2-18 3rd ed ~~1-43~~ Phys 203

$$^{55}_{24}Cr \longrightarrow \ ^{55}_{25}Mn + e^-$$

$$54.9279\,u \qquad 54.9244\,u \qquad 5.4858\times10^{-4}\,u$$

a) $\Delta m = 54.9279u - 54.9244u - 5.4858\times10^{-4}u$

$\Delta m = 0.002951u \cdot \dfrac{931.5\,MeV}{c^2\,u} = 2.7488\,\dfrac{MeV}{c^2}$ (2.75)

b) The e^- would have maximum possible kinetic energy if all the Δm was delivered to the e^-. Thus, the max. kinetic energy for the e^- would be 2.75 MeV.

An alternate way to view the situation:

The Δm between the two nuclei Cr & Mn is $\Delta m = 54.9279u - 54.9244u = .0035u$

where $\Delta E = 931.5\dfrac{MeV}{u}(.0035u) = 3.26$ MeV.

If this energy is entirely taken by the electron, then .512 MeV is its rest energy; the remainder is 2.75 MeV.

2-19 3rd ed

~~1-44~~

$^{12}_{6}C$ - 6 protons + 6 neutrons

mass = 12u

The binding energy is $|\Delta m c^2|$, where

$$\Delta m = 12u - 6(1.0072776u) - 6(1.008665u)$$

$$= 12u - 6.043656u - 6.05199u$$

$$= -0.095646u$$

Convert to MeV/c^2

$$\Delta m = -0.095646u \ \frac{MeV/c^2}{1.073 \times 10^{-3}u} = -89.14 \ \frac{MeV}{c^2}$$

The binding energy per nucleon is

$$E_B = \frac{|\Delta m c^2|}{12} = \frac{89.14 MeV}{12} = 7.43 MeV.$$

2-20 3rd ed

~~#45~~

Beta decay: $n \longrightarrow p + e + \bar{\nu}$

A neutron decays into a proton, an electron (the beta particle) and a neutrino. The decay products have a total kinetic energy of
$K = 0.781\,\text{MeV} \pm 0.005\,\text{MeV}$.

We need to show that the energy due to the loss of mass falls within the uncertainty of the observed K.

$$\Delta m = m_n - m_p - m_e - m_\nu$$

$$= 939.6\,\frac{\text{MeV}}{c^2} - 938.3\,\frac{\text{MeV}}{c^2} - 0.511\,\frac{\text{MeV}}{c^2} - 0$$

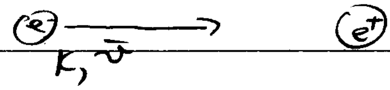
$$= 0.789\,\frac{\text{MeV}}{c^2}$$

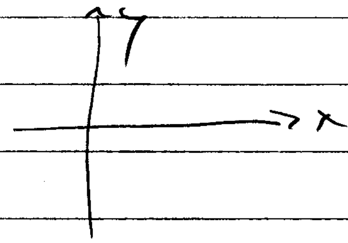
The energy released is 0.789 MeV, which *is* *within* the $\pm .005$ MeV.

2-21 3rd ed

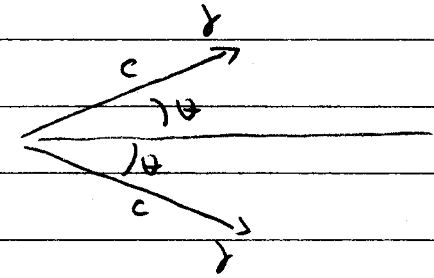
~~both~~

initially





finally



Energy and momentum are conserved in this collision.

The initial total energy is

$$E_i = K + 2m_e c^2 = 1.00\,\text{MeV} + 2(0.5110\,\text{MeV})$$
$$= 2.022\,\text{MeV}$$

The final total energy is

$$E_f = 2p_f c\,,$$ where p_f is the momentum of one of the γ-photons.

So we can get the magnitude of the final momentum of one of the γ-photons by

$$2p_f c = E_i$$
$$p_f = \frac{E_i}{2c} = \frac{2.022\,\text{MeV}}{2c} = 1.011\,\frac{\text{MeV}}{c}$$

2-21 3rd ed
continued

~~#43~~ The momentum is conserved. Initially
$\bar{p}_i = p_i \hat{x}$.

After the collision, in the x-direction
$p_{fx} = 2 p_f \cos\theta$ which equals p_i

i.e. $p_i = 2 p_f \cos\theta$ since $\bar{p}_i$ is entirely $\hat{x}$.

Solve for $\cos\theta = \dfrac{p_i}{2 p_f}$.

We need a number for p_i of the incident electron.

$E_i^2 = p_i^2 c^2 + m_e^2 c^4$

$p_i^2 c^2 = E_i^2 - m_e^2 c^4$

Now, $E_i = \gamma m_e c^2 = K_i + m_e c^2 = 1\,\text{MeV} + .511\,\text{MeV} = 1.511\,\text{MeV}$

So,
$p_i^2 c^2 = (1.511\,\text{MeV})^2 - (.511\,\text{MeV})^2 = 2.022\,\text{MeV}^2$

Whence $p_i = 1.422\,\dfrac{\text{MeV}}{c}$.

Finally, $\cos\theta = \dfrac{p_0}{2p_f} = \dfrac{1.422\,\frac{\text{MeV}}{c}}{2\left(1.011\,\frac{\text{MeV}}{c}\right)} = 0.7032$

$\theta = 45.3°$

2-23 3rd ed. | | Phys 203

~~1-48~~

initially $\quad m \quad v = 0 \qquad m = 3.34 \times 10^{-27}\,kg$

$= 1873\ \frac{MeV}{c^2}$

$\longrightarrow x$

finally $\quad v_1' = -.868c \quad (m_1) \qquad (m_2) \quad v_2' = +.987c$

The total Energy, E, and momentum, p, are conserved.

$$E = E'$$

$$mc^2 = \gamma_1 m_1 c^2 + \gamma_2 m_2 c^2 \Rightarrow m = \gamma_1 m_1 + \gamma_2 m_2$$

$$p = p' \qquad \text{(along x-axis)}$$

$$0 = \gamma_1 m_1 v_1' + \gamma_2 m_2 v_2'$$

where $\gamma_1 = \dfrac{1}{\sqrt{1 - \frac{v_1'^2}{c^2}}}$ and $\gamma_2 = \dfrac{1}{\sqrt{1 - \frac{v_2'^2}{c^2}}}$

$\gamma_1 = 2.014 \qquad \gamma_2 = 6.222$

So, we have 2 eqns and 2 unknowns, m_1 + m_2.

$$m = 2.014\, m_1 + 6.222\, m_2 \qquad (1)$$

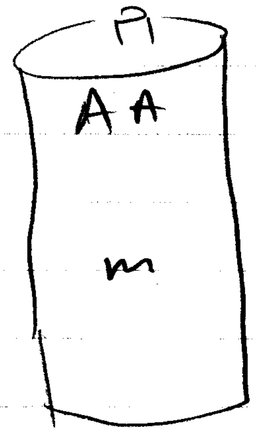
$$0 = -1.748\, m_1 + 6.141\, m_2 \qquad (2)$$

Solve (2) for m_1: $\quad m_1 = 3.513\, m_2$

substitute into (1): $\boxed{m_2 = 0.0752\, m = 2.51 \times 10^{-28}\,kg}$ $\quad 140\ MeV/c^2$

substitute back into (2): $\boxed{m_1 = 0.264\, m = 8.82 \times 10^{-28}\,kg}$ $\quad 495\ MeV/c^2$

2-28 3rd ed



$m = 25g = .025kg = 1.4 \times 10^{28} \frac{MeV}{c^2}$

Power out $= 1.20W$

$\Delta t = 50\ min \times \frac{60 sec}{1 min} = 3000 sec$

Stored energy is

$E_s = P\Delta t = 1.20W \; 3000 sec = 3600 J$

$= 2.25 \times 10^{16} MeV$

a) The mass equivalent of E_s is

$\Delta m = \frac{E_s}{c^2} = 2.25 \times 10^{16} \frac{MeV}{c^2} \left(= 4.01 \times 10^{-14} kg\right)$

or $\Delta m = \frac{3600 J}{c^2} = 4 \times 10^{-14} kg$

b) $\frac{\Delta m}{m} = \frac{2.25 \times 10^{16} MeV/c^2}{1.4 \times 10^{28} MeV/c^2} \overset{or}{=} \frac{4.01 \times 10^{-14} kg}{.025 kg}$

$\frac{\Delta m}{m} = 1.61 \times 10^{-12} \rightarrow$ really tiny