# Intermediate Dynamics: Group Exercises 4

## Energy and Momentum Conservation in Relativity

### 1 Particle annihilation

An electron and positron are initially at rest. Each has mass $0.511\,\mathrm{MeV/c^2}$ and they have equal and opposite charges. These particles annihilate each other, producing two photons.

a) Show that the particles cannot produce only one photon after annihilation.

b) Show that the energies of the photons after annihilation must be equal.

c) Determine the energy of each photon after annihilation.

d) The wavelength of the light corresponding to the photons can be determined via a quantum mechanical relationship,

$$\lambda = \frac{hc}{E_{\mathrm{photon}}}$$

where $h = 4.14 \times 10^{-15}\,\mathrm{eV{\cdot}s}$ is Planck's constant. Determine the wavelength of the emitted electromagnetic radiation.

### 2 Particle decay

An unknown subatomic particle is at rest in the lab and decays into a muon $\mu^-$ and a antineutrino $\overline{\nu}$. The muon has velocity $u = 0.271c$ in the lab frame. The muon has mass $105.7\,\mathrm{MeV}$ and the antineutrino has negligible mass.

a) Determine the mass of the unknown particle.

b) Identify the unknown particle.