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Materi: Fisika Modern

Tugas Perhitungan 7

1. $x'_1 = 0$ hingga $x'_2 = L_0$

$$L = x_2 - x_1$$

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

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

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

• Waktu sama ($t_1 = t_2$)

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

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

$$L_0 = x'_2 - x'_1$$

$$L_0 = \gamma(x_2 - ut) - \gamma(x_1 - ut)$$

$$L_0 = \gamma(x_2 - x_1) \text{ atau}$$

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

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

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

2. Diketahui: $E = 25 \text{ GeV}$

$$d = 3000 \text{ m}$$

$$m_0 = 0.511 \text{ MeV}/c^2$$

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

Ditanya: a). Kecepatan elektron yang energinya 25 GeV?

b). Waktu yang diperlukan elektron untuk menempuh jarak 3000 m?

c). Panjang akselerator dalam kerangka acuan universal elektron?

d). Waktu tempuh elektron dalam kerangka acuan universalnya?

Jawab:

a). $E = \gamma m_0 c^2$

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

$$= \frac{2.5 \times 10^9 \text{ eV}}{0.511 \times 10^6 \text{ eV}}$$

$$= 4.89 \times 10^9$$

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

$$\frac{v^2}{c^2} = 1 - \frac{1}{(4.89 \times 10^9)^2}$$

$$v = c \sqrt{1 - \frac{1}{(4.89 \times 10^9)^2}}$$

$$v = c (1 - 1.05 \times 10^{-19})$$

$$v \approx 2.99999 \times 10^8 \text{ m/s}$$

Selisih dengan kecepatan cahaya:

$$c - v \approx 0.031 \text{ m/s}$$

Jadi, elektron hampir bergerak dengan ke cahaya.

$$b). t = \frac{d}{v}$$

$$t = \frac{3000 \text{ m}}{2,9999 \times 10^8 \text{ m/s}}$$

$$t = 1,000\,000\,0001 \times 10^{-3} \text{ s}$$

$$= 10 \text{ ms}$$

$$c). L' = L \sqrt{1 - \frac{v^2}{c^2}}$$

$$\text{Karena } \gamma \approx 4,89 \times 10^9, \text{ maka}$$

$$L' = \frac{3000}{4,89 \times 10^9}$$

$$L \approx 0,61 \text{ m} = 6,1 \text{ cm}$$

$$d). t' = \frac{t}{\gamma}$$

$$t = \frac{10^{-5}}{4,89 \times 10^9}$$

$$t' \approx 2,04 \times 10^{-9} \text{ s}$$

$$= 0,204 \text{ ns}$$

$$3. \text{ Diketahui: } \lambda_0 = 122 \text{ nm} = 1,22 \times 10^{-7} \text{ m}$$

$$\lambda' = 366 \text{ nm} = 3,66 \times 10^{-7} \text{ m}$$

Ditanya: a. Kecepatan galaksi bergerak menjauhi garis spektrum?

b. Panjang gelombang garis spektrum bergerak menuju kita?

Jawab:

$$a. \frac{\lambda'}{\lambda_0} = \sqrt{\frac{1 + v/c}{1 - v/c}}$$

$$\frac{3,66 \times 10^{-7}}{1,22 \times 10^{-7}} = \sqrt{\frac{1 + v/c}{1 - v/c}}$$

$$3 = \sqrt{\frac{1 + v/c}{1 - v/c}}$$

$$\gamma = \frac{1 + v/c}{1 - v/c}$$

$$b. \frac{\lambda''}{\lambda_0} = \sqrt{\frac{1 - v/c}{1 + v/c}}$$

$$\lambda'' = \lambda_0 \sqrt{\frac{1 - v/c}{1 + v/c}}$$

$$\lambda'' = 122 \times \sqrt{\frac{0,2}{1,8}}$$

$$\lambda'' = 122 \times \sqrt{0,1111}$$

$$= 122 \times 0,333$$

$$\lambda'' \approx 40,67 \text{ nm}$$

$$\gamma(1 - v/c) = 1 + v/c$$

$$\gamma - \gamma v/c = 1 + v/c$$

$$\gamma - 1 = \gamma v/c + v/c$$

$$8 = 10 v/c$$

$$\frac{v}{c} = \frac{8}{10} = 0,8$$

$$v = \frac{v}{c} \cdot c$$

$$= 0,8 \times 3 \times 10^8 \text{ m/s}$$

$$= 2,4 \times 10^8 \text{ m/s}$$

4. Diketahui : $E = 200 \text{ MeV}$

$$m_u = 1 \text{ kg}$$

Ditanya : Δm

$$n = \frac{1000 \text{ g}}{235 \text{ g/mol}} = 4,255 \text{ mol}$$

$$N = n \times N_A$$

$$= 4,255 \times 6,022 \times 10^{23}$$

$$= 2,56 \times 10^{24}$$

$$E_{\text{total}} = N \cdot E$$

$$= 2,56 \times 10^{24} \cdot 200 \text{ MeV}$$

$$= 2,56 \times 10^{24} \times 200 \times 1,602 \times 10^{-13} \text{ J}$$

$$E_{\text{total}} = 8,2 \times 10^{13} \text{ Joule}$$

$$E_{\text{tot}} = \Delta m \cdot c^2$$

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

$$= \frac{8,2 \times 10^{13}}{(3 \times 10^8)^2}$$

$$= \frac{8,2 \times 10^{13}}{9 \times 10^{16}}$$

$$= 9,1 \times 10^{-4} \text{ kg}$$

$$\Delta m \approx 9,1 \times 10^{-4} \text{ kg}$$

5. Diketahui : ${}^4_2\text{He} = 4,001506 \text{ u}$

$$m_p = 1,007276 \text{ u}$$

$$m_n = 1,008665 \text{ u}$$

$$1 \text{ u} = 1,6605 \times 10^{-27} \text{ kg}$$

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

Ditanya : a). Energi ikat (E_b)?

b). Beda massa (kg) antara 2 inti atom helium dan partikel (Δm)?

Jawab :

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

$$= (2 \times 1,007276 \text{ u} + 2 \times 1,008665 \text{ u}) - 4,001506 \text{ u}$$

$$= (2,014552 + 2,01733) - 4,001506$$

$$= 4,031882 \text{ u} - 4,001506 \text{ u}$$

$$\Delta m = 0,030376 \text{ u}$$

$$a). E_b = \Delta m \times c^2$$

Kita bisa menggunakan $931,5 \text{ MeV/u}$ karena setara 1 u

$$= 0,030376 \times 931,5 \text{ MeV/u}$$

$$E_b = 28,3 \text{ MeV}$$

$$b). \Delta m_{\text{kg}} = 0,030376 \times 1,6605 \times 10^{-27} \text{ kg}$$

$$\approx 5,04 \times 10^{-29} \text{ kg}$$

$$\Delta m_{\text{inti}} = 2 \times 5,04 \times 10^{-29}$$

$$= 1,008 \times 10^{-28} \text{ kg}$$

6. Diketahui : $u = 0,8c$

$$u' = 0,6c$$

Ditanya : v ?

$$v = \frac{u + u'}{1 + \frac{u \cdot u'}{c^2}}$$

$$v = \frac{0,8c + 0,6c}{1 + \frac{0,8c \cdot 0,6c}{c^2}}$$

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

$$v \approx 0,946c$$

7. Diketahui: $P = 20$

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

$$\lambda = 589 \text{ nm} = 5,89 \times 10^{-7} \text{ m}$$

$$h = 6,626 \times 10^{-34} \text{ J}$$

Ditanya: N ?

$$\begin{aligned} E &= \frac{h \cdot c}{\lambda} \\ &= \frac{6,626 \times 10^{-34} \times 3 \times 10^8}{5,89 \times 10^{-7}} \\ &= \frac{1,9878 \times 10^{-25}}{5,89 \times 10^{-7}} \\ E &= 3,37 \times 10^{-19} \text{ J} \end{aligned}$$

$$\begin{aligned} N &= \frac{P}{E} \\ &= \frac{20}{3,37 \times 10^{-19}} \\ N &= 5,93 \times 10^{19} \text{ foton/detik} \end{aligned}$$

8. Diketahui: $\lambda = 3500 \text{ \AA} = 3,5 \times 10^{-7} \text{ m}$

$$W_0 = 2,2 \text{ eV}$$

Ditanya: E_k ?

$$\begin{aligned} E &= \frac{hc}{\lambda} \\ &= \frac{6,626 \times 10^{-34} \times 3 \times 10^8}{3,5 \times 10^{-7}} \\ &= \frac{1,9878 \times 10^{-25}}{3,5 \times 10^{-7}} \end{aligned}$$

$$E = 5,68 \times 10^{-19} \text{ J}$$

Konversi ke eV

$$E = \frac{5,68 \times 10^{-19}}{1,602 \times 10^{-19}}$$

$$E = 3,55 \text{ eV}$$

$$\begin{aligned} E_k &= E_{\text{foton}} - W_0 \\ &= 3,55 \text{ eV} - 2,2 \text{ eV} \\ &= 1,35 \text{ eV} \end{aligned}$$