SAMPLE QUESTION PAPER

BLUE PRINT

Time Allowed : 3 hours **Maximum Marks :** 70

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	2(2)	1(2)	–	1(5)	**6(16)**
2.	Current Electricity	1(4)	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	2(2)	2(4)	–	–	**8(17)**
4.	Electromagnetic Induction and Alternating Current	1(1)	1(2)	1(3)	1(5)	
5.	Electromagnetic Waves	2(2)	1(2)	–	–	**8(18)**
6.	Optics	2(5)	2(4)	–	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	–	1(3)	–	**6(12)**
8.	Atoms and Nuclei	2(2)	–	2(6)	–	
9.	Electronic Devices	3(3)	2(4)	–	–	**5(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : **042**

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) All questions are compulsory. There are 33 questions in all.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each. Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION - A

All questions are compulsory. In case of internal choices, attempt any one of them.

1. Is the source of magnetic field an analogue to the source of electric field?

2. What is the speed of e.m. wave in a medium of $\mu_r = 5$ and $\varepsilon_r = 20$?

OR

A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the direction of electric and magnetic field vectors?

3. A *p-n* junction photodiode is made of a material with a band gap of 2.0 eV. What is the minimum frequency of the radiation that can be absorbed by the material? [$h = 6.6 \times 10^{-34}$ J s]

4. On which principle is 'elecromagnetic damping' based upon?

OR

A bar magnet falls from height 'h' through a metal ring. Will its acceleration be equal to 'g' ? Give reason for your answer ?

5. An electron is not deflected, while moving through a certain region of space. Can we say that there is no magnetic field in the region?

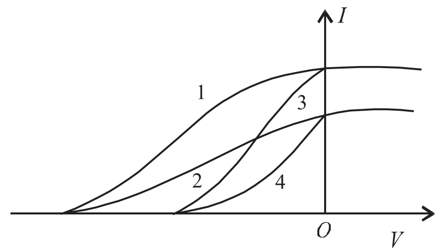
6. Based on the band theory of conductors, insulators and semiconductors, the forbidden energy gap is smallest in which one?

7. What should be the distance between nucleons for effective nuclear forces?

OR

Heavy stable nuclei have more neutrons than protons. Why?

8. The given graphs show the variation of photoelectric current (I) with the applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify the pairs of curves that correspond to different materials but same intensity of incident radiations.



9. In an unbiased *p*-*n* junction, holes diffuse from the *p*-region to *n*-region. Why ?

OR

In half wave rectification, what is the output frequency if the input frequency is 50 Hz ?

10. In hydrogen atom, if the electron is replaced by a particle which is 200 times heavier but has the same charge, how would its radius change ?

For question numbers 11, 12, 13 and 14, 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 A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

11. Assertion (A) : A charged particle free to move in an electric field always moves along an electric field line.
Reason (R) : The electric field lines diverge from a negative charge and converge at a positive charge.

12. Assertion (A) : When a white light is passed through a lens, violet light is more refracted than red light.
Reason (R) : Focal length for red light is greater than violet.

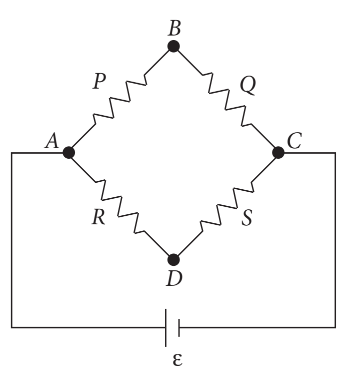
13. Assertion (A) : Dipole oscillations produces electromagnetic waves.
Reason (R) : Accelerated charge produces electromagnetic waves.

14. Assertion (A) : The force between the plates of a parallel plate capacitor varies linearly with charge on it.
Reason (R) : Electric force is equal to charge per unit area.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. A wheatstone bridge as showing in figure is almost balanced, where $P = 10\ \Omega$, $R = 5\ \Omega$, $S = 11\ \Omega$, $E = 48$ V and C is grounded.



(i) The potential of point B is

(a) 16 V (b) 24 V (c) 32 V (d) 36 V

(ii) If a galvanometer is connected between B and D, the direction of current through galvanometer is

(a) B to D

(b) D to B

(c) depends on resistance of galvanometer

(d) in the beginning from B to D and later on form D to B.

(iii) For what additional value of the resistance in arm BC in series/parallel would make the bridge balanced?

(a) 22 Ω (b) 2 Ω (c) 20 Ω (d) 44 Ω

(iv) In wheatstone method, the instrument used as null detector is

(a) ammeter (b) galvanometre (c) voltmetre (d) none of these.

(v) Balance condition can be obtained by

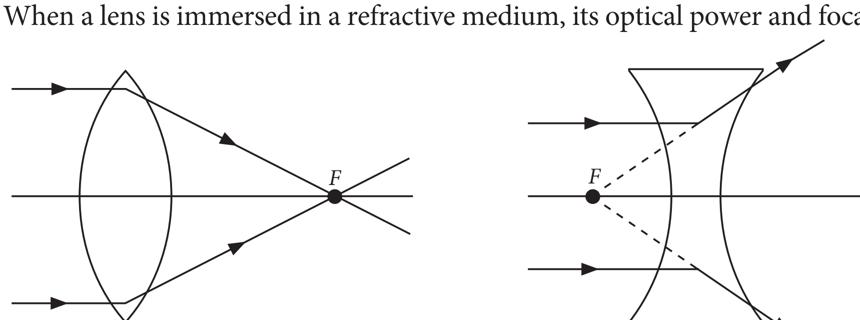
(a) varying the standard arm resistance

(b) varying the ratio arms resistance

(c) keeping the unknown resistance constant

(d) by making use of a null detector in wheatstone method.

16. Optical power (also referred as dioptric power, refractive power, focusing power, or convergence power) is the degree to which a lens, mirror, or other optical system converges or diverges light. It is equal to the reciprocal of the focal length of the device *i.e.*, $P = \frac{1}{f}$. The SI unit for optical power is the inverse meter (m^{-1}), which is commonly called the dioptre. Converging lenses have positive optical power, while diverging lenses have negative power. When a lens is immersed in a refractive medium, its optical power and focal length change.



High optical power

Low optical power

(i) What is the relation between the object distance u, image distance v and power P in a lens?

(a) $P = \frac{uv}{u-v}$ (b) $P = \frac{u-v}{uv}$ (c) $P = \frac{uv}{v+v}$ (d) $P = \frac{u+v}{uv}$

(ii) Two thin lenses are kept near each other at a distance of 4 mm. If the focal length of first and second lens are 20 cm and 25 cm respectively, find the power of the combination.

(a) 7.6 D (b) 8.9 D (c) −7.6 D (d) −8.9 D

(iii) A convex lens of focal length 20 cm made of glass is immersed in a liquid of refractive index 2.3. Its power will be

(a) positive

(b) can be positive or negative depending on the depth

(c) zero

(d) negative.

(iv) Focal length of a convex lens of refractive index 1.5 is 2 cm. Focal length of lens when immersed in a liquid of refractive index of 1.25 will be

(a) 5 cm (b) 4 cm (c) 2.5 cm (d) 1.2 cm

(v) Find the focal length of a lens of power (–2.0 D). What type of lens is this?

(a) –0.5 m, concave lens (b) 0.5 m, concave lens

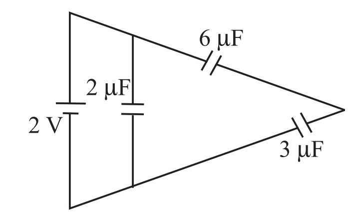
(c) 0.5 m, convex lens (d) –0.5 m, convex lens

SECTION - C

All questions are compulsory. In case of internal choices, attempt anyone.

17. Two identical loops, one of copper and another of aluminium are rotated with the same speed in a uniform magnetic field acting normal to the plane of loops. State with reason for which of the coils, the induced (a) EMF (b) current will be more and why?

18. Find the total energy stored in the condenser system shown in the figure.



OR

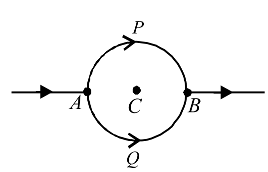
Four point charges $-Q$, $-q$, $2q$ and $2Q$ are placed, one at each corner of the square. If the potential at the centre of the square is zero then find the relation between Q and q.

19. Name the electromagnetic radiation to which waves of wavelength in the range of 10^{-2} m belong. Give one use of this part of electromagnetic spectrum.

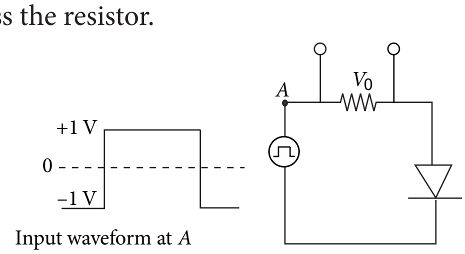
OR

How are electromagnetic waves produced?

20. Consider the circuit shown here where APB and AQB are semi-circles. What will be the magnetic field at the centre C of the circular loop?



21. Draw the output waveform across the resistor.



Input waveform at A

22. In which direction would a compass free to move in the vertical plane point to, if located right on the geomagnetic north or south pole?

OR

A proton has spin and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?

23. Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid?

24. Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV, respectively. Which ones will be able to detect light of wavelength 6000 Å?

25. A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.

SECTION - D

All questions are compulsory. In case of internal choices, attempt any one.

26. Sketch the graphs, showing the variation of stopping potential V_s with frequency υ of the incident radiations for two photosensitive materials A and B having threshold frequencies υ_0 and υ_0' respectively such that $\upsilon_0 > \upsilon_0'$.

(a) Which of the two metals A or B has higher work function?

(b) What information do you get from the slope of the graphs?

(c) What does the value of the intercept of graph A on the potential axis represent?

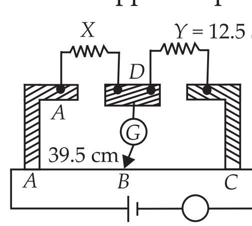
27. A cell of emf ε and internal resistance r is connected across a variable external resistance R. Plot graphs to show variation of

(i) E with R

(ii) Terminal p.d. of the cell (V) with R.

OR

(a) In a meter bridge as shown in figure, the balance point is found to be at 39.5 cm from the end A, when the resistor Y is of 12.5 Ω. Determine the resistance of X. Why are the connection between resistors in a wheatstone or meter bridge made of thick copper strips?



(b) Determine the balance point of the bridge above if X and Y are interchanged.

(c) What happens if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

28. Obtain the first Bohr's radius and the ground state energy of a muonic hydrogen atom [*i.e.*, an atom in which a negatively charged muon (μ^-) of mass about 207 m_e orbits around a proton].

29. We are given the following atomic masses:

${}_{92}U^{238}$ = 238.05079 u, ${}_{90}Th^{234}$ = 234.04363 u, ${}_{91}Pa^{237}$ = 237.05121 u, ${}_{1}H^{1}$ = 1.00783 u, ${}_{2}He^{4}$ = 4.00260 u

(a) Calculate the energy released during α-decay of ${}_{92}U^{238}$.

(b) Calculate the kinetic energy of emitted α-particle.

(c) Show that ${}_{92}U^{238}$ cannot spontaneously emit a proton.

30. A long solenoid S has n turns per metre, with diameter a. At the centre of this coil, we place a smaller coil of N turns and diameter b (where $b < a$). If the current in the solenoid increases linearly with time, what is the induced emf appearing in the smaller coil. Plot graph showing nature of variation in emf, if current varies as $(mt^2 + C)$.

OR

A series LCR circuit is made by taking $R = 100\ \Omega$, $L = 2/\pi$ H, $C = 100/\pi\ \mu$F. The series combination is connected across an a.c. source of 220 V, 50 Hz. Calculate

(a) the impedance of the circuit,

(b) the peak value of the current flowing in the circuit.

SECTION - E

All questions are compulsory. In case of internal choices, attempt any one.

31. **(a)** Draw a ray diagram to show the formation of the image of an object placed between the optical centre and focus of a convex lens. Deduce the relationship between the object distance, image distance and focal length under the conditions stated.

(b) A diverging lens of focal length f is cut into two identical parts, each forming a plano concave lens. What is the focal length of each part ?

OR

(a) A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.

(b) Answer the following questions :

(i) When a low-flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.

(ii) The principle of linear superposition of wave displacements is basic for understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle?

32. **(a)** Derive the relationship between the peak and the rms value of current in ac circuit.

(b) The electric current in an AC circuit is given by $I = I_0 \sin \omega t$. What is the time taken by the current to change from its maximum value to the rms value?

OR

(a) Draw a schematic arrangement for winding of primary and secondary coil in a transformer when the two coils are wound on top of each other.

(b) State the underlying principle of a transformer and obtain the expression for the ratio of secondary to primary voltage in terms of the number of secondary and primary windings and primary and secondary currents.

(c) Write the main assumption involved in deriving the above relations.

(d) Write any two reasons due to which energy losses may occur in actual transformers.

33. **(a)** Use Gauss' law to derive the expression for the electric field ($E_{\rightarrow}$) due to a straight uniformly charged infinite line of charge density λ C m^{-1}.

(b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.

(c) Find the work done in bringing a charge q from perpendicular distance r_1 to r_2 $(r_2 > r_1)$.

OR

A particle of mass m and charge $(-q)$ enters the region between the two charged plates initially moving along x-axis with speed v_x. The length of plate is L and an uniform electric field $\vec{E}$ is maintained between the plates. Show that the vertical deflection of the particle at the far edge of the plate is $qEL^2/(2mv_x^2)$.

SOLUTIONS

1. No. The source of electric field is an electric charge. The source of magnetic field is not a magnetic charge. Infact, moving electric charges produce magnetic field.

2. $v = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{3\times10^8}{\sqrt{5\times20}}$ = 3 × 107 m s^{-1}

OR

The electric and magnetic field vectors are perpendicular to each other and also perpendicular to the direction of propagation of the electromagnetic wave. If a plane electromagnetic wave is propagating along the z-direction, then the electric field is along x-axis, and magnetic field is along y-axis.

3. Band gap $E_g = h\upsilon = 2$ eV $= 2 \times 1.6 \times 10^{-19}$ J

∴ The minimum frequency is given by $h\upsilon_{min} = 2$ eV

$$\therefore \quad \upsilon_{min} = \frac{2\times1.6\times10^{-19}}{h} = \frac{3.2\times10^{-19}}{6.6\times10^{-34}} \simeq 0.5\times10^{+15}$$

$= 5 \times 10^{+14}$ Hz

4. Eddy currents

OR

Its acceleration will be less than g because the induced current in the ring opposes the motion of the magnet.

5. No. Magnetic field may exist in the region and electron is moving in the direction of magnetic field, and hence experiences no force due to magnetic field.

6. According to band theory the forbidden energy gap in conductors is $E_g \approx 0$, in insulators $E_g > 3$ eV and in semiconductors $E_g < 3$ eV. Thus, the forbidden energy gap is smallest in conductors.

7. Nuclear force is powerfully attractive between nucleons at a distance of about 1 femtometre, *i.e.*, 1×10^{-15} m.

OR

The stability of a nucleus depends on its neutron to proton ratio. More is the number of protons in the nucleus, greater is the electrostatic forces between them. Therefore, more neutrons are needed to provide the strong attractive force necessary to keep the nucleus stable.

8. (1, 3) and (2, 4).

As photoelectric saturation current for them is same, so incident radiations on them are of same intensity, however their stopping potential are different, so they correspond to different materials.

9. The hole concentration on p-side is greater than on n-side. So, diffusion take place.

OR

In half wave rectification, only one ripple is obtained per cycle in the output. But the output frequency remain same. So, output frequency = 50 Hz.

10. Radius of n^{th} orbit of H-atom with electron is

$$r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \quad \text{or} \quad r \propto \frac{1}{m}$$

So, if electron is replaced with a charged particle of same charge but of mass 200m, then radius of n^{th} orbit of H-atom will become

$$\frac{r'}{r} = \frac{m}{200m} = \frac{1}{200} \quad \text{or} \quad r' = \frac{r}{200}$$

i.e., will reduce to $\frac{1}{200}$ times that with electron.

11. (d) : Only a charged particle initially at rest moves along the electric field line. In case, the charged particle is in motion and its initial velocity is at an angle with the electric field line, the particle may follow a parabolic path.

12. (a) : When white light is passed through a lens, violet light is more refracted than red light because wavelength of violet is less than red light and therefore focal length for red light is greater than violet.

13. (a) : Assertion is true. The reason is also true according to the classical theory of Maxwell. The dipole oscillations gives radiation because the charges are accelerated.

14. (d) : The potential energy stored between the plates of a capacitor,

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q^2}{\varepsilon_0 A}x \qquad \left(\because \; C = \frac{\varepsilon_0 A}{x}\right)$$

$$\text{Force } F = \frac{-\partial U}{\partial x} = -\frac{\partial}{\partial x}\left(\frac{1}{2}\frac{Q^2 x}{\varepsilon_0 A}\right) = -\frac{1}{2}\frac{Q^2}{\varepsilon_0 A}$$

Negative sign shows force is attractive.

15. (i) (c)

(ii) (b)

(iii) (b)

(iv) (c) : Voltmeter is used as null detector in wheatstone method.

(v) The balance condition in a wheatstone bridge can be obtained by varying ratio arm resistances.

Null detector is used for determining balance condition.

16. (i) (b) : From len's formula,

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow f=\frac{uv}{u-v}$$

Since power, $P=\frac{1}{f}\Rightarrow P=\frac{u-v}{uv}$

(ii) (b) : Given, f_1 = 20 cm, f_2 = 25 cm and d = 4 mm = 0.4 cm.

Focal length, $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2}$

$$=\frac{1}{20}+\frac{1}{25}-\frac{0.4}{20\times 25} \quad \Rightarrow \quad F=11.21 \text{ cm}$$

$\therefore$ Power , $P=\frac{100}{F}$ = + 8.9 D

(iii) (d) : Given focal length, f_a = 20 cm

In air,

$$\frac{1}{f_a}=\left({}^a\mu_g-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(i)$$

In liquid

$$\frac{1}{f_l}=\left({}^l\mu_g-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(ii)$$

Dividing equation (i) by (ii), we get

$$\frac{f_l}{f_a}=\frac{({}^a\mu_g-1)}{({}^l\mu_g-1)}\Rightarrow\frac{f_l}{20}=\frac{(1\cdot 5-1)}{\left(\frac{1\cdot 5}{2\cdot 3}-1\right)}$$

$$\Rightarrow\ f_l=\frac{20(0.5)}{-0\cdot 348}=-28.75\text{cm}$$

$$\therefore\ P=\frac{100}{f_l}=\frac{-100}{28\cdot 75}=-3.4\text{ D}$$

(iv) (a) : Given μ_g = 1.5, f_a = 2 cm, μ_l = 1.25

In air,

$$\frac{1}{f_a}=\left({}^a\mu_g-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(i)$$

In liquid,

$$\frac{1}{f_l}=\left({}^l\mu_g-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(ii)$$

Dividing equation (i) by (ii), we get

$$\frac{f_l}{f_a}=\frac{{}^a\mu_g-1}{{}^l\mu_g-1}\Rightarrow f_l=\frac{2(1\cdot 5-1)}{\frac{1\cdot 5}{1\cdot 25}-1}=5\text{ cm}$$

(v) (a) : Given: power of lens, P = –2.0 D

Power $P=\frac{1}{f}\Rightarrow f=\frac{1}{P}$

$$\therefore\ f=-\frac{1}{2}=0.5\text{ m}$$

Since, focal length is negative, it is a concave lens.

17. (a) Induced EMF in both the loops will be same, as the two loops are of same area A and are rotated with same speed ω in same magnetic field B given by

$$\varepsilon = BA\,\omega \sin \omega t$$

(b) As $I=\frac{\varepsilon}{R}$, so in copper loop with less resistance, induced current will be more.

18. 3 μF and 6 μF are in series, $C'=\frac{3\times 6}{(3+6)}=2\,\mu\text{F}$

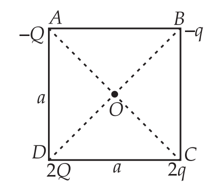
This is in parallel with 2 μF.

$\therefore$ Total capacitance in the circuit, C_{eq} = 4 μF

Energy = (1/2) V^2C_{eq} = (1/2) × 2^2 × 4 × 10^{-6} J = 8 μJ

OR

Let a be the side length of the square $ABCD$.



$$\therefore\ AC=BD=\sqrt{a^2+a^2}=a\sqrt{2}$$

$$OA=OB=OC=OD=\frac{a\sqrt{2}}{2}=\frac{a}{\sqrt{2}}$$

Potential is a scalar quantity.

Potential at the centre O due to given charge configuration is

$$V=\frac{1}{4\pi\varepsilon_0}\left[\frac{(-Q)}{\left(\frac{a}{\sqrt{2}}\right)}+\frac{(-q)}{\left(\frac{a}{\sqrt{2}}\right)}+\frac{(2q)}{\left(\frac{a}{\sqrt{2}}\right)}+\frac{2Q}{\left(\frac{a}{\sqrt{2}}\right)}\right]=0$$

$\Rightarrow$ $-Q-q+2q+2Q=0$

or $Q+q=0$ or $Q=-q$

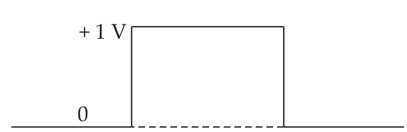
19. Radio wave: It is used for communication purposes like radio and television broadcast.

OR

An oscillating or accelerated charge is supposed to be source of an electromagnetic wave. An oscillating charge produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field, hence, keep on regenerating each other and an electromagnetic wave is produced.

20. Zero, because magnetic field of each half cancels each other. As it has same magnitude but opposite direction

21.



The diode acts as half wave rectifier, it offers low resistance when forward biased and high resistance when reverse biased.

22. At geomagnetic north or south pole, angle of dip is 90°, where horizontal component of earth's magnetic field B_H is zero. A compass needle can only turn in horizontal plane, so it can point in any direction as $B_H = 0$, which governs its direction.

OR

Magnetic moment of proton, $\mu_p \approx \frac{e\hbar}{2m_p}$

Magnetic moment of electron, $\mu_e \approx \frac{e\hbar}{2m_e}$

$\therefore \frac{\mu_e}{\mu_p} = \frac{m_p}{m_e} \approx 1837 >> 1$

or $\mu_e >> \mu_p$

23. When the refractive index of the biconvex lens is equal to the refractive index of the liquid in which lens is immersed then the biconvex lens behaves as a plane glass sheet. In this case, $\frac{1}{f} = 0$ or $f \to \infty$.

24. We know that, energy of incident photon

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

$\lambda = 6000$ Å $= 600$ nm (given)

$$E = \frac{1242 \text{ eVnm}}{600 \text{ nm}} = 2.07 \text{ eV}$$

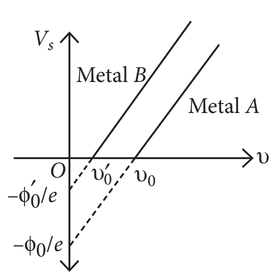
For the incident radiation to be detected by the photodiode, energy of incident radiation photon should be greater than the band gap. This is true only for D_2. Therefore, only D_2 will detect this radiation.

25. Position of first minimum in diffraction pattern

$$y = \frac{D\lambda}{a}$$

So, slit width $a = \frac{D\lambda}{y} = \frac{1 \times 500 \times 10^{-9}}{2.5 \times 10^{-3}} = 2 \times 10^{-4}$ m

26. The variation of stopping potential (V_s) with frequency (υ) of the incident radiations for two photosensitive materials is shown in figure.



(a) Metal A has higher work function, as

$\phi_0 = h\upsilon_0$ and $\phi_0' = h\upsilon_0'$, since $\upsilon_0 > \upsilon_0'$.

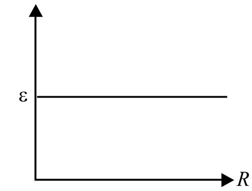
$\therefore \phi_0 > \phi_0'$

(b) Slope of $V_s - \upsilon$ graph $= h/e =$ constant

Slope of curve does not depend on type of material.

(c) Intercept of graph A on the potential axis $= -\frac{\phi_0}{e} = -\frac{h\upsilon_0}{e}$.

27. (i) As the emf ε of cell is independent of resistance R of the circuit, so it does not changes with increase in R.

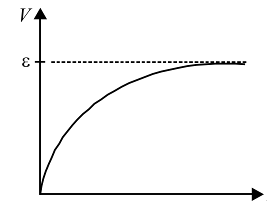


(ii) Terminal potential difference of cell is

$$V = IR = \frac{\varepsilon}{R+r}.R$$

or $V = \frac{\varepsilon}{1 + r/R}$

When $R \to \infty$, $V = \varepsilon$



OR

(a) At balance,

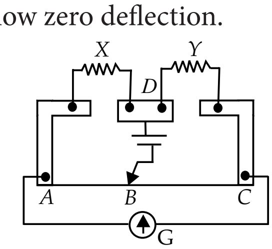
$$\frac{X}{Y} = \frac{l}{100-l} = \frac{39.5}{100-39.5} = \frac{39.5}{60.5}$$

or $\frac{X}{12.5} = \frac{395}{605}$ or $X = 8.16\ \Omega$

The connections are made of thick copper strips so as to provide negligible resistance by connecting wires.

(b) If X and Y are interchanged the balance point will be at 60.5 cm from A.

(c) In balanced condition of the bridge, the cell and the galvanometer can be exchanged, the galvanometer will still show zero deflection.



28. In Bohr's model, the radius of n^{th} orbit

$$r = \frac{n^2h^2\varepsilon_0}{\pi Zme^2}$$

In the given muonic hydrogen atom, a negatively charged muon (μ^-) of mass $207m_e$ revolve around a proton.

Therefore, radius of electron and muon can be written as

$$\frac{r_\mu}{r_e} = \frac{m_e}{m_\mu} = \frac{m_e}{207m_e}$$

$$r_\mu = \frac{r_e}{207} = \frac{0.53 \times 10^{-10}}{207} \text{ m} = 2.5 \times 10^{-13} \text{ m}$$

Energy of electron in the orbit $E = -\frac{me^4}{8\varepsilon_0 n^2 h^2}$

$$\frac{E_e}{E_\mu} = \frac{m_e}{m_\mu} = \frac{m_e}{207m_e}$$

$E_\mu = 207\ E_e = 207\ [-13.6 \text{ eV}] = -2.8$ keV.

29. (a) ${}_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4}$

$\Delta m = (238.05079 - 234.04363 - 4.00260)\ u = 0.00456\ u$

Energy released,

$Q = 0.00456 \times 931.5\ MeV = 4.25\ MeV$

(b) K.E. of α particle $= \left(\frac{A-4}{A}\right) \times Q$

$= \frac{238-4}{238} \times 4.25\ MeV = 4.18\ MeV$

(c) If ${}_{92}U^{238}$ emits a proton spontaneously,

${}_{92}U^{238} \rightarrow {}_{91}Pa^{237} + {}_{1}H^{1}$

$\Delta m = (238.05079 - 237.05121 - 1.00783)\ u$

$\therefore\ Q = -0.00825\ u = -0.00825 \times 931.5\ MeV$
$= -7.68\ MeV$

As the Q value is negative, the process cannot proceed spontaneously.

30. Magnetic field due to a solenoid S,

$B = \mu_0 n I$

Magnetic flux in smaller coil, $\phi = NBA$,

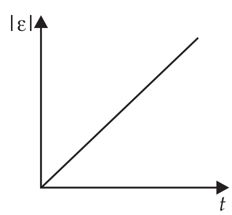
where $A = \pi b^2$

So, $\varepsilon = \frac{-d\phi}{dt} = \frac{-d}{dt}(NBA)$

$= -N\pi b^2\left(\frac{dB}{dt}\right) = -N\pi b^2 \frac{d}{dt}(\mu_0 n I) = -N\pi b^2 \mu_0 n \frac{dI}{dt}$

$= -Nn\pi\mu_0 b^2 \frac{d}{dt}(mt^2 + C) = -\mu_0 N n\pi b^2\, 2mt$

Negative sign signifies opposite nature of induced emf. The magnitude of emf varies linearly with time as shown in the figure.



OR

As per question, $R = 100\ \Omega$, $L = 2/\pi$ H

$C = \frac{100}{\pi}\ \mu F = \frac{100}{\pi} \times 10^{-6}\ F = \frac{1}{\pi} \times 10^{-4}\ F$

$V_{rms} = 220$ V and $\upsilon = 50$ Hz

(a) Inductive reactance, $X_L = \omega L = 2\pi\upsilon \times L$

$= 2\pi \times 50 \times \frac{2}{\pi} = 200\ \Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$

$= \frac{1}{2\pi \times 50 \times \left(\frac{10^{-4}}{\pi}\right)} = 100\ \Omega$

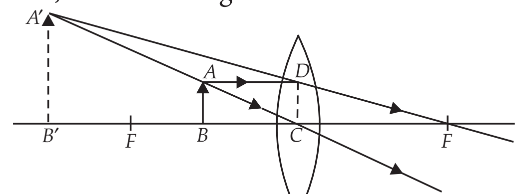
$\therefore$ Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(100)^2 + (200-100)^2} = 100\sqrt{2}\ \Omega$

(b) Peak value of current, $I_0 = \sqrt{2}\, I_{rms}$

$= \frac{\sqrt{2} \times V_{rms}}{Z} = \frac{\sqrt{2} \times 220}{100\sqrt{2}} = 2.2$ A

31. (a) Ray diagram for the formation of image of an object AB placed between the optical centre C and focus F of convex lens is shown below. The image $A'B'$ is virtual, erect and magnified.



$\Delta A'B'C$ and ΔABC are similar

$\therefore\ \frac{A'B'}{AB} = \frac{CB'}{CB}$ ...(i)

$\Delta A'B'F$ and ΔCDF are similar

$\therefore\ \frac{A'B'}{CD} = \frac{B'F}{CF}$

But $CD = AB$

$\therefore\ \frac{A'B'}{AB} = \frac{B'F}{CF}$ ...(ii)

From (i) and (ii), we get

$\frac{CB'}{CB} = \frac{B'F}{CF} = \frac{CB' + CF}{CF}$

According to new cartesian sign convention,

$CB = -u$, $CB' = -v$, $CF = +f$

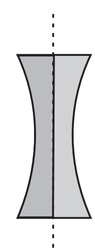
$\therefore\ \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or $uv - uf = -vf$ or $uv = uf - vf$

Dividing both sides by uvf, we get

or $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

This is the required thin lens formula.



(b) For single diverging lens,

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

Let $R_1 = -R$, $R_2 = R$

$\therefore\ \frac{1}{f} = (\mu - 1)\left(\frac{1}{-R} - \frac{1}{R}\right) = \frac{-2(\mu - 1)}{R}$ ...(i)

For each half (which is plano concave), as shown in figure,

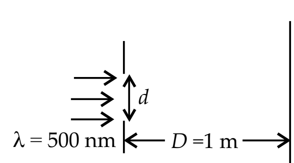
$R_1 = -R$ and $R_2 = \infty$

$\therefore\ \frac{1}{f_1} = \frac{1}{f_2} = (\mu - 1)\left(\frac{1}{-R} - \frac{1}{\infty}\right) = \frac{-1(\mu - 1)}{R} = \frac{1}{2f}$

$\therefore\ f_1 = f_2 = 2f$ (Using (i))

OR

(a)



First minimum is observed at a distance 2.5 mm from centre of the screen.

So, $x = 2.5 \text{ mm} = 2.5 \times 10^{-3}$ m

$\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m} = 5 \times 10^{-7}$ m

$D = 1$ m, $n = 1$

So, condition for minima is $\frac{dx}{D} = n\lambda$

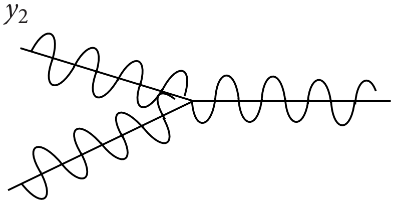
$\therefore$ Slit width $d = \frac{n\lambda D}{x}$

$$\therefore \quad d = \frac{5\times10^{-7}\times1\times1}{2.5\times10^{-3}} = 0.2 \text{ mm}$$

(b) (i) The low flying aircraft reflects the TV signals. Due to superposition between the direct signal received by the antenna and the reflected signals from aircraft. We sometimes notice slight shaking of the picture on the TV screen.

(ii) Superposition principle states how to explain the formation of resultant wave by combination of two or more waves. Let y_1 and y_2 represent instantaneous displacement of two superimposing waves, then instantaneous displacement for resultant waves is given by

$y = y_1 + y_2$



32. **(a)** The instantaneous value of ac passing through a resistance R is given by

$I = I_0 \sin \omega t$

The alternating current changes continuously with time. Suppose that the current through the resistance is constant for an infinitesimally small time dt.

The small amount of heat produced in the resistance R in time dt is given by

$dH = I^2 R\, dt = (I_0 \sin \omega t)^2 R\, dt = I_0^2 R \sin^2 \omega t\, dt$

The amount of heat produced in the resistance in time $T/2$ is

$$H = \int_0^{T/2} I_0^2 R \sin^2 \omega t\, dt = I_0^2 R \int_0^{T/2} \frac{1-\cos 2\omega t}{2} dt$$

$$H = \frac{I_0^2 R}{2}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^{T/2} = \frac{I_0^2 R}{2}\left[\frac{T}{2} - \frac{\sin 2\omega \cdot \frac{T}{2}}{2\omega} - 0\right]$$

$$H = \frac{I_0^2 R}{2}\left[\frac{T}{2} - \frac{\sin 2 \cdot \frac{2\pi}{T} \cdot \frac{T}{2}}{2\omega}\right] = \frac{I_0^2 R}{2}\left[\frac{T}{2} - \frac{\sin 2\pi}{2\omega}\right]$$

$$H = \frac{I_0^2 R}{2} \cdot \frac{T}{2} \qquad [\because \sin 2\pi = 0] \qquad \text{...(i)}$$

If I_{rms} be the rms value of ac then by definition

$$H = I_{rms}^2 R \frac{T}{2} \qquad \text{...(ii)}$$

From equation (i) and (ii), we have

$$I_{rms}^2 R \frac{T}{2} = \frac{I_0^2 R}{2} \cdot \frac{T}{2}$$

$$I_{rms}^2 = \frac{I_0^2}{2} \therefore I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0.$$

(b) Since $I_1 = I_0 \sin \omega t_1$

$\because$ $I_1 = I_0$, so, $I_0 = I_0 \sin \omega t_1$

$$t_1 = \frac{\pi/2}{2\pi/T} = \frac{T}{4}$$

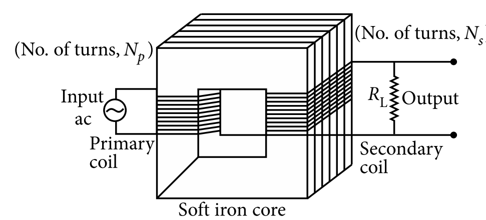
and $I_2 = \frac{I_0}{\sqrt{2}}$, hence $\frac{I_0}{\sqrt{2}} = I_0 \sin(\omega t_2)$

$$t_2 = \frac{\pi/4}{2\pi/T} = \frac{T}{8}$$

$$\Delta t = t_1 - t_2 = \frac{T}{4} - \frac{T}{8} = \frac{T}{8}$$

OR

(a)



(b) Step-up transformer (or transformer) is based on the principle of mutual induction.

An alternating potential (V_p) when applied to the primary coil induced emf in it.

$$\varepsilon_p = -N_p \frac{d\phi}{dt}$$

If resistance of primary coil is low $V_p = \varepsilon_p$.

$$i.e., \ V_p = -N_p \frac{d\phi}{dt}$$

As same flux is linked with the secondary coil with the help of soft iron core due to mutual induction emf is induced in it.

$$\varepsilon_s = -N_s \frac{d\phi}{dt}$$

If output circuit is open $V_s = \varepsilon_s$

$$V_s = -N_s \frac{d\phi}{dt}$$

Thus $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

For an ideal transformer, $P_{out} = P_{in}$

$$\Rightarrow I_s V_s = I_p V_p \quad \therefore \quad \frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$$

For step-up transformer $\frac{N_s}{N_p} > 1$

(c) The following three assumptions are involved

(i) The primary resistance and current are small.

(ii) The same flux links both with the primary and secondary windings as flux leakage from the core is negligibly small.

(iii) The terminals of the secondary are open or the current taken from it is small.

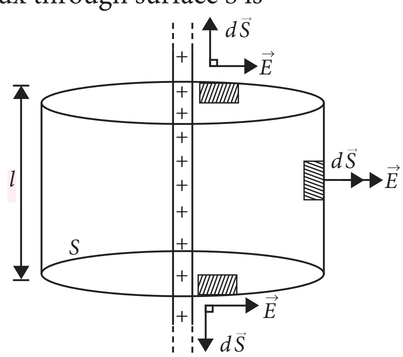
(d) There are number of energy losses in a transformer.

(i) Copper losses due to Joule's heating produced across the resistances of primary and secondary coils. It can be reduced by using copper wires.

(ii) Hysteresis losses due to repeated magnetization and demagnetization of the core of transformer. It is minimized by using soft iron core, as area of hysteresis loop for soft iron is small and hence energy loss also becomes small.

33. (a) Electric field intensity due to line charge or infinite long uniformly charged wire at point P at distance r from it is obtained as :

Assume a cylindrical gaussian surface S with charged wire on its axis and point P on its surface, then net electric flux through surface S is



$$\phi = \oint_S \vec{E}\cdot d\vec{S} = \int_{\substack{\text{upper}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ + \int_{\substack{\text{curved}\\\text{surface}}} EdS\cos 0^\circ + \int_{\substack{\text{lower}\\\text{plane}\\\text{face}}} EdS\cos 90^\circ$$

or $\phi = 0 + EA + 0$ or $\phi = E.2\pi rl$

But by Gauss's theorem $\phi = \dfrac{q}{\varepsilon_0} = \dfrac{\lambda l}{\varepsilon_0}$

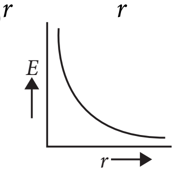
Where q is the charge on length l of wire enclosed by cylindrical surface S, and λ is uniform linear charge density of wire.

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

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

directed normal to the surface of charged wire.

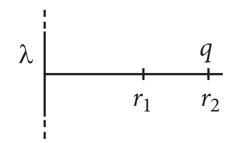
(b) Since $E = \dfrac{\lambda}{2\pi\varepsilon_0 r} \Rightarrow E \propto \dfrac{1}{r}$



Therefore plot of E versus r will be as shown.

(c) As per the situation, charge q is kept at a distance r_2 from line charge.

$E_{(r_2)} = \dfrac{\lambda}{2\pi\varepsilon_0 r_2}$ and $E'_{(r_1)} = \dfrac{\lambda}{2\pi\varepsilon_0 r_1}$



Work done in moving charge q form r_2 to r_1.

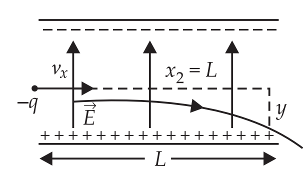
$$W = \int_{r_2}^{r_1} \vec{F}\cdot d\vec{r} = \int_{r_2}^{r_1} \frac{q\lambda}{2\pi\varepsilon_0 r} dr\cos 0^\circ = \frac{q\lambda}{2\pi\varepsilon_0}\int_{r_2}^{r_1}\frac{dr}{r}$$

$$= \frac{q\lambda}{2\pi\varepsilon_0}\left[\ln r\right]_{r_2}^{r_1} = \frac{q\lambda}{2\pi\varepsilon_0}\ln\frac{r_1}{r_2}$$

OR

Let the point at which the charged particle enters the electric field, be origin $O(0, 0)$, then after travelling a horizontal displacement L, it gets deflected by displacement y in vertical direction as it comes out of electric field.

So, co-ordinates of its initial position are $x_1 = 0$ and $y_1 = 0$ and final position on coming out of electric field are $x_2 = L$ and $y_2 = y$



Components of its acceleration are $a_x = 0$

and $a_y = \dfrac{F}{m} = \dfrac{qE}{m}$

and of initial velocity are $u_x = v_x$ and $u_y = 0$.

So, by 2nd equation of motion in horizontal direction,

$$y_2 - y_1 = u_x t + \frac{1}{2}a_x t^2$$

$$\text{or } \quad L - 0 = u_x t + 0$$

$$t = \frac{L}{u_x}$$

and by 2nd equation of motion in vertical direction,

$$y_2 - y_1 = u_y t + \frac{1}{2}a_y t^2$$

$$\text{or } \quad y - 0 = 0 + \frac{1}{2}\frac{qE}{m}\left(\frac{L}{v_x}\right)^2$$

$$\text{or } \quad y = \frac{qEL^2}{2mv_x^2}$$

This gives the vertical deflection of the particle at the far edge of the plate.

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