Physics 262 Fall 2010 Exam 4

$$x' = \gamma(x - Vt)$$

$$ct' = \gamma(ct - \frac{Vx}{c})$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$f = f_0\sqrt{\frac{1-v/c}{1+v/c}}$$

$$\Delta s = \sqrt{c^2t^2 - x^2}$$

$$v_{o/a} = \frac{v_{o/b} + v_{b/a}}{1 + \frac{v_{o/b}v_{b/a}}{c^2}}$$

1] A ruler on earth makes an angle of 30° with respect to the horizontal. To the nearest 10°, what angle to the horizontal does it make in the frame of a spaceship traveling at 0.95c, horizontally? (Enter 0 for 0°, 1 for 10°, 2 for 20°, etc.)

Two lightning strikes occur on Sandia Peak and on Mount Taylor, which is 110 km **west** of Sandia. According to an observer on Earth, the lightning on Mount Taylor occurred 0.2 milliseconds before the lightning on Sandia (after accounting for light travel time.)

2] Is there any inertial reference frame in which the strikes are simultaneous?

A] yes, a northward-moving frame
B] yes, a southward-moving frame
C] yes, an eastward-moving frame
D] yes, a westward-moving frame
E] no

3&4] What is the speed of a frame (in m/s) in which the strikes are simultaneous? (OR enter 0,0 for no simultaneous frame.)

5]A spaceship moves at 0.8 c from A to B, a distance of 5 light years. How much time, to the nearest year, elapses on the spaceship clock during this trip?

6] The spaceship launches a small probe toward B as the ship passes A. The speed of the probe relative to the spaceship is 0.8 c. How long, to the nearest year, does the probe take to make the trip *on its own clock?*

7&8] A relativistic train has a rest length of 1000 m. It moves into a tunnel of length 999 m. With what minimum speed must it move if (in the Earth's frame) the doors at both ends of the tunnel can be closed simultaneously (for an instant) while the train is inside, and then opened before the train crashes into the exit door? Answer in m/s.

9] Suppose the train is moving at 0.9 c, fast enough that the tunnel doors can be closed simultaneously, in the earth frame. The observer on the train sees that the door openings and closing are not simultaneous. What is the **order of door openings and closings**, according to a train observer?

A] entrance CLOSES, entrance OPENS, exit CLOSES, exit OPENS
B] entrance CLOSES, exit CLOSES, entrance OPENS, exit OPENS
C] entrance CLOSES, exit CLOSES, exit OPENS, entrance OPENS
D] exit CLOSES, exit OPENS, entrance CLOSES, entrance OPENS
E] exit CLOSES, entrance CLOSES, exit OPENS, entrance OPENS
F] exit CLOSES, entrance CLOSES, entrance OPENS, exit OPENS

10] When the train moves at 0.9 c, how long (to the nearest microsecond) can the doors be simultaneously closed?

11] An astronaut travels from Earth to a distant planet Zeta (which is stationary in the Earth's frame.) The Earth and the distant planet have synchronized their calendars. When the astronaut arrives, he has aged 5 years, but the planetary calendars have advanced 10 years. But while he was in motion, he noticed that the clocks on all planets he passed (all stationary wrt Earth) were moving at *half speed,* not at twice normal speed. How is this possible?

A] Since only the astronaut is in motion, only *his* clock really changes from true time.
B] While in inertial motion, the astronaut notices that clocks in the Earth frame are not synchronized: the clocks closer to Zeta are ahead of clocks closer to Earth.
C] While in inertial motion, the astronaut notices that clocks in the Earth frame are not synchronized: the clocks closer to Zeta are behind clocks closer to the Earth.

12] Two events are separated by a spacetime interval with a "length" Δs of 850 light seconds. This interval is
A] spacelike
B] lightlike
C] timelike

13&14] If, in one reference frame, these events occur 950 s apart in time, what is their spatial separation, in light seconds?

15&16] What is the largest possible temporal separation, for any observer? (Enter 0,0 for 0 and 0,1 for infinity.)

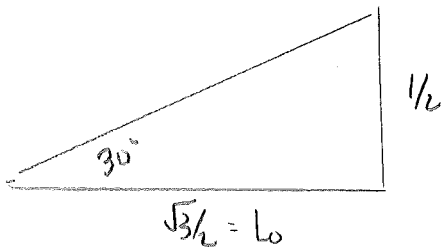
17] Soft x-rays, which have a frequency of 10^{16} Hz, are good candidates for ultrahigh resolution lithography (chip-making). You propose to make x-rays by bouncing 600 nm visible light ($f=5 \times 10^{14}$ Hz) off a moving mirror, to Doppler shift the frequency upward. With what approximate speed must you move the mirror?

A] 0.5c
B] 0.6c
C] 0.7c
D] 0.8c
E] 0.9c
F] 0.92c
G] 0.94c
H] 0.96c
I] 0.98c
J] 0.995c

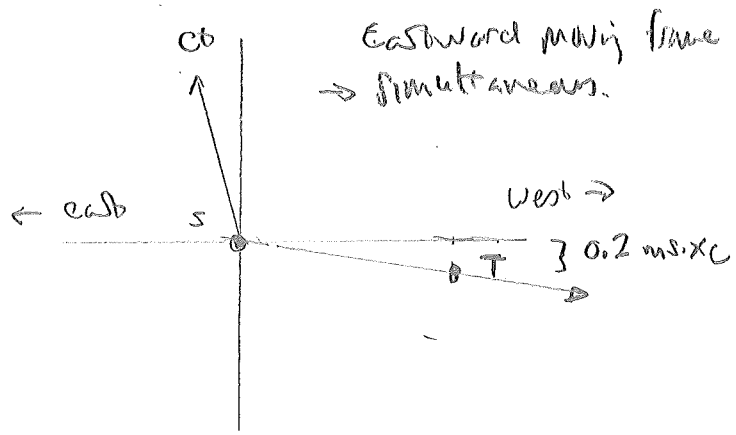
18] Do you need to move the mirror A] toward or B] away from the light source?

Exam 4 Solutions

1] $\frac{L_0}{\gamma} = 0.27 \qquad \theta' = \tan\frac{1/2}{0.27} = 62°$



2]



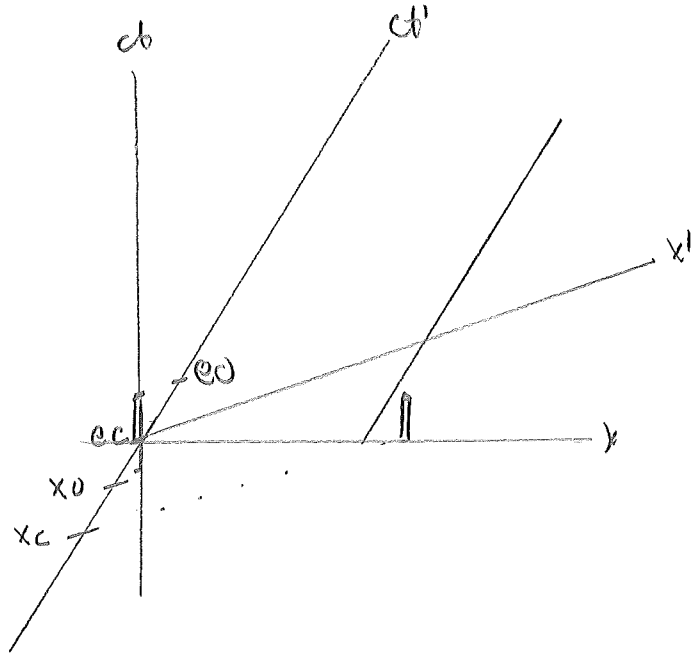
3&4] $\frac{V}{c} = \frac{0.2\ ms \cdot c}{110\ km} = 0.545 \qquad V = 1.63 \times 10^8\ m/s.$

5] $t_e = \frac{5}{0.8} = 6.25\ yr. \qquad \tau = \frac{t_0}{\gamma} \qquad \gamma = \frac{1}{0.6} \quad so \quad \tau = 3.75\ yr.$

6] $V_e = \frac{0.8 + 0.8}{1 + 0.8^2} = 0.976 \qquad \gamma = \frac{1}{0.22} \quad so \quad \tau_1 \approx \left(\frac{5}{0.976}\right) \cdot 0.22 = 1.13\ yrs$

7&8] $\gamma = \frac{1000}{899} = \frac{1}{\sqrt{1 - v^2/c^2}} \qquad \frac{V}{c} = 0.047 \qquad V = 1.34 \times 10^7\ m/s.$

(9)



(10) Train is 436 m long
Tunnel is 999 m.
Train can travel
999 − 436 m in tunnel
= 563 m. @ 0.9c,
this takes 1.88 μs.

(13,14) $\Delta s = \sqrt{c^2t^2 - x^2}$ $c^2t^2 - \Delta s^2 = x^2$ $x = 424$ light-sec.

(15 & 16) ∞. If x gets bigger, t gets bigger w/o limit.

(17) $f = \sqrt{\left(\frac{1+V}{1-V}\right)}\, f'$ for travel to & from mirror. Total

$f = \left(\frac{1+V}{1-V}\right) f'$ $\frac{f}{f'} = \frac{10^{16}}{5\times10^{14}} = 20 = \frac{1+V}{1-V}$

$20 - 20V = 1 + V$

$19 = 21V$

$0.9c = V$