

### Problem 5

1. Diket :

memendekkan panjang ( $\Delta L$ ) = 2% = 0,02

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$L = (1 - 0,02) L_0 = 0,98 L_0$$

Jawab :

$$0,98 = \sqrt{1 - \frac{v^2}{c^2}}$$

$$(0,98)^2 = 1 - \frac{v^2}{c^2}$$

$$0,9604 = 1 - \frac{v^2}{c^2}$$

$$\frac{v^2}{c^2} = 1 - 0,9604$$

$$= 0,0396$$

$$v = c \sqrt{0,0396}$$

$$= c \times 0,199$$

Jadi kecepatan roket adalah 0,199c atau sekitar 19,9% ke. Cahaya.

2. Diket :

$$L_0 = 12.740 \text{ km} = 1,274 \times 10^7 \text{ m}$$

$$v = 2 \times 10^8 \text{ m/s}$$

$$c = 3 \times 10^8 \text{ m/s}$$

Ditanya : penurunan diameter bumi

Jawab :

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$\frac{v^2}{c^2} = \left( \frac{2 \times 10^8}{3 \times 10^8} \right)^2 = \left( \frac{2}{3} \right)^2 = \frac{4}{9} = 0,4444$$

$$L = L_0 \sqrt{1 - 0,4444}$$

$$L = L_0 \sqrt{0,5556}$$

$$L = 1,274 \times 10^7 \times 0,7454$$

$$= 9,49 \times 10^6 \text{ m}$$

$$\Delta L = L_0 - L$$

$$\Delta L = 1,274 \times 10^7 - 9,49 \times 10^6$$

$$= 3,25 \times 10^6 \text{ m} = 3.250 \text{ km}$$

→ Diameter bumi akan berkurang sebesar 3250 km

3. Diket :

$$L_0 = 1 \text{ m}$$

$$v = 0,8c$$

$$\theta = 60^\circ$$

Ditanya :

komponen sejajar sumbu x  $\Rightarrow L_x = L_0 \cos \theta = 1 \times \cos 60^\circ = 0,5 \text{ m}$

komponen tegak lurus sumbu x  $\Rightarrow L_y = L_0 \sin \theta = 1 \times \sin 60^\circ = 0,866 \text{ m}$



$$L'_x = L_x \sqrt{1 - \frac{v^2}{c^2}}$$

$$L'_y = 0,866 \text{ m}$$

$$= 0,5 \sqrt{1 - (0,8)^2}$$

$$= 0,5 \sqrt{1 - 0,64}$$

$$= 0,5 \sqrt{0,36}$$

$$= 0,5 \times 0,6 = 0,3 \text{ m}$$

$$L' = \sqrt{(L'_x)^2 + (L'_y)^2}$$

$$= \sqrt{(0,3)^2 + (0,866)^2}$$

$$= \sqrt{0,09 + 0,75}$$

$$= \sqrt{0,84} = 0,916 \text{ m}$$

$$\tan \theta' = \frac{L'_y}{L'_x} = \frac{0,866}{0,3} = 2,887$$

$$\theta' = \tan^{-1}(2,887) = 70,9^\circ$$

Jadi panjang batang = 0,916 m  
sudut batang terhadap sumbu x  
berubah dari 60° menjadi 70,9°

4. Diket :

$$V_{\text{bus}} = 15 \text{ m/s}$$

$$V_{\text{penumpang}} = 2 \text{ m/s}$$

Ditanya : a). Pendekatan non-relativistik  
b). Pendekatan relativistik

Jawab :

$$\begin{aligned} \text{a). } V_{\text{total}} &= V_{\text{bus}} + V_{\text{penumpang}} \\ &= 15 \text{ m/s} + 2 \text{ m/s} \\ &= 17 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \text{b). } V &= \frac{V_1 + V_2}{1 + \frac{V_1 V_2}{c^2}} \\ &= \frac{15 + 2}{1 + \frac{15 \cdot 2}{(3 \times 10^8)^2}} = 17 \text{ m/s} \end{aligned}$$

5. Diket :  $V_A = 0,8 c$

$$V_B = 0,6 c$$

Ditanya : a). A dan B menurut pengamat di bumi ?  
b). Kec. A menurut B ?  
c). Kec. B menurut A ?

Jawab :

$$\text{a). Kecepatan A menurut pengamat} = 0,8 c$$

$$\text{Kecepatan B menurut pengamat} = 0,6 c$$



b). kec. pesawat A menurut B

$$v' = \frac{v_A - v_B}{1 - \frac{v_A v_B}{c^2}}$$

$$= \frac{0,8c - (-0,6c)}{1 - \frac{(0,8)(-0,6)}{c^2}}$$

$$= \frac{0,8c + 0,6c}{1 + 0,48} = \frac{1,4c}{1,48} = 0,946c$$

(2). diketahui:

$$D = 12,740 \text{ km}$$

$$L = 3 \times 10^8 \text{ m/s}$$

$$v = 3 \times 10^8 \text{ m/s}$$

( $L_0 - L$ )

Jawab:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \rightarrow \frac{v^2}{c^2} = \frac{(3 \times 10^8)^2}{(3 \times 10^8)^2} = 10^{-8}$$

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

$$\frac{1}{\sqrt{1-x}} \approx 1 + \frac{1}{2}x$$

$$\gamma \approx 1 + \frac{1}{2} \times 10^{-8}$$

$$\approx 5 \times 10^{-9}$$

$$L_0 - L = L - \frac{L_0}{\gamma}$$

$$L_0 - L = L \left(1 - \frac{1}{\gamma}\right)$$

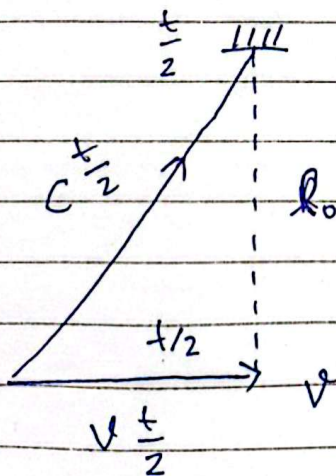
$$\frac{1}{\gamma} = 1 - \frac{1}{2} \times 10^{-8}$$



$$\begin{aligned} \frac{t_B}{t_A} &= \frac{2l_B}{\sqrt{c^2 - v^2}} \cdot \frac{2l_A c}{c^2 - v^2} = \frac{l_B (c^2 - v^2)}{l_A c \sqrt{c^2 - v^2}} \\ &= \frac{2l_B}{\sqrt{c^2 - v^2}} \times \frac{c^2 - v^2}{2l_A c} = \frac{l_B}{l_A c} \sqrt{c^2 - v^2} \\ &= \frac{4l_A l_B c}{c^2 - v^2} \end{aligned}$$

$$a = \frac{\cancel{\sqrt{a}} \cdot \sqrt{a}}{\cancel{\sqrt{a}}} = \sqrt{a}$$

Pemuaian waktu



$$\left(c \frac{t}{2}\right)^2 = l_0^2 + \left(v \frac{t}{2}\right)^2$$

$$\frac{c^2 t^2}{4} = l_0^2 + \frac{v^2 t^2}{4}$$

$$\begin{aligned} l_0^2 &= \frac{c^2 t^2}{4} - \frac{v^2 t^2}{4} \\ &= \frac{t^2}{4} [c^2 - v^2] \end{aligned}$$

$$4l_0^2 = t^2 [c^2 - v^2]$$

$$t^2 = \frac{4l_0^2}{c^2 - v^2} \rightarrow t = \frac{4l_0/c^2}{(1 - \frac{v^2}{c^2})} \rightarrow t = \frac{2l_0/c}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{l_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

muon

sebuah partikel muon mempunyai waktu hidup  $2,5 \times 10^{-6}$  s  
jika partikel bergerak  $0,9c$  berapa waktu hidup?

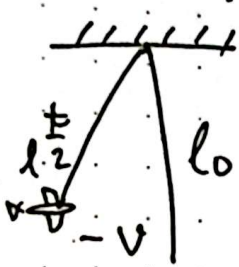
$$\Delta T = 2,5 \times 10^{-6} \text{ s}$$

$$v = 0,9c$$

$$\text{dit} = \Delta t = \frac{\Delta T}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{2,5 \times 10^{-6}}{\sqrt{1 - \frac{0,9^2 c^2}{c^2}}}$$

$$= \frac{2,5 \times 10^{-6}}{\sqrt{1 - 0,81}} = \frac{2,5 \times 10^{-6}}{0,49} = 2,7 \times 10^{-6}$$

$$= 13,15 \times 10^{-6}$$



$$l_0^2 = \left(c \frac{t_0}{2}\right)^2 - \left(v \frac{t_0}{2}\right)^2$$

$$= \frac{t_0^2}{4} (c^2 - v^2)$$

$$t^2 = \frac{4l_0^2}{c^2 \left(1 - \frac{v^2}{c^2}\right)}$$

$$t = \frac{2l_0}{\sqrt{1 - v^2/c^2}}$$

→ persamaan dilatasi waktu.

Dimana :

$t_0$  = waktu yang diukur dalam kerangka diam

$t$  = waktu yang diukur dalam kerangka bergerak

$v$  = kecepatan cahaya

Syarat - Syarat dalam transformasi waktu :

- pengamat dan objek melihat waktu dalam robot
- gerak relatif antara robot dan pengamat harus konstan.
- kecepatan  $u$  harus lebih kecil dari kecepatan cahaya  $c$  yaitu  $v < c$