Questão (1)

A função que descreve V_0 é dada do formulário:

$$eV_0 = hf - W$$

$$V_0 = \left(\frac{h}{e}\right)f - \frac{W}{e}$$

$\phi \equiv W$, é a função trabalho.

Assim:

$$V_0 = \left(\frac{h}{e}\right)f - \frac{\phi}{e}$$

Escolhendo dois pontos da reta:

$$P_1 = (5{,}2 \times 10^{14}\,Hz;\ 0{,}0\,V)$$

$$P_2 = (8{,}2 \times 10^{14}\,Hz;\ 1{,}0\,V)$$

$$Y = Ax + B;$$

$A = \frac{h}{e}$ e $B = -\frac{\phi}{e}$

substituindo os valores

dos coordenadas do

P1 e P2 na equação

da reta:

$$\begin{cases} P1: & 0 = A \times 5{,}2 \times 10^{14}\,Hz + B \\ P2: & 1 = A \times 8{,}2 \times 10^{14}\,Hz + B \end{cases}$$

a) subtraindo a segunda

da primeira:

$$1 - 0 = (8{,}2 - 5{,}2) \times 10^{14}\,Hz \times A$$

$$A = \frac{1\ V}{3 \times 10^{14}\,Hz}$$

$$\frac{h}{e} = \frac{1}{3 \times 10^{14}\,Hz} \quad V$$

$$h = \frac{e}{3} \times 10^{-14} \quad V \cdot s$$

$$h = \frac{2 \times 10^{-19}}{3} C \times 10^{-14} \; V \cdot s$$

$$h = 0{,}666 \times 10^{-33} \; CV \cdot s$$

$$h = 6{,}66 \times 10^{-34} \; J \cdot s$$

b) somando as duas equações

$$1 = (8{,}2 + 5{,}2) \times 10^{14} \, Hz \, A + 2B$$

$$1 - (8{,}2 + 5{,}2) \times \cancel{10^{14} \, Hz} \, \frac{1}{3 \times \cancel{10^{14} \, Hz}} V = 2B$$

$$2B = 1 - \frac{13{,}4}{3} V$$

13,4 | 3
14   4,4
2

$$2B = 1 - 4{,}4 V$$

$$B = -\frac{3{,}4 V}{2} \; ; \; B = -1{,}70 V$$

$$\phi = -e B$$

$$\phi = +1{,}7 V \cdot e$$

$$\phi = +1{,}7 \, eV$$

Questão (2)

a) Temos que:

$$\vec{E} = E_0 \cos(kz + \omega t)$$

O sentido de propagação da onda é $-\hat{z}$.

$$K = \frac{\pi}{100\,nm} = \frac{\pi}{100 \times 10^{-9}\,m}$$

$$K = 10^{7}\pi \quad m^{-1}$$

• $\vec{K} = -(10^{7}\pi \; m^{-1})\,\hat{z}$

$$\lambda = \frac{2\pi}{K} \; ; \; \lambda = \frac{2\pi}{10^{7}\pi}$$

• $\lambda = 2 \times 10^{-7}\, m = 0{,}2\, \mu m$

$$c = \lambda f \; ; \quad f = \frac{c}{\lambda}$$

• $f = \dfrac{3{,}0 \times 10^{8}\, m/s}{2 \times 10^{-7}\, m}$; $f = 1{,}5 \times 10^{15}\, Hz$

b)

$$\vec{S} = \frac{1}{\mu_0}\, \vec{E} \times \vec{B} \;;$$

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

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

$$B = \frac{E}{c}$$

$$\vec{S} = \frac{1}{\mu_0}\, E\,\hat{E} \times B\,\hat{B}$$

$$\vec{S} = \frac{1}{\mu_0}\, E\, \frac{E}{c}\, \hat{E} \times \hat{B}$$

$$\vec{S} = \frac{1}{\mu_0} \frac{E^2}{c}\, \hat{k}$$

$$\vec{S} = -\frac{1}{\mu_0} \frac{E^2}{c}\, \hat{z}$$

$$\vec{S} = -\frac{1}{\mu_0 \varepsilon_0}\, \varepsilon_0 \frac{E^2}{c}\, \hat{z}$$

$$\vec{S} = -\frac{c^2}{c}\varepsilon_0 E^2 \hat{z}$$

$$\vec{S} = -c\,\varepsilon_0 E^2 \hat{z}$$

$$\vec{S} = -c\,\varepsilon_0 \left\{ \left(8{,}0\,\frac{V}{m}\right) \cos\left[\frac{\pi}{(100\,mm)}(z+ct)\right] \right\}^2 \hat{z}$$

$$I = \langle S \rangle$$

$$I = c\,\varepsilon_0 \langle E^2 \rangle \longrightarrow \langle \cos^2 u \rangle = \frac{1}{2}$$

$$I = \frac{1}{2} c\,\varepsilon_0 E_0^2 \longrightarrow E_0 = 8{,}0\,\frac{V}{m}$$

$$I = \frac{1}{2} c\,\varepsilon_0 \left(8{,}0\,\frac{V}{m}\right)^2$$

$$I = \frac{1}{2}\,\cancel{3}^{1} \times 10^{8}\,\cancel{m}^{1}/s \times \frac{1}{\cancel{9}_{3}} \times 10^{-10}\,\frac{F}{\cancel{m}_{1}} \times 64\,\frac{V^2}{m^2}$$

$$I = \frac{64}{6} \times 10^{-2} \times \frac{F \cdot V^2}{m^2\,s}$$

$$64 \,\underline{|\, 6}$$
$$04\,0 \quad 10{,}6$$
$$6$$

$$I = 10{,}6 \times 10^{-2} \ \frac{FV^2}{m^2 s}$$

unidade de I:

$$Q = CV \ ; \quad [C] = F = \frac{C}{V}$$

energia

$$\frac{FV^2}{m^2 s} = \frac{C}{V}\,\frac{V^2}{m^2 s} = \frac{CV}{m^2 s} = \frac{J}{m^2 s}$$

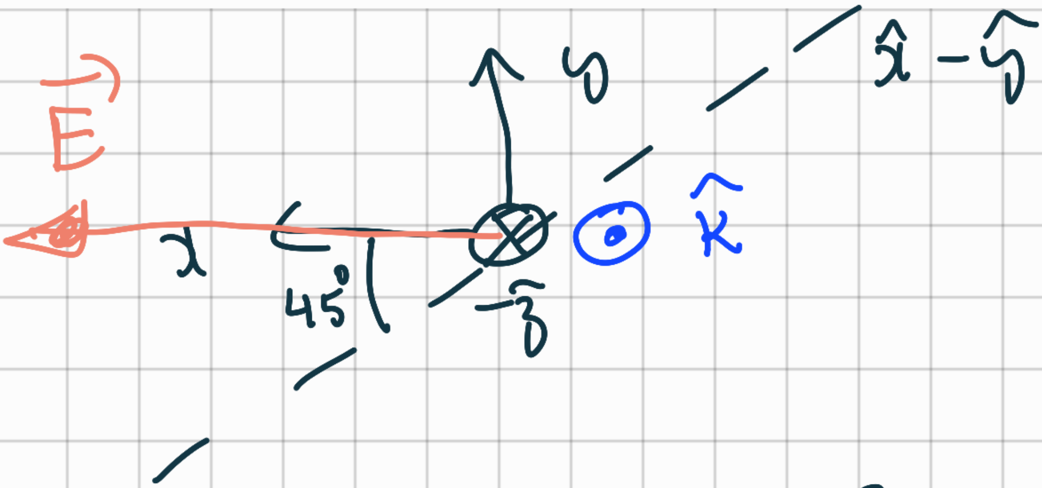
$$\frac{FV^2}{m^2 s} = \frac{W}{m^2}$$

$$I = 10{,}6 \times 10^{-2} \ \frac{W}{m^2}$$

$$I = 106 \times 10^{-3} \ \frac{W}{m^2}$$

e) A polarização dessa onde é linear, ao longo do eixo x:

$$\hat{k} = -\hat{z}$$



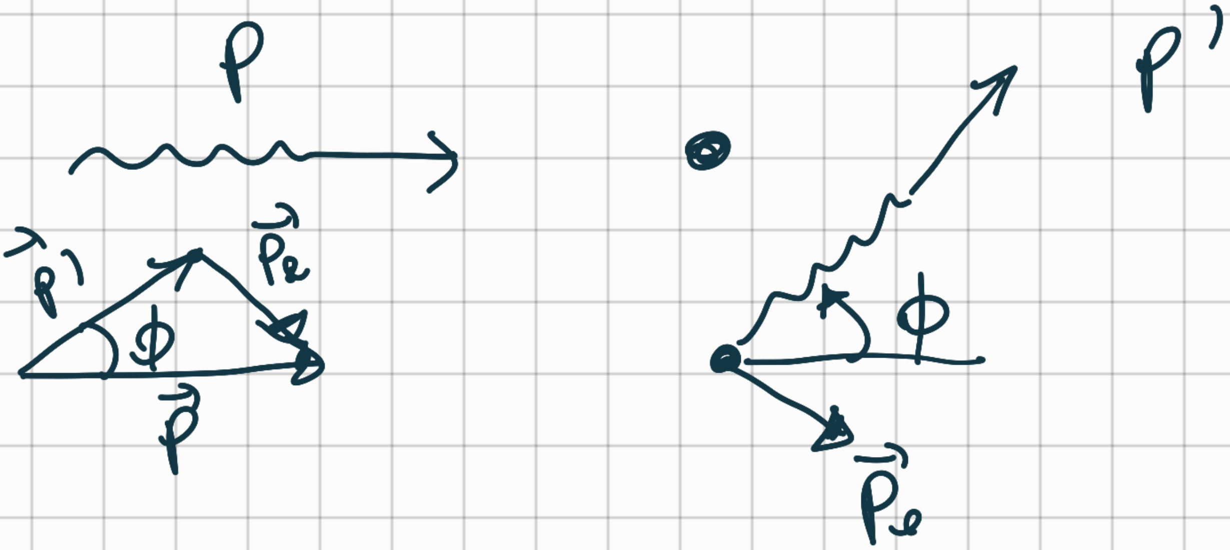
$$I_p = I(\cos 45)^2$$

$$I_p = I\left(\frac{\sqrt{2}}{2}\right)^2 ; \; I_p = \frac{I}{2}$$

$$I_p = 53 \times 10^{-3} \frac{W}{m^2}$$

Questão (3)

a) Temos que o fóton realiza espalhamento Compton :



A energia inicial do sistema é:

$$E_i = \frac{hc}{\lambda} + mc^2$$

e a energia final

$$E_f = \frac{hc}{\lambda'} + \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

Pela conservação da energia

$$\frac{hc}{\lambda} + mc^2 = \frac{hc}{\lambda'} + \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda'} + \left(\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2\right)$$

$$\frac{1}{\lambda} = \frac{1}{\lambda'} + \frac{mc^2}{hc}\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right]$$

$$\boxed{\frac{1}{\lambda} = \frac{1}{\lambda'} + \frac{mc}{h}\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right]}$$

b) $$K = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$$

$$K = mc^2\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right]$$

$$\frac{1}{\lambda} = \frac{1}{\lambda'} + \frac{mc^2}{hc}\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right]$$

$$\frac{1}{\lambda} - \frac{1}{\lambda'} = \frac{K}{hc}$$

$$\boxed{K = hc\,\frac{(\lambda' - \lambda)}{\lambda'\lambda}}$$

Questão (4)

a) Temos:

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

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

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

$$\vec{S} = \frac{1}{\mu_0} E \hat{E} \times B \hat{B}$$

$$\vec{S} = \frac{1}{\mu_0} \frac{E^2}{c} \hat{k}$$

$$\vec{S} = \frac{1}{\mu_0 \varepsilon_0} \frac{\varepsilon_0 E^2}{c} \hat{k}$$

$$\vec{S} = c \varepsilon_0 E^2 \hat{k}$$

$$I = \langle S \rangle = \langle c \varepsilon_0 E^2 \rangle$$

$$I_1 = \langle c\, \varepsilon_0 E_0^2 \cos^2(\omega t + \phi) \rangle$$

$$I_1 = \frac{1}{2} c\, \varepsilon_0 E_0^2$$

$$\langle \cos^2 u \rangle = \frac{1}{2}$$

$$I_2 = \langle c\, \varepsilon_0 E_0^2 \cos^2(\omega t - \phi) \rangle$$

$$I_2 = \frac{1}{2} c\, \varepsilon_0 E_0^2$$

$$I_1 = I_2 = I_0$$

b) O campo elétrico da onda resultante é dado por:

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

$$\vec{E} = E_0 \hat{y} \left[\cos(\omega t + \phi) + \cos(\omega t - \phi) \right]$$

$\omega t = a$ e $\phi = b$

$$\vec{E} = E_0 \hat{y} \; 2 \cos \omega t \cos \phi$$

$$I = \varepsilon_0 c \langle E^2 \rangle$$

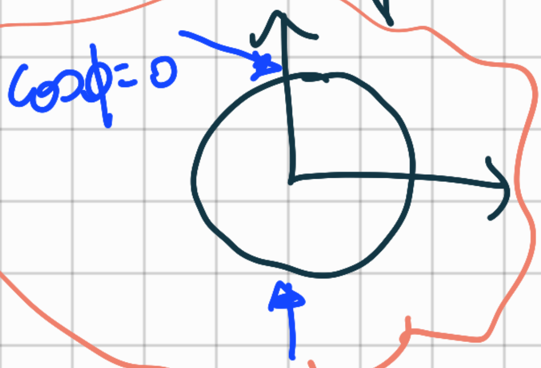
$$I = \varepsilon_0 c \left\langle E_0^2 \, 4 \cos^2 \omega t \cos^2 \phi \right\rangle$$

$$I = 4 \varepsilon_0 c \, E_0^2 \, \underbrace{\left\langle \cos^2 \omega t \right\rangle}_{\to \frac{1}{2}} \cos^2 \phi$$

$$I = 2 \varepsilon_0 c \, E_0^2 \cos^2 \phi$$

$$\boxed{I = 4 I_0 \cos^2 \phi}$$

c) Para haver interferência destrutiva:



$$\cos \phi = 0$$

$$\phi = \pm \frac{\pi}{2} \; ; \; \pm \frac{3\pi}{2} \; ; \; \pm \frac{5\pi}{2}$$

$$\boxed{\phi = (2n - 1) \frac{\pi}{2} \; ; \; n = \{0, \pm 1, \pm 2, \dots\}}$$