Nuclear and Particle Physics
Homework Question NPP 1

---

1. What are the natural units (in which $\hbar = c = 1$) of

a) angular momentum

b) a time derivative

c) forces

2. In the rest frame of a particle its 4-momentum is given by $p = (m, 0, 0, 0)$. In a boosted frame the 4-momentum is given by p',

$$p = \begin{pmatrix} E \\ p_1 \\ p_2 \\ p_3 \end{pmatrix} \rightarrow p' = \begin{pmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} E \\ p_1 \\ p_2 \\ p_3 \end{pmatrix}$$

with $\beta = v/c$ and $\gamma = 1/\sqrt{1-\beta^2}$.

a) Show that $p^2 = (p')^2 = p' \cdot p' = m^2$.

b) Use the energy-component (the 0-component) and the vector component of the boosted 4-momentum vector p' to show that $E^2 = |\vec{p}|^2 + m^2$

3. The mass of the ${}^{13}_{6}\mathrm{C}$ atom is given by $M({}^{13}_{6}\mathrm{C}) = 13.0036\,\mathrm{u}$. The mass of the ${}^{12}_{6}\mathrm{C}$ atom, which has 1 neutron less is given by $M({}^{12}_{6}\mathrm{C}) = 12\,\mathrm{u}$. Calculate the energy required to take one neutron away from ${}^{13}_{6}\mathrm{C}$.

4. Show that the mass density of nuclei is independent of its size (use $R = r_0 A^{1/3}$).