PH110: Tutorial Sheet 6

1. Two events A and B occur in frame S with coordinates $(x_A = 150\,m, t_A = 0.3\,\mu\,s)$ and $(x_B = 210\,m, t_B = 0.4\,\mu\,s)$ respectively. Could these events appear simultaneous to an observer in another frame? If yes, what is the velocity of that frame, relative to S?

2. Two spaceships pass each other, travelling in opposite directions. The speed of ship B, measured by a passenger in ship A is $0.96c$. This passenger has measured the length of the ship A as 100 mt and determines that the ship B is 30 mt long. What are the lengths of the two ships as measured by a passenger in ship B ? Ans: (28m, 107.14m)

3. An observer O is at the origin of an inertial frame. He notices a vehicle A to pass by him in $+x$ direction with constant speed. At this instant, the watch of the observer O and the watch of the driver of A show time equal to zero. 50 μs after A passed by, O sees another vehicle B pass by him, also in $+x$ direction and again with constant speed. After sometime B catches A and sends a light signal to O, which O receives at 200 μs according to his watch. The driver of B notices that, in his frame, the time between passing O and catching A is 90 μs Assume that drivers A and B are at the origins of their respective frames. Find

   (a) the speeds of B and A, in the frame of O.

   (b) position of A in O's frame when B passes O.

   (c) the position of O in the frame of A, when B passes O.

   Ans: ((81/17)c, (6/19)c, (90/19) km, -5 km)

4. Pioneer-11 spacecraft is moving away from earth at a speed of about 12,000 m/s. It communicates with earth by emitting microwaves of frequency 52.353×10^9 Hz. What should be the tuned frequency of the antenna on earth so that the signal from Pioneer-11 can be received? Ans: (52. 351 GHz).

5. The H_α line, emitted by hydrogen, is a bright red line with wave-length 656.1×10^{-9} m. The H_α lines measured from diametrically opposite ends of sun's equator differ in wave-lengths by 9×10^{-12} m. Assuming that this difference occurs due to the rotation of the sun, find the period of rotation of the sun. The diameter of the sun is 1.4×10^9 m. Ans: (25 days).

6. A particle has rest maass m_0 has energy $4m_0c^2$. What is its momentum, in units of m_0c What is the energy of this particle, when its momenum is $2m_0c$? Ans: $(\sqrt{15}m_0c, \sqrt{5}m_0c^2)$

7. A particle has rest mass energy 100 MeV. Calculate its total energy if it moves with speed (a) 0.9c, (b) 0.99c and (c) 0.999c.

8. A ρ-meson of rest-mass energy 760 MeV decays into two π-mesons, each of rest-mass energy 150 MeV. Find the speed of one π-meson relative to the other. Ans: (0.997c).

9. Let m_0 be the mass of electron and also of its anti-particle positron. Assume that a hypothetical particle X of mass $4m_0$ is produced in the collision of an electron and positron. Consider the following two situations:

   - The momentum of the electron is $p\hat{z}$ and that of positron is $-p\hat{z}$. Find p.
   - The electron is at rest and the positron has momentum $q\hat{z}$. Find q and the speed with which X is produced.

   Ans: $(\sqrt{3}m_0c, \sqrt{48}m_0c, (\sqrt{3}/2)c)$

10. A pion of rest mass energy 140 MeV (MeV is million electron-volts) decays into a muon of rest mass energy 100 MeV and a neutrino of rest mass energy zero. In the rest frame of pion, calculate the momentum of the muon in units of MeV/c. Also calculate its speed. Ans: (24.29 MeV/c, 0.324c).