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Q. 4. A converging lens is kept coaxially in contact with a diverging lens – both the lenses being equal focal lengths. What is the focal length of the combination?

Answer:

Let f_1 is the focal length of convex (converging) lens and

f_2 is the focal length of the concave (diverging) lens.

Equivalent focal length F for the two lenses in contact is given by

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

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2} = \frac{f_2 - f_1}{f_1 f_2}$$

[convex lens focal length taken as + ve and concave lens focal length taken as − ve]

$$\therefore \quad F = \frac{f_1 f_2}{f_2 - f_1}$$

Q. 5. Define ionisation energy. What is its value for a hydrogen atom?

Answer:

Definition: The minimum energy required in removing a single electron from the atom or molecule is called Ionisation energy.

Unit of Ionisation energy is Electron Volts (eV).

Depending upon the electron removed we have first ionisation energy, second ionisation energy etc.

1st ionization energy (Atom Ground state) $X \rightarrow X^+ + e^-$

2nd ionization energy (Single ionised state) $X^+ \rightarrow X^{2+} + e^-$

3rd ionization energy (Doubly ionised state) $X^{2+} \rightarrow X^{3+} + e^-$

Ionisation energy for hydrogen atom is 13.6 eV.

Q. 6. Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.

Answer:

We know that current is related to drift velocity (v_d) by

$I = n A e v_d$

v_{dx} = drift velocity in X

v_{dy} = drift velocity in Y

$n_x = 2n_y$

Since wires are in series (Current I is same) and X and Y have same diameter (Area A is same)

$$\therefore I_X = I_Y$$

$$\therefore n_x Ae v_{dx} = n_y Ae v_{dy}$$

$$2 n_y Ae v_{dx} = n_y Ae v_{dy} \Rightarrow \frac{v_{dx}}{v_{dy}} = \frac{1}{2}$$

$$\therefore v_{dx} : v_{dy} = 1 : 2$$

Q. 7. Name the part of electromagnetic spectrum whose wavelength lies in the range of 10^{-10} m. Give its one use.

Answer: We know that wavelength of range 0.01 to 10 nanometre (1 nanometre = 10^{-9} m) falls in X-ray region.

Therefore given wavelength 10^{-10} m= 0.1 nanometre is in X-ray region

Uses: Airport security luggage scanners use X-rays for inspecting the interior of luggage for security threats before loading on aircraft.

Q. 8. When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a decrease in the energy carried by the light wave? Justify your answer.

Answer: Frequency of light does not changes while passing from rarer to denser medium.

We know that **Energy** E = *hv*

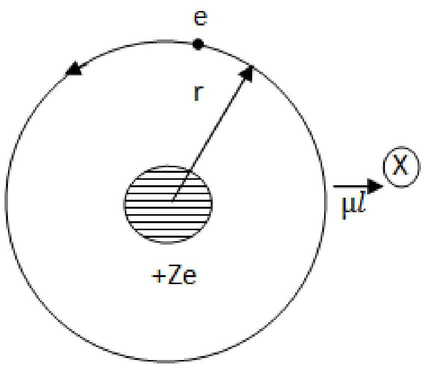
h = plank constant

v = frequency

Since both h and v remains same hence Energy does not change.

Q. 9. Deduce the expression for the magnetic dipole moment of an electron orbiting around the central nucleus.

Answer:



The electron of change (-e) executes uniform circular motion around a stationary heavy nucleus of change +Ze. We know that charge in motion constitutes a current.(current=charge/time).

$$\therefore \mathrm{I} = \frac{\mathrm{e}}{\mathrm{T}} \dots \dots \dots \text{(i)}$$

Given: T is the time period of revolution.

r be the orbital radius of electron

v the orbital speed.

Therefore distance = speed x time i.e $2\pi \mathrm{r} = \mathrm{T} \times \mathrm{v}$

$$\mathrm{T} = \frac{2\pi \mathrm{r}}{\mathrm{v}} \dots \dots \dots \text{(ii)}$$

Substituting the value of T in (i), we get

$$\mathrm{I} = \frac{\mathrm{ev}}{2\pi \mathrm{r}}$$

The magnetic moment $(product\ of\ current\ and\ area = IA)$associated with this circular current is

Magnetic Moment $= \mathrm{I}\, \pi \mathrm{r}^2 \;= \frac{\mathrm{ev}}{2\pi \mathrm{r}} . \pi \mathrm{r}^2 = \frac{\mathrm{evr}}{2}$

Magnitude of Magnetic moment = $\frac{\mathrm{evr}}{2}$. Now magnetic moment being vector quantity let's find direction.

To find direction magnetic moment: Current is opposite to the motion of electron i.e. if the electron rotates along anticlock wise direction as shown then current is along clock wise direction, rotating the right hand along the direction of current, thumb gives direction perpendicular to the plane of the paper and away from the observer i.e. into the plane of the paper symbolised by cross ⊗.

Q. 10. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge 'Q'. A charge 'q' is placed at the centre of the shell.

a) What is the surface charge density on the (I) inner surface, (II) outer surface of the shell?
b) Write the expression for the electric field at a point x > r_1 from the centre of the shell.

Answer:

Surface charge density on inner surface= $\boldsymbol{\frac{q}{4\pi r_1^2}}$

Surface charge density on the outer surface =$\frac{q+Q}{4\pi r_2^2}$

Let the point P lie outside the charged shell OP = $x > r_1$

We know that flux through the surface

$$\phi = \oint_s d\phi = \oint_s E dA = E\ 4\pi x^2 \rightarrow (1)$$

Applying the Gauss's theorem the flux through the Gaussian surface

$$\phi = \frac{\text{Charged enclosed}}{\varepsilon} = \frac{Q+q}{\varepsilon} \rightarrow (2)$$

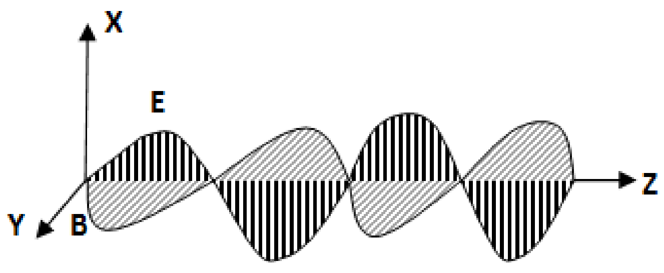
Equating (1) and (2):

$$E.4\pi x^2 = \frac{Q+q}{\varepsilon}$$

$$E = \frac{1}{4\pi\varepsilon}\frac{Q+q}{x^2} \rightarrow (3)$$

Q. 11. Draw a sketch of a plane electromagnetic wave propagating along the z – direction. Depict clearly the directions of electric and magnetic fields varying sinusoidally with z.

Answer: We know that direction of propagation is perpendicular to the plant of drawn through Electric and Magnetic Vector. Hence if Electric vector drawn along X axis, Magnetic vector along Y axis then propagation will be perpendicular to X-Y plane i.e. along Z axis as shown.



Q. 12. Show that the electric field at the surface of a charged conductor is given by $\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$, where σ is the surface charge density and $\hat{n}$ is a unit vector normal to the surface in the outward direction.

Answer:

Given : σ = surface density of charge i.e. charge per unit surface area

ε = permittivity of the surrounding medium

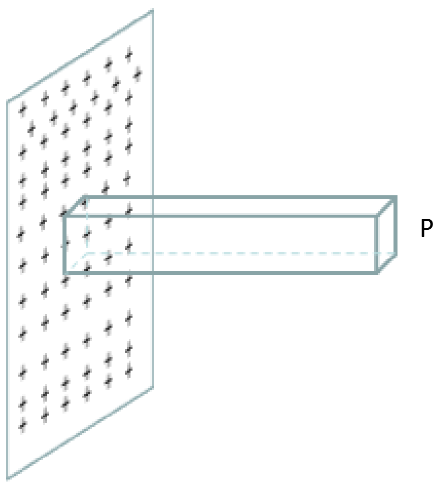
P is the given point close to the surface of the charged plate.

Let E be the intensity at P ?

Let us imagine a rectangular box passing through the points P. This closed surface is our Gaussian surface and is known as pill box.

Let A = Area of the side face of pillbox. Then Enclosed Charge $=\sigma A$. Hence by Gausses theorem

$$\phi = \frac{\sigma A}{\varepsilon} \rightarrow (1)$$



Since electric lines of force do not exist inside charged plate hence we have only one side of pill box i.e. outward. The lines of force are perpendicular to the end faces only.

$$\phi = 0 + 0 + 0 + 0 + EA = EA \rightarrow (2)$$

From (1) and (2)

$$EA = \frac{\sigma A}{\varepsilon}$$

$$E = \frac{\sigma}{\varepsilon}$$

Direction is away from the plate and perpendicular the plane of side face of pill box as shown in the figure.