PH3520 (Particle Physics) Autumn Term 2011/12
Problem sheet 1
To be turned in by 10:00 a.m., Thursday, 6 October, 2011.

1: Calculate the energy E and speed β of a charged pion (mass $m_\pi = 0.139$ GeV) moving with a momentum of $p = 0.01$, 0.1 and 1 GeV.

2: (a) A neutrino with an energy of 17 GeV hits a proton at rest. Treating the neutrino as massless, find the centre-of-mass energy of the two particle system in GeV. (The proton mass is $m_{\rm p} = 0.938$ GeV; treat the neutrino as having zero rest mass.)

(b) Suppose the neutrino has a mass of 2 eV. Show that the speed of the neutrino can be approximated by

$$\beta \approx 1 - \frac{m^2}{2E^2} \ ,$$

where the approximation is valid for $E \gg m$.

(c) If the neutrino flies a distance $L = 730\,\text{km}$ before arriving at a target, what time delay Δt as measured in the lab (earth) frame would the 2 eV mass result in relative to the arrival time based on the speed of light? Evaluate in seconds. What distance $\Delta x = c\Delta t$ does this correspond to in metres?

3: Which of the following reactions are allowed in the Standard Model? Check by calculating the total charge, baryon number and lepton number for the initial and final state of each reaction.

(a) $\mathrm{e^+e^-} \to \gamma\nu_\mu\overline{\nu}_\mu$

(b) $\mathrm{e^+\ n} \to \mathrm{p}\ \nu_{\rm e}$

(c) $\mathrm{e^+e^-} \to \tau^+\tau^-\gamma$

(d) $\mathrm{pp} \to \mathrm{p\overline{p}}\pi^+\pi^+$

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