Class XII Session 2023-24
Subject - Physics
Sample Question Paper - 7

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 depletion layer in the p-n junction is caused due to **[1]**

a) drift of electrons

b) migration of impurity ions

c) diffusion of carrier ions

d) drift of holes

2. A battery is charged at a potential of 15 V for 8 hours when the current flowing is 10 A. The battery on discharge supplies a current of 5 A for 15 hours. The mean terminal voltage during discharge is 14V. The watt-hour efficiency of the battery is: **[1]**

a) 80 %

b) 87.5 %

c) 90 %

d) 82.5 %

3. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will **[1]**

a) act as a concave lens irrespective of side on which the object lies

b) act as a convex lens only for the objects that lie on its curved side

c) act as a concave lens for the objects that lie on its curved side

d) act as a convex lens irrespective of the side on which the object lies

4. The radius of the coil of a Tangent Galvanometer which has 10 turns is 0.1 m. The current required to produce a deflection of 60° $\left(B_H = 4 \times 10^{-5} T\right)$ is **[1]**

a) 5.6 A

b) 2.6 A

c) 2.1 A

d) 1.1 A

5. Equal charges are given to two conducting spheres of different radii. The potential will **[1]**

a) be more on the bigger sphere

b) be equal on both the spheres

c) be less on the smaller sphere

d) depend on the radii of the sphere

6. The resistance of the coil of ammeter is R. The shunt resistance required to increase its range four fold should have a resistance equal to **[1]**

a) $\frac{R}{3}$

b) $\frac{R}{5}$

c) $\frac{R}{4}$

d) 4R

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. The universal property among all substances is **[1]**

a) ferromagnetism

b) non-magnetism

c) diamagnetism

d) paramagnetism

9. The phenomena which is not explained by Huygens' construction of wavefront is: **[1]**

a) diffraction

b) refraction

c) origin of spectra

d) reflection

10. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of $80.0 \mu \mathrm{C/m}^2$. Find the charge on the sphere. **[1]**

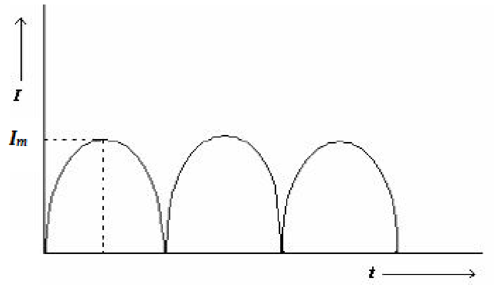
a) $1.25 \times 10^{-3} \mathrm{C}$

b) $1.55 \times 10^{-3} \mathrm{C}$

c) $1.45 \times 10^{-3} \mathrm{C}$

d) $1.35 \times 10^{-3} \mathrm{C}$

11. The output current I versus time (t) curve of a full wave rectifier is shown in the figure. The average value of the output current in this case is **[1]**



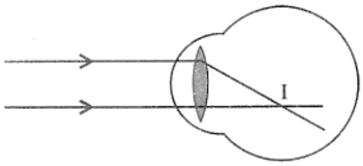
a) I_m

b) $\frac{2I_m}{\pi}$

c) $\frac{I_m}{\pi}$

d) Zero

12. In the figure, the image is formed of retina. The eye has: **[1]**



Human eye

a) myopia

b) colour blindness

c) hypermetropia

d) astigmatism

13. **Assertion (A):** In process of photoelectric emission, all emitted electrons do not have same kinetic energy. **[1]**
Reason (R): If radiation falling on the photosensitive surface of metal consists of different wavelengths then energy acquired by electrons absorbing photons of different wavelengths shall be different.

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 (A):** Two protons placed at different distances, between the plates of a parallel plate capacitor experience the same force. **[1]**
Reason (R): The electric field between the plates of the capacitor is constant.

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.

15. **Assertion (A):** Thin film such as soap bubbles or a thin layer of oil on water show beautiful colors when illuminated by white light. **[1]**
Reason (R): It happens due to the interference of light reflected from the upper and lower face of the thin film.

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):** Faraday's laws are consequences of the conservation of energy. **[1]**
Reason (R): In a purely resistive AC circuit, the current lags behind the emf in phase.

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.

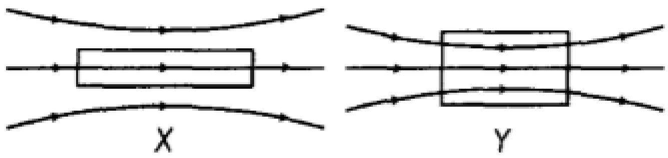
Section B

17. Electromagnetic waves with wavelength **[2]**

i. λ_1, are used to treat muscular strain
ii. λ_2, are used by a FM radio station for broadcasting.
iii. λ_3, are used to detect fracture in bones
iv. λ_4, are absorbed by the ozone layer of the atmosphere.

Identify and name the part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in decreasing order of magnitude.

18. When two materials are placed in an external magnetic field, the behaviour of magnetic field lines is as shown in the figure. Identify the magnetic nature of each of these two materials. **[2]**



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

20. In a Geiger-Marsden experiment, calculate the distance of the closest approach to the nucleus of Z = 80, when an α-particle of 8 MeV energy impinges on it before it comes to momentarily rest and reverses its direction. How will the distance of the closest approach be affected when the kinetic energy of the α-particle is doubled? **[2]**

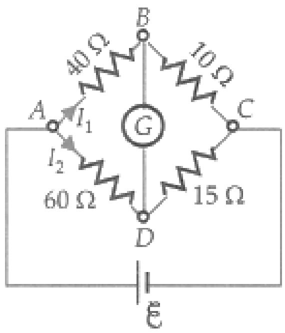
21. Write the expression for the magnetic force $\vec{F}$ acting on a charged particle q moving with velocity v in the presence of the magnetic field $\vec{B}$ in a vector form. Show that no work is done and no change in the magnitude of the velocity of the particle is produced by this force. Hence, define the unit of the magnetic field. **[2]**

OR

An electron is moving at 10^6 ms^{-1} in a direction parallel to a current of 5 A, flowing through an infinitely long straight wire, separated by a perpendicular distance of 10 cm in air. Calculate the magnitude of the force experienced by the electron.

Section C

22. Calculate the ratio of the heat produced in the four arms of the Wheatstone bridge shown in Figure. **[3]**

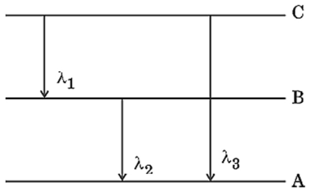


23. Write briefly the two important processes that occur during the formation of p-n junction. With the help of necessary diagrams, explain the terms depletion region and barrier potential. **[3]**

24. State how in a photo-cell, the work function of the metal influences the kinetic energy of emitted electrons. **[3]**
    a. If the intensity of incident radiation is doubled, what changes occur in
        i. the stopping potential and
        ii. the photoelectric current?
    b. If the frequency of the incident radiation is doubled, what changes occur in the
        i. stopping potential and
        ii. photoelectric current?

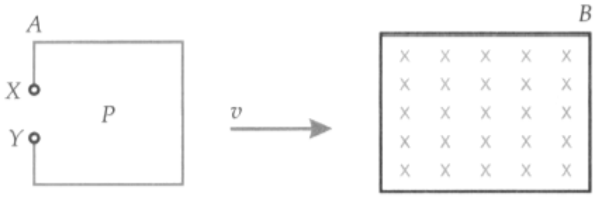
25. Calculate the energy generated in kilowatt hours, when 100 g of 3 Li are converted into $^{4}_{2}He$ by proton bombardment. Given: mass of $^{7}_{3}Li$ atom = 7.0183 amu, mass of 4 He atom = 4.0040 amu, mass of $^{1}_{1}H$ atom = 1.0081 amu. **[3]**

26. **[3]**
    a. State Bohr's quantization condition for defining stationary orbits.
    b. Use the energy level diagram shown below to obtain the relation between three wavelengths λ_1, λ_2 and λ_3 emitted due to the transition of electron from the energy states C and B.



27. Using Huygen's principle, for a plane wavefront incident on a plane reflecting surface, draw the reflected wavefront. Hence prove laws of reflection. **[3]**

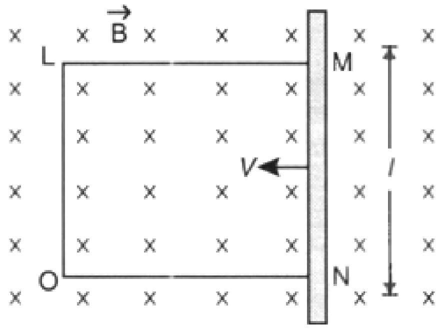
28. A rectangular coil P is moved from a point A to another point B with uniform velocity 'v' through a region of a uniform magnetic field acting normally inwards as shown in the figure. Show graphically (i) the variation of magnetic flux associated with the coil with time, (ii) the variation of induced emf across points X and Y of the coil with time. **[3]**



Explain the nature of variation in magnetic flux as represented by the graph in the first case.

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.

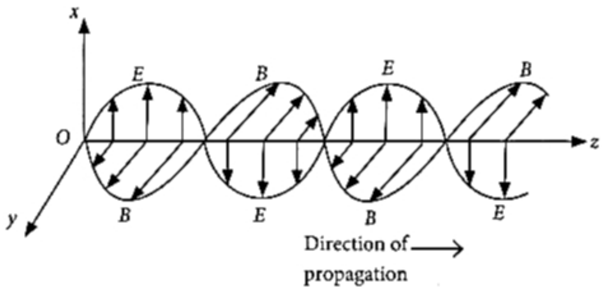


When the arm M N of length of 20 cm is moved towards left with a velocity of 10 ms^{-1}, calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.

Section D

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

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(i) Magnetic field in a plane electromagnetic wave is given by $\vec{B} = B_0 \sin(kx + \omega t)\hat{j}$ T

Expression for corresponding electric field will be (Where c is speed of light.)

a) $\vec{E}$ = B_0c sin (kx + ωt) $\hat{k}$ V/m

b) $\vec{E}$ = -B_0c sin (kx - ωt) $\hat{k}$ V/m

c) $\vec{E}$ = -B_0c sin (kx + ωt) $\hat{k}$ V/m

d) $\vec{E}$ = $\frac{B_0}{c}$ sin (kx + ωt) $\hat{k}$ V/m

(ii) The electric field component of a monochromatic radiation is given by $\vec{E}$ = 2$E_0\hat{i}$ cos kz cos ωt. Its magnetic field $\vec{B}$ is then given by

a) $-\frac{2E_0}{c}\ \hat{j}$ sin kz sin ωt

b) $\frac{2E_0}{c}\ \hat{j}$ sin kz sin ωt

c) $\frac{2E_0}{c}\ \hat{j}$ sin kz cos ωt

d) $\frac{2E_0}{c}\ \hat{j}$ cos kz cos ωt

(iii) A plane em wave of frequency 25 MHz travels in a free space along x-direction. At a particular point in space and time, E = (6.3 $\hat{j}$) V/m. What is magnetic field at that time?

a) 0.089 μT

b) 0.124 μT

c) 0.021 μT

d) 0.095 μT

OR

A plane electromagnetic wave travels in free space along x-axis. At a particular point in space, the electric field along y-axis is 9.3 V m^{-1}. The magnetic induction (B) along z-axis is

a) 3.1×10^{-8} T

b) 3×10^{-5} T

c) 3×10^{-6} T

d) 9.3×10^{-6} T

(iv) A plane electromagnetic wave travelling along the x-direction has a wavelength of 3 mm. The variation in the electric field occurs in the y-direction with an amplitude 66 V m^{-1}. The equations for the electric and magnetic fields as a function of x and t are respectively

a) $E_y = 11\cos 2\pi \times 10^{11}\left(t-\frac{x}{c}\right)$,
$B_y = 11 \times 10^{-7}\cos 2\pi \times 10^{11}\left(t-\frac{x}{c}\right)$

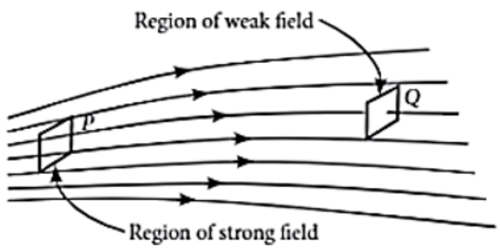
b) $E_y = 66\cos 2\pi \times 10^{11}\left(t-\frac{x}{c}\right)$,
$B_z = 2.2 \times 10^{-7}\cos 2\pi \times 10^{11}\left(t-\frac{x}{c}\right)$

c) $E_x = 33\cos \pi \times 10^{11}\left(t-\frac{x}{c}\right)$,
$B_x = 11 \times 10^{-7}\cos \pi \times 10^{11}\left(t-\frac{x}{c}\right)$

d) $E_y = 33\cos \pi \times 10^{11}\left(t-\frac{x}{c}\right)$,
$B_z = 1.1 \times 10^{-7}\cos \pi \times 10^{11}\left(t-\frac{x}{c}\right)$

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

Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in the given figure, the electric field at P is stronger that at Q.



(i) Electric lines of force are curved

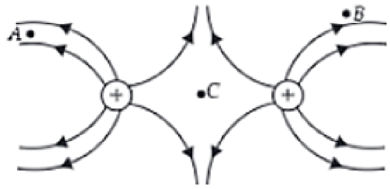
a) in the field of a single positive or negative charge

b) in the field of two like charges

c) both in the field of two equal and opposite charges and in the field of two like charges

d) in the field of two equal and opposite charges

(ii) The figure below shows the electric field lines due to two positive charges. The magnitudes E_A, E_B and E_C of the electric fields at points A, B and C respectively are related as



a) $E_A = E_B > E_C$
b) $E_A > E_B = E_C$
c) $E_A > E_B > E_C$
d) $E_B > E_A > E_C$

(iii) Electric lines of force about a positive point charge are

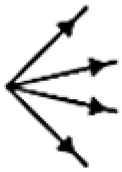
a) parallel straight lines
b) circular clockwise
c) radially outwards
d) radially inwards

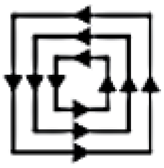
(iv) Which of the following is false for electric lines of force?

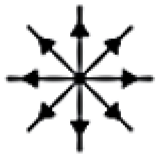
a) They are parallel and equally spaced in a region of uniform electric field.
b) They are always perpendicular to the surface of a charged conductor.
c) They always form closed loops.
d) They always start from positive charges and terminate on negative charges.

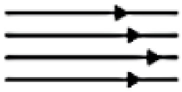
OR

Which one of the following pattern of electric line of force in not possible in filed due to stationary charges?

a) 

b) 

c) 

d) 

Section E

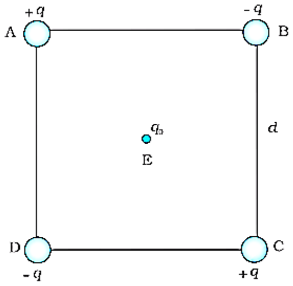
31. a. Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and eyepiece lenses in order to have large magnifying power and high resolution of the telescope. **[5]**

b. A compound microscope has an objective of focal length 1.25 cm and eyepiece of focal length 5 cm. A small object is kept at 2.5 cm from the objective. If the final image formed is at infinity, find the distance between the objective and the eyepiece.

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 $\theta = 0$, 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. Four charges are arranged at the corners of a square ABCD of side d, as shown in fig. **[5]**



a. Find the work required to put together this arrangement.

b. A charge q_0 is brought to the center E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?

OR

Calculate the potential energy of a point charge –q placed along the axis due to a charge +Q uniformly distributed along a ring of radius R. Sketch P.E. as a function of axial distance z from the centre of the ring. Looking at the graph, can you see what would happen if -q is displaced slightly from the centre of the ring (along the axis)?

33. An LC circuit contains a 20 mH inductor and a $50\mu F$ capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0. **[5]**

a. What is the total energy stored initially? Is it conserved during LC oscillations?

b. What is the natural frequency of the circuit?

c. At what time is the energy stored

i. completely electrical (i.e. stored in the capacitor)?

ii. completely magnetic (i.e. stored in the inductor)?

d. At what times is the total energy shared equally between the inductor and the capacitor?

e. If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

OR

A 25.0 pF capacitor, a 0.10 H inductor and a 25.0 ohm resistor are connected in series with an ac source whose emf is E = 310 sin 314t.

i. What is the frequency of the emf?

ii. Calculate

a. the reactance of the circuit

b. the impedance of the circuit and

c. the current in the circuit.

Solution

Section A

1.

(c) diffusion of carrier ions

Explanation: diffusion of carrier ions

2.

(b) 87.5 %

Explanation: Input energy when the battery is charged

= VIt = 15 V $\times$ 10 A $\times$ 8 h = 1200 Wh

The energy released when the battery is discharged

= 14 V $\times$ 5 A $\times$ 15 h = 1050 Wh

Watt-hour efficiency of the battery

= $\frac{\text{Energy output}}{\text{Energy input}} = \frac{1050}{1200}$ = 0.875 = 87.5 %

3.

(d) act as a convex lens irrespective of the side on which the object lies

Explanation:

The relation between focal length f, the refractive index of the given material μ, R_1 and R_2 is known as lens maker's formula and it is $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$R_1 = \infty, R_2 = -R$

$f = \frac{R}{(\mu-1)}$

Here, R = 20 cm, μ = 1.5. On substituting the values, we get

$f = \frac{R}{\mu-1} = \frac{20}{1.5-1} = 40\text{cm}$

As f > 0 means converging nature. Therefore, the lens act as a convex lens irrespective of the side on which the object lies.

4.

(d) 1.1 A

Explanation: When no current is passed through the coil, the magnetic needle is influenced only by B_H. When current I is passed, there is a magnetic field B along the axis of the coil, perpendicular to B_H. The magnetic needle comes to rest at an angle with B_H, such that,

$B = B_H \tan\theta$

Also magnetic field at centre of coil, B = $\mu_o NI/2R$

Hence $I = \frac{2RB_H tan\theta}{\mu_o N} = \frac{2\times0.1\times4\times10^{-5}\times\sqrt{3}}{4\pi\times10^{-7}\times10} = 1.1A$

5.

(d) depend on the radii of the sphere

Explanation: As potential on the surface of conducting sphere is given by

V = $\frac{q}{4\pi\epsilon_0 R}$ thus if q is same for both the sphere

V α $\frac{1}{R}$.

6. **(a)** $\frac{R}{3}$

Explanation: Shunt Resistance, $S = \frac{I_g}{I-I_g}R$

To increase the range of ammeter by n times, l = nl_g

Thus, the resistance of the shunt becomes,
Shunt Resistance, $S = \frac{R}{n-1} = \frac{R}{4-1} = \frac{R}{3}$

7.

(c) 30 Wb

Explanation: $\Delta\phi = M\Delta i = 1.5 \times 20 = 30\text{Wb}$

8.

(c) diamagnetism

Explanation: Diamagnetism is a universal property among all substances.

9.

(c) origin of spectra

Explanation: Huygen's construction of wavefront does not explain the phenomena of origin of spectra.

10.

(c) $1.45 \times 10^{-3}\text{C}$

Explanation: $r = \frac{d}{2} = \frac{2.4}{2} = 1.2m$

Surface charge density is :-

$\sigma = 80 \times 10^{-6} C/m^2$

$\sigma = \frac{q}{4\pi r^2}$

$80 \times 10^{-6} = \frac{q}{4 \times 3.14 \times (1.2)^2}$

$q = 1.447 \times 10^{-3} C \approx 1.45 \times 10^{-3} C$

11.

(b) $\frac{2I_m}{\pi}$

Explanation: Current waveform can be represented as, $I = I_m sin\omega t$ for $0 \leq \omega t \leq 2\pi$, where I_m = max load current

Average current, $I_{DC} = \frac{I_m}{\pi} \int_0^\pi \sin(\omega t)\, \mathrm{d}(\omega t)$

$= \frac{I_m}{\pi} [-cos(\omega t)]_0^\pi = \frac{2I_m}{\pi}$

12. **(a)** myopia

Explanation: myopia

13.

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

Explanation: Both statement are true; but even it radiation of single wavelength is incident on photosensitive surface, electrons of different KE will be emitted.

14. **(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.

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.

(c) A is true but R is false.

Explanation: Faraday's laws of electromagnetic induction are consequences of the conservation of energy. It involves only the transformation of energy into electrical energy. In a purely resistive circuit, current and voltage are in the same phase.

Section B

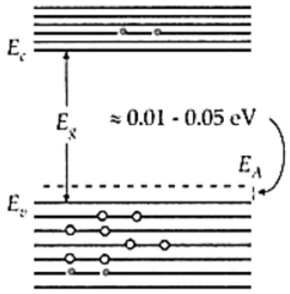
17. i. λ_1 belongs to Infrared radiations.
ii. λ_2 belongs to UHF radiowaves.
iii. λ_3 belongs to X-rays.
iv. λ_4 belongs to ultraviolet rays.

The arrangement of wavelengths in decreasing order of magnitude are $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$.

18. Material X is a paramagnetic substance. When a specimen of a paramagnetic substance is placed in a magnetising field, the lines of force are feebly attracted by the material and for that reason, only a few of them prefer to pass through the specimen rather than through air.

Material Y is a ferromagnetic substance. These are the substances in which a strong magnetism is produced in the same direction as the applied magnetic field. Magnetic field lines are strongly attracted by these kinds of materials. For that reason, most of the lines prefer to move through these materials which exhibit highly concentrated lines of force.

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



20. Given, Z = 80,

alpha particle energy = K = 8 MeV = 8×10^6 eV = $8 \times 10^6 \times 1.6 \times 10^{-19}$ J

$\because$ Energy, $K = \frac{(Ze)(2e)}{4\pi\varepsilon_0 r_0}$

Radius of closest approach,

$\Rightarrow \quad r_0 = 2Ze^2/4\pi\varepsilon_0(K)$

$\Rightarrow \quad r_0 = \frac{9\times10^9\times2\times80\times\left(1.6\times10^{-19}\right)^2}{8\times10^6\times1.6\times10^{-19}}$

$\Rightarrow \quad r_0 = \frac{9\times10^9\times2\times80\times\left(1.6\times10^{-19}\right)^2}{12.8\times10^{-13}}$

$\Rightarrow \quad r_0 = 2.88 \times 10^{-14}\text{m}$

As, $r_0 \propto (1/K)$

If KE gets doubled, distance of closest approach reduces to half.

21. The required expression is $\vec{F} = q(\vec{v} \times \vec{B})$

The magnetic force, at all instants, is, therefore, perpendicular to the instantaneous direction of $\vec{v}$, which is also the instantaneous direction of displacement ($\overrightarrow{ds}$).

Since F is perpendicular to ($\overrightarrow{ds}$), at all instants, work done =($\vec{F}.\overrightarrow{ds}$) as $\cos90^0$ is zero.

There being no work done, there can be no change in the magnitude of $\vec{v}$.

From $\vec{F} = q(\vec{v} \times \vec{B})$ we get

$|\vec{F}|$ = qvB sin θ

$\therefore$ F = B if q = 1, v = 1 and $\theta = \frac{\pi}{2}$

Hence, the magnetic field, $\vec{B}$ at a point equals one tesla if a charge of one coulomb, moving with a velocity of 1 m/s, along a direction perpendicular to the direction of $\vec{B}$, experiences a force of one newton.

OR

The magnetic field of the straight wire carrying a current of 2 A, at a distance of 10 cm or 0.1 m from it is

B = $\frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times5}{2\pi\times0.1}$ = 10^{-5} T

This field acts perpendicular to the direction of the electron. So magnetic force on the electron is

F = qvB sin 90^o

= $1.6 \times 10^{-19} \times 10^6 \times 10^{-5} \times 1$

= 1.6×10^{-18} N

Section C

22. As $\frac{40\Omega}{10\Omega} = \frac{60\Omega}{15\Omega}$

The bridge is balanced.

P.D. across AB = P.D. across AD

or 40 I_1 = 60 I_2

or $\frac{I_1}{I_2} = \frac{60}{40}$ = 1.5

or $I_1 = 1.5 I_2$

Heats produced in time t in different arms of Wheatstone bridge are

$H_{Ab} = I_1^2$ Rt = $(1.5 I_2)^2 \times 40 \times$ t = 90 I_2^2 t

$H_{BC} = I_1^2 \times 10 \times$ t = $(1.5 I_2)^2 \times 10 \times$ t = 22.5 I_2^2 t

$H_{Ad} = I_2^2 \times 60 \times$ t = 60 I_2^2 t

$H_{DC} = I_2^2 \times 15 \times$ t = 15 I_2^2 t

Hence the ratio of the heats produced in the four arms is

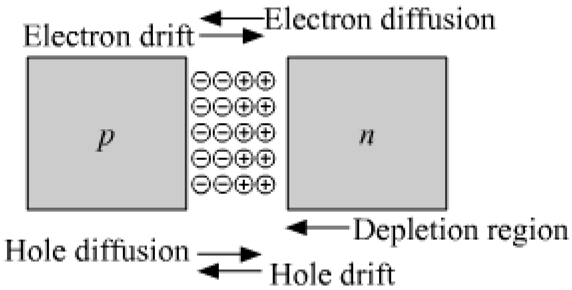
$H_{AB} : H_{BC} : H_{AD} : H_{DC}$

= 90 I_2^2 t : 22.5 I_2^2 t : 60 I_2^2 t : 15 I_2^2 t

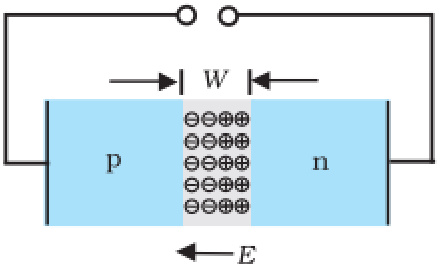
= 90 : 22.5 : 60 : 15 = 6 : 1.5 : 4 : 1

23. Diffusion and drift processes take place during the formation of the p-n junction.

The region near the junction which is free from the charge carriers is called the **depletion layer.** It is formed due to the combination of electrons and holes during the diffusion process due to the difference in the density of charge carriers in p and n semiconductors. It develops a layer of positive ions on n-side and negative ions on the p-side.



The positive ions and negative ions develops potential difference across the junction and an internal electric field E, directed from n-side top-side. The potential difference gets developed due to positive and negative ions across the depletion layer is called the **potential barrier**. It stops the diffusion process. This potential barrier reduces in forward biased mode and increases in reverse biased mode.



24. K.E. of the emitted electrons,

$K_{\max} = \frac{1}{2}mv_{\max}^2 = h\nu - W_0$

Higher is the work function (W_0) of the metal, the lesser will be the K.E. of the emitted electrons.

a. If the intensity of the radiation is doubled,
    i. stopping potential remains unchanged and
    ii. the photoelectric current gets doubled.
b. If the frequency of the incident radiation is doubled,
    i. the stopping potential gets doubled and
    ii. the photoelectric current remains unaffected.

25. Here, E = ?

The nuclear reaction is

${}_3Li^7 + {}_1H^1 \rightarrow 2.2He^4 + Q$

Mass defect, $\Delta m = 7.0183 + 1.0081 - 2 \times 4.0040$

= 0.0184 a.m.u.

Q = 0.00184 $\times$ 931MeV = 17.13 MeV

Number of nuclei in 100g of ${}_3Li^7$

$= \frac{6.023\times10^{23}}{7} \times 100$

= 8.6 $\times$ 10^{24} = 8.6 $\times$ 10^{24}

Total energy released when 100 g of $_3Li^7$ is converted into Helium

$= 17.13 \times 8.6 \times 10^{24}$ MeV

$= 17.13 \times 8.6 \times 1.6 \times 10^{-13} \times 10^{24}$J

As 1kWh = 3.6×10^6J

$\therefore E = \frac{17.13 \times 8.6 \times 1.6 \times 10^{11}}{3.6 \times 10^6} kWh$

E = 6.5475×10^6kWh

26. According to Bohr's quantization condition for defining stationary orbits is only those orbits around the nucleus are allowed and stable for electron to revolve for which the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$ where h is Planck's constant

$\mathrm{mvr} = \frac{nh}{2\pi}$

$\frac{1}{\lambda_1} = R\left(\frac{1}{n_B^2} - \frac{1}{n_C^2}\right)$ ...(i)

$\frac{1}{\lambda_2} = R\left(\frac{1}{n_A^2} - \frac{1}{n_B^2}\right)$ ...(ii)

$\frac{1}{\lambda_3} = R\left(\frac{1}{n_A^2} - \frac{1}{n_C^2}\right)$ ...(iii)

From (i)

$\frac{R}{n_B^2} = \frac{1}{\lambda_1} + \frac{R}{n_C^2}$

Substituting in (ii)

$\frac{1}{\lambda_2} = \frac{R}{n_A^2} - \frac{1}{\lambda_1} - \frac{R}{n_C^2}$

$\frac{1}{\lambda_2} + \frac{1}{\lambda_1} = R\left(\frac{1}{n_{A^2}} - \frac{1}{n_{C^2}}\right)$

$\frac{1}{\lambda_2} + \frac{1}{\lambda_1} = \frac{1}{\lambda_3}$

27. Consider a plane Mirror m_1 m_2

Let AB is the plane wavefront incident on the mirror such that ∠BAA' = ∠i

1, 2, 3 are corresponding incident rays perpendicular to AB.

Let the secondary wavelet from B strike mirror at A' in t seconds. As according to Huygen's principle

$A^{'}B^{'}$ acts as reflected wavefront.

BA' = c × t

c = velocity of light

similarly secondary wavelet travel in t time from A.

AB' = c × t

Thus A'B' is the secondary wavefront after t second. Hence A'B' is the true reflected wavefront.

In $\triangle^s$ AA'B and AA'B'

BA' = AB' = c × t

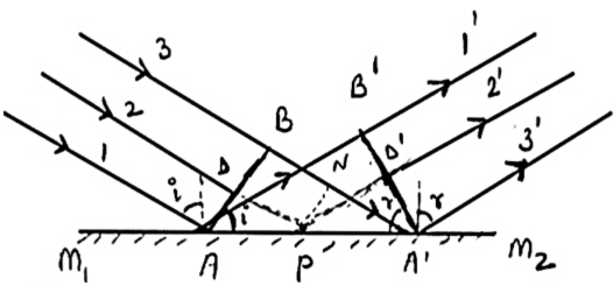
∠B = ∠B' = 90^o

AA' is common and thus $\triangle^s$ are congruent

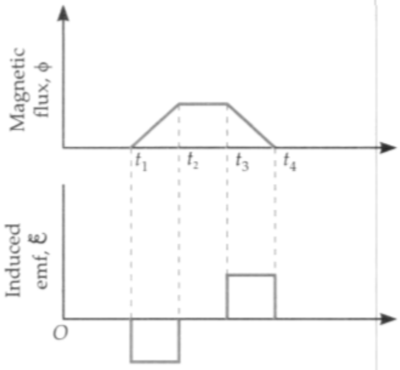
∴ ∠i = ∠r first law of reflection

Also, incident wavefront AB, the reflected wavefront A'B' and reflecting surface m_1m_2 all are perpendicular to the plane of the paper. Therefore, incident ray, normal to the mirror m_1m_2 and reflected ray all lie in the plane of the paper.

This is second law of reflection.



28. The graphs given in the figure show the variation of flux ϕ with time t and induced emf ε with time t, respectively.



Explanation of variation of magnetic time. Magnetic flux is proportional to the coil linked with flux. Initially, the coil lies magnetic field, flux through it is zero. As the field at time t_1 the flux begins to increase. with time. Between times t_2 and t_3, in the magnetic field, so flux remains: After this the flux decreases linearly with reduces to zero at time t_4, when the coil co the magnetic field.

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

$\varepsilon = \frac{-d\phi}{dt} = \frac{-d(\mathrm{B}lx)}{dt}$ = Blv

= 0.5 $\times$ 0.2 $\times$ 10 = 1 V

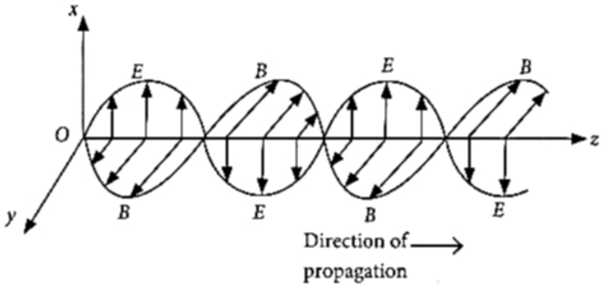
$\therefore$ Current in the arm,

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

Section D

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

A stationary charge produces only an electrostatic field while a charge in uniform motion produces a magnetic field, that does not change with time. An oscillating charge is an example of accelerating charge. It produces an oscillating magnetic field, which in turn produces an oscillating electric fields and so on. The oscillating electric and magnetic fields regenerate each other as a wave which propagates through space.



(i) **(a)** $\vec{E}$ = B_0c sin (kx + ωt) $\hat{k}$ V/m

Explanation: Given : $\vec{B}$ = B_0 sin (kx + ωt)$\hat{j}$T

The relation between electric and magnetic field is, c = $\frac{E}{B}$ or E = cB

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field.

Therefore, the electric field component along z-axis is obtained as $\vec{E}$ = cB_0 sin (kx + ωt) $\hat{k}$ V/m

(ii) **(b)** $\frac{2E_0}{c}$ $\hat{j}$ sin kz sin ωt

Explanation: $\frac{dE}{dz} = -\frac{dB}{dt}$

$\frac{dE}{dz}$ = -2 E_0k sin kz cos ωt = $-\frac{dB}{dt}$

dB = +2 E_0k sin kz cos ωt dt

B = +2 E_0k sin kz $\int$ cos ωt dt = +2 E_0 $\frac{k}{\omega}$ sin kz sin ωt

$\frac{E_0}{B_0} = \frac{\omega}{k} = c$

B = $\frac{2E_0}{c}$ sin kz sin ωt $\therefore$ $\vec{B}$ = $\frac{2E_0}{c}$ sin kz sin ωt $\hat{j}$

E is along y-direction and the wave propagates along x-axis.

$\therefore$ B should be in a direction perpendicular to both x-and y-axis.

(iii) **(c)** 0.021 μT

Explanation: Here, E = 6.3 $\hat{j}$; c = 3 $\times$ 10^8 m/s

The magnitude of B is

$B_z = \frac{E}{c} = \frac{6.3}{3\times10^8}$ = 2.1 $\times$ 10^{-8} T = 0.021 μ T

OR

(a) 3.1 $\times$ 10^{-8} T

Explanation: At a particular point, E = 9.3 V m^{-1}

$\therefore$ Magnetic field at the same point = $\frac{9.3}{3\times10^8}$

= 3.1 $\times$ 10^{-8} T

(iv) **(b)** $E_y = 66\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right), B_z = 2.2 \times 10^{-7}\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

Explanation: Here : E_0 = 66 V m^{-1}, E_y = 66 cos $\omega\left(t - \frac{x}{c}\right)$,

λ = 3 mm = 3 $\times$ 10^{-3} m, k = $\frac{2\pi}{\lambda}$

$\frac{\omega}{k}$ = c $\Rightarrow$ ω = ck = 3 $\times$ 10^8 $\times$ $\frac{2\pi}{3\times10^{-3}}$

or ω = 2π $\times$ 10^{11}

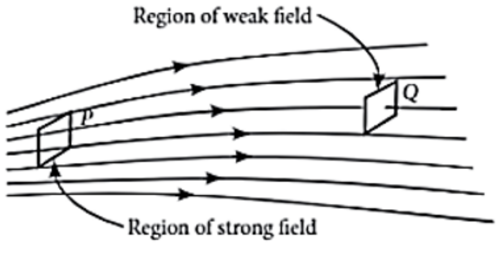
$\therefore$ E_y = 66 cos 2π $\times$ $10^{11}\left(t - \frac{x}{c}\right)$

$B_z = \frac{E_y}{c} = \left(\frac{66}{3\times10^8}\right)\cos 2\pi \times 10^{11}\left(t - \frac{x}{c}\right)$

= 2.2 $\times$ 10^{-7} cos 2π $\times$ $10^{11}\left(t - \frac{x}{c}\right)$

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

Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in the given figure, the electric field at P is stronger that at Q.



(i) **(c)** both in the field of two equal and opposite charges and in the field of two like charges

Explanation: both in the field of two equal and opposite charges and in the field of two like charges

(ii) **(c)** $E_A > E_B > E_C$

Explanation: $E_A > E_B > E_C$

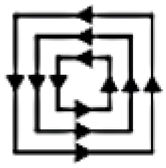
(iii) **(c)** radially outwards

Explanation: radially outwards

(iv) **(c)** They always form closed loops.

Explanation: Electric lines of force do not form any closed loops.

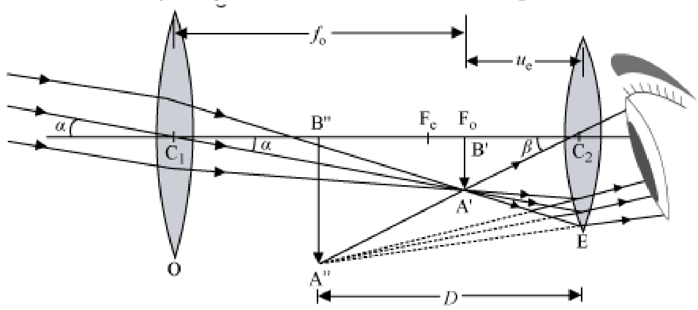
OR

(b) 

Explanation: Electric field lines can't be closed.

Section E

31. a. Consider the ray diagram of Astronomical telescope.



When the final image is formed at the least distance of distinct vision,

Magnifying power, $M=\frac{\beta}{\alpha}$

Since α and β are small, we have:

$\therefore M=\frac{\tan\beta}{\tan\alpha}$ ...(i)

In $\Delta \mathrm{A'B'C_2}, \tan\beta=\frac{\mathrm{A'B'}}{\mathrm{C_2B'}}$

In $\Delta A'B'C_1, \tan\alpha=\frac{\mathrm{A'B'}}{\mathrm{C_1B'}}$

From equation (i), we get:

$M=\frac{\mathrm{A'B'}}{\mathrm{C_2B'}}\times\frac{\mathrm{C_1B'}}{\mathrm{A'B'}}$

$\Rightarrow M=\frac{C_1B'}{C_2B'}$

Here, $\mathrm{C_1B'}=+f_0$

$\Rightarrow \mathrm{C_2B'}=-u_\mathrm{e}$

$\Rightarrow M=\frac{f_0}{-u_\mathrm{e}}$ ...(ii)

Using the lens equation $\left(\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\right)$ for the eyepieces, we get,

$\frac{1}{-D}-\frac{1}{-u_\mathrm{e}}=\frac{1}{f_\mathrm{e}}$

$-\frac{1}{D}+\frac{1}{u_\mathrm{e}}=\frac{1}{f_\mathrm{e}}$

$\Rightarrow \frac{1}{u_\mathrm{e}}=\frac{1}{f_\mathrm{e}}+\frac{1}{D}$

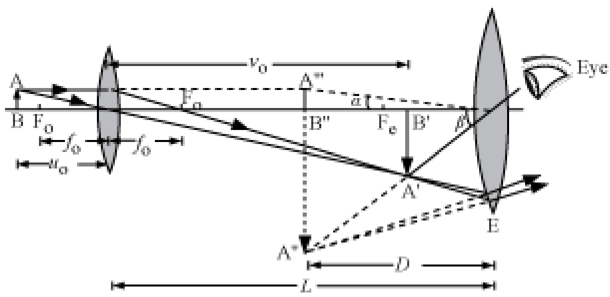
$\Rightarrow \frac{f_0}{u_e}=\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$

$\Rightarrow \frac{-f_0}{u_\mathrm{e}}=\frac{-f_0}{f_\mathrm{e}}\left(1+\frac{f_\mathrm{e}}{D}\right)$

or $M=-\frac{f_0}{f_\mathrm{e}}\left(1+\frac{f_\mathrm{e}}{D}\right)$

In order to have a large magnifying power and high resolution of the telescope, its objective lens should have a short length.

b.



Distance between the objective and the eyepiece, L = $v_0+|u_e|$

To find v_0, we have:

u_0 = -2.5 cm and f_0 = 1.25 cm

Now, $-\frac{1}{u_0}+\frac{1}{v_0}=\frac{1}{f_0}$

or v_0 = 2.5 cm

To find u_e, we have:

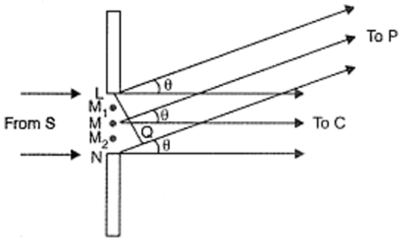
$v_e=\infty$ and f_e = 5 cm

Calculating using the same formula as above, we get:

u_e = -5 cm

$\therefore$ L = 2.5 + 5 = 7.5 cm

OR

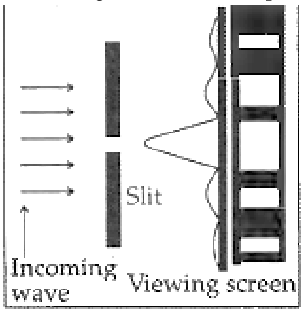
i. 

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. a. Since the work done depends on the final arrangement of the charges, and not on how they are put together, we calculate work needed for one way of putting the charges at A, B, C and D. Suppose, first the charge +q is brought to A, and then the charges –q, +q, and -q are brought to B, C, and D, respectively. The total work needed can be calculated in steps:

i. Work needed to bring charge +q to A when no charge is present elsewhere: this is zero.

ii. Work needed to bring –q to B when +q is at A. This is given by (charge at B) $\times$ (electrostatic potential at B due to charge +q at A)

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

iii. Work needed to bring charge +q to C when +q is at A and -q is at B. This is given by (charge at C) $\times$ (potential at C due to charges at A and B

$= +q\left(\frac{+q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{-q}{4\pi\varepsilon_0 d}\right)$

$= \frac{-q^2}{4\pi\varepsilon_0 d}\left(1 - \frac{1}{\sqrt{2}}\right)$

iv. Work needed to bring -q to D when +q at A, -q at B, and +q at C. This is given by (charge at D) $\times$ (potential at D due to charges at A, B, and C)

$= -q\left(\frac{+q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{q}{4\pi\varepsilon_0 d}\right)$

$= \frac{-q^2}{4\pi\varepsilon_0 d}\left(2 - \frac{1}{\sqrt{2}}\right)$

Add the work done in steps (i), (ii), (iii), and (iv). The total work required is

$= \frac{-q^2}{4\pi\varepsilon_0 d}\left\{(0) + (1) + \left(1 - \frac{1}{\sqrt{2}}\right) + \left(2 - \frac{1}{\sqrt{2}}\right)\right\}$

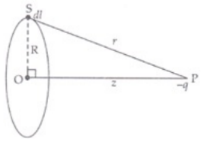
$= \frac{-q^2}{4\pi\varepsilon_0 d}(4 - \sqrt{2})$

The work done depends only on the arrangement of the charges, and not how they are assembled. By definition, this is the total electrostatic energy of the charges.

b. The extra work necessary to bring a charge q_0 to point E when the four charges are at A, B, C, and D is $q_0 \times$ (electrostatic potential at E due to the charges at A, B, C, and D). The electrostatic potential at E is clearly zero since potential due to A and C is cancelled by that due to B and D. Hence, no work is required to bring any charge to point E. Also, it can be said that the work done over a closed surface is zero. (charges are opposite in corners so work done during one cycle cancel out by another cycle) hence work done is zero.

OR

Let us consider a ring of radius R having charge +Q distributed uniformly over the ring. Also a point P at distance z on its axis passing through centre O and perpendicular to plane of
ring.



Again consider an element of ring at S of length dl having charge dq and SP is equal to r. Then potential energy due to element dl at P. If dq is charge on element dl of ring

$dV = \frac{-k\alpha lq}{r}$, where $k = \frac{1}{4\pi e_0}$ and as Q is positive charge so potential due to dq charge will be negative.

Charge on 2πR length of ring = Q

Charge on dl length of ring dq = $\frac{Q}{2\pi R}dl$

So potential due to element dl at P

$dV = \frac{-k.Q \cdot dl}{2\pi Rr}$

$\because$ dW = dV.q and r = $\sqrt{R^2 + z^2}$

So $\mathrm{dW} = \frac{-kQqdl}{2\pi R\sqrt{R^2+z^2}}$

Integrating both sides, over a ring, we have

$\int_0^W dW = -\int_0^{2\pi R} \frac{kqQdl}{2\pi R\sqrt{R^2+z^2}}$

$W = -\frac{kqQ2\pi R}{2\pi RR\sqrt{1+\frac{z^2}{R^2}}}$

This work done converts into P.E. at P, so

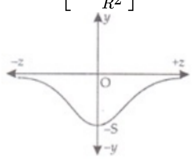
P.E., $V = \frac{-Qq}{4\pi\varepsilon_0 R\sqrt{1+\frac{z^2}{R^2}}}$

Let $\frac{Qq}{4\pi\varepsilon_0 R} = S$ (a new constant)

$V = \frac{-S}{\left[1+\frac{z^2}{R^2}\right]^{1/2}}$

At z = -∞

$V_z = \frac{-S}{\left[1+\frac{z^2}{R^2}\right]^{1/2}}$



$\because$ z >>> R

$\therefore$ z^2 >>> R^2

$\left(1 + \frac{z^2}{R^2}\right)^{1/2} = \infty$

$\therefore V_{-z} = \frac{-S}{\infty} \to 0$

$V_{-Z} \to 0^{\infty}$

$V_{+z} \to 0$

At z = 0

V = -S

IF charge −q is displaced slightly from the center of the ring along the axis of the ring, and left the charge would perform oscillations. However, by just looking at the graph, we cannot come to a firm conclusion about the nature of these oscillations.

33. a. Total initial energy,

$E = \frac{Q_0^2}{2C} = \frac{10^{-2} \times 10^{-2}}{2 \times 50 \times 10^{-6}}$ = 1 J

This energy shall remain conserved in the absence of resistance.

b. Angular frequency, $\omega = \frac{1}{\sqrt{LC}}$

$= \frac{1}{(20 \times 10^{-3} \times 50 \times 10^{-6})^{1/2}}$

= 10^3 $rads^{-1}$

$Thus, f = \frac{10^3}{2\pi} = 159 Hz$

c. $Q = Q_0 \cos \omega t$

Or $Q = Q_0 \cos \frac{2\pi}{T} t$, where $T = \frac{1}{f} = \frac{1}{159} s$ = 6.3 ms

Energy stored is completely electrical at t = 0, T/2, 3T/2 . . .

Electrical energy is zero i.e. energy stored is completely magnetic at

$t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \ldots$

d. At $t = \frac{T}{8}, \frac{3T}{8}, \frac{5T}{8}, \ldots$, the total energy is shared equally between the inductor and the capacitor. As,

$\because Q = Q_0 \cos \frac{\omega T}{8} = Q_0 \cos \frac{\pi}{4} = \frac{Q_0}{\sqrt{2}}$

$\therefore$ Electrical energy $= \frac{Q^2}{2C} = \frac{1}{2} \frac{Q_0^2}{2C}$, which is half of the total energy.

e. R damps out the LC oscillations eventually. The whole of the initial energy 1.0 J is eventually dissipated as heat.

OR

Given, C = 25 pF = 25 $\times$ 10^{-6} F, L = 0.10 H, R = 25.0 ohm, E_0 = 310 V

i. E = 310 sin 314t

Comparing with the equation E = E_0 sin ωt

ω = 314

$2\pi f$ = 314

Frequency, f = $\frac{314}{2\pi}$ = 50 Hz

ii. a. X_L= $2\pi f L$ = 2 $\times$ 3.14 $\times$ 50 $\times$ 0.10 = 2 $\times$ 3.14 $\times$ 5 = 31.4 ohm

X_C = $\frac{1}{2\pi f C}$

$= \frac{1}{2 \times 3.14 \times 50 \times 25 \times 10^{-6}}$ = 127.4 ohm

Thus the reactance of the circuit is,

X_C - X_L = 127.4 - 31.4 = 96 ohm

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

Z = $\sqrt{(25)^2 + (96)^2}$ = 99.2 ohm

c. Current, I = $\frac{E_{rms}}{Z}$

Now, E_{rms} = $\frac{E_o}{\sqrt{2}}$

Thus, I = $\frac{310}{\sqrt{2} \times 99.2}$ = 2.21 A