SAMPLE PAPER - 9

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. In an n-type silicon, which of the following statement is true: **[1]**

a) Holes are minority carriers and pentavalent atoms are the dopants.

b) Electrons are minority carriers and pentavalent atoms are the dopants.

c) Electrons are majority carriers and trivalent atoms are the dopants.

d) Holes are majority carriers and trivalent atoms are the dopants.

2. Ten identical cells each of emf E and internal resistance r are connected in series to form a closed circuit. An ideal voltmeter connected across three cells will read **[1]**

a) 3 E

b) 10 E

c) Zero

d) 7 E

3. Two-point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye? (Take wavelength of light = 500 nm) **[1]**

a) 1 m

b) 6 m

c) 3 m

d) 5 m

4. In a reverse-biased diode when the applied voltage changes by 1 V, the current is found to change by 0.5 μA. The reverse bias resistance of the diode is: **[1]**

a) $2 \times 10^5\ \Omega$

b) 200 Ω

c) 2 Ω

d) $2 \times 10^6\ \Omega$

5. The electric potential V at any point (x, y, z) (all in metres) in space is given by $V = 4x^2$ volt. The electric field at the point (1 m, 0, 2 m) in volt/metre: [1]

a) 8 along positive x-axis
b) 16 along positive x-axis
c) 16 along negative x-axis
d) 8 along negative x-axis

6. A proton (charge +e) enters a magnetic field of strength B (Tesla) with speed v, parallel to the direction of magnetic lines of force. The force on the proton is [1]

a) evB/2
b) 2evB
c) zero
d) evB

7. A coil of area 80 square cm and 50 turns is rotating with 2000 revolutions per minute about an axis perpendicular to a magnetic field of 0.05 tesla. The maximum value of the emf developed in it is: [1]

a) $\frac{2}{3}$ volt
b) 200π volt
c) $\frac{4\pi}{3}$ volt
d) $\frac{10\pi}{3}$ volt

8. The number of waves in one meter (wave no.) of a wave of wavelength 5000 $\overset{o}{A}$ is: [1]

a) 5×10^7
b) 2×10^6
c) 2×10^7
d) 4×10^6

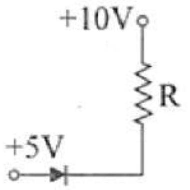
9. In Young's double-slit experiment, the slits are placed 0.320 mm apart. Light of wavelength λ = 500 nm is incident on the slits. The total number of bright fringes that are observed in the angular range -30° $\leq \theta \leq$ 30° is [1]

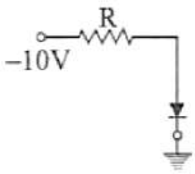
a) 321
b) 641
c) 640
d) 320

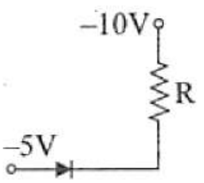
10. The charge on an electron was calculated by: [1]

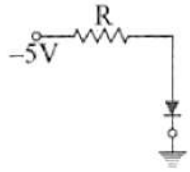
a) J.J. Thomson
b) Millikan
c) Einstein
d) Faraday

11. Which of the junction diodes shown below are forward biased? [1]

a) 

b) 

c) 

d) 

12. A short linear object of length L lies on the axis of a spherical mirror of focal length f at a distance u from the mirror. Its image has an axial length L' equal to: [1]

a) $L\left[\frac{f}{(u-f)}\right]^2$
b) $L\left[\frac{(u+f)}{f}\right]^{1/2}$
c) $L\left[\frac{(u-f)}{f}\right]^2$
d) $L\left[\frac{f}{(u+f)}\right]^2$

13. ________ phenomenon best supports the theory that matter has a wave nature. **[1]**

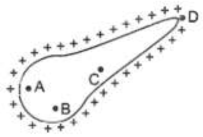
a) Electron diffraction

b) Photon momentum

c) Photon diffraction

d) Electron momentum

14. For the isolated charged conductor of the given figure, the electric fields at points A, B, C and D are E_A, E_B, E_C and E_D respectively. Then: **[1]**



a) $E_A = E_B > E_C > E_D$

b) $E_D > E_A > E_C$ but $E_B = 0$

c) $E_B = 0$, $E_A = E_C = E_D$

d) $E_D > E_C > E_B = E_A$

15. Light of wavelength 6000 $\overset{o}{A}$ falls on a single slit of width 0.1 mm. The second minimum will be formed for the angle of diffraction of: **[1]**

a) 0.06 radian

b) 0.12 radian

c) 0.08 radian

d) 0.012 radian

16. **Assertion (A):** The binding energy per nucleon for nuclei with atomic mass number A > 100, decreases with A. **[1]**
Reason (R): The nuclear forces are weak for heavier.

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 a charged particle moves in a circular path, it produces an electromagnetic wave. **[1]**
Reason (R): Charged particle has acceleration.

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):** Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. **[1]**
Reason (R): The magnetic field inside the solenoid is uniform.

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

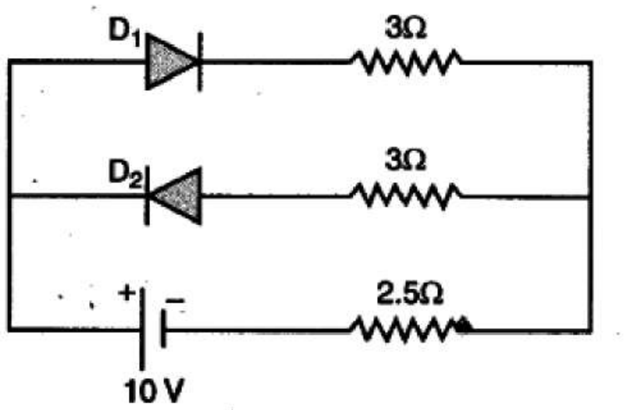
b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

19. Assuming that the two diodes D_1 and D_2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 2.5 Ω resistor **[2]**



20. How much is the energy possessed by an electron for $n = \infty$? **[2]**

21. i. Why are infrared waves often called heatwaves? Explain. **[2]**

ii. What do you understand by the statement, "Electromagnetic waves transport momentum"?

OR

How do you convince yourself that electromagnetic waves carry energy and momentum?

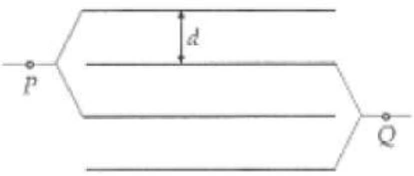
22. Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier. **[2]**

23. i. Write two characteristics of equipotential surfaces. **[2]**

ii. Draw the equipotential surfaces due to an electric dipole.

OR

What is the capacitance of arrangement of 4 plates of area A at distance **d** in the air in the given figure?



24. Light of intensity 10^{-5} Wm^{-2} falls on a sodium photo-cell of surface area 2 cm^2. Assuming that the top 5 layers of sodium absorb the incident energy, estimate time required for photoelectric emission in the wave-picture of radiation. The work function for the metal is given to be about 2 eV. What is the implication of your answer? **[2]**

25. Neutrons produced in fission can be slowed down even by using ordinary water. Then, why is heavy water used for this purpose? **[2]**

Section C

26. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength $975\overset{o}{A}$. **[3]**

i. How many different lines are possible in the resulting spectrum?

ii. Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atom as 13.6 eV.

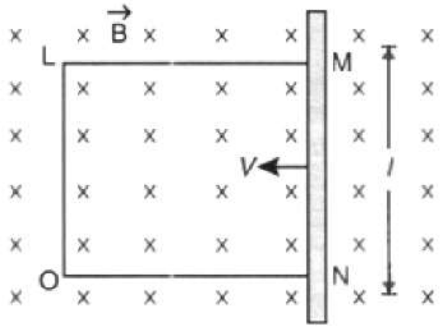
27. Why do we need a broad source for observing interference in thin films? **[3]**

28. i. Obtain the expression for the magnetic energy stored in a solenoid in terms of magnetic field B, area A and length l of the solenoid. **[3]**

ii. How does this magnetic energy compare with the electrostatic energy stored in a capacitor?

OR

A rectangular conductor LMNO is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor.



When the arm M N of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.

29. i. Which segment of electromagnetic waves has the highest frequency? How are these waves produced? Give one use of these waves. **[3]**

ii. Which EM waves lie near the high-frequency end of visible part of EM spectrum? Give its one use. In what way, this component of light has harmful effects on humans?

OR

Answer the following questions:

i. Name the EM waves which are used for the treatment of certain forms of cancer. Write their frequency range.

ii. The thin ozone layer on top of the stratosphere is crucial for human survival. Why?

iii. Why is the amount of momentum transferred by the EM waves incident on the surface so small?

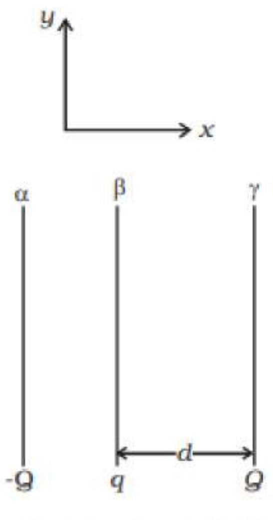
30. Derive an expression for the intensity of the magnetic field at an axial point of a short magnetic dipole. **[3]**

Section D

31. ABCD is a square of side 5 m. Charges of + 50 C, - 50 C and + 50 C are placed at A, C and D respectively. Find the resultant electric field at B. **[5]**

OR

Two fixed, identical conducting plates (α & β), each of surface area S are charged to – Q and q, respectively, where $Q > q > 0$. A third identical plate (γ), free to move is located on the other side of the plate with charge q at a distance d (Fig). The third plate is released and collides with the plate β. Assume the collision is elastic and the time of collision is sufficient to redistribute charge amongst β & γ



a. Find the electric field acting on the plate γ before collision.

b. Find the charges on β and γ after the collision.

c. Find the velocity of the plate γ after the collision and at a distance d from the plate β.

32. i. Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses. **[5]**

ii. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$th of the angle of prism. Calculate the speed of light in the prism.

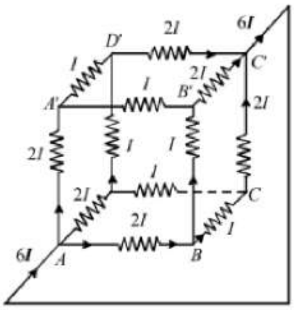
OR

a. Derive the expression for the angle of deviation for a ray of light passing through an equilateral prism of refracting angle A.

b. A prism is found to give a minimum deviation of 51°. The same prism gives a deviation of 62°48' for two values of the angles of incidence, namely, $46^{\circ}6'$ and $82^{\circ}42'$. Determine the refractive angle of the prism and the refractive index of its material.

33. i. State Kirchhoffs rules. **[5]**

ii. A battery of 10 V and negligible internal resistance is connected across the diagonally opposite corners of a cubical network consisting of 12 resistors each of 1Ω resistance.



Use Kirchhoffs rules to determine

a. the total current in the network.

b. the equivalent resistance of the network

Section E

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

A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in tesla). The direction of force is determined by the rules of cross product of two vectors. Force is perpendicular to both velocity and magnetic field. Its direction is given as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

(i) What kind of magnetic field is produced by an infinitely long current carrying conductor?

(ii) What happens to a stationary electron placed in magnetic field ?

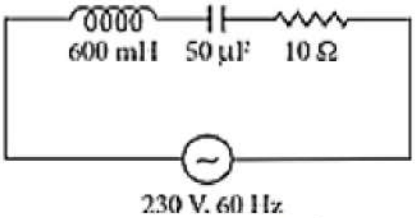
(iii) What happens to the velocity of a proton projected with a uniform velocity v along the axis of a current-carrying solenoid?

OR

What are the conditions under which a charged particle experiences magnetic force in a magnetic field?

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

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos \phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) What will be the value of average power transferred per cycle to the resistance?

(ii) What will be the value of the average power transferred per cycle to the capacitor?

(iii) What will be the total power transferred per cycle by all three circuit elements?

OR

What will be the electrical energy spent in running the circuit for one hour?

Solution

SAMPLE PAPER - 9

Class 12 - Physics

Section A

1. **(a)** Holes are minority carriers and pentavalent atoms are the dopants.
Explanation: In an n-type silicon, An n-type semiconductor is obtained by doping a semiconductor with a pentavalent impurity. The impurity so added produces free electrons. So the electrons are the majority carriers, while the holes are the minority carriers. An n-type semiconductor is obtained when pentavalent atoms, such as phosphorus, are doped in silicon atoms.

2. **(a)** 3 E
Explanation: Given: Initial number of cells (n_1) = 10; Potential of each cell = E
The internal resistance of each cell = r and
the final number of cell (n_2) = 3.
We know from the Ohm's law, the total voltage of ten cells = 10 × E = 10 E and
the total resistance in ten cells = 10 × r = 10 r
Therefore current in the circuit
$I = \frac{10E}{10r} = \frac{E}{r}$
or potential difference across three cell
$= I \times 3r = \frac{E}{r} \times 3r = 3E$
(Since the voltmeter is ideal, therefore it will read 3 E)

3. **(d)** 5 m
Explanation: Resolution limit = $\sin\theta = \theta = \frac{y}{D} = 1.22\frac{\lambda}{d}$
$D = \frac{yd}{1.22\lambda}$
$= \frac{10^{-3} \times 3 \times 10^{-3}}{1.22 \times 5 \times 10^{-7}}$
$= \frac{30}{6.1} = 5$ m

4. **(d)** $2 \times 10^6\ \Omega$
Explanation: Reverse resistance = $\frac{\Delta V}{\Delta I} = \frac{1}{0.5 \times 10^{-6}}$
$= 2 \times 10^6 \Omega$

5. **(d)** 8 along negative x-axis
Explanation: $\overrightarrow{\mathrm{E}} = -\left[\hat{\mathrm{i}}\frac{\partial \mathrm{V}}{\partial \mathrm{x}} + \hat{\mathrm{j}}\frac{\partial \mathrm{V}}{\partial \mathrm{y}} + \hat{\mathrm{k}}\frac{\partial \mathrm{V}}{\partial z}\right]$
$\overrightarrow{\mathrm{E}} = -[\hat{\mathrm{i}}(8\mathrm{x})]$
$\overrightarrow{\mathrm{E}}_{(1,0,2)} = -8\hat{\mathrm{i}}$
So electric field is 8 along negative x-axis.

6. **(c)** zero
Explanation: Lorentz force is given by $F = Bqv\sin\theta$
When the proton enters the magnetic field parallel to the direction of the lines of force, $\theta = 0$.
Therefore, F = 0

7. **(c)** $\frac{4\pi}{3}$ volt
Explanation: $e = NBA\omega$, $\omega = 2\pi f = 2\pi \times \frac{2000}{60}$
$\therefore E = 50 \times 0.05 \times 80 \times 10^{-4} \times 2\pi \times \frac{2000}{60} = \frac{4\pi}{3}$ volt

8. **(b)** 2×10^6
Explanation: 2×10^6

9. **(b)** 641
Explanation: For 'n' number of maximas
$d\sin\theta = n\lambda$

$0.32 \times 10^{-3} \sin 30° = n \times 500 \times 10^{-9}$

$\therefore n = \frac{0.32\times10^{-3}}{500\times10^{-9}} \times \frac{1}{2} = 320$

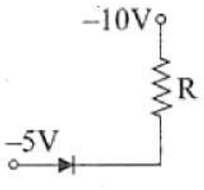
Hence total no. of maximas observed in angular range $-30° \leq \theta \leq 30°$

$= 320 + 1 + 320 = 641$

10. **(b)** Millikan

Explanation: Charge on an electron was calculated by Millikan.

11. **(c)**



Explanation: The p-n junction diode is forward biased when p is at high potential with respect to n. Hence this option is correct.

12. **(a)** $L\left[\frac{f}{(u-f)}\right]^2$

Explanation: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ or $-\frac{dv}{v^2} - \frac{du}{u^2} = 0$

i.e., $dv = -du/(v/u)^2$

But $v = \frac{uf}{(u-f)}$ or $\frac{v}{u} = \frac{f}{(u-f)}$

So, $dv = -du\left[\frac{f}{(u-f)}\right]^2$

Hence, $|dv| = L\left[\frac{f}{(u-f)}\right]^2$

13. **(a)** Electron diffraction

Explanation: The matter has a wave nature is best supported by the phenomenon of electron diffraction.

14. **(b)** $E_D > E_A > E_C$ but $E_B = 0$

Explanation: $E_D > E_A > E_C$ but $E_B = 0$

15. **(d)** 0.012 radian

Explanation: add explanation here

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

Explanation: Nuclear forces are nearly equally strong for all nuclei.

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

Explanation: The circular motion of the charged particles is an accelerated motion and an accelerated charge emits electromagnetic radiation.

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

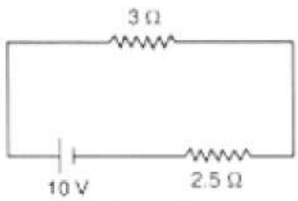
Explanation: Magnetic field lines can be entirely confined to the core of a toroid because toroid has no ends. It can confine the field within its core. A straight solenoid has two ends. If the entire flux were confined between these ends, the flux throughout the cross-section at each end would be non-zero.

Section B

19.

D_2 is reverse biased

$\therefore D_1$ conducts



$\therefore I = \frac{10}{3+2.5} = \frac{10}{5.5} = 1.8A$

20. Zero

For $n=\infty$ $E_n=-\frac{13.6}{n^2}\mathrm{eV}=0$

21. i. Infrared rays are readily absorbed by the (water) molecules in most of the substances and hence increases their thermal motion. Thus increases the internal energy and temperature of the molecules. This is the reason they are often called as heat waves.

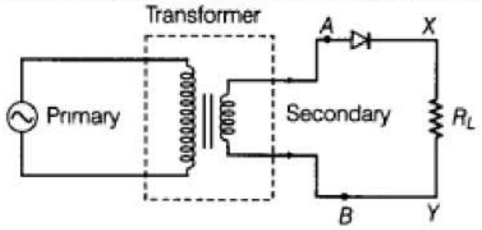
ii. Electromagnetic waves can set (and sustain) charges in motion. Hence, they are said to transport momentum.

OR

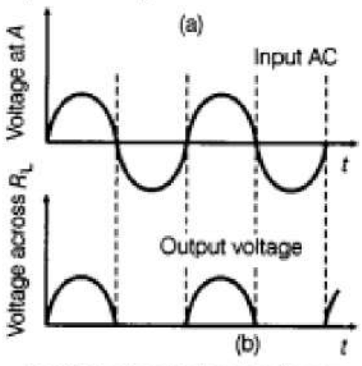
When an electromagnetic wave interacts with matter, its electric and magnetic fields set in oscillation the charges present in the matter. The charges thus acquire energy and momentum from the e.m. wave showing that it carries energy and momentum. (i) When the sun shines on our hands, the energy absorbed from the e.m. waves warms our hands, (ii) An e.m. wave carries momentum. When it falls on surface, it exerts pressure called radiation pressure.

22. A rectifier, which rectifies only one half of each a.c. input supply cycle, is called a half wave rectifier.

The arrangement is shown in the figure below.



Working: During one half of the input a.c., the diode is forward biased and a current flows through RL. During the other half of the input a.c., the diode is reverse biased and no current flows through the load RL. Hence, the given a.c. input is rectified. The input and output waveforms are shown in the figure below.

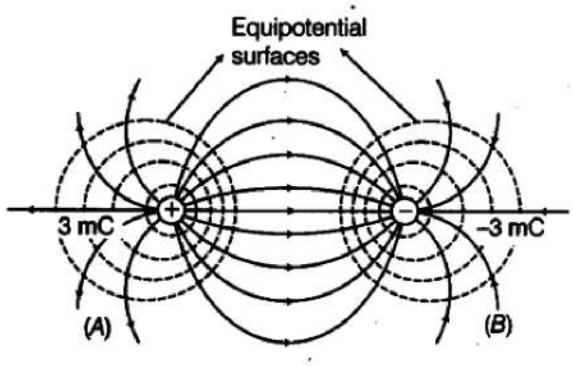


Input and output waveforms

23. i. a. Two equipotential surfaces do not intersect each other as normals at the point of intersection on two surfaces will give two different directions of same electric field which is impossible.

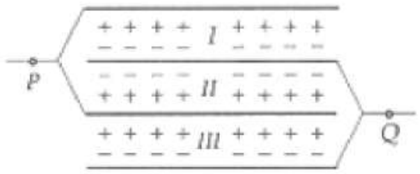
b. Closely spaced equipotential surfaces represent strong electric field and vice-versa.

ii. Equipotential surfaces of an electric dipole having charges +3 mC and -3 mC are shown below:



OR

As shown in Fig. suppose point P is connected to the positive terminal and point Q to the negative terminal of a battery. Clearly, we have three capacitors I, II, and III. Their positive plates are connected to the same point P while the negative plates are connected to the same point Q. So the three capacitors are in parallel



Equivalent capacitance,

$C_p = C_1 + C_2 + C_3 = 3C = \frac{3\varepsilon_0 A}{d}$

24. Given,

Intensity of light = 10^{-5} Wm^{-2}

Surface area of the sodium photocell, A = 2 cm^2

Top five layers of sodium absorb the incident energy. (given)

the work function for the metal $\phi_0 = 2\text{eV}$

Therefore,

Number of atoms in 5 layers of sodium is,

$= \frac{5\times \text{ area of each layer}}{\text{Effective area of atom}}$

$= \frac{5\times2\times10^{-4}}{10^{-20}} = 10^{17}$

Assume that there is only one conduction electron per sodium atom.

$\therefore$ Number of electrons in 5 layers = 10^{17}

Energy received by an electron per sec is,

$= \frac{\text{Power of incident light}}{\text{Number of electrons}}$

$\frac{10^{-5}\times2\times10^{-4}}{10^{17}} = 2\times10^{-26}$ W

thus the time required for photoemission is,

$= \frac{2\times1.6\times10^{-19}}{2\times10^{-26}}$

$= 1.6\times10^{7}\text{s}$

Thus, it is contrary to the observed fact that there is no time lag between the incidence of light and the emission of photoelectrons.

25. Neutrons produced during fission get slowed if they collide with a nucleus of the same mass. As ordinary water contains hydrogen atoms (of mass nearly that of neutrons), so it can be used as a moderator. But it absorbs neutrons at a fast rate via the reaction:

$n + p \rightarrow d + \gamma$

Here d is deuteron. To overcome this difficulty, heavy water is used as a moderator which has negligible cross-section for neutron absorption.

Section C

26. i. Energy of the ground state (n = 1) = – (ionization energy) = –13.6 eV

The wavelength of the incident radiation, $\lambda = 975\ \mathring{A}$

$\therefore$ The energy of the incident photon = hc/λ

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{975\times10^{-10}\times1.6\times10^{-19}}$ = 12.75 eV

Let electron is exerted to nth orbit,

$\Rightarrow 12.75 = 13.6\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$

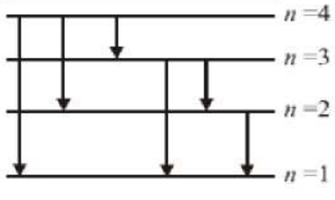
$\Rightarrow n = 4$

The quantum transitions to the less excited states gives six possible lines as follows:

n = 4 : $(4 \rightarrow 3), (4 \rightarrow 2), (4 \rightarrow 1)$

n = 3 : $(3 \rightarrow 2), (3 \rightarrow 1)$

n = 2 : $(2 \rightarrow 1)$



ii. The longest wavelength emitted is for the transitions $(4 \rightarrow 3)$ where energy difference is minimum.

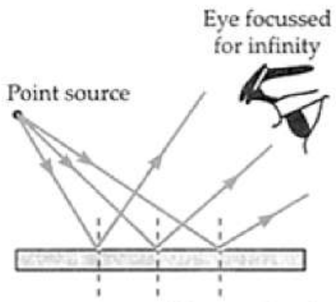
$E_{min} = (E_4 - E_3) = 13.6\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 0.661$ eV

Thus $\lambda_{max} = \frac{hc}{E_{min}}$

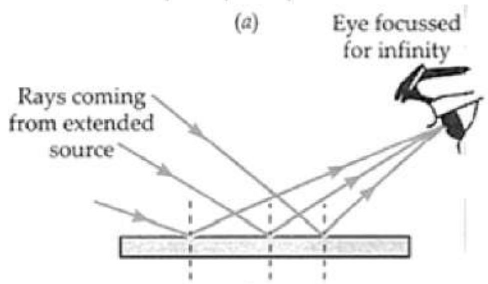
$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.661 \times 1.6 \times 10^{-19}} \text{m}$

$\approx 18807 \text{ Å}$

27. As shown in Fig. (a), when a point source is used, the rays reflected from the thin film get diverged through wide angles. Due to its small size, the eye lens cannot see the entire interference pattern.



(a)



(b)

But when an extended source of light is used, as shown in Fig. (b), the rays reflected by the thin film are converging. One can see the entire interference pattern by placing the eye in a suitable position.

28. i. The work done against the induced emf in building up the current from 0 to I is

$W = \int dW = \int \mathfrak{E} I dt = \int L \frac{dI}{dt} I dt = \int_0^I LI dI = \frac{1}{2} LI^2$

The magnetic energy stored in the solenoid is

$U_B = W = \frac{1}{2} LI^2 = \frac{1}{2} L \left(\frac{B}{\mu_0 n}\right)^2 \; [\because B = \mu_0 n I]$

$= \frac{1}{2} \left(\mu_0 n^2 A l\right) \left(\frac{B}{\mu_0 n}\right)^2 \; [\because L = \mu_0 n^2 A l]$

$U_B = \frac{1}{2\mu_0} B^2 A l$

ii. The magnetic energy stored per unit volume of the solenoid is

$u_B = \frac{U_B}{V} = \frac{U_B}{Al}$ [Here V is the volume that contains flux]

or $u_B = \frac{B^2}{2\mu_0}$ ....(i)

We know that the electrostatic energy stored per unit volume in a parallel plate capacitor is

$u_E = \frac{1}{2} \varepsilon_0 E^2$ .....(ii)

In both the cases energy is proportional to the square of the field strengths. Eqs. (i) and (ii) are general and valid for any region of space in which a magnetic field or/and an electric field exist.

OR

Let ON be at some point x. magnetic field B= 0.5 T and length of the arm is L=20 cm =0.2 m

The emf induced in the loop = ε

$\varepsilon = \frac{-d\phi}{dt} = \frac{-d(Blx)}{dt}$ = Blv

= 0.5 × 0.2 × 10 = 1 V

$\therefore$ Current in the arm,

I = $\frac{\varepsilon}{R} = \frac{1}{5}$ = 0.2 A

29. i. Gamma(γ) rays have the highest frequency (as these waves have the highest energy) in the electromagnetic waves. These rays are of the nuclear origin and are produced during the disintegration of radioactive atomic nuclei and during the decay of certain subatomic radioactive particles, associated with the decay of alpha(α) and beta(β) rays. They are used in the treatment of cancer and tumors i.e. in radiotherapy/chemotherapy.

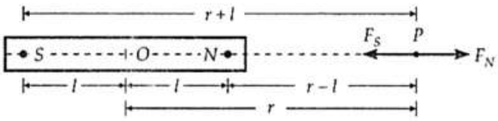
ii. Ultraviolet(UV) rays lie near the high-frequency end of visible part of EM spectrum. These rays are used to preserve food stuff and in water purifiers to kill the germs for giving pure drinking water. The harmful effect from exposure to ultraviolet

(UV) radiation can be life-threatening and include premature ageing of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

OR

i. Gamma(γ) rays are used for the treatment of certain forms of cancer. Its frequency range is 3×10^{19} Hz to 5×10^{22} Hz.
ii. The thin ozone layer residing on top of stratosphere behaves as a filter and absorbs most of the harmful ultraviolet rays (highly hazardous ultraviolet radiation of shorter wavelength) coming from the sun towards the earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the earth. Hence, this layer is crucial for human survival.
iii. An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers total energy, U to a surface in time t, then total linear momentum, p delivered to the surface is $p = \frac{U}{c} \Rightarrow p = \frac{h\nu}{c}$ (h and ν are Planck's constant and frequency of the electromagnetic wave respectively).
The amount of momentum transferred by the EM waves incident on the surface is very small due to the very large value of speed of light, c.

30. Let NS be a bar magnet of length 2l and of pole strength q_m. Suppose the magnetic field is to be determined at a point P which lies on the axis of the magnet at a distance r from its centre, as shown in figure.



Imagine a unit north pole placed at point P. Then from Coulomb's law of magnetic forces, the force exerted by the N-pole of strength q_m on unit north pole will be

$F_N = \frac{\mu_0}{4\pi} \cdot \frac{q_m}{(r-l)^2}$, along $\overrightarrow{NP}$

Similarly, the force exerted by S-pole on unit north pole is

$F_S = \frac{\mu_0}{4\pi} \cdot \frac{q_m}{(r+l)^2}$, along $\overrightarrow{PS}$

Therefore, the strength of the magnetic field $\vec{B}$ at point P is

B_{axial} = Force experienced by a unit north - pole at point P

$= F_N - F_S = \frac{\mu_0 q_m}{4\pi}\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]$

$= \frac{\mu_0 q_m}{4\pi} \cdot \frac{4rl}{\left(r^2-l^2\right)^2}$

But $q_m.2l = m$, is the magnetic dipole moment, so

$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2mr}{\left(r^2-l^2\right)^2}$

For a short bar magnet, l <<r, therefore, we have

$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$, along $\overrightarrow{NP}$ ....(i)

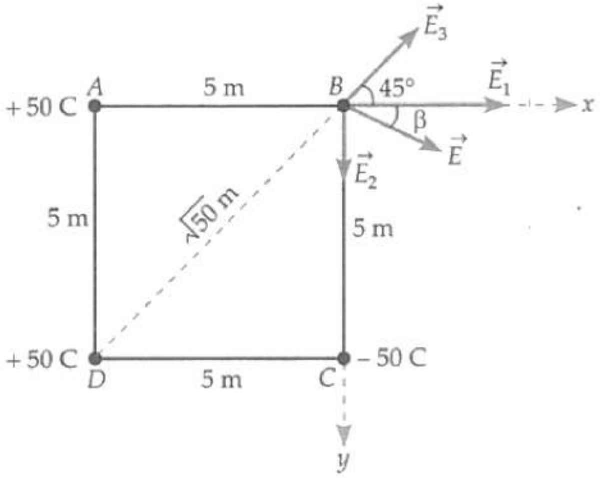
Clearly, the magnetic field at any axial point of magnetic dipole is in the same direction as that of its magnetic dipole moment i.e., from S-pole to N-pole, so we can write

$\vec{B}_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2\vec{m}}{r^3}$

Section D

31. Electric field at B due to + 50 C charge at A is

$E_1 = k \cdot \frac{q}{r^2} = k \cdot \frac{50}{5^2}$ = 2k, along AB



Electric field at B due to -50 C charge at C is

$E_2 = k \cdot \frac{50}{5^2}$ = 2k, along BC

Electric field at B due to + 50 C charge at D is

$E_3 = k \cdot \frac{50}{\left(\sqrt{5^2+5^2}\right)^2}$ = k, along DB

Component of E_1 along x-axis = 2 k (as it acts along x-axis)

Component of E_2 along x-axis = 0 (as it acts along y-axis)

Component of E_3 along x-axis

$= E_3 \cos 45^o = k \cdot \frac{1}{\sqrt{2}} = \frac{k}{\sqrt{2}}$

∴ Total electric field at B along x-axis

$E_x = 2k + 0 + \frac{k}{\sqrt{2}} = k\left(2 + \frac{1}{\sqrt{2}}\right)$

Now,

Component of E_1 along x-axis = 0

Component of E_2 along y-axis = 2k

Component of E_3 along y-axis

$E_y = E_3 \sin 45^o = k \cdot \frac{1}{\sqrt{2}} = \frac{k}{\sqrt{2}}$

But the components of E_2 and E_3 act in opposite directions, therefore, total electric field at B along y-axis

$= 2k - \frac{k}{\sqrt{2}} = k\left(2 - \frac{1}{\sqrt{2}}\right)$

∴ Resultant electric field at B will be

$E = \sqrt{E_x^2 + E_y^2}$

$= \sqrt{\left[k\left(2+\frac{1}{\sqrt{2}}\right)\right]^2 + \left[k\left(2-\frac{1}{\sqrt{2}}\right)\right]^2} = \sqrt{9k^2}$

$= 3k = 3 \times 9 \times 10^9 \text{ NC}^{-1} = 2.7 \times 10^{10} \text{ NC}^{-1}$

If the resultant field E makes angle β with x-axis, then

$\tan \beta = \frac{E_y}{E_x} = \frac{(2-1/\sqrt{2})k}{(2+1/\sqrt{2})k}$ = 0.4776 or $\beta = 25.5^o$

OR

a. Net electric field at plate γ before collision is vector sum of electric field at plate γ due to plate $\alpha$and β. Considering the right direction to be positive

 The electric field at γ due to the plate α is $-\frac{Q}{S(2\epsilon_o)}$ [i.e., towards left]

 The electric field at γ due to the plate β is $\frac{Q}{S(2\epsilon_o)}$ [i.e., towards right]

 The net electric field = $\frac{q-Q}{S(2\in_o)}$[Here, Q>q, so the direction will be towards left

b. During the collision plates β and γ are together so they must be at one potential. Charge on β is q_1 and on γ is q_2 . Consider a point O, in between the plates. The electric field here must be zero.

 Electric field at O due to $\alpha = \frac{-Q}{S(2\varepsilon_0)}$, to the left

Electric field at O due to $\beta = \frac{q_1}{S(2\varepsilon_0)}$, to the right

Electric field at O due $\gamma = \frac{q_2}{S(2\varepsilon_0)}$ to the left

As the electric field at O is zero, therefore

$\frac{Q+q}{S(2\varepsilon_0)} = \frac{q_1}{S(2\varepsilon_0)}$

$\therefore$ Q + q_2 - q_2, (i)

There is no loss of charge on collision, therefore

Q + q = q_1 + q_2 (ii)

On solving (i) and (ii), we get

q_1 = (Q + $\frac{q}{2}$) = charge on plates β

q_2 = ($\frac{q}{2}$) = charge on plate γ

c. Let the velocity be v at the distance d after the collision. If m is the mass of the plate γ, then the gain in K.E. over the round trip must be equal to the work done by the electric field. After the collision, the electric field at γ is

$E_2 = \frac{-Q}{2\varepsilon_0 S} + \frac{(Q+q/2)}{2\varepsilon_0 S} = \frac{q/2}{2\varepsilon_0 S}$

$F_2 = E_2 q/2 = \frac{(q/2)^2}{2\varepsilon_0 S}$

Total work done $=(F_1 + F_2)\, d = \left[\frac{(Q-q)Q}{2\varepsilon_0 S} + \frac{(q/2)^2}{2\varepsilon_0 S}\right] d = \frac{(Q-q/2)^2 d}{2\varepsilon_0 S}$

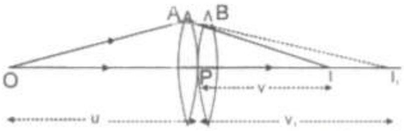
Using work energy theorem, we have

$\frac{1}{2} m w^2 = \frac{(Q-q/2)^2 d}{2\varepsilon_0 S}$

Further solving, we have

$v = (Q - \frac{q}{2})\left(\frac{d}{m\varepsilon_0 S}\right)^{1/2}$

32. i.



Two thin lenses, of focal length f_1 and f_2 are kept in contact. Let O be the position of the object and let u be the object distance. The distance of the image (which is at I_1), for the first lens is v_1

This image serves as object for the second lens. Let the final image be at I. We then have

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

$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1}$

Adding, we get

$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\therefore \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

$\therefore$ P = P_1 + P_2

ii. A ray of light passing from the air through an equilateral glass prism undergoes minimum deviation. Thus, At a minimum deviation

$r = \frac{A}{2} = 30^\circ$

We are given that, $i = \frac{3}{4}A = 45^\circ$

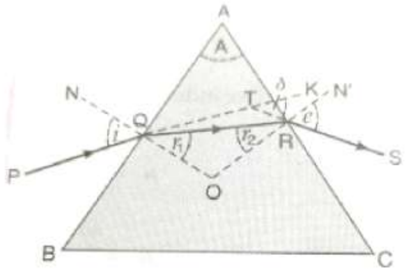
$\therefore \mu = \frac{\sin 45^\circ}{\sin 30^\circ} = \sqrt{2}$

$\therefore$ Speed of light in the prism v = $\frac{c}{\mu} = \frac{c}{\sqrt{2}}$

= (2.1×10^8 ms^{-1})

OR

a. Consider that a ray of light PQ is incident on the refracting face AB of the prism at point Q as shown in figure. When light passes through a prism refraction takes place at both the surfaces of the prism.



In figure, i and e are the angle of incidence and emergence respectively. Angles r_1 and r_2 are angle of refraction at both the surfaces of the prism. A is the angle of prism and δ be the angle of deviation.

The rays PQ, QR and RS are called incident ray, refracted ray and emergent ray respectively. Produce SR backwards, so as to meet the ray PQ at point T, when produced. Then, KTS = δ is called the angle of deviation.

Since $\angle$ TQO = i and $\angle$RQO = r_1, we have

$\angle TQR = i - r_1$

Also, $\angle$TRO = e and $\angle$QRO = r_2. Therefore,

$\angle TRQ = e - r_2$

Now, in triangle TQR, the side QT has been produced outwards. Therefore,

$\delta = \angle TQR + \angle TRQ = (i - r_1) + (e - r_2)$

or $\delta = (i + e) - (r_1 + r_2)$ ....(i)

In triangle QRO, the sum of the angles is 180^o. Therefore,

$r_1 + r_2 + \angle QOR = 180^o$ ...(ii)

In quadrilateral AQOR, each of the angles AQO and ARO is 90^o. Since the sum of the four angles of a quadrilateral is four angles, the sum of the remaining two angles should be 180^o i.e.

$A + \angle QOR = 180^o$ ....(iii)

From the equation (ii) and (iii), we have

$r_1 + r_2 = A$ ...(iv)

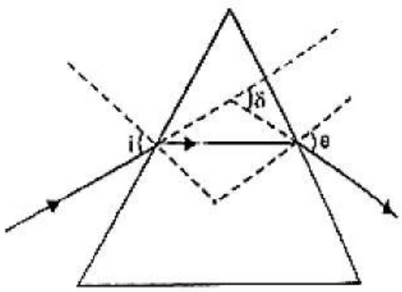
In the equation (i), substituting for $(r_1 + r_2)$ we have

$\delta = (i + e) - A$

or $A + \delta = i + e$

Hence, $\delta = (i + e) - A$

b. The incident ray is deviated through $\delta = 62^\circ 48'$ when angle i = $40^o6'$. From the principle of reversibility of light, it is clear from the figure that the emergent ray (for which angle e = $82^o42'$) is also deviated through the same angle δ. Now,



$\delta = (i + e) - A$

or $A = (i + e) - \delta$

$= 40^\circ 6' + 82^\circ 42' - 62^\circ 48'$

or A = 60°

which is the refractive angle of the prism.

For minimum deviation, i = e

Hence, $\delta_{\min} = 2i - A$

or $i = \left(\frac{\delta_{\min} + A}{2}\right)$

$= \frac{(51^\circ + 60^\circ)}{2} = 55^\circ 30'$

which is the angle of incidence at minimum deviation? The refractive index of the material of the prism is given by

$\mu = \frac{\sin \frac{(\delta_{min}+A)}{2}}{\sin \frac{A}{2}}$

or $\mu = \frac{\sin\left(\frac{51^\circ+60^\circ}{2}\right)}{\sin \frac{60^\circ}{2}}$

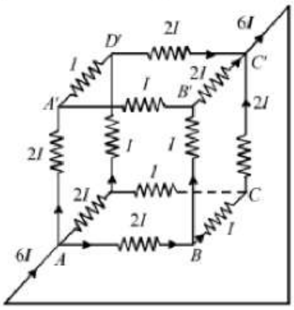
or $\mu = 1.648$

33. i. **Kirchhoffs Ist rule or Junction Rule:** The algebraic sum of electric currents at any junction of electric circuit is equal to zero i.e., $\sum I = 0$

Kirchhoff's IInd rule or Voltage Law: In any closed mesh of electrical circuit, the algebraic sum of emfs of cells and the product of currents and resistances is always equal to zero.

i.e., $\sum E + \sum IR = 0$

ii. a) Let 6I current be drawn from the cell. Since the paths AA', AD and AB are symmetrical, current through them is same. As per Kirchhoff's junction rule, the current distribution is shown in the figure.



Let the equivalent resistance across the combination be R.

E = V_A - V_B = (6I)R

⇒ 6IR = 10 [∵ E = 10 V] ....(i)

Applying Kirchoff's second rule in loop AA'B'C'A

- 2I × 1 - I × 1 - 2I × 1 + 10 = 0

⇒ 5I = 10

⇒ I = 2A

Total current in the network = 6I = 6 × 2 = 12 A

b) From Eq. (i), 6IR = 10

6 × 2 × R = 10

R = $\frac{10}{12}$ = $\frac{5}{6}\Omega$

Section E

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

A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in tesla). The direction of force is determined by the rules of cross product of two vectors. Force is perpendicular to both velocity and magnetic field. Its direction is given as $\vec{v} \times \vec{B}$ if q is positive and opposite of $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.

(i) Magnetic field lines are concentric circular loops in a plane perpendicular to the straight conductor. The centres of the circular magnetic field lines lie on the conductor.

(ii) remains stationary

For stationary electron, $\vec{v}$ = 0

∴ Force on the electron is, $\vec{F}_m = -e(\vec{v} \times \vec{B})$ = 0

(iii) the proton will continue to move with velocity v along the axis

Force on the proton, $\vec{F}_B = e(\vec{v} \times \vec{B})$

Since, $\vec{v}$ is parallel to $\vec{B}$

$\therefore \vec{F}_B = 0$

Hence proton will continue to move with velocity v along the axis of solenoid.

OR

The particle is moving and magnetic field is perpendicular to the velocity.

Magnetic force on the charged particle q is

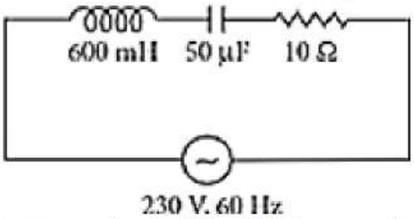
$\vec{F}_m = q(\vec{v} \times \vec{B})$ or $F_m = qvB\sin\theta$

where θ is the angle between $\vec{v}$ and $\vec{B}$.

Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force.

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

In an a.c. circuit, values of voltage and current change every instant. Therefore, the power of an a.c. circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle of a.c. is P = $E_v I_\gamma$. When the circuit is inductive, the average power per cycle is $E_v I_v \cos\phi$



In an a.c. circuit, 600 mH inductor and a 50 μF capacitor are connected in series with 10 Ω resistance. The a.c. supply to the circuit is 230 V, 60 Hz.

(i) Average power transferred per cycle to resistance is $P_v = I_v^2 R$

As $X_L = \omega L = 2\pi\nu L = 2 \times \frac{22}{7} \times 60 \times 0.6$ = 226.28 Ω

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{7}{2\times 22/7\times 60\times 50\times 10^{-6}}$

= 53.03 Ω

Z = $\sqrt{R^2 + (X_L - X_C)}^2$ = $\sqrt{(10)^2 + (226.28 - 53.03)^2}$ = 173.53 Ω

$I_v = \frac{E_v}{Z} = \frac{230}{173.53}$ = 1.32 A

$P_v = I_v^2 R = (1.32)^2 \times 10$ = 17.42 W

(ii) $P_L = E_v I_v \cos\phi$

In a capacitor, phase difference, $\phi = 90^o$

$P_L = E_v I_v \cos 90^\circ$ = zero

(iii) Total power absorbed per cycle $P = P_R + P_C + P_L$ = 17.42 + 0 + 0 = 17.42 W

OR

Energy spent = power × time

= 17.42 × 60 × 60 = 6.2 × 10^4 Joule