Sample Question Paper - 9
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. The energy of a hole is higher, the farther below it is from the top of the valence band. Give reason. **[2]**
2. Prove that the ionization energy of hydrogen atom is 13.6 eV. **[2]**

OR

State two important properties of the photon which are used to write Einstein's photoelectric equation. Define

i. stopping potential and
ii. threshold frequency, using Einstein equation and drawing necessary plot between relevant quantities

3. Determine the number density of donor atoms which have to be added to an intrinsic germanium semiconductor to produce an n-type semiconductor of conductivity 5 Ω^{-1} cm^{-1}, given that the mobility of electron in n-type Ge is 3900 cm^2 /Vs. Neglect the contribution of holes to conductivity. **[2]**

Section B

4. Using Bohr's total postulates, derive the expression for the total energy of the electron in the stationary states of hydrogen atom. **[3]**
5. Explain how the depletion layer and barrier potential are formed in a p-n junction diode. **[3]**
6. Draw a plot showing the variation of binding energy per nucleon with mass number A. Write two important conclusions which you can draw from this plot. Explain with the help of this plot, the release in energy in the processes of nuclear fusion and fission. **[3]**
7. What is the effect on the interference fringes in Young's double-slit experiment due to each of the following operations? Justify your answers. **[3]**

i. The screen is moved away from the plane of the slits.
ii. The separation between slits is increased.
iii. The source slit is moved closer to the plane of double slit.

8. i. Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also. **[3]**
ii. Using mirror formula, explain why does a convex mirror always produce a virtual image?

OR

A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed.

9. Red light, however bright it is, cannot produce the emission of electrons from a clean zinc surface. But even weak ultraviolet radiation can do so. Why? **[3]**
Electrons are emitted from the cathode of negligible work function, when photons of wavelength λ are incident on it. Derive the expression for the de Broglie wavelength of the electrons emitted in terms of the wavelength of the incident light.

10. i. How is the focal length of a spherical mirror affected when it is immersed in water? **[3]**
ii. A convex lens has 10 cm focal length in air. What is its focal length in water? (Refractive index of air-water = 1.33, refractive index of air-glass = 1.5)

11. Answer the following questions: **[3]**
i. Name the EM waves which are suitable for RADAR systems used in aircraft navigation. Write the range of frequency of these waves.
ii. If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
iii. An EM wave exerts pressure on the surface on which it is incident. Justify.

OR

Monochromatic light of wavelength λ is incident normally on a narrow slit of width 'a' to produce a diffraction pattern on the screen placed at a distance D from the slit With the help of a relevant diagram, deduce the conditions for maxima and minima on the screen. Use these conditions to show that the angular width of central maxima is twice the angular width of secondary maxima.

CASE STUDY

12. **Read the source given below and answer the following questions:** **[5]**
Power (P) of a lens is given by reciprocal of focal length (f) of the lens i.e., $P = \frac{1}{f}$, where f is in metre and P is in dioptre. For a convex lens, power is positive and for a concave lens, power is negative. When a number of thin lenses of powers P_1, P_2, P_3, ... are held in contact with one another, the power of the combination is given by algebraic sum of the powers of all the lenses i.e., $P = P_1 + P_2 + P_3 + ...$
i. A convex and a concave lens separated by distance d are then put in contact. The focal length of the combination
a. becomes 0
b. remains the same

c. decreases

d. increases.

ii. If two lenses of power +1.5 D and +1.0 D are placed in contact, then the effective power of combination will be

a. 2.5 D

b. 1.5 D

c. 0.5 D

d. 3.25 D

iii. If the power of a lens is +5 dioptre, what is the focal length of the lens?

a. 10 cm

b. 20 cm

c. 15 cm

d. 5 cm

iv. Two thin lenses of focal lengths +10 cm and -5 cm are kept in contact. The power of the combination is

a. -10 D

b. -20 D

c. 10 D

d. 15 D

v. A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. The system will be

a. converging in nature

b. diverging in nature

c. can be converging or diverging

d. None of the above

Solution

PHYSICS - 042

Class 12 - Physics

Section A

1. Imagine an electron being removed from the filled valence band to the bottom of the conduction band. This removal creates a vacancy or a hole in the valence band. Clearly, it requires more energy to remove an electron that is farther from the top of the valence band. Thus a valence hole state, farther from the top of the valence band, has higher energy just as a conduction electron farther from the bottom of the conduction band has higher energy.
2. We know that

   $W = k^2 \frac{2\pi^2 me^4}{h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

   Ionization energy is the energy required to remove an electron from ground state to infinity.

   Here, $n_1 = 1$, $n_2 = \infty$

   $\therefore W = k^2 \frac{2\pi^2 me^4}{h^2}\left(\frac{1}{1} - \frac{1}{\infty}\right)$

   $= k^2 \frac{2\pi^2 me^4}{h^2}$

   or $W = \frac{(9\times10^9)^2 \times 2(3.142)^2 \times 9\times10^{-31}\times(1.6\times10^{-19})^4}{(6.63\times10^{-34})^2}$

   $= 21.45 \times 10^{-19} J = \frac{21.45\times10^{-19}}{1.6\times10^{-19}} eV$ = 13.6 eV

   OR

   Properties of Photon:

   i. For a radiation of frequency v, each photon has an energy, E = hν, associated with it

   ii. The energy of a photon is independent of the intensity of incident radiation.

      a. Stopping potential, V_0, equals that value of the negative potential for which

      $|eV_0| = K_{\max}$

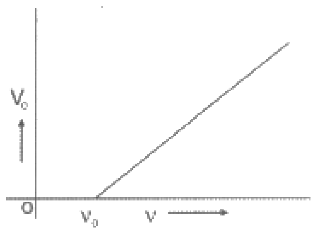
      (Alternatively: The stopping potential (V_0) equals that (least) value of the (negative) plate potential that just stops the most energetic emitted photoelectrons from reaching the plate.)

      b. Threshold frequency (ν_0) equals that value of the frequency of incident radiation for which

      K_{max} = 0

   (Or threshold frequency is the minimum value of the frequency of incident radiation for which photoelectrons can be just emitted from that surface or that maximum frequency of incident radiation below which no photoemission takes place.)

   The plot, between V_0 and v has the form shown :

3. Here $\sigma = 5\Omega^{-1}\ \text{cm}^{-1}$, μ_e = 3900 $cm^2\ V^{-1}\ s^{-1}$, n_e = ?

   If we neglect the contribution of holes to conductivity, then

   $\sigma = \frac{1}{\rho} = en_e\mu_e$

   $\therefore$ Electron density,

   $n_e = \frac{\sigma}{e\mu_e} = \frac{5}{1.6\times10^{-19}\times3900}$ cm^{-3}

   = 8.01×10^{15} cm^{-3}

Section B

4. According to Bohr's postulates, in a hydrogen atom, a single electron revolves around a nucleus of charge +e. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is

provided by Coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small. So,

$mv^2/r = ke^2/r^2$ (where, $k = 1/4\pi\varepsilon_0$)

or $mv^2 = ke^2/r$............(i)

where, m = mass of electron, r = radius of electronic orbit, v = velocity of electron

Again, by Bohr's second postulates

$mvr = nh/2\pi$

where, n = 1, 2, 3, ... or $v = nh/2\pi mr$

Putting the value of v in Eq. (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2kme^2} \text{....(ii)}$$

Kinetic energy of electron ,

$$E_K = \frac{1}{2}mv^2 = \frac{ke^2}{2r}\left(\because \frac{mv^2}{r} = \frac{ke^2}{r^2}\right)$$

Using Eq(ii), we get

$$E_K = \frac{ke^2}{2}\frac{4\pi^2kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy of electron,

$$E_P = -\frac{k(e)\times(e)}{r} = -\frac{ke^2}{r}$$

Using Eq(ii), we get

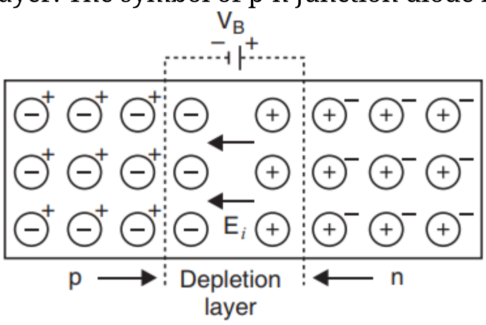
$$E_P = -ke^2 \times \frac{4\pi^2kme^2}{n^2h^2} = -\frac{4\pi^2k^2me^4}{n^2h^2}$$

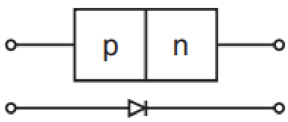
Hence, total energy of the electron in the n^{th} orbit

$$E = E_P + E_K = -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$$

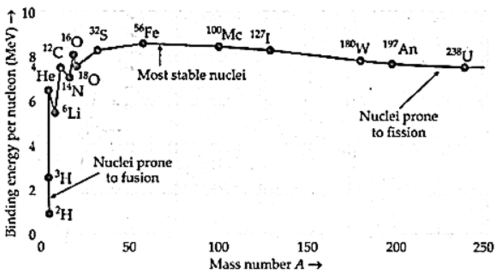
$$= -\frac{2\pi^2k^2me^4}{n^2h^2}$$

5. At the junction there is diffusion of charge carriers due to thermal agitation; so that some of electrons of n-region diffuse to p-region while some of holes of p-region diffuse into n-region. Some charge carriers combine with opposite charges to neutralise each other. Thus near the junction there is an excess of positively charged ions in n-region and an excess of negatively charged ions in p-region. This sets up a potential difference called potential barrier and hence an internal electric field E_i across the junctions. The field E_i is directed from n-region to p-region. This field stops the further diffusion of charge carriers. Thus the layers ($\approx10^{-4}$cm to 10^{-6}cm) on either side of the junction becomes free from mobile charge carriers and hence is called the depletion layer. The symbol of p-n junction diode is shown in Fig.





6.



Binding energy per nucleon as a function of mass number A.

Two important conclusions from this graph are:

i. Nuclear forces non-central and short ranged force.

ii. Nuclear forces between proton-neutron and neutron-neutron are strong and attractive in nature.

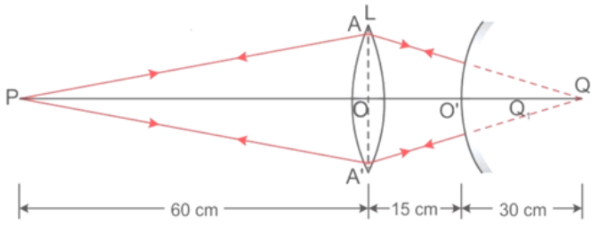
Explanation of Nuclear Fission: When a heavy nucleus (A $\geq$ 235 say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e, nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

Explanation of Nuclear Fusion: When two very light nuclei (A $\leq$ 10) join to form a heavy nucleus, the binding is energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

7. i. D is Distance between screen to slits, d is distance between the slits, λ is wavelength
   Fringe width $\beta = \frac{\lambda D}{d}$
   Since $\beta \propto D$, the fringe width will increase, as screen is moved away.
   ii. $\beta \propto \frac{1}{d}$, therefore fringe width will decrease as the separation between slits is increased.
   iii. Let s be the width of the source slit and S its distance from plane of two slit. For interference fringes to be distinctly seen, the condition
   $\frac{s}{S} < \frac{\lambda}{d}$
   should be satisfied, otherwise, the interference patterns produced will overlap.
8. i. Here it is given that, magnification (m) = -2 and R = -20 cm
   Thus, f = -10 cm $\left(\because f = \frac{R}{2}\right)$
   Now we have, $\frac{h_2}{h_1} = -2 = \frac{-v}{u} \Rightarrow u = \frac{v}{2}$ or $v = 2u$
   By using mirror formula,
   $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{2u} + \frac{1}{u} = \frac{1}{-10}$
   $\frac{1+2}{2u} = -\frac{1}{10}$
   $\frac{3}{2u} = -\frac{1}{10} \Rightarrow u = \frac{-10\times3}{2} = -15\text{cm}$
   Thus, $v = 2 \times u = 2 \times -15 = -30\text{cm}$
   Hence, the object distance and image distance are -15 cm and -30 cm respectively in front of the mirror.
   ii. According to mirror formula, we have,
   $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
   $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} \Rightarrow v = \frac{uf}{u-f}$
   From mirror formula, the distance of the object measured from pole of mirror is negative and focal length of the mirror is positive. Therefore, the value of v will be positive and v will be less than both u and f, irrespective of value of p. As v is positive, a virtual, erect and diminished image of the object will be formed behind the mirror.

OR

Focal length of convex lens is, f = +20 cm
Object distance from the lens, u = -60 cm
Distance between the mirror and the lens, d = 15 cm,
Focal length of the mirror, f = +10 cm
The ray diagram is shown in the figure:



Applying the lens formula,
$\frac{1}{20} = \frac{1}{v'} - \frac{1}{-60}$
After solving we get,
v' = +30 cm
This image is the object for the mirror, which is formed at 15 cm behind the mirror. So this is the case of a virtual object.
Applying the mirror formula, we get,

$\frac{1}{10} = \frac{1}{v} + \frac{1}{15}$

After solving we get,

v = +30 cm

So, the final image is formed 30 cm behind the mirror is virtual in nature.

9. The frequency of ultraviolet radiations is more while that of red light is less than the threshold frequency for a zinc surface, so ultraviolet radiations can cause the emission of electrons and red light cannot.

From Einstein's photoelectric equation, K.E. of a photoelectron is

$\frac{1}{2}m\nu^2 = h\nu - W_0 = h\nu - 0 = \frac{hc}{\lambda}$

or $v = \sqrt{\frac{2hc}{m\lambda}}$

de Broglie wavelength of electrons,

$\lambda_e = \frac{h}{mv}$

$= \frac{h}{m}\sqrt{\frac{m\lambda}{2hc}} = \sqrt{\frac{h\lambda}{2mc}}$

10. i. The focal length of mirror remains unchanged when it is dipped inside the water.
    ii. According to lens maker formula,

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

    For lens in air:

    $\mu_2 = 1.5\ and\ \mu_1 = 1$ and f = 10 cm

    So,

    $\frac{1}{10} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

    $\frac{1}{R_1} - \frac{1}{R_2}$ = 0.2 .....(2)

    For lens in water:

    $\mu_2 = 1.5\ and\ \mu_1 = 1.33$

    Let focal length in water is F. Then from (1) and (2) we have,

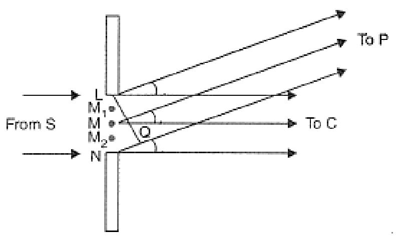
    $\frac{1}{F} = \left(\frac{0.17}{1.33}\right) \times 0.2 = 0.025$

    So, F = 40 cm

11. i. The EM waves suitable for radar systems is microwaves. These rays are produced by special vacuum tubes, namely klystrons, magnetrons and Gunn diodes. The frequency range for this wave is from 300 MHz to 300 GHz.
    ii. The temperature of the earth would be lower because the greenhouse effect of the atmosphere(which maintains the average temperature of earth) would be absent.
    iii. An EM wave has momentum, i.e. p = Energy(E) / Speed of light(c)

    That's why when it is incident upon a surface it exerts pressure on it, known as radiation pressure.

OR



According to the figure, the path difference is given by,

NP - LP = NQ

= a sin θ $\cong$ aθ

as θ <<< 1

$\therefore$ sin θ = θ

By dividing the slit into an appropriate number of parts, we find the point P for which

i. $\theta = \frac{n\lambda}{a}$ are points of minima.

ii. $\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a}$ are points of maxima

The angular width of central maxima,

$\theta = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right)$

$\theta_2 = \frac{2\lambda}{a}$

The angular width of the secondary maxima = $\theta_2 - \theta_1$

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

= $\frac{1}{2} \times$ Angular width of central maxima

CASE STUDY

12. i. (d)

ii. (a): $P = P_1 + P_2 = 1.5 + 1.0 = 2.5$ D

iii. (b): $f = \frac{1}{P} = \frac{1}{5}\ \mathrm{m} = +20\ \mathrm{cm}$

iv. (a): $P = P_1 + P_2 = \frac{1}{f_1} + \frac{1}{f_2}$

$= \frac{100}{10} + \frac{100}{-5} = -10D$

v. (b): $P = P_1 + P_2 = \frac{100}{f_1} + \frac{100}{f_2}$

$P = \frac{100}{25} + \frac{100}{-20} = -1D$

As the power is negative, the system will be diverging.