**electromagnetic energy of the proton**

From hadron spectroscopy we learn that the d quark is slightly more massive than the u quark. This accounts for the larger mass of the neutron compared to the proton. We expect that if the masses of the u and d quarks were equal the proton should be more massive than the neutron because it has a net charge.

Suppose the proton were a uniformly charged sphere of radius 1F and constant density,
$\rho_0 = e/(4\pi R^3/3)$.
a) Find the mean square radius of the proton's charge distribution, defined as

$< r^2 >= (1/e) \int_{vol} r^2 dq$, where $dq = \rho(r) dV$. Here $dq$ is the element of charge located at $r$.

b) Find the Coulomb energy of this charge distribution. You can solve this analytically or numerically.

A more realistic charge distribution for the proton which gives a good description of the electron-proton elastic scattering cross section to $Q^2$ around and less than 1 GeV$^2$ is an exponential decay:
$\rho(r) = e(\alpha^3/8\pi) exp(-\alpha r)$, where $\alpha = 4.26 F^{-1}$.

d) Find the mean square radius of the proton's charge distribution, defined as

$< r^2 >= (1/e) \int_{vol} r^2 dq$, where $dq = \rho(r) dV$. Here $dq$ is the element of charge located at $r$.

e) Find the Coulomb energy of this charge distribution. You can solve this analytically or numerically.

f) What would be the physical consequences of a d quark equal in mass or slightly less massive than the u quark? Feel free to speculate!

Note: A useful representation of the Coulomb energy in units of MeV and F is $V_{Coul} = Ze^2/R$ and $e^2 = 1.44 MeV \cdot F$.