

1. Diketahui: Panjang batang (kerangka batang) =  $l_0$   
 kerangka  $O'$  bergerak dengan kecepatan  $u$  relatif terhadap kerangka  $O$   
 Pengamat  $O$  mengukur panjang batang secara bersamaan.

Ditanya: Menurunkan hubungan antara panjang terukur  $L$  dalam kerangka  $O$  dan panjang diam  $l_0$ ?

Jawab:

Panjang batang dalam kerangka  $O'$  adalah  $l_0 = x'_2 - x'_1$

Menggunakan transformasi Lorentz:

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

$$t' = \gamma\left(t - \frac{ux}{c^2}\right)$$

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

$$x'_1 = \gamma(x_1 - ut)$$

$$x'_2 = \gamma(x_2 - ut)$$

$$l_0 = x'_2 - x'_1 = \gamma(x_2 - ut) - \gamma(x_1 - ut)$$

$$l_0 = \gamma(x_2 - x_1) = \gamma L$$

$$L = \frac{l_0}{\gamma}$$

$$L = l_0 \sqrt{1 - \frac{u^2}{c^2}}$$

2. Diketahui:  $L_0 = 3000 \text{ m}$

$$E = 25 \text{ GeV}$$

$$m_0 = 0.511 \text{ MeV}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

a. Hitung kecepatan elektron dengan energi 25 GeV

$$E = \gamma m_0 c^2$$

$$\gamma = \frac{E}{m_0 c^2}$$

$$E = 25 \text{ GeV dan } m_0 c^2 = 0.511$$

$$\gamma = \frac{25 \times 10^9}{0.511 \times 10^6} = \frac{25 \times 10^3}{0.511} \approx 4.89 \times 10^4$$

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

$$v = (3.0 \times 10^8) \sqrt{1 - \frac{1}{(4.89 \times 10^4)^2}}$$

$$v \approx (3.0 \times 10^8) \sqrt{1 - 4.19 \times 10^{-10}}$$

$$v \approx (3.0 \times 10^8) (1 - 2.09 \times 10^{-10})$$

$$v \approx 2.9999999937 \times 10^8 \text{ m/s}$$

$$c - v = 3.0 \times 10^8 - 2.9999999937 \times 10^8 \text{ m/s}$$

$$\Delta v \approx 6.3 \text{ m/s}$$

b. Waktu tempuh elektron dalam laboratorium

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

$$t \approx 3000 / 2.9999999937 \times 10^8$$

$$t \approx 1.000000021 \times 10^{-5} \text{ s} \approx 10.0 \text{ ns}$$

c. Panjang akselerator dalam kerangka elektron

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

$$l = 3000 \times \frac{\sqrt{1 - 1}}{(4.89 \times 10^4)^2}$$

$$l = 3000 \times \frac{1}{4.89 \times 10^4}$$

$$l \approx \frac{3000}{4.89 \times 10^4}$$

$$l \approx 0.0613 \text{ m} \approx 6.13 \text{ cm}$$

d. Waktu tempuh dalam kerangka elektron

$$t' = \frac{l}{v}$$

$$t' = \frac{0.0613}{2.999999937 \times 10^8}$$

$$t' \approx 2.04 \times 10^{-10} \text{ s} \approx 0.204 \text{ ns}$$

3. Diketahui:  $\lambda_0 = 122 \text{ nm}$   
 $\lambda' = 366 \text{ nm}$

a. Hitung kecepatan galaksi yang menjauhi kita

$$\lambda' = \lambda_0 \sqrt{\frac{1+\beta}{1-\beta}}$$

$$\frac{\lambda'}{\lambda_0} = \sqrt{\frac{1+\beta}{1-\beta}}$$

$$V = 0.8c = 0.8 \times 3.0 \times 10^8 \text{ m/s}$$

$$V = 2.4 \times 10^8 \text{ m/s}$$

$$\left(\frac{366}{122}\right)^2 = \frac{1+\beta}{1-\beta}$$

$$9 = \frac{1+\beta}{1-\beta}$$

$$9(1-\beta) = 1+\beta$$

$$9 - 9\beta = 1 + \beta$$

$$9 - 1 = 9\beta + \beta$$

$$8 = 10\beta$$

$$\beta = \frac{8}{10} = 0.8$$

b. Panjang gelombang jika galaksi bergerak mendekati kita

$$\lambda' = \lambda_0 \sqrt{\frac{1-\beta}{1+\beta}}$$

$$\lambda' = 122 \times \sqrt{\frac{1-0.8}{1+0.8}}$$

$$\lambda' = 122 \times \sqrt{\frac{0.2}{1.8}}$$

$$\lambda' = 122 \times \sqrt{0.1111}$$

$$\lambda' = 122 \times 0.3333$$

$$\lambda' \approx 40.7 \text{ nm}$$



4. Diketahui:  $E_{\text{per fisi}} = 200 \text{ MeV} = 200 \times 10^6 \times 1.6 \times 10^{-13} \text{ J}$

$$E_{\text{per fisi}} = 3.2 \times 10^{-11} \text{ J}$$

$$m_U = 235 \text{ u} = 235 \times 1.66 \times 10^{-27} \text{ kg}$$

$$N = \frac{1 \text{ kg}}{m_U} = \frac{1}{235 \times 1.66 \times 10^{-27}}$$

$$N \approx 2.56 \times 10^{24} \text{ atom}$$

Ditanya:  $\Delta m$ ?

Jawab:  $E = \Delta m c^2$

$$E_{\text{total}} = N \times E_{\text{per fisi}}$$

$$E_{\text{total}} = (2.56 \times 10^{24}) \times (3.2 \times 10^{-11})$$

$$E_{\text{total}} = 8.192 \times 10^{13} \text{ J}$$

$$\Delta m = \frac{E_{\text{total}}}{c^2}$$

$$\Delta m = \frac{8.192 \times 10^{13}}{(3.0 \times 10^8)^2}$$

$$\Delta m = \frac{8.192 \times 10^{13}}{9.0 \times 10^{16}}$$

$$\Delta m \approx 9.1 \times 10^{-4} \text{ kg}$$

5. Diketahui:  $m_p = 1.007276 \text{ u}$

$$m_n = 1.008665 \text{ u}$$

$$m_{\text{He}} = 4.001506 \text{ u}$$

$$1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

a. Energi ikat inti Helium

$$\Delta m = (2m_p + 2m_n) - m_{He}$$

$$\Delta m = (2 \times 1.007276 + 2 \times 1.008665 - 4.001506)$$

$$\Delta m = (2.014552 + 2.01733) - 4.001506$$

$$\Delta m = 4.031882 - 4.001506$$

$$\Delta m = 0.030376 \text{ u}$$

$$E = \Delta m \times c^2$$

$$E = (0.030376 \times 931.5) \text{ MeV}$$

$$E \approx 28.3 \text{ MeV}$$

b. Beda massa dalam kg

$$\Delta m = 0.030376 \times (1.66054 \times 10^{-27}) \text{ kg}$$

$$\Delta m \approx 5.04 \times 10^{-29} \text{ kg}$$

6. Diketahui:  $v_{AB} = 0.8c$

$$v_B = 0.6c$$

Ditanya: kecepatan pesawat A terhadap pengamat di bumi ( $v_A$ )

$$\text{Jawab: } v_A = \frac{v_{AB} + v_B}{1 + \frac{v_{AB}v_B}{c^2}}$$

$$v_A = \frac{0.8c + 0.6c}{1 + \frac{(0.8c)(0.6c)}{c^2}}$$

$$v_A = \frac{1.4c}{1 + 0.48}$$

$$v_A \approx 0.946c$$

7 Diketahui:  $P = 20 \text{ W}$

$$\lambda = 589 \text{ nm} = 589 \times 10^{-9} \text{ m}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

$$h = 6.626 \times 10^{-34} \text{ J/C}$$

Ditanya:  $N$ ?

Jawab:  $E = \frac{hc}{\lambda}$

$$E = \frac{(6.626 \times 10^{-34}) (3.0 \times 10^8)}{589 \times 10^{-9}}$$

$$E = \frac{1.9878 \times 10^{-25}}{589 \times 10^{-9}}$$

$$E \approx 3.37 \times 10^{-19} \text{ J}$$

$$N = \frac{P}{E}$$

$$N = \frac{20}{3.37 \times 10^{-19}}$$

$$N \approx 5.94 \times 10^{19} \text{ foton/detik}$$

8. Diketahui:  $\lambda = 3500 \text{ \AA} = 350 \text{ nm} = 350 \times 10^{-9} \text{ m}$

$$W = 2.2 \text{ eV}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

$$h = 6.626 \times 10^{-34} \text{ J/C}$$

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

Ditanya:  $K_{\text{max}}$ ?

Jawab:  $E = \frac{hc}{\lambda}$

$$E = \frac{(6.626 \times 10^{-34})(3.0 \times 10^8)}{350 \times 10^{-9}}$$

$$E = \frac{1.9878 \times 10^{-25}}{350 \times 10^{-9}}$$

$$E \approx 5.68 \times 10^{-19} \text{ J}$$

$$E = \frac{5.68 \times 10^{-19}}{1.6 \times 10^{-19}}$$

$$E \approx 3.55 \text{ eV}$$