Physics 2B: Special Relativity

Problem Set 2

This assignment/problem set will be assessed!

You will need to attempt and complete as many of the problems on this sheet as you can before your tutorial class on Wednesday 19 September, 3.30-4.30. 50% of the assessment will be based on the effort you have put in to answering the questions before class.

During the tutorial class you will work together to determine the best answer, identify the key points and key steps to answering these questions, annotating you answers IN RED PEN ONLY as you go.

At the end of the class you will submit your annotated responses. The remaining 50% of the mark for this assignment will be based on your assessment and annotations of your initial response.

Q1) Relativistic kinematics

(a) In the laboratory reference frame, two particles move apart, both travelling at speed $0.5c$. If we travelled with one of the particles, how fast would the other particle seem to be receding?

(b) Two photons (particles of light) travel along the x-axis of S, with a constant distance L between them. Show that the distance between the photons in S', which travels at speed v with respect to S, is $L\sqrt{\frac{c+v}{c-v}}$. [Hint: consider transforming the two events $(x,t) = (0,0)$ and $(L,0)$ to space-time co-ordinates (x',t') in S'.]

Q2) Rest mass, energy and momentum

(a) Explain briefly why eV/c^2 is a unit of mass. How many kilograms is $1\ eV/c^2$?

(b) An electron has rest mass $511\ keV/c^2$. If its total energy is $1\ MeV$, find its momentum and kinetic energy. How fast is the electron travelling?

[please turn over for Q3]

Q3) Particle decays

A particle called the neutral pi meson (symbol π^0) can decay into two photons. The π^0 has a rest mass energy of $135\ MeV$ and before the decay it travels at speed $u = 0.9c$ through the laboratory. After the decay, one photon travels in the same direction as the π^0 and the other photon travels in the opposite direction.

(a) What is the energy and momentum of the π^0 before the collision, in the laboratory frame?

(b) Write down equations describing conservation of relativistic energy and conservation of relativistic momentum during the decay.

(c) Hence find the energies of the two photons in the laboratory after the collision.

(d) The forward-moving photon (that is, the one moving in the same direction as the original π^0) is absorbed by a stationary proton (rest mass energy $m_p c^2 = 938\ MeV$), producing a single new particle of mass M travelling with speed U. Use conservation of relativistic energy and momentum to find M and U.