Problem Set 15.2: General revision questions

1. Using $\lambda = \dfrac{hc}{pc}$

   Where $pc = \sqrt{2.E_K.m_0c^2}$
   Here $E_K = 7.0 \times 10^{12}$ eV
   $pc = 1.1469 \times 10^{11}$ eV
   $m_0c^2 = 511 \times 10^3$ eV
   $hc = 1239.84$ eV.nm (this is a constant)
   $l = 1.08 \times 10^{-17}$ m

1. $\lambda = \dfrac{h}{p}$ $p = \dfrac{mv}{\sqrt{1-v^2/c^2}}$

$= \dfrac{6.63\times10^{-34}}{\left(\dfrac{1.67\times10^{-27} \times 0.999997 \times 3\times10^8}{\sqrt{1-0.999997^2}}\right)}$

$= 3.24 \times 10^{-18}$ m

new book

2. Using $\dfrac{v}{c} \approx 1 - \frac{1}{2}\left(\dfrac{m_0c^2}{E_{tot}}\right)^2$ for $v \approx c$

   Where $E_{tot} \approx E_K = 3.00 \times 10^9$ eV and $m_0c^2 = 5.11 \times 10^5$ eV
   $v = 0.999999985493c$

2.a) $E = \dfrac{mc^2}{\sqrt{1-v^2/c^2}}$ = KE + mc2

mc^2 + $3.000\times10^9 \times 1.6\times10^{-19} = \dfrac{9.11\times10^{-31} \times (3\times10^8)^2}{\sqrt{1-v^2/c^2}}$

4.8008 $\times10^{-10} = \dfrac{8.199\times10^{-14}}{\sqrt{1-v^2/c^2}}$

$\sqrt{1-v^2/c^2} = 1.708\times10^{-4}$

$1-v^2/c^2 = 2.9\times10^{-8}$

$v^2/c^2 = 0.9999997$

$v/c = 0.999999985$

$v = 0.999999985c$

b) $\lambda = \dfrac{h}{p}$ $p = \dfrac{mv}{\sqrt{1-v^2/c^2}} = 1.60\times10^{-18}$ kgms^{-1}

$\lambda = 4.143\times10^{-16}$ m

c) $m = \dfrac{m_0}{\sqrt{1-v^2/c^2}} = 5.33\times10^{-27}$ kg

3. Using $m_{Rel} = g.m_0$ where $g = 707.1$ and $m_0 = 1.67 \times 10^{-27}$ kg
   $m_{Rel} = 1.18 \times 10^{-24}$ kg.

q1

4. $E = 7.53 \times 10^{-13}$ J
   $m = E/c^2$
   Mass = 8.38×10^{-30} kg

q2

5. (a). $m_ec^2 = 8.19 \times 10^{-14}$ J, 5.11×10^5 eV
   (b). $gm_ec^2 = 3.12 \times 10^{-13}$ J, 1.95×10^6 eV
   (c). $E_K = (g-1)\, m_ec^2 = 2.303 \times 10^{-13}$ J, 1.44×10^6 eV

q3

6. Using: $\dfrac{v}{c} \approx \sqrt{1-\left(\dfrac{m_0c^2}{E_{tot}}\right)^2}$

   $E_{tot} = E_k + m_ec^2$
   $E_K = 40{,}000$ eV
   (a). $v_{max} = 0.374c$
   (b). 40,000 eV

a) $E_{TOT} = 1.6\times10^{-19} \times 40\,000 + m_0c^2$

$E_{TOT} = \dfrac{mc^2}{\sqrt{1-v^2/c^2}} = 8.839\times10^{-14}$

$1-v^2/c^2 = 0.86043$

$v = 0.374c$

b) 40 000 eV

q4

7. No energy is released – 605 MeV is required to make this reaction occur:
   (139.6 + 938.3) - (1189.4 + 493.7) = -605MeV

q5

8. Mass Pa236 = 236.04868 u
   Mass U236 = 236.045568 u
   Mass difference = 0.003112 u
   Dmc^2 = = 2.9 MeV
   KE of recoil nucleus = approx. 33eV which is negligible
   E beta = 2.9 MeV
   V beta = 0.989c

a) $E_{TOT} = KE + m_0c^2$

$v = 0.984c$

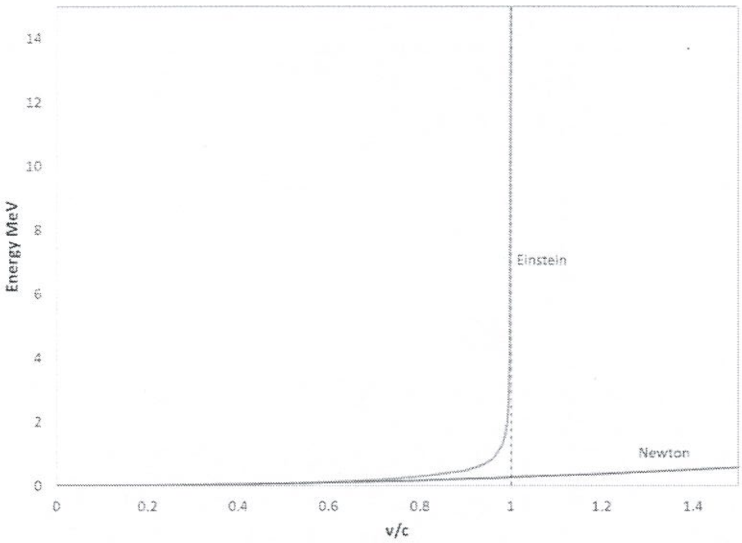
9. g = 707.1 $m_{rel} = 1.18 \times 10^{-24}$ kg

q6

10. 2.16×10^{-23} kg   0.00209 km

q7

11. In the Synchrotron electrons are accelerated to velocities approaching the velocity of light. The graphs of both the non-relativistic energy and the relativistic energy are shown



q8

12. (a). 0.511 MeV
    (b). $p_{rel} = 2.05 \times 10^{-14}$ kg.m/s' $p_{classical} = 2.73 \times 10^{-22}$ kg.m/s
    (c). 6.15×10^{-06} J, 3.84×10^{13} eV × 3.34×10^{-9} J

$p_{cl} = 1.12 \times 10^{-17}$ kgms^{-1}
Ratio = 41 000 × heavier

13. See problem 2.

q12

14. It is moving away (red shifted)

    Using: $$\frac{v}{c} = \frac{\left(\frac{\lambda_0}{\lambda}\right)^2 - 1}{\left(\frac{\lambda_0}{\lambda}\right)^2 + 1}$$

    v = 0.72c (moving apart)

17.a) $\Sigma p = 0$
b) $p = \frac{mv}{\sqrt{1 - v^2/c^2}} = 2.67 \times 10^{-22}$ kgms^{-1} for 1e$^-$
For both $P_{total} = 0$

$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} = 1.15 \times 10^{-13}$ J

q10

15. Wavelength green light = 540nm (±30nm)
    Wavelength red light = 700nm (±30nm)
    v = 0.25c toward the light

c) p = 9.11 x 10^31 x 0.7 x 3 x 10^8
E = mc^2

q11

16. Relativistic mass $= 2.00 \times 10^{-30}$ kg
    KE: 9.77×10^{-14} J, 6.10×10^{5} eV

q13

18 ~~17~~. Gamma x 26 ms = 3.2 x 26 ms = 83 μs

q14

19. See 18 – note here the half-life is stated at 260 ms not 26 ms.
    (a) They will appear to have a half-life of ~~830 ms~~. 833μs = 8.33×10^{-8} s
    (b) distance travelled = 0.95 x c m/s x 830 x 10^{-9} s = 236m 23.7m
    (c). 74m 7.41m

q15

20. (a). Toward the Earth
    (b). 0.2c 0.18c
    (c). Apart
    (d) 0.24c