UNL2206, Nature's Threads: Tutorial 9

1) If you were traveling with respect to the stars at a speed close to the speed of light you could detect it because: (a) your mass would increase, (b) your heart rate would slow down, (c) you would shrink, (d) all of these effects would occur together, (e) you could never tell your speed by changes in you.

2) There are many different kinds of clocks: hour glasses, mechanical clocks, quartz clocks, atomic clocks, light clocks and biological clocks (your heart beat for example). We have seen that motion appears to slow down one particular type of clock viz. a light clock; does it necessarily follow that all other kinds of clocks must be affected equally? If so, why?

3) You are holding a long pole parallel to the ground and near its mid point when you drop it. As you perceive it, the ends of the pole, A and B, strike the ground simultaneously and

hence you think that the pole has fallen horizontally. But your friend who is dashing past you in the direction AB at nearly the speed of light, perceives end B strike the ground before end A and therefore thinks the pole is tilted to the right as it fell. Is this true or false?

4) Which of the following facts, if definitely established experimentally, would violate the *Special Theory of Relativity*?

(a) Objects can travel faster than the speed of light
(b) Nothing can go faster than the speed of light
(c) If an object is traveling faster than the speed of light, it immediately slows to a speed less than that of light.

5) A car traveling 100 km/h covers a certain distance in 10.00 s according to the driver's watch. What does an observer stationary with respect to the earth measure for the time interval?

6) A clock moves along the x-axis at a speed of 0.600c and reads zero as it passes the origin. What time does the clock read when it passes x= 180m?

7) What will be the mean lifetime of a muon (a 'heavy electron') as measured in the laboratory if it were travelling at $v = 0.60c = 1.8 \times 10^8$ m/s with respect to the laboratory? Its mean life at rest is 2.2×10^{-6} s. How far does the muon travel in the laboratory on average, before decaying?

8) A rectangular painting measures 1.00 m tall and 1.50 m wide. It is hung on the side wall of a spaceship which is moving past the Earth at a speed of 0.90c. (a) What are the dimensions of the picture according to the captain of the spaceship? (b) What are the dimensions as seen by an observer on Earth?

9) The rest radius of the Earth is 6370km, and its orbital speed about the Sun is 30km/s. Suppose Earth moves past an observer (who is stationary with respect to the Sun) at this speed. To this observer, by how much would the Earth's diameter be contracted along the direction of motion?

10) An electron moving at 0.999 987c moves along the axis of an evacuated tube (secured to a laboratory bench) that has a length of 3.00 m as measured by an observer S who is at rest in the laboratory. Consider an observer S' at rest relative to the electron; what length would S' measure for the tube?

11) Calculate the mass of a electron when it has a speed of (a) 4.00×10^7 m/s in the CRT of a television set, and (b) 0.98c in an accelerator used for cancer therapy.

12) One of the elementary particles that exists in nature is the charge neutral pion or π° meson. Say such a π° meson (rest mass, $m_o = 2.4 \times 10^{-28}$ kg) travels at a speed $v = 0.80c = 2.4 \times 10^8$m/s; (a) what is its kinetic energy? Compare this to a classical calculation. (b) How much energy would be released if the π° is transformed completely into electromagnetic radiation?

13) Suppose an atomic bomb was exploded in a box that was strong enough to contain all the energy released by the bomb. After the explosion the box would weigh (a) more than before the explosion (b) less than before (c) the same as it did before?

14) Energy release in a fission or *'atom' bomb*.

(a) How much energy is released in the explosion of a fission bomb containing 3.0 kg of fissionable material (eg Uranium 235 or Plutonium 239)? Assume that 0.10% of the mass is converted into released energy.
(b) What mass of TNT would have to explode to provide the same energy release? Assume that each mole of TNT liberates 3.4 MJ (Mega joules) of energy upon exploding. The molecular mass of TNT 0.227kg/mol.
(c) For the same mass of explosive, how many times more effective are atom bombs compared to TNT explosions? [*ie compare the fractions of the mass that are converted to energy in each case.*]

15) The famous equation $E=mc^2$ or $m=E/c^2$ tells us how much mass loss, m, must be suffered by a nuclear reactor in order to generate a given amount of energy E. Which of the following statements is correct?
(a) The same equation also tells us how much mass loss, m, must be suffered by a flashlight battery when the flashlight puts out a given amount of energy, E.
(b) The equation applies only to nuclear energy in a reactor, but not to chemical energy in a battery.

16) Consider a motorcycle powered with super-powerful electric batteries, and an electrically powered MRT train that are each driven to speeds approaching the speed of light. Measurements of each from the point of view of an observer at rest on the ground will indicate an increase in the mass of the
(a) motorcycle (b) MRT train (c) both (d) neither.

17) Derive, starting from Einstein's famous relation $E=mc^2$, the following equation:

$$E^2 = p^2c^2 + m_0^2 c^4$$

where E is the relativistic energy, p the relativistic momentum, m_0 the 'rest' or proper mass and c the speed of light. *Hint: use the relationship between the relativistic and rest masses of a particle* $m = m_0\sqrt{(1 - v^2/c^2)}$.

What can you deduce about a particle that is at rest (as measured in it's proper or rest frame)? What can you say about a particle that happens to have vanishing rest mass m_0?