**904.**

**Problem 56.6 (RHK)**

*Observation of neutrinos emitted by the supernova* SN1987a *in the large Magellanic Cloud place an upper limit on the rest mass energy of the electron neutrino of* 20 eV. *If the rest energy of the neutrino, rather than being zero, is in fact equal to* 20 eV, *we have to find how much slower than light is a* 1.5-MeV *neutrino, emitted in a* $\beta$*-decay.*

**Solution:**

We assume that the rest mass energy of the electron neutrino $m_\nu c^2 = 20$ eV.

The relativistic energy of a particle of rest mass energy $m_\nu c^2$ moving with speed $v$ is given by the expression

$$E = \frac{m_\nu c^2}{\sqrt{1-(v/c)^2}}.$$

A 1.5 MeV neutrino will therefore be moving with speed $v$ ,which is related to the energy $E$ and the rest mass energy $m_\nu c^2$ by the following relation:

$$\sqrt{1-(v/c)^2} = \frac{m_\nu c^2}{E} = \frac{20\times10^{-6}\ \text{MeV}}{1.5\ \text{MeV}} = 13.33\times10^{-6},$$

$$1-(v/c)^2 = 177.77\times10^{-12},$$

and

$$1-(v/c);\ \frac{177.77\times10^{-12}}{2} = 8.88\times10^{-11},$$

and

$$c-v = 8.88\times10^{-11}\times3\times10^{10}\ \text{cm s}^{-1} = 2.66\ \text{cm s}^{-1}.$$