HW3

1. 2. $S = (P_1 + P_2)^2$

$S = (E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2 c^2$

IN LAB frame $\vec{p}_2 = 0$ $E_2 = m_2 c^2$

$S_{LAB} = E_1^2 + 2E_1 m_2 c^2 + (m_2 c^2)^2 - p_1^2 c^2$

since $E_1^2 - p_1^2 c^2 = (m_1 c^2)^2$

$S_{LAB} = (m_1 c^2)^2 + 2E_1 m_2 c^2 + (m_2 c^2)^2$

For $E_1 \gg m_1 c^2$ or $m_2 c^2$

$S_{LAB} \approx 2E_1 m_2 c^2$

$\boxed{\sqrt{S_{LAB}} = \sqrt{2E_1 m_2 c^2}}$

IN CM frame $\vec{p}_1 + \vec{p}_2 = 0$

$S_{CM} = E_1^2 + 2E_1 E_2 + E_2^2$

for $E_1 = E_2$

$S_{CM} = 4E^2$

$\boxed{\sqrt{S_{CM}} = 2E}$

3. $\sqrt{S} = 14\ TeV = \sqrt{2E_1 m_2 c^2}$

$E_1 = \frac{S}{2m_2 c^2} = \frac{14^2\ TeV^2}{2 \times 0.938\ GeV} = 104\ TeV \times \frac{TeV}{GeV}$ ($\frac{TeV}{GeV} = 1000$)

$E_1 = \boxed{1.04 \times 10^5\ TeV}$

4. Ferbel 1.7 $p_e = 0.511\ MeV/c$

$\boxed{E} = \sqrt{p^2c^2 + (mc^2)^2} = \sqrt{(0.511)^2 + (0.511)^2} = \sqrt{2} \cdot 0.511\ MeV = \boxed{0.723\ MeV}$

$E = \gamma mc^2 \Rightarrow \boxed{\gamma} = \sqrt{2} = \boxed{1.41}$

$\boxed{KE} = (\gamma - 1)mc^2 = \boxed{0.212\ MeV}$

($E = KE + mc^2 \Rightarrow \gamma mc^2 = KE + mc^2$

$KE = (\gamma - 1)mc^2$

$\gamma = \frac{1}{\sqrt{1-\beta^2}}$ $\gamma^2 = \frac{1}{1-\beta^2}$

$1 - \beta^2 = \frac{1}{\gamma^2}$

$\beta^2 = 1 - \frac{1}{\gamma^2} = \frac{\gamma^2 - 1}{\gamma^2} \Rightarrow \boxed{\beta} = \sqrt{\gamma^2 - 1}/\gamma = \frac{1}{\sqrt{2}} = \boxed{0.707}$

Hw 4 Solutions

1) $\rho = \frac{M}{V} = \frac{Z m_p + (A-Z) m_n}{\frac{4}{3}\pi R^3} \approx \frac{A m_p}{\frac{4}{3}\pi (1.2\,fm\, A^{1/3})^3} = \frac{m_p \cdot A}{\frac{4}{3}\pi (1.2)^3 A}$

$= \frac{938\ MeV/c^2}{7.24\ fm^3} = 130\ \frac{MeV/c^2}{fm^3}$ (independent of A)

$= 130\ \frac{MeV}{c^2\ fm^3} \times \frac{10^6 eV}{MeV} \times \frac{1.6\times10^{-12}\ erg}{eV} \times \frac{(fm)^3}{(10^{-13}\ cm)^3} \times \frac{1}{9\times10^{20}\ \frac{cm^2}{s^2}}$

$= 23 \times \frac{10^{-6}}{10^{-19}}\ \frac{erg}{cm^5/s^2} = \boxed{2.3\times10^{14}\ \frac{g}{cm^3}}$

$\frac{g\cdot cm^2}{s^2} / cm^5/s^2 = \frac{g}{cm^3}$

or $2.3\times10^{14}\ \frac{g}{cm^3} \times \frac{1kg}{1000g} \times \frac{(100\ cm)^3}{m^3}$

$= \boxed{2.3\times10^{17}\ \frac{1kg}{m^3}}$

2. Relativistic approximation: $E = \sqrt{p^2c^2 + m^2c^4} \approx pc$

$$\lambda\!\!\!^{-} = \frac{\hbar}{p} = \frac{\hbar c}{pc} = \frac{197 Mev - fm}{1 Tev} \approx 0.197\, fm$$

$$\lambda\!\!\!^{-}_7 = \lambda\!\!\!^{-}_1 / 7 = 0.197 / 7 = 0.028$$

$$\lambda\!\!\!^{-}_{0.5} = \lambda\!\!\!^{-}_1 / 0.5 = 2 * 0.197 = 0.394$$

5.

$$\mu_B = \frac{e\hbar}{2m_e c} = e \times \frac{\hbar c}{2m_e c^2}$$

$$= 4.8 \times 10^{-10}\ \text{esu} \times \frac{197\ \text{MeV-fm}}{2 \times 511\ \text{MeV}}$$

$$= \frac{4.8 \times 197}{1022} \times 10^{-10} \times 10^{-13}\ \text{esu} \cdot \text{cm}$$

$$= \frac{925}{\cancel{1022}} \times 10^{-23}\ \text{esu} \cdot \text{cm}$$

$$= 925 \times 10^{-23}\ \frac{\text{erg}}{\text{G}} \times \frac{10^4\ \text{G}}{\text{T}}$$

$$= 925 \times 10^{-19}\ \frac{\text{erg}}{\text{T}} \times \frac{6.25 \times 10^5\ \text{MeV}}{\text{erg}}$$

$$= \boxed{5.8 \times 10^{-11}\ \frac{\text{MeV}}{\text{T}}}$$

$F = \frac{qvB}{c} \Rightarrow$

dynes: esu · Gauss

$E = F \cdot d \Rightarrow$

erg = dyne · cm

or $\text{dyne} = \frac{\text{erg}}{\text{cm}}$

$\Rightarrow \text{esu} \cdot \text{G} = \frac{\text{erg}}{\text{cm}}$

or $\boxed{\text{esu} \cdot \text{cm} = \frac{\text{erg}}{\text{G}}}$

$\text{eV} = 1.6 \times 10^{-19}\ \text{J} = 1.6 \times 10^{-12}\ \text{erg}$

$\text{MeV} = 1.6 \times 10^{-6}\ \text{erg}$

$\text{erg} = 6.25 \times 10^5\ \text{MeV}$