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Elastic and Inelastic scattering
1) Show that

$$[\bar{u}(k')\gamma^{\mu}u(k)]^{\dagger} = \bar{u}(k)\gamma^{\mu}u(k') \tag{1}$$

3) In a fixed-targed electron-proton elastic scattering:

$$Q^2 = 2m_p(E_1 - E_3) = 2m_p E_1 y \tag{2}$$

and

$$Q^2 = 4E_1E_3 sin^2(\frac{\theta}{2}) \tag{3}$$

a) Use these relations to show that

$$sin^2(\frac{\theta}{2}) = \frac{E_1}{E_3}\frac{m_p^2}{Q^2}y^2 \tag{4}$$

and hence

$$\frac{E_3}{E_1}cos^2(\frac{\theta}{2}) = 1 - y - \frac{m_p^2 y^2}{Q^2} \tag{5}$$

b) Assuming azimuthal symmetry and using the equations

$$E_3 = \frac{E_1 m_p}{m_p + E_1(1 - cos\theta)} \tag{6}$$

and

$$Q^2 = \frac{2m_p E_1^2(1 - cos\theta)}{m_p + E_1(1 - cos\theta)} \tag{7}$$

show that:

$$\frac{d\sigma}{dQ^2} = |\frac{d\Omega}{dQ^2}|\frac{d\sigma}{d\Omega} = \frac{\pi}{E_3^2}\frac{d\sigma}{d\Omega} \tag{8}$$

c) Using the results of a) and b), show that the Rosenbluth equation

$$\frac{d\sigma}{dQ^2} = \frac{\alpha^2}{4E_1^2 sin^4(\frac{\theta}{2})} \frac{E_3}{E_1} (\frac{G_E^2 + \tau G_M^2}{(1+\tau)} cos^2\frac{\theta}{2} + 2\tau G_M^2 sin^2\frac{\theta}{2}) \tag{9}$$

can be written in the Lorentz-invariant form:

$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2}{Q^4} [\frac{G_E^2 + \tau G_M^2}{(1+\tau)} (1 - y - \frac{m_p^2 y^2}{Q^2}) + \frac{1}{2} y^2 G_M^2] \tag{10}$$