SR.

2-7

$$ct' = \gamma ct - \beta\gamma x$$
$$x' = -\beta\gamma ct + \gamma x$$
$$y' = y$$
$$z' = z$$

$$t' = \gamma\left(t - (\beta/c)x\right)$$
$$= \frac{5}{4}\left(2(-7) - \frac{0.6}{3(8)}\,50\right)$$
$$t' = \frac{5}{4} \times 10^{-7} \text{ sec}$$

(a) $\boxed{t' = 1.25 \times 10^{-7} \text{ sec}}$

(b) $\Delta t' = t_2' - t_1'$ w/ $t_1' = 1.25 \times 10^{-7}$ sec

$$t_2' = \frac{5}{4}\left(3(-7) - \frac{0.6}{3(8)}\,10\right)$$
$$= 3.5 \times 10^{-7} \text{ sec}$$

$$\boxed{\therefore \Delta t' = 2.25 \times 10^{-7} \text{ s}}$$

4-9

FROM MODERN PHYSICS

$E = \gamma m c^2$

$\gamma = E/mc^2 = 10^{19}\ eV / 938\ MeV$

$\gamma \simeq 10^{10}$

$\Rightarrow \beta \simeq 1$

(a)

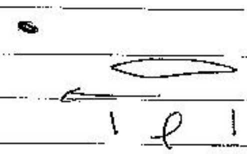
GALAXY

FROM GALAXY'S REST FRAME

$\Delta t = \Delta x / v = \dfrac{10^5\ l\text{-}y}{c}$

$\Delta t = 10^5$ YEARS $= \pi \times 10^{12}$ sec.

(b) FROM PARTICLE'S REST FRAME



$l = 10^5\ l\text{-}y / \gamma$

$= 10^{-5}\ l\text{-}y$

& $v_{GALAXY} \simeq c$

S.R.
4-4, CONT.

$$\Delta t' = \Delta x'/c$$

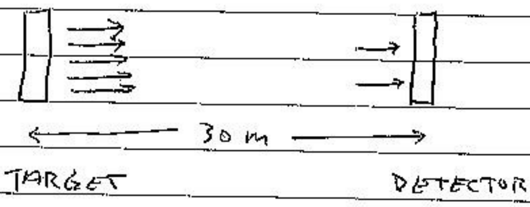
$$= 10^{-5}\ \ell y/c$$

$$= 10^{-5}\ \text{YEARS} = \pi \times 10^{2}\ \text{sec}$$

$$\boxed{\Delta t' \cong 314\ \text{sec} \simeq 5\ \text{MINS}}$$

SR

4-10 PAY ATTENTION TO DIFFERENT REST FRAME



LAB FRAME

"HIGH ENERGY" $\Rightarrow \beta_\pi \simeq 1$

$$\Delta t \simeq 30\,m/c = 1\times10^{-7}\,\text{sec} = 10\times10^{-8}\,\text{sec}$$

(LAB FRAME)

EVERYBODY AGREES ON T

THIS A ~~PATH~~ PROPERTY INTRINSIC TO PARTICLE.

$$\Delta t/T \simeq 5$$

HENCE, LAB FRAME SEES 5 HALF-LIVES PASS.

WHAT DOES THE PION SEE?

IN PION REST FRAME

$$N = N_0(2)^{-\Delta t'/T} \qquad \text{w/ } N/N_0 = 2/3$$

$$T = 2\times10^{-8}\,\text{sec}$$

$$\Rightarrow \Delta t'/T = 0.585$$

SR

4-10 CONT.

COMPARING 2 REST FRAMES.

$$\gamma = 5/0.585$$

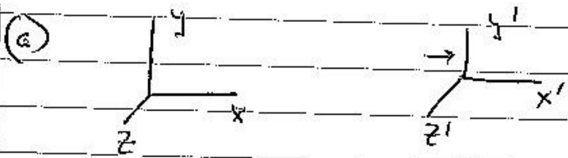
$$= 8.55$$

$$\boxed{E_\pi = 8.55\, E_0 \qquad \text{LAB FRAME}}$$

SR.

9-12.

(a)



S = EARTH   S' = SPACE SHIP

$$ct' = \gamma ct - \beta\gamma x \qquad ct = \gamma ct' + \beta\gamma x'$$
$$x' = -\beta\gamma ct + \gamma x \qquad x = +\beta\gamma ct' + \gamma x'$$

S-SHIP CLOCK DOES NOT MOVE IN S'

THINK OF SS CLOCK AS A MUON:

$$\Delta t = \gamma \Delta t' \qquad \gamma = (1 - (5/3)^2)^{-1/2}$$
$$= 5/3 * 30 \text{ MIN}$$

$\Delta t = 50$ MIN   EARTH TIME

SINCE STATION TIME & EARTH TIME ARE THE SAME

$\boxed{t = 12{:}50 \text{ PM} \quad \text{EARTH/STN TIME}}$

S.R.

4-12

(b) $\beta = 0.8 \Rightarrow \gamma = 5/3$

S-SHIP FRAME SEES EARTH RECEDING

$$\Delta x' = v t'$$

$$= (0.8c)(30 \text{ min})$$

$$\Delta x' = 4.32 \times 10^{11} \text{ m}$$

EARTH-NAV STN DISTANCE
SEEN BY S-SHIP.

THINK OF THIS DISTANCE AS MOVING METER STICK SEEN BY SS.

NOW, EARTH SEES METER STICK @ REST

$$l = l_0/\gamma$$

$$l_0 = \gamma . l$$
$$= 5/3 \; \Delta x'$$

$$\boxed{l = 7.2 \times 10^{11} \text{ m}}$$

SR

4-12

(c) FROM EARTH, WHAT IS TRANSIT TIME Δt?

$$\Delta t = l_0 / c$$

$$= 7.2 \times 10^{11} / 3 \times 10^{8} \text{ sec}$$

$$= 40 \text{ MINUTES}$$

EARTH TIME = 12 NOON + 50 MIN + 40 MIN

$$\boxed{\text{EARTH TIME} = 1{:}30 \text{ PM}}$$

SR

4-12

(d) ONE STRATEGY IS TO MEASURE POSITION OF SS (SEEN BY EARTH), FIGURE OUT HOW LONG (BY EARTH) TO GET THERE, AND THEN TIME DILATE TO GET SS TIME.

EARTH SENDS SIGNAL @ 1:30 PM (EARTH TIME). AT THIS TIME, SS (BY EARTH) IS AT DISTANCE Δl_1

$$\Delta l_1 = \beta c \Delta t$$

$$= (0.8\, c) \times 90 \text{ MIN}$$

$$= 1.296 \times 10^{12} \text{ m}$$

SIGNAL TAKES TIME Δt TO "CATCH" SS:

$$c\Delta t = \Delta l_1 + v\Delta t$$

$$\Delta t = \frac{\Delta l_1}{c - v} \qquad \text{w/ } v = \frac{4}{5}c$$

$$= \frac{5}{c}\Delta l_1$$

$$= \frac{5}{c}\left(\frac{4}{5}c \times 90 \text{ MIN}\right)$$

$$\Delta t = 6 \text{ HRS}$$

SR

4-12

(d) HENCE, SIGNAL REACHES SS AT

$t = $ 1:30 PM + 6 HRS

$t = $ 7:30 PM EARTH TIME

AT THIS TIME WHERE (BY EARTH) IS SS?

$$\Delta x\,(SS) = \Delta l_1 + \beta c\,\Delta t$$

$$= \Delta l_1 + \frac{4}{5}c * 5\Delta l_1/c$$

$$\Delta x(SS) = 5\Delta l_1 \quad \text{(EARTH FRAME)}$$

IN SS FRAME,

$$\Delta x' = \Delta x/\gamma$$

$$\Delta x' = 3\Delta l_1 \quad \text{(SS FRAME)}$$

HOW LONG DID THIS TAKE (BY SS)?

$$\Delta t' = \Delta x'/v$$

$$= 3\Delta l_1 / \tfrac{4}{5}c$$

SR

4-12

(d)

$$\Delta t' = \frac{5}{4} * 3\Delta l_1/c$$

$$= \frac{5}{4} * \frac{3}{c} * \frac{4c}{5} * 90 \text{ MIN}$$

$$= 3 \times 90 \text{ MIN}$$

$$= 4.5 \text{ HRS}$$

$$\Rightarrow \boxed{t' = 4:30 \text{ PM} \quad (SS)}$$

ANOTHER WAY

USE X AND t VALUES AS MEASURED BY EARTH, AND THEN LORENTZ TRANSFORM

$$ct' = \gamma ct - \beta\gamma x$$
$$t' = \gamma t - \frac{\beta}{c}\gamma x$$

$$t = 7:30 \text{ PM}$$
$$x = 5\Delta l_1$$

$$t' = \gamma\left(7.5 * 3600 - \frac{4}{5c} 5\Delta l_1\right)$$
$$= \frac{5}{3} * 9.72 \times 10^3 \text{ sec}$$
$$= 16200 \text{ sec} = 4.5 \text{ HRS}$$
$$t' = 4:30 \text{ PM} \quad (SS \text{ TIME})$$