Sample Question Paper - 6
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time Allowed: 2 hours **Maximum Marks: 35**

General Instructions:

1. There are 12 questions in all. All questions are compulsory.
2. This question paper has three sections: Section A, Section B and Section C.
3. Section A contains three questions of two marks each, Section B contains eight questions of three marks each, Section C contains one case study-based question of five marks.
4. There is no overall choice. However, an internal choice has been provided in one question of two marks and two questions of three marks. You have to attempt only one of the choices in such questions.
5. You may use log tables if necessary but use of calculator is not allowed.

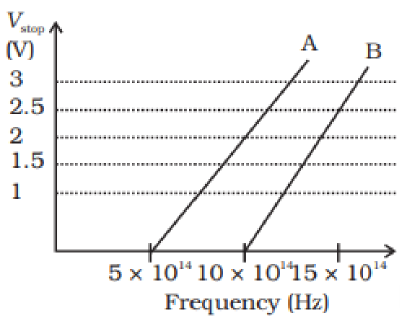
Section A

1. Draw the circuit diagram of an illuminated photodiode in reverse bias. How is photodiode used to measure light intensity? **[2]**

2. In the Auger process an atom makes a transition to a lower state without emitting a photon. The excess energy is transferred to an outer electron which may be ejected by the atom. (This is called an Auger electron). Assuming the nucleus to be massive, calculate the kinetic energy of an n = 4 Auger electron emitted by Chromium by absorbing the energy from n = 2 to n = 1 transition. **[2]**

OR

A student performs an experiment on the photoelectric effect, using two materials A and B. A plot of V_{stop} vs ν is given in Figure.



a. Which material A or B has a higher work function?

b. Given the electric charge of an electron = 1.6×10^{-19} C, find the value of h obtained from the experiment for both A and B. Comment on whether it is consistent with Einstein's theory:

3. In half wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full wave rectifier for the same input frequency. **[2]**

Section B

4. Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when the atom makes a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number $n_f (n_f < n_i)$. **[3]**

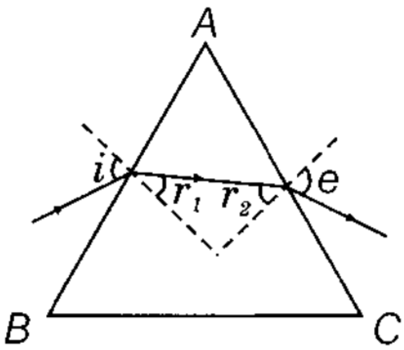
5. Draw the circuit diagram showing how a p-n junction diode is **[3]**
   i. forward biased
   ii. reverse biased

   How is the width of depletion layer affected in the two cases?

6. Explain the concept of nuclear energy with reference to binding energy curve. **[3]**

7. Explain how Newton's Corpuscular theory predicts the speed of light in a medium, say water, to be greater than the speed of light in vacuum. Is the prediction confirmed by the experimental determination of speed of light in water? If not, which alternative picture of light is consistent with experiment? **[3]**

8. In the given figure, for what value of $\angle i$ should a ray of light be incident on the face of a prism of refracting angle 60°, so that it just suffers total internal reflection at other face? (For prism, $\mu = 1.524$) **[3]**



OR

A man with normal near point (25 cm) reads a book with small print using a magnifying glass: a thin convex lens of focal length 5 cm.
   i. What is the closest and the farthest distance at which he should keep the lens from the page, so that he can read the book when viewing through the magnifying glass?
   ii. What is the maximum and the minimum angular magnification (magnifying power) possible using the above simple microscope?

9. a. A monoenergetic electron beam with the electron speed of 5.20×10^6 ms^{-1} is subject to a magnetic field of 1.30×10^{-4} T normal to the beam velocity. What is the radius of the circle traced by the beam, given e/m for electron equals 1.76×10^{11}C kg^{-1}? **[3]**
   b. Is the formula you employ in (a) valid for calculating the radius of the path of a 20 MeV electron beam? If not, in what way is it modified?

10. i. Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light. **[3]**
   ii. A double convex lens is made of a glass of refractive index 1.55 with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm.

11. The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula E = hν (for the energy of a quantum of radiation: photon) and obtain the photon **[3]**

energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation?

OR

Red light of wavelength 750 nm enters a glass plate of refractive index 1.5. If the velocity of light in a vacuum is 3×10^8 ms^{-1}, calculate in the glass

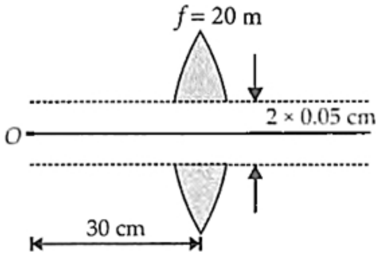
i. frequency
ii. velocity and
iii. wavelength of light.

CASE STUDY

12. **Read the source given below and answer the following questions:** **[5]**

A convex or converging lens is thicker at the centre than at the edges. It converges a parallel beam of light on refraction through it. It has a real focus. Convex lens is of three types : (i) Double convex lens (ii) Plano-convex lens (iii) Concavo-convex lens. Concave lens is thinner at the centre than at the edges. It diverges a parallel beam of light on refraction through it. It has a virtual focus.

i. A point object O is placed at a distance of 0.3 m from a convex lens (focal length 0.2 m) cut into two halves each of which is displaced by 0.0005 m as shown in figure.



What will be the location of the image?

a. 30 cm right of lens
b. 60 cm right of lens
c. 70 cm left of lens
d. 40 cm left of lens

ii. Two thin lenses are in contact and the focal length of the combination is 80 cm. If the focal length of one lens is 20 cm, the focal length of the other would be.

a. -26.7 cm
b. 60 cm
c. 80 cm
d. 20 cm

iii. A spherical air bubble is embedded in a piece of glass. For a ray of light passing through the bubble, it behaves like a

a. converging lens
b. diverging lens
c. piano-converging lens
d. piano-diverging lens

iv. Lens used in magnifying glass is

a. Concave lens
b. Convex lens
c. Both (a) and (b)
d. None of the above

v. The magnification of an image by a convex lens is positive only when the object is placed

a. at its focus F
b. between F and 2F
c. at 2F
d. between F and optical centre

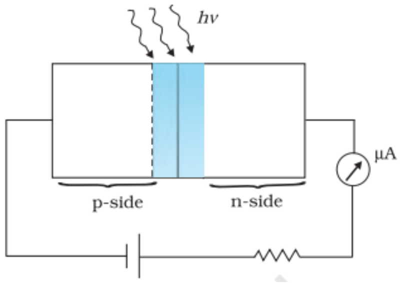
Solution

PHYSICS - 042

Class 12 - Physics

Section A

1. The circuit diagram of an illuminated photodiode in reverse bias is shown in the Figure.



It is operated under reverse bias. When the photodiode is illuminated with light (photons) with energy ($h\nu$) greater than the energy gap (E_g) of the semiconductor, then electron-hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light (photocurrent is proportional to incident light intensity). This can be used for measuring the intensity of incident light.

2. As the nucleus is massive, recoil momentum of the atom may be neglected and the entire energy of the transition may be considered transferred to the Auger electron. As there is a single valence electron in Cr, the energy states may be thought of as given by the Bohr model. The energy E_n of the nth state

$E_n = +Z^2R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right] = Z^2R\left(\frac{1}{1}-\frac{1}{4}\right)$ (for $n_1 = 1, n_2 = 2$)

Z = 24, R = Rydberg constant,

$\therefore E_n = \frac{3}{4}Z^2R$

The energy required to eject an electron from n = 4 state is

$E_4 = Z^2R\,\frac{1}{4^2} = \frac{1}{16}Z^2R$

Energy given to electron is converted into K.E. of ejected electron.

Hence, the K.E. of Auger (ejected) electron = $E_n - E_4$

K.E. = $Z^2R\,\frac{3}{4} - \frac{1}{16}Z^2R = \frac{11}{16}Z^2R = \frac{11}{16} \times 24 \times 24 \times 13.6$ eV

K.E. = $11 \times 36 \times 13.6$ = 5385.6 eV

OR

a. Here threshold frequency of, $\nu_{0A} = 5 \times 10^{14}$Hz and of B, is given by

$\nu_{OB} = 10 \times 10^{14} Hz$

The work function is given by $\phi_0 = h\nu_o$ or $\phi_0 \propto \nu_0$

$\therefore \frac{\phi_{0A}}{\phi_{0B}} = \frac{5\times10^{14}}{10\times10^{14}} < 1$ or $\phi_{0A} < \phi_{0B}$

Therefore, the work function is higher for material B than A.

b. For metal A,

slope $= \frac{h}{e} = \frac{2}{(10-5)\times10^{14}}$ or $h = \frac{2\times e}{5\times10^{14}} = \frac{2\times1.6\times10^{-19}}{5\times10^{14}} = 6.4 \times 10^{-34}$Js

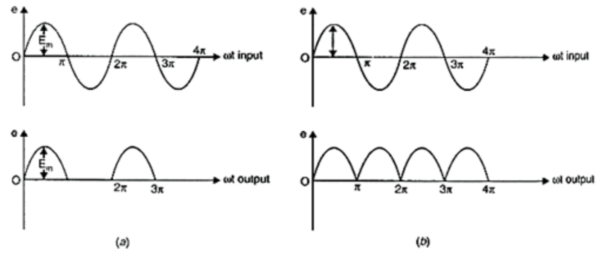
For metal B,

Slope $= \frac{h}{e} = \frac{2}{(15-10)\times10^{14}}$ or $h = \frac{2.5\times e}{5\times10^{14}} = \frac{2.5\times1.6\times10^{19}}{5\times10^{14}} = 8 \times 10^{-34} Js$

Since the value of h from the experiment for metals A and B is different. Hence, the experiment is not consistent with the theory.

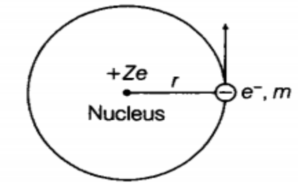
3. Input and output waveforms of half wave and full wave rectifier are shown in figure (a) and (b) respectively. During a cycle, half wave rectifier conducts once and full wave rectifier conducts twice, hence the output

frequency for the half-wave rectifier will be same i.e. 50 Hz, whereas the output frequency for the full wave rectifier will be double, i.e., output frequency = 2 × 50 = 100 Hz.



Section B

4. Let an electron revolves around the nucleus of hydrogen atom. The necessary centripetal force is provided by electrostatic force of attraction.



$\therefore \quad \frac{mv^2}{r} = \frac{ke^2}{r^2} \Rightarrow r = \frac{ke^2}{mv^2}$ ....(i)

By Bohr's second postulates,

$mvr = nh/2\pi$ where, n = 1, 2, 3....

$r = nh/2\pi mv$ ....(ii)

On comparing Eqs. (i) and (ii), we get

$\frac{ke^2}{mv^2} = \frac{nh}{2\pi mv} \Rightarrow v = \frac{2\pi ke^2}{nh}$

Substituting in Eq. (ii), we get

$r = \frac{n^2h^2}{4\pi^2 mke^2}$.........(iii)

Now, kinetic energy of electron

$\mathbf{KE} = 1/2mv^2 = ke^2/2r$

Also, potential energy, PE= - ke^2 /2r

Energy of electron in n^{th} orbit,

$E_n = -\frac{ke^2}{2r} = -\frac{ke^2}{2} \cdot \frac{4\pi^2 mke^2}{n^2h^2}$

$\Rightarrow \quad E_n = -\frac{2\pi^2 mk^2e^4}{n^2h^2}$............(iv)

where, $R = \frac{2\pi^2 mk^2e^4}{ch^3} \Rightarrow E_n = -\frac{Rhc}{n^2}$ ....(v)

where, n = 1, 2, 3....

For $n = n_i \Rightarrow E_n \propto \frac{1}{n^2}$

$E_{n_i} = -\frac{Rhc}{n_i^2}$ and $E_{n_f} = -\frac{Rhc}{n_f^2}$

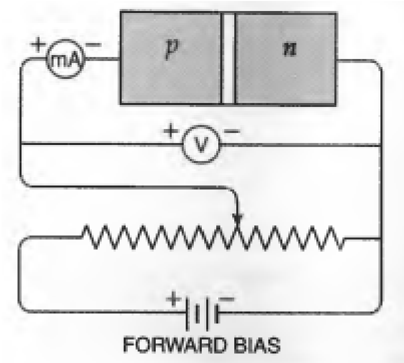
By Bohr's postulates,

$E_{n_f} - E_{n_t} = h\nu \Rightarrow Rhc\left[1/n_i^2 - 1/n_f^2\right] = h\nu$

$\nu = Rc\left[n/n_i^2 - 1/n_f^2\right]$

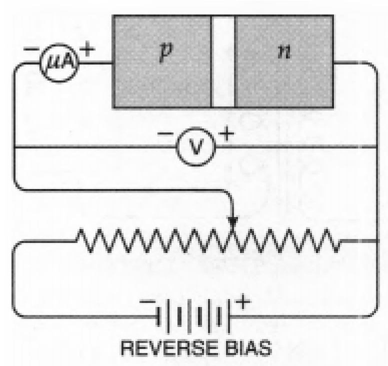
This is required expression for frequency associated with photon.

5. i. The forward-bias connections of a p-n junction are as shown in Fig.



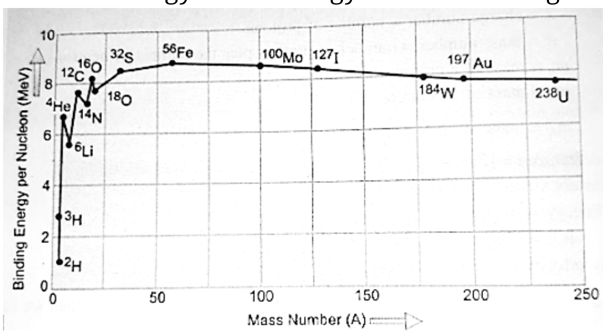
When the p-n junction is forward biased, the depletion layer becomes thin. It is because, the polarity of the external d.c. source opposes the fictitious battery developed across the junction. As a result, the potential drop across the junction decreases making the depletion layer thin. It leads to the low resistance of the junction diode during forward bias.

ii. The reverse-bias connections of a p-n junction are as shown in Fig.



When the p-n junction is reverse biased, the depletion layer becomes thick. It is because, the external d.c. source aids the fictitious battery. It results in the increase of potential drop across the junction and the depletion layer appears thick. Because of the increased thickness of the depletion layer, the p-n junction offers high resistance during reverse bias.

6. Nuclear energy is the energy released during a nuclear reaction.



The curve of average binding energy per nucleon ($\bar{B}$) against mass number (Figure) shows a long flat region from about A = 30 to A = 170. In this region, $\bar{B}$ is almost constant. However, for nuclei with A < 30 and A > 170, value of $\bar{B}$ is less than the plateau value. Clearly, nuclei with mass numbers in the range $30 \leq A \leq 170$ are more tightly bound than the nuclei with A < 30 and nuclei with A > 170. Hence when we transmute less tightly bound nuclei into more tightly bound nuclei through nuclear reactions, the nuclear energy may be released.

The nuclear reaction can thus prove to be a source of energy. Nuclear energy is released on account of mass defect in the reaction.

The nuclear reactions which can be practical sources of energy are of two broad types.

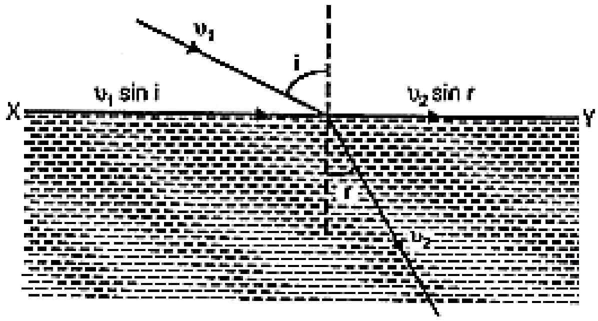
(i) Nuclear fission, in which a heavier nucleus breaks into lighter ones.

(ii) Nuclear fusion, in which lighter nuclei fuse into a heavier one.

In both the cases, energy released is estimated from mass defect (Δm) from Einstein's mass energy relation, $E = (\Delta m)\, c^2$

7. According to Newton's Corpuscular theory of light, when corpuscles of light strike the interface XY, figure separating a denser medium from a rarer medium, the component of their velocity along XY remains the

same.



If v_1 is velocity of light in rarer medium (air),

v_2 is velocity of light in denser medium (water),

i is the angle of incidence,
r is angle of refraction,
Then component of v_1 along XY = $v_1 \sin i$

Component of v_2 along XY = $v_2 \sin r$

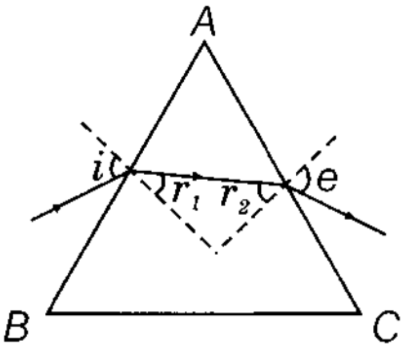
As $v_1 \sin i = v_2 \sin r$

$\therefore \frac{v_2}{v_1} = \frac{\sin i}{\sin r} = \mu$

As $\mu > 1 \therefore v_2 > v_1$

i.e. light should travel faster in water than in air. This prediction of Newton's theory is opposite to the experiment result.
Huygens wave theory predicts that $v_2 < v_1$, which is consistent with experiment.

8.



According to the question, light ray suffers total internal reflection at the second surface. So, if we observe the figure, then we find that angle of emergence, e = 90°.
Now, applying Snell's law at face AC, we have

$\frac{\sin e}{\sin r_2} = \mu$

$\Rightarrow \sin r_2 = \frac{1}{\mu} \times \sin 90^\circ$

$\Rightarrow \sin r_2 = \frac{1}{1.524} \times 1$

$\Rightarrow r_2 = sin^{-1}(0.656)$

$\Rightarrow r_2 = 41^\circ$

From geometry,

$\angle A = \angle r_1 + \angle r_2$

$\Rightarrow \angle r_1 = \angle A - \angle r_2$

$= 60^\circ - 41^\circ$

$= 19^\circ$

Applying Snell's law at face AB, we have

$\mu = \frac{\sin i}{\sin r_1}$

$\Rightarrow \sin i = (\mu) \sin r_1$

$\Rightarrow \sin i = 1.524 \times \sin 19^\circ$

$\Rightarrow i = \sin^{-1}(0.496)$

$\Rightarrow i = 29.74^\circ$

So angle of incidence must be equal to 29.74 degrees for total internal reflection to occur at the interface.

OR

i. Focal length, f = +5 cm, v = -25 cm

It is for the closest distance.

Using the lens formula,

$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

$\Rightarrow \frac{1}{5}=\frac{1}{-25}-\frac{1}{u}$

$\Rightarrow \frac{1}{u}=-\frac{1}{25}-\frac{1}{5}=\frac{-1-5}{25}=-\frac{6}{25}$

$u=-\frac{25}{6}$ = -4.2 cm

This is the closest distance he can read the book. for the farthest distance.

For the farthest distance, v' = ∞ and f = 5 cm

$\therefore \frac{1}{f}=\frac{1}{v'}-\frac{1}{u'}$

$\Rightarrow \frac{1}{5}=\frac{1}{\infty}-\frac{1}{u'}$

⇒ u' = -5 cm

This is the farthest distance at which he can read the book.

ii. Maximum angular magnification,

$m_{max}=\frac{D}{u}=\frac{25}{\frac{25}{6}}$ = 6

Minimum angular magnification is at the farthest distance,

$m_{min}=\frac{D}{u'}=\frac{25}{5}$ = 5

9. a. Here, $v=5.20\times10^{6}\mathrm{ms}^{-1}, B=1.30\times10^{-4}\mathrm{T}, \frac{e}{m}=1.76\times10^{11}\mathrm{Ckg}^{-1}, \theta=90^{\circ}$

Force exerted by the magnetic field on the electron

$F=e|\vec{v}\times\vec{B}|=evB\sin\theta=evB$ ($\because \sin 90^0 = 1$)

since, the normal magnetic field provides the centripetal force, this gives (condition For the electron to move in a circle)

$\therefore evB=\frac{mv^2}{r}$ or $r=\frac{mv}{eB}=\frac{v}{(e/m)B}=\frac{5.20\times10^{6}}{1.76\times10^{11}\times1.30\times10^{-4}}$ = 0.27m = 22.7 cm

b. Energy,

E = 20 MeV $=20\times1.6\times10^{-13}J=\frac{1}{2}mv^2 \therefore v=\left(\frac{2\times20\times1.6\times10^{-13}}{9\times10^{-31}}\right)^{1/2}$ = $2.67\times10^{9}\mathrm{m/s}$

Which is greater than the velocity of light.

Therefore the formula r = $\frac{mv}{eB}$ is not valid for calculating the radius of the path of 20 MeV electron beam because electron with such high energy has a velocity in the relativistic domain (ie. comparable with the velocity of light, For this, we use relativistic formula as follows.

$r=\frac{mv}{eB}=\left(\frac{m_0}{\sqrt{1-v^2/c^2}}\right)\frac{v}{eB}$

10. i. As we know that in refraction, the frequency of the light remains same so, we can write:

$f_{\text{refracted beam}} = f_{\text{incident beam}}$

Also, we have $\mu_{21}=\frac{v_1}{v_2}=\frac{f\lambda_1}{f\lambda_2}=\frac{\lambda_1}{\lambda_2}$ $[\because v=f\lambda]$

$\Rightarrow v_2=\frac{v_1}{\mu_{21}}=\frac{3\times10^{8}}{1.33}=2.25\times10^{8}\mathrm{ms}^{-1}$

and, $\lambda_2=\frac{\lambda_1}{\mu_{21}}=\frac{589}{1.33}=442.85\approx 443\mathrm{nm}$

So, wavelength of reflected bearn = 443 nm and its speed = 2.25×10^{8} ms^{-1}

ii. For a biconvex lens, using lens maker's formula,

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

Here, it is given that f = 20 cm, $\mu=1.55, R_1=+R$ and R_2 = - R

Therefore, we have, $\frac{1}{f}=(\mu-1)\frac{2}{R}$

$\Rightarrow R=2(\mu-1)f=2\times(1.55-1)\times20=22\mathrm{cm}$

Hence, the radius of curvature 22 cm is required.

11. Energy of a photon is given as:

E = hv $= \frac{hc}{\lambda}$

where,

h - Planck's constant = 6.6 × 10^{-34} Js

c = Speed of light = 3 × 10^8 m/s

λ = Wavelength of radiation

$\therefore E = \frac{6.6\times10^{-34}\times3\times10^8}{\lambda} = \frac{19.8\times10^{-26}}{\lambda}J$

$= \frac{19.8\times10^{-26}}{\lambda\times1.6\times10^{-19}} = \frac{12.375\times10^{-7}}{\lambda}\text{eV}$

The given table lists the photon energies for different parts of an electromagnetic spectrum for different λ.

λ (m)	10^3	1	10^{-3}	10^{-6}	10^{-8}	10^{-10}	10^{-12}
E (ev)	12.375 × 10^{-10}	12.375 × 10^{-7}	12.375 × 10^{-4}	12.375 × 10^{-1}	12.375 × 10^1	10.375 × 10^3	12.375 × 10^5

The Energy of a photon that a source produces indicates the spacing of relevant energy levels of the source

OR

Given,

Refractive index of the glass plate, n_g = 1.5

Wavelength of light in vacuum, λ_v = 750 × 10^{-9} m

Velocity of light in vacuum, c = 3 × 10^8 ms^{-1}

Frequency of light in vacuum,

v = $\frac{c}{\lambda_v}$

$= \frac{3\times10^8 \text{ ms}^{-1}}{750\times10^{-9} \text{ m}}$

= 4 × 10^{14} Hz

For the light refracted in glass, frequency v remains unchanged but, wavelength and speed changes.

i. Frequency of light in glass = Frequency of light in vacuum = 4 × 10^{14} Hz

ii. Velocity of light in glass, v_g = $\frac{c}{n_g} = \frac{3\times10^8 ms^{-1}}{1.5}$ = 2 $\frac{c}{n_g} = \frac{3\times10^8 ms^{-1}}{1.5}$ = 2 × 10^8 ms^{-1}

iii. Wavelength of light in glass, $\lambda_g = \frac{\lambda_v}{n_g} = \frac{750\text{nm}}{1.5}$ = 500 nm

CASE STUDY

12. i. (b): Each half lens will form an image in the same plane. The optic axes of the lenses are displaced,

$\frac{1}{v} - \frac{1}{(-30)} = \frac{1}{20}; v = 60 \text{ cm}$

ii. (a): Here f_1 =20 cm; f_2 = ?

F = 80 cm

As $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{F} \Rightarrow \frac{1}{f_2} = \frac{1}{F} - \frac{1}{f_1}$

$\frac{1}{\pi_2} = \frac{1}{80} - \frac{1}{20} = \frac{-3}{80}$

$f_2 = \frac{-80}{3} = -26.7 \text{ cm}$

iii. (b): The bubble behaves libe a diverging lens.

iv. (b): Convex lens is used in magnifying glass.

v. (d)