Class: XII

SESSION : 2022-2023

SUBJECT: PHYSICS (THEORY)

SAMPLE QUESTION PAPER - 5

with SOLUTION

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

**General Instructions:**

(1) There are 35 questions in all. All questions are compulsory

(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

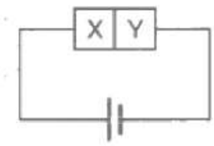
(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

5. Use of calculators is not allowed.

## Section A

1. A semiconductor X is made by doping a germanium crystal with arsenic (Z = 33). A second semiconductor Y is made by doping germanium with indium (Z = 49). The two are joined end to end and connected to a battery as shown. Which of the following statements is correct? **[1]**




a) X is p-type, Y is n-type and the junction is forward biased

b) X is n-type, Y is p-type and the junction is reverse biased

c) X is p-type, Y is n-type and the junction is reverse biased

d) X is n-type, Y is p-type and the junction is forward biased

2. A good photographic print is obtained by an exposure of two seconds at a distance of 20 cm from the lamp. The time of exposure required to get an equally good result at a distance of 40 cm is: **[1]**

a) 1 second

b) 8 second

c) 2 second

d) 4 second

3. The internal resistance of a cell: **[1]**

a) always acts in the cell in open circuit

b) acts only in closed circuit and it reduces the EMF

c) acts only in closed circuit and it reduces the current

d) none of these

**[1]**

4. Four capacitors of equal capacitance have an equivalent capacitance $C_1$ when connected in series and an equivalent capacitance $C_2$ when connected in parallel. The ratio $\frac{C_1}{C_2}$ is:

a) $\frac{1}{12}$
b) $\frac{1}{4}$
c) $\frac{1}{16}$
d) $\frac{1}{8}$

5. If $n_e$ and $n_h$ represent the number of free electrons and holes respectively in a semiconducting material, then for A-type semiconducting material: **[1]**

a) $n_e << n_h$
b) $n_e = n_h$
c) $n_e >> n_h$
d) $n_e = n_h = 0$

6. A resistance coil is held horizontally and a magnet is allowed to fall vertically through it. Then, the acceleration of the magnet is: **[1]**

i. equal to g
ii. non-uniform and less than g
iii. uniform and less than g
iv. more than g

a) iv and i
b) iii and iv
c) only ii
d) i and ii

7. A magnetic needle is kept in a non-uniform magnetic field. It experiences **[1]**

a) A force and a torque
b) Neither a force nor a torque
c) A force but not a torque
d) A torque but not a force

8. What will be the angular momentum of an electron, if the energy of this electron in H-atom is -1.5 eV (in J-sec)? **[1]**

a) $3.15 \times 10^{-34}$
b) $1.05 \times 10^{-34}$
c) $2.1 \times 10^{-34}$
d) $-2.1 \times 10^{-34}$

9. Charge motion with in the Gaussian surface gives changing physical quantity as: **[1]**

a) electric flux
b) Gaussian surface area
c) electric field
d) charge

10. In an interference experiment, the ratio of amplitudes of coherent waves is $\frac{a_1}{a_2} = \frac{1}{3}$. The ratio of maximum and minimum intensities of fringes will be **[1]**

a) 2
b) 9

c) 18

d) 4

11. A convex mirror of focal length f produces an image (1/n)th of the size of the object. The distance of the object from the mirror is: [1]

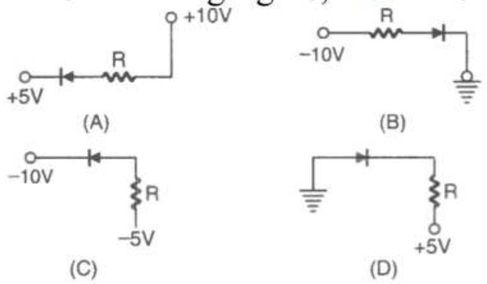
a) nf

b) (n + 1)f

c) f/n

d) (n - 1)f

12. In the following figure, the diodes which are forward biased, are: [1]




a) (C) and (A)

b) (B) and (D)

c) (C) only

d) (A) (B) and (D)

13. A hydrogen atom moving at a speed v absorbs a photon of wavelength 122 nm and stops. Find the value of v. (Mass of hydrogen atom $=1.67 \times 10^{-27}$ kg) [1]

a) 3.5 m/s

b) 3.05 m/s

c) 3.25 m/s

d) 32.5 m/s

14. Fraunhofer lines of the solar system is an example of: [1]

a) line absorption spectrum

b) continuous emission spectrum

c) emission line spectrum

d) emission band spectrum

15. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire, then in equilibrium position, the ratio of the magnitude of electric fields at the surface of the spheres A and B is: [1]

a) 1 : 4

b) 4 : 1

c) 1 : 2

d) 2 : 1

16. **Assertion (A):** Mass is not conserved, but mass and energy are conserved as a single entity called mass-energy. [1]
**Reason (R):** Mass and energy are inter-convertible in accordance with Einstein's relation.

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 but R is true.

17. **Assertion (A):** Radiowaves can be polarised. **[1]**
**Reason (R):** Sound waves in air are longitudinal in nature.

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 but R is true.

18. **Assertion (A):** Iron is not a magnet. **[1]**
**Reason (R):** Iron is diamagnetic substance.

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 but R is true.

## Section B

19. In the ground state of hydrogen atom, its Bohr radius is given as $5.3 \times 10^{-11}$ m.The atom is excited such that the radius becomes $21.2 \times 10^{-11}$ m. Find (i) the value of the principal quantum number and (ii) the total energy of the atom in this excited state. **[2]**

20. Carbon and silicon are known to have similar lattice structures. However, the four bonding electrons of carbon are present in second orbit while those of silicon are present in its third orbit. How does this difference result in a difference in their electrical conductivities? **[2]**

21. Determine the number density of donor atoms which have to be added to an intrinsic germanium semiconductor to produce an n-type semiconductor of conductivity 5 $\Omega^{-1}$ $cm^{-1}$, given that the mobility of electron in n-type Ge is 3900 $cm^2$ /Vs. Neglect the contribution of holes to conductivity. **[2]**

22. A plane electromagnetic wave is moving along x-direction. The frequency of the wave is $10^{15}$ Hz and the electric field at any point is varying sinu-soidally with time with an amplitude of 2 $Vm^{-1}$. Calculate the average densities of the electric and magnetic fields. **[2]**

OR

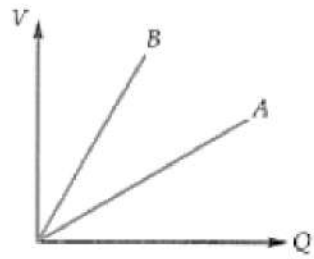
How does the concept of displacement current associate symmetry in the behaviour of electric and magnetic fields?

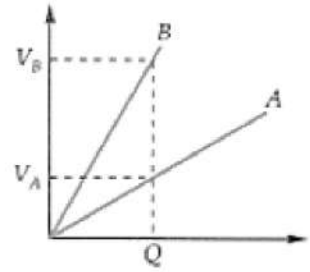
23. What two main observations in photoelectricity led Einstein to suggest the photon theory for the interaction of light with the free electron in metal? Obtain an expression for threshold frequency for photoelectric emission in terms of the work function of the metal. **[2]**

24. What is mass defect of a nucleus? Express it mathematically. How do you account for it? **[2]**

25. The graph [Fig.(a)] shows the variation of voltage V across the plates of two capacitors A and B versus increase of charge Q stored on them. Which of the **[2]**

capacitors has higher capacitance? Give reason for your answer.




OR

Assuming an expression for the potential of an isolated conductor, show that the capacitance of such a sphere will be increased by a factor n if it is enclosed within an earthed concentric sphere, the ratio of the radii of the spheres being $\frac{n}{(n-1)}$.

**Section C**

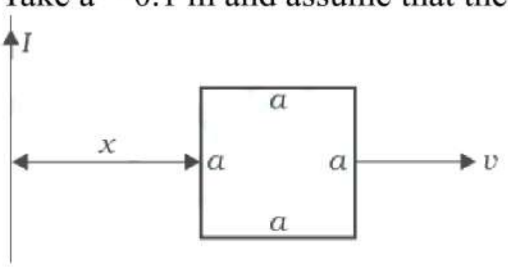
26. a. Using the Bohr's model, calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels. **[3]**

b. Calculate the orbital period in each of these levels.

27. In a Young's double-slit experiment, the slits are separated by 0.5 mm and the screen is placed 1.0 m away. It is found that the ninth bright fringe is at a distance of 8.835 mm from the second dark fringe. Find the wavelength of light used. **[3]**

28. a. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in Figure. **[3]**

b. Now assume that the straight wire carries a current of 50 A and the loop is moved to the right with a constant velocity, v = 10 m/s.
Calculate the induced emf in the loop at the instant when x = 0.2 m.
Take a = 0.1 m and assume that the loop has a large resistance.




OR

Define the term mutual inductance between the two coils. Obtain the expression for mutual inductance of a pair of long co-axial solenoids each of length l and radii $r_1$ and $r_2$ ($r_2 >> r_1$). The total number of turns in the two solenoids are $N_1$ and $N_2$ respectively.

29. Answer the following questions. **[3]**

i. Name the waves which are produced during radioactive decay of a nucleus. Write their frequency range.

ii. Welders wear special glass goggles while working. Why? Explain.

iii. Why are infrared waves often called as heatwaves? Give their one application.

OR

Calculate the electric and magnetic fields produced by the radiation coming from a 100 W bulb at a distance of 3 m. Assume that the efficiency of the bulb is 2.5% and it is a point source.

30. A bar magnet of the magnetic moment $\vec{m}$ and moment of inertia I (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to the length. Let T be the period of oscillations of the original magnet about an axis through the midpoint, perpendicular to the length, in a magnetic field B. What would be the similar period T′ for each piece? **[3]**

## Section D

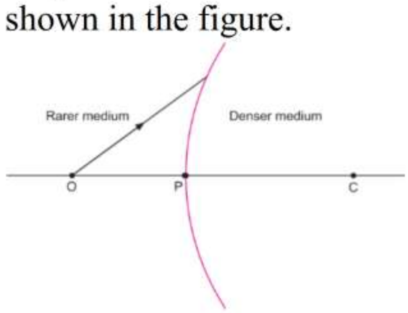
31. If light passes near a massive object, the gravitational interaction causes a bending of the ray. This can be thought of as happening due to a change in the effective refractive index of the medium given by **[5]**

$n(r) = 1 + \frac{2GM}{rc^2}$

where r is the distance of the point of consideration from the centre of the mass of the massive body, G is the universal gravitational constant, M the mass of the body and c the speed of light in vacuum. Considering a spherical object find the deviation of the ray from the original path as it grazes the object.

OR

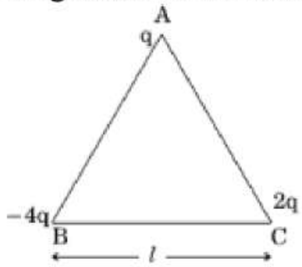
A spherical surface of radius of curvature R, separates a rarer and a denser medium as shown in the figure.




Complete the path of an incident ray of light, showing the formation of a real image. Hence derive the relation connecting object distance u, image distance v, radius of curvature R, and the refractive indices $n_1$ and $n_2$ of the two media.

Briefly explain, how the focal length of a convex lens changes, with an increase in wavelength of the incident light.

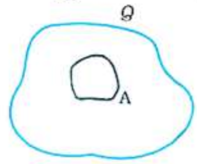
32. i. Three point charges q, – 4q and 2q are placed at the vertices of an equilateral triangle ABC of side $l$ as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q. **[5]**



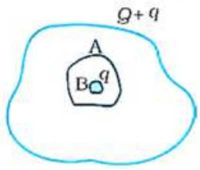

ii. Find out the amount of the work done to separate the charges at infinite distance.

OR

a. A conductor A with a cavity as shown in fig is given a charge Q. Show that the entire charge must appear on the outer surface of the conductor.

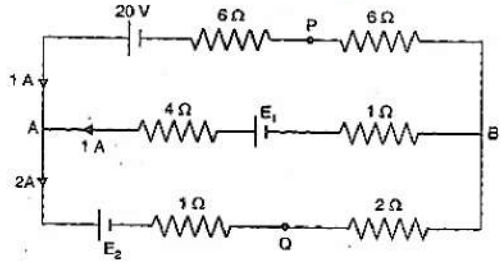



b. Another conductor B with charge q is inserted into the cavity keeping B insulated from A. Show that the total charge on the outside surface of A is Q + q [fig].




c. A sensitive instrument is to be shielded from the strong electrostatic fields in its environment. Suggest a possible way.

33. i. Find the emf $E_1$ and $E_2$ in the circuit of the following diagram and the potential difference between the points A and B. **[5]**

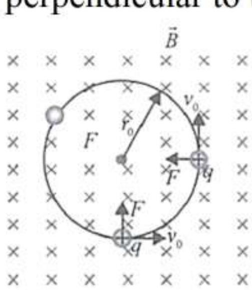



ii. If in the circuit, the polarity of the battery $E_1$, be reversed, what will be the potential difference between A and B?

## Section E

34. **Read the text carefully and answer the questions:** **[4]**

An electron with speed $v_0 << c$ moves in a circle of radius $r_0$ in a uniform magnetic field. This electron is able to traverse a circular path as magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is $T_0$.



(i) If the speed of the electron is doubled to $2v_0$ What will be the radius of the circle if the initial radius is $r_0$?

(ii) If the speed of particle gets doubled, what will be the new time period of particle?

(iii)

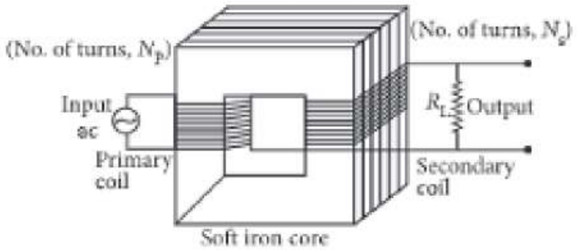
A charged particles is projected in a magnetic field $\vec{B} = (2\hat{i} + 4\hat{j}) \times 10^2$ T . The acceleration of the particle is found to be $\vec{a} = (x\hat{i} + 2\hat{j})\text{ms}^{-2}$ . Find the value of x

**OR**

What will be the trajectory of electron If the direction of velocity of the electron makes an acute angle with the direction of magnetic field?

35. **Read the text carefully and answer the questions:** **[4]**

A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction i.e. whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.




It can be shown that $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p}$ = k

where the symbols have their standard meanings.

For a step-up transformer, $n_S > n_P$; $E_S > E_P$; $k > 1$; $\therefore I_S < I_P$

For a step down transformer, $n_S < n_P$; $E_S < E_P$; $k < 1$

The above relations are on the assumption that efficiency of transformer is 100%.

Infact, efficiency $\eta = \frac{\text{output power}}{\text{intput power}} = \frac{E_s I_s}{E_p I_p}$

(i) The number of turns in the primary coil of a transformer is 20 and the number of turns in a secondary is 10. If the voltage across the primary is 220 ac V, what is the voltage across the secondary?

(ii) In a transformer, the number of primary turns is four times that of the secondary turns. Its primary is connected to an a.c. source of voltage V. What will be the current through its secondary?

(iii) A transformer is used to light 100 W - 110 V lamps from 220 V mains. If the main current is 0.5 A, then what will be the efficiency of the transformer?

**OR**

Which quantity remains constant in an ideal transformer?

## SOLUTION

### Section A

1. **(b)** X is n-type, Y is p-type and the junction is reverse biased
   **Explanation:** X is n-type, Y is p-type and the junction is reverse biased
2. **(b)** 8 second
   **Explanation:** We know that the intensity of tight varier^nverseiy as the (distance)$^2$. When distance is doubled, the intensity becomes one-fourth, So, the time of exposure should be four times, Hence, time of exposure = 2 × 4 = 8 sec.
3. **(c)** acts only in closed circuit and it reduces the current
   **Explanation:** The internal resistance of a cell acts only in a closed circuit and it reduces the current.
4. **(c)** $\frac{1}{16}$
   **Explanation:** $\frac{1}{16}$
5. **(c)** $n_e >> n_h$
   **Explanation:** $n_e >> n_h$
6. **(c)** only ii
   **Explanation:** add explanation here
7. **(a)** A force and a torque
   **Explanation:** In non-uniform magnetic field, the needle will experience both a force and a torque.
8. **(a)** $3.15 \times 10^{-34}$
   **Explanation:** $3.15 \times 10^{-34}$
9. **(c)** electric field
   **Explanation:** electric field
10. **(d)** 4
    **Explanation:** In Young's double-slit experiment, ratio of maxima and minima intensity is given by
    $\frac{I_{\max}}{I_{\min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 = \left(\frac{\sqrt{I_1/I_2}+1}{\sqrt{I_1/I_2}-1}\right)^2$
    As, intensity (l) ∝ [amplitude (a)]$^2$
    $\therefore \frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$
    So, $\frac{I_{\max}}{I_{\min}} = \left(\frac{\frac{1}{3}+1}{\frac{1}{3}-1}\right)^2 = 4:1$
11. **(d)** (n - 1)f
    **Explanation:** As the image formed by a convex mirror is always virtual or erect, so
    m = -(v/u) = +(1/n) or $v = -\frac{u}{n}$
    $\therefore \quad \frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ or $-\frac{n}{u} + \frac{1}{u} = \frac{1}{+f}$
    or $\frac{-(n-1)}{u} = \frac{1}{f}$ or u = -(n - 1)f
    i.e., object is infront of mirror at a distance (n - 1)f
12. **(a)** (C) and (A)
    **Explanation:** p - n junction is said to be forward biased when p side is at high potential than n side. It is for circuit (A) and (C).

13. **(c)** 3.25 m/s

**Explanation:** The linear momentum of the photon,

$mv = \frac{h}{\lambda}$

$= \frac{6.63\times10^{-34}}{122\times10^{-9}}$

$= 5.43 \times 10^{-27} \frac{kg-m}{s}$

p = mv

$\Rightarrow v = \frac{p}{m}$

$\Rightarrow v = \frac{5.43\times10^{-27}}{1.67\times10^{-27}}$

= 3.25 m/s

14. **(a)** line absorption spectrum

**Explanation:** We know that the solar spectrum consists of a large number of dark lines distributed through the whole length of the spectrum. These dark lines are called Fraunhofer lines. These lines are produced by the absorption of rays of the sun in the atmosphere. When the white light from the photosphere passes through chromosphere, the vapours and gases present in it absorb certain wavelengths and produce dark lines.

15. **(d)** 2 : 1

**Explanation:** When joined by a wire, the two spheres attain common potential V.

$\therefore$ Intensity, $E_A = \frac{1}{4\pi\varepsilon_0}\frac{q_A}{R_A^2}$

$= \frac{C_A V}{4\pi\varepsilon_0 R_A^2} = \frac{4\pi\varepsilon_0 R_A V}{4\pi\varepsilon_0 R_A^2} = \frac{V}{R_A}$

Similarly, $E_B = \frac{V}{R_B}$

$\therefore \frac{E_A}{E_B} = \frac{R_B}{R_A} = \frac{2}{1}$

16. **(a)** Both A and R are true and R is the correct explanation of A.

**Explanation:** Both A and R are true and R is the correct explanation of A.

17. **(b)** Both A and R are true but R is not the correct explanation of A.

**Explanation:** Radiowaves are transverse waves, they can be polarised.
Both A and R are true but R is not the correct explanation of A.

18. **(c)** A is true but R is false.

**Explanation:** Iron is a ferromagnetic material. But in iron, the atomic magnetic dipoles are randomly oriented in the form of small domains, such that the net magnetic moment of the specimen is zero. It becomes magnet only on applying external magnetic field. When external field is applied, the magnetic dipoles align along the direction of the field and the specimen becomes magnet as it now possesses non zero magnetic moment.

**Section B**

19. i. According to the question,

Given, $r_1 = 5.3 \times 10^{-11}$ m and $r_2 = 21.2\times10^{-11}$ m

$n_1 = 1$

We know that, $r \propto n^2$

$\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \Rightarrow \frac{1}{n_2^2} = \frac{5.3\times10^{-11}}{21.2\times10^{-11}}$

$\Rightarrow \quad n_2^2 = 4 \Rightarrow n_2 = 2$

ii. We know that,

$E = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4\text{eV}$

20. The energy required to take out an electron from Si atom is much smaller than that in the case of C atom. Hence the number of free electrons for conduction in Si is quite significant

but negligibly small for C. Consequently the conductivity of silicon is much greater than that of carbon.

21. Here $\sigma = 5\Omega^{-1}\ \text{cm}^{-1}$, $\mu_e = 3900\ \text{cm}^2\ \text{V}^{-1}\ \text{s}^{-1}$, $n_e = ?$

If we neglect the contribution of holes to conductivity, then

$\sigma = \frac{1}{\rho} = e n_e \mu_e$

$\therefore$ Electron density,

$n_e = \frac{\sigma}{e\mu_e} = \frac{5}{1.6\times10^{-19}\times3900}\ \text{cm}^{-3}$

$= 8.01 \times 10^{15}\ \text{cm}^{-3}$

22. Here, $v = 6 \times 10^{14}$ Hz, $E_0 = 2\text{Vm}^{-1}$

   i. Average energy density of the electric field

   $u_E = \frac{1}{4} \in_0 E_0^2 = \frac{1}{4} \times \left(8.85 \times 10^{-12}\right) \times 2^2$

   $= 8.85 \times 10^{-12}\text{Jm}^{-3}$

   ii. Average energy density of magnetic field

   $u_B = \frac{B_0^2}{4\mu_0} = \frac{1}{4} \times \frac{(E_0/c)^2}{\mu_0} = \frac{1}{4}\frac{E_0^2}{\mu_0 c^2}$

   $= \frac{1}{4} \times \frac{2^2}{(4\pi\times10^{-7})\times(3\times10^8)^2}$

   $= 8.85 \times 10^{-12}\text{Jm}^{-3}$

OR

According to Faraday's law of electromagnetic induction, a time-varying magnetic field produces an induced emf. According to Maxwell, a time-varying electric field sets up a current and hence a magnetic field. Such a current is called displacement current. It follows that a time-varying electric field produces a magnetic field and vice-versa. Hence the behaviours of electric and magnetic fields are symmetrical.

23. **The two main observations are:**

   i. The maximum kinetic energy of emitted photoelectron is independent of intensity of light.

   ii. For each photoelectron, there must be a threshold frequency of incident light below which no emission takes place.

For the metal of work function $\phi$. The kinetic energy of photoelectron emitted due to falling of photon of frequency $\nu$ is

$\frac{1}{2}mv_{\text{max}}^2 = h\nu - \phi$

For just emission, $v_{max} = 0$

$\therefore h\nu = h\nu_0 = \phi$

where $\nu_0$ is the threshold frequency.

or $\nu_0 = \frac{\phi}{h}$

24. It is found that the mass of a stable nucleus is always less than the sum of the masses of its constituent protons and neutrons in their free state.

The difference between the rest mass of a nucleus and the sum of the rest masses of its constituent nucleons is called its mass defect.

Consider the nucleus ${}_Z^AX$. It has Z pro (A - Z) neutrons. Therefore, its mass defect will be

$\Delta m = Zm_p + (A - Z)m_n - m$

where mp, $m_n$ and m are the rest masses of a proton, neutron and the nucleus ${}_Z^AX$ respectively.

25. From Fig.(b),

$C_A = \frac{Q}{V_A}$ and $C_B = \frac{Q}{V_B}$

But $V_A < V_B$, therefore, $C_A > C_B$

OR

The capacitance of an isolated conducting sphere of radius a is $C = 4\pi\varepsilon_0 a$

When surrounded by an earthed sphere of radius b, its capacitance becomes

$C' = 4\pi\varepsilon_0 \cdot \frac{ab}{b-a}$

$\therefore \frac{C'}{C} = \frac{ab}{a(b-a)} = \frac{b}{b-a} = \frac{1}{1-\frac{a}{b}} = \frac{1}{1-\frac{n-1}{n}} = n$

**Section C**

26. a. Now, $v = \frac{c}{n}\alpha$,

where $\alpha = \frac{2\pi Ke^2}{ch} = 0.0073$

$v_1 = \frac{3\times10^8}{1} \times 0.0073 = 2.19 \times 10^6 m/s$

$v_2 = \frac{3\times10^8}{3} \times 0.0073 = 1.095 \times 10^6 m/s$

$v_3 = \frac{3\times10^8}{3} \times 0.0073 = 7.3 \times 10^5 m/s$

b. Orbital period, $T = \frac{2\pi r}{v}$

As $r_1 = 0.53 \times 10^{-10} m$

$T_1 = \frac{2\pi\times0.53\times10^{-10}}{2.19\times10^6} = 1.52 \times 10^{-16} s$

As $r_2 = 4\ r_1$ and $v_2 = \frac{1}{2}v_1$

$T_2 = 8\ T_1 = 8 \times 1.52 \times 10^{-16} s = 1.216 \times 10^{-15} s$

As $r_3 = 9r_1$ and $v_3 = \frac{1}{3}v_1$

$\therefore T_3 = 27\ T_1 = 27 \times 1.52 \times 10^{-16} s = 4.1 \times 10^{-15} s$

27. The distance of nth bright fringe from the central bright fringe is

$x_n = \frac{nD\lambda}{d} = n\beta$

$\therefore x_9 = 9\beta$

The distance of nth dark fringe from the central bright fringe is

$x'_n = (2n - 1)\ \frac{D\lambda}{2d} = (2n - 1)\ \frac{\beta}{2}$

$\therefore x'_2 = \frac{3}{2}\beta$

But $x_9 - x'_2 = 8.835$ mm [Given]

or $9\beta - \frac{3}{2}\beta = 8.835$ mm or $\frac{15}{2}\beta = 8.835$ mm

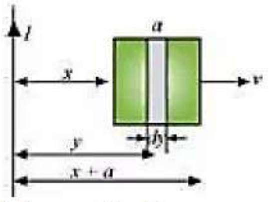
or $\beta = \frac{8.835\times2}{15}$ mm

$= 1.178$ mm $= 1.178 \times 10^{-3}$ m

Hence $\lambda = \frac{\beta d}{D} = \frac{1.178\times10^{-3}\times0.5\times10^{-3}}{1.0}$ m

$= 0.5890 \times 10^{-6}$ m $= 5890\ \mathring{A}$

28. a. Take a small element dy in the loop at a distance y from the long straight wire (as shown in the given figure).




Magnetic flux associated with element day, $d\phi = BdA$

Where,

dA = Area of element dy = a dy

B = Magnetic field at distance y

$= \frac{\mu_0 I}{2\pi y}$

I = current in the wire

$\mu_0$ = Permeability of free space = $4\pi \times 10^{-7}$ T $mA^{-1}$

$\therefore d\phi = \frac{\mu_0 I a}{2\pi} \frac{dy}{y}$

$\phi = \frac{\mu_0 I a}{2\pi} \int \frac{dy}{y}$

y tends from x to a + x

$\therefore \phi = \frac{\mu_0 I a}{2\pi} \int_x^{a+x} \frac{dy}{y}$

$= \frac{\mu_0 I a}{2\pi} [\log_e y]_x^{a+x}$

$= \frac{\mu_0 \text{la}}{2\pi} \log_e \left(\frac{a+x}{x}\right)$

For mutual inductance M, the flux is given as:

$\phi = MI$

$\therefore MI = \frac{\mu_0 I a}{2\pi} \log_e \left(\frac{a}{x} + 1\right)$ thus by comparing the equations we get,

$M = \frac{\mu_0 a}{2\pi} \log_e \left(\frac{a}{x} + 1\right)$

b. Emf induced in the loop, e = B'av $= \left(\frac{\mu_0 I}{2\pi x}\right) av$

Given,

I = 50 A

x = 0.2 m

a = 0.1 m

v = 10 m/s

$e = \frac{4\pi \times 10^{-7} \times 50 \times 0.1 \times 10}{2\pi \times 0.2}$

$e = 5 \times 10^{-5}$V

OR

A coil B kept near another coil A has magnetic flux passing through it when kept near coil A. The ratio of magnetic flux through the coil B to the current in the coil A is called as mutual inductance of coils. or **Mutual Inductance** is the interaction of one coils magnetic field on another coil as it induces a voltage in the adjacent coil

$M_{12} = \frac{\phi_2}{i}$

Let $S_1$ carries a current i.

Magnetic field inside $S_1$ will be $B = \frac{\mu_o N_1 i}{l}$

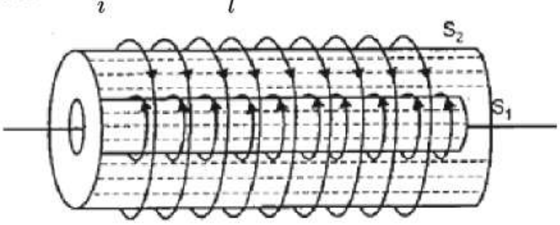
Flux through each turn of $S_2$ is $\phi = B \times \pi r_2^2$

$\phi = \frac{\mu_o N_1 \pi r_2^2 i N_2}{l}$

Flux through each turn of $S_2$ is $\phi_B = \phi N_2$

$\phi_B = \frac{\mu_o N_1 \pi r_2^2 i N_2}{l}$

$M = \frac{\phi_B}{i} = \frac{\mu_o N_1 N_2 \pi r_2^2}{l}$



29. i. $\gamma$-rays are produced during radioactive decay of a nucleus. Its frequency range is from $3\times10^{18}$ Hz to $5\times10^{22}$ Hz.
ii. Welders wear special glass goggles while working to protect their eyes from radiation hazards of ultraviolet rays(UV rays). The range of UV rays is $10^{15}$ Hz to $10^{17}$ Hz.
iii. Infrared waves are called heat waves because they cause the atoms and molecules to vibrate when they encounter a substance. This increases the velocity and hence internal energy of atoms and molecules. Thereby, increasing the temperature of the substance as the heat produced in the matter is directly proportional to the internal energy of atoms and molecules. They are used in physical therapy and weather forecasting.

OR

The bulb, as a point source, radiates light in all directions uniformly. At a distance of 3 m, the surface area of the surrounding sphere is

$A = 4\pi r^2 = 4\pi(3)^2 = 113\ m^2$

The intensity I at this distance is

$I = \frac{\text{Power}}{\text{Area}} = \frac{100\text{W}\times2.5}{113\text{m}^2}\ \%$

$= 0.022\ W/m^2$

Half of this intensity is provided by the electric field and half by the magnetic field is given by:

$\frac{1}{2}I = \frac{1}{2}\left(\varepsilon_0 E_{rms}^2 c\right)$

$= \frac{1}{2}\ (0.022\ W/m^2)$

$E_{rms} = \sqrt{\frac{0.022}{(8.85\times10^{-12})(3\times10^{8})}}\text{V/m}$

$= 2.9\ V/m$

The value of E found above is the root mean square value of the electric field. Since the electric field in a light beam is sinusoidal, the peak electric field, $E_0$ is

$E_0 = \sqrt{2}E_{\text{rms}} = \sqrt{2}\times2.9\text{V/m}$

$= 4.07\ V/m$

Thus, the electric field strength for reading is fairly large. Compare it with an electric field strength of TV or FM waves, which is of the order of a few microvolts per metre.

Now, let us calculate the strength of the magnetic field.

$B_{rms} = \frac{E_{rms}}{c} = \frac{2.9\text{Vm}^{-1}}{3\times10^{8}\text{ms}^{-1}} = 9.6\times10^{-9}\ T$

Again, since the field in the light beam is sinusoidal, the peak magnetic field is $B_0 = \sqrt{2}$ $B_{rms} = 1.4\times10^{-8}$ T. Note that although the energy in the magnetic field is equal to the energy in the electric field, the magnetic field strength is evidently very weak.

30. The magnetic moment of each part of magnet $M' = \frac{M}{2}$

If m is the mass of the original magnet, then the mass of each two magnets m' will be $\frac{m}{2}$.

The length of the new magnet = $l' = \frac{l}{2}$

Now, the moment of inertia,

$I = \frac{ml^2}{12}$

and time period $T = 2\pi\sqrt{\frac{I}{MB}}$

Thus,

$\frac{T}{T'} = \frac{2\pi\sqrt{\frac{I}{MB}}}{2\pi\sqrt{\frac{I'}{M'B}}} = \sqrt{\frac{I}{M}\cdot\frac{M'}{I'}}$ or $\frac{T'}{T} = \sqrt{\frac{M}{M'}\cdot\frac{I'}{I}}$

Now, $\frac{I'}{I}=\frac{\frac{m'l'^2}{12}}{\frac{ml^2}{12}}=\frac{\frac{m}{2}\cdot\left(\frac{l}{2}\right)^2}{ml^2}$

$\frac{I'}{I}=\frac{\frac{m}{2}\cdot\frac{l^2}{4}}{ml^2}=\frac{1}{8}$

and $\frac{M}{M'}=\frac{M}{\frac{M}{2}}=\frac{2}{1}$

$\therefore \frac{T'}{T}=\sqrt{\frac{2}{1}\times\frac{1}{8}}=\sqrt{\frac{1}{4}}$

$\frac{T'}{T}=\frac{1}{2}$ or $T'=\frac{T}{2}$

## Section D

31. If light passes near a massive object, the gravitational interaction causes a bending of the ray. Consider two planes at r and r + dr. Let the light be incident at an angle $\theta$ at the plane at r and leave r + dr at an angle $\theta+d\theta$

Then from Snell's law

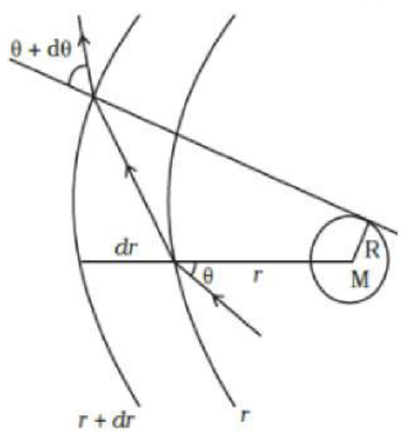
$n(r)\sin\theta=n(r+dr)\sin(\theta+d\theta)$

$\Rightarrow n(r)\sin\theta=\left(n(r)+\frac{dn}{dr}dr\right)\ (\sin\theta\cos d\theta+\cos\theta\sin d\theta)\ ;$

$\left(n(r)+\frac{dn}{dr}dr\right)(\sin\theta+\cos\theta d\theta)$

Neglecting products of differentials.

$n(r)\sin\theta=n(r)\sin\theta+\frac{dn}{dr}\ dr\sin\theta+n(r)\cos\theta d\theta$




$\Rightarrow -\frac{dn}{dr}\tan\theta=n(r)\frac{d\theta}{dr}$

$\Rightarrow \frac{2GM}{r^2c^2}\tan\theta=\left(1+\frac{2GM}{rc^2}\right)\frac{d\theta}{dr}\approx\frac{d\theta}{dr}$

$\int\limits_0^{\theta_0} d\theta=\frac{2GM}{c^2}\int\limits_{-\infty}^{\infty}\frac{\tan\theta dr}{r^2}$

Now $r^2=x^2+R^2$ and $\tan\theta=\frac{R}{x}$

2rdr = 2xdx

$\int\limits_0^{\theta_0} d\theta=\frac{2GM}{c^2}\int\limits_{-\infty}^{\infty}\frac{R}{x}\frac{xdx}{(x^2+R^2)^2}$

Put x = R tan $\phi$

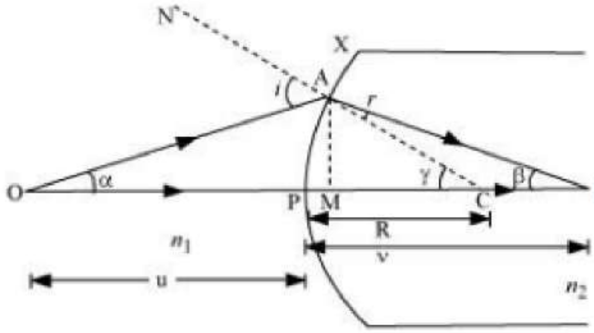
dx = $R\,\mathrm{Sec}^2\,\phi d\phi$

$\theta_0=\frac{2GMR}{c^2}\int\limits_{-\pi/2}^{\pi/2}\frac{R\sec^2\phi d\phi}{R^3\sec^3\phi}$

$=\frac{2\mathrm{GM}}{Rc^2}\int\limits_{-\pi/2}^{\pi/2}\cos\phi d\rho=\frac{4GM}{Rc^2}$

OR

The complete path is shown in the figure.




Let a spherical refracting surface XY separate a rarer medium of refractive index $n_1$ from a denser medium of refractive index $n_2$. Let P be the pole, C be the centre and R = PC be the radius of curvature of this surface.

Consider a point object O lying on the principal axis of the surface.

Let $\angle AOM = \alpha, \angle AIM = \beta, \angle ACM = \gamma$

As external angle of a triangle is equal to sum of internal opposite angles, therefore, in $\Delta$IAC,

$r + \beta = \gamma$

$r = \gamma - \beta$ ....(i)

Similarly, in $\Delta$OAC , $i = \alpha + \gamma$ ...(ii)

According to Snell's law,

$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \frac{i}{r}$ ...(ii) ($\because$ angles are small)

$\therefore n_1 i = n_2 r$

Using (i) and (ii), we obtain

$n_1(\alpha + \gamma) = n_2(\gamma - \beta)$

As angles $\alpha$, $\beta$ and $\gamma$ are small, and applying trigonometric functions, we obtain

$\therefore n_1\left(\frac{AM}{MO} + \frac{AM}{MC}\right) = n_2\left(\frac{AM}{MC} - \frac{AM}{MI}\right)$ ...(iii)

As aperture of the spherical surface is small, M is close to P. Therefore, MO $\approx$ PO, MI $\approx$ PI, MC $\approx$ PC

From (iii),

$n_1\left(\frac{1}{PO} + \frac{1}{PC}\right) = n_2\left(\frac{1}{PC} - \frac{1}{PI}\right)$

$\therefore \frac{n_1}{PO} + \frac{n_2}{PI} = \frac{n_2 - n_1}{PC}$

Using new Cartesian sign conventions, we put

PO = -u, PI = +v, PC = R

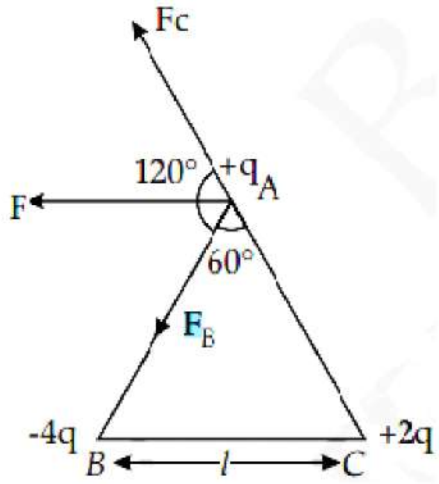
$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$

This is the required relation.

Now, $f \propto \frac{1}{\mu - 1}$ (from lens maker formula)

As a wavelength of incident light increases, $\mu$ decreases. Hence, the focal length f increases.

32. i. Consider the figure shown below. The forces acting on charge q at A due to charges -4q at B and 2q at C are $F_1$ along AB and $F_2$ along CA respectively.




$|\vec{F}_1| = \frac{1}{4\pi\varepsilon_0}\frac{(4q)(q)}{l^2} = \frac{1}{4\pi\varepsilon_0}\frac{(4q^2)}{l^2} = \frac{1}{\pi\varepsilon_0}\frac{q^2}{l^2}$

$|\vec{F}_2| = \frac{1}{4\pi\varepsilon_0}\frac{(2q)(q)}{l^2} = \frac{1}{2\pi\varepsilon_0}\frac{q^2}{l^2}$

Thus, $F_1 = 2F_2$

Now angle between $\vec{F}_1$ and $\vec{F}_2$ is $120^{\circ}$. Thus magnitude of the resultant force F is given by,

$F = \sqrt{F_1^1 + F_2^2 + 2F_1F_2\cos 120^\circ}$

$F = \sqrt{(2F_2)^2 + F_2^2 + 4F_2^2\cos 120^\circ}$

$F = \sqrt{4F_2^2 + F_2^2 - 2F_2^2}$

$F = \sqrt{3F_2^2}$

$F = \frac{\sqrt{3}}{2\pi\varepsilon_0}\frac{q^2}{l^2}$

ii. The amount of work done to separate the charges to infinity will be equal to potential energy of the system of charges.

$U = \frac{1}{4\pi\varepsilon_0 l}[q \times (-4q) + (q \times 2q) + (-4q \times 2q)]$

$U = \frac{1}{4\pi\varepsilon_0 l}[-4q^2 + 2q^2 - 8q^2]$

$U = \frac{1}{4\pi\varepsilon_0 l}[-10q^2]$

$U = -\frac{1}{4\pi\varepsilon_0 l}[10q^2]$

OR

a. Let us consider a Gaussian surface that is Iying wholly within a conductor and enclosing the cavity. The electric field intensity E inside the charged conductor is zero. Let q is the charge inside the conductor and $\in_o$ is the permittivity of free space. According to Gauss's law,

Flux, $\phi = \overrightarrow{E}.\overrightarrow{ds} = \frac{q}{\epsilon_0}$

Here, E = 0

$\frac{q}{\epsilon^0} = 0$

$\therefore \epsilon_o \neq 0$

$\therefore q = 0$

Therefore, the charge inside the conductor is zero.

The entire charge Q appears on the outer surface of the conductor.

b. The outer surface of conductor A has a charge of amount Q. Another conductor B having charge +q is kept inside conductor A and it is insulated from A. Hence, a charge of the amount -q will be induced in the inner surface of conductor A and +q is induced on the outer surface of conductor A. Therefore, the total charge on the outer surface of conductor A is Q+q.

c. A sensitive instrument can be shielded from the strong electrostatic field in its environment by enclosing it fully inside a metallic surface. A closed metallic body acts as an electrostatic shield.

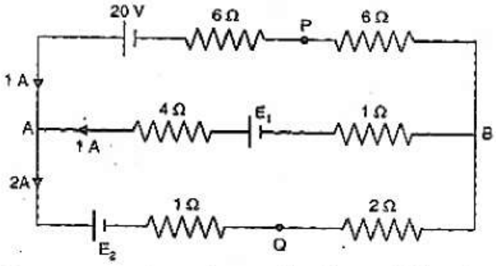
33. i. It is clear that 1 A current flows in the circuit from B to A.

Applying Kirchhoff's law to the loop PAQBP,

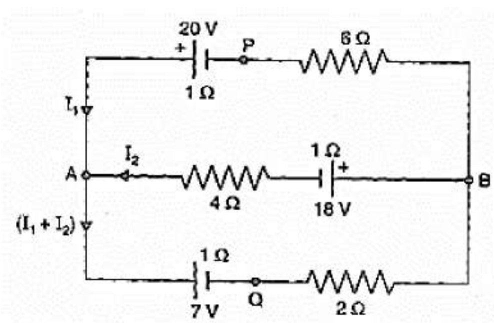
$20 - E_2 = 12 \times 1 + (1 \times 2) + (2 \times 2) = 18$

Hence, $E_2 = 2V$

Thus the potential difference between the points A and B is:




ii. On reversing the polarity of the battery $E_1$, the current distributions will be changed. Let the currents be $I_1$ and $I_2$ as shown in the following figure.




Applying Kirchhoff's law for the loop PABP,

$20 + E_1 = (6 + 1)I_1 - (4 + 1)I_2$

or $38 = 7I_1 - 5I_2$ ...... (i)

Similarly for the loop ABQA,

$4I_2 + I_2 + 18 + 2(I_1 + I_2) + (I_1 + I_2) + 7 = 0$

Or $3I_1 + 8I_2 = -25$ ...... (ii)

Solving equation (i) and (ii) for $I_1$ and $I_2$ we get

$I_1 = 2.52$ and $I_2 = -4.07A$

Hence, $V_{ab} = -5 \times (4.07) + 18$

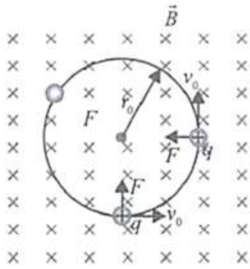
$= -20.35 + 18$

$= -2.35V$

## Section E

34. **Read the text carefully and answer the questions:**

An electron with speed $v_0 << c$ moves in a circle of radius $r_0$ in a uniform magnetic field. This electron is able to traverse a circular path as magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and q. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is $T_0$.



(i) $2r_0$

As, $r_0 = \frac{mv}{qB} \Rightarrow r' = \frac{m(2v_0)}{qB} = 2r_0$

(ii) $T_0$

As, $T = \frac{2\pi m}{qB}$

Thus, it remains same as it is independent of velocity.

(iii)As $F \perp B$

Hence, $a \perp B$

$\therefore \vec{a} \cdot \vec{B} = 0$

$\Rightarrow (x\hat{i} + 2\hat{j}) \cdot (2\hat{i} + 4\hat{j}) = 0$

$2x + 8 = 0 \Rightarrow x = -4\ ms^{-2}$

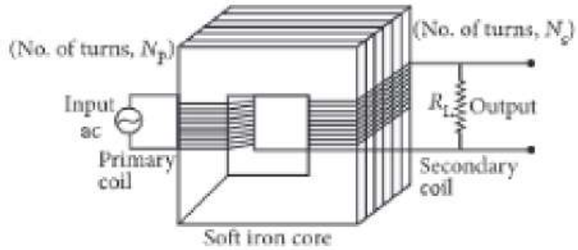
OR

If the charged particle has a velocity not perpendicular to $\vec{B}$, then the component of velocity along $\vec{B}$ remains unchanged as the motion along the $\vec{B}$ will not be affected by $\vec{B}$.

Then, the motion of the particle in a plane perpendicular to $\vec{B}$ is as before circular one. Thereby, producing helical motion.

35. **Read the text carefully and answer the questions:**

A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction i.e. whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.




It can be shown that $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p} = k$

where the symbols have their standard meanings.

For a step-up transformer, $n_s > n_p$; $E_s > E_p$; $k > 1$; $\therefore I_s < I_p$

For a step down transformer, $n_s < n_p$; $E_s < E_p$; $k < 1$

The above relations are on the assumption that efficiency of transformer is 100%.

Infact, efficiency $\eta = \frac{\text{output power}}{\text{intput power}} = \frac{E_sI_s}{E_pI_p}$

(i) For a transformer, $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

Where N denotes the number of turns and V = voltage.

$\therefore \frac{V_s}{220} = \frac{10}{20}$

$\therefore V_S = 110$ ac V

(ii) In a transformer, the primary and secondary currents are related by

$I_S = \left(\frac{N_p}{N_s}\right) I_p$

and the voltage are related by

$V_S = \left(\frac{N_s}{N_p}\right) V_p$

where subscripts p and s refer to the primary and secondary of the transformer.

Here, $V_p = V \cdot \frac{N_p}{N_s} = 4 \;\therefore I_S = 4I_p$

and $V_S = \left(\frac{1}{4}\right) V = \frac{V}{4}$

(iii) The efficiency of the transformer is $\eta = \frac{\text{Output power } (P_{\text{out}})}{\text{Input power } (P_{\text{in}})} \times 100$

Here, $P_{out} = 100$ W, $P_{in} = (220 \text{ V})(0.5 \text{ A}) = 110$ W

$\therefore \eta = \frac{100 \text{ W}}{110 \text{ W}} \times 100 = 90\%$

OR

In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (i.e 100 %) i.e. input power = output power.