Homework #6

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1) We often default to thinking in terms of particles but I don't see why they should have to behave like classical particles when it is just a name we gave to them based on early observations.

2) $\lambda = \frac{h}{p} = \frac{hc}{pc}$ $\quad v = 10^6$ m/s

$v < 0.01c$

$\lambda \approx \frac{h}{mv} = \frac{6.626\times10^{-34}\ J\cdot s}{1.673\times10^{-27}\ kg \cdot 10^6\ m/s}$

$= 3.95\times10^{-13}\ m = 395\ fm$

3) $\lambda = \frac{h}{p}$

$E^2 = p^2c^2 + \cancel{m_0^2c^4} = K^2 + 2Km_0c^2 + \cancel{m_0^2c^4}$

$p^2 = \frac{K^2}{c^2} + 2Km_0$

$p = \sqrt{\frac{K^2}{c^2} + 2Km_0}$

$\lambda = \frac{hc}{\sqrt{K^2 + 2Km_0c^2}}$

	e^-	p^+
10 eV	1.181×10^{-7} m	9.029×10^{-9} m
10 MeV	1.240×10^{-13} m	1.240×10^{-13} m
10 GeV	1.240×10^{-16} m	1.240×10^{-16} m
10 TeV	1.240×10^{-19} m	1.240×10^{-19} m

4) 10 GeV, because the resultant wavelength is smaller than the diameter of a proton.

5) $\lambda = \frac{hc}{\sqrt{K^2 + 2m_0c^2}}$

$K^2 + 2Km_0c^2 = \left(\frac{hc}{\lambda}\right)^2$

$K = \frac{-2m_0c^2 \pm \sqrt{4m_0^2c^4 + 4\left(\frac{hc}{\lambda}\right)^2}}{2}$

$= -m_0c^2 \pm \sqrt{m_0^2c^4 + \left(\frac{hc}{\lambda}\right)^2}$

$= -0.511\ MeV + \sqrt{(0.511\ MeV)^2 + \left(\frac{4.136\times10^{-15}\ eV\cdot s \cdot 2.998\times10^8\ m/s}{10^{-14}\ m}\right)^2}$

$= 123\ MeV$

6. (a) $\Delta n = \dfrac{k^2 Z^2 e^4 N n A}{4R^2 \left(\frac{1}{2} m_\alpha v_\alpha^2\right) \sin(\phi/2)}$

$\Delta n_{20} \quad 250 = \dfrac{k^2 Z^2 e^4 N n A}{4R^2 \left(\frac{1}{2} m_\alpha v_\alpha^2\right) \sin(10^\circ)}$

$250 \cdot \sin 10^\circ = \dfrac{k^2 Z^2 e^4 N n A}{4R^2 \left(\frac{1}{2} m_\alpha v_\alpha^2\right)}$

$\Delta n_{40} = 250 \dfrac{\sin 10^\circ}{\sin 20^\circ}$

$= 127$ particles

$\Delta n_{80} = 250 \dfrac{\sin 10^\circ}{\sin(40^\circ)}$

$= 68$ particles

$\Delta n_{120} = 250 \dfrac{\sin 10^\circ}{\sin 60^\circ}$

$= 50$ particles

(b) $\Delta n = \dfrac{k^2 Z^2 e^4 N n A}{4R^2 \left(\frac{1}{2} m_\alpha (2 v_\alpha)^2\right) \sin(10)}$

$= \dfrac{\Delta n_{20}}{4}$

$= 62.5$ particles

(c) $\lambda = \dfrac{h}{p}$

$p = \sqrt{\dfrac{k^2}{c^2} + 2 k m_\alpha}$

$p_1 = \sqrt{64 MeV^2/c^2 + 2 \cdot 8 \cdot 3.7227 GeV^2/c^2}$

$= 244.33\ MeV/c$

$\lambda_1 = \dfrac{4.136 \times 10^{-15} eV \cdot s}{122.768 \times 10^6 eV} \cdot 2.998 \times 10^8\ m/s$

$= 5.07 \times 10^{-15}\ m$

$p_1 = \dfrac{v_1 m_\alpha}{\sqrt{1 - v^2/c^2}}$

$\dfrac{p_1^2}{m_\alpha^2} = \dfrac{v_1^2}{1 - v_1^2/c^2}$

$\dfrac{p_1^2}{m_\alpha^2} - \dfrac{p_1^2}{m_\alpha^2 c^2} v_1^2 = v_1^2$

$\dfrac{p_1}{m_\alpha} \Big/ \left(1 + \dfrac{p_1^2}{m_\alpha^2 c^2}\right)^{1/2} = v_1$

$v_1 = 0.065c$

$$v_2 = 2 \cdot v_1 = 0.13c$$

$$p_2 = \frac{v_2 m\alpha}{\sqrt{1 - v_2^2/c^2}}$$

$$= \frac{0.25955c \cdot 3727 MeV/c^2}{\sqrt{1 - 0.25955^2}}$$

$$= 488.67 \text{ MeV}/c$$

$$\lambda_2 = \frac{h}{p}$$

$$= 2.537 \times 10^{-15} \text{ m}$$

(d) $d \sin\phi = n\lambda$

$n=1$: $\lambda = 288.4 \text{ pm} \sin 45^\circ$

$$= 203.09 \text{ pm}$$

$$K = -m_0 c^2 + \sqrt{m_0^2 c^4 + \frac{hc}{\lambda}^2}$$

$$= 0.005 \text{ eV}$$

(e) $K = 36.5 \text{ eV}$