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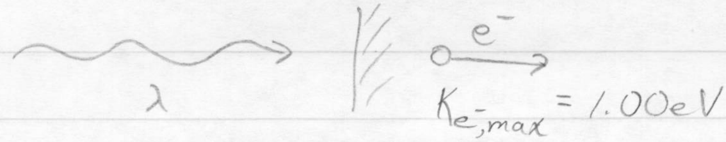
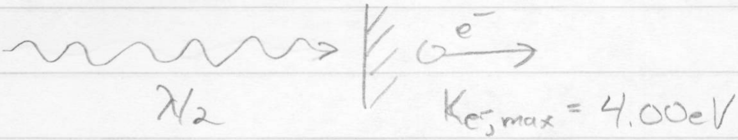


photo electric effect



What is the work function of the metal?

The relevant equation is (3.23):

$$K_{max} = hf - \phi$$

For a photon, we have: $f = \dfrac{c}{\lambda}$

$$\Rightarrow K_{max} = \frac{hc}{\lambda} - \phi$$ where ϕ is the work function

We are given:

$$\left.\begin{aligned} 1.00 eV &= \frac{hc}{\lambda} - \phi \\ \text{and} \quad 4.00 eV &= \frac{hc}{(\lambda/2)} - \phi \end{aligned}\right\}$$ the work function does not depend on λ

Eliminating λ and solving for ϕ yields:

$$4.00 eV = 2(1.00 eV + \phi) - \phi$$

$$\Rightarrow \boxed{\phi = 2.00 eV}$$

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Calculate the energy and momentum of a photon, $\lambda = 500 nm$.

$$E = \frac{hc}{\lambda} = \frac{1240 eV\,nm}{500\,nm} = \boxed{2.48\,eV}$$

$$p = \frac{h}{\lambda} = \frac{6.626\times10^{-34}\,Js}{500\times10^{-9}\,m} = \boxed{1.33\times10^{-27}\,kg\,m/s}$$

Make sure to pay attention to what units you are given and what you want to get.

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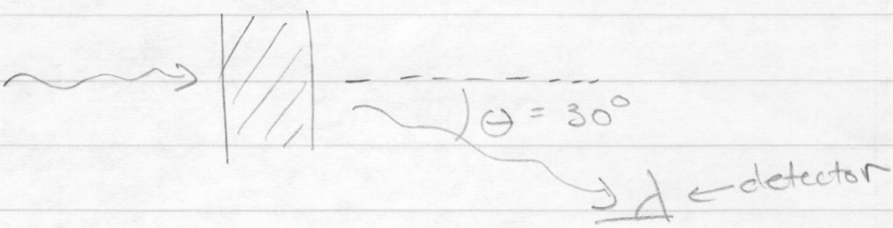
X-rays, $E = 300 keV$, compton scattering



(a) Find the compton shift @ $\theta = 30°$

The compton effect is discussed on pages 86-93

$$\text{Eq. (3.27): } \Delta\lambda = \frac{h}{m_e c}(1-\cos\theta) = \frac{hc}{m_e c^2}(1-\cos\theta)$$

$hc = 1240\,eVnm$ and $\longrightarrow$ $= \frac{1240\,eVnm}{0.511\,MeV}(1-\cos(30°))$

$m_e c^2 = 0.511\,MeV$ are both useful

$$= \boxed{3.25\times10^{-4}\,nm, \text{ small}}$$

(b) $E' = hc/\lambda' = hc/(\lambda+\Delta\lambda)$, first we need λ

$$\Rightarrow E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{1240\,eVnm}{300\,keV} = 4.133\times10^{-3}\,nm$$

$$\lambda' = \lambda + \Delta\lambda = 4.133\times10^{-3}\,nm + 3.25\times10^{-4}\,nm = 4.46\times10^{-3}\,nm$$

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$$E' = \frac{hc}{\lambda'} = \frac{1240\ eV\,nm}{4.46\times10^{-3}\ nm} = \boxed{2.78\times10^{5}\ eV}$$

(c) What is the energy of the recoiling electron?

This question is a little ambiguous because (since you were just studying relativity) you may wonder if they mean E or K.

In this case, they want K.

Conservation of energy:

$$E = E' + K_{e^-} \Rightarrow K_{e^-} = E - E' = \boxed{2.19\times10^{4}\ eV}$$

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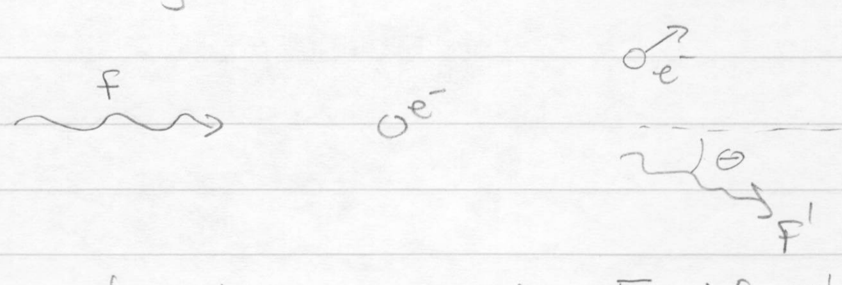
Show that a photon cannot transfer all of its energy to a free electron.

This essentially a compton scattering problem, despite the way that it is worded.



The energy of a photon is given by $E = hf$, $E' = hf'$.

In other words, $f' = 0$ if ALL the energy is transferred.

Conservation of energy: $hf + m_{e^-}c^2 = \sqrt{m_{e^-}^2 c^4 + p_{e^-}^2 c^2}$

conservation of momentum: $\frac{hf}{c} = p_{e^-}$

Combining these two: $hf + m_{e^-} c^2 = \sqrt{m_{e^-}^2 c^4 + (hf)^2}$

Squaring both sides: $2hf\,m_{e^-} c^2 = 0$, clearly a contradiction

all non-zero

$\Rightarrow \boxed{f' \neq 0}$

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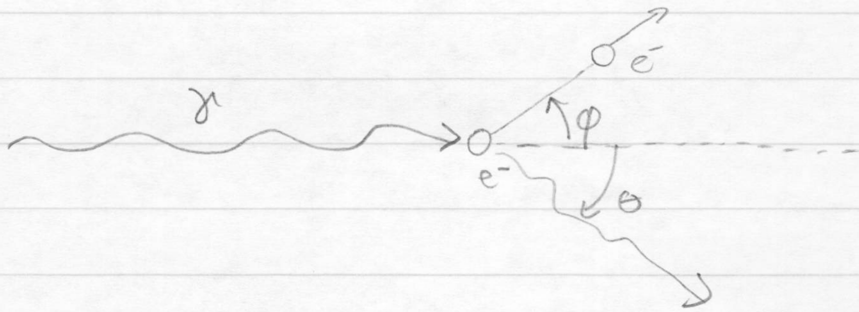
Gamma rays scattered from e^- at rest



Consider the special case $\phi = \theta$.

(a) What is θ?

Conservation of momentum (x): $p_\gamma = p'_\gamma \cos\theta + p'_{e^-} \cos\theta$ ①

(y): $0 = p'_{e^-} \sin\theta - p'_\gamma \sin\theta$ ②

$p_\gamma = \frac{h}{\lambda}$, $p'_\gamma = \frac{h}{\lambda'} \Rightarrow p'_e = \frac{h}{\lambda'}$

① $\Rightarrow \frac{h}{\lambda} = \frac{h}{\lambda'}\cos\theta + \frac{h}{\lambda'}\cos\theta = \frac{2h}{\lambda'}\cos\theta$ ③

From Eq. (3.27) we know how λ and λ' are related:

$$\lambda' - \lambda = \frac{h}{m_{e^-}c}(1-\cos\theta) \quad ④$$

Solving for λ' (the only unknown) gives:

(3+4) $\Rightarrow 2\lambda\cos\theta = \frac{h}{m_{e^-}c}(1-\cos\theta) + \lambda = \frac{h}{m_{e^-}c} - \frac{h}{m_{e^-}c}\cos\theta + \lambda$

Finally, solving for θ: $\boxed{\cos\theta = \frac{h/m_{e^-}c + \lambda}{(2\lambda + h/m_{e^-}c)}}$

Now you can use this to get the angle for any energy using $E = hc/\lambda$. $\boxed{E = 1.02\,\text{MeV} \Rightarrow \theta = 41.5^\circ}$

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(b) What is the energy of the scattered photons?

Back to the compton formula: $\Delta\lambda = \frac{h}{m_e c}(1-\cos\theta)$

and our usual $E' = hc/\lambda' \Rightarrow \theta = 41.5° \Rightarrow \boxed{E = 0.679\,\text{MeV}}$

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Show that: $E_e = hf - hf' + m_e c^2$

$$p_e^2 = \left(\frac{hf'}{c}\right)^2 + \left(\frac{hf}{c}\right)^2 - \frac{2h^2 ff' \cos\theta}{c^2}$$

$$E_e^2 = p_e^2 c^2 + m_e^2 c^4$$

implies $\lambda - \lambda' = \frac{h}{m_e c}(1-\cos\theta)$.

$$(hf - hf' + m_e c^2)^2 = \left[\left(\frac{hf'}{c}\right)^2 + \left(\frac{hf}{c}\right)^2 - \frac{2h^2 ff' \cos\theta}{c^2}\right]c^2 + m_e^2 c^4$$

$$\cancel{(hf)^2} + \cancel{(hf')^2} + \cancel{m_e^2 c^4} - 2h^2 ff' + 2hf m_e c^2 - 2hf' m_e c^2 = \cancel{(hf')^2} + \cancel{(hf)^2} - 2h^2 ff' \cos\theta + \cancel{m_e^2 c^4}$$

$$-2h^2 ff' + 2hf m_e c^2 - 2hf' m_e c^2 = -2h^2 ff' \cos\theta$$

divide by $2h$

$$-hff' + (f - f') m_e c^2 = -hff' \cos\theta$$

$$hff'(-1+\cos\theta) = (f' - f) m_e c^2, \text{ divide by } ff'$$

$$h(-1+\cos\theta) = \left(\frac{1}{f} - \frac{1}{f'}\right) m_e c^2, \quad f = c/\lambda$$

$$h(-1+\cos\theta) = (\lambda - \lambda') m_e c, \text{ multiply by } -1, \text{ divide by } m_e c$$

$$\boxed{\frac{h}{m_e c}(1-\cos\theta) = \Delta\lambda}$$

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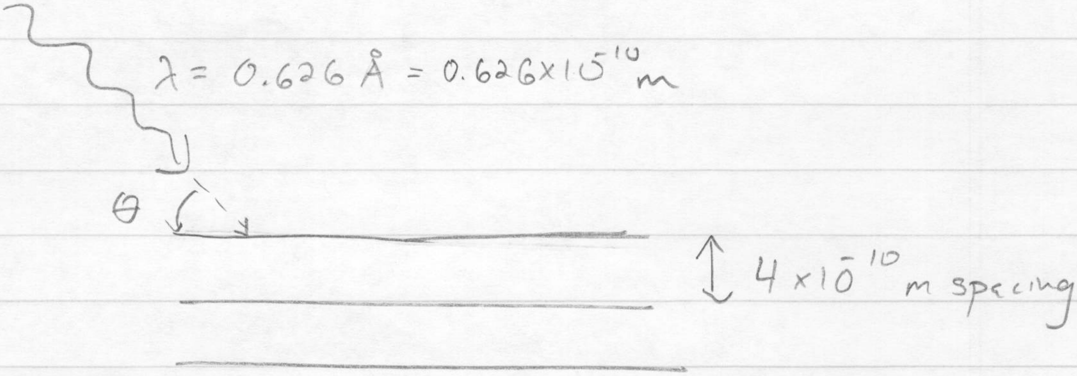

For what θ is the diffracted beam a maximum in intensity?

This is discussed on pages 86-89.

$n\lambda = 2d\sin\theta \Rightarrow \theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$, $d = 4 \times 10^{-10}$ m

$$\boxed{\begin{array}{l} n=1 \Rightarrow \theta = 4.49^\circ \\ n=2 \Rightarrow \theta = 9.00^\circ \\ n=3 \Rightarrow \theta = 13.6^\circ \end{array}}$$

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$n\lambda = 2d\sin\theta$, $n=1 \Rightarrow \lambda = 2d\sin\theta$, $\theta = 6.41^\circ$

$\Rightarrow d = \frac{\lambda}{2\sin(6.41^\circ)} = 2.8 \times 10^{-10}$ m

½ NaCl / primitive cell

We know NaCl has $58.4 \frac{g}{mole}$ and we are told it has a density of $\rho = 2.17\ g/cm^3$

NaCls per cell

The volume of a cell is d^3.

single NaCl mass

$\Rightarrow \left(54.8 \frac{g}{mole} \frac{1}{N_A}\right) \times \frac{1}{2} \times \frac{1}{d^3} = 2.17 \frac{g}{cm^3}$, solve for N_A

$\Rightarrow N_A = 6.13 \times 10^{23}$ /mole