

MARKING SCHEME FOR ANSWERS TO THE THEORETICAL QUESTION IV

Part	MARKING SCHEME - THE THEORETICAL QUESTION IV- COMPTON SCATTERING	Total Scores
IV.	For: the situation before the first scattering of photon the momentum $\vec{p}_i$ and the energy E_i of the initial photon $\begin{cases} \vec{p}_i = \frac{h}{\lambda_i} = \frac{h \cdot f_i}{c} \\ E_i = h \cdot f_i \end{cases}$ the frequency of initial photon $f_i = \frac{c}{\lambda_i}$ the momentum $\vec{p}_{oe}$ and the energy E_{oe} of initial, free electron in motion $\begin{cases} \vec{p}_{oe} = m \cdot \vec{v}_{1e} = \frac{m_0 \cdot \vec{v}_{1e}}{\sqrt{1-\beta^2}} \\ E_{oe} = m \cdot c^2 = \frac{m_0 \cdot c^2}{\sqrt{1-\beta^2}} \end{cases}$ De Broglie wavelength of the first electron $\lambda_{oe} = \frac{h}{p_{0e}} = \frac{h}{m_0 \cdot v_{1e}} \sqrt{1-\beta^2}$ the situation after the scattering of photon the momentum $\vec{p}_o$ and the energy E_o of the scattered photon $\begin{cases} \vec{p}_o = \frac{h}{\lambda_o} = \frac{h \cdot f_o}{c} \\ E_o = h \cdot f_o \end{cases}$ the frequency of scattered photon $f_o = \frac{c}{\lambda_o}$	7.0 points 0.3p 0.1p 0.3p 0.2p 0.3p 0.1p

the principles of conservation of moments and energy $\begin{cases} \vec{P}_i + \vec{p}_{oe} = \vec{p}_0 \\ E_i + E_{oe} = E_0 + E_{1e} \end{cases}$ 0.3p

the conservation of moment on Ox direction $\frac{h \cdot f_i}{c} + m \cdot v_{1e} \cdot \cos \alpha = \frac{h \cdot f_0}{c} \cos \theta$ 0.3p

the conservation of moment on Oy $m \cdot v_{1e} \cdot \sin \alpha = \frac{h \cdot f_0}{c} \sin \theta$ 0.3p

$$\frac{m_0^2 \cdot c^2}{1 - \left(\frac{v_{1e}}{c}\right)^2} \cdot v_{1e}^2 = h^2 \cdot (f_0^2 + f_i^2 - 2f_0 \cdot f_i \cdot \cos \theta)$$
 0.4p

The conservation of energy $m \cdot c^2 + h \cdot f_i = m_0 \cdot c^2 + h \cdot f_0$ 0.3p

$$\text{or } \frac{m_0 \cdot c^2}{\sqrt{1 - \left(\frac{v_{1e}}{c}\right)^2}} = m_0 \cdot c^2 + h \cdot (f_0 - f_i)$$
 0.2p

$$\frac{m_0^2 \cdot c^4}{1 - \left(\frac{v_{1e}}{c}\right)^2} = m_0^2 \cdot c^4 + h^2 \cdot (f_0 - f_i)^2 + m_0 \cdot h \cdot c^2 \cdot (f_0 - f_i)$$
 0.2p

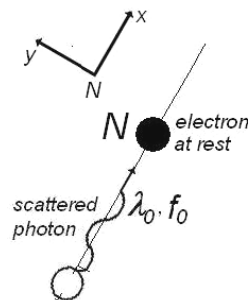
$$\frac{h}{m_0 \cdot c} (1 - \cos \theta) = \frac{c}{f_i} - \frac{c}{f_0}$$
 0.2p

$$\Lambda = \frac{h}{m_0 \cdot c}$$
 0.2p

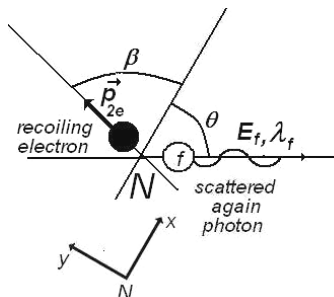
the wavelength of scattered photon $\lambda_0 = \lambda_i - \Lambda \cdot (1 - \cos \theta)$ 0.3p

$$\begin{cases} \lambda_i < \lambda_0 \\ E_i > E_0 \end{cases}$$
 0.1p

the situation before the second collision



the situation after this scattering process



	The conservation principle for moment in the scattering process $\begin{cases} \frac{h}{\lambda_0} = \frac{h}{\lambda_f} \cos \theta + m \cdot v_{2e} \cdot \cos \beta \\ \frac{h}{\lambda_f} \sin \theta - m \cdot v_{2e} \cdot \sin \beta = 0 \end{cases}$ 0.3p $\left(\frac{h}{\lambda_f}\right)^2 + \left(\frac{h}{\lambda_0}\right)^2 - \frac{2 \cdot h^2}{\lambda_0 \cdot \lambda_f} \cos \theta = (m \cdot v_{2e})^2$ 0.3p $\begin{cases} \frac{h}{m_0 \cdot c} \cdot (1 - \cos \theta) = \lambda_f - \lambda_0 \\ \lambda_f - \lambda_0 = \Lambda \cdot (1 - \cos \theta) \end{cases}$ 0.5p $\begin{cases} \lambda_f > \lambda_0 \\ E_f < E_0 \end{cases}$ 0.1p $\begin{cases} \lambda_f = 1,25 \times 10^{-10} \text{ m} \\ \Lambda = \frac{6,6 \times 10^{-34}}{9,1 \times 10^{-31} \cdot 3 \times 10^8} \text{ m} = 2,41 \times 10^{-12} \text{ m} = 0,02 \times 10^{-10} \text{ m} \end{cases}$ 0.2p the value of wavelength of photon before the second scattering $\lambda_0 = 1,23 \times 10^{-10} \text{ m}$ 0.1p $\lambda_i = \lambda_f$ 0.3p $\begin{cases} \vec{p}_{1e} = \vec{p}_{2e} \\ E_{1e} = E_{2e} \end{cases}$ 0.2p the moment of final electron $p_{2e} = h \sqrt{\frac{1}{\lambda_f^2} + \frac{1}{(\lambda_f - \Lambda(1 - \cos \theta))^2} - \frac{2 \cdot \cos \theta}{\lambda_f \cdot (\lambda_f - \Lambda(1 - \cos \theta))}}$ 0.4p The de Broglie wavelength of second electron after scattering (and of first electron before scattering) $\lambda_{1e} = \lambda_{2e} = 1 / \left(\sqrt{\frac{1}{\lambda_f^2} + \frac{1}{(\lambda_f - \Lambda(1 - \cos \theta))^2} - \frac{2 \cdot \cos \theta}{\lambda_f \cdot (\lambda_f - \Lambda(1 - \cos \theta))}} \right)$ 0.3p final result: $\lambda_{1e} = \lambda_{2e} = 1,24 \times 10^{-10} \text{ m}$ 0.2p	
Total score theoretical question IV		7.0 points

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