Class XII Session 2025-26
Subject - Physics
Sample Question Paper - 2

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. Which of the following is the weakest kind of bonding in solids? **[1]**

a) Ionic
b) Metallic
c) Van der Waals
d) Covalent

2. In a hydrogen discharge tube, the number of protons drifting across a cross section per second is 1.0×10^{18}, while the number of electrons drifting in the opposite direction across the same cross section is 2.7×10^{18} per second. Find the current flowing in the tube: **[1]**

a) 3.420 A
b) 0.592 A
c) 5.092 A
d) 0.342 A

3. How will the image formed by a convex lens be affected if the central portion of the lens is wrapped in a black paper? **[1]**

a) Central portion of the image will be absent
b) Full image will be formed but will be less bright
c) Two images will be formed
d) No image is formed by the remaining portion of the lens

4. Magnetism in substances is caused by **[1]**

a) orbital motion of electrons only
b) hidden magnets

c) spin motion of electrons only

d) due to spin and orbital motions of electrons both

5. The electric potential at a point (x, y, z) is given by V = -x^2y - xz^3 + 4. The electric field $\vec{E}$ at that point is: **[1]**

a) $\vec{E} = \hat{i}2xy + \hat{j}\left(x^2 + y^2\right) + \hat{k}\left(3xz - y^2\right)$

b) $\vec{E} = \hat{i}\left(2xy - z^3\right) + \hat{j}xu^2 + \hat{k}3z^2x$

c) $\vec{E} = \hat{i}z^3 + \hat{j}xyz + \hat{k}z^2$

d) $\vec{E} = \hat{i}\left(2xy + z^3\right) + \hat{j}x^2 + \hat{k}3xz^2$

6. When a charged particle enters in a uniform magnetic field, its kinetic energy. **[1]**

a) remains constant

b) decreases

c) increases

d) becomes zero

7. The self inductance L of a solenoid of length l and area of crosssection A, with a fixed number of turns N increases as **[1]**

a) Both l and A decrease

b) l increases and A decreases

c) l and A increase

d) l decreases and A increases

8. According to Gauss's law for magnetism, **[1]**

a) $\int \vec{B}.\overrightarrow{ds} = \mu_0$

b) $\int \vec{B}.\overrightarrow{ds} = 0$

c) $\oint \vec{B}.\overrightarrow{ds} = \mu_0$

d) $\oint \vec{B}.\overrightarrow{ds} = 0$

9. The penetration of light into the region of geometrical shadow is called **[1]**

a) Diffraction

b) Refraction

c) Polarisation

d) Interference

10. A ring of charge with radius 0.5 m has $0.002\pi\, m$ gap. If the ring carries a charge +1C, the electric field at the center is: **[1]**

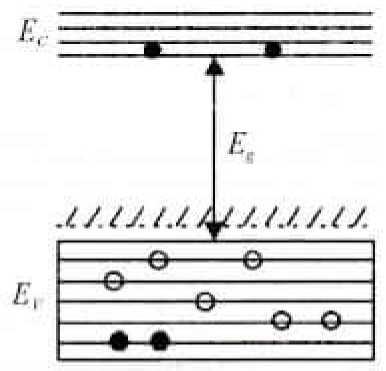
a) $7.5 \times 10^7 NC^{-1}$

b) $6.5 \times 10^7 NC^{-1}$

c) $6.2 \times 10^7 NC^{-1}$

d) $7.2 \times 10^7 NC^{-1}$

11. In the energy band diagram of a material as given below, the open circles and filled circles denote holes and electrons respectively. The material is a/an **[1]**



a) insulator

b) p-type semiconductor

c) n-type semiconductor

d) metal

12. The magnifying power of the telescope can be increased by **[1]**

a) increasing the distance of an object

b) fitting eye-piece of low power

c) increasing the focal length of eyepiece

d) fitting eye-piece of high power

13. **Assertion (A):** Photoelectric current increases with an increase in intensity of incident radiation, for a given frequency of incident radiation and the accelerating potential. **[1]**

Reason (R): Increase in the intensity of incident radiation results in an increase in the number of photoelectrons emitted per second and hence an increase in the photocurrent.

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

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

c) Assertion (A) is true, but Reason (R) is false.

d) Assertion (A) is false and Reason (R) is also false.

14. **Assertion:** Circuits containing high capacity capacitors, charged to high voltage should be handled with caution, even when the current in the circuit is switched off. **[1]**

Reason: When an isolated capacitor is touched by hand or any other part of the human body, there is an easy path to the ground available for the discharge of the capacitor.

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):** Colours are seen in thin layers of oil on the surface of the water. **[1]**

Reason (R): White light is composed of several colours.

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):** The dc and ac both can be measured by a hot wire instrument. **[1]**

Reason (R): The hot wire instrument is based on the principle of magnetic effect of current.

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

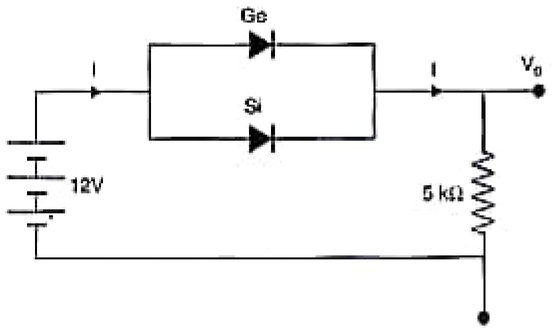
17. Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of 20 cm^2, find the average force exerted on the surface during a 30-minute time span. **[2]**

18. Two magnetic poles, one of which is four times stronger than the other, exert a force of 5gf on each other when placed at a distance of 10 cm. Find the strength of each pole. **[2]**

OR

An iron rod of 0.2 cm^2 cross-sectional area is subjected to a magnetising field of 1200 Am^{-1}. The susceptibility of iron is 599. Find the permeability and the magnetic flux produced.

19. Calculate the value of V_o and I, if the Si diode and the Ge diode conduct at 0.7 V and 0.3 V respectively, in the circuit given in figure. If now Ge diode connections are reversed, what will be the new values of V_o and I. **[2]**



20. Draw the graph showing the variation of the number (N) of scattered alpha particles with scattering angle (θ) in Geiger - Marsden experiment. Infer two conclusions from the graph. **[2]**

21. Two infinitely long straight wires A_1 and A_2 carrying currents I and 2I flowing in the same direction are kept **d** distance apart. Where should a third straight wire A_3 carrying current 1.5 I be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2? Does the net force acting on A_3 depend on the current flowing through it? **[2]**

Section C

22. **[3]**
   i. You are required to select a carbon resistor of resistance $47\text{k}\Omega \pm 10\%$ from a large collection. What should be the sequence of colour bands used to code it?
   ii. Write the characteristics of manganin which make it suitable for making standard resistance.

23. Red light, however bright it is, cannot produce the emission of electrons from a clean zinc surface. But even weak ultraviolet radiation can do so. Why? **[3]**
Electrons are emitted from the cathode of negligible work function, when photons of wavelength λ are incident on it. Derive the expression for the de Broglie wavelength of the electrons emitted in terms of the wavelength of the incident light.

24. Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams. **[3]**

25. Obtain the binding energy of the nuclei $^{56}_{26}Fe$ and $^{209}_{83}Bi$ in units of MeV from the following data: **[3]**
m ($^{56}_{26}Fe$) = 55.934939 u
m ($^{209}_{83}Bi$) = 208.980388 u

26. Write down the expression for the radii of orbits of the hydrogen atom. Calculate the radius of the smallest orbit. **[3]**

27. A plane wavefront of light of wavelength λ is incident normally on a narrow slit of width **a** and a diffraction pattern is observed on a screen at a distance **D** from the slit. **[3]**
   a. Depict the intensity distribution in the pattern observed.
   b. Obtain the expression for the first maximum from the central maximum.

28. Derive the expression for the magnetic energy stored in a solenoid in terms of magnetic field B, area A and length l of the solenoid carrying a steady current I. How does this magnetic energy per unit volume compare with the electrostatic energy density stored in a parallel plate capacitor? **[3]**

OR

   a. A toroidal solenoid with an air core has an average radius of 0.15 m, area of cross section $12 \times 10^{-4} m^2$ and 1200 turns. Obtain the self inductance of the toroid. Ignore field variation across the cross section of the toroid.
   b. A second coil of 300 turns is wound closely on the toroid above. If the current in the primary coil is increased from zero to 2.0 A in 0.05 s, obtain the induced emf in the secondary coil.

Section D

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

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by c = $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(a) The dimensions of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 : permittivity of free space; E = electric field) is

a) ML^2T^{-2}

b) MLT^{-1}

c) ML^2T^{-1}

d) $ML^{-1}T^{-2}$

(b) Let $[\varepsilon_0]$ denote the dimensional formula of the permittivity of the vacuum. If M = mass, L = length, T = time and A = electric current, then

a) $[\varepsilon_0]$ = $MLT^{-2}A^{-2}$

b) $[\varepsilon_0]$ = ML^2T^{-1}

c) $[\varepsilon_0]$ = $M^{-1}L^{-3}T^4A^2$

d) $[\varepsilon_0]$ = $M^{-1}L^{-3}T^2A$

(c) An electromagnetic wave of frequency 3 MHz passes from vacuum into a dielectric medium with permittivity ε = 4. Then

a) wavelength is doubled and the frequency becomes half

b) wavelength and frequency both remain unchanged

c) wavelength is doubled and the frequency remains unchanged

d) wavelength is halved and the frequency remains unchanged.

OR

The electromagnetic waves travel with

a) the speed of light c = 3 $\times$ 10^8 m s^{-1} in free space

b) the same speed in all media

c) the speed of light c = 3 $\times$ 10 m s^{-1} in solid medium

d) the speed of light c = 3 $\times$ 10^8 m s^{-1} in fluid medium.

(d) Which of the following are not electromagnetic waves?

cosmic rays, γ-rays, β-rays, X-rays

a) γ-rays

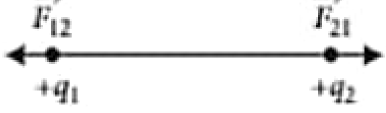
b) β-rays

c) X-rays

d) cosmic rays

30. Coulomb's law states that the electrostatic force of attraction or repulsion acting between two stationary point charges is given by **[4]**

F = $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$



where F denotes the force between two charges q_1 and q_2 separated by a distance r in free space, ε_0 is a constant known as the permittivity of free space. Free space is a vacuum and may be taken to be air practically. If free space is replaced by a medium, then ε_0 is replaced by $(\varepsilon_0 k)$ or $(\varepsilon_0 \varepsilon_r)$ where k is known as dielectric constant or relative permittivity.

i. In coulomb's law, F = $k\frac{q_1 q_2}{r^2}$, then on which of the following factors does the proportionality constant k depends?

ii. What is the dimensional formula for the permittivity constant ε_0 of free space?

iii. What is the force of repulsion between two charges of 1 C each, kept 1m apart in vaccum?

iv. Two identical charges repel each other with a force equal to 10 mgwt when they are 0.6 m apart in air. (g = 10 m s^{-2}). Then find the value of each charge.

Section E

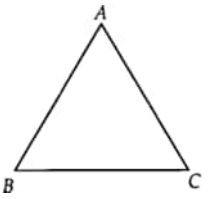
31. i. Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δ_{m}). **[5]**

ii. The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is -5.0 D.

OR

a. Write two points of difference between an interference pattern and a diffraction pattern.

b. i. A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.



ii. Find the angle of incidence at face AB so that the emergent ray grazes along the face AC.

32. a. Derive an expression for the potential energy of an electric dipole in a uniform electric field. Explain conditions for stable and unstable equilibrium. **[5]**

b. Is the electrostatic potential necessarily zero at a point where the electric field is zero? Give an example to support your answer.

OR

Derive an expression for potential due to a dipole for distances large compared to the size of the dipole. How is the potential due to dipole different from that due to a single charge?

33. i. Draw a labelled diagram of a step-down transformer. State the principle of its working. **[5]**

ii. Express the turn ratio in terms of voltages.

iii. Find the ratio of primary and secondary currents in terms of turn ratio in an ideal transformer.

iv. How much current is drawn by the primary of a transformer connected to 220 V supply when it delivers power to a 110 V - 550 W refrigerator?

OR

A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.

a. What is the source frequency for which the current amplitude is maximum? Obtain this maximum value
b. What is the source frequency for which average power absorbed by the circuit is maximum? Obtain the value of this maximum power.
c. For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current amplitude at these frequencies?
d. What is the Q-factor of the given circuit?

Solution

Section A

1.

(c) Van der Waals

Explanation:

Vander walls bond is the weakest kind of bonding is solids.

2.

(b) 0.592 A

Explanation:

To find the current flowing in the tube, we need to calculate the total charge per second due to the movement of protons and electrons.

i. **Charge of Protons and Electrons:** The charge of a proton (or electron) is approximately 1.6×10^{-19} coulombs.
ii. **Current from Protons:** The current due to protons can be calculated using the formula: $I_p = n_p \times e$ where n_p is the number of protons per second and e is the charge of a proton. Substituting the values: $I_p = 1.0 \times 10^{18} \times 1.6 \times 10^{-19} = 0.16 \mathrm{~A}$
iii. **Current from Electrons:** The current due to electrons is calculated similarly: $I_e = n_e \times e$ where n_e is the number of electrons per second. Substituting the values: $I_e = 2.7 \times 10^{18} \times 1.6 \times 10^{-19} = 0.432 \mathrm{~A}$
iv. **Total Current:** Since the protons and electrons are moving in opposite directions, the total current is the difference between the two: $I_{total} = I_e - I_p = 0.432 \mathrm{~A} - 0.16 \mathrm{~A} = 0.272 \mathrm{~A}$

However, the total current should be calculated by considering the net charge flow. Since electrons are negatively charged and moving in the opposite direction, we consider the absolute value of the current contributions:
$I_{total} = I_p + I_e = 0.16 \mathrm{~A} + 0.432 \mathrm{~A} = 0.592 \mathrm{~A}$
Thus, the total current flowing in the tube is 0.592 A, which matches the provided solution.

3.

(b) Full image will be formed but will be less bright

Explanation:

Image will be formed at the same position and same height but intensity of image formed will be less hence its brightness will be less as less number of light rays will form the image. Light rays from the covered portion will not contribute to image formation.

4.

(d) due to spin and orbital motions of electrons both

Explanation:

due to spin and orbital motions of electrons both

5.

(d) $\vec{E} = \hat{i}\left(2xy + z^3\right) + \hat{j}x^2 + \hat{k}3xz^2$

Explanation:

$\vec{E} = -\frac{\partial V}{\partial r} = \left[-\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}\right]$
$= \left[\left(2xy + z^3\right)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}\right]$

6. **(a)** remains constant

Explanation:

As the magnetic force always at right angle to the direction of motion of charged particle. So work done is zero, hence kinetic energy remains constant.

7.

(d) l decreases and A increases

Explanation:

L= self-inductance, A = area of cross-section.

As we know, $L = \mu_r \mu_0 \frac{N^2}{ll} Al$

$L = \mu_r \mu_0 \frac{N^2 A}{l}$

as L is constant for a coil

$L \propto A$ and $L \propto \frac{1}{l}$

As, μ_r and N are constant here so, to increase L for a coil, area A must be increased and l must be decreased.

8.

(d) $\oint \vec{B}.\overrightarrow{ds} = 0$

Explanation:

Since magnetic monopoles do not exist, flux entering the closed surface is equal to flux leaving the surface. Hence net magnetic flux through a closed surface is zero.

9. **(a)** Diffraction

Explanation:

When the light bends round an obstacle it enters into an area of geometrical shadow. This phenomenon is called as diffraction of light.

10.

(d) $7.2 \times 10^7 NC^{-1}$

Explanation:

The electric field at the center of a uniformly charged ring is typically zero due to symmetry. However, in this case, the ring has a gap, which disrupts the symmetry. The charge is uniformly distributed along the ring, except for the gap, which means that the electric field will not cancel out completely. To find the electric field at the center, we can use the formula for the electric field due to a charged ring with a gap. The electric field can be calculated by considering the contributions from the charged segments on either side of the gap. The total electric field is then derived from the geometry of the ring and the amount of charge. Given the radius of the ring (0.5 m) and the charge (+1 C), the calculations yield an electric field of approximately 7.2×10^7 N/C at the center, which matches the provided solution. This value takes into account the effect of the gap and the distribution of charge around the ring.

11.

(b) p-type semiconductor

Explanation:

One can see in the figure that number of holes are greater than number of electrons. Hence it is p−type semi conductor.

12.

(d) fitting eye-piece of high power

Explanation:

Magnification of telescope can be increased by using eyepiece of lower focal length (f_e). Since power is inversely proportional to focal length, eyepiece of large power will increase magnification of the telescope.

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

Explanation:

Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

Explanation:

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

15.

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

Explanation:

Both assertion and reason true but the reason is not the correct explanation of assertion. Colours are seen due to interference between light waves reflected by the upper and lower surfaces of the thin oil film.

16.

(c) A is true but R is false.

Explanation:

Both ac and dc produce heat, which is proportional to the square of the current. The reversal of direction of current in ac is immaterial so far as production of heat is concerned.

Section B

17. t = 30 minute = 30 $\times$ 60 = 1800 sec = 0.18 $\times$ 10^4 sec.

The total energy falling on the surface is

U = (18 W/cm^2) $\times$ (20 cm^2) $\times$ (30 $\times$ 60 s)

= 6.48 $\times$ 10^5 J

Therefore, the total momentum delivered (for complete absorption) is

$p = \frac{U}{c} = \frac{6.48 \times 10^5 \mathrm{J}}{3 \times 10^8 \mathrm{m/s}}$ = 2.16 $\times$ 10^{-3} kg m/s

The average force exerted on the surface is

$F = \frac{p}{t} = \frac{2.16 \times 10^{-3}}{0.18 \times 10^4}$ = 1.2 $\times$ 10^{-6} N

18. Let the pole strengths of the two dipoles be q_m and $4q_m$.

Here F = 5 gf = 5 $\times$ 10^{-3} kgf = 5 $\times$ 10^{-3} $\times$ 9.8 N, r = 10 cm = 0.1 m

Using Coulomb's law of magnetism,

F = $\frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} q_{m_2}}{r^2}$

$\therefore$ 5 $\times$ 10^{-3} $\times$ 9.8 = $\frac{10^{-7} \times q_m \times 4q_m}{(0.1)^2}$

or $q_m^2 = \frac{5 \times 9.8 \times (0.1)^2 \times 10^4}{4}$ = 25 $\times$ 49

or q_m = 5 $\times$ 7 = 35 Am and $4q_m$ = 4 $\times$ 35 = 140 Am

OR

Here A = 0.2 cm^2 = 0.2 $\times$ 10^{-4} m^2, H = 1200 Am^{-1}, χ_m = 599

Permeability, $\mu = \mu_0 (1 + \chi_m)$

= $4\pi \times 10^{-7} \times (1 + 599)$ = 7.536 $\times$ 10^{-4} TmA^{-1}

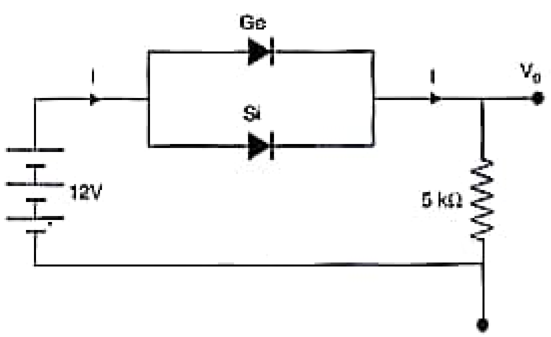
Magnetic induction,

B = μH = 7.536 $\times$ 10^{-4} $\times$ 1200 = 0.904 T

Magnetic flux,

$\phi = BA$ = 0.904 $\times$ 0.2 $\times$ 10^{-4} = 1.81 $\times$ 10^{-5} Wb

19.



Current, $I = \frac{12 - 0.3}{5 \times 10^3}$ = 2.34 mA

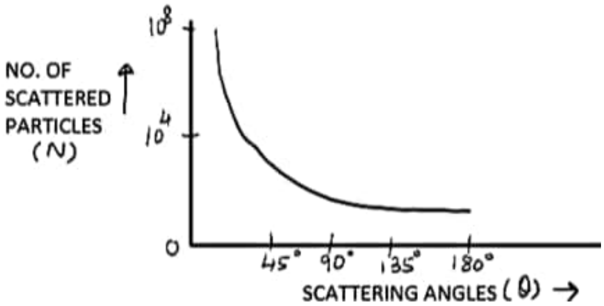
Output voltage, $V_o = RI = (5 \times 10^3) \times (2.34 \times 10^{-3})$ = 11.7 V

When the connections of Ge diode are reversed, then current will be through silicon.

In this case, $I' = \frac{12-0.7}{5\times10^3}$ = 2.26 mA

and

$V_o' = I'R = (2.26 \times 10^{-3}) \times (5 \times 10^3)$ = 11.3 V

20. 

CONCLUSIONS FROM GRAPH:

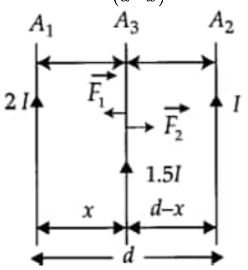
i. Decreasing slope shows that most of the particles passes straight through the gold foil without deflection. So most of the space within the atom must be empty.

ii. A few particles, about 1 in 800 got deflected through 90 degree or more, depending on the impact parameter.

21. Finding the position of third wire Reason

$F_1 = \frac{\mu_0}{4\pi}\frac{I\times1.5I}{x}$

$F_2 = \frac{\mu_0}{4\pi}\frac{2I\times1.5I}{(d-x)}$



For no force on the conductor, A_3

$\frac{\mu_0}{4\pi}\frac{I\times1.5I}{x} = \frac{\mu_0}{4\pi}\frac{2I\times1.5I}{(d-x)}$

$\frac{1}{x} = \frac{2}{(d-x)}$

3x = d

$x = \frac{d}{3}$

The net force acting on A_3 is zero only when current through is 1.5I. So, it depends on the current flowing through it.

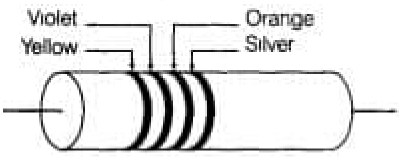
[**Note:** Also accept in general, it will depend on the value of I_3.]

Section C

22. i. Given, resistance $= 47k\Omega \pm 10\%$

$= 47 \times 10^3\Omega \pm 10\%$

∴ 1st colour band should be yellow as code for it is 4, 2nd colour band should be violet as code for it is 7, 3rd colour band should be orange as code for it is 3, 4th colour band should be silver because approximation is ± 10%.



ii. Two properties of manganin are:

a. low temperature coefficient of resistance.

b. high value of resistivity of material of manganin make it suitable for making a standard resistor.

23. The frequency of ultraviolet radiations is more while that of red light is less than the threshold frequency for a zinc surface, so ultraviolet radiations can cause the emission of electrons and red light cannot.

From Einstein's photoelectric equation, K.E. of a photoelectron is

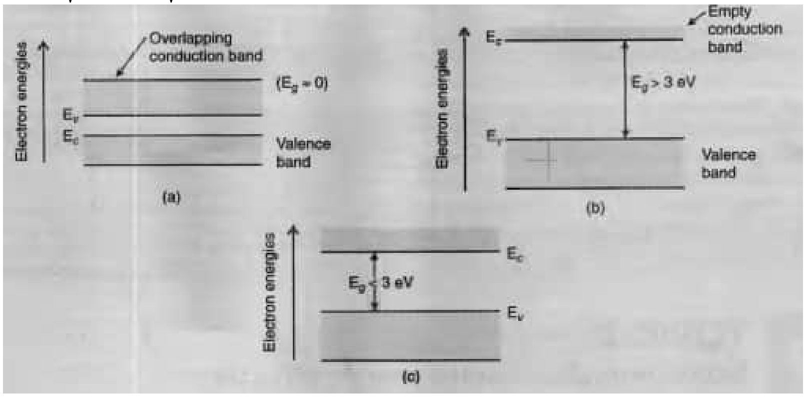
$\frac{1}{2}m\nu^2 = h\nu - W_0 = h\nu - 0 = \frac{hc}{\lambda}$

or $v = \sqrt{\frac{2hc}{m\lambda}}$

de Broglie wavelength of electrons,

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

$= \frac{h}{m}\sqrt{\frac{m\lambda}{2hc}} = \sqrt{\frac{h\lambda}{2mc}}$

24. 

Two distinguishing features are given below :

i. In conductors, the valence band and conduction band tends to overlap (or nearly overlap) each other , while in insulators they are separated by a large energy gap and in semiconductors they are separated by a small energy gap.
ii. The conduction band of a conductor, has a large number of electrons available for electrical conduction. However, the conduction band of insulators is almost empty while that of the semi-conductor has only a (very) small number of such electrons available for electrical conduction

25. The number of neutron and Proton both in a $^{56}Fe_{26}$ atom is respectively 30 and 26.

The mass defect $\triangle m = m_p + m_n - m_{Fe}$

And Binding energy is given by $E_B = \triangle mc^2$

Mass of a proton = 1.007825 u

Mass of a neutron = 1.008665 u

In this case mass defect = Δm = (26 × 1.007825 + 30 × 1.008665-55.934939)u = 0.528461u

We know, 1a.m. u = 931.5 MeV/c^2

So, E = $\triangle mc^2$ = 0.528461, △ 931.5(MeV/c^2) × c^2 = 492.26MeV

So, Binding Energy per Nucleon = $\frac{\text{Total Binding Energy}}{\text{Total No Of Nucleon}} = \frac{492.26}{56}$ = 8.79MeV

The number of neutron and Proton both in a $^{209}Bi_{83}$ atom is respectively 126 and 83.

The mass defect $\Delta m = m_p + m_n - m_{Bi}$

And Binding energy is given by $E_B = \triangle mc^2$

Mass of a proton = 1.007825 u

Mass of a neutron = 1.008665 u

Mass Defect = △m = 83 × 1.007825 + 126 × 1.008665 - 208.980388 = 1.760877 u

We know, 1a.m.u = 931.5 MeV/c^2

So, E = $\triangle mc^2$ = 1.760877 × 931.5 (MeV/c^2) × c^2 = 1640.26 MeV

Average binding energy per nucleon = $\frac{1640.26}{209}$ = 7.848 MeV

Hence, these are the required values.

26. The radius of the nth orbit of a hydrogen atom is given by $r = \frac{n^2h^2}{4\pi^2mke^2}$

Radius of the innermost orbit, called Bohr's radius, is obtained by putting n = 1 It is denoted by r_0

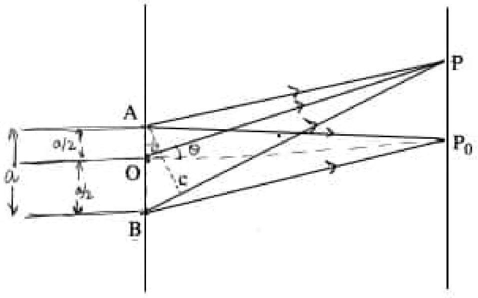
$\therefore \quad r_0 = \frac{h^2}{4\pi^2mke^2}$

$= \frac{\left(6.6\times10^{-34}\right)^2}{4\pi^2\times9.1\times10^{-31}\times9\times10^9\times\left(1.6\times10^{-19}\right)^2}\,\mathrm{m}$

- 0.53 × 10^{10} m = 0.53 $\dot{A}$.

27. Let us consider consider a slit AB is made up of two slits each of width $\frac{a}{2}$.

As P_0 is point equidistant from all the huygen's sources therefore all will be in phase to give central maxima for first minima path differences between waves from A and O = $\frac{\lambda}{2}$



Let OP subtends angle θ at the slit then in $\triangle^{s}$ ABC and OP_0P

With P as the centre and PA as radius, strike an are intersecting PB at C

AC can be considered as straight line at right angle to PB thus $\triangle^{s}$ ABC $\sim$ OP_0P

$\therefore$ BC = a sin θ

(PB - PO) + (PO - PA) = a sin θ

$\frac{\lambda}{2}+\frac{\lambda}{2}$ = λ = a sin θ

sin θ = $\frac{\lambda}{a}$

and θ is small so, $\theta_n = \frac{n\lambda}{a}$

n = 1, 2, 3 dark fringes

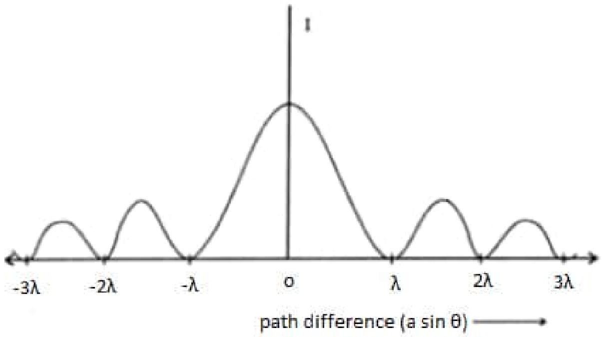
Similarly for secondary maxima

a sin θ = $\frac{\lambda}{2}$

sin θ = $\frac{\lambda}{2a}$

θn = $\left(n+\frac{1}{2}\right)\frac{\lambda}{a}$

n = 1, 2, 3...... bright fringes

a. 

b. θn = $\left(n+\frac{1}{2}\right)\frac{\lambda}{a}$

$\frac{x}{D}=\frac{3}{2}\frac{\lambda}{a}$

n = 1 for first maxima

x = $\frac{3\lambda D}{2a}$

28. Rate of work done,

$\frac{dW}{dt}$ = $|\varepsilon| i$

dW = $\left(LI\frac{dI}{dt}\right)dt$

dW = LI dl

Total amount of work done,

$\int dW = \int LIdI$

W = $\frac{1}{2}LI^2$

For the solenoid:

Inductance, L = $\mu_0 n^2 AE$; B = $\mu_0 nI$

$\therefore$ W = U_B = $\frac{1}{2}LI^2$

= $\frac{1}{2}\left(\mu_0 n^2 Al\right)\left(\frac{B}{\mu_0 n}\right)^2$

= $\frac{B^2 Al}{2\mu_0}$

Magnetic energy per unit volume

Electrostatic Energy Stored Per Unit Volume stored in parallel plate capacitor = $\frac{1}{2}\varepsilon_0 E^2$

OR

a. $B=\mu_0 n_1 I=\frac{\mu_0 N_1 I}{l}=\frac{\mu_0 N_1 I}{2\pi r}$

Total magnetic flux, $\phi_B=N_1 BA=\frac{\mu_0 N_1^2 IA}{2\pi r}$

But $\phi_B=LI$

$\therefore L=\frac{\mu_0 N_1^2 A}{2\pi r}$

Or $L=\frac{4\pi\times10^{-7}\times1200\times1200\times12\times10^{-4}}{2\pi\times0.15}$

$=2.3\times10^{-3} H$ = 2.3 mH

b. $|E|=\frac{d}{dt}(\phi_2)$ where ϕ_2 is the total magnetic flux linked with the second coil.

$|E|=\frac{d}{dt}(N_2 BA)=\frac{d}{dt}\left[N_2\frac{\mu_0 N_1 I}{2\pi r}A\right]$

$|E|=\frac{\mu_0 N_1 N_2 A}{2\pi r}\frac{dI}{dt}$

$|E|=\frac{4\pi\times10^{-7}\times1200\times300\times12\times10^{-4}\times2}{2\pi\times0.15\times0.05}$ = 0.023 V

Section D

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

Maxwell showed that the speed of an electromagnetic wave depends on the permeability and permittivity of the medium through which it travels. The speed of an electromagnetic wave in free space is given by c = $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$. The fact led Maxwell to predict that light is an electromagnetic wave. The emergence of the speed of light from purely electromagnetic considerations is the crowning achievement of Maxwell's electromagnetic theory. The speed of an electromagnetic wave in any medium of permeability μ and permittivity ε will be $\frac{c}{\sqrt{K\mu_r}}$ where K is the dielectric constant of the medium and μ_r is the relative permeability.

(i) **(d)** $ML^{-1}T^{-2}$

Explanation:

$\frac{1}{2}\varepsilon_0 E^2$ = energy density = $\frac{\text{Energy}}{\text{Volume}}$

$\therefore\left[\frac{1}{2}\varepsilon_0 E^2\right]=\frac{ML^2T^{-2}}{L^3}$ = $[ML^{-1}T^{-2}]$

(ii) **(c)** $[\varepsilon_0]$ = $M^{-1}L^{-3}T^4A^2$

Explanation:

As ε_0 = $\frac{q_1q_2}{4\pi FR^2}$ (from Coulomb's law)

ε_0 = $\frac{C^2}{Nm^2}\frac{[AT]^2}{MLT^{-2}L^2}$ = $M^{-1}L^{-3}T^4A^2$

(iii) **(d)** wavelength is halved and the frequency remains unchanged.

Explanation:

The frequency of the electromagnetic wave remains same when it passes from one medium to another.

Refractive index of the medium, n = $\sqrt{\frac{\varepsilon}{\varepsilon_0}}=\sqrt{\frac{4}{1}}$ = 2

Wavelength of the electromagnetic wave in the medium,

$\lambda_{\text{med}}=\frac{\lambda}{n}=\frac{\lambda}{2}$

OR

(a) the speed of light c = 3×10^8 m s^{-1} in free space

Explanation:

The velocity of electromagnetic waves in free space (vacuum) is equal to velocity of light in vacuum (i.e., 3×10^8 m s^{-1}).

(iv) **(b)** β-rays

Explanation:

β-rays consists of electrons which are not electromagnetic in nature.

30. i. The proportionality constant k depends on the nature of the medium between the two charges.

ii. The dimensional formula for the permittivity constant is $[ML^{-3}T^4A^2]$.

iii. The force of repulsion will be 9×10^9 N.

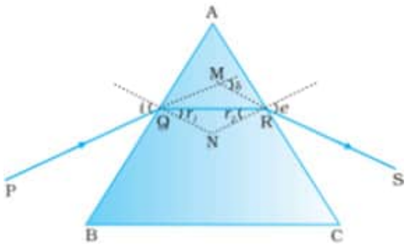
iv. F = $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{d^2}$

$\therefore (10\times10^{-3})\times10=\frac{(9\times10^9)\times q^2}{(0.6)^2}$

or $q^2 = \frac{10^{-1}\times 0.36}{9\times 10^9}$ = 4 × 10^{-12}

or q = 2 × 10^{-6} C = 2 μC

Section E

31. i. 

In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180^o.

$\angle A + \angle QNR = 180^o$

From the triangle QNR, $r_1 + r_2 + \angle QNR = 180^o$

Comparing these two equations, we get

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

The total deviation δ is the sum of deviations at the two faces,

$\delta = (i - r_1) + (e - r_2)$ that is, $\delta = i + e - A$ ...(ii)

When $\delta = \delta_m$; i = e & $r_1 = r_2$

From (i); 2r = A or r = $\frac{A}{2}$

From (ii); δ_m = 2i - A or i = $\frac{A+\delta_{mu}}{2}$

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$

hence, this is the relation of angle of prism (A) and angle of minimum deviation (δ_m).

ii. Given; P = -5D

f (in cm) = $\frac{100}{(-5)}$ = -20 cm

Using Lens Maker's formula; $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$\frac{1}{(-20)} = (\mu - 1)\left[\frac{1}{(-20)} - \frac{1}{(+20)}\right]$

$\frac{1}{(-20)} = (\mu - 1)\left[-\frac{1}{10}\right]$; $\mu - 1 = \frac{1}{2}$

$\Rightarrow \mu = \frac{3}{2}$ = 1.5

OR

a. i. The interference pattern has a number of equally spaced bright and dark bands. The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side.

ii. We calculate the interference pattern by superposing two waves originating from the two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

b. i. $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} = \frac{\sin\left(\frac{90}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}}$

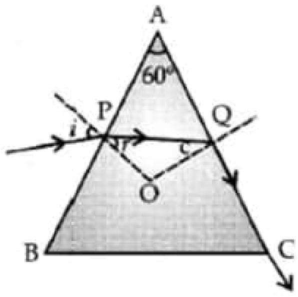
$= \sqrt{2}$

Here A = 60^o, δ_m = 30^o.

Now $\mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu}$:

$\Rightarrow v = \frac{3\times 10^8}{\sqrt{2}}$ = 2.12 × 10^8 ms^{-1}

the speed of light through the prism is 2.12 × 10^8 ms^{-1}

ii. 

n = $\sqrt{2}$

$\therefore$ n = $\frac{1}{\sin c}$ (for face AC)

$\sqrt{2}$ = $\frac{1}{\sin c}$

$\Rightarrow$ sin c = $\frac{1}{\sqrt{2}}$ = sin 45^{o}

$\Rightarrow$ c = 45^{o}

$\therefore \angle$APQ = 180^{o} - (60^{o} + 45^{o})

= 75^{o}

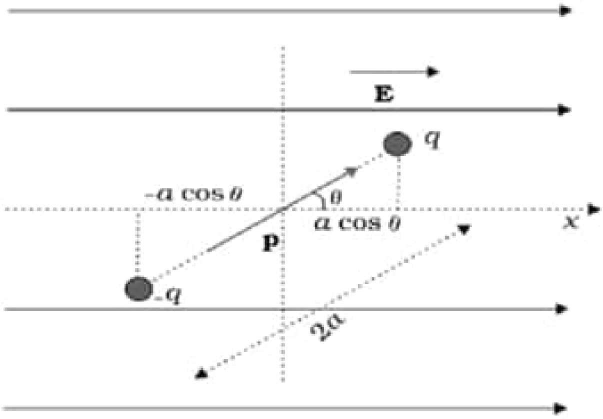
$\therefore$ r = 90^{o} - 75^{o} = 15^{o}

i = ?

n = $\frac{\sin i}{\sin r}$

$\Rightarrow \sqrt{2} = \frac{\sin i}{\sin 15''}$

$\Rightarrow$ sin i = $\sqrt{2} \times \sin 15''$ = $\sqrt{2} \times$ 0.2588

32. a. 

Since torque acting on dipole

$\vec{\tau} = \vec{\mathrm{p}} \times \vec{\mathrm{E}}$

$\vec{\tau} = \mathrm{pE} \sin \theta \cdot \hat{\mathrm{n}}$

work done $\mathrm{d}\omega = \tau . \mathrm{d}\theta$

$= \mathrm{pE} \sin \theta \mathrm{d}\theta$

$\mathrm{w} = \int_{\theta_1}^{\theta_2} \mathrm{dw} \quad \mathrm{pE} \int_{\theta_1}^{\theta_2} \sin \theta \mathrm{d}\theta$

$\mathrm{w} = \mathrm{pE}[-\cos \theta]_{\theta_1}^{\theta_2}$

$= \mathrm{pE}\left[\cos \theta_1 - \cos \theta_2\right]$

if $\theta_1 = 0, \theta_2 = \theta$

w = pE (1 - cosθ)

Conditions-

For stable equilibrium - When electric dipole is parallel to electric field.

For unstable equilibrium - Anti Parallel to electric field.

b. No.

Inside equipotential surface

OR

Consider origin at the centre of dipole. As per superposition principle, potential due to dipole will be the sum of potentials due to charges q and -q

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

Where,

r_1 and r_2 = distances of point P from q and -q.

$r_1^2 = r^2 + a^2 - 2 ar\cos\theta$

$r_2^2 = r^2 + a^2 + 2 ar\cos\theta$

If r is greater than a, and taking terms upto first order in a/r

$r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

$= r^2\left[1 - \frac{2a\cos\theta}{r}\right]$

Also, $r_2^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right]$

With the help of Binomial theorem, keeping terms upto first order is shown below:

$\frac{1}{r_1} \equiv \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$

$\frac{1}{r_2} \equiv \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$

$\equiv \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$

As p = qa

$V = \frac{1}{4\pi\varepsilon_0}\frac{q(2a)\cos\theta}{r^2}$

$V = \frac{p}{4\pi\varepsilon_0} \cdot \frac{\cos\theta}{r^2}$

Now, $p\cos\theta = \vec{p}.\hat{r}$

where $\hat{r}$ is unit vector along position vector.

Hence electric potential of dipole for distances large compared to size of dipole is given as below :

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p}\hat{r}}{r^2}$ for r >>a

---For potential at any point on axis, $\theta = [0, \pi]$

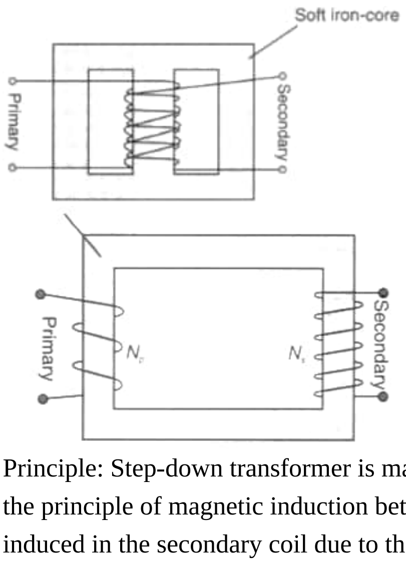
$V = \pm\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$

potential is positive when $\theta = 0$

potential is negative when $\theta = \pi$

Hence, electric potential falls at large distance, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$

33. i.



Principle: Step-down transformer is made up of two or more coil wound on the iron core of the transformer. It works on the principle of magnetic induction between the coils. When the current flowing through the primary coil changes, an emf is induced in the secondary coil due to the change in magnetic flux linked with it.

ii. $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

iii. For an ideal transformer,

$i_p V_p = i_s V_s$

$\therefore \frac{i_p}{i_s} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$

iv. We have

$i_p V_p = i_s V_s = 550$ W

$V_p = 220$ V

$i_p = \frac{550}{220} = \frac{5}{2}$ = 2.5 A

OR

Inductance, L = 0.12 H

Capacitance, C = 480 nF = 480 $\times$ 10^{-9} F

Resistance, R = 23 Ω

Supply voltage, V = 230 V

Peak voltage is given as:

$V_0 = \sqrt{2} \times 230$ = 352.22 V

a. the source frequency for which the current amplitude is maximum is given by:-Current flowing in the circuit is given by the relation, $I_0 = \frac{V_0}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$

Where,

I_0 = maximum at resonance

At resonance, we have

$\omega_R L - \frac{1}{\omega_R C} = 0$

Where,

ω_R = Resonance angular frequency

$\therefore \omega_R = \frac{1}{\sqrt{LC}}$

$= \frac{1}{\sqrt{0.12\times480\times10^{-9}}}$ = 4166.67 rad/s

$\therefore$ Resonant frequency, $v_R = \frac{\omega_R}{2\pi} = \frac{4166.67}{2\times3.14}$ = 663.48 Hz

And, maximum current in he given circuit $(I_0)_{Max} = \frac{V_0}{R} = \frac{325.22}{23}$ = 14.14 A

b. Maximum average power absorbed by the circuit is given as:

$(P_{av})_{Max} = \frac{1}{2} (I_0)^2_{Max} R$

$= \frac{1}{2} \times (14.14)^2 \times 23$ = 2299.3 W

Also ,the resonant frequency (ν_R) is 663.48 Hz.

c. The power transferred to the circuit is half the power at resonant frequency.

Frequencies at which power transferred is half, $= \omega_r \pm \triangle\omega$

$= 2\pi\left(v_R \pm \triangle v\right)$

where,

$\triangle\omega = \frac{R}{2L}$

$= \frac{23}{2\times0.12}$ = 95.83 rad/s

Hence, change in frequency, $\triangle v = \frac{1}{2\pi}\triangle\omega = \frac{95.83}{2\pi}$ = 15.26 Hz

$\therefore \nu_R$ + $\triangle$v = 663.48 + 15.26 = 678.74 Hz

And, ν_R - $\triangle$v = 663.48 - 15.26 = 648.22 Hz

Hence, at 648.22 Hz and 678.74 Hz frequencies, the power transferred is half.

At these frequencies, the current amplitude can be given as:

$I' = \frac{1}{\sqrt{2}} \times (I_0)_{Max}$

$= \frac{14.14}{\sqrt{2}} = 10\text{A}$

d. Q -factor of the given circuit can be obtained using the relation, $Q = \frac{\omega_R L}{R}$

$= \frac{4166.67\times0.12}{23}$ = 21.74

Hence, the Q -factor of the given circuit is = 21.74