Shwartz 2.2(a)

$$14\,\overset{T}{\cancel{M}}eV = 2\gamma mc^2$$

$$m_{proton} \approx 938\ MeV/c^2$$

$$\frac{14\,\overset{T}{\cancel{M}}eV}{2\times 938\ MeV} = 7.5 = \gamma . = (1-\beta^2)^{-1/2}.$$

$$\Rightarrow \beta^2 \approx 0.982,$$

$$\beta \approx 0.99$$

$$\frac{(1-0.99)\times 3\times10^8\ m/s}{10^3\ m} \times \frac{\cancel{1\,hr}\ 3600\ s}{1\ hr} \times 10^3\ m$$

$$= \frac{0.01\times 3\times 10^8 \times 3600}{10^3} \times \frac{10^3 m}{hr}$$

$$= \boxed{10{,}800{,}000\ km/hr}$$

Davidson Cheng

3.6.2024

Schwartz 2.2 (b)

In COM frame, we had

$p^0 = 2\gamma$, now we move to rest frame of one of the particles, we now have

$$p^0 = 1 + \gamma'$$

Equating them gives $2\gamma = 1 + \gamma'$, plugging $\gamma = 7.5$ from part (a), we have $\gamma' = 14$.

$$14 = \frac{1}{\sqrt{1-\beta^2}},$$

$$\boxed{\beta \approx 0.997}$$

Davidson Cheng

3.6.2024