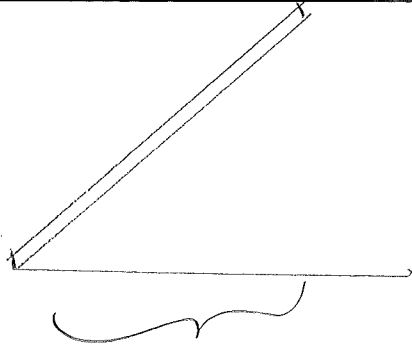
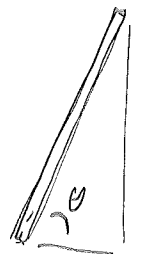


①



Lorentz contraction

$$x = \frac{x_0}{\gamma} = 0.436 x_0 \text{ for } \beta = 0.9$$



0.436

$$\tan \theta = \frac{1}{0.436} \Rightarrow \theta = 66.4^\circ$$

②

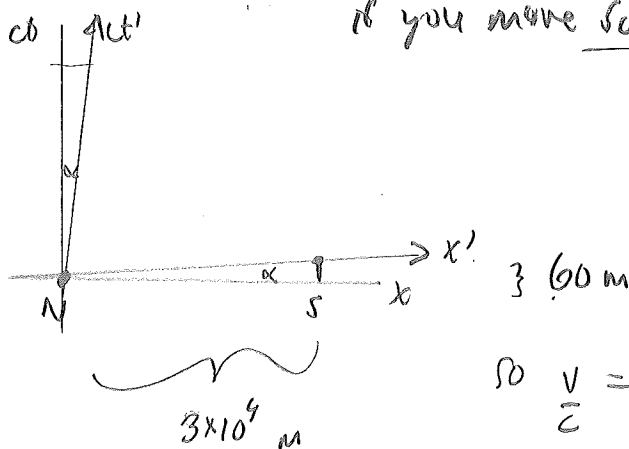
$$\Delta s^2 = c^2 t^2 - x^2$$

$$= 3600 \text{ m}^2 - 9 \times 10^8 \text{ m}^2 < 0$$

spacelike - YES, there is a simultaneous frame.

From Minkowski, simultaneous

if you move south at correct speed. B



$$\text{so } \frac{v}{c} = \frac{60 \text{ m}}{3 \times 10^4 \text{ m}} = 2 \times 10^{-3}$$

$$v = 6 \times 10^5 \text{ m/s.}$$

384

$$\text{⑤ } t_e = \frac{5 \text{ ly}}{0.7c} = 7.143 \text{ years.}$$

$$\text{From time dilation } t_{ss} = \frac{t_e}{\gamma} = 5.1 \text{ years.}$$

$$\text{Use vel. addn formula } v_{pe} = \frac{0.7 + 0.7}{1 + 0.7^2} = 0.94c.$$

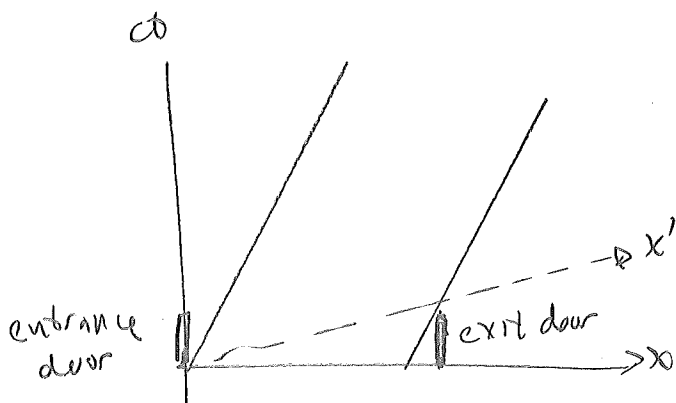
$$t_{pe} = \frac{5 \text{ ly}}{0.94c} = 5.32 \text{ years}$$

$$t_{pp} = \frac{t_{pe}}{\gamma_{pe}} = \sqrt{1 - 0.94^2} \cdot 5.32 \text{ yrs} = 1.82 \text{ yrs} \quad \text{⑥}$$

2 & 8] Length contraction:  $\gamma = \frac{1}{0.98} = 1.02 = \frac{1}{\sqrt{1 - v^2/c^2}}$

$\frac{v}{c} = 0.2 \quad v = 6 \times 10^7 \text{ m/s.}$

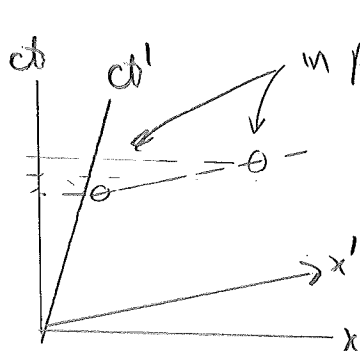
9.]



Exit door opens before entrance door closes

C]

10]



in primed frame, clocks at larger x are ahead of where they should be.

B]

11]

$\Delta s = \sqrt{c^2 t^2 - x^2}$  if imaginary, SPACELIKE. A]

12 & 13]

$\Delta s^2 = -3.34 \times 10^5 = c^2 t^2 - x^2$  with  $t = 10 \text{ s,}$

$x^2 = 3.34 \times 10^5 + 100 \rightarrow x = 578 \text{ lightseconds.}$

14 & 15]

Largest  $x \rightarrow \infty$  if  $ct \rightarrow \infty$ . O I]

16 & 17] Doppler shift to mirror  $f' = f \sqrt{\frac{1 - v/c}{1 + v/c}}$

Doppler shift from mirror is the same, so

$f'' = f \left( \frac{1 - v/c}{1 + v/c} \right) = f \left( \frac{1 - 0.5}{1 + 0.5} \right) = f/3$

$= 11 \text{ MHz.} = 1.1 \times 10^7 \text{ Hz.}$