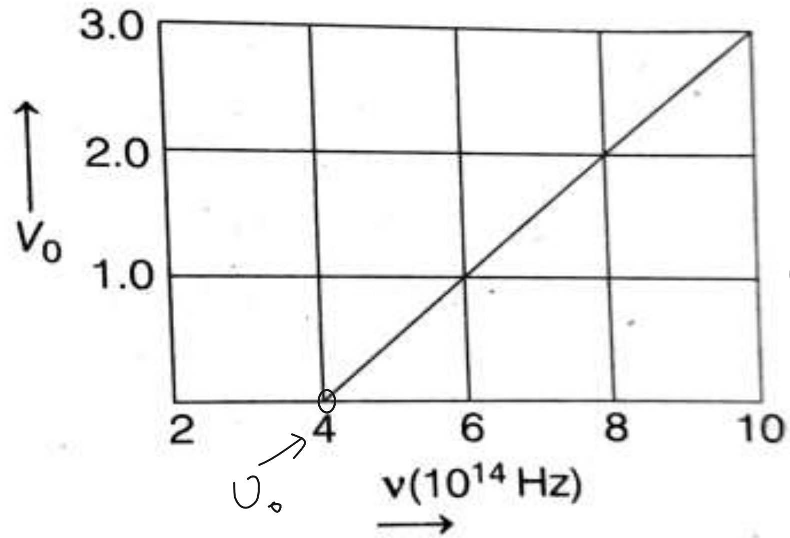
Objective Questions I (Only one correct option)

1. The stopping potential V_0 (in volt) as a function of frequency (ν) for a sodium emitter, is shown in the figure. The work function of sodium, from the data plotted in the figure, will be (Take, Planck's constant $(h) = 6.63 \times 10^{-34}$ J-s, electron charge, $e = 1.6 \times 10^{-19}$ C] **(Main 2019, 12 April I)**



(a) 1.82 eV (b) 1.66 eV
(c) 1.95 eV (d) 2.12 eV

$KE_{max} = h\nu - h\nu_0$

$\phi = h\nu_0$

$\phi = 6.63 \times 10^{-34} \times 4 \times 10^{14}$ J

$\phi = \dfrac{6.63 \times 10^{-34} \times 4 \times 10^{14}}{1.6 \times 10^{-19}}$

$\phi = 1.6575$ eV

A 2 mW laser operates at a wavelength of 500 nm. The number of photons that will be emitted per second is

[Given, Planck's constant $h = 6.6 \times 10^{-34}$ Js, speed of light $c = 3.0 \times 10^{8}$ m/s]

(Main 2019, 10 April II)

(a) 1×10^{16}

(b) 5×10^{15}

(c) 1.5×10^{16}

(d) 2×10^{16}

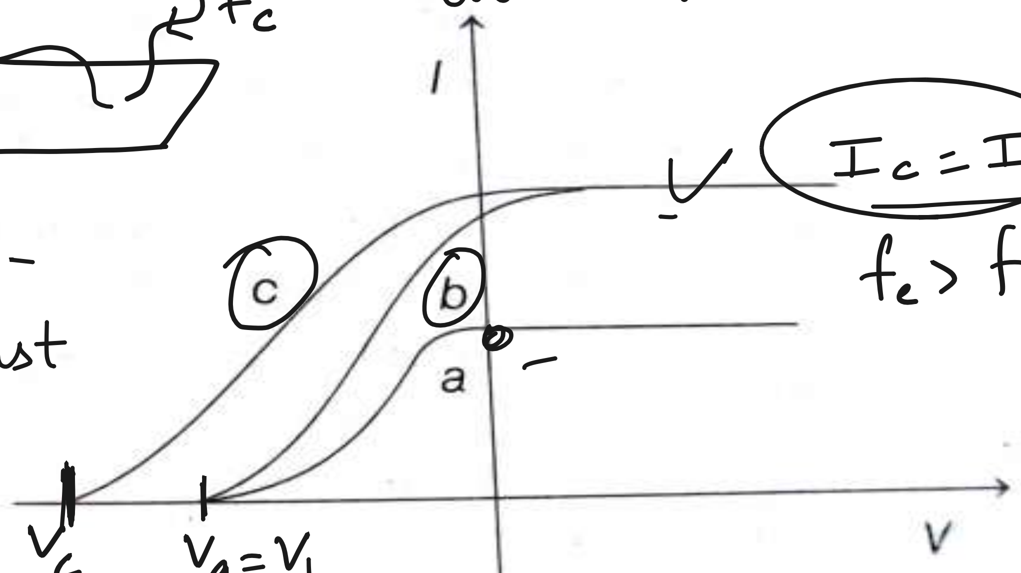
Hint $E = \frac{hc}{\lambda}$, $E = n\frac{hc}{\lambda}$

$$\text{Power} = \frac{E}{t} = \frac{nhc}{\lambda \times 1}$$

$$2 \times 10^{-3} = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9}}$$

$n = 5 \times 10^{15}$ photons per sec.

Q 37. The figure shows the variation of photocurrent with anode potential for a photosensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves a, b and c respectively **(2004, 2M)**

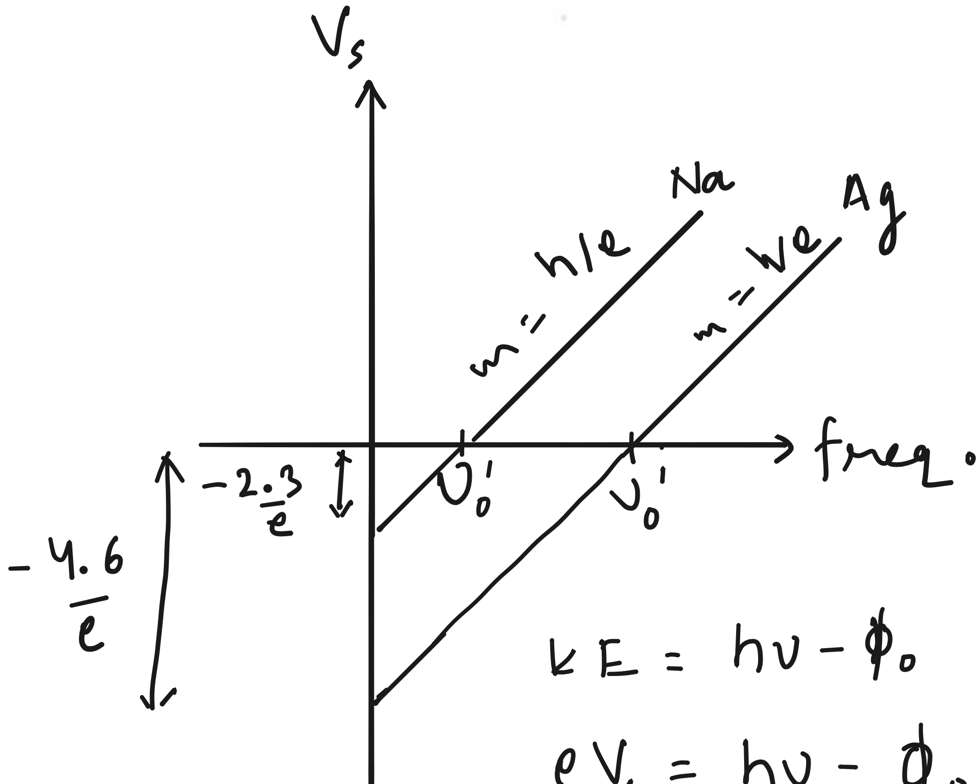


(a) $f_a = f_b$ and $I_a \neq I_b$
(b) $f_a = f_c$ and $I_a = I_c$
(c) $f_a = f_b$ and $I_a = I_b$
(d) $f_b = f_c$ and $I_b = I_c$

Integer type.

Q 4. The work functions of silver and sodium are 4.6 and 2.3 eV, respectively. The ratio of the slope of the stopping potential *versus* frequency plot for silver to that of sodium is

(2013 Adv.)



$KE = h\nu - \phi_0$

$eV_s = h\nu - \phi_0$

$V_s = \frac{h\nu}{e} - \frac{\phi_0}{e}$

↓

$\frac{\text{Slope}_{Na}}{\text{Slope}_{Ag}} = 1$

$c = -\frac{\phi_0}{e}$

$m = \frac{h}{e}$

$y = mx + c$

Q5. A particle A of mass 'm' and charge 'q' is accelerated by a potential difference of 50 V. Another particle B of mass '$4m$' and charge 'q' is accelerated by a potential difference of 2500 V. The ratio of de-Broglie wavelengths $\frac{\lambda_A}{\lambda_B}$ is close to

(Main 2019, 12 Jan I)

(a) 4.47
(b) 10.00
(c) 0.07
(d) 14.14

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{2mq\Delta V}}$$

$$\frac{\lambda_A}{\lambda_B} = \frac{\frac{h}{\sqrt{2m\,q \times 50}}}{\frac{h}{\sqrt{2 \times 4m \times q \times 2500}}} = \frac{\sqrt{2500 \times 8}}{\sqrt{50 \times 2}} = \sqrt{200} = 10\sqrt{2}$$

Q6. A particle A of mass m and initial velocity v collides with a particle B of mass $\frac{m}{2}$ which is at rest. The collision is held on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is (2017 Main)

(a) $\frac{\lambda_A}{\lambda_B} = 2$ ✓ (b) $\frac{\lambda_A}{\lambda_B} = \frac{2}{3}$ (c) $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$ (d) $\frac{\lambda_A}{\lambda_B} = \frac{1}{3}$

A B m m/2

$m_1 = m$, $v = u_1$, $m_2 = m/2$, $u_2 = 0$ at rest

$\frac{v}{3} = V_1$, $V_2 = \frac{4v}{3}$

$\lambda_A = \frac{h}{m\frac{v}{3}}$, $\lambda_B = \frac{h}{\frac{m}{2}\frac{4v}{3}}$

$P_i = mv + 0$

$V_1 = \frac{(m_1-m_2)u_1}{m_1+m_2} + \frac{2m_2u_2}{m_1+m_2} = \frac{(m-\frac{m}{2})v}{\frac{3m}{2}} + 0$

$V_1 = \frac{\frac{m}{2}v}{\frac{3m}{2}} = \frac{v}{3}$

$V_2 = \frac{(m_2-m_1)u_2}{m_1+m_2} + \frac{2m_1u_1}{m_1+m_2}$

$V_2 = \frac{(\frac{m}{2}-m)\times 0}{} + \frac{2mv}{3m} = \frac{4v}{3}$

$3m/2$ $\frac{\ }{2}$

Q7. K_α wavelength emitted by an atom of atomic number $Z = 11$ is λ. Find the atomic number for an atom that emits K_α radiation with wavelength 4λ **(2005, 2M)**

(a) $Z = 6$ ✓
(b) $Z = 4$
(c) $Z = 11$
(d) $Z = 44$

Hint $\sqrt{\nu} = a(z-b)$

Freq.

$\nu = \frac{c}{\lambda}$

$\sqrt{\nu} = a(11-1)$

$\sqrt{\frac{\nu}{4}} = a(z-1)$

$$\frac{\sqrt{\frac{\nu}{4}}}{\sqrt{\nu}} = \frac{a(z-1)}{a(11-1)}$$

$\frac{1}{2} = \frac{z-1}{10}$

$10 = 2z - 2$

$\frac{12}{2} = z = 6$

Q
8 If λ_{Cu} is the wavelength of K_{α}, X-ray line of copper (atomic number 29) and λ_{MO} is the wavelength of the K_{α}, X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{Cu} / \lambda_{Mo}$ is close to

(2014 Adv.)

(a) 1.99 ✓(b) 2.14

(c) 0.50 (d) 0.48

$$\sqrt{\nu} = a(Z-1)$$

$$\sqrt{\frac{c}{\lambda_{cu}}} = a(Z_{cu}-1) \quad \text{— (A)} \qquad \sqrt{\frac{c}{\lambda_{Mo}}} = a(Z_{Mo}-1) \quad \text{— (B)}$$

$$\frac{\sqrt{\frac{c}{\lambda_{MO}}}}{\sqrt{\frac{c}{\lambda_{cu}}}} = \sqrt{\frac{\lambda_{cu}}{\lambda_{MO}}} = \frac{a(Z_{MO}-1)}{a(Z_{cu}-1)} = \frac{(42-1)}{29-1} = \frac{41}{28}$$

$\sqrt{\lambda_{cu}}$

Q9. $\sqrt{\lambda_{cu}}$ $\frac{\lambda_{cu}}{\lambda_{Mo}} = 2.14$ $\sqrt{\frac{\lambda_{cu}}{\lambda_{Mo}}} = 1.46$

Which one of the following statements is wrong in the context of X-rays generated from an X-ray tube ? (2008, 3M)

(a) Wavelength of characteristic X-rays decreases when the atomic number of the target increases

(b) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target

$\lambda_{min} = \frac{hc}{eV}$ cut off wave length is independent from atomic No.

(c) Intensity of the characteristic X-rays depends on the electrical power given to the X-ray tube

(d) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

$\sqrt{\frac{c}{\lambda}} = a(Z-b)$, $\frac{c}{\lambda} = a^2(Z-1)^2$

$\lambda = \frac{c}{a^2(Z-1)^2}$

Characteristics X-ray wave length.

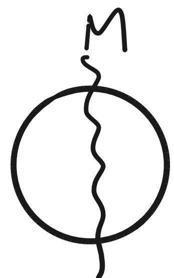
Q10.

A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles λ_1/λ_2 is (1999, 2M)

(a) m_1/m_2 (b) m_2/m_1 ✓(c) 1 (d) $\sqrt{m_2}/\sqrt{m_1}$

(Mains 2019)

$\lambda = \frac{h}{p}$



at rest

$P_i = 0$

$P_i = P_f$

$0 = m_2V_2 - m_1V_1$

$m_1V_1 = m_2V_2$

$P_f = m_2V_2 - m_1V_1$

Q11.

An α-particle and a proton are accelerated from rest by a potential difference of 100 V. After this, their de-Broglie wavelengths are λ_α and λ_p respectively. The ratio $\frac{\lambda_p}{\lambda_\alpha}$, to the nearest integer, is (2010)

$\Delta V = 100V$

$\lambda = \frac{h}{\sqrt{2m q \Delta V}}$

$m_\alpha = 4m_p$

$q_\alpha = 2q_p$

$q_p = e$ $m_p = m$

$q_\alpha = 2e$ $m_\alpha = 4m$

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{\frac{h}{\sqrt{2 m_p q_p \Delta V}}}{\frac{h}{\sqrt{2 m_\alpha q_\alpha \Delta V}}}$$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m \times 2e}{m e}} = \sqrt{8} \simeq 3$$

$=$

V.IMP NEET latest

Q12. The energy of a photon is equal to the kinetic energy of a proton. The energy of the photon is E. Let λ_1 be the de-Broglie wavelength of the proton and λ_2 be the wavelength of the photon. The ratio $\frac{\lambda_1}{\lambda_2}$ is proportional to (2004, 2M)

(a) E^0 (b) $E^{1/2}$ ✓ (c) E^{-1} (d) E^{-2}

Hint For photon

$$E = \frac{hc}{\lambda_2}$$

$$\lambda_2 = \frac{hc}{E}$$

For Proton

$$\lambda_1 = \frac{h}{\sqrt{2mE}}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{h}{\sqrt{2mE}}}{\frac{hc}{E}} \propto \frac{E}{\sqrt{E}}$$

$$\frac{\lambda_1}{\lambda_2} \propto \sqrt{E}$$

leave Qustion

Q13. When a certain photosensitive surface is illuminated with monochromatic light of frequency ν, the stopping potential for the photocurrent is $-V_0/2$. When the surface is illuminated by monochromatic light of frequency $\nu/2$, the stopping potential is $-V_0$. The threshold frequency for photoelectric emission is **(Main 2019, 12 Jan II)**

(a) $\frac{4}{3}\nu$

(b) 2ν

(c) $\frac{3\nu}{2}$

(d) $\frac{5\nu}{3}$

$e\frac{V_0}{2} = h\frac{\nu}{2} - \phi_0$

$eV_s = h\nu - \phi_0$

$e\frac{V_0}{2} = h\nu - \phi_0$ — (A)

$eV_0 = 2h\nu - 2\phi_0$

$eV_0 = \frac{h\nu}{2} - \phi_0$

$2h\nu - 2\phi_0 = \frac{h\nu}{2} - \phi_0$

$\frac{3h\nu}{2} = \phi_0$

$\phi_0 = h\nu$ (A)

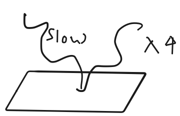
Q14. Surface of certain metal is first illuminated with light of wavelength $\lambda_1 = 350$ nm and then by light of wavelength $\lambda_2 = 540$ n-m. It is found that the maximum speed of the photoelectrons in the two cases differ by a factor of 2. The work function of the metal (in eV) is close to

$$\left(\text{energy of photon} = \frac{1240}{\lambda \text{ (in n - m)}} \text{ eV}\right)$$

(Main 2019, 9 Jan I)

(a) 5.6 (b) 2.5 (c) 1.8 (d) 1.4

$\frac{hc}{\lambda \uparrow} = E \downarrow$



$KE = \frac{hc}{\lambda} - \phi_0$

$KE = \frac{1240}{540 \text{ nm}} - \phi_0$ — (A)

$4KE = \frac{1240}{350 \text{nm}} - \phi_0$ — (B)

$KE = 2.29 - \phi_0$ — (A*)

$4KE = 3.54 - \phi_0$ — (B*)

$\frac{B^*}{A^*} \quad \frac{4KE}{KE} = \frac{3.54 - \phi_0}{2.29 - \phi_0}$

$4 \times 2.29 - 4\phi_0 = 3.54 - \phi_0$

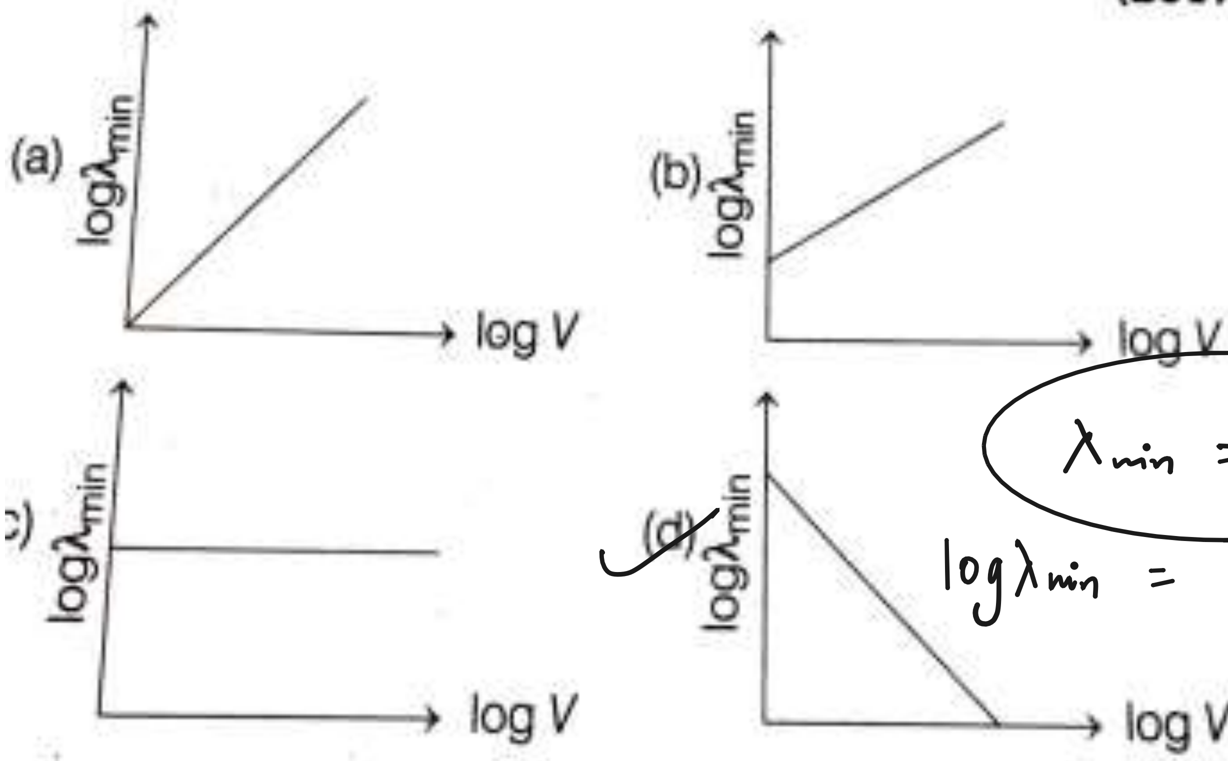
$9.16 - 3.54 = 3\phi_0$

$\phi_0 = 1.87$ eV

Q15. NEET

An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of X-rays in the spectrum, the variation of $\log \lambda_{min}$ with $\log V$ is correctly represented in

(2017 Main)



$$\lambda_{min} = \frac{hc}{eV}$$

$$\log \lambda_{min} = \log \frac{hc}{eV}$$

$$\log \lambda_{min} = \log hc - \log eV$$

$y = c - mx$

Q 16

Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be (2016 Main)

$E_{incident} = \frac{4}{3} E$ $\quad KE = \frac{1}{2} m v^2$

(a) $> v\left(\frac{4}{3}\right)^{1/2}$ ✓

(b) $< v\left(\frac{4}{3}\right)^{1/2}$

(c) $= v\left(\frac{4}{3}\right)^{1/2}$

(d) $= v\left(\frac{3}{4}\right)^{1/2}$

KE increases more then $\frac{4}{3}$ time

$v > \sqrt{\frac{4}{3}}$

$KE = h\nu - \phi_0$

$KE = 5eV - 2eV$

$KE = 3eV$

$KE = 10eV - 2eV$

$KE = 8eV$

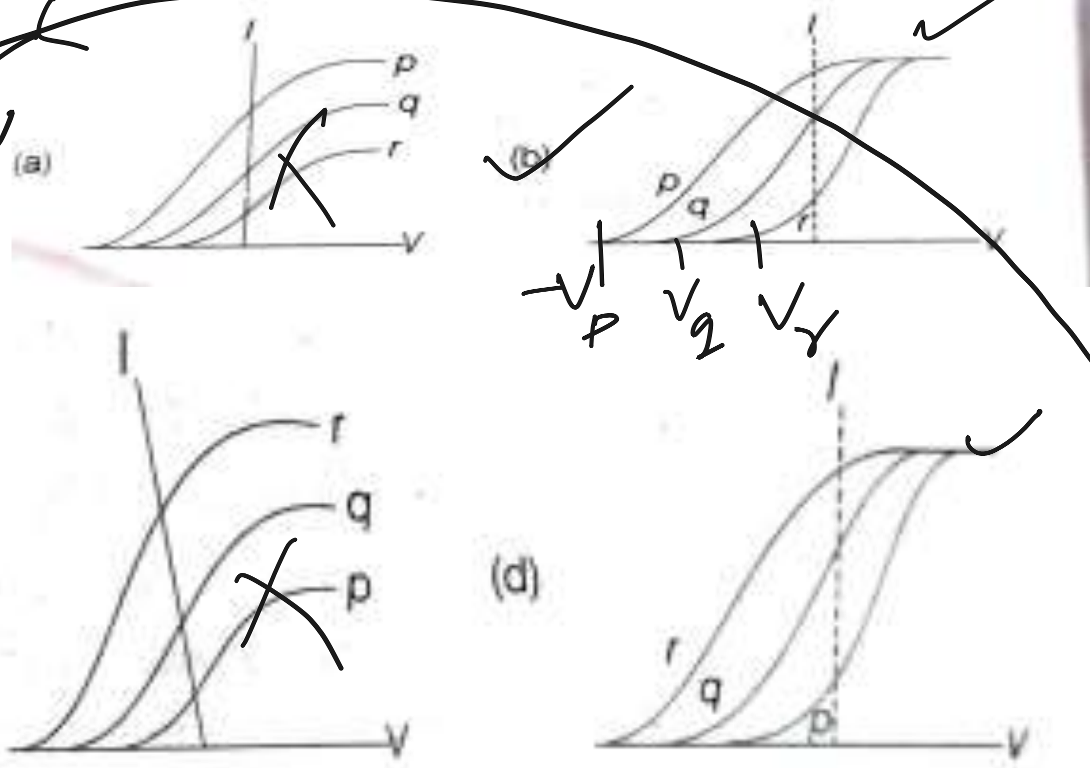
Q17.

Photoelectric effect experiments are performed using three different metal plates p, q and r having work functions $\phi_p = 2.0\text{eV}$, $\phi_q = 2.5\text{eV}$ and $\phi_r = 3.0\text{eV}$, respectively. A light beam containing wavelengths of 550 nm, 450 nm and 350 nm with equal intensities illuminates each of the plates. The correct I-V graph for the experiment is (2009)

$\phi_p = 2\text{eV}$

$\phi_q = 2.5\text{eV}$

$\phi_r = 3\text{eV}$



$\lambda = 550\text{ nm}$

$\lambda = 450\text{ nm}$

$\lambda = 350\text{ nm}$

(18)

The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately (1998, 2M)

(a) 540 nm (b) 400 nm ✓(c) 310 nm (d) 220 nm

$$\phi = 4eV = \frac{hc}{\lambda_0}$$

$$4eV = \frac{1240}{\lambda \text{ in nm}}$$

$$\lambda = \frac{1240}{4} = 310 nm$$

Q19 NEET

The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential in volt is

(1997, 1M)

(a) 2 (b) 4 (c) 6 (d) 10

$KE = E - \phi_0$

$4eV = 6eV - \phi_0$

$\phi_0 = 2eV.$

$KE = eV_s$

$4eV = eV_s$

$KE_{max} = eV_{stopping}$

$4eV = eV_{stop}$

If in a region there is a time varying electric field then which of the following Maxwell's equation will be most suitable?

(1) $\oint \vec{B}.\vec{dl} = I + \varepsilon_0 \frac{d\phi_E}{dt}$

(2) $\oint \vec{B}.\vec{dl} = \mu_0 I$

(3) $\oint \vec{B}.\vec{dl} = \mu_0 \left[I + \varepsilon_0 \frac{d\phi_E}{dt} \right]$

(4) $\oint \vec{B}.\vec{dl} = \mu_0 \left[I + \varepsilon_0 \frac{d\phi_B}{dt} \right]$

$\oint \vec{B}\cdot\vec{dl} = \mu_0 (i_c + i_d)$

$i_d = \frac{dCV}{dt}$

$= \frac{\varepsilon_0 A}{d} \frac{dV}{dt}$

$= \varepsilon_0 A \frac{dE}{dt} = \frac{\varepsilon_0 d\phi_E}{dt}$

Q21 Which of the following is not an electromagnetic wave?

(1) X-rays (2) β-rays

(3) Cosmic rays (4) Both (2) & (3)

β rays represent fast moving electrons.

are very high energetic rays.

Q22

Hertz's experiment confirms that

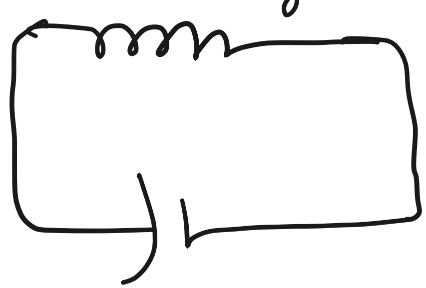
(1) An electron at rest produces EM waves

✓(2) An oscillating electron produces EM waves

(3) An electron in conductor moving with drift velocity produces EM wave

(4) All of these

q	q	q
at rest	→ v (constant)	accelerating
only E	E & B	E ✓ B ✓



If an electromagnetic wave propagating through vacuum is described by

$E_y = E_0 \sin(kx - \omega t)$; $B_z = B_0 \sin(kx - \omega t)$, then

(1) $E_0 k = B_0 \omega$

(2) $E_0 B_0 = \omega k$

(3) $E_0 \omega = B_0 k$

(4) $E_0 B_0 = \frac{\omega}{k}$

Speed of em wave $\rightarrow c = \frac{E_0}{B_0} = \frac{\omega}{k}$

$y = A \sin(\omega t - kx)$

$v = \frac{\omega}{k}$

$E_0 k = B_0 \omega$

: The oscillating magnetic field in a plane electromagnetic wave is given as

$B_y = 8 \times 10^{-6} \sin(5000\pi x - 3 \times 10^{11}\pi t)$ T.

Calculate

(a) Frequency

(b) Wavelength

(c) Speed of the wave

(d) Electric field amplitude

(e) Write down expression for oscillating electric field.

IIT mains 2019

$$B_y = 8\times10^{-6}\sin(5000\pi x - 3\times10^{11}\pi t)$$

ω

$\frac{E}{B} = c$, $E = B\times C$

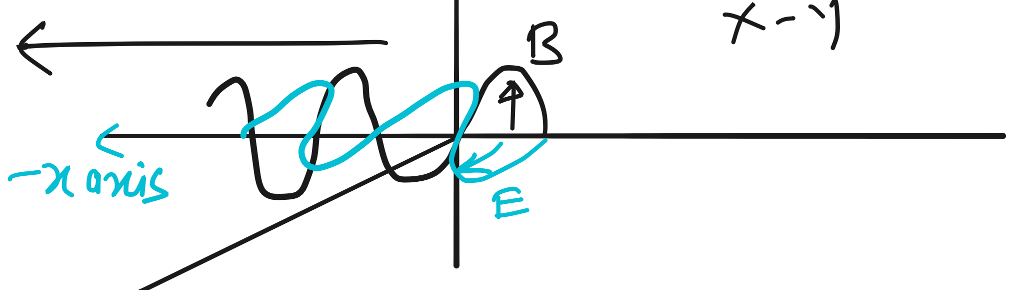
$E = 8\times10^{-6}\times3\times10^{8}$

$E = 24\times10^{2}\ \frac{N}{C}$

$\omega = 2\pi f = 3\times10^{11}\pi$

$f = 1.5\times10^{11}$ Hz

$f = \frac{c}{\lambda}$, $\lambda = \frac{c}{f} = \frac{3\times10^{8}}{1.5\times10^{11}} = 2\times10^{-3}$ m.



$$E_z = 24\times10^{2}\sin(5000\pi x - 3\times10^{11}\pi t)$$

An electromagnetic wave with frequency ω and wavelength λ travels in the +y direction. Its magnetic field is along - x axis. The vector equation for the associated electric field (of amplitude E_0) is :-

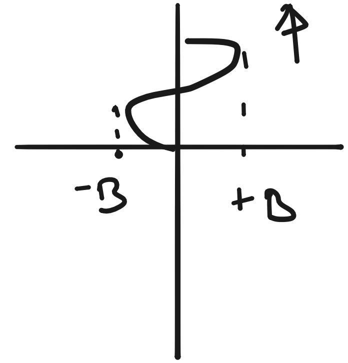
[AIEEE-2012 (Online)]

(1) $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda} y\right)\hat{x}$

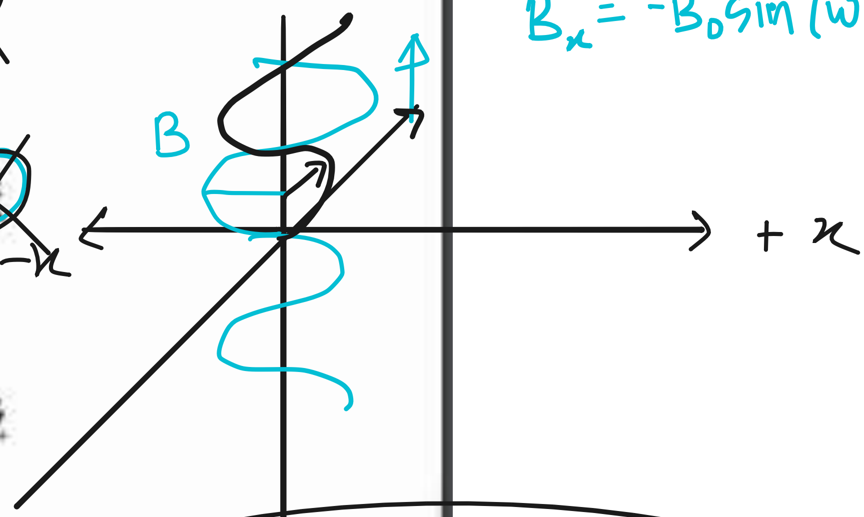
(2) $\vec{E} = -E_0 \cos\left(\omega t + \frac{2\pi}{\lambda} y\right)\hat{x}$

(3) $\vec{E} = -E_0 \cos\left(\omega t + \frac{2\pi}{\lambda} y\right)\hat{z}$

(4) $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda} y\right)\hat{z}$



$B_x = -B_0 \sin(\omega t - ky)$



$E_z = -E_0 \cos(\omega t - ky)$

During the propagation of electromagnetic waves in a medium : [JEE(Main)-2014]

(1) Electric energy density is equal to the magnetic energy density

(2) Both electric magnetic energy densities are zero

(3) Electric energy density is double of the magnetic energy density

(4) Electric energy density is half of the magnetic energy density.

$$\frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\frac{B^2}{\mu_0}$$