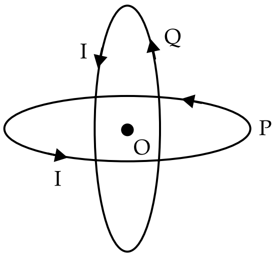


Distance from Q to D $= \dfrac{\sqrt{3}}{2}L$

$$V_D = K\left[\frac{Q}{\frac{\sqrt{3}L}{2}}+\frac{-q}{\frac{L}{2}}+\frac{+q}{\frac{L}{2}}\right]$$

$$= \frac{2KQ}{\sqrt{3}L}$$

23. (a) Two identical circular loops P and Q, each of radius R carrying current I are kept in perpendicular planes such that they have s common centre O as shown in the figure.

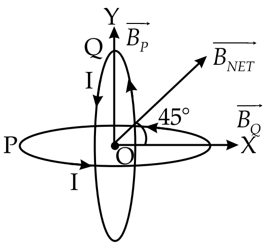


Find the magnitude and direction of the net magnetic field at point O. **2**

OR

(b) A long straight conductor kept along X′ X axis, caries a steady current I along + x direction. At an instant t, a particle of mass m and charge q at point (x, y) moves with a velocity $\vec{v}$ along + y direction. Find the magnitude and direction of the force on the particle due to the conductor. **2**

Ans. (a)



Magnetic field due to loop P

$$\vec{B_P} = \frac{\mu_0 nI}{2R}\hat{j}$$

Magnetic field due to loop Q

$$\vec{B_Q} = \frac{\mu_0 nI}{2R}\hat{i}$$

$$\vec{B_{NET}} = \frac{\mu_0 nI}{2R}\hat{i}+\frac{\mu_0 nI}{2R}\hat{j}$$

$$= \frac{\mu_0 nI}{2R}(\hat{i}+\hat{j})$$

Its magnitude $= |\vec{B_{NET}}|$

$$= \frac{\mu_0 nI}{2R}\sqrt{1^2+1^2}$$

$$= \frac{\mu_0 nI}{\sqrt{2}R}$$

Its direction,

$$\hat{B_{NET}} = \frac{\vec{B_{NET}}}{|\vec{B_{NET}}|}$$

$$= \frac{\frac{\mu_0 nI}{2R}(\hat{i}+\hat{j})}{\frac{\mu_0 nI}{\sqrt{2}R}} = \frac{\hat{i}+\hat{j}}{\sqrt{2}}$$

So, the direction will be 45° with $\vec{B_P}$ and $\vec{B_Q}$.

(b) The magnetic due to the straight conductor is $\dfrac{\mu_0 I}{2\pi y}\hat{k}$

Velocity of the charged particle is $v\hat{j}$

So, the force acting on the particle is

$$\vec{F} = q(\vec{v}\times\vec{B})$$

or, $$\vec{F} = q\left[v\hat{j}\times\frac{\mu_0 I}{2\pi y}\hat{k}\right]$$

or, $$\vec{F} = \frac{qv\mu_0 I}{2\pi y}[\hat{j}\times\hat{k}]$$

$\therefore$ $$\vec{F} = \frac{qv\mu_0 I}{2\pi y}\hat{j}$$

24. Two conductors, made of the same material have equal lengths but different cross-sectional areas A_1 and A_2 ($A_1 > A_2$). They are connected in parallel across a cell. Show that the drift velocities of electrons in two conductors are equal.

Ans. When two conductors are connected parallel to a cell, then the potential difference across the two conductors will be same.

So, $V_1 = V_2$

Or, $I_1R_1 = I_2R_2$ (from Ohm's law)

Or, $neA_1\nu_{d1}R_1 = neA_2\nu_{d2}R_2$

Or, $A_1 v_{d1} R_1 = A_2 \nu_{d2} R_2$

Or, $A_1 v_{d1} \rho \frac{l}{A_1} = A_2 v d_2 \rho \frac{l}{A_2}$

(since $R = \rho \frac{l}{A}$)

$\therefore \quad v_{d1} = v_{d2}$

SECTION - C

27. An alternating current $I = 14 \sin(100\,\pi t)$ A passes through a series combination of a resistor of 30 Ω and an inductor of $\left(\frac{2}{5\pi}\right)$ H. Taking $\sqrt{2} = 1.4$, calculate the

(i) rms value of the voltage drops across the resistor and the inductor, and

(ii) power factor of the circuit. 3

Ans. (i) V_{rms} drop across resistor, R

$$= I_{rms} \times R$$
$$= \frac{14}{\sqrt{2}} \times 30$$
$$= 294\text{V}$$

V_{rms} drop across inductor, L

$$= I_{rms} \times \omega L$$
$$= (14/\sqrt{2}) \times (100\pi) \times (2/5\pi)$$
$$= 392\text{V}$$

(ii) Power factor, R/Z

$$\frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_L^2}}$$

$$\frac{R}{Z} = \frac{30}{\sqrt{30^2 + \left(100\pi \times \frac{2}{5\pi}\right)^2}}$$

$$= \frac{30}{\sqrt{30^2 + 40^2}}$$

$$= \frac{30}{50}$$

$$= 0.6$$

30. (a) Calculate the binding energy of an alpha particle in MeV. Given
mass of a proton = 1.007825 u
mass of a neutron = 1.008665 u
mas of He nucleus = 4.002800 u
1u = 931 MeV/c² 3

OR

(b) A heavy nucleus P of mass number 240 and binding energy 7.6 MeV per nucleon splits into two nuclei Q and R of mass number 110 and 130 and binding energy per nucleon 8.5 MeV and 8.4 MeV respectively. Calculate the energy released in the fission. 3

Ans. (a) Mass defect = Mass of protons + mass of neutrons – Mass of Helium nucleus

Or, Mass defect $= (2 \times 1.007825 + 2 \times 1.008665 - 4.002800)$u

$\therefore$ Mass defect $= 0.03018$ u

Binding energy $= 0.03018 \times 931$

$= 28.09785$ MeV

OR

(b) According to the question

$^{240}P \rightarrow {}^{110}Q + {}^{130}R + Q$

$Q = 110 \times 8.5 + 130 \times 8.4 - 240 \times 7.6$

Or, $Q = 935 + 1092 - 1824$

$\therefore \quad Q = 202$ MeV

Outside Delhi Set-1 55/2/1

SECTION - A

1. The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 $\frac{\text{N}}{\text{C}}$. From the same charged object the electric field of magnitude, 16 $\frac{\text{N}}{\text{C}}$ will be at a distance of

(A) 1 m **(B)** 2 m
(C) 3 m **(D)** 6 m 1

Ans. Option (C) is correct.

Explanation: In 1st case,

$$E = \frac{kq}{r^2}$$

Or, $9 = \frac{kq}{4^2}$ [$r = 4.0$ m]

$\therefore \quad kq = 9 \times 16$

In 2nd case,

$$E' = \frac{kq}{(r')^2}$$

Or, $16 = \frac{9 \times 16}{(r')^2}$

Or, $(r')^2 = 9$

$\therefore \quad r' = 3$ m

2. A point P lies at a distance x from the mid point of an electric dipole on its axis. The electric potential at point P is proportional to

(A) $\frac{1}{x^2}$ **(B)** $\frac{1}{x^3}$

(C) $\frac{1}{x^4}$ **(D)** $\frac{1}{x^{1/2}}$ 1

Ans. Option (A) is correct.

Explanation: Expression for electric potential due to dipole in given as $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{x^2}$

So, $V \propto \frac{1}{x^2}$

3. A current of 0.8 A flows in a conductor of 40 Ω for 1 minute. The heat produced in the conductor will be

(A) 1445 J **(B)** 1536 J

(C) 1569 J **(D)** 1640 J **1**

Ans. Option (B) is correct.

Explanation: Given, $R = 40\Omega$ and $I = 0.8A$

t = 1 minute = 60s

Heat produced $= H = I^2Rt$

Or, $H = (0.8)^2 \times 40 \times 60$

$\therefore$ H = 1536 Joule

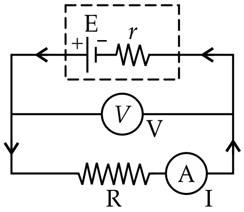
4. A cell of emf E is connected across an external resistance R. When current 'I' is drawn from the cell, the potential difference across the electrodes of the cell drops to V. The internal resistance 'r' of the cell is

(A) $\left(\frac{E-V}{E}\right)R$ **(B)** $\left(\frac{E-V}{R}\right)$

(C) $\frac{(E-V)R}{I}$ **(D)** $\left(\frac{(E-V)}{V}\right)R$ **1**

Ans. Option (D) is correct.

Explanation:



Since, $I = \frac{E}{R+r}$

So, $E = Ir + V$

$\therefore$ $r = \frac{E-V}{I}$

Or, $r = \left(\frac{E-V}{V}\right)R$ [$\because$ V = IR]

5. Beams of electrons and protons move parallel to each other in the same direction. They

(A) attract each other.

(B) repel each other.

(C) neither attract nor repel.

(D) force of attraction or repulsion depends upon speed of beams. **1**

Ans. Option (A) is correct.

Explanation: Since, electron and proton has opposite charge and moving in the same direction, So there must be an attractive force between them.

6. A long straight wire of radius 'a' carries a steady current I. The current is uniformly distributed across its area of cross-section. The ratio of magnitude of magnetic field $\vec{B}_1$ at $\frac{a}{2}$ and $\vec{B}_2$ at distance 2a is

(A) $\frac{1}{2}$ **(B)** 1

(C) 2 **(D)** 4 **1**

Ans. Option (B) is correct.

Explanation: Magnetic field inside

$$B_1 = \frac{\mu_0 ir}{2\pi a^2} = \frac{\mu_0 i(a/2)}{2\pi a^2} = \frac{\mu_0 i}{4\pi a}$$

(Here, $r = a/2$)

Magnetic field outside $= B_2 = \frac{\mu_0 i}{2\pi r} = \frac{\mu_0 i}{2\pi(2a)} = \frac{\mu_0 i}{4\pi a}$

(Here, $r = 2a$)

So, The required ratio $\frac{B_1}{B_2} = 1$

7. $\vec{E}$ and $\vec{B}$ represent the electric and the magnetic field of an electro- magnetic wave respectively. The direction of propagation of the wave is along

(A) $\vec{B}$ **(B)** $\vec{E}$

(C) $\vec{E}\times\vec{B}$ **(D)** $\vec{B}\times\vec{E}$ **1**

Ans. Option (C) is correct.

8. A ray of monochromatic light propagating in air, is incident on the surface of water. Which of the following will be the same for the reflected and refracted rays?

(A) Energy carried **(B)** Speed

(C) Frequency **(D)** Wavelength **1**

Ans. Option (C) is correct.

Explanation: Frequency of light does not depend on medium through which light travels.

9. A beam of light travels from air into a medium. Its speed and wavelength in the medium are 1.5 × 10^8 ms^{-1} and 230 nm respectively. The wavelength of light in air will be

(A) 230 nm **(B)** 345 nm

(C) 460 nm **(D)** 690 nm **1**

Ans. Option (C) is correct.

Explanation: In the medium

$c = n\lambda$

or, $1.5 \times 10^8 = n \times 230 \times 10^{-9}$

or, $n = \frac{1.5\times10^8}{230\times10^{-9}}$

$\therefore$ $n = \frac{1.5}{230}\times10^{17}\,\text{Hz}$

In air,

Frequency remains unchanged. So,

$n = \frac{1.5}{230}\times10^{17}\,\text{Hz}$

$v' = n\lambda'$

or, $3 \times 10^8 = \frac{1.5}{230} \times 10^{17} \times \lambda'$

$\therefore \quad \lambda' = 3 \times \frac{230}{1.5} \times 10^{-9}$

$= 460$ nm

10. Which one of the following metals does not exhibit emission of electrons from its surface when irradiated by visible light?

(A) Rubidium **(B)** Sodium

(C) Cadmium **(D)** Caesium **1**

Ans. Option (C) is correct.

Explanation: Cadmium emits electrons when irradiated by visible light.

11. A hydrogen atom makes a transition from $n = 5$ to $n = 1$ orbit. The wavelength of photon emitted is λ. The wavelength of photon emitted when it makes a transition from $n = 5$ to $n = 2$ orbit is

(A) $\frac{8}{7}\lambda$ **(B)** $\frac{16}{7}\lambda$

(C) $\frac{24}{7}\lambda$ **(D)** $\frac{32}{7}\lambda$ **1**

Ans. Option (D) is correct.

Explanation: In 1st case

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{5^2}\right]$$

or, $$\frac{1}{\lambda} = R\left[1 - \frac{1}{25}\right] = R\left[\frac{24}{25}\right]$$

$\therefore$ $$R = \frac{25}{24} \times \frac{1}{\lambda}$$

In 2nd case

$$\frac{1}{\lambda'} = R\left[\frac{1}{2^2} - \frac{1}{5^2}\right]$$

or, $$\frac{1}{\lambda'} = R\left[\frac{1}{4} - \frac{1}{25}\right] = R \times \frac{21}{100}$$

or, $$\frac{1}{\lambda'} = \frac{\cancel{25}}{24} \times \frac{1}{\lambda} \times \frac{21}{\underset{4}{\cancel{100}}}$$

or, $$\frac{1}{\lambda'} = \frac{21}{96\lambda}$$

$\therefore$ $$\lambda' = \frac{96}{21}\lambda = \frac{32}{7}\lambda$$

12. The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is

(A) radioactive

(B) unstable

(C) easily fissionable

(D) more stable nucleus than its neighbours **1**

Ans. Option (D) is correct.

Explanation: A nucleus becomes stable when its binding energy per nucleon is around 8 MeV. The peak indicates the binding energy per nucleon of He element is closer to 8 MeV. Binding energy per nucleon of He in actually 7.1 MeV. So, it is stable than its neighbours.

13. In an extrinsic semiconductor, the number density of holes is 4×10^{20} m^{-3}. If the number density of intrinsic carriers is 1.2×10^{15} m^3, the number density of electrons in it is

(A) 1.8×10^9 m^{-3} **(B)** 2.4×10^{10} m^{-3}

(C) 3.6×10^9 m^{-3} **(D)** 3.2×10^{10} m^{-3} **1**

Ans. Option (C) is correct.

Explanation: From law of mass action,

$$n_i^2 = n_e \times n_h$$

or, $$(1.2 \times 10^{15})^2 = n_e \times 4 \times 10^{20}$$

or, $$n_e = (0.3 \times 1.2) \times 10^{10}$$

$\therefore$ $$n_e = 3.6 \times 10^9 \text{ m}^{-3}$$

14. Pieces of copper and of silicon are initially at room temperature. Both are heated to temperature T. The conductivity of

(A) both increases.

(B) both decreases.

(C) copper increases and silicon decreases.

(D) copper decreases and silicon increases. **1**

Ans. Option (D) is correct.

Explanation: Copper is a conductor. As the temperature of copper increases the ions vibrate vigorously. So, the number of collisions between the free electrons and the ions increases. Hence, the resistance increases and conductivity decreases.

Silicon is a semiconductor. As the temperature increases, more covalent bonds rupture generating more free charge carriers. Hence, the resistance decreases and conductivity increases.

15. The formation of depletion region in a *p-n* junction diode is due to

(A) movement of dopant atoms

(B) diffusion of both electrons and holes

(C) drift of electrons only

(D) drift of holes only **1**

Ans. Option (B) is correct.

Explanation: During formation of p-n junction, the electrons diffuse from n-side to p-side (since, electron concentration is more in n-side compared to p-side) and the holes diffuse from p-side to n-side (since, hole concentration is more in p-side compared to n-side).

Note: In question number 16 to 18, two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

(B) Both Assertion (A) and Reason (R) are true and Reason (R) is NOT the correct explanation of Assertion (A).

(C) Assertion (A) is true and Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

16. Assertion (A): Diamagnetic substances exhibit magnetism.

Reason (R): Diamagnetic materials do not have permanent magnetic dipole moment. 1

Ans. Option (A) is correct.

Explanation: The assertion is true. Diamagnetic substance shows faint repulsion. It is a property of magnetism. So, assertion is true.

The above property is observed in the substances which have even number of electrons in each atom/molecule. Electrons with opposite spins form pairs and so no net dipole moment is generated. Diamagnetic substances are such substances and hence exhibit the above magnetic property . So, the reason is true it explains the assertion.

17. Assertion (A): Work done in moving a charge around a closed path, in an electric field is always zero.

Reason (R): Electrostatic force is a conservative force. 1

Ans. Option (A) is correct.

Explanation: Electric field is said to be conservative since, work done in this field is path independent. It depends on the end points only. So, in an electric field, total work done in moving a charge from a point to the next point and again back to the first point is zero.

Hence, assertion and reason both are true and reason explains the assertion.

18. Assertion (A): In Young's double slit experiment all fringes are of equal width.

Reason (R): The fringe width depends upon wavelength of light (λ) used, distance of screen from plane of slits (D) and slits separation (*d*). 1

Ans. Option (A) is correct.

Explanation: Interference fringe width = $\beta = \lambda D/d$

It depends on wavelength of light used, distance between slits and distance of screen from the slit only. Hence, all fringes have equal width.

So, assertion and reason both are true and the reason explains the assertion.

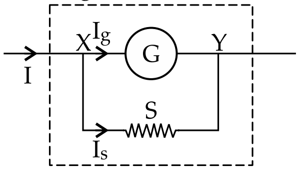
SECTION - B

19. Briefly explain why and how a galvanometer is converted into an ammeter. 2

Ans. Conversion of galvanometer into ammeter:

Ammeter is connected in series in a circuit. So, its resistance should be such that it does not increase the equivalent resistance value of the circuit appreciably.

So, to convert a galvanometer into an ammeter a very low resistance value shunt is to be connected in parallel with the galvanometer.



If potential difference between points X and Y be $V_x - V_y$, then

$$V_x - V_y = I_g \times G = I_s \times S$$

Or, $$I_g \times G = I_s \times S$$

$$\therefore \quad S = \frac{I_g}{I_s} \times G \qquad ...(1)$$

Again $$I = I_s + I_g$$

$$\therefore \quad I_s = I - I_g$$

Putting in equation (1)

$$S = \frac{I_g}{I - I_g} \times G$$

20. (a) How are infrared waves produced? Why are these waves referred to as heat waves ? Give any two uses of infrared waves. 2

OR

(b) How are X-rays produced? Give any two uses of these.

Ans. (a) **Production of infrared waves:**

- Any object having temperature emits infrared (even ice emits infrared).
- Sun is a source of infrared.
- Infrared is produced by Nernst lamp, infrared laser etc.

Infrared waves are heat waves:

- It increases the vibration of atoms of the substances on which it falls and thus increases the internal energy and temperature of the substance.

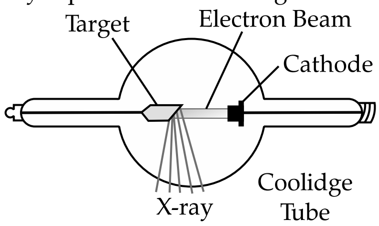
Uses of infrared:

- It is used for photography at night and through fog.
- It is used for relieve of muscular pain.

OR

(b) Production of X-rays:

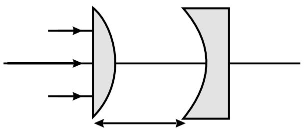
- X-rays are produced when high energy electron beam bombards metallic target of high melting and point heavy atomic weight.
- X-ray is produced in Coolidge tube.



Uses of X-ray:

- It is used to photograph bones for the diagnosis of any fracture and dislocation.
- It is used to radiotherapy to destroy cancerous cells and to shrink tumors.

21. In the given figure the radius of curvature of curved face in the plano- convex and the plano-concave lens is 15 cm each. The refractive index of the material of the lenses is 1.5. Find the final position of the image formed. 2



Ans. Focal length of plano-convex lens be f_1

$$\frac{1}{f_1} = (1.5-1)\left(\frac{1}{15}-\frac{1}{\infty}\right)$$

Or $$\frac{1}{f_1} = \frac{1}{30}$$

$\therefore$ $$f_1 = 30 \text{ cm}$$

Focal length of plano-concave lens be f_2

$$\frac{1}{f_2} = (1.5-1)\left(\frac{1}{\infty}-\frac{1}{15}\right)$$

$\therefore$ $$f_2 = -30 \text{ cm}$$

since, parallel rays are incident on the plano convex lens it will form an image at a distance 30 cm from the lens (since, focal length is 30 cm).

This image will act as an object for the plano concave lens.

Object distance $= 30 - 20 = 10$ cm

Applying lens formula,

$$\frac{1}{v_2}-\frac{1}{u_2} = \frac{1}{f_2}$$

Or, $$\frac{1}{v_2}-\frac{1}{10} = -\frac{1}{30}$$

So, $$v_2 = 15 \text{ cm}$$

22. What happens to the interference pattern when two coherent sources are

(a) infinitely close, and

(b) far apart from each other **2**

Ans. Interference fringe width is given by

$$\beta_2 = \lambda \frac{D}{d}$$

So, $$\beta \propto \frac{1}{d}$$

(i) If the coherent sources are infinitely close then the fringe width will be so large that a single fringe will occupy the whole screen. So, no interference pattern will be detected.

(ii) If the coherent sources are far apart, then d is very large. So, the fringe width will be so small that those cannot be resolved separately. So, no interference pattern will be detected.

23. (a) What is meant by ionisation energy? Write its value for hydrogen atom. **2**

OR

(b) Define the term, mass defect. How is it related to stability of the nucleus ?

Ans. (a) Ionisation energy:

Ionisation energy is the minimum amount of energy which is to be supplied to an atom in its ground state so that it gets converted into an ion i.e., the minimum energy requires to shift an electron from $n = 1$ to $n = \infty$.

The value of ionization energy for Hydrogen is 13.6 eV.

OR

(b) Mass defect:

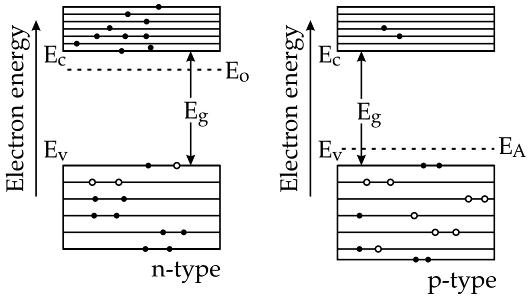
Mass defect is the difference of total mass of all the nucleons present in a nucleus and the rest mass of the nucleus.

$$\text{Mass defect} = \Delta m = Zm_p + (A-Z)m_n - M$$

As the mass defect increases, binding energy of the nucleus increases. This means the stability of the nucleus increases as mass defect increases.

24. Draw energy band diagram for an *n*-type and *p*-type semiconductor at T>0 K. **2**

Ans.



25. Answer the following giving reasons:

(i) A *p-n* junction diode is damaged by a strong current.

(ii) Impurities are added in intrinsic semiconductors. **2**

Ans. (a) A p-n junction diode is damaged by strong current due to generation of heat.

(b) Impurities are added to intrinsic semiconductor to convert it to extrinsic semiconductor so that they achieve conductivity even at 0K.

SECTION - C

26. (a) Two charged conducting spheres of radii *a* and *b* are connected to each other by a wire. Find the ratio of the electric fields at their surfaces. **3**

OR

(b) A parallel plate capacitor (A) of capacitance C is charged by a battery to voltage V. The battery is disconnected and an uncharged capacitor (B) of capacitance 2C is connected across A. Find the ratio of

(i) final charges on A and B.

(ii) total electrostatic energy stored in A and B finally and that stored in A initially.

Ans. (a) For sphere with radius a,

Potential = V

(since, both the charged spheres are connected by a wire)

Charge $= Q_a$

Capacitance $= C_a$

Electric field, $= E_a = \dfrac{Q_a}{4\pi\varepsilon_0 a^2}$

For sphere with radius b,
Potential $= V$

(since both the charged spheres are connected by a wire)

$$\text{Charge} = Q_b$$
$$\text{Capacitance} = C_b$$
$$\text{Electric field} = E_b = \frac{Q_b}{4\pi\varepsilon_0 b^2}$$

Now,
$$\frac{E_a}{E_b} = \frac{Q_a}{Q_b} \times \frac{b^2}{a^2} \quad ...(1)$$
$$\frac{Q_a}{Q_b} = \frac{C_a V}{C_b V}$$
Or,
$$\frac{Q_a}{Q_b} = \frac{C_a}{C_b}$$
Or,
$$\frac{Q_a}{Q_b} = \frac{a}{b} \quad ...(2)$$
(since, $C_a/C_b = a/b$)

Putting in equation (1)
$$\frac{E_a}{E_b} = \left(\frac{a}{b}\right) \times \left(\frac{b^2}{a^2}\right)$$
$$\therefore \quad \frac{E_a}{E_b} = \frac{b}{a}$$

OR

(b) (i) Initially,
Charge on A capacitor $= CV$
Charge on B capacitor $= 0$
After connecting A with B,
$$\text{Final potential} = V' = \frac{\text{Total Charge}}{\text{total capacitance}}$$
$$= \frac{Q+0}{C+2C} = \frac{Q}{3C}$$

Final charge on A capacitor after redistribution
$$= CV' = \frac{CQ}{3C} = \frac{Q}{3}$$

Final charge on B capacitor after redistribution
$$= 2CV' = \frac{2CQ}{3C} = \frac{2Q}{3}$$

So, the ratio of charges $= \dfrac{Q/3}{2Q/3} = 1:2$

(ii) Initially energy stored in A $= \dfrac{1}{2}CV^2$

Finally energy stored in A $= \dfrac{1}{2}CV'^2$
$$= \frac{1}{2} \times C \times \left(\frac{Q}{3C}\right)^2$$
$$= \frac{1}{2} \times C \times \left(\frac{V}{3}\right)^2$$
$$= \frac{CV^2}{18}$$

Finally energy stored in B $= \dfrac{1}{2}2CV'^2$
$$= \frac{1}{2} \times 2C \times \left(\frac{Q}{3C}\right)^2$$
$$= \frac{1}{2} \times 2C \times \left(\frac{V}{3}\right)^2$$
$$= \frac{CV^2}{9}$$

Total energy stored in A and B
$$= \frac{CV^2}{18} + \frac{CV^2}{9}$$
$$= \frac{CV^2}{6}$$

So, the required ratio $= \dfrac{\text{Find energy stored in A and B}}{\text{Initial energy stored in A}}$
$$= \frac{CV^2/6}{CV^2/2}$$
$$= \frac{1}{3}$$

27. Define current density and relaxation time. Derive an expression for resistivity of a conductor in terms of number density of charge carriers in the conductor and relaxation time. 3

Ans. Current density: Current density is the current per unit area of cross-section of a conductor.
$$J = \frac{I}{A}$$

Relaxation time: Relaxation time is the time interval between two successive collisions of electrons in a conductor.

Expression for resistivity:
$$v_d = \frac{eE}{m}\tau$$
or,
$$v_d = \frac{eV}{ml}\tau \quad \left(\text{since, } E = \frac{V}{l}\right)$$
or,
$$V = \frac{v_d ml}{e\tau}$$
or,
$$IR = \frac{v_d ml}{e\tau}$$
(since from Ohm's law, $V = IR$)

or,
$$R = \frac{v_d ml}{e\tau I}$$
or,
$$\frac{\rho l}{A} = \frac{v_d ml}{e\tau I} \quad \left(\text{since } R = \frac{\rho l}{A}\right)$$
or,
$$\rho = \frac{v_d mA}{e\tau I}$$

or, $\rho = \dfrac{v_d mA}{e\tau(neAv_d)}$

(since, $I = neAv_d$)

$\therefore \quad \rho = \dfrac{m}{ne^2\tau}$

28. A series CR circuit with R = 200 Ω and C = (50/π) μF is connected across an ac source of peak voltage ε_0, = 100 V and frequency ν = 50 Hz. Calculate (a) impedance of the circuit (Z), (b) phase angle (ϕ), and (c) voltage across the resistor. 3

Ans. (a) Given, R = 200 Ω, C = $\dfrac{50}{\pi}\mu F$

Impedance: $Z = \sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}$

Or, $Z = \sqrt{(200)^2 + \left(\dfrac{1}{2\pi \times 50 \times \dfrac{50}{\pi} \times 10^{-6}}\right)^2}$

Or, $Z = \sqrt{(200)^2 + (200)^2}$

$\therefore \quad Z = 200\sqrt{2}\,|$

(b) Phase angle:

$\theta = \tan^{-1}\dfrac{1}{\omega CR}$

or, $\theta = \tan^{-1}\left(\dfrac{1}{2\pi \times 50 \times \dfrac{50}{\pi} \times 10^{-6} \times 200}\right)$

or, $\theta = \tan^{-1} 1$

$\therefore \quad \theta = 45^0$

(c) Voltage across resistor:

$I_{RMS} = \dfrac{\varepsilon_{RMS}}{Z}$

Or, $I_{RMS} = \dfrac{\dfrac{\varepsilon_0}{\sqrt{2}}}{Z}$

Or, $I_{RMS} = \dfrac{\dfrac{100}{\sqrt{2}}}{200\sqrt{2}}$

$\therefore \quad I_{RMS} = \dfrac{1}{4}\text{A}$

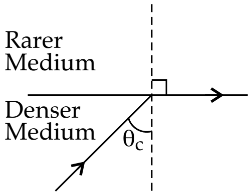
$V_R = I_{RMS} \times R$

Or, $V_R = \dfrac{1}{4} \times 200$

$\therefore \quad V_R = 50\text{V}$

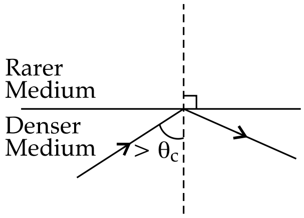
29. Define critical angle for a given pair of media and total internal reflection. Obtain the relation between the critical angle and refractive index of the medium. 3

Ans. Critical angle:



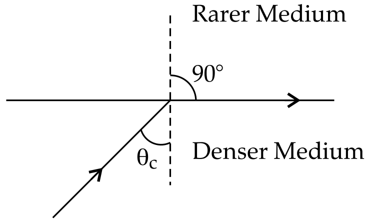
When light refracts from a denser to a rarer medium, the angle of incidence for which the angle of refraction is 90° is known as the critical angle.

Total internal reflection:



When light refracts from a denser to a rarer medium, if the angle of incidence is greater than the critical angle, the light is reflected back to the denser medium. This phenomenon is known as total internal reflection.

Relation between critical angle and refractive index:



Refractive index of denser medium = μ_{denser}
Refractive index of rarer medium = μ_{rarer}
Critical angle = θ_c

$\therefore \quad {}_{\text{denser}}\mu_{\text{rarer}} = \dfrac{\sin\theta_c}{\sin 90°}$

$\dfrac{\mu_{\text{rarer}}}{\mu_{\text{denser}}} = \sin\theta_c$

or, $\dfrac{\mu_{\text{denser}}}{\mu_{\text{rarer}}} = \dfrac{1}{\sin\theta_c}$

If the rarer medium is air, then $\mu_{\text{rarer}} = 1$

$\therefore \quad \mu = \dfrac{1}{\sin\theta_c}$

30. (a) (i) Distinguish between nuclear fission and fusion giving an example of each.

(ii) Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nucleon curve. 3

OR

(b) (i) How is the size of a nucleus found experimentally? Write the relation between the radius and mass number of a nucleus.

(ii) Prove that the density of a nucleus is independent of its mass number.

Ans. (a) (i) Nuclear fission & fusion:

Nuclear fission	Nuclear fusion
Heavy nucleus splits into comparatively lighter nuclei.	Lighter nuclei fuse to form comparatively heavier nuclei.
Energy released is less than that of fusion.	Energy released is more than that of fission.
Does not naturally occur.	Occur naturally in stars.
Comparatively less amount of energy required to start the process.	Huge amount of energy is required to start the process.
Application: Atomic bomb	Application: Hydrogen bomb
Example: ${}_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_{0}n^{1} + Q$	Example: ${}_{1}H^{1} + {}_{1}H^{1} \rightarrow {}_{1}H^{2} + {}_{+1}e^{0} + \nu + Q$

(ii) In nuclear fusion, the binding energy of the products is greater than the binding energy of reactants.

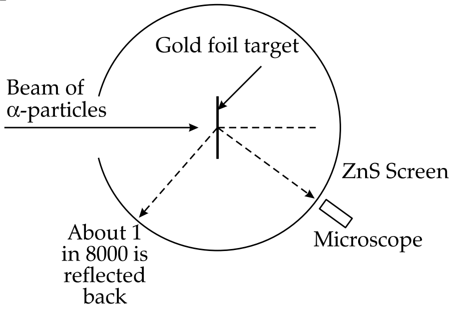
In nuclear fission, binding energy of fragments is greater than the binding energy of the parent.

This difference in binding energy is released in form of energy.

OR

(b) (i) Experimental determination of size of nucleus:

Size of nucleus was determined experimentally by Rutherford by his alpha particle scattering experiment.



In the experiment, a gold foil of thickness 2.1×10^{-7} was bombarded by energetic α-particles generated from ${}_{83}Bi^{214}$ source.

Scattered α-particles were observed on a ZnS screen with the help of a microscope.

It was observed that most of the α-particles passed through the gold foil undeviated.

About 14% α-particles were scattered by an angle more than 1^0.

1 out of 8000 α-particles was scattered by an angle more than 90^0.

Very few α-particles was scattered by an angle 180^0.

From these observations Rutherford calculated the impact parameter and distance of closest approach and concluded that the size of nucleus lies between 10^{-15}m and 10^{-14} m.

Relation between radius and mass number:

$$r = R_0A^{1/3} \text{ (where } R_0 = 1.25\text{fm)}$$

(ii) Density of nucleus is independent of mass number:

$$\rho = \frac{M}{V}$$

or,
$$\rho = \frac{mA}{\frac{4}{3}\pi r^3}$$

or,
$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \quad (\text{since } r = R_0A^{1/3})$$

$\therefore$
$$\rho = \frac{m}{\frac{4}{3}\pi R_0^3}$$

Hence, it is independent of mass number.

31. (a) (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.

(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed *v* such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ. **5**

OR

(b) (i) Consider two identical point charges located at points (0, 0) and (a, 0).

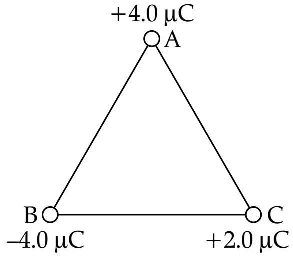
(1) Is there a point on the line joining them at which the electric field is zero?

(2) Is there a point on the line joining them at which the electric potential is zero?

Justify your answers for each case.

(ii) State the significance of negative value of electrostatic potential energy of a system of charges.

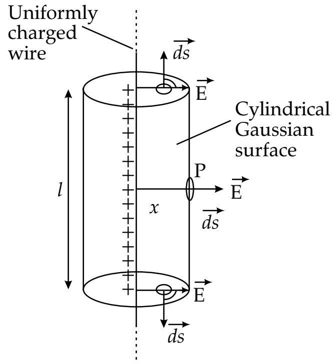
Three charges are placed at the corners of an equilateral triangle ABC of side 2.0 m as shown in figure. Calculate the electric potential energy of the system of three charges.



Ans. (a) (i) Electric field due to an infinitely long thin straight wire with uniform linear charge density:

Linear charge density = λ

A point P is considered at a distance *x* where the electric field is to be determined.



A cylindrical Gaussian surface of length l and radius x is considered with the wire as its axis.

Magnitude of electric field at every point the curved surface of the cylinder is same and is directed outward making an angle 0^0 with the direction of area vector .

Electric fields at the two flat surfaces of the cylinder are zero since, the direction of electric field through those surfaces and the direction of area vector are perpendicular.

So, total flux through the curved surface

$$= \phi = E \times 2\pi xl$$

According to Gauss' law, $\phi = \dfrac{l\lambda}{\varepsilon_0}$

$$\therefore \quad E \times 2\pi xl = \frac{l\lambda}{\varepsilon_0}$$

$$\therefore \quad E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{x}$$

(ii) Electric field produced by an infinitely long straight charged wire,

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

This field provides the centripetal force to the revolving electron.

$$eE = \frac{mv^2}{r}$$

or, $$\frac{\lambda}{2\pi\varepsilon_0 r} = \frac{mv^2}{r}$$

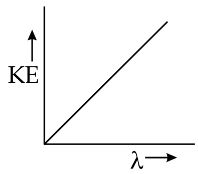
or, $$mv^2 = \frac{e\lambda}{2\pi\varepsilon_0}$$

$\therefore$ Kinetic energy (KE) $= \dfrac{1}{2}mv^2 = \dfrac{e\lambda}{4\pi\varepsilon_0}$

(iii) The required equation,

$$\frac{1}{2}mv^2 = \frac{e\lambda}{4\pi\varepsilon_0}$$

It is the equation of a straight line passing through the origin.



OR

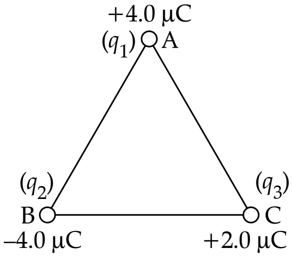
(b) (i) (1) Yes, Electric field will be zero at $\left(\dfrac{a}{2}, 0\right)$ point.

At this point the magnitudes of both the electric fields are same in magnitude and are oppositely directed.

(2) Electric potential will not be zero at any point since at every point the potential will be the summation of both the potentials and both charges are of similar nature.

(ii) Significance of negative electrostatic potential energy:

Negative electrostatic potential energy of a system of charges means work is to be done against the field to move the charges apart.



Potential energy due to charges at A and B

$$U_1 = \frac{kq_1q_2}{r}$$

Or, $$U_1 = \frac{9\times10^9\times(-4)\times(4)\times10^{-12}}{2}$$

$\therefore$ $$U_1 = -72\times10^{-3}\text{ J}$$

Potential energy due to charges at A and C

$$U_2 = \frac{kq_1q_3}{r}$$

Or, $$U_1 = \frac{9\times10^9\times(4)\times(2)\times10^{-12}}{2}$$

$\therefore$ $$U_2 = 36\times10^{-3}\text{ J}$$

Potential energy due to charges at B and C

$$U_3 = \frac{kq_2q_3}{r}$$

Or, $$U_3 = \frac{9\times10^9\times(-4)\times(2)\times10^{-12}}{2}$$

$\therefore$ $$U_3 = -36\times10^{-3}\text{ J}$$

Net potential energy of the system of three charges.

$$U = U_1 + U_2 + U_3$$

Or, $$U = -72\times10^{-3}\text{ J} + 36\times10^{-3}\text{ J} - 36\times10^{-3}\text{ J}$$

$\therefore$ $$U = -72\times10^{-3}\text{ J}$$

32. (a) (i) Define coefficient of self-induction. Obtain an expression for self-inductance of a long solenoid of length l, area of cross- section A having N turns.

(ii) Calculate the self-inductance of a coil using the following data of obtained when an AC source of frequency $\left(\frac{200}{\pi}\right)$ Hz and a DC source is applied across the coil. **5**

AC Source		
S.No.	V(Volts)	I(A)
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

DC Source		
S.No.	V(Volts)	I(A)
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

OR

(b) (i) With the help of a labelled diagram, describe the principle and working of an ac generator. Hence, obtain an expression for the instantaneous value of the emf generated.

(ii) The coil of an ac generator consists of 100 turns of wire, each of area 0.5 m^2. The resistance of the wire is 100 Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

Ans. (a) (i) Coefficient of self induction: Coefficient of self induction of a coil is defined as the emf induced in the coil per unit rate of change of current in the same coil.

Self-inductance of a long solenoid:

Length of the solenoid = l

Total number of turns = N

Area of cross section = A

Current flowing through the solenoid = i

Magnetic flux associated with each turn = $\mu_0\mu_r\, n\, i\, A$

Magnetic flux at any point on the axis

$$= \mu_0\mu_r\left(\frac{N}{l}\right) i$$

Magnetic flux associated with each turn

$$= \mu_0\mu_r\left(\frac{N}{l}\right) iA$$

Total magnetic flux associated with the solenoid = ϕ

$$= \mu_0\mu_r\left(\frac{N}{l}\right) iAN$$

$$= \mu_0\mu_r\left(\frac{N^2}{l}\right) iA$$

Self inductance of the solenoid = $L = \frac{\phi}{i}$

$$= \mu_0\mu_r\left(\frac{N^2}{l}\right)A \text{ Henry}$$

(ii) Calculation of self inductance:

DC SOURCE				
S. No.	V(Volts)	I(Ampere)	Resistance (Ohms)	Average resistance value (R)
1	4.0	1.0	4.0	4.0Ω
2	6.0	1.5	4.0	
3	8.0	2.0	4.0	

AC SOURCE				
S. No.	V(Volts)	I(Ampere)	Impedance (Ohms)	Average Impedance value (Z)
1	3.0	0.5	6.0	6.0Ω
2	6.0	1.0	6.0	
3	9.0	1.5	6.0	

$$X_L = \sqrt{Z^2 - R^2}$$

Or, $$2\pi fL = \sqrt{6^2 - 4^2}$$

Or, $$2\pi fL = \sqrt{20}$$

Or, $$2\pi\times\frac{200}{\pi}\times L = \sqrt{20}$$

$\therefore$ $$L = \frac{1}{40}\sqrt{5} \text{ Henry}$$

OR

(b) (i) Refer the answer of Q28 of CBSE 12 DELHI, Set-1.

(ii) Given,

N = 100

A = 0.5 m^2

ω = 60 radians/second

B = 0.8T

r = 100Ω

Maximum emf generated = NBAω

Or, Maximum emf generated = $100 \times 0.8 \times 0.5 \times 60$

$\therefore$ Maximum emf generated = E_0 = 2400 V

Maximum current = $I_0 = \dfrac{E_0}{R} = \dfrac{2400}{100}$ = 24A

Power dissipation = $E_0I_0 = 2400 \times 24 = 57600$ Watt

33. (a) (i) State Huygen's principle. With the help of a diagram, show how a plane wave is reflected from a surface. Hence, verify the law of reflection.

(ii) A concave mirror of focal length 12 cm forms a three times magnified virtual image of an object. Find the distance of the object from the mirror. 5

OR

(b) (i) Draw a labelled ray diagram showing the image formation by a refracting telescope. Define its magnifying power. Write two limitations of a refracting telescope over a reflecting telescope.

(ii) The focal lengths of the objective and the eye-piece of a compound microscope are 1.0 cm and 2.5 cm respectively. Find the tube length of the microscope for obtaining a magnification of 300.

Ans. (a) (i) Huygens' principle:

Each point on primary wavefront act as a source of secondary wavelets sending out disturbances in all directions in the similar manner as the original source of light does.

Verification of laws of reflection:

Refer the answer of Q26 (OR) of CBSE 12 DELHI, Set-1.

(ii) Magnification $= -\dfrac{v}{u}$

Or, $3 = -\dfrac{v}{u}$

$\therefore$ $v = -3u$

Applying mirror formula,

$$\frac{1}{v}+\frac{1}{u} = \frac{1}{f}$$

Or, $$-\frac{1}{3u}+\frac{1}{u} = -\frac{1}{12}$$

Or, $$\frac{2}{3}u = -\frac{1}{12}$$

$\therefore$ $u = -8$ cm

OR

(b) (i) Refer the answer of Q33 (OR) (i) of CBSE 12 DELHI, Set-1.

Limitation of refracting telescope:

- Refracting telescope suffer from chromatic aberration.
- Large size Refracting telescopes are too heavy and too costly due to large size of lenses

(ii) Given, $f_0 = 1$ cm

$F_E = 2.5$ cm

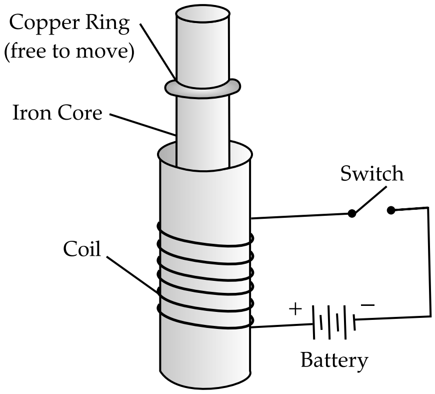
$m = 300$

Since, $$m = \frac{L \times D}{f_0 \times f_E}$$

or, $$300 = \frac{L \times 25}{1 \times 2.5}$$

$\therefore$ $L = 30$ cm

34. (a) Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



Answer the following questions:

(i) Explain the reason of jumping of the ring when the switch is closed in the circuit.

(ii) What will happen if the terminals of the battery are reversed and the switch is closed? Explain.

(iii) Explain the two laws that help us understand this phenomenon. 4

OR

(b) Briefly explain various ways to increase the strength of magnetic field produced by a given solenoid.

Ans. (a) (i) When the switch is closed, a current flows through the solenoid and an emf is induced in the ring. An induced current flows in the ring.

Lenz's Law states that an induced current always flows in the opposite direction of that which produced it. In other words, the emf induced by the solenoid creates a current in the ring that flows in the opposite direction of the solenoid's current. These opposite currents repel one another, so the ring jumps up being repelled by the solenoid.

(ii) When the battery is reversed, the directions of currents in both solenoid and ring change and the ultimately same phenomenon is observed.

(iii) The laws which explain the phenomenon:

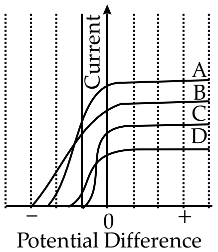
- **Faraday's law of electromagnetic induction:** An emf is induced in a conductor when it is placed in a varying magnetic field.
- **Lenz's law:** Induced current flows in a direction such that the current opposes the change that induced it.

OR

(b) Various ways to increase the magnetic field produced by a solenoid:

- By placing a soft iron core.
- By increasing the number of turns per unit length.
- By increasing the strength of current.

35. (a) Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams A, B, C and D of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions:



(i) Which light beam has the highest frequency and why?

(ii) Which light beam has the longest wavelength and why?

(iii) Which light beam ejects photoelectrons with maximum momentum and why? **4**

OR

(b) What is the effect on threshold frequency and stopping potential on increasing the frequency of incident beam of light? Justify your answer.

Ans. (a) (i) Light beam B has the highest frequency. As the frequency increases, work function remaining same, the stopping potential increases.

For light beam B stopping potential is maximum. Hence, it has the highest frequency.

(ii) Light beam C has the lowest frequency. Hence, this beam has the longest wavelength.

(iii) Light beam B has the highest frequency. So, electrons ejected due to this radiation will have maximum kinetic energy and hence maximum momentum.

OR

(b)
- Stopping potential increases with increase of frequency of incident beam of light.

  From Einsten's equation,

  $$h\nu = h\nu_0 + eV_S$$

  ν_0 is constant for a particular substance. So, as ν increases, V_S increases.

- There is no effect on threshold frequency. Threshold frequency (ν_0) is a constant for a substance. If frequency of incident light is lower than this, no photoemission will take place. If frequency of incident light is higher than this, photoemission will take place.

Outside Delhi Set-2 — 55/2/2

Note: Except these, all other questions are from Outside Delhi Set-1

SECTION - A

1. The ratio of the magnitudes of the electric field and magnetic field of a plane electromagnetic wave is

(A) 1 **(B)** $\frac{1}{c}$

(C) c **(D)** $\frac{1}{c^2}$ **1**

Ans. Option (A) is correct

2. Specify the transition of electron in the wavelength of the line in the Bohr model of hydrogen atom which gives rise to the spectral line of highest wavelength.

(A) $n = 3$ to $n = 1$ **(B)** $n = 3$ to $n = 2$

(C) $n = 4$ to $n = 1$ **(D)** $n = 4$ to $n = 2$ **1**

Ans. Option (B) is correct.

Explanation: By using the formula $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For (A), $\lambda = \frac{1.125}{R}$

For (B), $\lambda = \frac{7.2}{R}$

For (C), $\lambda = \frac{1.1}{R}$

For (D), $\lambda = \frac{5.3}{R}$

5. An isolated point charge particle produces an electric filed $\vec{E}$ at a point 3 m away from it. The distance of the point at which the filed is $\frac{\vec{E}}{4}$ will be

(A) 2 m **(B)** 3 m

(C) 4 m **(D)** 6 m **1**

Ans. Option (D) is correct.

Explanation: $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

In 1st case,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{3^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{9} \quad ...(1)$$

In 2nd case,

$$\frac{E}{4} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \quad ...(2)$$

Taking ratio,

$$4 = \frac{r^2}{9}$$

$$\therefore \quad r = 6\text{m}$$

7. A steady current of 8 mA flows through a wire. The number of electrons passing through a cross-section of the wire in 10 s is

(A) 4.0×10^{16} **(B)** 5.0×10^{17}

(C) 1.6×10^{16} **(D)** 1.0×10^{17} **1**

Ans. Option (B) is correct.

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

Or, $$n = \frac{8\times10^{-3}\times10}{1.6\times10^{-19}}$$

$\therefore$ $$n = 5 \times 10^{17}$$

8. Which one of the following elements will require the highest energy to take out an electron from them ?

Pb, Ge, C and Si

(A) Ge **(B)** C

(C) Si **(D)** Pb **1**

Ans. Option (B) is correct.

Explanation: Carbon has the highest ionisation energy among the form elements.

9. A conductor of 10 Ω is connected across a 6 V ideal source. The power supplied by the source to the conductor is

(A) 1.8 W **(B)** 2.4 W

(C) 3.6 W **(D)** 7.2 W **1**

Ans. Option (C) is correct.

Explanation: $$P = \frac{V^2}{R}$$

Or, $$P = \frac{6^2}{10}$$

$\therefore$ $$P = 3.6\text{W}$$

12. A photon of wavelengths 663 nm is incident on a metal surface. The work function of the metal is 1.50 eV. The maximum kinetic energy of the emitted photo electrons is

(A) 3.0×10^{-20} J **(B)** 6.0×10^{-20} J

(C) 4.5×10^{-20} J **(D)** 9.0×10^{-20} J **1**

Ans. Option (B) is correct.

Explanation:

$$h\nu = \phi_0 + KE_{max}$$

or, $$\frac{hc}{\lambda} = \phi_0 + KE_{max}$$

or, $$\frac{6.62\times10^{-34}\times3\times10^{8}}{663\times10^{-9}} = 1.5 \times 1.6 \times 10^{-19} + \text{KE}_{max}$$

$\therefore$ $$KE_{max} = 0.6 \times 10^{-19}$$
$$= 6 \times 10^{-20}\text{ J}$$

14. A ray of light of wavelength 600 nm propagates from air into a medium. If its wavelength in the medium becomes 400 nm, the refractive index of the medium is

(A) 1.4 **(B)** 1.5

(C) 1.6 **(D)** 1.8 **1**

Ans. Option (B) is correct.

Explanation: $$\lambda_{medium} = \lambda_{air}/\mu$$

Or, $$400 = \frac{600}{\mu}$$

$\therefore$ $$\mu = \frac{600}{400} = 1.5$$

19. In Young's double slit experiment, the separation between the two slits in d and distance of the screen from the slits is 1000 d. If the first minima falls at a distance d from the central maximum, obtain the relation between d and λ. **2**

Ans. Position of n^{th} dark fringe from the centre is

$$y_{n^-} = (2n-1)\frac{\lambda D}{d}$$

For 1st minima,

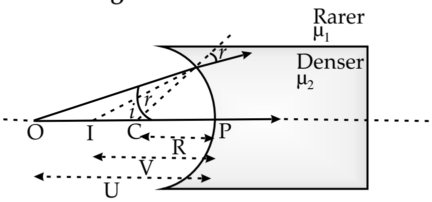
$$y_1 = \frac{\lambda D}{2d}$$

or, $$d = \frac{\lambda\times1000d}{2d}$$

$\therefore$ $$d = 500\lambda$$

25. A point object in air is placed symmetrically at a distance of 60 cm in front of a concave spherical surface of refractive index 1.5. If the radius of curvature of the surface is 20 cm, find the position of the image formed. **2**

Ans.



For refraction from concave spherical surface,

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{R}$$

or, $$\frac{1.5}{v} - \frac{1}{(-60)} = \frac{1.5-1}{-20}$$

or, $$\frac{1.5}{v} + \frac{1}{60} = -\frac{0.5}{20}$$

or, $$\frac{1.5}{v} + \frac{1}{60} = -\frac{1}{40}$$

or, $$\frac{1.5}{v} = -\frac{1}{40} - \frac{1}{60}$$

$\therefore$ $$v = -36\text{ cm}$$

Image in formed in the medium where the object lies at a distance 36 cm from point P.

SECTION - C

26. A series RL circuit with $R = 10\,\Omega$ and $L = \left(\frac{100}{\pi}\right)$mH is connected to an ac source of voltage $V = 141 \sin (100\,\pi\, t)$, where V is in volts and t is in seconds. Calculate

(a) impedance of the circuit

(b) phase angle, and

(c) voltage drop across the inductor **3**

Ans. (a) Given,

$$R = 10\Omega$$

$$L = \left(\frac{100}{\pi}\right) mH$$

$$V = 141\sin(100\pi t)$$

$$\text{Impedance} = Z = \sqrt{R^2 + (\omega L)^2}$$

Or,
$$Z = \sqrt{10^2 + (100\pi \times \frac{100}{\pi} \times 10^{-3})^2}$$

Or,
$$Z = \sqrt{10^2 + 10^2}$$

$$\therefore \quad Z = 10\sqrt{2}\,\Omega$$

(b)
$$\text{Phase angle} = \tan^{-1}\frac{\omega L}{R}$$

Or,
$$\text{Phase angle} = \tan^{-1}\left(\frac{100\pi \times \frac{100}{\pi} \times 10^{-3}}{10}\right)$$

Or,
$$\text{Phase angle} = \tan^{-1} 1$$

$$\therefore \quad \text{Phase angle} = 45^0$$

(c)
$$V_0 = 141\ V$$

$$X_L = \omega L$$

$$= 100\pi \times \frac{100}{\pi} \times 10^{-3}$$

$$= 10\Omega$$

$$I_0 = \frac{V_0}{Z} = \frac{141}{10\sqrt{2}}$$

Voltage drop across inductor $= V_L = I_0 X_L$

Or,
$$V_L = \frac{141}{10\sqrt{2}} \times 10$$

$$\therefore \quad V_L = 100\text{V}$$

27. A ray of light is incident on a glass prism of refractive index μ and refracting angle A. If it just suffers total internal reflection at the other face, obtain a relation between the angle of incidence, angle of prism and critical angle. **3**

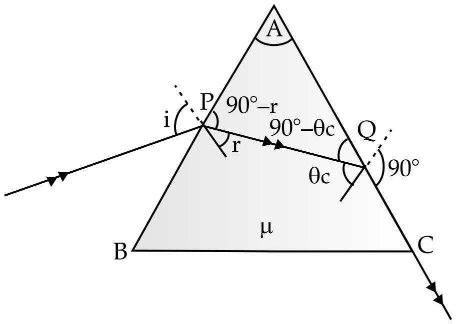
Ans. ABC is the prism.

A ray is incident on face AB.

Angle of incidence = i

It is refracted at an angle r and incident on AC face.

There is just suffers total internal reflection means, the angle of incidence is critical angle (θ_C) and the angle of emergence is 90^0.



$$\angle APQ = 90° - r$$

$$\angle AQP = 90° - \theta_C$$

So, in ΔAPQ,

$$90° - r + 90° - \theta_C + A = 180°$$

$$\therefore \quad r = A - \theta_C$$

Applying Snell's law at point P,

$1 \times \sin i = \mu \times \sin r$[considered the surrounding medium is air and its refractive index is 1]

Or,
$$\sin i = \mu \sin(A - \theta_C)$$

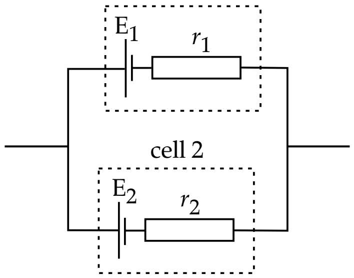
Or,
$$\sin i = \frac{1}{\sin\theta c} \times \sin(A - \theta_c)$$

$$\therefore \quad i = \sin^{-1}\left[\frac{\sin(A-\theta_c)}{\sin\theta_c}\right]$$

This is the required relation.

29. Two cells of emf E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel, with their terminals of the same polarity connected together. Obtain an expression for the equivalent emf of the combination. **3**

Ans.



Terminal p.d of 1st cell,

$$V = E_1 - I_1 r_1$$

$$\therefore \quad I_1 = \frac{E_1 - V}{r_1}$$

Terminal p.d of 2nd cell,

$$V = E_2 - I_2 r_2$$

$$\therefore \quad I_2 = \frac{E_2 - V}{r_2}$$

Now,
$$I = I_1 + I_2$$

Or,
$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$$

Or,
$$Ir_1r_2 = r_2(E_1 - V) + r_1(E_2 - V)$$

Or,
$$V(r_1 + r_2) = E_1r_2 + E_2r_1 - Ir_1r_2$$

Or,
$$V = \frac{E_1r_2 + E_2r_1}{r_1 + r_2} - I\frac{r_2r_1}{r_1 + r_2}$$

Comparing with $V = E - Ir$

$$\text{Equivalent emf} = E = \frac{E_1r_2 + E_2r_1}{r_1 + r_2}$$

Outside Delhi Set-3 55/2/3

Note: Except these, all other questions are from Outside Delhi Set-1&2

SECTION - A

2. The energy of a photon of wavelength 663 nm is

(A) 6.64×10^{-20} J **(B)** 5.18×10^{-19} J

(C) 3.0×10^{-19} J **(D)** 2.0×10^{-20} J **1**

Ans. Option (C) is correct.

Explanation:

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

$$= \frac{6.6\times10^{-34}\times3\times10^{8}}{663\times10^{-9}}$$

$$= 2.98\times10^{-19}\text{ J}$$

$$\approx 3.0\times10^{-19}\text{ J}$$

3. An electromagnetic wave is produced by a charge

(A) moving with a constant velocity

(B) moving with a constant speed parallel to a magnetic filed

(C) moving with an acceleration

(D) at rest **1**

Ans. Option (C) is correct.

4. A semiconductor device is connected in series with a battery, an ammeter and a resistor. A current flows in the circuit. If the polarity of the battery is reversed, the current in the circuit almost becomes zero. The device is a/an

(A) intrinsic semiconductor

(B) p-type semiconductor

(C) n-type semiconductor

(D) p-n junction diode **1**

4. Option (D) is correct.

Explanation: Initially the *p-n* junction diode was forward biased and then it was reverse biased.

Ans. Option (A) is correct.

Explanation: $R = R_0A^{1/3}$

For X, $R = R_0(27)^{1/3}$

Or, $R = 3R_0$

$\therefore$ $R_0 = \dfrac{R}{3}$

For Y, $R' = R_0(125)^{1/3}$

Or, $R' = 5R_0$

$\therefore$ $R' = \dfrac{5R}{3}$

6. The radius of $^{27}_{13}$X nucleus is R. The radius of $^{125}_{53}$Y nucleus will be

(A) $\dfrac{5}{3}$R **(B)** $\left(\dfrac{13}{53}\right)^{1/3}$R

(C) $\left(\dfrac{5}{3}\text{R}\right)^{1/3}$ **(D)** $\left(\dfrac{13}{53}\text{R}\right)^{1/3}$ **1**

7. An electric dipole moment 2×10^{-8} C-m in a uniform electric field experiences a maximum torque of 6×10^{-4} N-m. The Magnitude of electric field is

(A) 2.2×10^3 Vm^{-1} **(B)** 1.2×10^1 Vm^{-1}

(C) 3.0×10^4 Vm^{-1} **(D)** 4.2×10^3 Vm^{-1} **1**

Ans. Option (C) is correct.

Explanation: Maximum torque experienced by the dipole is

$$\tau_{max} = PE$$

or, $6 \times 10^{-4} = 2 \times 10^{-8} \times E$

$\therefore$ $E = 3 \times 10^4$ Vm^{-1}

11. The current is a device varies with time t as $I = 6\,t$, where I is in mA and t is in s. The amount of charge that passes through the device during t = 0s to t = 3s is

(A) 10 mC **(B)** 18 mC

(C) 27 mC **(D)** 54 mC **1**

Ans. Option (C) is correct.

Explanation: $I = \dfrac{dO}{dt}$

Or, $dQ = Idt$

Or, $dQ = 6tdt$

Or, $\int dQ = \int_0^3 6tdt$

Or, $Q = 6\int_0^3 tdt$

Or, $Q = 6\left[\dfrac{t^2}{2}\right]_0^3$

Or, $Q = 27$ mC

12. A ray of light travels a distance of 12.0 m in a transparent sheet in 60 ns. The refractive index of the sheet is

(A) 1.33 **(B)** 1.50

(C) 1.65 **(D)** 1.75 **1**

Ans. Option (B) is correct

Explanation: Speed of light in the sheet

$$= \frac{12\text{m}}{60\times10^{-9}s}$$

$$= 2 \times 10^8\ \text{ms}^{-1}$$

Speed of light in vacuum = 3×10^8 ms^{-1}

So, the refractive index of the sheet = $\dfrac{3\times10^8}{2\times10^8} = 1.5$

SECTION - B

19. What happen to the interference pattern when two coherent sources are

(a) infinitely close, and

(b) far apart from each other **2**

Ans. (a) Fringe width is proportional to $\dfrac{1}{d}$.

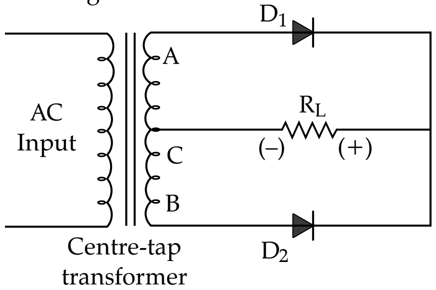
So, when convent sources are infinity close to one another the fringe width will be too large. Even a single fringe way occupy the whole screen. Hence no interference pattern will be visible.

(b) Fringe width is proportional to $\frac{1}{d}$.

So, when convent sources are very far apart from each other, the fringe will be so small that they will not be reasonable. Hence, no interference pattern will be visible.

21. With the help of a circuit diagram, explain how a full wave rectifier gives output rectified voltage corresponding to both halves of the input ac voltage. **2**

Ans. The circuit diagram of a full wave rectifies:



A centre tap transformer and two identical divides D_1 and D_2 are used to diagram a full wave rectifies.
The centre-tap transformer has 3 output terminals.
Centre tap is C is always at OV.
Drawing positive half cycle of AC, A is +ve and B is –ve. For negative half cycle, B is +ve and A is – ve.

So, when positive half cycle appears, A is +ve, B is –ve and c is O.

So, divide D_1 is forward biased and divide D_2 is reverse biased.

When negative half cycle appears,

A is –ve, B is +Ve and C is O

So, divide D_2 is forward biased and divide D_1 is reverse biased.

So, for each half cycle one divide conducts current through R_L flows unidirectionally. Hence the voltage developed across R_L is a DC.

23. The power of a thin lens is +5 D. When it is immersed in a liquid, it behaves like a concave lens of focal length 100 cm. Calculate the refractive index of the liquid. Given refractive index of glass = 1.5.2

Ans. Power of the lens = $+5D$

Focal length of the lens = $f = \frac{1}{D}$

Or, $$f = \frac{1}{5} \text{ cm}$$

$\therefore$ $$f = 20 \text{ cm}$$

Using lens makers' formula,

$$\frac{1}{f_{air}} = \left(\frac{\mu_{glass} - \mu_{air}}{\mu_{air}}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Or, $$\frac{1}{20} = \left(\frac{1.5-1}{1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Or, $$\frac{1}{20} = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\therefore$ $$\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{10}$$

When immersed in liquid,

$$\frac{1}{f_{liquid}} = \left(\frac{\mu_{glass} - \mu_{liquid}}{\mu_{liquid}}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Or, $$-\frac{1}{100} = \left(\frac{1.5 - \mu_{liquid}}{\mu_{liquid}}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Or, $$-\frac{1}{100} = \left(\frac{1.5 - \mu_{liquid}}{\mu_{liquid}}\right)\left(\frac{1}{10}\right)$$

$$\left[\text{Putting } \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{10}\right]$$

Or, $$\frac{1}{10} = \left(\frac{1.5 - \mu_{liquid}}{\mu_{liquid}}\right)$$

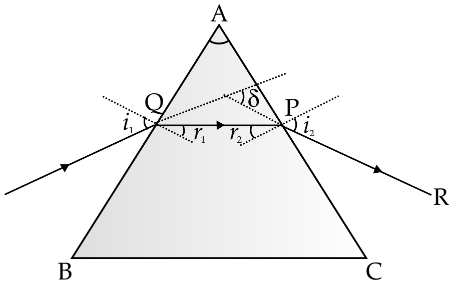
Or, $$9\mu_{liquid} = 15$$

$\therefore$ $$\mu_{liquid} = \frac{15}{9} = \frac{5}{3}$$

SECTION - C

26. A ray of light is refracted by a glass prism. Obtain an expression for the refractive index of the glass in terms of the angle of prism A and the angle of minimum deviation δm. **3**

Ans. A ray is refracted by a glass prism.



Angle of deviation = $\delta = i_1 + i_2 + A$

Angle of prism = $A = r_1 + r_2$

For minimum deviation,

$$i_1 = i_2 \text{ and } r_1 = r_2$$

$\therefore$ $$\delta_{min} = 2i_1 - A$$

$\therefore$ $$i_1 = \frac{A + \delta_m}{2}$$

Also, $$A = 2r_1$$

$\therefore$ $$r_1 = \frac{A}{2}$$

$\therefore$ Refractive index = μ

$$= \frac{\sin i_1}{\sin r_1} = \frac{\sin \frac{A+\delta_m}{2}}{\sin \frac{A}{2}}$$

29. A potential difference V is applied across a conductor of length l and cross-sectional area A. Briefly explain how the current density j in the conductor will be affected if

(a) the potential difference V is doubled.

(b) the conductor were gradually stretched to reduce its cross- sectional area to $\frac{A}{2}$ and then the same potential difference V is applied across it. **3**

Ans. Initial current $= I = \frac{V}{R} = \frac{V}{\rho.\frac{L}{A}} = \frac{VA}{\rho L}$

Initial current density $= J = \frac{V}{\rho L}$

(a) Final current density $= J' = \frac{2V}{\rho L} = 2J$

So the current density becomes double.

(b) When area of cross section becomes $\frac{A}{2}$,

The length becomes 2L.

So, final current density $= J'' = \frac{V}{\rho L'}$

$$J'' = \frac{V}{2\rho L} = \frac{1}{2}J$$

So, the current density becomes half

30. A resistor of 50 Ω, a capacitor of $\left(\frac{25}{\pi}\right)\mu F$ and an inductor of $\left(\frac{4}{\pi}\right)H$ are connected in series across an ac source whose voltage (in volt) is given by $V = 70 \sin(100\,\pi\, t)$. Calculate:

(a) the net reactance of the circuit.

(b) the impedance of the circuit

(c) the effective value of current in the circuit. **3**

Ans. (a) The net reactance $= X_L - X_C$

$$= \omega_L - \frac{1}{\omega c}$$

$$= 100\pi \times \frac{4}{\pi} - \frac{1}{100\pi \times \frac{25}{\pi} \times 10^{-6}}$$

$$= 400 - \frac{10^6}{2500} = 400 - 400$$

$$= 0$$

(b) The impedance of the Circuit

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{50^2 + 0}$$

$$= 50\ \Omega$$

(c) Peak current in the circuit $= \frac{70}{50}A$

So, the effective value of current is

$$I_{\text{eff}} = \frac{70}{50} \times \frac{1}{\sqrt{2}} = \frac{7}{5\sqrt{2}}A$$

❑❑