

- Teori Relativitas -

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27 Sept 2025

Tugas ke 1

1) $t_{\text{bumi}} = 3600 \text{ s}$

$t_{\text{roket}} (\tau) = 3599 \text{ s}$ (1 detik lebih lambat)

$v = \dots ?$

Jawab :

* Dilatasi waktu :

$$t = \gamma \tau$$

$$\gamma = \frac{t}{\tau} = \frac{3600}{3599} \approx 1,000278$$

* Faktor Lorentz :

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

* hasil komputasi :

$$\beta = \frac{v}{c} \approx 0,02357$$

$$v \approx 7,07 \times 10^6 \text{ m/s}$$

$$v \approx 7,1 \times 10^6 \text{ m/s}$$

2) Meson dengan umur $T_0 = 2,5 \cdot 10^{-8} \text{ s}$

$$v = 0,99c$$

$$h = 200 \text{ km} = 200.000 \text{ m}$$

h saat mencapai permukaan laut = ...?

Jawab :

* Faktor Lorentz :

$$\gamma = \frac{1}{\sqrt{1-(0,99)^2}} \approx 7,09$$

* Waktu hidup teramati :

$$t = \gamma T_0$$

$$t = 7,09 \times 2,5 \cdot 10^{-8}$$

$$t \approx 1,77 \times 10^{-7} \text{ s}$$

* Jarak tempuh :

$$d = vt$$

$$d \approx 0,99 \times 1,77 \cdot 10^{-7}$$

$$d \approx 52,6 \text{ m}$$

* Sisa ketinggian : $200.000 - 52,6 \approx 199,947 \text{ m}$

3) Pesawat angkasa menjauhi bumi dgn kecepatan $0,97c$ memancarkan sinyal $f_0 = 10^4 \text{ pulsa/s}$.

Berapa laju frekuensi yg diterima bumi?

* Efek Doppler relativistik :

$$f = f_0 \sqrt{\frac{1-\beta}{1+\beta}}, \text{ dengan } \beta = 0,97$$

$$f = 10^4 \sqrt{\frac{1-0,97}{1+0,97}}$$

$$f = 10^4 \sqrt{\frac{0,03}{1,97}}$$

$$f \approx 10^4 \times 0,1235 \approx 1235 \text{ Hz}$$

4) $v = 0,6c$
 $L = 45 \text{ m}$

a) Waktu kereta melewati satu titik di peron

$$t = \frac{L_{\text{kereta}}}{v}$$

panjang kereta = panjang peron = 45 m

$$t = \frac{45}{0,6c} \approx 2,5 \times 10^{-7} \text{ s}$$

b) Panjang sebenarnya kereta

$$L_0 = \gamma L \rightarrow \gamma = \frac{1}{\sqrt{1-0,6^2}} \approx 1,25$$

$$L_0 = 1,25 \times 45$$

$$L_0 = 56,25 \text{ m}$$

c) Panjang peron menurut kereta

$$L' = \frac{L}{\gamma} = \frac{45}{1,25} = 36 \text{ m}$$

d) Waktu peron butuh untuk melewati kereta penuh

$$L_0 = 56,25$$

$$t = \frac{L_0}{v}$$

$$t = \frac{56,25}{0,6c} = 3,13 \times 10^{-7} s$$

e) Selisih waktu antara depan & belakang kereta melewati ujung peron

$$\Delta t' = \gamma \frac{v \Delta x}{c^2}$$

dengan $\Delta x = 45 \text{ m}$, $v = 0,6c$

$$\Delta t' = 1,25 \times \frac{0,6 \times 45}{c^2}$$

$$\Delta t' \approx 1,13 \times 10^{-7} s$$

5) . Pesawat amerika : $0,9c$ terhadap bumi

- Pesawat rusia : $0,5c$ terhadap amerika.
- Berapa v rusia terhadap bumi ?

a) Mekanika klasik

$$v = v_A + v_{R/A}$$

$$v = 0,9c + 0,5c$$

$$v = 1,4c$$

b) Relativitas Einstein :

$$V = \frac{V_A + V_{R/A}}{1 + \frac{V_A V_{R/A}}{c^2}}$$

$$V = \frac{0,9c + 0,5c}{1 + (0,9)(0,5)} = \frac{1,4c}{1 + 0,45} = \frac{1,4c}{1,45} \approx 0,966c$$

c) pria bermassa 100 kg di bumi. Ketika di roket massanya menjadi 101 kg menurut pengamat di bumi. Berapa v roket ?

$$m = \gamma m_0$$

$$\gamma = \frac{m}{m_0} = \frac{101}{100} \approx 1,01$$

* Cari kecepatan:

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

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

$$\frac{v}{c} = \sqrt{1 - \frac{1}{1,01^2}}$$

$$\beta \approx \sqrt{1 - 0,9803} = \sqrt{0,0197} \approx 0,140$$

$$v \approx 0,14c \approx 4,2 \times 10^7 \text{ m/s}$$

7) Elektron dipercepat oleh beda potensial 5 MV

- Potensial $V = 5 \times 10^6 \text{ V}$
- muatan $e = 1,6 \times 10^{-19} \text{ C}$
- $m_0 = 9,11 \times 10^{-31} \text{ kg}$
- $c = 3 \times 10^8 \text{ m/s}$

a) Energi Kinetik :

$$E_k = eV$$

$$E_k = (1,6 \times 10^{-19})(5 \times 10^6)$$

$$E_k = 8,0 \times 10^{-13} \text{ J}$$

$$E_k \approx 5 \text{ MeV}$$

b) Massa Relativistik :

Total Energi :

$$E = E_k + E_0 \rightarrow E_0 = m_0 c^2 = 511 \text{ eV}$$

$$= 0,511 \text{ MeV}$$

$$\gamma = \frac{E}{E_0}$$

$$\gamma = \frac{5 + 0,511}{0,511}$$

$$\gamma \approx 10,79$$

$$m = \gamma m_0$$

$$\approx 10,79 \times 9,11 \times 10^{-31}$$

$$\approx 9,83 \times 10^{-30} \text{ Kg}$$

c) Kecepatan elektron

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

$$v = c \sqrt{1 - \frac{1}{10.79^2}}$$

$$v \approx c \times 0.996 \approx 0.996c$$

$$v \approx 2.99 \times 10^8 \text{ m/s}$$