Date: 20/05/2022

SET No. 3

Question Paper Code

55/5/3

Time: 2 hrs.

Class-XII

Max. Marks: 35

PHYSICS (Theory)

Term-II

(CBSE-2022)

GENERAL INSTRUCTIONS

Please read the following instructions carefully and follow them :

(i) This question paper contains **12** questions. **All** questions are compulsory.

(ii) This question paper is divided into **THREE** sections, **Section A, B** and **C**.

(iii) **Section A** - Question number 1 to 3 are of **2** marks each.

(iv) **Section B** - Question number 4 to 11 are of **3** marks each.

(v) **Section C** - Question number 12 is a case study based question of **5** marks.

(vi) There is no overall choice in the question paper. However, internal choice has been provided in some of the questions. Attempt any one of the alternatives in such questions.

(vii) Use of log tables is permitted, if necessary, but use of calculators is **not** permitted.

SECTION-A

1. Give two differences between a half wave rectifier and a full wave rectifier. [2]

Sol. Two differences are :

(a) Centre – tapping of the secondary windings is needed in a full-wave rectifier while no such tapping is needed in a half-wave rectifier.

(b) For a full-wave rectifier, voltage rectified by each diode (of the total two diodes) is only half the total secondary voltage while for a half-wave rectifier, the total secondary voltage is rectified.

2. Why a photo-diode is operated in reverse bias whereas current in the forward bias is much larger than that in the reverse bias? Explain.

Mention its two uses. [2]

Sol. A photodiode is operated in reverse bias because it is easier to observe the change in current with change in the light intensity.

Uses:

(a) Photodetector to detect optical signals.

(b) Measurement of the intensity of light.

3. (a) What results do you expect if α-particle scattering experiment is repeated using a thin sheet of hydrogen in place of a gold foil? Explain. (Hydrogen is a solid at temperature below 14 K) [2]

OR

(b) Why it is the frequency and not the intensity of light source that determines whether emission of photoelectrons will occur or not? Explain. [2]

Sol. (a) If α-particle scattering experiment is repeated using a thin sheet of hydrogen in place of a gold foil, the scattering angle would not be large enough. This will happen because mass of hydrogen is less than the mass of incident α-particle (around 4 times less).

OR

(b) Frequency decides the energy of a photon while intensity decides the number of photons incident. So, for emission of photoelectrons where some minimum energy is required, the deciding factor is frequency and not intensity.

SECTION-B

4. (a) (i) Define SI unit of power of a lens. [3]

(ii) A plano convex lens is made of glass of refractive index 1.5.

The radius of curvature of the convex surface is 25 cm.

(ii.i) Calculate the focal length of the lens.

(ii.ii) If an object is placed 50 cm in front of the lens, find the nature and position of the image formed.

OR

(b) A slit of width 0.6 mm is illuminated by a beam of light consisting of two wavelengths 600 nm and 480 nm. The diffraction pattern is observed on a screen 1.0 m from the slit. Find [3]

(i) The distance of the second bright fringe from the central maximum pertaining to light of 600 nm.

(ii) The least distance from the central maximum at which bright fringes due to both the wavelengths coincide.

Sol. (a) (i) The power of a lens of focal length of 1 metre is one dioptre. The SI unit for power of a lens is dioptre (D). 1D = 1 m^{-1}.

(ii) (ii.i) We know the relation

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

$$\Rightarrow \quad \frac{1}{f}=(0.5)\left(\frac{1}{25}-0\right)\text{cm}^{-1}$$

$$\Rightarrow \quad f = 50 \text{ cm}$$

(ii.ii) We know the relation

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

$$\Rightarrow \quad \frac{1}{v}-\frac{1}{-50\text{ cm}}=\frac{1}{50\text{ cm}}$$

$$\Rightarrow \quad v \to \infty$$

$\Rightarrow$ Image is formed at infinity.

OR

(b) (i) Second bright fringe is located at

$$\theta=\frac{5\lambda}{2a}$$

$$\Rightarrow \quad y \simeq D\times\frac{5\lambda}{2a}=2.5\text{ mm}$$

(ii) Let the least distance be l.

$$\Rightarrow \quad l=\left(m+\frac{1}{2}\right)\frac{\lambda_1}{a}=\left(n+\frac{1}{2}\right)\frac{\lambda_2}{a}$$

$$\Rightarrow \quad (2m+1)5=(2n+1)4$$

LHS would always be an odd number.

RHS would always be an even number.

Hence, two sides of the equation can never be equal. So, for the given pair of wavelengths, there won't be any such position, where maximas can coincide.

5. An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies. [3]

(i) When will such transitions result in (a) Lyman (b) Balmer series?

(ii) Find the ratio of the longest wavelength in Lyman series to the shortest wavelength in Balmer series.

Sol. (i) When the electrons transition is from higher orbit to ground state (1st orbit), the transition results in Lyman series and when this transition is from higher orbit to 1st excited state (2nd orbit), the transition results in Balmer series.

(ii) Longest wavelength will be created when the electron jumps from 2nd orbit to 1st orbit, so

$$\frac{1}{\lambda_l} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4} \quad \text{...(i)}$$

Shortest wavelength is created when the electron jumps from outside atom to 2nd orbit, so

$$\frac{1}{\lambda_s} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

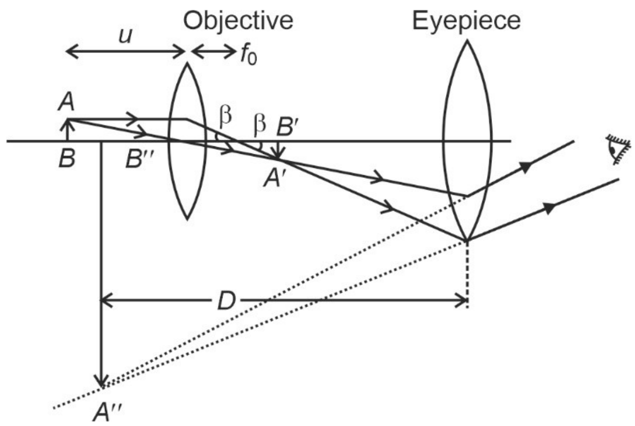
$$\frac{1}{\lambda_s} = \frac{R}{4} \quad \text{...(ii)}$$

On dividing equation (ii) with equation (i), then

$$\frac{\lambda_l}{\lambda_s} = \frac{1}{3}$$

6. With the help of a ray diagram, show how a compound microscope forms a magnified image of a tiny object, at least distance of distinct vision. Hence derive an expression for the magnification produced by it. [3]

Sol.



$$m_0 = \frac{A'B'}{AB} \simeq \frac{L}{f_0}$$

and the image of eye piece is at minimum distance of clear vision so

$$m_e = \left(1 + \frac{D}{f_e}\right)$$

So, total magnification

$m = m_0 \times m_e$

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

7. (a) Give an example each of a metal from which photoelectric emission takes place when irradiated by (i) UV light (ii) visible light. [3]

(b) The work function of a metal is 4.50 eV. Find the frequency of light to be used to eject electrons from the metal surface with a maximum kinetic energy of 6.06×10^{-19} J.

Sol. (a) UV radiation range for wavelength belongs to 100 – 400 nm, for this the work function range will be $\left(\text{using } \phi = \frac{hc}{\lambda}\right)$ 3.1 eV $\le \phi \le$ 12.4 eV. The metals that fall in this range are Ca, Mo, Pb, Al, Hg, Cu, Ag, Ni and Pt.

Visible light range for wavelength belongs to 400 nm – 700 nm, for this the work function range will be $\left(\text{using } \phi = \frac{hc}{\lambda}\right)$ 1.78 eV $\le \phi \le$ 3.1 eV. The metals that fall in this range are Cs, K, Na.

Note: UV radiation can also create photoelectric emission in the metals which are also showing photoelectric emission with visible light but reverse is not true.

(b) Kinetic energy of photon required is

$E_0 = \phi + \text{KE}$

$= 4.5\,\text{eV} + \frac{6.06 \times 10^{-19}}{1.6 \times 10^{-19}}\text{eV}$

= 8.29 eV

So, frequency $\nu = \frac{E_0}{h}$

$= \frac{8.29}{4.14 \times 10^{-15}}$

$\simeq 2 \times 10^{15}\,\text{Hz}$

8. In a fission event of ${}^{238}_{92}\text{U}$ by fast moving neutrons, no neutrons are emitted and final products, after the beta decay of the primary fragments, are ${}^{140}_{58}\text{Ce}$ and ${}^{99}_{44}\text{Ru}$. Calculate Q for this process. Neglect the masses of electrons/positrons emitted during the intermediate steps. [3]

Given : $m\left({}^{238}_{92}\text{U}\right) = 238.05079\text{u}; m\left({}^{140}_{58}\text{Ce}\right) = 139.90543\text{u}$

$m\left({}^{99}_{44}\text{Ru}\right) = 98.90594\text{u}; m\left({}^{1}_{0}\text{n}\right) = 1.008665\text{u}$

Sol. The given fission event can be represented by the following nuclear reaction equation

$${}^{1}_{0}\text{n} + {}^{238}_{92}\text{U} \rightarrow {}^{140}_{58}\text{Ce} + {}^{99}_{44}\text{Ru} + 10\,{}^{0}_{-1}\text{e}$$

Mass of electrons and positrons are to be neglected.

Now, Q value of the process

= Mass defect × c^2

= [(Mass on parent nuclei) – (Mass of daughter nuclei)]c^2

$= \left[m\left({}^{238}_{92}\text{U}\right) + m\left({}^{1}_{0}\text{n}\right) - m\left({}^{140}_{58}\text{Ce}\right) - m\left({}^{99}_{44}\text{Ru}\right)\right]c^2$

= [238.05079 + 1.008665 – 139.90543 – 98.90594]uc^2

$= \frac{3.73 \times 10^{-27+16}}{1.6 \times 10^{-19}}\text{eV}$

= 233.125 MeV

9. (a) (i) Arrange the following electromagnetic radiation in the ascending order of their frequencies: [3]

X-rays, microwaves, gamma rays, radio waves

(ii) Write two uses of any two of these radiation.

OR

(b) With the help of a ray diagram explain the working of a reflecting telescope. Mention two advantages of a reflecting telescope over a refracting telescope. [3]

Sol. (a) (i) As we know higher energy rays would have higher frequency so given radiations can be arranged in order of increasing frequency as following i.e.

Radio waves < Microwaves < X-rays < Gamma rays

(ii) X-rays uses

(1) X-rays are used to detect internal injuries and bone fractures.

(2) X-rays are used to detect cracks or defects within the volume of materials

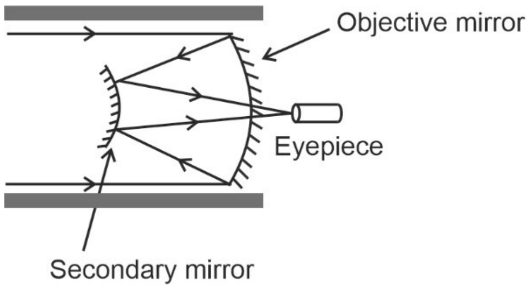
Radio waves uses

(1) Radio waves are used in radio communication systems to broadcast information

(2) For modulation purpose Radio waves are used as carrier waves

OR

(b) Reflecting telescope uses mirrors to collect and focus the light towards the eyepiece. The following ray diagram suggests the path traced by the rays in a schematic reflecting telescope setup.



A curved primary mirror is used the gather to light from the source and direct towards a secondary mirror. The eyepiece is directed at secondary mirror from where it receives the light rays. The eyepiece magnifies and enhances the image for our viewing.

The primary mirror used is parabolic in shape to allow the rays incident parallel to channel to focus on secondary mirror.

Advantages of reflective telescope over refracting telescope

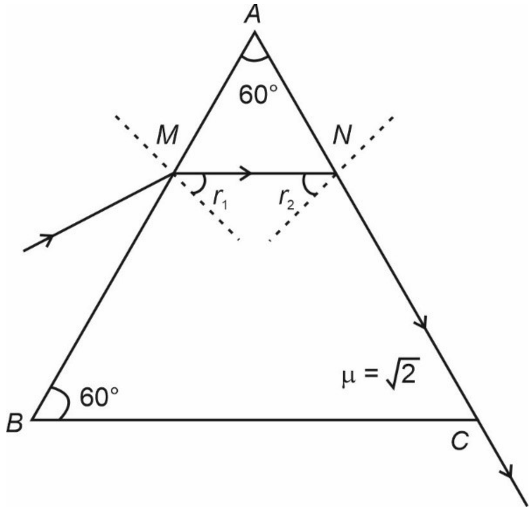
(A) The parabolic mirror is easier to manufacture and operate in comparison to bulky spherical lens.

(B) The parabolic mirror reduces spherical aberration.

(C) Size of parabolic mirror can be made bigger in comparison to lenses.

(D) Due to bigger size of mirror the images formed are brighter and sharp than refracting telescope.

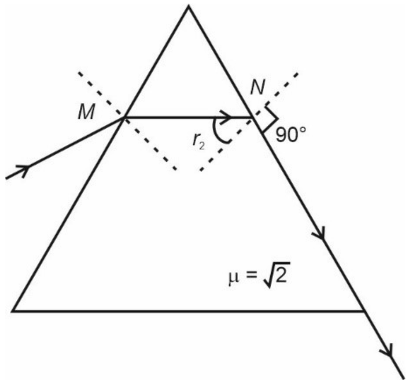
10. A ray of light passes through a prism of refractive index $\sqrt{2}$ as shown in the figure. Find: [3]



(i) The angle of incidence ($\angle r_2$) at face AC.

(ii) The angle of minimum deviation for this prism.

Sol. (i)



As shown in the diagram, angle of refraction at N is 90°.

So, applying Snell's law at N :

$$\mu \sin r_2 = 1 \sin 90°$$

$$\Rightarrow \sqrt{2} \sin r_2 = 1$$

$$\Rightarrow \sin r_2 = \frac{1}{\sqrt{2}}$$

Or, $r_2 = 45°$

(ii) If A is the angle of prism and δ_m is angle of minimum deviation,

We know :

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \quad \text{...(i)}$$

Putting $\mu = \sqrt{2}$, $A = 60°$ in (i),

$$\sqrt{2} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

Or, $\sin\left(\frac{60° + \delta_m}{2}\right) = \sqrt{2}\sin 30°$

$$= \sqrt{2} \times \frac{1}{2}$$

Or, $\sin\left(\frac{60° + \delta_m}{2}\right) = \frac{1}{\sqrt{2}} = \sin(45°)$

Thus, $\frac{60° + \delta_m}{2} = 45°$

$\Rightarrow 60° + \delta_m = 2 \times 45° = 90°$

$\Rightarrow \delta_m = 90° - 60°$

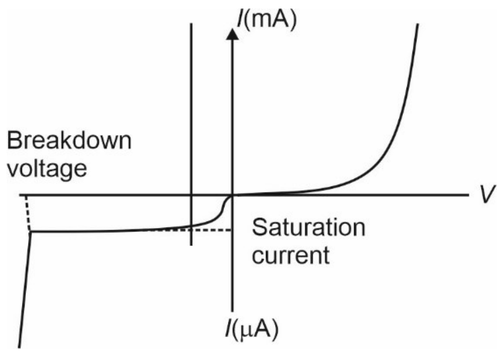
$\Rightarrow \delta_m = 30°$

11. (i) Draw V-I characteristics of a p-n Junction diode. [3]

(ii) Differentiate between the threshold voltage and the breakdown voltage for a diode.

(iii) Write the property of a junction diode which makes it suitable for rectification of ac voltages.

Sol. (i) V-I characteristics of a p-n Junction diode are shown in the graph below



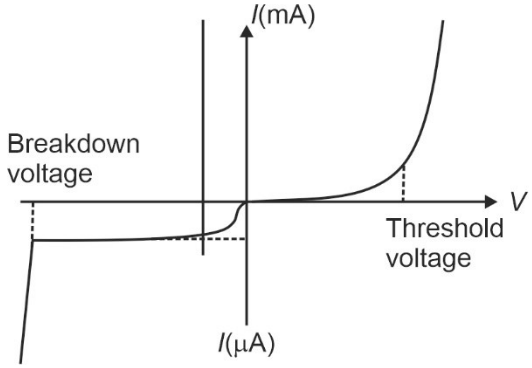
Salient points

- In forward bias, current readings are in mA while in reverse bias, current reading are in μA.
- In reverse bias, as the biasing voltage increases, current value reaches a maximum value and remains constant (saturation).
- As reverse bias voltage is increased even further, it reaches a "breakdown" point when the reverse bias current suddenly increases.

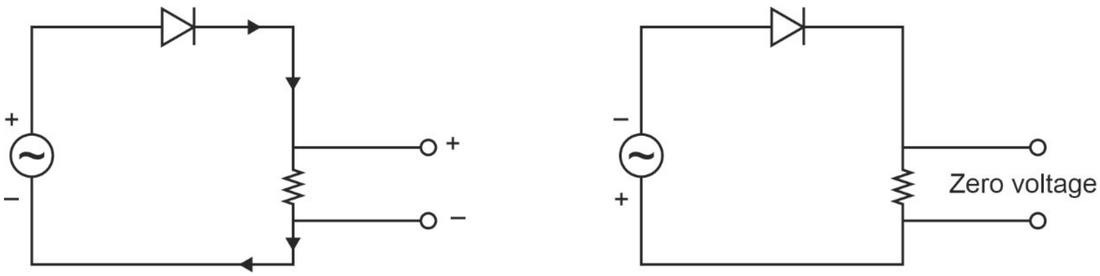
(ii)

	Threshold voltage		Breakdown voltage
1.	For forward bias	1.	For reverse bias
2.	As forward bias voltage is increased, the diode becomes "ON" or the current values become significant after a certain minimum threshold voltage. This is the point where the applied forward bias voltage is able to overcome the barrier potential across the p-n junction.	2.	For reverse bias, current is almost negligible for very small until the reverse bias voltage reaches the "breakdown" point. At this point the electric field due to applied voltage is high enough to "break" the molecules or pull the electrons away from host atoms. This causes sudden increase in number of charge carries and hence the current, without further significant increase in reverse bias voltage.

These two voltages are also marked on following graph.



(iii) Under normal operation, a diode is conducting or "ON" only for one polarity i.e. forward bias. For reverse bias, diode current is negligible or the diode is "OFF". This property makes it suitable for rectification of ac voltages.

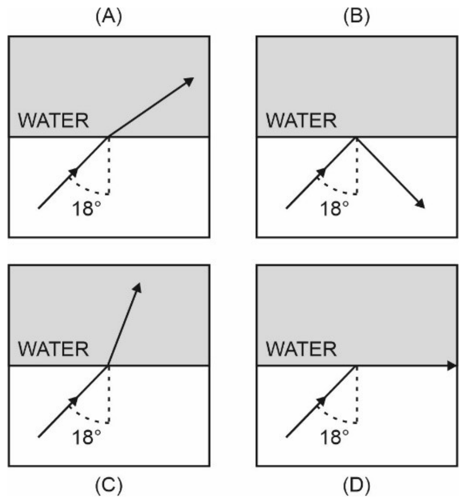


As shown in these diagrams, the diode conducts in only one polarity *i.e.*, forward bias.

SECTION-C

12. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interface of two media. The angle of incidence for which it happens is called critical angle. If the angle of incidence is increased further the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light. [5]

(i) A ray of light travels from a medium into water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light?



(ii) A point source of light is placed at the bottom of a tank filled with water, of refractive index μ, to a depth d. The area of the surface of water through which light from the source can emerge, is

(a) $\dfrac{\pi d^2}{2\left(\mu^2-1\right)}$ (b) $\dfrac{\pi d^2}{\left(\mu^2-1\right)}$

(c) $\dfrac{\pi d^2}{\sqrt{2}\sqrt{\mu^2-1}}$ (d) $\dfrac{2\pi d^2}{\left(\mu^2-1\right)}$

(iii) For which of the following media, with respect to air, the value of critical angle is maximum?

(a) Crown glass (b) Flint glass

(c) Water (d) Diamond

(iv) The critical angle for a pair of two media A and B of refractive indices 2.0 and 1.0 respectively is

(a) 0° (b) 30°

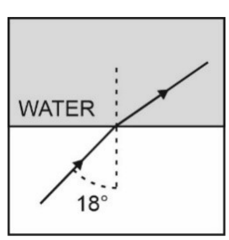
(c) 45° (d) 60°

(v) The critical angle of pair of a medium and air is 30°. The speed of light in the medium is

(a) 1×10^8 m s^{-1} (b) 1.5×10^8 m s^{-1}

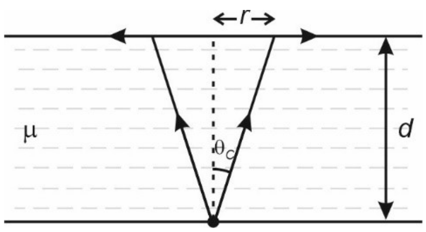
(c) 2.2×10^8 m s^{-1} (d) 2.8×10^8 m s^{-1}

Sol. (i) **(A)** As the critical angle is 20° and angle of incidence is 18°, the incident ray emerges into other medium at larger angle of refraction.



Therefore, option (A) is correct.

(ii) **(b)** $\sin\theta_C = \frac{1}{\mu}$



and, $r = d\tan\theta_C$

$$= d \times \frac{1}{\sqrt{\mu^2 - 1}}$$

∴ Area on the surface through which light emerges is

$A = \pi r^2$

$$\Rightarrow \quad A = \pi \times \frac{d^2}{(\mu^2 - 1)}$$

Therefore, option (b) is correct.

(iii) **(c)** $\because \quad \sin\theta_C = \frac{1}{\mu}$

For maximum critical angle, μ should be minimum.

∴ Among given option, water has minimum μ.

Therefore, option (c) is correct.

(iv) **(b)** Critical angle (θ_C) is given by

$$\theta_C = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$$

$$\Rightarrow \quad \theta_C = \sin^{-1}\left(\frac{1.0}{2.0}\right) = 30^\circ$$

Therefore, option (b) is correct.

(v) **(b)** $\because \quad \sin\theta_C = \frac{\mu_2}{\mu_1}$

$$\Rightarrow \quad \sin(30^\circ) = \frac{1}{\mu}$$

$$\Rightarrow \quad \mu = 2$$

and, $\mu = \frac{c}{v}$

$$\Rightarrow \quad 2 = \frac{3 \times 10^8}{v}$$

$$\Rightarrow \quad v = 1.5 \times 10^8 \text{ m/s}$$

Therefore, option (b) is correct.

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