Sample Question Paper - 15
Physics (042)
Class- XII, Session: 2021-22
TERM II

Time : 2 Hours *Max. Marks : 35*

General Instructions :

(i) There are 12 questions in all. All questions are compulsory.
(ii) This question paper has three sections: Section A, Section B and Section C.
(iii) 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.
(iv) 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.
(v) You may use log tables if necessary but use of calculator is not allowed.

SECTION - A

1. (a) Mention the important considerations required while fabricating a *p-n* junction diode to be used as a light emitting diode (LED).
(b) What should be the order of band gap of an LED if it is required to emit light in the visible range?

2. A beam of light converges at a point *P*. Now a convex lens is placed in the path of the convergent beam at 15 cm from point *P*. At what point does a beam converge if the convex lens has a focal length 10 cm ?

3. Distinguish between a metal and an insulator on the basis of energy band diagrams.

OR

Draw a plot showing the variation of resistivity of a (i) conductor and (ii) semiconductor, with the increase in temperature.

SECTION - B

4. (a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which of them will not be able to detect light of wavelength 500 nm ?
(b) Why photodiodes are required to operate in reverse bias ? Explain.

5. (a) Complete the following nuclear reactions:
(i) ${}^{208}_{84}\text{Po} \rightarrow {}^{204}_{82}\text{Pb} + \ldots\ldots$ (ii) ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + \ldots\ldots$
(b) Write the basic process involved in nuclei responsible for (i) β^- and (ii) β^+ decay.
(c) Why is it found experimentally difficult to detect neutrinos?

6. In a typical nuclear reaction, *e.g.*
$${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^3_2\text{He} + {}^1_0n + 3.27\text{ MeV},$$
although number of nucleons is conserved, yet energy is released. How? Explain.

7. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33.

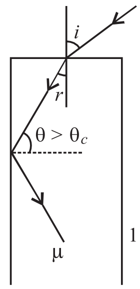
(a) Will it behave as a converging or a diverging lens in the two cases?

(b) How will its focal length change in the two media?

OR

Two slits are made one millimetre apart and the screen is placed one metre away. What is the fringe separation when blue-green light of wavelength 500 nm is used?

8. In the figure shown for an angle of incidence *i* at the top of the surface, what is the minimum refractive index for total internal reflection at the vertical surface?

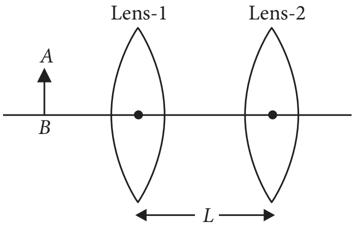


9. In a double slit experiment, the distance between slits is 5.0 mm and the slits are 1.0 m from the screen. Two interference patterns can be seen on the screen : one due to light of wavelength 480 nm and the other due to light of wavelength 600 nm. What is the separation on the screen between the third order bright fringes of the two interference patterns?

OR

In a *YDSE*, the slits are 2 mm apart and are illuminated with a mixture of two wavelengths $\lambda = 750$ nm and $\lambda' = 900$ nm. At what distance from the common central bright fringe on a screen 2 m from the slits will a bright fringe from one interference pattern coincide with a bright fringe from the other?

10. Figure shows an object *AB* placed in front of two thin coaxial lenses 1 and 2 with focal lengths 24 cm and 9.0 cm, respectively. The object is 6.0 cm from the lens 1 and the lens separation is $L = 10$ cm. Where does the system of two lenses produce an image of the object *AB* ?



11. (a) Arrange the following electromagnetic waves in the descending order of their wavelengths :

(i) Microwaves

(ii) Infra-red rays

(iii) Ultra-violet-radiation

(iv) Gamma rays

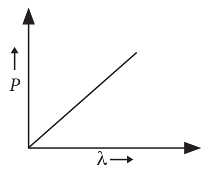
(b) Write one use each of any two of them.

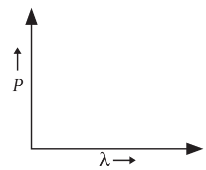
SECTION - C

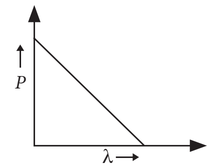
12. CASE STUDY : PHOTOELECTRIC EFFECT

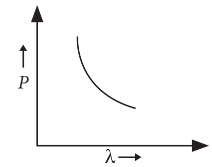
According to Einstein, when a photon of light of frequency υ or wavelength λ is incident on a photosensitive metal surface of work function ϕ_0, where $\phi_0 < h\upsilon$ (here, h is Planck's constant), then the emission of photoelectrons takes place. The maximum kinetic energy of the emitted photoelectrons is given by $K_{max} = h\upsilon - \phi_0$. If the frequency of the incident light is υ_0 called thresold frequency, the photoelectrons are emitted from metal without any kinetic energy. So $h\upsilon_0 = \phi_0$.

(i) Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?

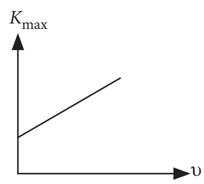
(a) 

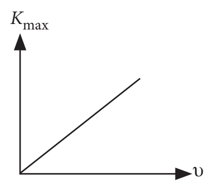
(b) 

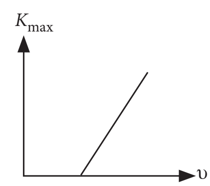
(c) 

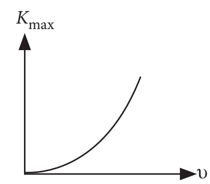
(d) 

(ii) The variation of maximum kinetic energy (K_{max}) of the emitted photoelectrons with frequency (υ) of the incident radiations can be represented by

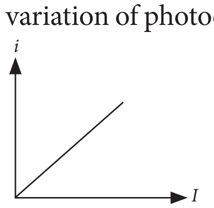
(a) 

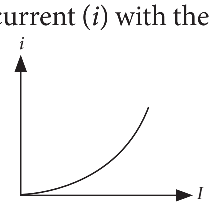
(b) 

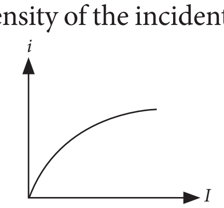
(c) 

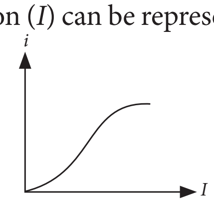
(d) 

(iii) The variation of photoelectric current (i) with the intensity of the incident radiation (I) can be represented by

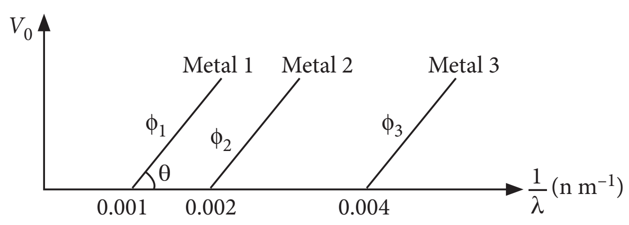
(a) 

(b) 

(c) 

(d) 

(iv) The graph between the stopping potential (V_0) and $\left(\frac{1}{\lambda}\right)$ is shown in the figure. ϕ_1, ϕ_2, ϕ_3 are work function. Which of the following options is correct?



(a) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 3$
(b) $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$
(c) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$
(d) Ultraviolet light can be used to emit photoelectrons from metal 2 and metal 3 only.

(v) A metal of work function 3·3 eV is illuminated by light of wavelength 300 nm. The maximum kinetic energy of photoelectrons emitted is (taking $h = 6{\cdot}6 \times 10^{-34}$ J s)

(a) 0·413 eV (b) 0·825 eV (c) 1·65 eV (d) 1·32 eV

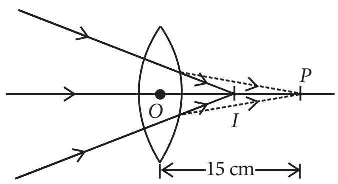
Solution

PHYSICS - 042

Class 12 - Physics

1. (a) (i) There is very little resistance to limit the current in LED. Therefore, a resistor must be used in series with the LED to avoid any damage to it.
(ii) The reverse breakdown voltages of LEDs are very low, typically around 5 V. So care should be taken while fabricating a *p-n*-junction diode so that the *p* side should only attached to the positive of battery and vice versa as LED easily get damaged by a small reverse voltage.
(b) The semiconductor used for fabrication of visible LEDs must have at least a band gap of 1.8 eV because spectral range of visible light is about 0.4 mm to 0.7 mm, i.e., about 3 eV to 1.8 eV.

2. $f = 10$ cm, $u = 15$ cm, $v = ?$

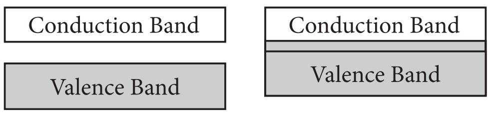


Using lens formula,

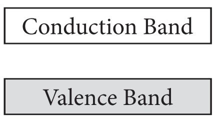
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ or, } \frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{15} + \frac{1}{10} = \frac{5}{30}$$

$v = 6$ cm

3. Metals : For metals, the valence band is completely filled and the conduction band can have two possibilities-either it is partially filled with an extremely small energy gap between the valence and conduction bands or it is empty, with the two bands overlapping each other as shown in the figure.



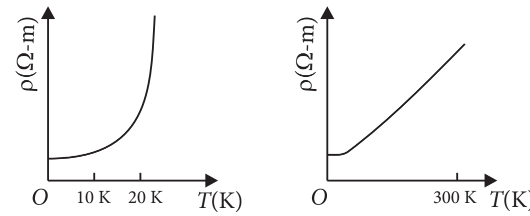
On applying even an small electric field, metals can conduct electricity.
Insulators : For insulators, the energy gap between the conduction and valence bands is very large. Also, the conduction band is practically empty, as shown in the figure.



When an electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy to reach the conduction band. Thus, the conduction band continues to be empty. That is why no current flows through insulators.

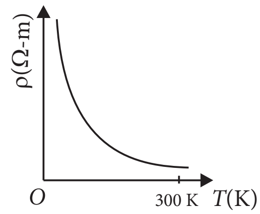
OR

(i) The resistivity of a conductor increases non-linearly with increase in temperature.



(For low temperature) (For high temperature)

(ii) The resistivity of a semiconductor decreases with increase in temperature.



4. (a) Given, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{5 \times 10^{-7} \times 1.6 \times 10^{-19}} \text{ eV } = 2.47 \text{ eV}$$

As, energy gaps of diodes D_1 and D_3 are greater than the given energy of the incident radiation. Hence diodes D_1 and D_3 will not be able to detect light of wavelength 600 nm.
(b) In reverse bias condition of photodiode, the change in saturation reverse current is directly proportional to the change in the incident light flux or light intensity, which can be measured accurately. It is not so when photodiode is forward biased.

5. (a) (i) ${}^{208}_{84}\text{Po} \rightarrow {}^{204}_{82}\text{Pb} + {}^{4}_{2}\text{He}$
$208 = 204 + A$
$A = 208 - 204 = 4$
$84 = 82 + Z$; $Z = 84 - 82 = 2$
(ii) ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + {}_{-1}e^{0} + \bar{\nu}$

$32 + 32 + A$
$A = 32 - 32 = 0$; $A = 0$
$15 = 16 + Z$;
$Z = 15 - 16 = -1$
(b) In both processes the conversion of neutron to proton and proton to neutron take place inside the nucleus.

$_Z^AX \rightarrow \beta^- + {}_{Z+1}^{\quad A}Y + \bar{\nu}$ (β^- decay)

$_Z^AX \rightarrow \beta^+ + {}_{Z-1}^{\quad A}Y + \nu$ (β^+ decay)

(c) Neutrinos are chargeless (neutral) and almost massless particles that hardly interact with matter.

6. In a nuclear reaction, the sum of the masses of the target nucleus ($_1^2$H) and the bombarding particle ($_1^2$H) may be greater than the product nucleus ($_2^3$He) and the outgoing neutron $_0^1n$. So from the law of conservation of mass-energy some energy (3.27 MeV) is evolved due to mass defect in the nuclear reaction. This energy is called Q-value of the nuclear reaction.

7. Here, $^a\mu_g = 1.5$

Let f_{air} be the focal length of the lens in air, Then,

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\text{or} \quad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}({}^a\mu_g - 1)} = \frac{1}{f_{air}(1.5-1)}$$

$$\text{or} \quad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad \text{... (i)}$$

(i) When lens is dipped in medium A

Here, $^a\mu_A = 1.65$

Let f_A be the focal length of the lens, when dipped in medium A. Then,

$$\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using the equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.65} - 1\right) \times \frac{2}{f_{air}} = -\frac{1}{5.5 f_{air}}$$

or $f_A = -5.5 f_{air}$

As the sign of f_A is opposite to that of f_{air} the lens will behave as a diverging lens.

(ii) When lens is dipped in medium B

Here, $^a\mu_B = 1.33$

Let f_B be the focal length of the lens, when dipped in medium B. Then,

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using the equation (i), we have

$$\frac{1}{f_B} = \left(\frac{1.5}{1.33} - 1\right) \times \frac{2}{f_{air}} = \frac{0.34}{1.33 f_{air}}$$

or $f_B = 3.91 f_{air}$

As the sign of f_B is same as that of f_{air}, the lens will behave as a converging lens.

OR

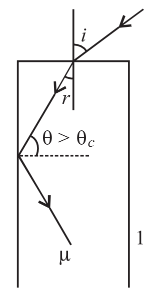
Here, $d = 1$ mm $= 1 \times 10^{-3}$ m

$D = 1$ m, $\lambda = 500$ nm $= 5 \times 10^{-7}$ m

Fringe spacing,

$$\beta = \frac{\lambda D}{d} = \frac{5 \times 10^{-7} \times 1}{1 \times 10^{-3}} = 5 \times 10^{-4} \text{ m} = 0.5 \text{ mm}$$

8. The ray will total internally reflect at the vertical surface if $\theta > \theta_c$.



Now, $r = (90° - \theta)$ and

Snell's law is $\sin i = \mu \sin r$

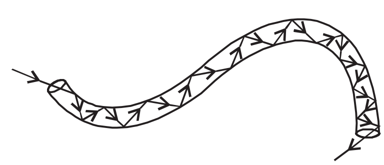
$$\frac{\sin i}{\mu} = \sin(90° - \theta)$$

$$\Rightarrow \cos\theta = \frac{\sin i}{\mu}$$

$$\text{or } \sin\theta = \sqrt{1 - \cos^2\theta} = \sqrt{1 - \frac{\sin^2 i}{\mu^2}}$$

If $\theta > \theta_C$, then $\sin\theta > \sin\theta_C$ (As $\sin\theta$ is an increasing function for $0 < \theta < 90°$)

$$\sqrt{1 - \frac{\sin^2 i}{\mu^2}} > \frac{1}{\mu}$$



$$1 - \frac{\sin^2 i}{\mu^2} > \frac{1}{\mu^2}$$

$\mu^2 - \sin^2 i > 1$ or $(\mu^2 - 1) > \sin^2 i$

If total internal reflection has to be larger for all value, the above inequality must be satisfied for all $(\sin^2 i)_{max} = 1$

$\Rightarrow \mu^2 - 1 > 1$ or $\mu > \sqrt{2}$

This total internal reflection phenomenon is used in fibre optics to bend light in a curved path.

9. The position of n^{th} order bright fringe from the central bright fringe is

$$x_n = \frac{n\lambda D}{d}$$

where, λ = wavelength of light used

D = Distance of screen from the slits

d = Distance between the slits

For wavelength λ(= 480 nm), the position of 3^{rd} order bright fringe from the central bright fringe is

$$x_3 = \frac{3\lambda D}{d}$$

For wavelength λ' (= 600 nm), the position of 3^{rd} order bright fringe from the central bright fringe is

$$x_3' = \frac{3\lambda' D}{d}$$

$\therefore$ The separation between the third order bright fringes of the two interferene patterns is

$$x_3' - x_3 = \frac{3(\lambda' - \lambda)D}{d}$$

Here, $\lambda = 480$ nm $= 480 \times 10^{-9}$ m
$\lambda' = 600$ nm $= 600 \times 10^{-9}$ m
$D = 1.0$ m
$d = 5.0$ mm $= 5.0 \times 10^{-3}$ mm

$$\therefore \; x_3' - x_3 = \frac{3(600-480)\times 10^{-9} \times 1.0}{5.0 \times 10^{-3}}$$

$= 0.07 \times 10^{-3}$ m $= 0.07$ mm

OR

The n^{th} bright fringe of the λ pattern and the n'^{th} bright fringe of the λ' pattern are situated at $yn = n \cdot \frac{D\lambda}{d}$ and $yn' = n' \frac{D\lambda'}{d}$.

As this coincide, $yn = yn'$

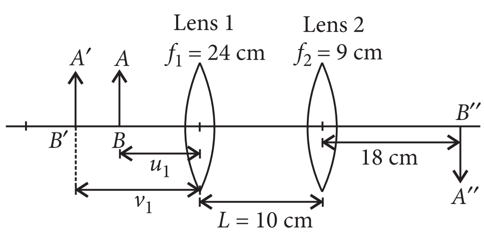
$$\Rightarrow \frac{nD\lambda}{d} = \frac{n'D\lambda'}{d}$$

$$\Rightarrow \frac{n}{n'} = \frac{\lambda'}{\lambda} = \frac{900}{750} = \frac{6}{5}$$

hence the first position where overlapping occur is

$$y_5' = y_6 = \frac{nD\lambda}{d} = \frac{6(2\text{m})(750\times 10^{-9}\text{m})}{(2\times 10^{-3}\text{m})} = 4.5 \text{ mm.}$$

10.



First image is formed by lens 1.
Here, $u_1 = -6$ cm, $f_1 = 24$ cm, $v_1 = ?$
Using lens formula,

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1} \Rightarrow \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1}$$

$$\Rightarrow \frac{1}{v_1} = \frac{1}{24} - \frac{1}{6} = \frac{-3}{24} = -\frac{1}{8}$$

$\therefore$ $v_1 = -8$ cm (*i.e.*, image is virtual formed on same side of lens 1)

Image formed by lens 1 acts as an object for lens 2. Therefore final image is formed by lens 2.

Here, $u_2 = -|v_1 + L| = -(8 + 10) = -18$ cm
$f_2 = 9$ cm, $v_2 = ?$
Using lens formula,

$$\frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} \Rightarrow \frac{1}{v_2} = \frac{1}{9} - \frac{1}{18} = \frac{1}{18}$$

$\Rightarrow$ $v_2 = 18$ cm

11. (a) Descending order of wavelengths for given electromagnetic waves is:
Microwaves ($10^{-3} - 10^{-1}$) m
Infra-red rays ($7.5 \times 10^{-7} - 10^{-3}$) m
Ultra-violet radiation ($10^{-9} - 4 \times 10^{-7}$) m
Gamma rays ($< 10^{-12}$) m
(b) Microwaves :
Frequency range $\to 3 \times 10^8$ Hz $- 3 \times 10^{11}$ Hz.
These are suitable for the radar system, used in aircraft navigation.
Gamma rays :
Frequency range $\to > 3 \times 10^{21}$ Hz.
These wave are used for the treatment of cancer cells.

12. (i) **(d) :** de-Broglie wavelength

$$\lambda = \frac{h}{p} \; i.e., \lambda \propto \frac{1}{p}$$

So the graph between (d) represent the variation of particle momentum and the asociated de-Broglie wavelength.

(ii) **(c) :** $K_{max} = h\upsilon - \phi_0$,
When $\upsilon = \upsilon_0$, $K_{max} = 0$
$\therefore$ $0 = h\upsilon_0 - \phi_0$ or $\phi_0 = h\upsilon_0$
If $\upsilon < \upsilon_0$, then K_{max} is negative, *i.e.*, no photoelectric emission takes place. Thus, graph (c) is possible.

(iii) **(a) :** Photoelectric current (i) is proportional to the intensity of the emission light. Thus, graph (a) is possible.

(iv) **(c) :** From Einstein's photoelectric equation,

$$K_{max} = eV_0 = \frac{hc}{\lambda} - \phi \quad \text{or} \quad V_0 = \frac{hc}{e} \cdot \frac{1}{\lambda} - \frac{\phi}{e}$$

Graph of V_0 versus $\frac{1}{\lambda}$ is a straight line

Slope of straight line, $\tan\theta = \frac{hc}{e}$

At $V_0 = 0$, we have

$$\phi_1 : \phi_2 : \phi_3 = \frac{hc}{\lambda_{01}} : \frac{hc}{\lambda_{02}} : \frac{hc}{\lambda_{03}}$$

$0.001\, hc : 0.002\, hc : 0.004\, hc$
Therefore, the ratio is 1 : 2 : 4

(v) **(b) :** $K_{max} = h\upsilon - \phi_0 = \frac{hc}{\lambda} - \phi_0$

$$= \frac{(6\cdot 6\times 10^{-34})\times(3\times 10^{8})}{(300\times 10^{-9})\times(1\cdot 6\times 10^{-19})} - 3\cdot 3$$

$= 4.125 \times 3.3 = 0.825$ eV