UNL2206, Nature's Threads: Tutorial 10

1) A traveller makes a journey between two towns A and B, taking the super-fast *Einstein Express.* Immediately before his train departs from station A, the traveller *synchronises* his wrist watch with the station clock, which reads 9 o'clock. The train then travels towards town B at a uniform velocity of 4/5 *c* and arrives at station B (which happens to be 864 million km away) exactly one hour later.

Upon arrival, the traveller again consults his wrist watch and finds that it reads 9.36 instead of 10 o'clock.

Is the traveller's wrist watch faulty?

2) The personal time lapse for all persons traveling between two events (for example lunch today and tomorrow), is the same regardless of which *(spacetime)* path is taken between the two events. Is this statement true or false?

3) A space traveller takes off from Earth and moves at speed 0.99c toward the star Vega, which is 26 ly distant. How much time will have elapsed by Earth clocks (a) when the traveller reaches Vega and (b) when Earth observers receive word from the traveller that she has arrived? (c) How much older will Earth observers calculate the traveller to be (according to her) when she reaches Vega than she was when she started the trip?

4) A comet is chasing a spacecraft. Let V be the speed of the comet, p its momentum and E its energy, all as perceived by the astronaut when the comet hits the spacecraft. In what way would increasing the spacecraft's speed alter the astronaut's perceived values of v, p and E?

(a) v, p, E will all not change (b) v, p, E will all decrease (c) v, p will get smaller but E will not change (d) v and E will decrease but p will not change (e) E and p will decrease while v will not change.

5) The 'Doppler Effect' is responsible for the siren of an approaching fire engine having a higher pitch or frequency as perceived by a stationary observer, and correspondingly, a receding fire engine siren to have a lower frequency (as perceived by a stationary observer).
Is it true or false that the Doppler frequency shift produced by you receding from the source of sound is the same as the shift produced by the source of sound receding from you?

6) The special relativistic formula for the Doppler shift is:

$$\lambda' = \lambda \frac{\sqrt{(1+ v/c)}}{\sqrt{(1- v/c)}}$$

where λ is the emitted wavelength as measured in the source's reference frame, and λ′ is the wavelength measured in a frame moving with speed v away from the source along the line of sight ie v is the relative velocity between source and detector. (For relative motion toward each other, v<0 in this formula.) For speeds not too close to the speed of light, ie v<<c, show that this formula reduces to

$$\frac{\lambda' - \lambda}{\lambda} = \frac{\Delta\lambda}{\lambda} = \pm \frac{v}{c}$$

7) The same spacecraft as in question 4 is now being chased by a powerful laser beam. Let v, p and E be the velocity, momentum and energy of a photon in the laser beam as perceived by the astronaut when it hits the spacecraft. As in the previous question, in what way will increasing the spacecraft's speed alter the astronaut's perceived values of v, p and E? Choose one of (a) – (e) given in the previous question 1).

8) A spaceship is traveling between two planets, A and B and emits flashes of light every 6 minutes. It travels away from A and towards B. If its flashes are seen at 3 minute intervals on B, then on planet A the flashes are seen at:-

(a) 3 minute (b) 6 minute (c) 9 minute (d) 12 minute intervals.

9) Suppose the spaceship (which leaves planet A at 12 noon) is able to abruptly turn around when it emits its 10^{th} flash and then returns to planet A at the same high speed. It continues sending flashes every 6 minutes and emits 10 in its hour of return. But these flashes are seen at 3 minute intervals on planet A. So although a clock aboard the spaceship will read 2:00 o'clock when the ship gets back (1 hour out and 1 hour back), clocks on planet A will read

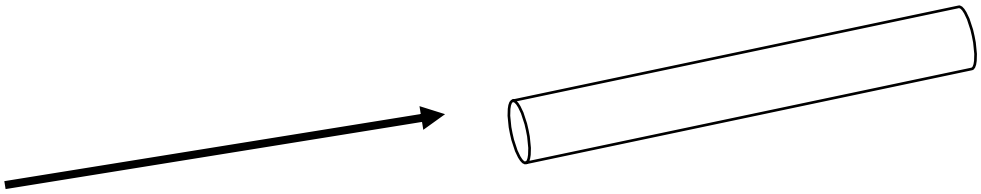
(a) 2:00 o'clock also (b) 2:30 o'clock (c) neither of these.

10) When a spaceship passes the earth, an alien aged 20 Earth-years falls in love with a terrestrial student whom she sees on her monitor screen. At the time the student is also exactly 20 years old. The relationship is discouraged by the alien authorities and the spaceship continues to move at constant speed $v = 0.998c$. After one year (spaceship time) the alien is able to send a radio message to the student. How old is the student when the message arrives at Earth?

11) You are in a spacecraft that happens to be 1 km long. An alien spacecraft flies past you. When the passing alien is alongside you, you note that the alien craft is exactly as long as your own craft. That is, the alien craft nose is abreast of your tail when the alien craft tail is abreast of your nose – according to your time. Answer the following questions and provide brief justifications for your answers.

(i) Are the two craft identical in length?
(ii) Does the alien measure its craft to be as long as, longer or shorter than yours?
(iii) Since you measure the alien craft nose, which is abreast of your tail, *at the same time* the alien tail is abreast of your nose, why doesn't the alien observe the same coincidence of events?

12) A spear 10 m long is thrown at a relativistic speed through a pipe that is 10 m long. Both these dimensions are measured when each are at rest. When the spear passes through the pipe, which of the following statements best describes what is observed?



a) The spear shrinks so that the pipe completely covers it at some point.
b) The pipe shrinks so that the spear extends from both ends at some point.
c) Both shrink equally so that the pipe just covers the spear at some point.
d) Any of these, depending on the motion of the observer.

13) When current flows through a pair of parallel wires they are magnetically attracted if the current in both wires is in the same direction, and repelled if the currents are in opposite directions. This magnetic force is

a) the relativistic result of imbalanced electrostatic forces.
b) an outcome of mass-energy equivalence.
c) a fundamental force of nature.
d) all of these.
e) none of these.