SAMPLE PAPER - 6

Class 12 - Physics

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

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. Copper has fee structure. Its atomic weight is 63.5 and atomic radius is 1.273 $\overset{o}{A}$; then the density is: **[1]**

a) 9043 kg/m^3 b) 3.6×10^{-10}

c) 4391 kg/m^3 d) 2195 kg/m^3

2. A battery of emf 10 V and internal resistance 3 ohms is connected to a resistor. The current in the circuit is 0.5 amp. The terminal voltage of the battery when the circuit is closed is: **[1]**

a) 10 V b) 1.5 V

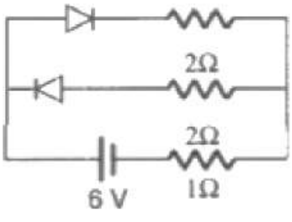
c) zero d) 8.5 V

3. A young boy has accommodation of his eye such that the power of his eye lens can change between 50D and 60D. His far point is at infinity. The distance of his retina from the eye-lens and his near point are respectively (in cm): **[1]**

a) 3.5, 12 b) 2, 10

c) 3, 15 d) 2.5, 12

4. Find the current through 1 Ω resistance: **[1]**



a) 3 amp

b) 1 amp

c) 2 amp

d) none of these

5. Van de Graaff generator: **[1]**

a) is an electromagnetic machine

b) is used to produce charged particles like protons

c) is an electrostatic machine

d) is an electrodynamic machine

6. A particle of mass m and charge q is in an electric and magnetic field is given by $\vec{E} = 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}}, \vec{B} = 4\hat{\mathbf{j}} + 6\hat{\mathbf{k}}$. The charged particle is shifted from the origin to the point P(x = 1; y = l) along a straight path. The magnitude of the total work done is **[1]**

a) 5 q

b) (2.5) q

c) (0.35) q

d) (0.15) q

7. The flux linked with a coil at any instant t is given by $\phi = 10\,t^2 - 50\,t + 250$. The induced emf at t = 3 sec is: **[1]**

a) 10 volt

b) -190 volt

c) 190 volt

d) -10 volt

8. Given the value of Rydberg constant is $10^7\ m^{-1}$, the wave number of the last line of the Balmer series in the hydrogen spectrum will be: **[1]**

a) $0.5 \times 10^7\ m^{-1}$

b) $0.25 \times 10^4\ m^{-1}$

c) $0.25 \times 10^7\ m^{-1}$

d) $2.5 \times 10^7\ m^{-1}$

9. A diffraction pattern is obtained using a beam of red light. What happens if the red light is replaced by blue light? **[1]**

a) Bands become broader and farther apart

b) No change

c) Bands disappear

d) Diffraction bands become narrower and crowded together

10. A spherical conducting shell has a charge q. If a point charge Q is placed at the centre, then the charge on inner and outer surface of the shell respectively are: **[1]**

a) q, Q - q

b) Q, Q + q

c) -Q, Q + q

d) 0, Q

11. The forward-biased diode is: **[1]**

a) 

b) 

c) 

d) 

12. The focal length of the objective lens of a telescope is: **[1]**

a) equal to the focal length of the eye-piece

b) either smaller than the focal length of the eye-piece and equal to the focal length of the eye-piece

c) larger than the focal length of the eye-piece

d) smaller than the focal length of the eye-piece

13. Which of the following has the longest de Broglie wavelength if they are moving with the same velocity? **[1]**

a) Proton

b) Neutron

c) α-particle

d) β-particle

14. Along the x-axis, three charges $\frac{q}{2}$, - q and $\frac{q}{2}$ are placed at x' = 0, x = a and x = 2a respectively. The resultant electric potential at x = a + r (if a < < r) is: ($\in_0$ is the permittivity of free space) **[1]**

a) $\frac{q\left(a^2/4\right)}{4\pi\varepsilon_0 r^3}$

b) $\frac{q}{4\pi\varepsilon_0 r}$

c) $\frac{qa^2}{4\pi\varepsilon_0 r^3}$

d) $\frac{qa}{4\pi\varepsilon_0 r^2}$

15. In Young's double-slit experiment 60 fringes are visible in the field of view with sodium lamp (5 893$\overset{o}{A}$). If another light of wavelength 4200$\overset{o}{A}$ is used in place of the first source, the number of fringes visible in the field of view is about: **[1]**

a) 84

b) 72

c) 56

d) 60

16. **Assertion (A):** Radioactivity of 10^8 undecayed radioactive nuclei of half life of 50 days is equal to that of 1.2 $\times$ 10^8 number of undecayed nuclei of some other material with half-life of 60 days. **[1]**

Reason (R): Radioactivity is proportional to half-life.

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):** When variable frequency ac source is connected to a capacitor, displacement current increases with an increase in frequency. **[1]**

Reason (R): As frequency increases, conduction current also increases.

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):** Electromagnetic are made of soft iron. **[1]**

Reason (R): Coercivity of soft iron is small.

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. How is a p-type semiconductor formed? Name the major charge carriers in it. Draw the energy band diagram of a p-type semiconductor. **[2]**

20. Calculate the impact parameter of a 5 MeV particle scattered by 90° when it approaches a gold nucleus. **[2]**

21. i. Identify the part of the electromagnetic spectrum used in **[2]**

a. radar and

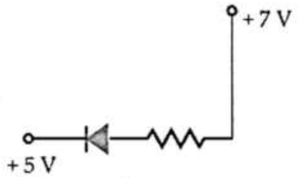
b. eye surgery. Write their frequency range.

ii. Prove that the average energy density of the oscillating electric fields is equal to that of the oscillating magnetic field.

OR

Show that the radiation pressure exerted by an EM wave of intensity I on a surface kept in vacuum is $\frac{I}{c}$.

22. In the following diagrams indicate which of the diodes are forward biased and which are reverse biased. **[2]**

i.


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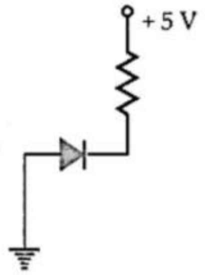

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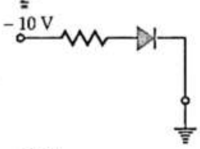

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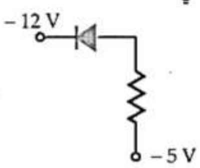


23. The electric field due to a point charge at a distance r depends according to the inverse square law $\left(\propto \frac{1}{r^2}\right)$. **[2]**

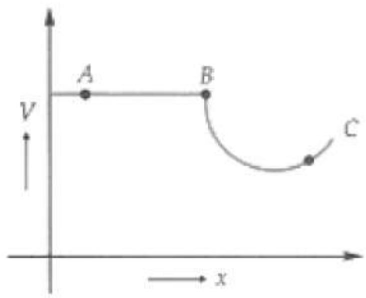
State how the following quantities depend upon r:

i. potential due to a point charge

ii. potential at a distance r from the centre of a charged metallic sphere of radius R (r < R).

OR

The figure shows the variation of electrostatic potential V with distance x for a given charge



distribution. From the points marked A, B, and C, identify the point at which the electric field is:

i. zero

ii. maximum

Explain your answer in each case.

24. a. In the explanation of the photoelectric effect, we assume one photon of frequency ν collides with an electron and transfers its energy. This leads to the equation for the maximum energy E_{max} of the emitted electron as **[2]**

$E_{max} = h\nu - \phi_0$

here ϕ_0 is the work function of the metal. If an electron absorbs 2 photons (each of frequency ν) what will be the maximum energy for the emitted electron?

b. Why is this fact (two photon absorption) not taken into consideration in our discussion of the stopping potential?

25. Suppose, we think of fission of a $_{26}^{56}Fe$ nucleus into two equal fragments, $_{13}^{28}Al$. Is the fission energetically possible? Argue by working out Q of the process. Given m ($_{26}^{56}Fe$) = 55.93494 u and m ($_{13}^{28}Al$) = 27.98191 u. **[2]**

Section C

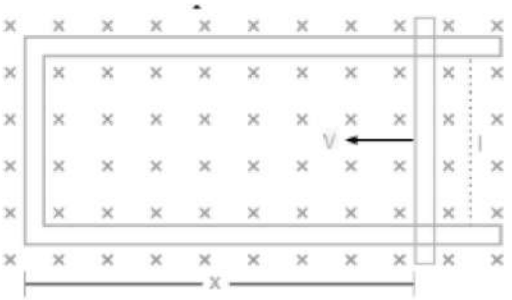
26. Using Bohr's postulates derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). When electron in hydrogen atom jumps from energy state n_i = 4 to n_f = 3, 2, 1, identify the spectral series to which the emission lines belong. **[3]**

27. What is diffraction of light? Draw a graph showing the variation of intensity with angle in a single slit diffraction experiment. Write one feature which distinguish the observed pattern from the double slit interference pattern. How would the diffraction pattern of a single slit be affected when: **[3]**

i. the width of the slit is decreased?

ii. the monochromatic source of light is replaced by a source of white light?

28. i. A rod of length l is moved horizontally with a uniform velocity v in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod. **[3]**



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

OR

Write Faraday's law of electromagnetic induction. Express it mathematically. A conducting rod of length l, with one end pivoted, is rotated with a uniform angular speed of ω in a vertical plane, normal to a uniform magnetic field B. Deduce an expression for the emf induced in this rod.

29. Mrs. Rajlakshmi had a sudden fall and was thereafter unable to stand straight. She was in great pain. Her daughter Rita took her to the doctor. The doctor took a photograph of Mrs. Rajlakshmi's bones and found that she had suffered a fracture. **[3]**

He advised her to rest and take the required treatment.

i. Name the electromagnetic radiation used to take the photograph of the bones.

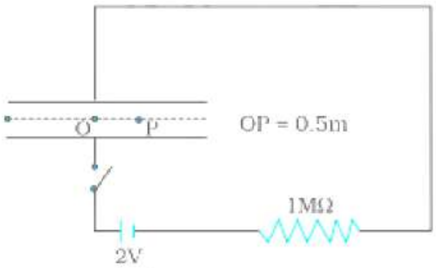
ii. How is this radiation produced?

iii. Mention the range of the wavelength of this electromagnetic radiation.

iv. Write two values displayed by Rita.

OR

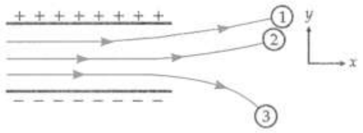
A parallel plate capacitor with circular plates of radius 1 m has a capacitance of 1 nF. At t = 0, it is connected for charging in series with a resistor R = 1 MΩ across a 2V battery (Fig.). Calculate the magnetic field at a point P, halfway between the centre and the periphery of the plates, after t = 10^{-3} s. (The charge on the capacitor at time t is q (t) = CV [1 - exp (-t/τ)], where the time constant τ is equal to CR.)



30. A solenoid of 500 turns per metre is carrying a current of 3A. Its core is made of iron, which has a relative permeability of 5000. Determine the magnitudes of magnetic intensity, magnetization and magnetic field inside the core. **[3]**

Section D

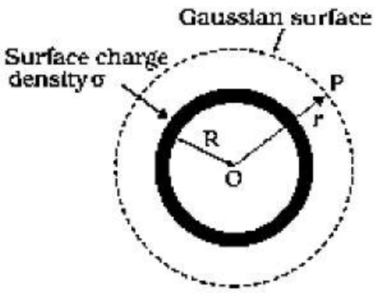
31. Figure shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to the mass ratio? **[5]**



a. Suppose that a particle is attracted towards the positive plate. What must the charge on it be?
b. Suppose, two particles have identical curved trajectories. Which of the following are necessarily true?
   i. They have same charge;
   ii. They have same mass;
   iii. The charges have the same sign;
   iv. They have the same $\frac{e}{m}$ ratio.
c. You are given the initial velocity v of a beam particle and the length of the capacitor l. What other measurements would enable one to find $\frac{e}{m}$?

OR

a. Using Gauss's law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density $\sigma\ C/m^2$. Draw the field lines when the charge density of the sphere is (i) positive, (ii) negative.



b. A uniformly charged conducting sphere of 2.5 m in diameter has a surface charge density of $100\mu C/m^2$. Calculate
   (i) Charge on the sphere (ii) Total electric flux passing through the sphere.

32. An angular magnification of 30X is desired using an objective of focal length 1.25 cm and an eyepiece of focal length 5 cm. How will you set up the compound microscope? **[5]**

OR

In many experimental set-ups, the source and screen are fixed at a distance say D and the lens is movable. Show that there are two positions for the lens for which an image is formed on the screen. Find the distance between these points and the ratio of the image sizes for these two points.

33. i. Derive an expression for drift velocity of electrons in a conductor. Hence, deduce Ohm's law. [5]

ii. A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?

a. Drift speed

b. Current density

c. Electric current

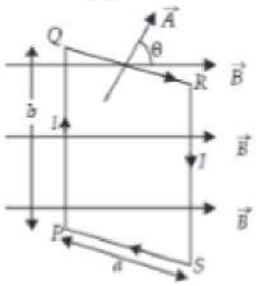
d. Electric field

Justify your answer.

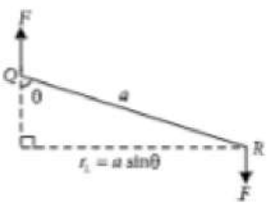
Section E

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

When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90° = IbB and perpendicular distance between two non-collinear forces is r_1 = a sin θ



So, torque on the loop, $\tau = IAB\sin\theta$

In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) A circular loop of area 1 cm^2, carrying a current of 10 A is placed in a magnetic field of 0.1 T perpendicular to the plane of the loop. Calculate the torque acting on the loop due to the magnetic field.

(ii) Write the relation between magnetic moment and angular velocity of the coil.

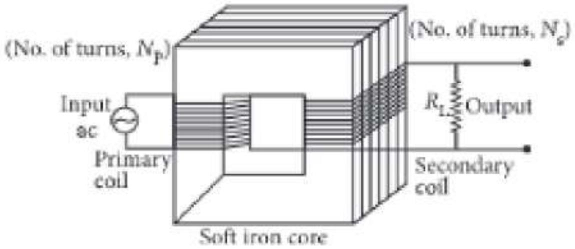
(iii) A current loop is lying in a magnetic field, what are conditions for it to be in stable and unstable equilibrium?

OR

How does the magnetic moment of a current I carrying circular coil of radius r and number of turns N varies with radius of the coil?

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

SAMPLE PAPER - 6

Class 12 - Physics

Section A

1. **(a)** 9043 kg/m^3

   Explanation: A = 63.5 kg and r = 1.273×10^{-10}m

   For fcc: n = 4

   Further $a = (4r/\sqrt{2}) = 3.6 \times 10^{-10}$m

   N = 6.02×10^{26}

   V = $a^3 = (3.6 \times 10^{-10})^3$ $metre^3$

   $\therefore \quad d = \frac{nA}{NV} = \frac{4 \times 63.5}{6.02 \times 10^{26} \times (3.6 \times 10^{-10})^3}$

   = 9043 kg/m^3

2. **(d)** 8.5 V

   Explanation: Terminal voltage, V = E - Ir

   V = 10 - 0.5 $\times$ 3 = 10 -1.5 = 8.5 V

3. **(b)** 2, 10

   Explanation: When an eye is fully relaxed its focal length is the largest and the power of the eye-lens is minimum. This power is 50D according to the given data. The focal length is (1/50)m = 2 cm.

   As the far point is at infinity, the parallel rays coming from infinity are focussed on the retina in the fully relaxed condition. Hence, the distance of the retina from the lens equals the focal length, which is 2 cm.

   When the eye is focussed at the near point, the power is maximum, which is 60D. The focal length in this case is f = (1/60)m = (5/3) cm. The image is formed on the retina.

   Thus, v = 2 cm

   Now, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

   or $\frac{1}{u} = \frac{1}{v} - \frac{1}{f} = \frac{1}{2\text{cm}} - \frac{3}{5\text{cm}}$

   or u = -10 cm

   Thus, the near point is at 10 cm

4. **(c)** 2 amp

   Explanation: 2 amp

5. **(c)** is an electrostatic machine

   Explanation: Van de Graaff generator is an electrostatic machine.

6. **(a)** 5 q

   Explanation: Here, $E = 2\hat{i} + 3\hat{j}$, $B = 4\hat{j} + 6\hat{k}$

   q = charge on a particle.

   Initial position, r_1 = (0,0)

   Final position, r_2 =(1,1)

   Net force experienced by charge particle inside electromagnetic field is

   $\text{F}_{\text{net}} = q\text{E} + q(\text{v} \times \text{B})$

   $= q(2\hat{i} + 3\hat{j})$ [Here, v $\times$ B = 0]

   $= (2q\hat{i} + 3q\hat{j})$

   $\therefore$ dW = $F_{net}.\overrightarrow{dr}$

   $\Rightarrow \int dW = \int_{r_1}^{r_2} (2q\hat{\mathbf{i}} + 3q\hat{\mathbf{j}}) \cdot (dx\hat{\mathbf{i}} + dy\hat{\mathbf{j}})$ [Here, dr = $dx\hat{i} + dy, \hat{j}$]

   $\Rightarrow$ W = $2q\int_0^1 dx + 3q\int_0^1 dy$

   or w = 2q + 3q or W = 5q

7. **(d)** -10 volt

   Explanation: $\phi = 10t^2 - 50t + 250$

Induced emf = $-\frac{d\phi}{dt} = -\frac{d}{dt}$ (10 t^2 - 50 t + 250)
= -(20 t - 50)
The induced emf at t = 3 sec
e = - (20 × 3 - 50) = -(60 - 50)
= -10 volt

8. **(c)** 0.25 × 10^7 m^{-1}
Explanation: Here, R = 10^7 m^{-1}
The wave number of the last line of the Balmer series in the hydrogen spectrum is given by
$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} = \frac{10^7}{4}$ = 0.25 × 10^7 m^{-1}

9. **(d)** Diffraction bands become narrower and crowded together
Explanation: Diffraction bands become narrower and crowded together.

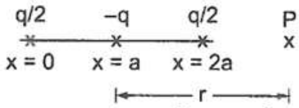
10. **(c)** -Q, Q + q
Explanation: The point charge placed at the centre of the shell induces an equal amount of negative charge (-Q) on the inner surface and hence a positive charge +Q at the outer surface. The net charge on the outer surface becomes q + Q.

11. **(b)**

Explanation: In forward biasing, the anode of the diode is connected to the positive terminal of the battery whereas the cathode of the diode is connected to the negative terminal of the battery.

12. **(c)** larger than the focal length of the eye-piece
Explanation: larger than the focal length of the eye-piece

13. **(d)** β-particle
Explanation: $\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{m}$
Now, $m_\alpha > m_n > m_p > m_\beta$
$\Rightarrow \lambda_\alpha < \lambda_n < \lambda_p < \lambda_\beta$
$\therefore$ β-particle has the longest wavelength.

14. **(c)** $\frac{qa^2}{4\pi\varepsilon_0 r^3}$
Explanation:


Potential at P due to $\frac{q}{2} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{2(r+a)}\right]$
Potential at P due to -q = $\frac{-1}{4\pi\varepsilon_0}\left[\frac{q}{r}\right]$
Potential at P due to $\frac{q}{2} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{2(r-a)}\right]$
$\therefore$ Resultant potential at P
= $\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{2(r+a)} - \frac{q}{r} + \frac{q}{2(r-a)}\right]$
= $\frac{qa^2}{4\pi\varepsilon_0 r^3}$

15. **(a)** 84
Explanation: If n is the number of fringes of fringe width β and l is the length of field of view, then l = nβ. Hence, according to the given problem
$n_1\beta_1 = n_2\beta_2$
or $n_1\left(\frac{D\lambda_1}{d}\right) = n_2\left(\frac{D\lambda_2}{d}\right)$
or $n_1\lambda_1 = n_2\lambda_2$
or $n_2 = \frac{n_1\lambda_1}{\lambda_2}$
Number of fringes (when λ_2 is fixed) visible in the field of view, is given by

$n_2 = \frac{n_1\lambda_1}{\lambda_2} = 60 \times \frac{5893\times10^{-10}}{4200\times10^{-10}}$
$\simeq 60 \times \frac{5893}{4200} = 60 \times \frac{1}{0.7} \simeq 85$

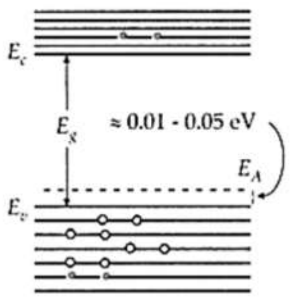
16. **(c)** A is true but R is false.
Explanation: A is true but R is false.

17. **(a)** Both A and R are true and R is the correct explanation of A
Explanation: An increase in frequency causes decreases in impedance of the capacitor and a consequent increase in current which equals displacement current between the plates of the capacitor.

18. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation: Electromagnets are magnets, which can be turned on and off by switching the current on and off. As the material in electromagnets is subjected to cyclic change (magnification and demagnetisation), the hysteresis loss of the material must be small. The material should attain high value of I and B with low value of magnetising field intensity H. As soft iron has small coercivity, so it is a best choice for this purpose.

Section B

19. If trivalent impurity atoms of B, Al, or In are doped in a pure semiconductor of Si or Ge, we get a p-type semiconductor. Holes are the major charge carriers in it. For the energy band diagram see.



20. Here K = 5 MeV = 5 × 1.6 × 10^{-13} J, θ = 90°, Z = 79
Impact parameter
$b = \frac{kZe^2 \cot\frac{\theta}{2}}{K}$
$= \frac{9\times10^9\times79\times(1.6\times10^{-19})^2 \cot 45^\circ}{5\times1.6\times10^{-13}}$
= 2.27 × 10^{-14} m

21. i. Microwaves: Frequency range ($\sim 10^{10}$ to 10^{12} Hz)
Ultraviolet rays: Frequency range ($\sim 10^{15}$ to 10^{17} Hz)
ii. Average energy density of the electric field = $\frac{1}{2}\epsilon_0 E^2$
$= \frac{1}{2}\epsilon_0 (cB)^2$
$= \frac{1}{2}\epsilon_0 \frac{1}{\mu_0\epsilon_0} B^2$
$= \frac{1}{2}\frac{B^2}{\mu_0}$
= Average energy density of the magnetic field.

OR

Let us consider a surface exposed to electromagnetic radiation. The radiation is falling normally on the surface. Further, intensity of radiation is I and area of surface exposed to radiation is A.
E = Energy received by surface per second = I.A
N = Number of photons received by surface per second
$N = \frac{E}{E_{\text{photon}}} = \frac{E\lambda}{hc} = \frac{IA\lambda}{hc}$
Let the surface is perfectly absorbing, $\triangle P_{\text{onephoton}} = \frac{h}{\lambda}$
$\Rightarrow$ F = N × $\Delta P_{\text{one photon}} = \frac{IA}{c}$
Also, Pressure $P = \frac{F}{A} = \frac{I}{c}$, this is the required result.

22. i. Forward biased, because p-side is at higher potential (+7 V) than n-side (+ 5 V).
ii. Reverse biased, because the p-side is at lower potential (0V) than the n-side (+5 V).
iii. Reverse biased, because p-side is at lower potential (-10 V) than n-side (0 V).
iv. Forward biased, because p-side is at higher potential (- 5 V) than n-side (- 12 V).

23. i. Potential due to a point charge,

$V = \frac{1}{4\pi r_0} \cdot \frac{q}{r}$ i.e., $V \propto \frac{1}{r}$

ii. In the case of a charged metallic sphere

$V_{\text{inside}} = V_{\text{surface}} = \frac{q}{4\pi\varepsilon_0 R}$ = constant

$\therefore$ Potential V does not depend on r.

OR

At any point, we have

$E = -\frac{dV}{dx}$ = Negative slope of V-x graph

At point A, $\frac{dV}{dx} = 0$

At point B, $\frac{dV}{dx} < 0$

At point C, $\frac{dV}{dx} > 0$

Therefore,

i. E is zero at point A.

ii. E is maximum at point B.

24. a. Here, 2 photons transfer its energy to one electron as E = hν

$\therefore \mathrm{E_e} = \mathrm{E_p}$

hν_e = 2hν

$\nu_e = 2\nu$

The maximum energy of the emitted electron is given by ;-

$E_{\max} = h\nu_{e^-}\phi_0 = h(2\nu) - \phi_0 = 2h\nu - \phi_0$

b. The probability of absorbing 2 photons by an electron is very low due to their mass difference. So the possibilities of such emission of electrons are negligible.

25. The fission reaction can be given as: $^{56}_{26}\mathrm{Fe} \to 2^{28}_{13}\mathrm{Al}$

The Q value for this reaction will be given as = [m($^{56}_{26}$Fe) - 2 $\times$ m(2$^{28}_{13}$Al)] $\times$ c^2

= (55.93494 - 2 $\times$ 27.98191)u $\times$ c^2

= -0.02888u $\times$ c^2

= -0.02888 $\times$ 931.5 (1 u = 931.5 MeV/c^2)

= -26.902 MeV

The Q value is negative which suggests this reaction is endothermic, but we know fission reactions are exothermic. Hence, this fission reaction is not energetically possible.

Section C

26. According to Bohr's frequency condition, if an electron jumps from an energy level E_i to E_f, then the frequency of the emitted radiation is given by

$h\nu = E_i - E_f$ ...(i)

Let n_i and n_f be the corresponding orbits, then

$E_i = -\frac{2\pi^2 me^4k^2}{n_i^2h^2}$

and $E_f = -\frac{2\pi^2 me^4k^2}{n_f^2h^2}$

Substituting in equation (i), we have

$h\nu = -\frac{2\pi^2 me^4k^2}{n_i^2h^2} - \left(-\frac{2\pi^2 me^4k^2}{n_f^2h^2}\right)$

$= \frac{2\pi^2 me^4k^2}{h^2}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Rewriting the above equation, we have

$\nu = \frac{2\pi^2 me^4k^2}{h^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

This gives the frequency of the emitted radiation.

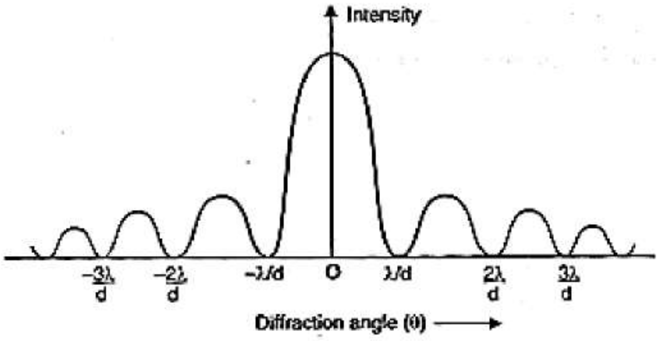
When n_i = 4 and n_f = 3, Paschen series

When n_i = 4 and n_f = 2, Balmer series

When n_i = 4 and n_f = 1, Lyman series

27. Diffraction of light: Phenomenon of bending of light around the corners of an obstacle or aperture is called diffraction.

The intensity distribution wave for diffraction is shown in the diagram below:



In interference, by 2 slits all bright fringes are of same intensity. In diffraction, the intensity of bright fringes decreases with the increase in distance from the central bright fringe.

i. The diffraction pattern becomes narrower if the width of the slit is decreased.

ii. When the monochromatic source is replaced by a white light source, we get a coloured diffraction pattern. The central band is white, but the other bands are coloured. As bandwidth is proportional to λ, the red band of higher wavelength is wider than the violet band with smaller wavelength.

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

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

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

Using Lenz's law,

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

$\therefore \quad \varepsilon = Blv$

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

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

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

W = F.l

W = qvBl

Since emf is the work done per unit charge

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

This equation gives emf induced across the rod.

OR

According to Faraday's law of electromagnetic induction, the magnitude of induced emf is equal to the rate of change of magnetic flux linked with the closed circuit (or coil). Mathematically,

$E = -N\frac{d\phi_B}{dt}$

where N is the number of turns in the circuit and ϕ_B is the magnetic flux linked with each turn.

Suppose the conducting rod completes one revolution in time T. Then

Change in flux $= B \times Area\ swept = B \times \pi l^2$

Induced emf $= \frac{\text{Change in flux}}{\text{Time}}$

$\varepsilon = \frac{B \times \pi l^2}{T}$

But $T = \frac{2\pi}{\omega}$

$\therefore \varepsilon = \frac{B \times \pi l^2}{\frac{2\pi}{\omega}} = \frac{1}{2}Bl^2\omega$

29. a. X-rays

b. By using X-rays tubes (Or: By bombarding a metal target with high energy electrons)

c. The wavelength range of X-rays is from (10 nm to 10 pm)

d. Alertness, empathy; concern for her mother, knowledgeable.

OR

The time constant of the CR circuit is given by τ = CR = 10^{-3} s. Then,

we have q(t) = CV [1 - exp $(\frac{-t}{\tau})$] (given in the question)

$= 2 \times 10^{-9}$ [1 - exp $(\frac{-t}{10^{-3}})$]

The electric field in between the plates at time t is

$E = \frac{q(t)}{\varepsilon_0 A} = \frac{q}{\pi \varepsilon_0}$: A = π $(1)^2$ m^2 = area of the plates.

Consider now a circular loop of the radius $(\frac{1}{2})$ m parallel to the plates passing through P. The magnetic field B at all points on the loop is along the loop and of the same value.

The flux ϕ_E through this loop is

ϕ_E = E $\times$ area of the loop

$= E \times \pi \times \left(\frac{1}{2}\right)^2 = \frac{\pi E}{4} = \frac{q}{4\varepsilon_0}$

The displacement current

$i_d = \varepsilon_0 \frac{d\phi_p}{dt} = \frac{1}{4} \frac{dq}{dt}$ = 0.5 $\times$ 10^{-6} exp (-1)

and t = 10^{-3} s. Now, applying Ampere-Maxwell law to the loop, we get

$B \times 2\pi \times \left(\frac{1}{2}\right) = \mu_0 \left(i_c + i_d\right) = \mu_0 \left(0 + i_d\right)$ = $4\pi \times 10^{-7} \times 0.5 \times 10^{-6}$ exp (-1)

or, B = 0.74 $\times$ 10^{-13} T

30. Given, n = 500 turns/m, i = 3 A, $\mu_r = 5000$

Magnetic intensity, $H = ni = 500 \times 3 = 1500 Am^{-1}$

Since $\mu_r = 1 + \chi_m$

$\therefore \chi_m = \mu_r - 1 = 5000 - 1$ = 4999 $\approx$ 5000

Also, $\mu_r = \frac{\mu}{\mu_0} = 5000$

$\therefore \mu = 5000\mu_0$

Magnetisation, $I = \chi_m H$

$= 5000 \times 1500 = 7.5 \times 10^6 Am^{-1}$

Magnetic field inside the core,

$B = \mu H = 5000\mu_0 H$

$= 5000(4\pi \times 10^{-7}) \times 1500$

$B = 3\pi = 3 \times \frac{22}{7}$ = 9.4 T

Section D

31. Particles 1 and 2 have negative charges because they are being deflected towards the positive plate of the electrostatic field.

Particle 3 has a positive charge because it is being deflected towards the negative plate.

Acceleration acting on charge q in y-direction,

a = $\frac{F}{m} = \frac{qE}{m}$

Therefore, deflection of charged particle in time t in y-direction is

h = 0 $\times$ t + $\frac{1}{2}$ at^2 = $\frac{1}{2} \frac{qE}{m}$

i.e., h $\propto \frac{q}{m}$

As the particle 3 suffers maximum deflection in y-direction, so it has highest charge to mass $(\frac{q}{m})$ ratio.

a. Negative charge.
b. (iii) and (iv). The particles must have charges of the same sign and same $\frac{e}{m}$ ratio.
c. To find $\frac{e}{m}$, we measure the vertical displacement h as the particle crosses the capacitor plates.

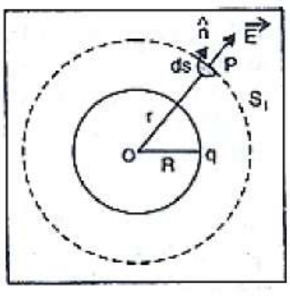
Time taken by a particle to cross the capacitor plates,

t = $\frac{l}{v}$

$\therefore$ h = $\frac{1}{2} \frac{qE}{m}$ t^2 = 0.5 $\frac{eE}{m} \left(\frac{l}{v}\right)^2$

OR

a. Consider a thin spherical shell of radius R with centre O. Let charge +q is uniformly distributed over the surface of the shell.



Let P be any point on the sphere S_1 with centre O and radius r.

According to Gauss's law:

$$\oint_s \vec{E} \cdot \overrightarrow{ds} = \frac{q}{\epsilon_0}$$

$$\therefore E \oint ds = \frac{q}{\epsilon_0} \Rightarrow E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$$

$$\therefore E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$$

If σ is charge density,

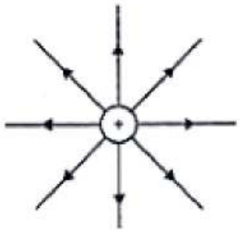
$$\therefore q = 4\pi R^2 \sigma$$

So, $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{4\pi R^2 \sigma}{r^2}$

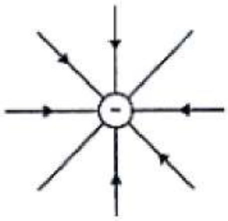
$$E = \frac{\sigma}{\varepsilon_0} \frac{R^2}{r^2}$$

Electric field lines when the charged density of the sphere:

i. Positive



ii. Negative



b. Here diameter = 2.5 m

$$\therefore R = \frac{2.5}{2} = 1.25m$$

Charge density $\sigma = 100\mu C/m^2 = 100 \times 10^{-6} = 10^{-4} C/m^2$

i. $q = 4\pi R^2 \sigma$

$= 4 \times 3.14(1.25)^2 \times 10^{-4}$

$= 19.625 \times 10^{-4}$

$= 1.96 \times 10^{-3} C$

ii. Total electric flux,

$$\phi_E = \frac{q}{\epsilon_0}$$

$$\therefore \phi_E = \frac{1.96 \times 10^{-3}}{8.85 \times 10^{-12}} = 0.221 \times 10^9 = 2.21 \times 10^8 Nm^2C^{-1}$$

32. In normal adjustment, image is formed at least distance of distinct vision,

d = 25 cm

Angular magnification of eyepiece $= \left(1 + \frac{D}{f_e}\right)$

$= \left(1 + \frac{25}{5}\right) = 6$

Since the total magnification is 30, magnification of objective lens,

$$m = \frac{30}{6} = 5$$

Now, $m = -\frac{v_0}{u_0} = 5$ or $v_0 = -5u_0$

As $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$$\therefore \frac{1}{-5u_0} - \frac{1}{u_0} = \frac{1}{1.25}$$

$$-\frac{6}{5u_0} = \frac{1}{1.25}$$

$$u_0 = -\frac{6 \times 1.25}{5} = -1.5cm$$

i.e. object should be held at 1.5 cm in front of objective lens.

As $v_0 = -5u_0$

$$\therefore v_0 = -5(-1.5) = 7.5cm$$

Now, $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

$\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{5} = -\frac{6}{25}$

$u_e = -\frac{25}{6} = -4.17cm$

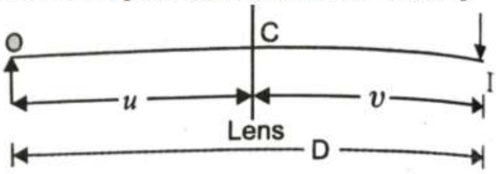
Separation between the objective lens and eyepiece $= |u_e| + |v_0|$

= 4.17 + 7.5 = 11.67 cm

OR

the source and screen are fixed at a distance say DD and the lens is movable In the lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ ...(i)

we find that u and v are reversible. Therefore, there are two positions of the object, for which there will be an image on the screen. Let the first position be when lens is at C, Fig.



$\therefore$ -u + v = D = distance between source (O) and screen I.

or u = -(D - v)

Put in (i)

$\frac{1}{v} + \frac{1}{D-v} = \frac{1}{f}$ or $\frac{D-v+v}{v(D-v)} = \frac{1}{f}$ or Dv - v^2 = Df or v^2 - Dv + Df = 0

$\therefore v = \frac{D \pm \sqrt{D^2-4Df}}{2} = \frac{D}{2} \pm \frac{\sqrt{D^2-4Df}}{2}$

and u = -(D - v) $= -\left[\frac{D}{2} \pm \frac{\sqrt{D^2-4Df}}{2}\right]$

Thus if object distance is $u = \frac{D}{2} + \frac{\sqrt{D^2-4Df}}{2}$, then image distance is $v = \frac{D}{2} - \frac{\sqrt{D^2-4Df}}{2}$

The distance between two positions of the lens for these two object distance is

$d = \frac{D}{2} + \frac{\sqrt{D^2-4Df}}{2} - \frac{D}{2} + \frac{\sqrt{D^2-4Df}}{2} = \sqrt{D^2 - 4Df}$

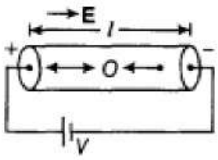
If $u = \frac{D}{2} + \frac{d}{2}$, then $v = \frac{D}{2} - \frac{d}{2}$

$\therefore$ Magnification, $m_1 = \frac{v}{u} = \frac{D-d}{D+d}$

If $u = \frac{D}{2} - \frac{d}{2}$, then $v = \frac{D}{2} + \frac{d}{2}$

$\therefore$ Magnification, $\frac{v}{u} = \frac{D+d}{D-d}$

33. i. Let v_d be the drift velocity.



Electric field produced inside the wire is

E = V/l ...(i)

Force on an electron, F = -Ee

Acceleration of each electron = -Ee/m [$\because$ from Newton's law, a = F/m]

where, m is mass of electron.

Velocity created due to this acceleration $= \frac{Ee}{m}\tau$.

where, τ is the time span between two consecutive collisions. This ultimately becomes the drift velocity in steady state.

So, $v_d = \frac{Ee}{m}\tau = \frac{e}{m}\tau \times \frac{V}{l}$ [from Eq. (i)]

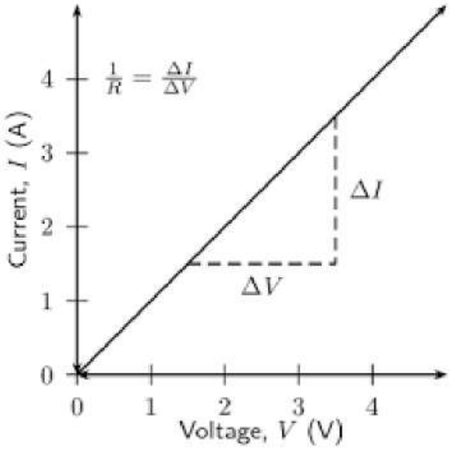
We know that current in the conductor i = neAv_d (where, n is number of free electrons in a conductor per unit volume)

$i = neA \times \frac{e}{m}\tau\frac{V}{l} \Rightarrow i = \frac{ne^2A\tau V}{ml}$

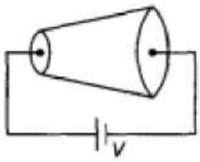
$\Rightarrow \quad i = V/R \quad [\because R = ml/ne^2A\tau]$

$i \propto V$ as resistance of the wire remains constant throughout the experiment.

This is Ohm's law.



ii. The setup is shown in the figure. Here, the electric current remains constant throughout the length of the wire. The electric field also remains constant which equals to V/l. Current density changes as an area of cross-section changes continuously and hence drift speed change according to the formula, $j = nev_d$

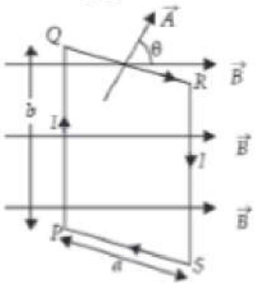


here, n = number of electrons per unit volume
e = electronic charge
v_d = drift velocity

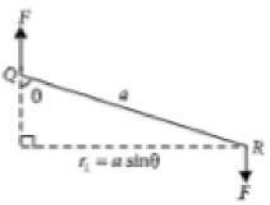
Section E

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

When a rectangular loop PQRS of sides a and b carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with the direction of the magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is F = IbB sin 90^o = IbB and perpendicular distance between two non-collinear forces is $r_1 = a \sin \theta$



So, torque on the loop, $\tau = IAB \sin \theta$
In vector form torque, $\vec{\tau} = \vec{M} \times \vec{B}$
where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ i.e., normal to the plane of loop.

(i) zero

Torque on a current carrying loop in magnetic field, $\tau = IBA \sin \theta$

Here, I = 10A, B = 0.1 T, A = 1 $cm^2 = 10^{-4}$ m^2, $\theta = 0^o$

$\therefore \tau = 10 \times 0.1 \times 10^{-4} \sin 0^{\circ} = 0$

(ii) $M \propto \omega$

Magnetic moment, M = IA = $I\left(\pi r^2\right) = \frac{q}{T} \times \pi r^2$

As $\omega = \frac{2\pi}{T}$ $\therefore M = \frac{q\omega r^2}{2}$ or $M \propto \omega$

(iii) It can be in equilibrium in two orientations, one stable while the other is unstable

When a current loop is placed in a magnetic field it experiences a torque. It is given by

$\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.

or $\tau = MB\sin\theta$ where θ is angle between M and B

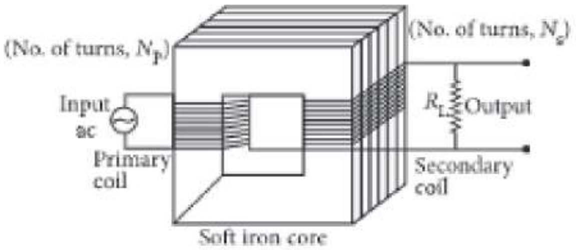
When $\vec{M}$ and $\vec{B}$ are parallel (i.e. $\theta = 0^o$) the equilibrium is stable and when they are antiparallel (i.e. $\theta = \pi$) the equilibrium is unstable.

OR

Magnetic moment, M = NIA = $NI\pi r^2$ i.e., $M \propto r^2$

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

(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 V)(0.5 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 η = 1 (i.e 100 %) i.e. input power = output power.