

# JF TP Special Relativity Tutorial Problems

(Solutions in class on Monday 19<sup>th</sup> Nov.)

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- 1 A reference frame  $S'$  has speed  $v = 0.6c$  relative to reference frame  $S$ . Clocks in each frame are adjusted so that  $t = t' = 0$  at  $x = x' = 0$ .
  - (a) A first event occurs in  $S$  at  $t = 2 \times 10^{-7}$ s and  $x = 50$ m. At what time does this event occur as measured in  $S'$ ?
  - (b) A second event occurs in  $S$  at  $t = 4 \times 10^{-7}$ s and  $x = 50$ m. At what time does this event occur in  $S'$ , and what is the time interval between the first and second events as measured in  $S'$ ?
  - (c) A third event occurs in  $S$  at  $t = 3 \times 10^{-7}$ s and  $x = 10$ m. What is the time interval between the first and third events as measured in  $S'$ ?
- 2 A rod of rest length 2m is at rest in frame  $S'$ . It lies in the  $x'y'$  plane at an angle of  $30^\circ$  with the  $x'$  axis.  $S'$  moves at velocity  $v$  with respect to another frame  $S$ . What is the value of  $v$  if, as measured in  $S$ , the rod makes an angle of  $50^\circ$  to the  $x$  axis? What is the length of the rod as measured in  $S$  for these conditions.
- 3 A pion (rest energy of 0.14 GeV) is created 100 km above sea level. Initially, the pion has a total energy of 110 GeV and is travelling vertically downwards. If the pion decays after an interval of 30 ns as measured in its own rest frame, at what height above sea level does an observer on Earth measure the decay to occur?
- 4 Mary is in a spacecraft that flies past Stanley on Earth at a velocity of  $0.6c$  relative to Earth. At the instant she passes, both start their clocks.
  - (a) At what time, as measured by Stanley, will Mary reach a marker  $9 \times 10^7$  m away from Stanley's position?
  - (b) What time does Mary's clock read when she passes the marker?
  - (c) As Mary passes the marker, what time does she observe on: (i) a clock on earth at the marker, (ii) Stanley's clock?
- 5 How fast must you be approaching a red traffic light ( $\lambda = 675$  nm) for it to appear yellow ( $\lambda = 575$  nm)?
- 6 Two neutrons, A and B, are approaching each other along a common straight line. Each has a speed of  $0.8c$  as measured in the laboratory frame. Determine the total energy of neutron B as measured in the rest frame of A. (Neutron rest mass:  $1.675 \times 10^{-27}$ kg)
- 7 A photon of wavelength 0.2nm has a head-on collision with an electron moving at velocity  $v$ , as measured in the laboratory frame. What must be the value of  $v$  if the collision results in a photon recoiling backwards with the same wavelength as the incident photon?
- 8 An anti-proton with  $\frac{2}{3}$  GeV kinetic energy strikes a proton at rest in the laboratory. They annihilate yielding two photons which travel forward and backward along the line on which the proton entered. Take the rest energy of the proton and anti-proton to be 1 GeV each.
  - (a) What energies do the photons have as measured in the laboratory frame?
  - (b) In which direction is each travelling?
  - (c) What energy does each photon have as measured in the rest frame of the anti-proton?