Solution

PHY

Class 12 - Physics

Section A

1. **(a)** 0.5 eV

   Explanation:

   $E_g = \frac{hc}{\lambda} = \frac{1240\ eVnm}{2800\ nm} = 0.5eV$

2. **(b)** is zero

   Explanation:

   At the neutral temperature,

   $\frac{d\varepsilon}{dT}$ = 0

3. **(b)** 10 s

   Explanation:

   Exposure time, $t \propto d^2$

   $\therefore t_2 = \frac{d_2^2}{d_1^2} t_1 = \frac{120^2}{60^2} \times 2.5 = 10s$

4. **(a)** Copper

   Explanation:

   as Copper is diamagnetic substance.

5. **(a)** -36

   Explanation:

   $Electric\ field\ = -\frac{dv}{dr} = -\frac{d(6Z^2)}{dz} = -12Z$

   $for\ (x, y, z)\ = (2, -1, 3)$

   $we\ get$

   $E = -12 \times 3\ = -36\ N/C$

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, $I = nI_g$

   Thus, the resistance of the shunt becomes,

   Shunt Resistance, $S = \frac{R}{n-1} = \frac{R}{4-1} = \frac{R}{3}$

7. **(d)** Faraday's law

   Explanation:

   According to Faraday's laws,

   $|\varepsilon| = \frac{d\phi}{dt}$

8. **(d)** 27 : 1

   Explanation:

   27 : 1

9.

(c) twice

Explanation:

twice

10.

(c) four times.

Explanation:

four times.

11.

(b) 0.5 A

Explanation:

Diode D_1 conducts as it is forward biased.

Diode D_2 does not conduct as it is reverse biased.

$\therefore$ I = $\frac{5\text{ V}}{10\Omega}$ = 0.5 A

12.

(b) $\frac{5}{3}$

Explanation:

f = $\frac{1}{P}$ = $\frac{1}{5}$ m = 20 cm

Now, $\frac{1}{f}=\left(\frac{\mu_2}{\mu_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

In air, $\frac{1}{20}=\left(\frac{1.5}{1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=0.5\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ....(i)

In liquid, $\frac{1}{-100}=\left(\frac{1.5}{\mu_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ....(ii)

Dividing (i) by (ii), we get

$-5=\frac{0.5}{\left(\frac{1.5}{\mu_1}-1\right)}$

On solving we get, $\mu_1=\frac{5}{3}=1.67$

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

Explanation:

The energy of electrons just after they absorb photons incident on the metal surface may be lost in a collision with other atoms in the metal before the electron is ejected out of the metal which results in the ejected photoelectrons with different energies despite monochromatic incident radiation.

14.

(c) A is true but R is false.

Explanation:

The reason is false because the work done in bringing a unit positive charge from infinity to a point in the equatorial plane is equal and opposite for the two charges of the dipole.

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

Explanation:

The central spot of Newton's rings is dark when the medium between plano convex lens and plane glass is rarer than the medium of lens and glass. The central spot is dark because the phase change of π is introduced between the rays reflected from surfaces of denser to rarer and rarer to denser media.

16.

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

Explanation:

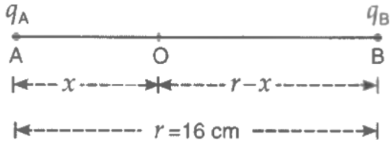
Quality factor of a series LCR circuit is Q = $\frac{1}{R}\sqrt{\frac{L}{C}}$. Assertion is true.

Quality factor is also defined as Q = $\frac{\text{Resonant frequency}}{\text{Bandwidth}}$. So, as bandwidth decreases, Q increases. So, reason is also true. But reason does not explain the assertion.

Section B

17. Here $q_A = 5 \times 10^{-8}$ C; $q_B = -3 \times 10^{-8}$ C ; r = 16 cm = 0.16 m

Let O be the point, where the electric potential is zero due to the two charges as shown in figure given below.



Suppose that the distance AO = x. Then

BO = r - x = 0.16 - x

Electric potential at point O due to q_A,

$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_A}{AO}$

$= 9 \times 10^9 \times \frac{5\times10^{-8}}{x} = \frac{450}{x}$

Electric potential at point O due to q_B,

$\mathrm{V_B} = \frac{1}{4\pi\varepsilon_0}\frac{q_\mathrm{B}}{\mathrm{BO}}$

$= 9 \times 10^9 \times \frac{(-3\times10^{-8})}{0{\cdot}16-x}$

$= -\frac{270}{0.16-x}$

Since the electric potential at point O is zero, we have

$\mathrm{V_A} + \mathrm{V_B} = 0$

or $\frac{450}{x} + \left(-\frac{270}{0{\cdot}16-x}\right) = 0$

or $\frac{450}{x} = \frac{270}{0{\cdot}16-x}$

or x = 0·1 m = 10 cm (from charge of 5×10^{-8} C)

18. Magnetic materials are of three types :
    i. Diamagnetic materials :
        a. They are feebly repelled by magnets.
        b. χ is negative and very small.
    ii. Paramagnetic materials :
        a. They are feebly attracted by magnets.
        b. χ is positive and small.
    iii. Ferromagnetic substances :
        a. They are strongly attracted by magnets.
        b. χ is positive and large.

19. Since $n_e > n_h$, the semiconductor is n-type. The conductivity of the semi conductor is $e(n_e\mu_e + n_h\mu_h)$

$= 1.6 \times 10^{19}$ ((8×10^{13})(24000) + (4×10^{13})(200))mho/cm

= 0.32 mho cm^{-1}

=320 m mho cm^{-1}

20. The ratio of the radius of electron’s orbit to the radius of a nucleus is (10^{-10} m)/(10^{-15} m) = 10^5, that is, the radius of the electron’s orbit is 10^5 times larger than the radius of the nucleus. If the radius of the earth’s orbit around the sun were 10^5 times larger than the radius of the sun, the radius of the earth’s orbit would be $10^5 \times 7 \times 10^8$ m = 7×10^{13} m. This is more than 100 times greater than the actual orbital radius of the earth. Thus, the earth would be much farther away from the sun. It implies that an atom contains a much greater fraction of empty space than our solar system does.

21. B = $\frac{\mu oi}{2r}$ or r = $\frac{\mu oi}{2B}$

r = $\frac{4\pi\times5\times10^{-7}}{2\pi\times10^{-3}}$ = 1×10^{-3} m

m = iA = i πr^2

$= 5\pi \times 10^{-6}$ A-m^2

$= 1.57 \times 10^{-5}$ A-m^2

Hence, the magnetic moment of the loop is 1.57×10^{-5} A-m^2

OR

It is an example of magnetic field due to current in a wire of infinite length.

$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 90}{2\pi \times 1.5}$

$= \frac{180}{1.5} \times 10^{-7} = 1.2 \times 10^{-5} T$

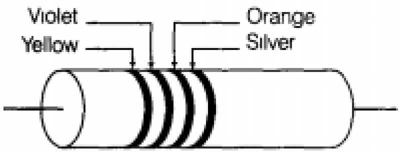
Applying the right hand thumb rule, we find that the magnetic field at the observation point is directed towards south.

Section C

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

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

$\therefore$ 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%.



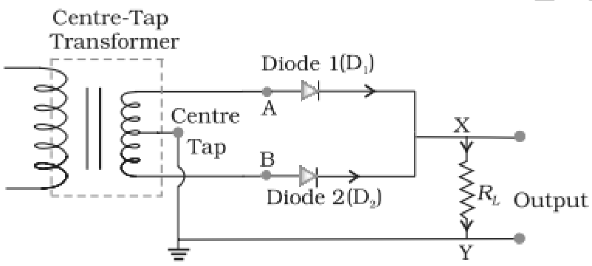
ii. Two properties of manganin are:

a. low temperature coefficient of resistance.

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

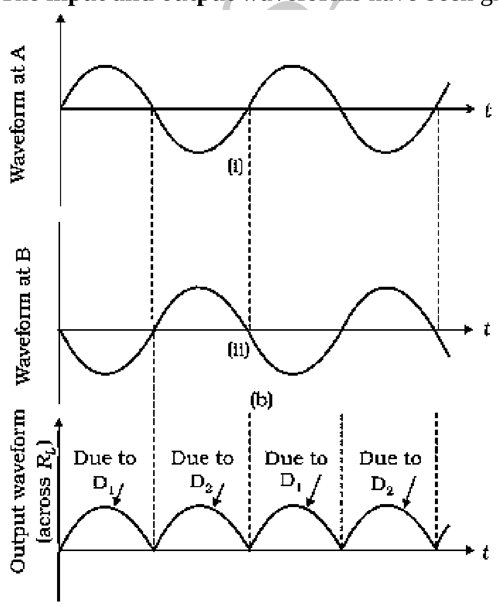
23. A rectifier which rectifies both halves of each a.c. input cycle is called a full wave rectifier. To make use of both the halves of input cycle, two junction diodes are used.

The **circuit diagram** of full-wave rectifier is shown below:

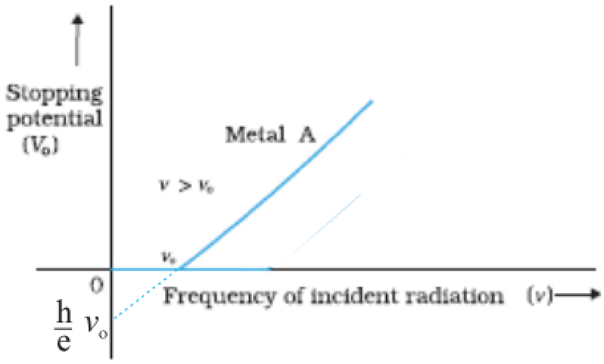


Principle: It also works on the principle that a junction diode offers low resistance during forward bias and high resistance, when reverse biased. Here, two junction diodes are connected in such a manner that if one diode gets forward biased during the first half cycle of a.c. input, the other gets reverse biased but when the next opposite half cycle comes, the first diode gets reverse biased and the second forward biased. Thus, output is obtained during both the half cycles of the a.c. input.

The **input and output waveforms** have been given below:



24. a.



b. From Einstein's Equation

$eV_o = h\nu - h\nu_o$

$V_o = \frac{h}{e}v - \frac{h}{e}v_o$

comparing

y = mx + c

i. Threshold frequency ν_o is the intercept along v axis.

(Alternatively, intercept on V_o axis, $c = \frac{h}{e}v_o \;\; v_o = \frac{ec}{h}$)

ii. Planck's constant h = e x slope

25. i. In a nuclear reaction, the sum of the masses of the target nucleus $\left({}_1^2H\right)$ and the bombarding particle $\left({}_1^2H\right)$ may be greater or less than the sum of the masses of the product nucleus $\left({}_2^3He\right)$ and the outgoing particle $\left({}_0^1n\right)$. So, from the law of conservation of mass-energy, some energy (3.27 MeV) is evolved or involved in a nuclear reaction. This energy is called Q - value of the nuclear reaction.

ii. The relation between radius and mass number of the nucleus is $R = R_0 A^{1/3}$

where, $R_0 = 1.1 \times 10^{-15}$ is the range of nuclear force, R = radius of nucleus and A = mass number

Nuclear density,

$\rho = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3}$

Or $\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \Rightarrow \rho = \frac{m}{\frac{4}{3}\pi R_0^3}$

So as per above formula, density of nucleus does not depend on mass number of nucleus rather it is same for all the atoms and it is roughly in the order of 10^{17} kg/m^3 which is very large as compared to our everyday observed densities.

26. Electrons can exhibit wavelike behavior by showing an interference pattern for electrons travelling through a regular atomic pattern in a crystal.

The de Broglie's wavelength

$\lambda = \frac{h}{mV}$ ...(i)

For stationary orbit

$2\pi r = n\lambda$ ...(ii)

Substituting the value of λ from (i) and (ii)

$2\pi r = \frac{nh}{mV}$

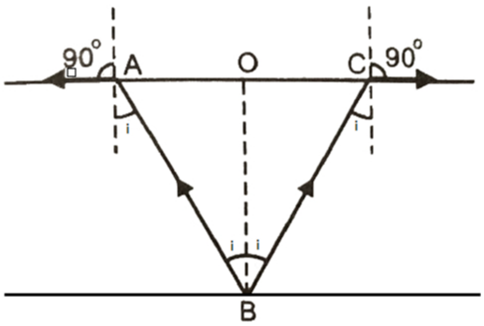
$mVr = \frac{nh}{2\pi}$

mVr = L (Orbital angular momentum)

$L = \frac{nh}{2\pi}$

27. a. No, it depends on the colour of light. μ of violet colour is more than red colour and thus speed of violet light is less than red light.

b.



Actual depth of bulb d_1 = 0.7 m

μ = $\frac{4}{3}$ = 1.33

By snell law $\frac{1}{\mu} = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin 90^{\circ}}$

$\frac{3}{4} = \frac{\sin i}{1}$

sin i = $\frac{3}{4}$

i = 48.75^{o}

In $\triangle$OBC tan i = $\frac{OC}{OB} = \frac{OC}{0.7}$

OC = tan 48.75 $\times$ 0.7

= 0.8 m , this can be considered as radius of circle,

Area = πR^2

= 3.14 $\times$ $(0.8)^2$

= 2.01 m^2

28. a. The induced emf in the moving conductor MNOP

e = Blv

The induced current, i $= \frac{\mathrm{e}}{\mathrm{R}} = \frac{\mathrm{Blv}}{\mathrm{R}}$

Force on the arm 'ON', F = Bil

$= \frac{\mathrm{B}^2\mathrm{I}^2\ \mathrm{V}}{\mathrm{R}}$

The force is directed in the direction opposite to the velocity of rod (v)

b. Power P = F $\times$ v where F =

$= \frac{\mathrm{B}^2\mathrm{I}^2\ \mathrm{V}}{\mathrm{R}}$ therefore, $P = \frac{B^2 l^2 V^2}{r}$

OR

By the relation between electric field and potential we get,

The induced emf = Electric field E $\times$ $(2\pi b)$ (Because V = E $\times$ d) ..... (i)

If E is the electric field generated around the charged ring of radius b, then as e By Faraday's law:

$|\varepsilon| = \frac{d\phi}{dt} = A\frac{dB}{dt}$

$|\varepsilon| = \frac{B\pi a^2}{\Delta t}$ ...... (ii)

From Eqs. (i) and (ii), we have

$2\pi bE = \varepsilon = \frac{B\pi a^2}{\Delta t}$

As we know the electric force experienced by the charged ring, F_e = QE

his force try to rotate the coil, and the torque is given by

Torque = b $\times$ Force

$\tau = QEb = Q\left[\frac{B\pi a^2}{2\pi b\Delta t}\right]b$

$\Rightarrow \quad \tau = Q\frac{Ba^2}{2\Delta t}$

If ΔL is the change in angular momentum of the charged ring then,

$\Delta L = \text{ Torque } \times \Delta t = Q\frac{Ba^2}{2}$

since, initial angular momentum = 0

And Torque $\times \Delta t$ = Change in angular momentum

Final angular momentum $= mb^2\omega = \frac{QBa^2}{2}$

Where, mb^2 = I (moment of inertia of ring)

$\omega = \frac{QBa^2}{2mb^2}$

On rearranging the term, we have the required expression of angular speed.

Section D

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

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is p = $\frac{U}{c}$. When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) **(a)** $\frac{I}{c}$

Explanation:

Pressure exerted by an electromagnetic radiation, $P = \frac{I}{c}$

(ii) **(b)** 6×10^{-4} N/m^2

Explanation:

$P_{\text{rad}} = \frac{\text{Energy flux}}{\text{Speed of light}} = \frac{18 \text{ W/cm}^2}{3\times10^8 \text{ m/s}}$

= $\frac{18\times10^4 \text{ W/m}^2}{3\times10^8 \text{ m/s}}$ = 6×10^{-4} N/m^2

(iii) **(c)** 0.166×10^{-8} N m^{-2}

Explanation:

$P = \frac{I}{c} = \frac{0.5}{3\times10^8}$ = 0.166×10^{-8} N m^{-2}

OR

(b) 10^{-6} N/m^2

Explanation:

The radiation pressure of visible light

= 7×10^{-6} N/m^2

(iv) **(d)** 100

Explanation:

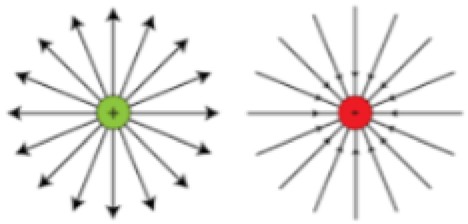
Intensity of EM wave is given by $I = \frac{P}{4\pi R^2}$ $V_{av} = \frac{1}{2}\varepsilon_0 E_0^2 \times c$

$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}} = \sqrt{\frac{1500}{2\times3.14(3)^2\times8.85\times10^{-12}\times3\times10^8}}$

= $\sqrt{10,000}$ = 100 V m^{-1}

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

A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic field. Charges are scalar in nature and they add up like real numbers. Also, the total charge of an isolated system is always conserved. When the objects rub against each other charges acquired by them must be equal and opposite.



Electric field lines of a positive point charge   Electric field lines of a negative point charge

(i) **(c)** the actual transfer of electrons

Explanation:

the actual transfer of electrons

(ii) **(d)** Option (ii)

Explanation:

The glass rod gives electrons to silk when they are rubbed against each other.

(iii) **(a)** 1.97×10^{-8} N
Explanation:
1.97×10^{-8} N

(iv) **(c)** both electric and magnetic effects
Explanation:
both electric and magnetic effects

OR

(a) transfer of an integral number of electrons
Explanation:
transfer of an integral number of electrons

Section E

31. Here, f_1 = 30 cm, f_2 = -20 cm, d = 8.0 cm

Let a parallel beam be incident on the convex lens first. If second lens were absent, then
$\therefore u_1 = \infty$ and f_1 = 30 cm
As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$
$\therefore \frac{1}{v_1} - \frac{1}{\infty} = \frac{1}{30}$
or v_1 = 30 cm

This image would now act as virtual object for second lens.
$\therefore$ u_2 = +(30 - 8) = +22 cm

f_2 = -20 cm
Since, $\frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2}$
$\therefore \frac{1}{v_2} = \frac{1}{-20} + \frac{1}{22}$
$= \frac{-11+10}{220} = \frac{-1}{220}$
v_2 = -220 cm

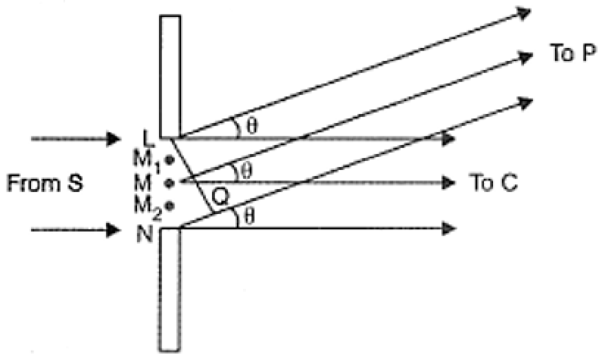
$\therefore$ Parallel incident beam would appear to diverge from a point 220 - 4 = 216 cm from the centre of the two lens system.
Assume that a parallel beam of light from the left is incident first on the concave lens.
$\therefore u_1 = -\infty$, f_1 = -20 cm
As $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$
$\therefore \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{-20} + \frac{1}{-\infty} = -\frac{1}{20}$
v_1 = -20cm

This image acts as a real object for the second lens
u_2 = -(20 + 8) = -28cm, f_2 = 30 cm
Since, $\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$
$\therefore \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = \frac{1}{30} - \frac{1}{28} = \frac{14-15}{420}$
v_2 = -420 cm

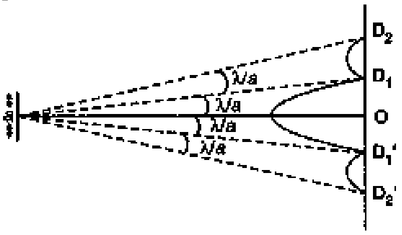
The parallel beam appears to diverge from a point 420 - 4 = 416 cm, on the left of the centre of the two lens system.
We finally conclude that the answer depends on the side of the lens system where the parallel beam is incident. Therefore, the notion of effective focal length does not seem to be meaningful here.

OR

i. We can regard the total contributions of the wavefront LN at some point P on the screen, as the resultant effect of the superposition of its wavelets like LM, MM_2, M_2N. These have to be superposed taking into account their proper phase differences.



We, therefore, get maxima and minima, i.e., a diffraction pattern, on the screen. **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.

ii. 

Conditions for first minima on the screen

asin θ = λ

$\Rightarrow \quad \theta=\frac{\lambda}{a}$

$\therefore$ Angular width of the central fringe on the screen (from the figure)

$=2\theta=\frac{2\lambda}{a}$

Angular width of first diffraction fringe (From fig)

$=\frac{\lambda}{a}$

For the first diffraction, the angular width of the fringe is half that of the central fringe.

iii. Maxima becomes weaker and weaker with increasing n. This is because the effective part of the wavefront, contributing to the maxima becomes smaller and smaller, with increasing n.

32. a. Work done in adding a charge dq = dW

= Vdq

= $\frac{q}{c}dq$

$\therefore$ Total Amount of work(W) in charging a capacitor

W = $\int dW=\frac{1}{C}\int_0^Q qdq$

W = $\frac{Q^2}{2C}$

= $\frac{(CV)^2}{2C}=\frac{1}{2}CV^2$

The electrostatic Energy/ potential energy is stored in the electric field between the plates.

b. C = 1μF = 1 $\times$ 10^{-6} F; V = 10 volt

Q = CV

= 1 $\times$ 10^{-6} $\times$ 10

= 10^{-5} coulomb

hence, the amount of charge supplied by the battery in charging the capacitor fully is 10^{-5} coulomb.

OR

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)

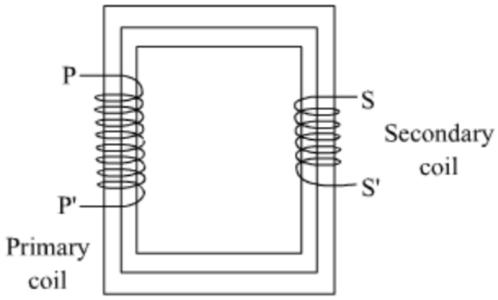
$=-q\times\left(\frac{q}{4\pi\varepsilon_0 d}\right)=-\frac{q^2}{4\pi\varepsilon_0 d}$

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.

33. i. A transformer is a device that changes a low alternating voltage into a high alternating voltage or vice versa. The transformer works on the principle of mutual induction. A changing alternate current in the primary coil produces a changing magnetic field, which induces a changing alternating current in the secondary coil.



Energy losses in the transformer:
a. Flux leakage due to poor structure of the core and air gaps in the core.
b. Loss of energy due to heat produced by the resistance of the windings.
c. Eddy currents due to alternating magnetic flux in the iron core, which leads to loss of energy due to heat.
d. Hysterisis, frequent and periodic magnetisation and demagnetisation of the core, leading to loss of energy due to heat.

ii. a. Now,
$N = \frac{N_s}{N_p}$
$\Rightarrow \frac{N_S}{100} = 100$
$\Rightarrow N_S = 10000$ turns

b. Current in primary is given by,
$I_P V_P = P$
$\Rightarrow I_P = \frac{1100}{220} = 5A$

c. Voltage across secondary is given by,
$\frac{V_s}{V_p} = \frac{N_s}{N_p} = N$
$\Rightarrow V_S = 100 \times 220 = 22000$ V

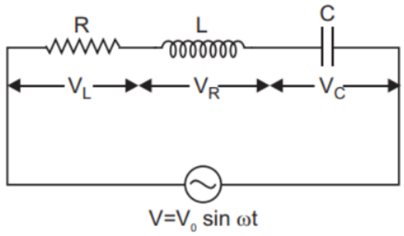
d. Current in secondary is given by
$V_S I_S = P$
$\Rightarrow I_S = \frac{P}{V_s} = \frac{1100}{22000} = 0.05$ A

e. In an ideal transformer,

Power in secondary = Power in primary = 1100 W

OR

Suppose resistance R, inductance L and capacitance C are connected in series and an alternating source of voltage $V = V_0 \sin \omega t$ is applied across it. (fig. a) On account of being in series, the current (i) flowing through all of them is the same.



(a)

Suppose the voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C. The voltage V_R and current i are in the same phase, the voltage V_L will lead the current by angle 90^o while the voltage V_C will lag behind the current by angle 90^o. Clearly V_C and V_L are in opposite directions, therefore their resultant potential difference = V_C - V_L (if $V_C > V_L$).

Thus V_R and (V_C - V_L) are mutually perpendicular and the phase difference between them is 90^o. As applied voltage across the circuit is V, the resultant of V_R and (V_C - V_L) will also be V.

From fig.

$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2}$ ......(i)

But $V_R = Ri$, $V_C = X_C i$ and $V_L = X_L i$ .....(ii)

capacitance reactance and $X_L = \omega$ L = inductive reactance

$\therefore V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$

$\therefore$ Impedance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e., $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$

Instantaneous current

$I = \frac{V_0 \sin(\omega t + \phi)}{\sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}}$

Condition for resonance to occur in series LCR ac circuit:

For resonance, the current produced in the circuit and emf applied must always be in the same phase.

Phase difference (ϕ) in series LCR circuit is given by

$\tan \phi = \frac{X_C - X_L}{R}$

For resonance $\phi = 0 \Rightarrow X_C - X_L = 0$

or $X_C = X_L$

If ω_r is resonant frequency, then

and $X_L = \omega_r L$

$\therefore \frac{1}{\omega_r C} = \omega_r L \Rightarrow \omega_r = \frac{1}{\sqrt{LC}}$

Power factor is the cosine of phase angle ϕ, i.e., cos ϕ = R/Z.

For maximum power cos ϕ = 1 or Z = R

i.e., circuit is purely resistive.

For minimum power cos ϕ = 0 or R = 0

i.e., circuit should be free from ohmic resistance.