Physics 2B: Special Relativity

Problem Set 1

Q1) The framework of relativity

(a) State the meaning of an inertial reference frame, a local observer, synchronized clocks and the space-time co-ordinates of an event *(write one sentence for each).*

(b) List three ways in which Einstein's postulates of relativity contradict classical physics.

(c) A commercial aeroplane pilot takes one round-the-world trip a week for a year. Considering only the effects of special relativity, how much less time will they age compared to their twin who remains on the ground?

Q2) Muons and time dilation

Particles called muons are produced in the Earth's atmosphere by bombarding cosmic rays. Muons travel at speed $v = 0.999c$, and decay into an electron after average time $\tau = 2\ \mu s$, as measured in a frame of reference in which the muon is at rest.

(a) Ignoring any effects of relativity, how far does an average muon travel in its lifetime?

(b) Many muons nonetheless reach the ground, a distance of $10\ km$. Consider the situation from the rest frame of the ground. Using the phenomenon of time dilation, what is the average muon lifetime as measured by observers on the ground? How far can an average muon travel in its lifetime as measured by ground observers?

(c) Now consider the situation as seen from the muon rest frame. Using the phenomenon of length contraction, by what factor is distance as measured by ground observers contracted when measured by observers travelling with the muon? How far can a muon actually travel in the ground frame before decaying?

Q3) Length contraction

(a) A rod of length L_0 is at rest in S', lying in the xy-plane at angle θ' to the x'-axis. Find its length as measured in S in terms of its speed v, and its angle θ with the x-axis.

(b) A runner, carrying a $10\ m$ pole horizontally, approaches a barn at a speed of $0.75c$. The barn has been measured to have a length of $8\ m$ (in its rest frame). Continuing to hold the pole horizontally, the runner enters the barn. Does the pole fit in the barn? Explain the result from the point of view of both the runner and the barn.