Chapter 7: QCD, jets and gluons

The Coulomb potential represents a point charge. When an electrostatic potential is instead represented by a spherically symmetric charge density $\rho(r)$, the differential scattering cross section differs from the Rutherford cross section by a form factor squared, $G^2_E(q^2)$ (Chapter 7.3):

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_R G_E^2(q^2)$$

where

$$G_E(q^2) = \int d^3x \rho(r) e^{i(q \cdot x)}$$

Perform the angular integration of the form factor and show that

* $G_E(q^2)$ is a function of q^2 only.

* the mean squared radius of $\rho(r)$ equals

$$\bar{r}^2 = \int d^3x r^2 \rho(r) = -6 \frac{dG_E(q^2)}{dq^2}\bigg|_{q^2 = 0}$$

* (“Bonus“ Problem - not mandatory but you can get an extra point)
Explain the effect on the differential cross section (wrt the scattering angle θ) when a point charge (infinitely narrow distribution) is replaced by a charge density $\rho(r)$, represented by a Gaussian (normal) distribution.
Note that the Fourier transform of a “narrow“ Gaussian becomes a “wide“ Gaussian distribution (and vice versa). Both charge distributions are normalized to 1.

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Chapter 8: Weak interactions: W and Z bosons

In the lowest order weak interactions, decays proceed via single W-boson exchange. Explain why the decay $\Sigma^- \rightarrow n + e^- + \bar{\nu}_e$ have been observed, while $\Sigma^+ \rightarrow n + e^+ + \nu_e$ - never. Σ^- has quark contents of (dds), and Σ^+ - (uus). Plot the quark diagram for the Σ^- decay.

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Chapter 9: Weak interactions: Electroweak unification

Which of the following processes are allowed in electromagnetic, and which - in weak interactions?
Consider only single boson exchange processes.

1. $\Sigma^- \rightarrow \pi^- + n$
2. $\Sigma^0 \rightarrow \Lambda + \gamma$
3. $B^+ \rightarrow K^+ + e^+ + e^-$
4. $K^+ \rightarrow \pi^0 + \mu^+ + \nu_\mu$