Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 1

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

General Instructions:

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

Section A

1. The cations and anions are arranged in alternate form in **[1]**

a) ionic crystal b) semiconductor crystal

c) covalent crystal d) metallic crystal

2. Current density of a conductor is **[1]**

a) Is always zero b) the net charge flowing through the area

c) measure of the flow of electric charge in amperes per unit area of cross-section d) the net charge flowing through the area per unit time

3. The focal length of a concave mirror is f. An object is placed at a distance x from the focus. The magnification is **[1]**

a) $\frac{f}{(f+x)}$ b) $\frac{(f+x)}{f}$

c) $\frac{f}{x}$ d) $\frac{x}{f}$

4. A magnet of magnetic moment M is suspended in a uniform magnetic field B. The maximum value of torque acting on the magnet is **[1]**

a) zero b) MB

c) 2MB d) $\frac{1}{2}MB$

5. A parallel plate capacitor of plate area A has a charge Q. The force on each plate of the capacitor is **[1]**

a) $\frac{2q^2}{\epsilon_o A}$

b) zero

c) $\frac{q^2}{\epsilon_o A}$

d) $\frac{q^2}{2\epsilon_o A}$

6. An electron is travelling along the X-direction. It encounters a magnetic field in the Y-direction. Its subsequent motion will be: **[1]**

a) a circle in the YZ-plane

b) straight line along the X-direction

c) a circle in the XZ-plane

d) a circle in the XY-plane

7. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, change of flux linkage with the other coil is **[1]**

a) 45 Wb

b) 35 Wb

c) 30 Wb

d) 40 Wb

8. An aeroplane having a wingspan of 35m files due north with the speed of 90 m/s, given B = 4×10^{-5} T. The potential difference between the tips of the wings will be **[1]**

a) 0.126 V

b) 1.26 V

c) 0.013 V

d) 12.6 V

9. The shape of the wavefront of the portion of the wavefront of light from a distant star intercepted by the earth is **[1]**

a) plane

b) spherical

c) conical

d) hyperboloid

10. If an electron is accelerated by $8.8\times10^{14}\mathrm{m/s^2}$, then electric field required for acceleration is (given specific charge of the electron = $1.76\times10^{11}\mathrm{Ckg^{-1}}$) **[1]**

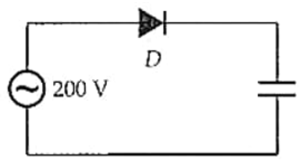
a) 52 V $\mathrm{cm^{-1}}$

b) 50 V $\mathrm{cm^{-1}}$

c) 54 V $\mathrm{cm^{-1}}$

d) 56 V $\mathrm{cm^{-1}}$

11. In the circuit given in the figure, an a.c. source of 200 V is connected through a diode D to a capacitor. The potential difference across the capacitor will be **[1]**



a) 283 V

b) 100 V

c) 310 V

d) 200 V

12. Green light of wavelength 5,460 $\overset{\circ}{A}$ is incident on an air-glass interface. If the refractive index of glass is $1\cdot5$, the wavelength of light in glass would be (Given that the velocity of light in air, c = 3×10^{8} m s^{-1}) **[1]**

a) 6731 $\overset{\circ}{A}$

b) 3,640 $\overset{\circ}{A}$

c) 5,460 $\overset{\circ}{A}$

d) 4,861 $\overset{\circ}{A}$

13. **Assertion (A):** The photoelectrons produced by a monochromatic light beam incident on a metal surface, have a spread in their kinetic energies. **[1]**

Reason (R): The work function of the metal varies as a function of depth from the surface.

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.

14. **Assertion:** For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q. **[1]**

Reason: The net work done by a conservative force on an object moving along a closed loop is zero.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** Light added to light can produce darkness. **[1]**

Reason (R): When two coherent light waves interfere, there is darkness at position of destructive interference.

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.

16. **Assertion (A):** A step-up transformer cannot be used as a step-down transformer. **[1]**

Reason (R): A transformer works only in one direction.

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.

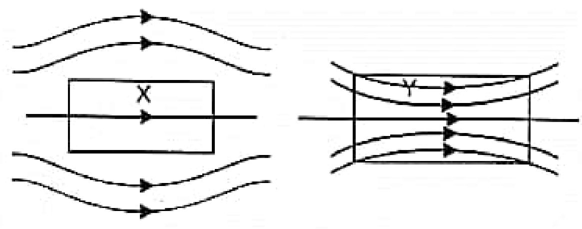
c) A is true but R is false.

d) A is false but R is true.

Section B

17. A light beam travelling in the x-direction is described by the electric field: $E_y = 270 \sin \omega \left(t - \frac{x}{c}\right)$. An electron is constrained to move along the y-direction with a speed of 2.0×10^7 ms^{-1}. Find the maximum electric force and maximum magnetic force on the electron. **[2]**

18. A uniform magnetic field gets modified as shown below, when two specimens X and Y are placed in it. **[2]**



i. Identify the two specimens X and Y.

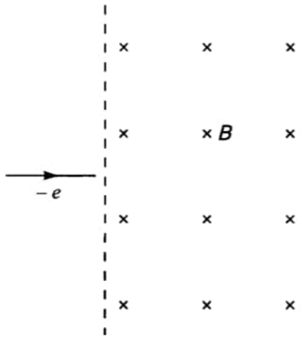
ii. State the reason for the behaviour of the field lines in X and Y.

19. Explain the formation of potential barrier and depletion region in a p-n junction diode. What is effect of applying forward bias on the width of depletion region? **[2]**

20. If the short series limit of the Balmer series for hydrogen is $3646\overset{o}{A}$, calculate the atomic number of the element which gives X-ray wavelengths down to $1.0\overset{o}{A}$. Identify the element. **[2]**

21. a. An electron moving horizontally with a velocity of 4×10^4 m/s enters a region of uniform magnetic field of 10^{-5} T acting vertically upward as shown in the figure. Draw its trajectory and find out the time it takes to **[2]**

come out of the region of magnetic field.



b. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid air by a uniform magnetic field B. What is the magnitude of the magnetic field?

OR

What information would you wish to know about the galvanometer before converting it into an ammeter or voltmeter?

Section C

22. Two cells of EMFs 1 V, 2 V and internal resistance 2 Ω and 1 Ωrespectively are connected in **[3]**

i. series,
ii. parallel. What should be the external resistance in the circuit so that the current through the resistance be the same in the two cases? In which case, more heat is generated in the cells?

23. **[3]**
i. Differentiate between three segments of a transistor on the basis of their size and level of doping.
ii. When is a transistor said to be in active state?
iii. Draw a plot of transfer characteristic V_0 vs. V_i) and show which portion of the characteristic is used in amplification and why?
iv. Draw the circuit diagram of the base bias transistor amplifier in CE configuration and briefly explain its working.

24. Photoelectrons are emitted from a metal surface when illuminated with UV light of wavelength 330 nm. The minimum amount of energy required to emit the electrons from the surface is 3.5×10^{-19} J. Calculate : **[3]**

a. the energy of the incident radiation, and
b. the kinetic energy of the photoelectron.

25. **[3]**
a. Differentiate between nuclear fission and nuclear fusion.
b. Deuterium undergoes fusion as per the reaction:
$${}_1^2\mathrm{H} + {}_1^2\mathrm{H} \longrightarrow {}_2^3\mathrm{He} + {}_0^1\mathrm{n} + 3.27 MeV$$
Find the duration for which an electric bulb of 500 W can be kept glowing by the fusion of 100 g of deuterium.

26. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom. **[3]**

27. A beam of light consisting of two wavelengths, 650 nm and 520 nm, are used to obtain interference fringes in a Young's double slit experiment. **[3]**

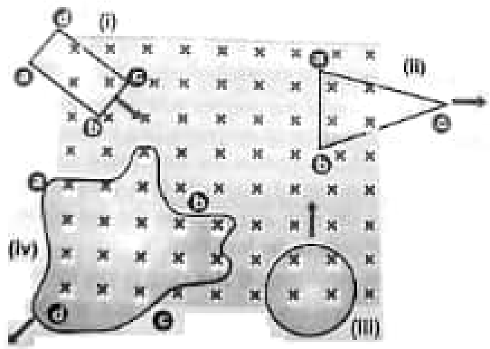
a. Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.
b. What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

28. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long **[3]**

coaxial solenoids of the same length wound one over the other.

OR

The figure below shows planer loops of different shapes moving out of or into a region of the magnetic field which is directed normal to the plane of the loops away from the reader. Determine the direction of induced current in each loop using Lenz's law. Check if you would obtain the same answers by considering the magnetic force on the charge inside the moving loops.



Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(a) As compared to visible light microwave has frequency and energy

a) Frequency is less but energy is more
b) less than visible light
c) more than visible light
d) equal to visible light

(b) When the temperature of a body rises

a) the energy of the random motion of atoms and molecules decreases.
b) the energy of the random motion of atoms and molecules remains same.
c) the energy of the random motion of atoms and molecules increases
d) the random motion of atoms and molecules becomes streamlined.

(c) The frequency of rotation of water molecules is about

a) 2.45 THz
b) 2.45 kHz
c) 2.45 MHz
d) 2.45 GHz

OR

In the microwave oven

a) Energy is directly delivered to the food grains.
b) The vessel gets heated first and then the water molecules collect heat from the body of the vessel
c) Energy is directly delivered to water molecules which is shared by the entire food
d) The vessel gets heated first, and then the food grains inside

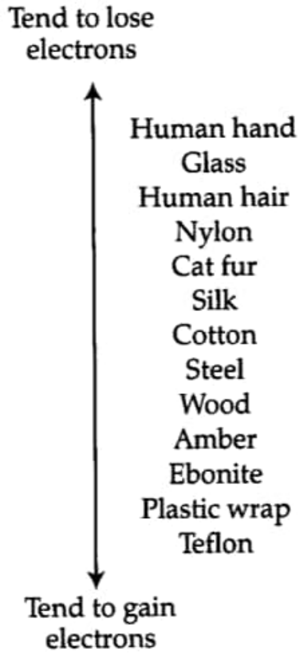
(d) Why should one use porcelain vessels and non-metal containers in a microwave oven?

a) Because it will prevent the food items to become hot
b) Because it will get too much hot
c) Because of the danger of getting a shock from accumulated electric charges
d) Because it may crack due to high frequency

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

The triboelectric series is a list that ranks materials according to their tendency to gain or lose electrons. The process of electron transfer as a result of two objects coming into contact with one another and then separating is called triboelectric charging. During such an interaction, one of the two objects will always gain electrons (becoming negatively charged) and the other object will lose electrons (becoming positively charged). The relative position of the two objects on the triboelectric series will define which object gains electrons and which object loses electrons.

In triboelectric series, materials are ranked from high to low in terms of the tendency for the material to lose electron. If an object high up on this list (Glass, for example) is rubbed with an object low down on the list (Teflon, for example), the glass will lose electrons to the teflon. The glass will, in this case, become positively charged and the teflon will become negatively charged. Materials in the middle of the list (steel and wood, for example) are items those do not have a strong tendency to give up or accept electrons.



(a) Materials in the upper position have ________ tendency to become positively charged.

a) no
b) medium
c) high
d) low

(b) Name two materials which do not have a strong tendency to give up or accept electrons.

a) Steel, wood
b) Plastic wrap, Teflon
c) Ebonite, Nylon
d) Nylon, cat fur

(c) If human hair is rubbed with amber, how those will be charged?

a) Hair will be negatively charged, Amber will be positively charged.
b) Both positive
c) Hair will be positively charged, Amber will be negatively charged.
d) Both negative

(d) Triboelectric charging is the process of electron transfer between two objects

a) By contact
b) Without contact
c) By anyone of these
d) By none of these

OR

The object which loses electron becomes ________ charged and the object gains electron becomes ________ charged.

a) positively, positively
b) negatively, positively
c) negatively, negatively
d) positively, negatively

Section E

31. A compound microscope consists of an objective lens of focal length 2.0 cm and an eyepiece of focal length 6.25 cm separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at **[5]**

a. the least distance of distinct vision (25 cm), and

b. at infinity?

What is the magnifying power of the microscope in each case?

OR

When a parallel beam of a monochromatic source of light of wavelength λ is incident on a single slit of width a, show how the diffraction pattern is formed at the screen by the interference of the wavelets from the slit. Show that, besides the central maxima at θ = 0, secondary maxima are observed at $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ and the minima at $\theta = \frac{n\lambda}{a}$. Why do secondary maxima get weaker in intensity with increasing n?

32. A parallel plate capacitor is charged by a battery. After some time the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. What change, in any will take place in **[5]**

i. charge on the plates
ii. electric field intensity between the plates
iii. the capacitance of the capacitor,
iv. a potential difference between the plates and
v. the energy stored in the capacitor? Justify your answer in each case.

OR

Derive an expression for the electric potential at a point due to an electric dipole. Mention the contrasting features of electric potential of a dipole at a point as compared to that due to a single charge.

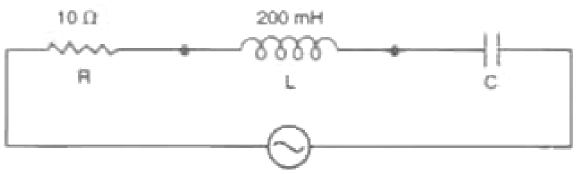
33. i. Prove that an ideal capacitor in an ac circuit does not dissipate power. **[5]**

ii. An inductor of 200 mH, a capacitor of 400 μf, and a resistor of 10 Ω are connected in series to ac source of 50 V of variable frequency. Calculate the
   a. the angular frequency at which maximum power dissipation occurs in the circuit and the corresponding value of the effective current and
   b. value of Q-factor in the circuit.

OR

In the following circuit, calculate:

i. the capacitance of the capacitor, if the power factor of the circuit is unity,
ii. the Q-factor of this circuit. What is the significance of the Q-factor in ac circuit? Given the angular frequency of the ac source to be 100 rad/s. Calculate the average power dissipated in the circuit.



Solution

Section A

1. **(a)** ionic crystal
   Explanation: In an ionic crystal, cations and anions are arranged in alternate form.
2. **(c)** measure of the flow of electric charge in amperes per unit area of cross-section
   Explanation: Current density J = $\frac{I}{A}$
   In electromagnetism, current density is the electric current per unit area of cross section. Or It is the measure of the flow of electric charge in amperes per unit area of cross-section .It is a vector and has a direction along the area vector.
3. **(c)** $\frac{f}{x}$
   Explanation: u = f + x
   Using mirror formula,
   $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$
   Or, $\frac{1}{v}-\frac{1}{(f+x)}=-\frac{1}{f}$
   $\therefore$ v = -$\frac{f(f+x)}{x}$
   So, the magnification = |m| = $\frac{v}{u}=\frac{f}{x}$
4. **(b)** MB
   Explanation: $\tau = MBsin\theta$
   $\tau_{max} = MBsin90^o = MB$
5. **(d)** $\frac{q^2}{2\epsilon_o A}$
   Explanation: Force between two plates of the capacitor
   F = u A, where $u=\frac{1}{2}\varepsilon_0 E^2$ is the energy density and A = Area of each plate
   Also the electric field, $E=\frac{\sigma}{\varepsilon_0}$ and the charge density, $\sigma=\frac{q}{A}$
   Therefore, $F=\frac{1}{2}\varepsilon_0 E^2 A=\frac{1}{2}\varepsilon_0\left(\frac{\sigma}{\varepsilon_0}\right)^2 A=\frac{1}{2}\frac{\sigma^2 A}{\varepsilon_0}=\frac{1}{2}\left(\frac{q}{A}\right)^2\frac{A}{\varepsilon_0}=\frac{q^2}{2A\varepsilon_0}$
6. **(c)** a circle in the XZ-plane
   Explanation: $\vec{F}=q(\vec{v}\times\vec{B})=-e(v\hat{i}\times B\hat{j})$
   $=-evBi\times\hat{j}=-evB\hat{k}$
7. **(c)** 30 Wb
   Explanation: $\Delta\phi = M\Delta i = 1.5\times 20 = 30\text{Wb}$
8. **(a)** 0.126 V
   Explanation: $\varepsilon = Blv$
   $=4\times 10^{-5}\times 35\times 90$
   $=126\times 10^{-3}$ V = 0.126 V
9. **(a)** plane
   Explanation: Stars are very far away from earth. Near the star the shape is spherical but by the time its light reaches earth, the portion of the wavefront is plane due to increase in radius.
10. **(b)** 50 V cm^{-1}
    Explanation: $a=8.8\times 10^{14} m/s^2$

$\frac{e}{m} = 1.76 \times 10^{11} C\ kg^{-1}$
$a = \frac{F}{m} = \frac{eE}{m} = \left(\frac{e}{m}\right) E$
$8.8 \times 10^{14} = 1.76 \times 10^{11} \times E$
$E = \frac{8.8 \times 10^{14}}{1.76 \times 10^{11}} = 5000 Vm^{-1} = 50 Vcm^{-1}$

11. **(a)** 283 V
Explanation: A diode conducts only during the positive half cycle of a.c. Accordingly, the capacitor charges and discharges. During charging, the p.d. across capacitor
= 200 $\times \sqrt{2}$ = 283 V

12.
(b) 3,640 $\overset{\circ}{A}$
Explanation: Now, $\lambda' = \frac{\lambda}{\mu} = \frac{5460}{1 \cdot 5}$ = 3640 $\overset{\circ}{A}$

13. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation: Electrons being emitted as photoelectrons have different velocities. Actually, all the electrons do not occupy the same level of energy but they occupy continuous band and levels. So, electrons being knocked off from different levels come out with different energies. The work function is the energy required to pull the electron out of the metal surface. Naturally, electrons on the surface will require less energy to be pulled out hence will have lesser work function as compared with those deep inside the metal.
So, Both A and R are true and R is the correct explanation of A.

14.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
Explanation: Work done by conservative force does not depend on the path. The electrostatic force is a conservative force.

15. **(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.

16.
(b) Both A and R are true but R is not the correct explanation of A.
Explanation: Step-up transformer cannot be used as a step down transformer or vice versa. The assertion is true. So, the transformer is a uni-directional device. The reason is also true. But the reason does not explain the assertion.

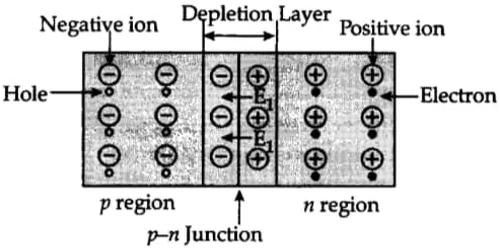
Section B

17. Maximum electric field,
E_0 = 270 Vm^{-1}
Maximum magnetic field,
$B_0 = \frac{E_0}{c} = \frac{270}{3 \times 10^8}$ = 9×10^{-7} T,
directed along z-direction
Maximum electric force on the electron,
$F_e = qE_0 = 1.6 \times 10^{-19} \times 270 = 4.32 \times 10^{-17}$ N
Maximum electric force on the electron
$F_m = qvB_0 = 1.6 \times 10^{-19} \times 2.0 \times 10^7 \times 9 \times 10^{-7}$
$= 2.88 \times 10^{-18}$ N.

18. i. X is a diamagnetic substance.
Y is a paramagnetic substance.
ii. X - The field lines are repelled or expelled and the field inside the material is reduced when a diamagnetic bar is placed in an external field.
Y - The field lines get concentrated inside the material and the field is increased when a paramagnetic bar is placed in an external field.

19. **Formation of depletion region:** In the p-type semiconductor, holes are the majority carrier and in the n-type semiconductor, electrons are the majority carrier.
When a p-n junction is formed, some of the electrons from the n-region which have reached the conduction band are free to diffuse across the junction and combine with holes.

Filling a hole, makes a negative ion in p-side and a positive ion in the n-side. Thus, free charges get depleted and a depletion region is formed, which inhibits any further electron transfer.



Applying forward bias, the depletion region reduces and again electrons can diffuse.

20. The short limit of the Balmer series is given by

$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4}$

$\therefore R = \frac{4}{\lambda} = \frac{4}{3646} \times 10^{10} m^{-1}$

Further the wavelengths of the K_α series are given by the relation,

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

The maximum wave number corresponds to $n = \infty$ and, therefore, we have

$\bar{\nu} = \frac{1}{\lambda} = R(Z-1)^2$

Or $(Z-1)^2 = \frac{1}{R\lambda} = \frac{3646 \times 10^{-10}}{4 \times 1 \times 10^{-10}} = 911.5$

$\therefore (Z-1) = \sqrt{911.5}$

or $\cong 30.2$

or $Z = 31.2 \cong 31$

Thus, the atomic number of the element concerned is 31.

The element having atomic number Z = 31 is Gallium.

21. a. From Flemings left hand rule, the electron deflects in anticlockwise direction.

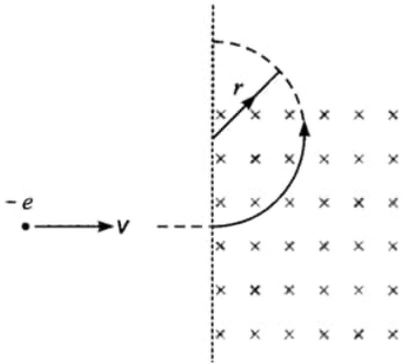
As the electron comes out the magnetic field region, it will describe a semi-circular path. Magnetic force provides a centripetal force. So,

$evB = \frac{mv^2}{r}$ or $eB = \frac{mv}{r}$

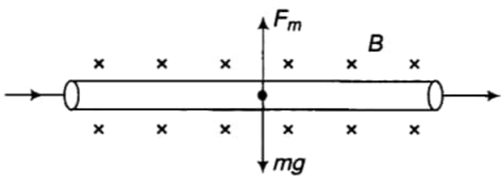
Time taken, $T = \frac{\pi r}{v} = \frac{\pi m}{eB}$

$T = \frac{3.14 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 10^{-5}}$

$= \frac{3.14 \times 9.1 \times 10^{-7}}{1.6}$ = 1.97×10^{-7} second



b. If Ampere's force acts in upward direction and balances the weight, that is



F_m = mg

BIl = mg $B = \frac{mg}{Il} = \frac{0.2 \times 10}{2 \times 1.5} = \frac{2}{3} = \mathbf{0.67T}$

OR

For converting galvanometer into ammeter or voltmeter, we must know:

i. Resistance of the galvanometer (R_g)

ii. Current (I_g) required to produce full scale deflection in the galvanometer.

Section C

22. Current in series circuit is given by

$$I_s = \frac{\varepsilon_1 + \varepsilon_2}{r_1 + r_2 + R} = \frac{1+2}{2+1+2} = \frac{3}{3+R}$$

When the two cells are connected in parallel,

$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} = \frac{1 \times 1 + 2\times 2}{2+1} = \frac{5}{3}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2} = \frac{1 \times 2}{1+2} = \frac{2}{3}$$

Current in the parallel circuit is given by

$$I_p = \frac{\varepsilon_{eq}}{r_{eq} + R} = \frac{\frac{5}{3}}{\frac{2}{3} + R} = \frac{5}{2+3R}$$

As $I_s = I_p$

$$\therefore \quad \frac{3}{3+R} = \frac{5}{2+3R}$$

or 6 + 9R = 15 + 5R

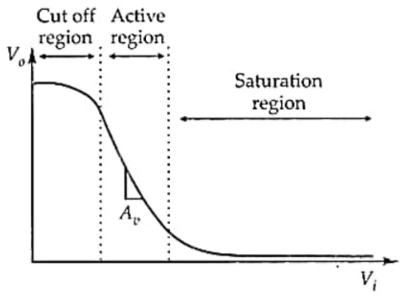
or R = $\frac{9}{4}$ = 2.25 Ω

More heat will be generated in series case due to larger resistance.

23. i. **Emitter:** It is of moderate size and heavily doped semiconductor.
Base: It is very thin and lightly doped.
Collector: It is moderately doped and larger in size than the emitter.

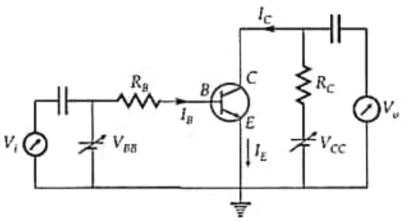
ii. A transistor is said to be in active state when its emitter-base junction is forward biased and the base-collector junction is reverse biased. A Si transistor is in active state when its input (E-B) voltage is between 0.6 V and 1.0 V.

iii. A transfer characteristic is a graph of output voltage (V_0) vs. input voltage (V_i) for a base-biased transistor. It is of the type shown in the figure.



The active region of the transfer characteristic is used for the amplification purpose. This is because in this region, I_C increases almost linearly with the increase of V_i.

iv. The circuit diagram for the base biased n-p-n transistor amplifier, in CE configuration, is shown in the figure.



Working: When a small sinusoidal voltage is superposed on the dc base bias, the base current will have sinusoidal variations superposed on the value of I_B. As a consequence, the collector current also will have sinusoidal variations superposed on the value of I_C. The output, between the collector and the ground, will be an amplified version of the input sinusoidal voltage.

24. i. Energy of incident radiation

E = hv = h$\frac{c}{\lambda}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{330\times10^{-9}}$

= 6.027 × 10^{-19} J

ii. Kinetic energy of photoelectron

K.E. = $E - \phi_0$

= (6.027 × 10^{-19} - 3.5 × 10^{-19}) J

= 2.527 × 10^{-19} J

25. a.

Nuclear fission	Nuclear fusion

It is the process of disintegration of a heavy nuclei into smaller daughter nuclei of comparable masses with a release of huge amount of energy.	It is the process of combining two lighter nuclei to form a heavy nuclei with the release of huge energy.
It can be possible in nuclear reactors.	It can be possible on the surface of sun.
Example ${}_{92}^{235}U \rightarrow {}_{56}^{142}\mathrm{Ba} + {}_{36}^{91}\mathrm{kr} + 3{}_0^1 n$ + heat	Example ${}_1^2 H + {}_1^2 H \rightarrow {}_2^3 He + {}_0^1 n$ + heat
It is a controllable process.	It is uncontrollable process.

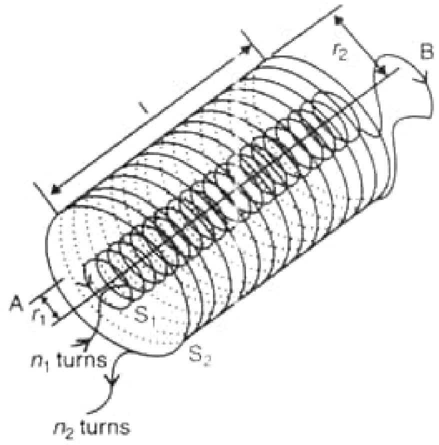
b. ${}_1^2 H + {}_1^2 H \rightarrow {}_2^3\mathrm{He} + {}_0^1 n$ + 3.27 M ev
when 2 atoms of deuterium $\left({}_1^2 H\right)$ combine energy released = 3.27 M ev
= $3.27 \times 10^6 \times 1.6 \times 10^{-19}$J
= 5.232×10^{-15}J
So, No. of atoms in 2g of deuterium = 6.022×10^{23} atoms
No. of atoms in 100g of deuterium = $\frac{6.022 \times 10^{23} \times 100}{2}$
= 3.011×10^{25} atoms
So total energy released by fusion of 100g of deuterium
= $3.011 \times 10^{25} \times 5.232 \times 10^{-15}$ J
= 15.75×10^{10} J
Power of bulb = 500 W
Energy consumed by bulb in 1 second = 500×1
500 J
So, time required to consume released energy = $\frac{15.75 \times 10^{10}}{500}$
= 0.0315×10^{10} sec
= 9.989 years

26. According to the Bohr's theory of hydrogen atom, the angular momentum of revolving electron is given by
$mvr = \frac{nh}{2\pi}$ ....(i)
where, m = mass of the electron, v = velocity of the electron.
r = radius of the orbit, h = Planck's constant and n = principal quantum number of the atom.
If an electron of mass m and velocity v is moving in a circular orbit of radius r, then the centripetal force is given by
$F_c = mv^2/r$........(ii)
Also, if the charge on the nucleus is Ze, then the force of electrostatic attraction between the nucleus and the electron will provide the necessary centripetal force
$\Rightarrow F_c = F_e$
$\Rightarrow \quad \frac{mv^2}{r} = \frac{ke^2}{r^2} \quad [\because Z = 1]$
$\Rightarrow \quad r = \frac{e^2 \cdot k}{mv^2}$ ....(iii)
$r = \frac{ke^2 4\pi^2 m^2 r^2}{m \cdot n^2 h^2}$ [from eq. (i)]
$\Rightarrow \quad r = \frac{n^2 h^2}{ke^2 4\pi^2 m} \Rightarrow r \propto n^2$

27. Here, $\lambda_1 = 650\ nm = 650 \times 10^{-9} m$
$\lambda_2 = 520\ nm = 520 \times 10^{-9} m$
Suppose, d = distance between two slits
D = Distance of screen from the slits
a. For third bright fringe, n = 3
$x = n\ \lambda_1 \cdot \frac{D}{d}$
$= 3 \times 650 \times \frac{D}{d} = 1950 \frac{D}{d}$
b. Let nth bright fringe due to wavelength 650 nm coincide with (n -1)th due to wavelength 520 nm.
Therefore, $n\ \lambda_2 = (n-1)\,\lambda_1$
or, $n \times 520 = (n-1) \times 650 \Rightarrow n = 5$
Hence, the least distance from the central maximum can be obtained by the relation:
$x = n\lambda_2 \frac{D}{d} = 5 \times 520 \frac{D}{d} = 2600 \frac{D}{d}\ nm$
Note: The value of d and D are not given in the question.

28. i. Mutual inductance is numerically equal to the induced emf in the secondary coil when the current in the primary coil changes by unity.

ii. in the question mutual inductance of two long coaxial solenoids of same length l wound one over the other is given by:-



Let a current l_2 flow in the secondary coil

$\therefore B_2 = \frac{\mu_0 N_2 i_2}{l}$

$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

= $M_{12}i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_1}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

OR

i. Due to motion, the magnetic flux linked with the loop abcd increases. According to Lenz's law, this increase in flux is opposed by the induced current. Therefore, the induced current must flow along bcdab.
ii. Due to motion, magnetic flux linked with abc decreases. The induced current is along bacb.
iii. The magnetic flux increases in this case. Therefore, the induced current is anticlockwise.
iv. As magnetic flux decreases due to motion, the induced current is along cdabc.

Yes, we would obtain the same answers by considering the magnetic force on the charges inside the loop.

Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(i) **(b)** less than visible light
Explanation: Microwaves have frequency and energy smaller than visible light and wavelength larger than it.

(ii) **(c)** the energy of the random motion of atoms and molecules increases
Explanation: When the energy of the random motion of atoms and molecules of a substance increases and the molecules travel or vibrate or rotate with higher energies, the substance becomes hot.

(iii) **(d)** 2.45 GHz

Explanation: The frequency of rotation of water molecules is about 2.45 gigahertz.

OR

(c) Energy is directly delivered to water molecules which is shared by the entire food

Explanation: In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

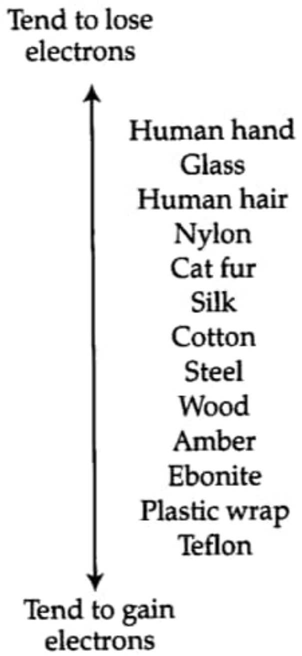
(iv) **(c)** Because of the danger of getting a shock from accumulated electric charges

Explanation: One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies and thus cannot absorb microwaves. Hence, they do not get heated up.

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

The triboelectric series is a list that ranks materials according to their tendency to gain or lose electrons. The process of electron transfer as a result of two objects coming into contact with one another and then separating is called triboelectric charging. During such an interaction, one of the two objects will always gain electrons (becoming negatively charged) and the other object will lose electrons (becoming positively charged). The relative position of the two objects on the triboelectric series will define which object gains electrons and which object loses electrons.

In triboelectric series, materials are ranked from high to low in terms of the tendency for the material to lose electron. If an object high up on this list (Glass, for example) is rubbed with an object low down on the list (Teflon, for example), the glass will lose electrons to the teflon. The glass will, in this case, become positively charged and the teflon will become negatively charged. Materials in the middle of the list (steel and wood, for example) are items those do not have a strong tendency to give up or accept electrons.



(i) **(c)** high

Explanation: In triboelectric series, materials are ranked from high to low in terms of the tendency for the material to lose electron i.e., they are ranked high to low tendency of getting positively charged.

(ii) **(a)** Steel, wood

Explanation: Materials in the middle of the list (steel and wood, for example) are items those do not have a strong tendency to give up or accept electrons.

(iii) **(c)** Hair will be positively charged, Amber will be negatively charged.

Explanation: Since, human hair is placed at the upper portion of the list, it will leave electron and will be positively charged. Since, amber is placed at the lower portion of the list, it will accept the electron and will be negatively charged.

(iv) **(a)** By contact

Explanation: The process of electron transfer as a result of two objects corning into contact with one another and then separating is called triboelectric charging.

OR

(d) positively, negatively

Explanation: During triboelectric charging, one of the two objects always gains electrons and become negatively charged. The other object loses electrons and become positively charged.

Section E

31. Given that,

Focal length of the objective lens, f_1 = 2.0 cm

Focal length of the eyepiece, f_2 = 6.25 cm

Distance between the objective lens and the eyepiece, d = 15 cm

a. Given that, Least distance of distinct vision, d' = 25 cm

Image distance for the eyepiece, v_2 = -25 cm

Object distance for the eyepiece = u_2

According to the lens formula,

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

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

$= \frac{1}{-25} - \frac{1}{6.25} = \frac{-1-4}{25} = \frac{-5}{25}$

$\therefore u_2$ = -5cm

Image distance for the objective lens, $v_1 = d + u_2$ = 15 - 5 = 10 cm

Object distance for the objective lens = u_1

According to the lens formula,

$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\frac{1}{u_1} = \frac{1}{v_1} - \frac{1}{f_1} = \frac{1}{10} - \frac{1}{2} = \frac{1-5}{10} = \frac{-4}{10}$

$\therefore u_1$ = -2.5 cm

Magnitude of the object distance, $|u_1| = 2.5\text{cm}$

The magnifying power of a compound microscope is:

$m = \frac{v_1}{|u_1|}\left(1 + \frac{d'}{f_2}\right) = \frac{10}{2.5}\left(1 + \frac{25}{6.25}\right) = 4(1+4) = 20$

b. The final image is formed at infinity.

Therefore, image distance for the eyepiece, $v_2 = \infty$

Object distance for the eyepiece = u_2

According to the lens formula, we have the relation,

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

$\frac{1}{\infty} - \frac{1}{u_2} = \frac{1}{6.25}$

$\therefore u_2$ = -6.25 cm

Image distance for the objective lens, $v_1 = d + u_2$ = 15 - 6.25 = 8.75 cm

Object distance for the objective lens = u_1

According to the lens formula,

$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\frac{1}{u_1} = \frac{1}{v_1} - \frac{1}{f_1} = \frac{1}{8.75} - \frac{1}{2.0} = \frac{2-8.75}{17.5}$

$\therefore \quad u_1 = -\frac{17.5}{6.75} = -2.59\text{cm}$

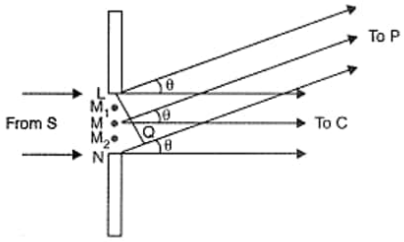
Magnitude of the object distance, $|u_1| =$ 2.59 cm

The magnifying power of a compound microscope is,

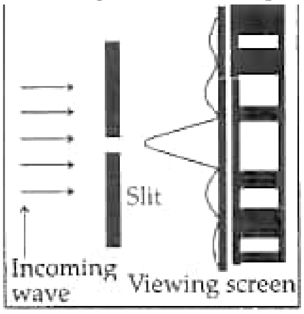
$m = \frac{v_1}{|u_1|}\left(\frac{d'}{|u_2|}\right) = \frac{8.75}{2.59} \times \frac{25}{6.25} = 13.51$

Thus, the magnifying power of the microscope is 13.51

OR

i. 

The diffraction pattern formed can be understood by adding the contributions from the different wavelets of the incident wavefront, with their proper phase differences. For the central point, we imagine the slit to be divided into two equal halves. The contribution of corresponding wavelets, in the two halves, are in phase with each other. Hence we get a maxima at the central point. The entire incident wavefront contributes to this maxima. **Maxima and minima** are produced when the path difference between waves is a whole number of wavelengths or an odd number of half wavelengths respectively.
All other points, for which $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$, get a net non zero contribution from all the wavelets. Hence all such points are at the points of maxima.
Points for which $\theta = \frac{n\lambda}{a}$, the net contribution, from all the wavelets, is zero. Hence these points are point of minima.
We thus get a diffraction pattern on the screen, made up of points of maxima and minima.



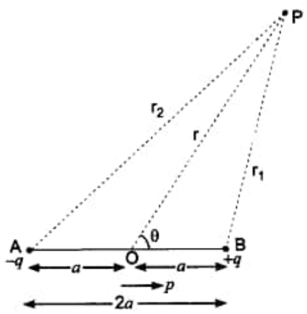
Secondary maxima keep on getting weaker in
intensity, with increasing n. This is because, at the

ii. First secondary maxima, the net contribution is only from (effectively) $\frac{1}{3}^{\text{rd}}$ of the incident wavefront on the slit.
iii. Second secondary maxima, the net contribution is only from (effectively) $\frac{1}{5}^{\text{th}}$ of the incident wavefront on the slit and so on.

32. i. The charge q_0 on the capacitor plates remains the same because the battery has been disconnected, before placing the dielectric slab.
ii. The surface charges induced on the dielectric slab reduce electric field intensity to a new value given by $E = \frac{E_0}{\kappa}$
iii. The reduction in the electric field induces the potential difference $V = Ed = \frac{E_0 d}{k} = \frac{V_0}{k}$
iv. Due to the decrease in p.d., the capacitance increases k times $C = \frac{q_0}{V} = \frac{q_0}{V_0/\mathrm{k}} = \mathrm{K}\frac{q_0}{V_0} = \kappa \mathrm{C}_0$
v. Energy stored decreases by a factor of κ:
$U = \frac{1}{2}CV^2 = \frac{1}{2}(\kappa C_0)\left(\frac{V_0}{K}\right)^2 = \frac{1}{\kappa} \cdot \frac{1}{2}C_0 V_0^2 = \frac{U_0}{\kappa}$

OR

Consider an electric dipole having charges -q and +q at separation '2a'. The dipole moment of dipole is $\vec{p} = q(\overrightarrow{2\,a})$, directed from -q to +q.
The electric potential due to dipole is the algebraic sum of potentials due to charges +q to -q
If r_1 and r_2 are distances of any point P from charge +q to -q respectively as shown in the figure, then the potential due to electric dipole at point P, is



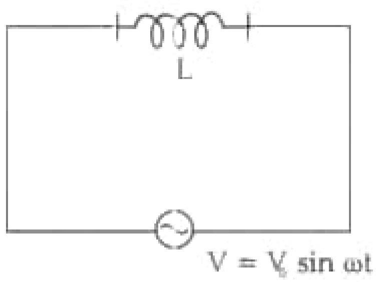
$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$ ...(i)

If (r, θ) are polar coordinates of point P with respect to mid-point O of dipole, then
By geometry,
$r_1^2 = r^2 + a^2 - 2ar\cos\theta$ ...(ii)
and, $r_2^2 = r^2 + a^2 - 2ar\cos\theta$ ...(iii)
From (ii), $r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$
If r >> a i e., $\frac{a}{r}$ <<1, then it is sufficient to retain terms only upto first order in $\left(\frac{a}{r}\right)$.
$\therefore r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r}\right] \Rightarrow r_1 = r\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(iv)
Similarly from (iii), ${r_2}^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right] \Rightarrow r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(v)
From (iv) and (v), $\frac{1}{r_1} = \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$ and, $\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$
Using binomial theorem and retaining terms upto first order in $\left(\frac{a}{r}\right)$ only, we have
$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r}\right] = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$ ...(vi)
and, $\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$ ...(vii)
Substituting these values in (i), we get
$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$
$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[1 + \frac{a}{r}\cos\theta - 1 + \frac{a}{r}\cos\theta\right]$
$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[\frac{2a}{r}\cos\theta\right] = \frac{1}{4\pi\varepsilon_0}\frac{(q\cdot 2a)\cos\theta}{r^2}$
or, $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$ ...(viii)
But, $p\cos\theta = \vec{p}\cdot\hat{r}$ where, $\hat{r}$ is unit vector along position vector $\vec{OP} = \vec{r}$.
Electric potential due to an electric dipole is
$V = \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$ (for r >> a) $= \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$ ...(ix)
Contrasting features: The electric potential due to a dipole depends on distance r and also on the angle between position vector $\vec{r}$ and dipole moment $\vec{p}$. The electrostatic potential at large distances falls off, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$ which is the characteristic of potential due to a single charge.
Special Cases:

i. When point P lies on the axis of dipole, then $\theta = 0^o$
$\therefore \cos\theta = \cos 0 = 1$
$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

ii. When point P lies on the equatorial plane of the dipole, then
$\therefore \cos\theta = \cos 90^o = 0$
$\therefore$ V = 0
It may be noted that the electric potential at any point on the equitorial line of a dipole is zero.

33. i. Given: V = $V_0 \sin\omega t$
V = $L\frac{di}{dt} \Rightarrow di = \frac{V}{L}dt$



$\therefore di = \frac{V_0}{L}\sin\omega t dt$
Integrating, I= $-\frac{V_0}{\omega L}\cos\omega t$
$\therefore I = -\frac{V_0}{\omega L}\sin\left(\frac{\pi}{2} - \omega t\right) = -I_0\sin\left(\frac{\pi}{2} - \omega t\right)$
where, $I_0 = \frac{V_0}{\omega L}$
Average power,

$P_{av} = \int_0^T VIdt$

$= \frac{-V_0^2}{\omega L} \int_0^T$ sin ωt cos ωt dt

$= \frac{-V_0^2}{2\omega L} \int_0^T$ sin $(2\omega t)$ dt sin is an odd function so integral results into 0.

= 0, thus the power dissipated by the conductor is zero.

ii.

a. $\omega_0 = \frac{1}{\sqrt{LC}}$

$= \frac{1}{(200\times10^{-3}\times400\times40^{-6})^{1/2}}$

$= \frac{1}{\sqrt{8\times10^{-5}}}\text{rad/s}$

$= \frac{10^3}{\sqrt{80}}\text{rad/s}$

= 111 rad/s

$I = \frac{V}{R} = \frac{50}{10}$ = 5A

b. $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200\times10^{-3}}{400\times10^{-6}}} = \sqrt{5}$

OR

i. Calculation of Capacitance

As power factor is unity,

$\therefore$ X_L = X_C also L=200mH and R= 10 Ω

$\Rightarrow \omega = \frac{1}{\sqrt{LC}}$

100 = $\frac{1}{\sqrt{200\times10^{-3}\times C}}$

$10^4 \times 2 \times 10^2 \times 10^{-3} \times$ C = 1

hence ca[pacitance is given by ,C = $\frac{1}{2\times10^3}$ F

= 0.5 $\times$ 10^{-3} F

= 0.5mF

ii. Q-factor of circuit and its importance Calculation of average power dissipated

Quality factor, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200\times10^{-3}}{0.5\times10^{-3}}}$

$= \frac{1}{10}\times$ 20 = 2

Significance: It measures the sharpness of resnance.

Average Power dissipated,

P = V_{rms} I_{rms} cos ϕ

$= 50 \times \frac{50}{10}\times$ 1 W

= 250 watts