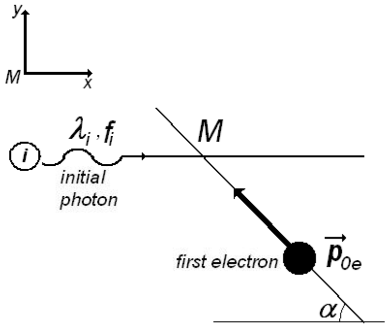
MARKING SCHEME FOR ANSWERS TO THE THEORETICAL QUESTION IV

Part	*MARKING SCHEME - THE THEORETICAL QUESTION IV- COMPTON SCATTERING*	*Total Scores*
IV.	For: the situation before the first scattering of photon	**7.0 points**



the momentum $\vec{p}_i$ and the energy E_i of the initial photon $\begin{cases} \vec{P}_i = \dfrac{h}{\lambda_i} = \dfrac{h \cdot f_i}{c} \\ E_i = h \cdot f_i \end{cases}$ 0.3p

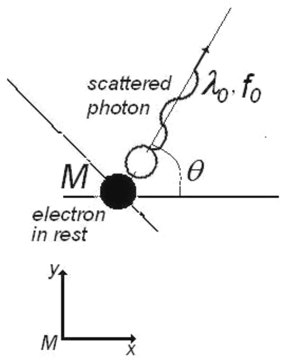
the frequency of initial photon $f_i = \dfrac{c}{\lambda_i}$ 0.1p

the momentum $\vec{p}_{oe}$ and the energy E_{oe} of initial, free electron in motion

$$\begin{cases} \vec{P}_{oe} = m \cdot \vec{v}_{1e} = \dfrac{m_0 \cdot \vec{v}_{1e}}{\sqrt{1-\beta^2}} \\ E_{oe} = m \cdot c^2 = \dfrac{m_0 \cdot c^2}{\sqrt{1-\beta^2}} \end{cases}$$ 0.3p

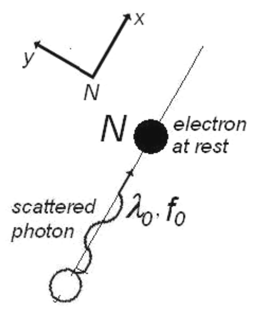
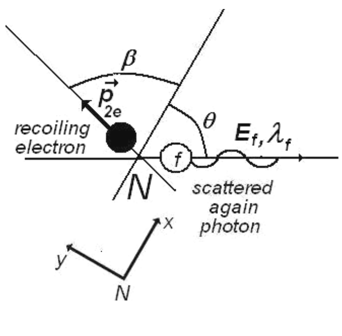
De Broglie wavelength of the first electron $\lambda_{oe} = \dfrac{h}{p_{0e}} = \dfrac{h \cdot}{m_0 \cdot v_{1e}} \sqrt{1-\beta^2}$ 0.2p

the situation after the scattering of photon



the momentum $\vec{p}_0$ and the energy E_0 of the scattered photon $\begin{cases} \vec{P}_o = \dfrac{h}{\lambda_o} = \dfrac{h \cdot f_o}{c} \\ E_o = h \cdot f_o \end{cases}$ 0.3p

the frequency of scattered photon $f_o = \dfrac{c}{\lambda_0}$ 0.1p

	the principles of conservation of moments and energy $\begin{cases}\vec{P}_i + \vec{p}_{oe} = \vec{p}_0 \\ E_i + E_{0e} = E_0 + E_{1e}\end{cases}$	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
	$\frac{m_0^2 \cdot c^2}{1-\left(\frac{v_{1e}}{c}\right)^2} \cdot v_{1e}^2 = h^2 \cdot \left(f_0^2 + f_1^2 - 2f_0 \cdot f_i \cdot \cos\theta\right)$	0.4p
	The conservation of energy $m \cdot c^2 + h \cdot f_1 = m_0 \cdot c^2 + h \cdot f_0$	0.3p
	or $\frac{m_0 \cdot c^2}{\sqrt{1-\left(\frac{v_{1e}}{c}\right)^2}} = m_0 \cdot c^2 + h \cdot (f_0 - f_1)$	0.2p
	$\frac{m_0^2 \cdot c^4}{1-\left(\frac{v_{1e}}{c}\right)^2} = m_0^2 \cdot c^4 + h^2 \cdot (f_0 - f_1)^2 + m_0 \cdot h \cdot c^2 \cdot (f_0 - f_1)$	0.2p
	$\frac{h}{m_0 \cdot c}(1-\cos\theta) = \frac{c}{f_1} - \frac{c}{f_0}$	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

$$\begin{cases} \dfrac{h}{\lambda_0} = \dfrac{h}{\lambda_f}\cos\theta + m\cdot v_{2e}\cdot\cos\beta \\ \dfrac{h}{\lambda_f}\sin\theta - m\cdot v_{2e}\cdot\sin\beta = 0 \end{cases}$$ 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

$$\begin{cases} \dfrac{h}{m_0\cdot c}\cdot(1-\cos\theta) = \lambda_f - \lambda_0 \\ \lambda_f - \lambda_0 = \Lambda\cdot(1-\cos\theta) \end{cases}$$ 0.5p

$$\begin{cases} \lambda_f > \lambda_0 \\ E_f < E_0 \end{cases}$$ 0.1p

$$\begin{cases} \lambda_f = 1{,}25\times10^{-10}\,m \\ \Lambda = \dfrac{6{,}6\times10^{-34}}{9{,}1\times10^{-31}\cdot3\times10^{8}}\,m = 2{,}41\times10^{-12}\,m = 0{,}02\times10^{-10}\,m \end{cases}$$ 0.2p

the value of wavelength of photon before the second scattering $\lambda_0 = 1{,}23\times10^{-10}\,m$ 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)

$$\lambda_{1e} = \lambda_{2e} = 1\Bigg/\left(\sqrt{\frac{1}{\lambda_f^2} + \frac{1}{(\lambda_f - \Lambda(1-\cos\theta))^2} - \frac{2\cdot\cos\theta}{\lambda_f\cdot(\lambda_f - \Lambda(1-\cos\theta))}}\right)$$ 0.3p

final result: $\lambda_{1e} = \lambda_{2e} = 1{,}24\times10^{-10}\,m$ 0.2p

Total score theoretical question IV	***7.0 points***

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