Sample Question Paper - 10
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. What are holes? Give their important characteristics. **[2]**

2. The energy of the electron in the ground state of hydrogen atom is -13.6 eV. **[2]**
   i. What does the negative sign signify?
   ii. How much energy is required to take an electron in this atom from the ground state to the first excited state?

OR

The wavelength λ, of a photon and the de-Broglie wavelength of an electron have the same value. Show that energy of a photon is $\frac{2\lambda mc}{h}$ times the kinetic energy of electron, where m, c and h have their usual meaning.

3. What happens when a forward bias is applied to the p-n junction? **[2]**

Section B

4. The total energy of an electron in the first excited state of the hydrogen atom is about –3.4 eV. **[3]**
   a. What is the kinetic energy of the electron in this state?
   b. What is the potential energy of the electron in this state?
   c. Which of the answers above would change if the choice of the zero of potential energy is changed?

5. With the help of a suitable diagram, explain the formation of depletion region and potential barrier in a p-n junction. How does its width change when the junction is **[3]**
   i. forward biased and
   ii. reverse biased?

6. i. What characteristic property of nuclear force explains the constancy of binding energy per **[3]**

nucleon (BE/A) in the range of mass number A lying 30< A<170?

ii. Show that the density of nucleus over a wide range of nuclei is constant and independent of mass number A.

7. Using Huygens' construction, explain how a parallel beam of light on reflection from a concave mirror gets converged. **[3]**

8. Define power of a lens. Write its units. Deduce the relation $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$ for two thin lenses kept in contact coaxially. **[3]**

OR

A card sheet divided into squares each of size 1 mm^2 is being viewed at a distance of 9 cm through a magnifying glass (a converging lens of focal length 10 cm) held close to the eye.

a. What is the magnification produced by the lens? How much is the area of each square in the virtual image?
b. What is the angular magnification (magnifying power) of the lens?
c. Is the magnification in (a) equal to the magnifying power in (b)? Explain.

9. The wavelength of light in the visible region is about 390 nm for violet colour, about 550 nm (average wavelength) for yellow-green colour and about 760 nm for red colour. What are the energies of photons in (eV) at the **[3]**

i. violet and
ii. average wavelength, yellow-green colour, and
iii. red end of the visible spectrum? (Take h = $6.63 \times 10^{-34} Js$ and 1eV $= 1.6 \times 10^{19} J$)

10. A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Give the location of the image and the magnification. Describe what happens as the needle is moved farther from the mirror. **[3]**

11. Answer the following questions: **[3]**

i. Name the EM waves which are used for the treatment of certain forms of cancer. Write their frequency range.
ii. The thin ozone layer on top of the stratosphere is crucial for human survival. Why?
iii. Why is the amount of momentum transferred by the EM waves incident on the surface so small?

OR

Explain by drawing a suitable diagram that the interference pattern in a double-slit is actually a superposition of single-slit diffraction from each slit.
Write two basic features that distinguish the interference pattern from those seen in a coherently illuminated single slit.

CASE STUDY

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

Refraction of light is the change in the path of light as it passes obliquely from one transparent medium to another medium. According to law of refraction $\frac{\sin i}{\sin r} = {}^1\mu_2$, where ${}^1\mu_2$ is called refractive index of second medium with respect to first medium. From refraction at a convex spherical surface, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2-\mu_1}{R}$. Similarly from refraction at a concave spherical surface when object lies in the rarer medium, we have $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ and when object lies in the denser medium, we have $\frac{\mu_1}{v} - \frac{\mu_2}{u} = \frac{\mu_1 - \mu_2}{R}$.

i. Refractive index of a medium depends upon
   a. nature of the medium
   b. wavelength of the light used
   c. temperature
   d. all of these

ii. A ray of light of frequency 5×10^{14} Hz is passed through a liquid. The wavelength of light measured inside the liquid is found to be 450×10^{-9} m. The refractive index of the liquid is
   a. 1.33
   b. 2.52
   c. 2.22
   d. 0.75

iii. A ray of light is incident at an angle of 60° on one face of a rectangular glass slab of refractive index 1.5 . The angle of refraction is
   a. $\sin^{-1}(0.95)$
   b. $\sin^{-1}(0.58)$
   c. $\sin^{-1}(0.79)$
   d. $\sin^{-1}(0.86)$

iv. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of sphere is
   a. 2 cm
   b. 4 cm
   c. 6 cm
   d. 12 cm

v. In refraction, light waves are bent on passing from one medium to the second medium because in the second medium
   a. the frequency is different
   b. the co-efficient of elasticity is different
   c. the speed is different
   d. the amplitude is smaller.

Solution

PHYSICS - 042

Class 12 - Physics

Section A

1. Hole is a seat of positive charge which is produced when an electron breaks away from a covalent bond in a semiconductor. The important Characteristics of a hole:
    i. The hole carries a unit positive charge.
    ii. It has the same magnitude of charge as that of the electron.
    iii. The energy of a hole is high as compared to that of the electron.
    iv. The mobility of the hole is smaller than that of the electron.
    v. In an external electric field, holes move in a direction opposite to that of electrons.
2. According to the question,
   The energy of the electron in the ground state of hydrogen atom is -13.6 eV.
    i. The negative sign imply that electrons are bound to the nucleus by means of electrostatic force of attraction.
    ii. Energy of electron in nth orbit of hydrogen atom is given by, $E_n = -\frac{13.6}{n^2}\text{eV}$
       For first excited state, n = 2
       $E_2 = -\frac{13.6}{2^2}\text{eV} = -\frac{13.6}{4} = -3.4\text{eV}$
       Energy required = 3.4 eV- (-13.6 eV) = 10.2 eV

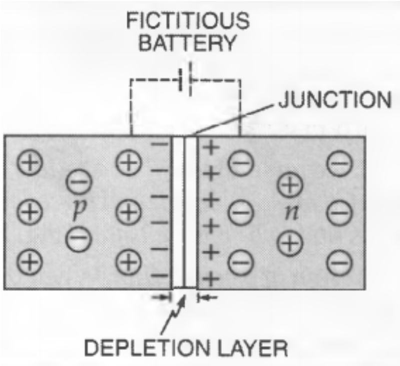
   OR

   The de-Broglie wavelength of the electron is $\lambda = \frac{h}{mv}$
   K.E of electron,
   $E_e = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{h}{m\lambda}\right)^2 = \frac{h^2}{2m\lambda^2}$.......(i)
   We know that energy of photon is $E_p = \frac{hc}{\lambda}$ ....(ii)
   On dividing Eq. (i) by Eq. (ii), we get,
   $\frac{E_e}{E_p} = \frac{h^2}{2m\lambda^2} \times \frac{\lambda}{hc} \Rightarrow E_p = \frac{2\lambda mc}{h}E_e$
3. When a p-n junction is forward biased:
    i. the potential barrier across decreases
    ii. the width of the depletion layer decreases
    iii. the effective resistance across the junction decreases
    iv. the junction conducts current

Section B

4. a. Given: The total energy of an electron in the first excited state of the hydrogen atom is about –3.4 eV.
      The kinetic energy of the electron in this state = negative of the total energy = -E
      Kinetic energy of the electron in this state = -(-3.4)eV = + 3.4 eV
   b. Potential energy is given as the negative of the twice of the kinetic energy U = -2 × (3.4) eV
      U = -6.8eV
      Hence the potential energy of the electron in the given state is − 6.8 eV.
   c. If the choice of the zero of potential energy is changed, then the value of potential energy of the system also changes and as we know the total energy is the sum of kinetic energy as well as potential energy. Therefore, the potential energy will also change.

5. A p-n juntion is a basic semiconductor device.

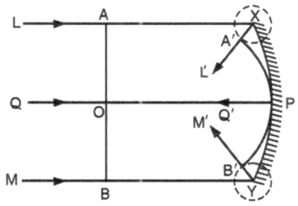


When a p-type crystal is placed in contact with n-type crystal so as to form one piece, the assembly so obtained is called p-n junction or junction diode or crystal diode. The surface of contact of p and n-type crystals is called junction. In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electron meets a hole, the two cancel the effect of each other and as a result, a thin layer at the junction becomes devoid of charge carriers. This is called the depletion layer as shown in Fig.

i. When a p-n junction is forward biased, the width of the depletion layer decreases. As a result, it offers low resistance during forward bias.
ii. When a p-n junction is reverse biased, the width of the depletion layer increases. As a result, it offers high resistance during reverse bias.

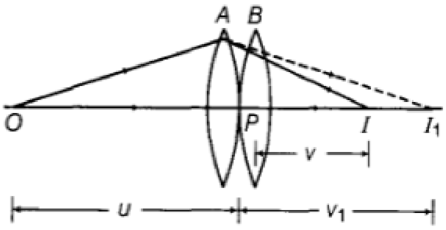
6. i. The characteristic property of nuclear force that explains the constancy of binding energy per nucleon is the saturation or short range nature of nuclear forces.
In heavy nuclei, nuclear size > a range of nuclear force.
ii. Using the formula for the radius of the nucleon, we have
$R = R_0 A^{\frac{1}{3}}$
Let, m be the mass of a nucleon,
therefore,
density, $\rho = \frac{mA}{\frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{m}{\frac{4}{3}\pi R_0^3}$
Thus, we can see that density is constant and independent of mass number A.

7. Consider that a plane wavefront AB is incident on a concave spherical mirror The lines LA, QO and MB (normals to the incident wavefront AB at the points A, O and B) represent the incident rays.



Since the distance AX or BY is smaller than the distance OP, the disturbance will reach the points X and Y on the mirror earlier than it reaches the point P. Therefore, the instant, when the disturbance reaches the point P, the secondary wavelets from the points X and Y will grow into spheres of radii (OP - AX) and (OP - BY) respectively. At this instant, the point P on the mirror has just become the source of secondary wavelet and therefore, the secondary wavelet originating from the point P will be of zero radius at that instant.
To find the reflected wavefront (new position of the wavefront after reflection from the concave mirror); with the points X and Y as centres, draw spheres of radii XA' = (OP - AX) and YB' = (OP - BY) respectively. Then, the sphere A'PB', the common envelope of the secondary wavelets issuing out from the points X, P and Y gives the reflected wavefront and the normals A'L', PQ' and B'M' to the reflected wavefront represent the reflected rays. It follows that a plane wavefront incident on a concave spherical mirror is reflected as a converging spherical wavefront.
It, thus, explains that why a parallel beam of light on reflection from a concave mirror gets converged.

8. Power of a lens is the reciprocal of its focal length when it is measured in metre. Power of a lens, P = $\frac{1}{f}$. Its SI unit ts dioptre (D).



Consider two lenses A and B of focal lengths, f_1 and f_2 placed in contact with each other .

The first lens produces an image (real image) at I_1 which serves as a virtual object for the second lens B producing the final image at I.

For the image formed by the first lens A,

$\frac{1}{v_1}-\frac{1}{u}=\frac{1}{f_1}$ ....(i)

For the image formed by the second lens B,

$\frac{1}{v}-\frac{1}{v_1}=\frac{1}{f_2}$ ....(ii)

Adding Eqs. (i) and (ii), we obtain

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f_1}+\frac{1}{f_2}$ ....(iii)

If the two lenses system is regarded as equivalent to a single lens of focal length f, we have

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ ....(iv)

From Eqs. (iii) and (iv), we obtain

$\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{f}$

OR

a. Area of each square, A = 1 mm^2
   Object distance, u = -9 cm
   Focal length of a converging lens, f = 10 cm
   For image distance v, the lens formula can be written as;
   $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$
   $\frac{1}{10}=\frac{1}{v}+\frac{1}{9}$
   $\frac{1}{v}=-\frac{1}{90}$
   $\therefore v=-90\text{cm}$
   Magnification is given by , $m=\frac{v}{u}=\frac{-90}{-9}=10$
   Area of each square in the virtual image = $(10)^2$A = $10^2\times 1$ = 100 mm^2
   = 1 cm^2
b. Magnifying power of the lens $=\frac{d}{|u|}=\frac{25}{9}=2.8$
c. No, magnification of an image by a lens and angular magnification (or magnifying power) of an optical instrument are two separate things. The magnification in (a) is not the same as the magnifying power in (b) The magnification magnitude is $\left(\left|\frac{v}{u}\right|\right)$ and the magnifying power is $\left(\frac{d}{|u|}\right)$. The two quantities will be equal when the images is formed at the near point (25 cm).

9. Energy of the incident photon,
   $E=h\nu=\frac{hc}{\lambda}$
   $\Rightarrow E=\frac{(6.63\times10^{-34}Js)\ (3\times10^8ms^{-1})}{\lambda}$
   $=\frac{1.989\times10^{-25}}{\lambda}J$
   i. For violet light, λ_1 = 390 nm (lower wavelength end)
      Incident photon energy,
      $E_1=\frac{1.989\times10^{-25}}{390\times10^{-9}}=5.10\times10^{-19}J$
      $=\frac{5.10\times10^{-19}}{1.6\times10^{-19}}=3.19eV$
   ii. For yellow-green light, $\lambda_2=550nm$ (average wavelength)
      Incident photon energy,

$E_2 = \frac{1.989 \times 10^{-25}}{550 \times 10^{-9}}$

$\Rightarrow E_2 = 3.62 \times 10^{-19} J = 2.26\ eV$

iii. For red light, λ_3= 760 nm (higher wavelength end)

Incident photon energy, $E_3 = \frac{1.989 \times 10^{-25}}{760 \times 10^{-9}}$

$E_3 = 2.62 \times 10^{-19} J = 1.64\ eV$

10. u = -12 cm, f = +15 cm, O = 4.5 cm

As, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} + \frac{1}{12} = \frac{4+5}{60} = \frac{9}{60}$

$v = \frac{60}{9} = 6.7 cm$

i.e., image is formed 6.7 cm behind the convex mirror. It must be virtual and erect.

As, $m = \frac{I}{O} = -\frac{v}{u}$

$\therefore \frac{I}{4.5} = \frac{6.7}{-12}$ or $I = \frac{6.7 \times 4.5}{12}$ = 2.5 cm

∴ Image is erect, and virtual.

As the needle is moved farther from the mirror, image moves away from the the mirror till it is at focus F of the mirror. The size of the image goes on decreasing.

11. i. Gamma(γ) rays are used for the treatment of certain forms of cancer. Its frequency range is 3×10^{19} Hz to 5×10^{22} Hz.

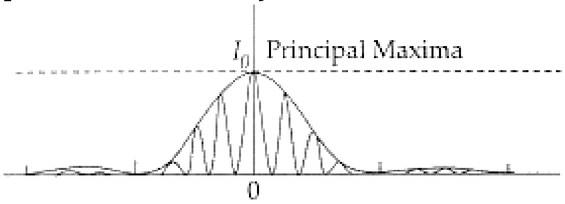
ii. The thin ozone layer residing on top of stratosphere behaves as a filter and absorbs most of the harmful ultraviolet rays (highly hazardous ultraviolet radiation of shorter wavelength) coming from the sun towards the earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the earth. Hence, this layer is crucial for human survival.

iii. An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers total energy, U to a surface in time t, then total linear momentum, p delivered to the surface is $p = \frac{U}{c} \Rightarrow p = \frac{h\nu}{c}$ (h and ν are Planck's constant and frequency of the electromagnetic wave respectively).

The amount of momentum transferred by the EM waves incident on the surface is very small due to the very large value of speed of light, c.

OR

The diagram, given here, shows several fringes, due to double-slit interference, 'contained' in a broad diffraction peak. When the separation between the slits is large compared to their width, the diffraction pattern becomes very flat and we observe the two-slit interference pattern.



Basic features that distinguish the interference pattern from those seen in a coherently illuminated single slit.:

i. The interference pattern has a number of equally spaced bright and dark bands while the diffraction pattern has a central bright maxima which is twice as wide as the other maxima.

ii. Interference pattern is the superposition of two waves originating from two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

iii. For a single slit of width 'a' the first null of diffraction pattern occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance a.

CASE STUDY

12. i. (d): Refractive index of a medium depends upon nature and temperature of the medium, wavelength of light.

ii. (a): Here v = 5×10^{14} Hz; $\lambda = 450 \times 10^{-9}$ m

$c = 3 \times 10^{8}\ ms^{-1}$

Refractive index of the liquid,

$\mu=\frac{c}{v}=\frac{c}{v\lambda}=\frac{3\times10^{8}}{5\times10^{14}\times450\times10^{-9}}$

μ = 1.33

iii. (b): Here i = 60°; μ = 1.5

By snell's law, $\mu=\frac{\sin i}{\sin r}$

$\sin r=\frac{\sin i}{\mu}=\frac{\sin 60^{\circ}}{1.5}=\frac{0.866}{1.5}$

sin r = 0.5773 or r = $\sin^{-1}(0.58)$

iv. (c): As object is at the centre of the sphere, the image must be at the centre only.

∴ Distance of virtual image from centre of sphere = 6 cm.

v. (c): Speed of light in second medium is different than that in first medium