Solution

Class 12 - Physics

2020-2021 - Paper-5

Section A

1. i. In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light as fringe width is directly proportional to wavelength. Therefore, red fringe with higher wavelength is wider than violet fringe with smaller wavelength.
   ii. In higher order spectra, the dispersion is more and it results in overlapping different colours.
2. Yes, decrease, the apparent depth of a tank of water changes when viewed obliquely. This is because light bends on travelling from one medium to another. The apparent depth of the tank when viewed obliquely is less than the near-normal viewing.
3. X-rays are used for studying the crystal structure of solids. The frequency range of X-rays is 10^{16}Hz to 10^{21} Hz.

   OR

   Displacement current is 0.25 A since displacement current is equal to conduction current.
4. For a prism of the angle A, of refractive index n_2 placed in a medium of refractive index n_1,
   $$n_{21} = \frac{n_2}{n_1} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$
   where δ_m is the angle of minimum deviation.
5. This will happen only when the refractive index of the lens is equal to the refractive index of liquid.

   OR

   Here, distance between object and screen, D = 90 cm
   Distance between two locations of convex lens, d = 20 cm
   Since, $f = \frac{D^2-d^2}{4D}$
   $\therefore f = \frac{(90)^2-(20)^2}{4\times90} = \frac{(90+20)(90-20)}{360} = \frac{110\times7}{36}$
   f = 21.4 cm
6. X-rays are used
   i. For the detection of explosives, opium and gold in the body of the smugglers.
   ii. In detecting fractures, diseased organs in human body.
7. Frequency of wave = 30MHz
   $\vec{E}$ and $\vec{B}$ lie in x-y plane and are mutually perpendicular.
   Since,
   $c = \nu\lambda$
   $\lambda = \frac{c}{\nu} = \frac{3\times10^8}{30\times10^6} = 10m$
   Thus, the wavelength of the wave is 10m.
8. On comparing the two equations we can see that phase difference between current and voltage is $\frac{\pi}{2}$.
   Therefore, the power consumption in the circuit is 0. [because cos $\frac{\pi}{2}$ = 0]
9. Given, input voltage (V_1) = 2200 V

   Number of turns (N_1) = 3000

   Output voltage (V_2) = 220 V

   As, $\frac{V_2}{V_1} = \frac{N_2}{N_1} \Rightarrow \frac{220}{2200} = \frac{N_2}{3000}$
   $\Rightarrow \quad N_2 = \frac{220}{2200} \times 3000$ = 300 turns
10. Given: μ_2 = 1.5, μ_1 = 1.4, R_1 = -R and R_2 = R
    Focal length, f = $\frac{1}{P}$ = $\frac{1}{-5}$m = -$\frac{100}{5}$ cm = -20 cm
    Now, $\frac{1}{f}$ = ($\frac{\mu_2}{\mu_1}$ - 1) ($\frac{1}{R_1}$ - $\frac{1}{R_2}$)
    $\frac{1}{-20}$ = ($\frac{1.5}{1.4}$ - 1) (-$\frac{1}{R}$ - $\frac{1}{R}$)

$\frac{1}{-20} = (\frac{0.1}{1.4})(-\frac{2}{R})$

Thus, R = $\frac{20}{7}$cm = 2.86 cm

11. **(a)** Both A and R are true and R is the correct explanation of A
Explanation: When the sun is close to setting, refraction will affect the top part of the sun differently from the bottom half. The top half will radiate its image truly while the bottom half will send an apparent image since the bottom portion of the sun is being seen through a thicker more dense atmosphere. The bottom image is being sent intensely and gives the impression of being flattened or elliptical shape.

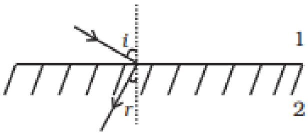
12. **(d)** A is false and R is also false
Explanation: A is false and R is also false

13. **(a)** Both A and R are true and R is the correct explanation of A
Explanation: All electromagnetic waves have the same speed in a vacuum. X-ray is a high energy electromagnetic wave.

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

Section B

15. **(c)**



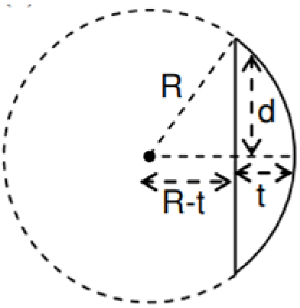
Explanation: According to Snell's law, μ= sini/sinr, The materials with negative refractive index responds to Snell's law just the opposite way. If incident ray from air (Medium 1) incident on those materials, the ray refract or bend the same side of the normal.

16. **(a)** 32 cm
Explanation: $\frac{1}{f} = (\frac{\mu_2}{\mu_1} - 1)(\frac{1}{R_1} - \frac{1}{R_2})$
In air,
$\frac{1}{f} = (\frac{1.5}{1} - 1)(\frac{1}{R_1} - \frac{1}{R_2}) = 0.5(\frac{1}{R_1} - \frac{1}{R_2})$
In water,
$\frac{1}{f'} = (\frac{1.5}{4/3} - 1)(\frac{1}{R_1} - \frac{1}{R_2}) = \frac{1}{8}(\frac{1}{R_1} - \frac{1}{R_2})$
Hence, f' = 4f = 4×8 = 32 cm

17. **(d)** red color
Explanation: For a glass prism, the angle of minimum deviation will be smallest for the light of red color. As wavelength of red color is maximum among all, hence, $\mu \propto \frac{1}{\lambda}$, hence $\mu$is smaller. As μ decreases, angle of deviation decreases.

18. **(b)** 30 cm

Explanation:



$\mu = \frac{c}{v} = \frac{3}{2}$
From figure, $R^2 = d^2 + (R - t)^2$
$R^2 - d^2 = R^2\left\{1 - \frac{t}{R}\right\}^2$
$1 - \frac{d^2}{R^2} = 1 - \frac{2t}{R}$ [neglecting higher terms]
Thus, $R = \frac{d^2}{2t} = \frac{(3)^2}{2\times(0.3)} = \frac{90}{6} = 15cm$

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

$\frac{1}{f}=\left(\frac{3}{2}-1\right)\left(\frac{1}{15}\right)$

f = 30 cm

19. **(a)** $\frac{\pi}{2}$

Explanation: An ac voltage v = v_m sinωt applied to a capacitor drives a current in the capacitor i = i_m sin (ωt + $\frac{\pi}{2}$). Thus, the current through the capacitor is $\frac{\pi}{2}$ ahead of the applied voltage.

20. **(c)** 14.4 W

Explanation: According to the problem, X_L= 1Ω, R = 2Ω,

Erms = 6V, P_{av} = ?

Average power dissipated in the circuit

$P_{\mathrm{av}}=E_{\mathrm{rms}} I_{\mathrm{rms}} \cos \phi$ ..... (i)

$I_{\mathrm{rms}}=\frac{E_{\mathrm{rms}}}{Z}$

impedence of the circuit is given by:-

$Z=\sqrt{R^2+X_L^2}$

$=\sqrt{4+1}=\sqrt{5}$

$I_{\mathrm{rms}}=\frac{6}{\sqrt{5}} \mathrm{~A}$

$\cos \phi=\frac{R}{Z}=\frac{2}{\sqrt{5}}$

$P_{\mathrm{av}}=6 \times \frac{6}{\sqrt{5}} \times \frac{2}{\sqrt{5}}$ [from eq. (i)]

$=\frac{72}{\sqrt{5} \sqrt{5}}=\frac{72}{5}=14.4 \mathrm{W}$

21. **(d)** $\vec{E}_r$ = E_0 $\hat{i}$ cos (kz + ωt)

Explanation: When a wave is reflected from a denser medium or perfectly reflecting wall made with optically inactive material, then the type of wave doesn't change but only its phase changes by 180° or π radian. Therefore, the reflected wave is with z = −z, i = −i and additional phase of π in the incident wave.

22. **(c)** X-rays

Explanation: The X-rays are the most widely used electromagnetic waves as a diagnostic tool in medicine. The X-rays penetrate through the skin and produce the image of the inner parts of the body and X-rays are used to obtain images of the structures inside the human body, like bones, unwanted stones, etc

Section C

23. a. The frequency at which the resonance occurs is

$\omega_0=\frac{1}{\sqrt{LC}}=\frac{1}{\sqrt{25.48 \times 10^{-3} \times 796 \times 10^{-6}}}$

= 222.1 rad/s

$\nu_r=\frac{\omega_0}{2 \pi}=\frac{221.1}{2 \times 3.14} \mathrm{Hz}$ = 35.4 Hz

b. The impedance Z at resonant condition is equal to the resistance:

Z = R = 3 Ω

The rms current at resonance is I :-

$=\frac{V}{Z}=\frac{V}{R}=\left(\frac{283}{\sqrt{2}}\right) \frac{1}{3}$ = 66.7 A

The power dissipated at resonance is given by:-

P = $I^2 \times R = (66.7)^2 \times 3$ = 13.35 kW

24. As ac voltage can be represented by V=V_0 sin wt.

i. from the equation V = 70 sin 100 πt

$2 \pi \nu=100 \pi$

ν = 50 Hz

ii. Peak voltage = 70 V

peak current = 70/25 = 2.8 A

rms Current =$0.707 \times$ peak current $=0.707 \times 2.8=1.98 \mathrm{~A}$

25. i. $E_{rms} = \frac{E_0}{\sqrt{2}} = \frac{50}{\sqrt{2}} = 25\sqrt{2}V$
    ii. Frequency, $f = \frac{\omega}{2\pi} = \frac{200\pi}{2\pi} = 100Hz$
    iii. Initial phase $= \frac{\pi}{4}$
    iv. $I_{rms} = \frac{1}{\sqrt{2}}\frac{E_0}{R} = \frac{1}{\sqrt{2}} \times \frac{50}{10} = 5\sqrt{2}A$

OR

Current in phase with voltage means the angle between emf and current is 0. Thus at resonance condition , inductive reactance = capacitive reactance.
$\Rightarrow$ X(L) = X(C)
ωL = $\frac{1}{\omega c}$ (here ω is omega)
So, C = $\frac{1}{\omega^2 L}$
Sustitute value of L (given) and ω = 2πf = $2\pi \times 50$
You get C = $\frac{1}{30000}$ farad
Impedance of reasonating circuit = resistance = 100 ohm
Power = Vl = $\frac{V^2}{R}$ = $\frac{200^2}{100}$ = 400 watt

26. i. Ultraviolet Radiations with the wavelength shorter than visible light is used for Water Purification
    ii. Ultraviolet rays/Laser

27. Electromagnetic radiation is the transfer of energy by electromagnetic waves. Basically it is the movement of waves from one place to another. Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane, will be set in motion by the electric and magnetic fields of EM wave, incident on this plane. This illustrates that EM waves carry energy and momentum.

28. i. Average surface temperature would be lower. Because there would be no greenhouse effect in the absence of atmosphere. As a result, the temperature of the Earth would decrease rapidly, making it difficult for human survival.
    ii. Since electromagnetic waves carry both energy and momentum, therefore, they exert pressure on the surface on which they are incident.

OR

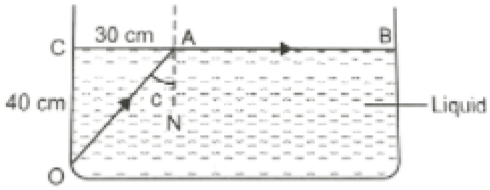
Two light sources are said to be coherent if they have exactly same frequency, have zero or constant phase difference and emitting light of the same wavelength such that the originating phase difference between them is either zero or has a fixed constant value.
Interference will be sustained if there is a constant phase difference between the two interfering waves. This is possible if the two waves are coherent.
The phenomenon of interference can be seen in the colours produced in thin films of oil.

29. Yes, the magnifying power of a microscope depends on the colour of the light used.
    Justification, $m \propto \frac{1}{f_o f_e}$
    And focal length depends on colour/μ
    The magnifying power of the microscope $\propto \frac{1}{f_o f_e}$
    Where f_0 and f_e are the focal lengths of the objective lens and eyepiece lens respectively.

    The focal length of a lens depends upon the refractive index and different colour of light has a different refractive index with respect to the medium of lens material. Hence, the magnifying power of a microscope depends on the colour of the light used.

30. i. Refractive index of a medium is the ratio of the speed of light (c) in free space to the speed of light (v) in that medium. It is a dimensionless quantity.
    $\mu = \frac{c}{v}$
    ii. $\mu = \frac{c}{v} = \frac{1}{\sin i_c}, \frac{1}{sin i_c} = \frac{OA}{CA}, \frac{OA}{CA} = \frac{\sqrt{30^2+40^2}}{30} = \frac{50}{30}$
    $= \frac{3\times10^8}{v} = \frac{50}{30}$
    $v = \frac{30}{50} \times 3 \times 10^8$

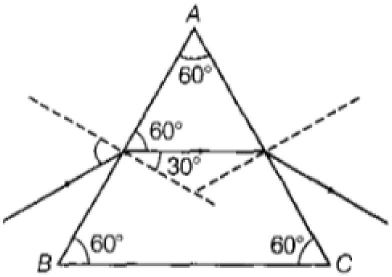
= 1.8×10^8 m/s



31. Here, $i_c = 45^0$
    i. By definition of critical angle, i.e.
    $\Rightarrow \quad \mu = \frac{1}{\sin i_C} = \frac{1}{\sin 45^\circ} = \sqrt{2}$
    Now, $\mu = \sqrt{2} = \frac{c}{v} \Rightarrow v = \frac{c}{\sqrt{2}} = \frac{3 \times 10^8}{1.414}$
    Thus, $v = 212 \times 10^8 \mathrm{m/s}$
    ii. By brewster's law,
    $\mu = \tan i_p \Rightarrow i_p = \tan^{-1} \mu = \tan^{-1}(\sqrt{2})$
    $i_p = \tan^{-1}(\sqrt{2}) = 54.65^\circ \approx 55^o$
    This particular angle of incidence is known as polarising angle.

OR

The reflection of light through a prism is shown as below.



By geometry, angle of refraction, r = 30^0 .
Given, refractive index, $\mu = \sqrt{3}$
Using snell's law,
$\mu = \sin i / \sin r$
$\Rightarrow \quad \sin i = \mu \sin r = (\sqrt{3}) \sin(30^\circ) = \sqrt{3}/2$
$i = sin^{-1}(0.85)$
$\therefore i = 60^o$

So, the angle of incidence on the prism is 60^0 for which incident ray will be parallel to the base of the prism,

Section D

32. The various losses in a transformer are:
    (i) **Flux Leakage:** There is always some flux leakage; that is, not all of the flux due to primary passes through the secondary due to poor design of the core or the air gaps in the core. It can be reduced by winding the primary and secondary coils one over the other.
    (ii) **Resistance of the windings:** The wire used for the winding has some resistance and so, energy is lost due to heat produced in the wire (I^2R). In high current, low voltage windings, these are minimised by using thick wire.
    (iii) **Eddy currents**: The alternating magnetic flux induces eddy currents in the iron core and causes heating. The effect is reduced by using a laminated core.
    (iv) **Hysteresis:** The magnetisation of the core is repeatedly reversed by the alternating magnetic field. The resulting expenditure of energy in the core appears as heat and is kept to a minimum by using a magnetic material which has a low hysteresis loss.
33. Given equation is:
    $B_y = (8 \times 10^{-6}) \sin\left[2 \times 10^{11} t + 300\pi x\right] T$
    i. Comparing the given equation with the equation of magnetic field varying sinusoidally with x and t,
    $B_y = B_0 \sin\left(\frac{2\pi x}{\lambda} + \frac{2\pi t}{T}\right)$, we get

$\frac{2\pi}{\lambda} = 300\pi$

Thus, the wavelength of the electromagnetic wave is,

$\lambda = \frac{2}{300} = 0.0067m$

ii. $B_0 = 8 \times 10^{-6}T$

$E_0 = cB_0 = 3 \times 10^8 \times 8 \times 10^{-6}$

$= 24 \times 10^2 = 2400Vm^{-1}$

$\therefore$ The required expression for the oscillating electric field is,

$E_z = E_0 \sin\left(\frac{2\pi x}{\lambda} + \frac{2\pi t}{T}\right)$

$= 2400 \sin(300\pi x + 2 \times 10^{11} t)V/m$

OR

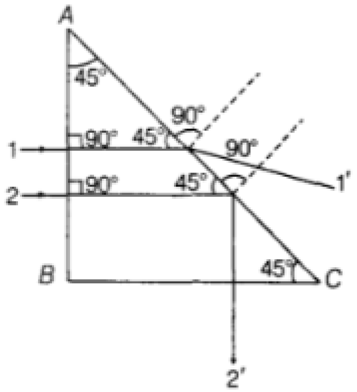
a. X-rays

b. By using X-rays tubes (Or: By bombarding a metal target with high energy electrons)

c. The wavelength range of X-rays is from (10 nm to 10 pm)

d. Alertness, empathy; concern for her mother, knowledgeable.

34.



From the figure, angle of incidence for ray 1 is 45^0 .

For ray 1, sin i = sin 45^0 = $\frac{1}{\sqrt{2}} = \frac{1}{1.414}$

For ray 1,

$\mu = 1.35$

$\mu = \frac{1}{\sin c} \Rightarrow \sin c = \frac{1}{\mu} = \frac{1}{1.35}$

Here, $\frac{1}{1.414} < \frac{1}{1.35}$

i.e. sin i < sin c or i < c, so ray 1 will be refracted by the prism.

For ray 2, angle of incidence, i = 45^0

sin i = sin 45^0 = $\frac{1}{\sqrt{2}} = \frac{1}{1.414}$

For ray 2, $\mu = 1.45$

$\mu = \frac{1}{\sin c} \Rightarrow \sin c = \frac{1}{\mu} = \frac{1}{1.45}$

Here, $\frac{1}{1.414} > \frac{1}{1.45}$

i.e. sin i > sin c or i > c, so, ray 2 will get total internally reflected.

35. A telescope has objective lenses producing long focal lengths, while a microscope has objective lenses producing short focal lengths. Telescopes and microscopes also substantially differ in the diameters of their lenses.

Given: f_0 = 1.25 cm, f_e = 5 cm

M = -30 (Magnifying power is negative)

We know,

$M = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$

Where, v_0 = Distance of image from objective, u_0 = Distance of object from objective, D = Distance of least distinct vision

Thus,

-30 = $\frac{v_0}{u_0}\left(1+\frac{25}{5}\right)$

Thus, $v_0 = -5 u_0$

Using lens formula,

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

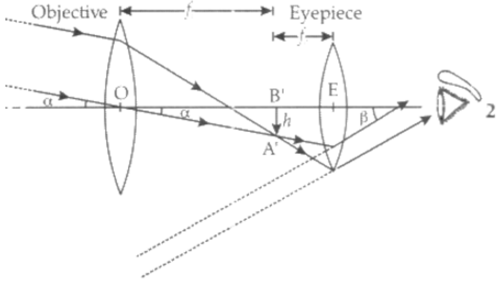
$\frac{1}{1.25}=-\frac{1}{u_0}-\frac{1}{5u_0}$

So, $u_0 = -1.5$ cm

Thus the object must be at a distance of 1.5 cm from objective lens.

OR

Ray diagram:



Drawbacks:

1. Large-sized lenses area heavy and difficult to support.
2. Large-sized lenses suffer from chromatic and spherical aberration.
3. It is difficult and expensive to make such large-sized lenses.

36. a. Potential difference across resistance,

$V_R = iR = 5\times 16 = 80\ volt$

Potential difference across inductance,

$V_L = i\times(\omega L) = 5\times 24 = 120\ volt$

Potential difference across condenser,

$V_C = i\times\left(\frac{1}{\omega C}\right) = 5\times 12 = 60\ volt$

b. The impedance of the circuit is given as,

$$Z=\sqrt{\left[R^2+\left(\omega L-\frac{1}{\omega C}\right)^2\right]}$$

$$=\sqrt{\left[(16)^2+(24-12)^2\right]}=20\ ohm$$

c. The voltage of a.c. supply is given by

$V = i\ Z = 5\times 20$ = 100 volt

d. Phase angle,

$$\phi=\tan^{-1}\left[\frac{\omega L-\left(\frac{1}{\omega C}\right)}{R}\right]$$

= $\tan^{-1}\left[\frac{24-12}{16}\right]$

$=\tan^{-1}(0.75)=36.87^o$

OR

To decrease the X_C Capacitor must be connected in parallel. The current leads the voltage in phase.

Hence, $X_C > X_L$

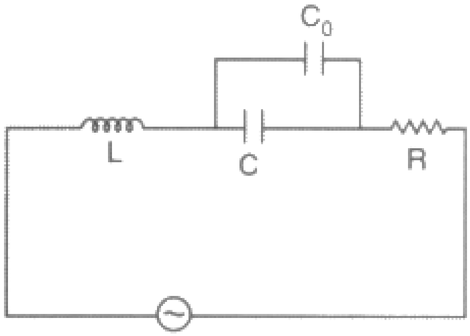
For resonance, we must have

New value of $X_C = X_L$

We, therefore, need to decrease $X_C = \left(\frac{1}{\omega C}\right)$

This requires an increase in the value of C. Hence, capacitor C_0 should be connected in parallel across C.

The diagram of the modified circuit is as shown



V = $V_0 \sin \omega t$

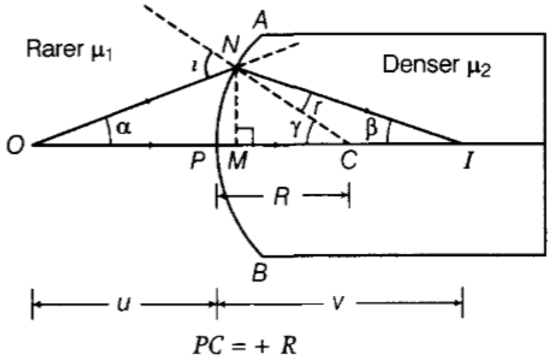
For resonance, we have

$\frac{1}{\omega(C+C_0)} = \omega L$

$\therefore C_0 = \left[\frac{1}{\omega^2 L} - C\right]$

Section E

37. The ray diagram is shown in the figure.



Let, NM = h

The convex spherical refracting surface forms the image of object O at I. The radius of curvature is R

Here $PI = +v \; and \; PO = -u$

In $\triangle NCO$, $i = \gamma + \alpha$ ...(i)

In $\triangle NCI$, $\gamma = r + \beta$

$\Rightarrow \quad r = \gamma - \beta$ ...(ii)

For small angles α, β and γ and assuming M is very close to P, we have

$\alpha \approx \tan\alpha = \frac{MN}{MO} = \frac{MN}{PO} = \frac{+h}{-u}$

$\beta \approx \tan\beta = \frac{MN}{MI} = \frac{MN}{PI} = \frac{h}{v}$

$\gamma \approx \tan\gamma = \frac{MN}{MC} = \frac{MN}{PC} = \frac{h}{+R}$

By Snell's law,

$\frac{\mu_2}{\mu_1} = \mu = \frac{\sin i}{\sin r}$

For small i and r,

$\frac{\mu_2}{\mu_1} = \frac{i}{r}$ or $r\mu_2 = i\mu_1$

$\mu_2(\gamma - \beta) = (\alpha + \gamma)\mu_1$ [From Eqs. (i) and (ii)]

$(\mu_2 - \mu_1)\gamma = \mu_1\alpha + \mu_2\beta$

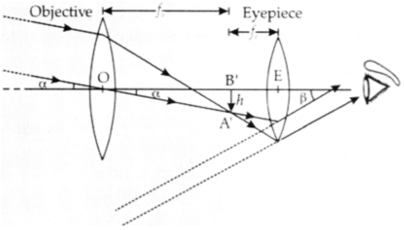
$(\mu_2 - \mu_1)\left(\frac{h}{R}\right) = \mu_1\left(\frac{h}{-u}\right) + \mu_2\left(\frac{h}{v}\right)$

$\Rightarrow \quad \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

This is the required relation.

OR

i. ray diagram is given by;



Magnifying power is given by ,

$m=\frac{\tan\beta}{\tan\alpha}\cong\frac{\beta}{\alpha}$

The angles are small

Final image is formed at infinity when the image A'B' is formed by the objective lens at the focus of the eyepiece,

$m=\frac{h}{f_e}\times\frac{f_0}{h}$

$m=\frac{f_0}{f_e}$

ii. Given,

$f_0 + f_e = 105$, $f_0 = 20f_e$

$20f_e + f_e = 105$

$f_c=\frac{105}{21}=5\text{cm}$

$f_0 = 20\times 5 = 100$ cm

Magnification is given by, $m=\frac{f_0}{f_e}=\frac{100}{5}=20$

38. Here, L = 5.0 H, $R=40\Omega$

$C=80\mu F=80\times10^{-6}F$

E_V = 230 volt

$E_0=\sqrt{2}E_v=\sqrt{2}\times230V$

i. Resonance angular frequency,

$\omega_r=\frac{1}{\sqrt{LC}}$

$=\frac{1}{\sqrt{5\times80\times10^{-6}}}=\frac{1}{2\times10^{-7}}$ = 50 rad/sec

ii. Impedance, $Z=\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}$

At resonance, $\omega L=\frac{1}{\omega C}$

$Z=\sqrt{R^2}=R=40\Omega$

Amplitude of current at resonating frequency,

$I_0=\frac{E_0}{Z}=\frac{\sqrt{2}\times230}{40}$ = 8.13 A

$I_v=\frac{I_0}{\sqrt{2}}=\frac{8.13}{\sqrt{2}}=5.75$ A

iii. Potential drop across L,

$V_L=I_v\omega_rL=5.75\times50\times5.0$ = 1437.5 V

Potential drop across R,

$V_R=I_v\times R=5.75\times40$ = 230 V

Potential drop across C,

$V_C=I_v(\frac{1}{\omega_rC})$

$=5.75\times\frac{1}{50\times80\times10^{-6}}$

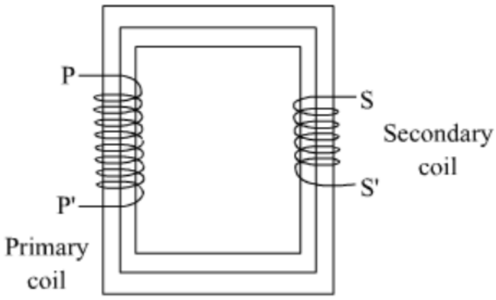
$=\frac{5.75}{4}\times10^3$ = 1437.5 V

Potential drop across LC circuit,

$V_{LC}=V_L-V_C=0$

OR

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

39. i. Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane, will be set in motion by the electric and magnetic fields of EM wave, incident on this plane. This is only possible if the EM wave constitutes momentum (the momentum value of an EM wave can be obtained using De Broglie's formula) and energy. Thus, this illustrates that EM waves carry energy and momentum.

ii. Microwaves are produced by a special vacuum tube like the klystron, magnetron and Gunn diode. The frequency of microwaves is selected to match the resonant frequency of water molecules causing more and more vibrations to the water molecules. Thus, the vibrations cause the increase in velocity, so that energy is transformed efficiently to increase the kinetic energy of the molecules. Hence, a microwave oven can cook food with water molecules inside.

iii. Uses of Infrared Rays:

a. In knowing the atomic and molecular structure of solid substances and therapy to heal muscular pain.

b. In remote control of TV, VCR, etc.

OR

a. Total energy carried by electromagnetic wave is due to electric field vector and magnetic field vector. In electromagnetic wave, E and B vary from point to point and from moment to moment.

The energy density due to electric field E is given by:-

$u_E = \frac{1}{2}\varepsilon_0 E^2$

The energy density due to magnetic field B is given by:

$u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

The total energy density of the electromagnetic wave is given by:

u = u_E + $u_B = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$

Given that The electric field vector and magnetic field vector be represented by

E = E_0 sin (kz - ωt)

B = B_0 sin (kz - ωt)

The values of E^2 and B^2 vary from point to point and from moment to moment. Hence, the effective values of E^2 and B^2 are their time averages over complete cycle.

We know, $\left\langle\sin^2\theta\right\rangle = \frac{\int_0^{2\pi}\sin^2\theta d\theta}{2\pi} = \frac{1}{2}$

and $\left\langle\cos^2\theta\right\rangle = \frac{\int_0^{2\pi}\cos^2\theta d\theta}{2\pi} = \frac{1}{2}$

Hence, the time average value of E^2 over complete cycle is given by,

$\left\langle B^2\right\rangle = \frac{\int_0^T [B_0\sin(kz-\omega t)]^2 dt}{T} = \frac{B_0^2}{2}$

The time average of energy density over complete cycle is given by-

$u_{\text{av}} = \frac{1}{2}\frac{\varepsilon_0 E_0^2}{2} + \frac{1}{2}\mu_0\left(\frac{B_0^2}{2}\right)$

$\Rightarrow u_{\text{av}} = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0^2}{\mu_0}$

b. We know $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \frac{E_0}{B_0}$

where μ_0 = Absolute permeability, ε_0 = Absolute permittivity, E_0 and B_0 = Amplitudes of electric field and magnetic field vectors

The time average of energy density due to magnetic field B is

$u_B = \frac{1}{2}\frac{B_0^2}{\mu_0} = \frac{1}{4}\frac{\left(E_0^2/c^2\right)}{\mu_0}$

$= \frac{E_0^2}{4\mu_0} \times \mu_0\varepsilon_0 = \frac{1}{4}\varepsilon_0 E_0^2$

Hence, u_B = u_E; the time average of energy density due to magnetic field.

$\Rightarrow u_{\text{av}} = \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0^2}{\mu_0}$

$= \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\varepsilon_0 E_0^2$

$= \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\frac{B_0^2}{\mu_0}$

Time average intensity of the wave is given by:

I_{av} = u_{av}c $= \left(\frac{1}{2}\varepsilon_0 E_0^2\right)c = \frac{1}{2}c\varepsilon_0 E_0^2$