

1. Kolikšna je starost geološkega sloja v katerem smo našli mineral, ki vsebuje ~~7,5 g~~ $7,5 \text{ g } U_{92}^{238}$ in Pb_{82}^{206} , pri čemer je Pb_{82}^{206} nastal z radioaktivnim razpadom urana. Razpolovni čas urana je $F2$ $4,5 \cdot 10^9$ let.

$$m' = 1 \text{ mg}, m = 7,5 \cdot 10^{-3} \text{ kg}$$

$$t_{1/2} = 4,5 \cdot 10^9 \text{ let}$$

$$N = N_0 e^{-\lambda t}$$

$$\ln \frac{1}{2} = -\lambda \cdot t_{1/2} \Rightarrow \lambda = \ln 2 / t_{1/2}$$

$m \rightarrow N \equiv$ število nerozp. at. urana
 $m' \rightarrow N' \equiv$ število atomov svineca

$$N = (N + N') e^{-\frac{\ln 2 \cdot t}{t_{1/2}}}$$

$$t = \frac{t_{1/2}}{\ln 2} \cdot \ln \left(1 + \frac{N'}{N} \right)$$

$$\frac{N'}{m'} = \frac{N_0}{M'}$$

$$\frac{N'}{N} = \frac{m' \frac{NA}{M'}}{m \frac{NA}{M}} =$$

$$t = \frac{t_{1/2}}{\ln 2} \ln \left[1 + \frac{m' \cdot M}{M' \cdot m} \right] = \underline{\underline{10^6 \text{ let}}}$$

1. Pioni se gibljejo s hitrostjo $2,74 \cdot 10^8$ m/s skozi 110 cm širok stevec. Kolikšen del pionov razpade v stevcu, če je lastni razpadni čas pionov $2,6 \cdot 10^{-8}$ s in se delci v stevcu gibljejo skoraj neovirano?

18pp3

$v = 2,74 \cdot 10^8 \frac{m}{s}$, $x = 1,1 m$, $\tau = 2,6 \cdot 10^{-8} s$, $c = 3 \cdot 10^8 s$

$\tau' = \gamma \cdot \tau = (1 - \frac{v^2}{c^2})^{-1/2} \cdot \tau$

$N = N_0 e^{-t/\tau'}$ $t = \frac{x}{v}$

$v = 2,74 \cdot 10^8 m/s$
 $x = 1,1 m$
 $\tau = 2,6 \cdot 10^{-8} s$

$\tau' > \tau$
 $\gamma \approx 2.45$

PIONI imajo en pozitiven in en negativen osnovni naboj in 274 x mabo elektronov

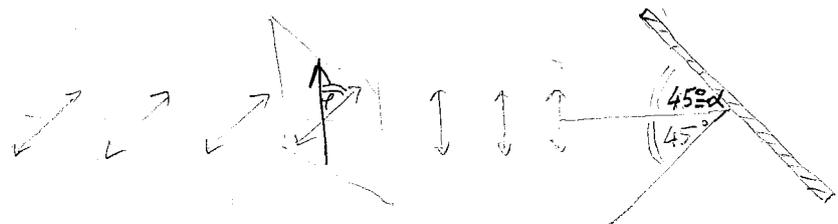
$\frac{N_0 - N}{N_0} = 1 - \frac{N}{N_0} = 1 - e^{-\frac{x}{v \gamma \tau}} = 0.061$

$\gamma = \frac{1}{\sqrt{1 - (\frac{v}{c})^2}} = 2.456$

3. Na idealni polarizator pada pravokotno na njegovo površino vzporeden snop linearno polarizirane svetlobe ~~z valovno dolžino~~ z gostoto energijskega toka $0,1 W/m^2$. Nihajna ravnina vpadajočega valovanja oklepa kot 45° s prepustno smerjo polarizatorja. Svetloba, ki pride skozi polarizator, osvetljuje zaslon, ki je postavljen pod kotom 45° glede na smer žarkov. Kolikšna je osvetljenost zaslona merjena v W/m^2 ?

4.9.

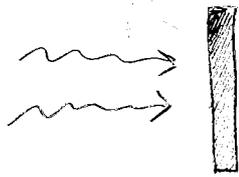
$\lambda = 560 nm$
 $I = 0.1 W/m^2$
 $\varphi = 45^\circ$, $\alpha = 45^\circ$



$E = I_0 \cdot \cos^2 \varphi \cdot \cos \alpha = 3,53 \cdot 10^{-2} W/m^2$

4. Pravokotno na tanko kvadratno zglajeno kovinsko ploščico, ki se nahaja v vakuumu, usmerimo monokromatski svetlobni tok ($\lambda = 500 \text{ nm}$), ki deluje na ploščico s tlakom 10^{-9} N/cm^2 . Kolikšna je stacionarna temperatura ploščice? Koliko fotonov zadane ploščico v eni sekundi? Odbojnost ploščice za vpadno svetlobo je 0,8, stranica ploščice pa je dolga 1 cm.

$$P_{\text{abs}} = (1 - \alpha) P$$



$$\lambda = 500 \text{ nm}$$

$$P = \frac{F}{S} = 10^{-9} \text{ N/cm}^2, \quad S = 1 \text{ cm}^2$$

$$\alpha = 0,8$$

$$F = 10^{-9} \text{ N}$$

$$F = p \cdot S = 10^{-9} \text{ N/cm}^2$$

$$F = (1 + \alpha) \frac{P}{c_0} \Rightarrow P = \frac{F c_0}{(1 + \alpha)} = 0,166 \text{ W}$$

$$\frac{dN}{dt} = \frac{P}{h\nu} = 4,18 \cdot 10^{17} \text{ s}^{-1}$$

$$P = \frac{dN}{dt} h\nu$$

$$(1 - \alpha) P = (1 - \alpha) \delta T^4 \cdot 2S$$



$$T = \left(\frac{P}{2S\delta} \right)^{1/4} = 347,8 \text{ K}$$

$$0,166$$

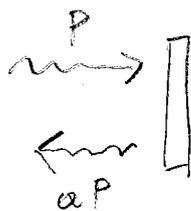
$$2 \cdot 5 \cdot 5,67 \cdot 10^{-8}$$

4. Pravokotno na zglajeno kovinsko ploščico usmerimo svetlobni tok 0,09 W. Sila s katero deluje svetlobni curek na ploščico je enaka $4 \cdot 10^{-10}$ N. Ploščica se nahaja v vakuumu. Kakšna je odbojnost ploščice za vpadni svetlobni curek?

$$P = 0,09 \text{ W}$$

$$F = 4 \cdot 10^{-10} \text{ N}$$

$$a = ?$$



$$P_{\text{abs}} = (1-a)P$$

fotoni: $W^2 = W_0^2 + c^2 G^2$

$W = c \cdot G = h\nu \Rightarrow$

$$\Rightarrow G = \frac{W}{c} = \frac{h\nu}{c_0} = \frac{h}{\lambda}$$

št. el. fotona:

$$\frac{P_{\text{ab}} \cdot t}{h \cdot \nu} = \frac{(1-a)P \cdot t}{h\nu}$$

št. odbitih fotona:

$$\frac{aPt}{h\nu}$$

$\Delta G_{\text{od fotone}}$

$$\Delta G_{\text{od}} = \frac{aPt}{h\nu} \left[\left(-\frac{h\nu}{c_0} \right) - \frac{h\nu}{c_0} \right] = \frac{-2aPt}{c_0}$$

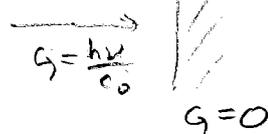
$\Delta G_{\text{absorbirane fotone}}$

$$\Delta G_{\text{abs}} = \frac{(1-a) \cdot P \cdot t}{h\nu} \left[0 - \frac{h\nu}{c_0} \right] = \frac{-(1-a)Pt}{c_0}$$

odbiti fotoni:



abs. fotoni:



$$\Delta G = \Delta G_{\text{od}} + \Delta G_{\text{abs}} = F' \cdot t$$

F' = sila ploščice na curek svetlobe

$$-\frac{2aPt}{c_0} - \frac{(1-a)Pt}{c_0} = F' \cdot t \Rightarrow F' = \frac{-(1+a)P}{c_0}$$

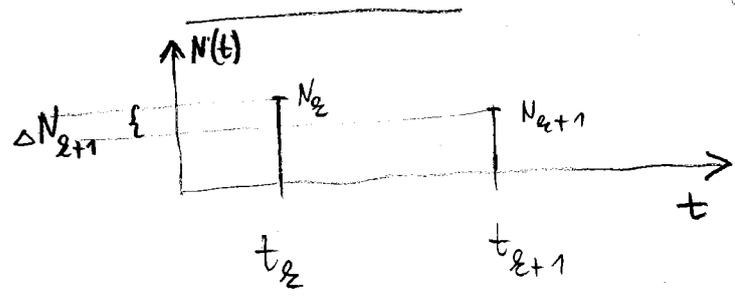
$$F = -F'$$

$$F = (1+a) \cdot P / c_0 \Rightarrow F \cdot c_0 = P + Pa$$

$$a = \frac{F \cdot c_0}{P} - 1 = \underline{\underline{0,33}}$$

5. Pri radioaktivnem razpadu izotopa broma (${}_{35}\text{Br}^{78}$) je v časovnem intervalu 60 sekund verjetnost razpada 0,1042. Kakšen je razpolovni čas tega izotopa broma?

$\Delta t = 60 \text{ s}$
 $P = 0,1042$
 $t_{1/2} = ?$



$dN = -N \lambda dt \Rightarrow N_{2+1} = N_2 e^{-\lambda \Delta t}$

$N = N_0 e^{-\lambda t}$

$\frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}}$

\Downarrow

$\ln 2 = \lambda t_{1/2} \Rightarrow t_{1/2} = \frac{\ln 2}{\lambda}$

$\Delta t = t_{2+1} - t_2$

$\Delta N_{2+1} = N_2 - N_{2+1}$

$P = \frac{N_2 - N_{2+1}}{N_2} = 1 - \frac{N_{2+1}}{N_2} = 1 - e^{-\lambda \Delta t}$

$e^{-\lambda \Delta t} = 1 - P \Rightarrow$

$\Rightarrow \lambda \Delta t = \ln \left[\frac{1}{1 - P} \right] \Rightarrow \lambda = \frac{1}{\Delta t} \ln \left[\frac{1}{1 - P} \right]$

$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2 \cdot \Delta t}{\ln \left[\frac{1}{1 - P} \right]} = 378 \text{ s}$

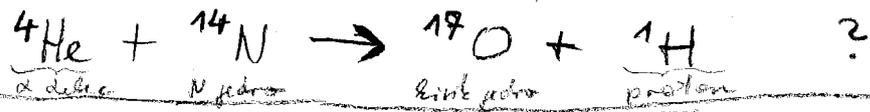
378 s

$\text{Br}^{78} \rightarrow \text{A} \equiv \text{normalno sterilo}$
 3τ
 \downarrow
 $Z \equiv \text{vrsta sterila}$

ATS

Nejmanj kolikšno kinetično energijo morajo imeti He jedra (2protona + 2neutrona), da poteka reakcija

proton = 938 MeV
elektron = 0.51 MeV
neutron = 939 MeV



$$a + X \rightarrow Y + b \quad \text{polna energija:}$$

$$W = m_p c_0^2 = T + m c_0^2$$

ohromiter polne energije:

$$T_a + m_a c_0^2 + m_x c_0^2 = T_y + m_y c_0^2 + T_b + m_b c_0^2$$

$$T_a - (T_y + T_b) = Q = (m_y + m_b - m_a - m_x) c_0^2 = 1,19 \text{ MeV}$$

nerelativistično: $Q = \frac{1}{2} m_a v_a^2 - \frac{1}{2} m_y v_y^2 - \frac{1}{2} m_b v_b^2 \quad (1)$

ohromiter gib. količine: $m_a v_a = m_y v_y + m_b v_b \quad (2)$

$$v_y = v_b \quad \text{vstavim v (2)}$$

$$m_a v_a = (m_y + m_b) v_y \quad \text{ali}$$

$$m_a v_a = (m_y + m_b) v_b$$

$$v_y = v_b = m_a v_a / (m_y + m_b)$$

to vstavim v (1)

$$Q = \frac{1}{2} m_a v_a^2 - \frac{1}{2} \frac{m_a^2 m_y v_a^2 + m_b m_a^2 v_a^2}{(m_y + m_b)^2} \Rightarrow$$

$$Q = \frac{1}{2} m_a v_a^2 - \frac{1}{2} m_a^2 v_a^2 / (m_y + m_b)$$

$$Q = \frac{1}{2} m_a v_a^2 \left[1 - \frac{m_a}{m_y + m_b} \right]$$

$$\left(\frac{1}{2} m_a v_a^2 \right)_{\text{prog}} = Q / \left[1 - \frac{m_a}{m_y + m_b} \right] =$$

$$\approx 1,53 \text{ MeV}$$

če smo v težiščnem sistemu,

$$V_T = \frac{m_a v_a + m_x \cdot 0}{m_a + m_x} = \frac{m_a v_a}{m_a + m_x}$$

$$v_a^* = v_a - V_T \quad v_x^* = 0 - V_T$$

$$m_a v_a^* + m_x v_x^* = 0 \quad \left. \begin{array}{l} \text{skupna} \\ \text{gibalna} \\ \text{količina} \\ \text{nič} \end{array} \right\}$$



po tem tudi gib. kol. nič:

$$m_y v_y^* + m_b v_b^* = 0$$

nojnepodnejša rešitev: $v_y^* = v_b^* = 0$

v laboratorijskem sistemu:

$$v_y = v_b \neq V_T$$

top: + 1005

5. Za obsevanje potrebujemo radioaktivni izvor z aktivnostjo vsaj 10^9 razpadov v sekundi. Izračunaj kolikšna mora biti aktivnost izvora ob dobavi, da bo uporaben vsaj dva meseca? Razpolovni čas izotopa je 5 mesecev.

$$N = N_0 e^{-\lambda t} \Rightarrow A = -\frac{dN}{dt} = +N_0 \lambda e^{-\lambda t} \Rightarrow A = A_0 e^{-\lambda t}$$



$$\frac{1}{2} = e^{-\lambda t_{1/2}}$$

$$\ln 2 = \lambda t_{1/2} \Rightarrow \lambda = \frac{\ln 2}{t_{1/2}}$$

$$t_M = 2 \text{ meseca}$$

$$t_{1/2} = 5 \text{ mesecev}$$

$$A(t_M) = 10^9 \text{ s}^{-1}$$

$$A(t_M) = A_0 e^{-\frac{\ln 2}{t_{1/2}} \cdot t_M}$$

↓

$$A_0 = A(t_M) e^{\frac{\ln 2 \cdot t_M}{t_{1/2}}} = \underline{\underline{1.32 \cdot 10^9 \text{ s}^{-1}}} \quad \checkmark$$



4. He jedro, ki vstopa v reakcijo ${}^4\text{He} + {}^{14}\text{N} \rightarrow {}^{17}\text{O} + {}^1\text{H}$, ima tako kinetično energijo, da sta hitrosti ${}^{17}\text{O}$ in ${}^1\text{H}$ po reakciji ravno enaki. Kolikšna je omenjena hitrost ${}^{17}\text{O}$ in ${}^1\text{H}$, če je dušikovo jedro pred reakcijo mirovalo? *Produkti reakcije letita v smeri vpadnega delca.*

($m_{\text{He}} = 4,002603$, $m_{\text{N}} = 14,003074$, $m_{\text{O}} = 16,999134$, $m_{\text{H}} = 1,007825$)

4.8.

proton $\rightarrow 938 \text{ MeV}$

elektron $\rightarrow 0,51 \text{ MeV}$

neutron $\rightarrow 939 \text{ MeV}$



$$W = m_0 c^2 = T + m_0 c^2$$

$$v_Y = v_B$$

obr. gib. količine $m_a \cdot v_a = (m_Y + m_B) \cdot v_b \Rightarrow$

$$\Rightarrow v_b = m_a \cdot v_a / (m_Y + m_B)$$

obr. polne energije: $\frac{1}{2} m_a v_a^2 + m_a c^2 + m_x c^2 = \frac{1}{2} m_Y v_b^2 + m_Y c^2 + \frac{1}{2} m_B v_b^2 + m_B c^2$

\Downarrow

$$\frac{1}{2} m_a v_a^2 - \frac{1}{2} (m_Y + m_B) v_b^2 = (m_Y + m_B - m_a - m_x) c^2 = Q = 1,19 \text{ MeV}$$

\Downarrow

$$\frac{1}{2} m_a v_a^2 - \frac{1}{2} (m_Y + m_B) \frac{m_a^2 v_a^2}{(m_Y + m_B)^2} = Q \Rightarrow \frac{1}{2} m_a v_a^2 \left(1 - \frac{m_a}{m_Y + m_B} \right) = Q$$

$$v_a = \sqrt{2Q / \left[m_a \cdot \left(1 - \frac{m_a}{m_Y + m_B} \right) \right]} = 8,58 \cdot 10^6 \frac{\text{m}}{\text{s}}$$

2. Z izvorom Co^{60} , ki razpada z razpolovnim časom 5,3 let in pri tem oddaja žarke gama z energijo 1,2 MeV, pet minut obsevamo 50 g težak površinski tumor. Doza, ki jo tumor prejme, je 5 J/kg (Gy). Izračunaj maso kobalta, če predpostaviš, da se v tumorju absorbira vsak petstoti izsevani žarek.

Aktivnost (A) sorazmerna številu radioaktivnih jeder v njej:

$$A = -\frac{dN}{dt} = \lambda N \Rightarrow N = N_0 e^{-\lambda t}$$

razpolovni čas $\rightarrow \frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}}$

$$\ln 2 = \lambda \cdot t_{1/2} \Rightarrow t_{1/2} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \ln 2 / t_{1/2}$$

Absorbirana doza: $D = \frac{\Delta E}{\Delta m} [J/kg] \equiv [1 Gy]$ (dovodena energija na enoto mase)

$$\Delta N = \lambda N_0 t$$

$$m_{Co} = N_0 \cdot m_1 = N_0 \cdot \frac{M_{Co}}{N_A}$$

$$N_0 = \frac{m_{Co} \cdot N_A}{M_{Co}}$$

$$D = \frac{W}{m_t} = \frac{W_{\gamma} \cdot \Delta N \cdot \eta}{m_t} = \frac{W_{\gamma} \cdot \lambda \cdot N_0 \cdot t \cdot \eta}{m_t}$$

$$= \frac{W_{\gamma} \cdot \ln 2 \cdot m_{Co} \cdot N_A \cdot t \cdot \eta}{m_t \cdot t_{1/2} \cdot M_{Co}} = D$$

$$m_{Co} = \frac{D \cdot m_t \cdot t_{1/2} \cdot M_{Co}}{W_{\gamma} \cdot \ln 2 \cdot N_A \cdot t \cdot \eta} = 5.2 \cdot 10^{-5} \text{ kg}$$

- $t_{1/2} = 5,3 \text{ let}$
- $W_{\gamma} = 1,2 \text{ MeV}$
- $m_t = 50 \text{ g}$
- $D = 5 \text{ J/kg}$
- $t = 5 \text{ minut}$
- $\eta = \frac{1}{500} = 2 \cdot 10^{-3}$
- $M_{Co} = 60 \text{ kg}$

$$m_{Co} = ?$$

3. Polonij (${}_{84}^{210}\text{Po}$) emitira α delce z razpolovnim časom 138,4 dni. Koliko časa je potrebno pri $T = 273 \text{ K}$ in $p = 10^5 \text{ Pa}$, da je volumen helijevega plina, nastal iz α delcev, ki jih emitira 2 g vzorec polonija, enak 100 cm^3 ? Predpostavljamo, da se v času opazovanja vsi α delci pretvorijo v helij.

1996

$$\tilde{m}_0 = 2 \cdot 10^{-3} \text{ kg}$$

$$t_{1/2} = 138,4 \text{ dni}$$

$$T = 273 \text{ K}$$

$$p = 10^5 \text{ N/m}^2$$

$$V = 100 \text{ cm}^3$$

$$M_{\text{He}} = 4 \text{ kg/kmol}$$

$$N = N_0 e^{-\lambda t}$$

$$N = N_0 e^{-\frac{\ln 2 \cdot t}{t_{1/2}}}$$

$$\Delta N = (N_0 - N) = N_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$${}_{84}^{210}\text{Po}: \Delta \tilde{m} = \tilde{m}_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$t = ?$$

$$\alpha, \text{He}: \Delta m = \frac{4}{210} \cdot \tilde{m}_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$pV = \frac{\Delta m}{M} RT$$

$$\frac{pVM}{RT} = \Delta m = \frac{4}{210} \cdot \tilde{m}_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$\frac{pVM}{RT} \cdot \frac{210}{4 \cdot \tilde{m}_0} = 1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right)$$

$$\left[-\frac{\ln 2 \cdot t}{t_{1/2}} \right] = \ln \left[1 - \frac{p \cdot V \cdot M}{R \cdot T \cdot \tilde{m}_0} \cdot \frac{210}{4} \right]$$

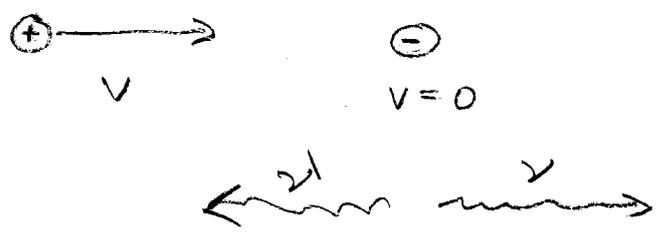
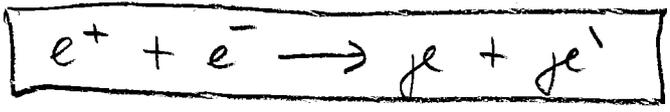
$$t = -\frac{t_{1/2}}{\ln 2} \cdot \ln \left[1 - \frac{pVM}{R \cdot T \cdot \tilde{m}_0} \cdot \frac{210}{4} \right] = \underline{\underline{124 \text{ dni}}}$$

$$t = -\frac{138,4}{\ln 2} \ln \left[1 - \frac{10^5 \cdot 10^2 \cdot 10^{-6} \cdot 4 \cdot 210}{8314 \cdot 273 \cdot 2 \cdot 10^{-3} \cdot 4} \right]$$

$$t = -\frac{138,4}{\ln 2} \cdot \ln \left[1 - \frac{10^4 \cdot 4 \cdot 210}{8314 \cdot 273 \cdot 8} \right] = \underline{\underline{124 \text{ dni}}} \checkmark$$

6. Pozitron s kinetično energijo 20 MeV sreča mirujoč elektron in se z njim v letu anihilira. Za koliko se razlikujeta energiji nastalih zarkov γ , od katerih odleti eden v smeri leta pozitrona, drugi pa v nasprotni smeri?

$T = 20 \text{ MeV}$
 $W_0 = m_e \cdot c^2 = 0,51 \text{ MeV}$



elektron:
 $W^2 = W_0^2 + c_0^2 P^2$
 $(T + W_0)^2 = W_0^2 + c_0^2 P^2$
 $T^2 + 2TW_0 + W_0^2 = W_0^2 + c_0^2 P^2 \Rightarrow$

$c_0 P = \sqrt{T^2 + 2TW_0}$

ohromiter gib. količina:

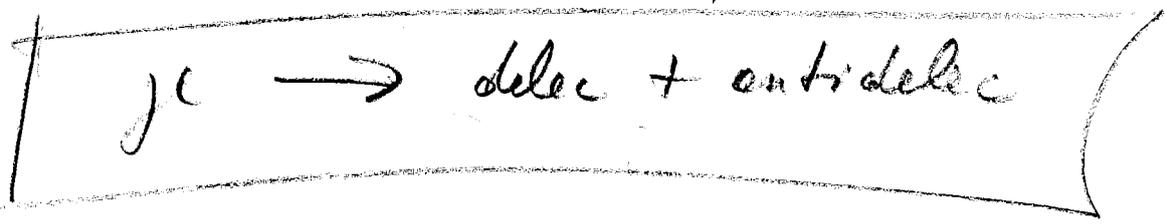
foton: $P_\gamma = \frac{W_\gamma}{c_0} = \frac{h\nu}{c_0}$

$P = \frac{h\nu}{c_0} - \frac{h\nu'}{c_0}$

$c_0 P = h(\nu - \nu') = \sqrt{T^2 + 2TW_0} = 20,5 \text{ MeV}$

ΔW_γ

nasprotje: TVORBA PARA
 $= 3,28 \cdot 10^{-12} \text{ J}$



- (+e) proton, anti proton (-e)
- neutron, antineutron
- (-e) elektron, pozitron (+e)

p. Bogart 1991

6. V kristalu so kristalne ravnine v razmiku 0,21 nm. Kolikšno najmanjšo napetost morajo preleteti v začetku mirujoči elektroni, da pri usmeritvi curka elektronov na površino tega kristala se dobimo Braggov odboj?

(v kemiji počasi elektroni ne morejo prodreti v notranjost kristala in se sprostijo na ionih v majhni plastici (Strnad str. 120.)
 ↓ razen če napetost n \bar{c} i deset keV

$$a = 0,21 \text{ nm}$$

$$\Delta = 2a \cdot \cos \alpha = N \cdot \lambda \quad (\text{oj \bar{c} enja})$$

$$\cos \alpha = 1, \quad N = 1$$

$$2a = \lambda_M \quad \lambda_M \equiv \text{maksimalen } \lambda$$

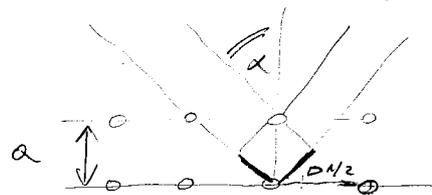
$$\frac{1}{2} m v^2 = e_0 U$$

$$U = \frac{m v^2}{2 e_0} = \frac{m h^2}{2 e_0 m^2 \lambda_M^2} =$$

$$= \frac{h^2}{2 e_0 \cdot m \cdot \lambda_M^2} =$$

$$= \frac{h^2}{2 \cdot e_0 \cdot m \cdot 4 \cdot a^2} \Rightarrow$$

$$U = \frac{h^2}{8 m e_0 a^2} = \underline{\underline{8,53 \text{ V}}}$$



$$\cos \alpha = \frac{\Delta_{N/2}}{a} \Rightarrow \Delta_{N/2} = a \cdot \cos \alpha$$

$$\Delta = \Delta_{N/2} + \Delta_{N/2} = \underline{\underline{2 a \cos \alpha}}$$

$$W^2 = W_0^2 + c^2 p^2$$

potoni: $W = c p$

$$c = v \cdot \lambda$$

$$h v = c p \Rightarrow p = \frac{h v}{c} = \frac{h}{\lambda}$$

elektroni: $\lambda_B = \frac{h}{p} = \frac{h}{m v}$

$$\Downarrow$$

$$m v = \frac{h}{\lambda_B} \Rightarrow v = \frac{h}{m \cdot \lambda_B}$$

$$\frac{v}{c} = \frac{h}{m \cdot \lambda_B \cdot c} \approx \underline{\underline{0,6 \cdot 10^{-2}}}$$

$$\frac{(6,62)^2 \cdot 10^{-68}}{8 \cdot 9,1 \cdot 10^{-31} \cdot 1,6 \cdot 10^{-19} \cdot (2,1)^2 \cdot 10^{-20}} = \frac{(6,62)^2 \cdot 10^6}{8 \cdot 9,1 \cdot 1,6 \cdot (2,1)^2} = 0,0853 \cdot 10^6 \text{ V}$$

7. Na kovinsko ploščico z izstopnim delom 3,5 eV pada snop svetlobe z valovno dolžino 90 nm. Ploščica je v vakuumu in v homogenem magnetnem polju z gostoto 0,0016 T. Magnetno polje je vzporedno s ploščico. Kako daleč od ploščice, v smeri pravokotno na površino ploščice, še lahko zaznamo izbite elektrone? Kakšno kinetično energijo imajo elektroni na tej maksimalni oddaljenosti? Koliko časa potrebujejo elektroni, da dosežejo maksimalno oddaljenost od ploščice?

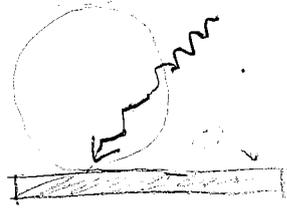
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$$W_0 = 3,5 \text{ eV}$$

$$\lambda = 90 \text{ nm}$$

$$B = 0,0016 \text{ T}$$



⊙ B

$$m_e = 9,1 \cdot 10^{-31} \text{ kg}$$

$$h = 6,62 \cdot 10^{-34} \text{ Js}$$

$$W_e = h\nu - W_0$$

$$c = \nu \cdot \lambda$$

$$\frac{mv^2}{2} = \frac{hc}{\lambda} - W_0 = 1,75 \cdot 10^{-19} \text{ J}$$

⇓

$$v = \sqrt{\frac{2}{m} \left(\frac{hc}{\lambda} - W_0 \right)} = 2,00 \cdot 10^6 \frac{\text{m}}{\text{s}}$$

rozženje v
mag. polju

$$e v B = m \frac{v^2}{r}$$

$$e B r = m v \Rightarrow$$

$$r = \frac{m v}{e B}$$

$$2r = \frac{2 m v}{e B} = 33,34 \cdot 10^{-4} \text{ m}$$

$$r = 16,67 \text{ cm}$$

$$t_m = \frac{2\pi r / 2}{v} = \frac{\pi r}{v} = 11,166 \cdot 10^{-9} \text{ s}$$

2. Radioaktivni vzorec ~~stoji na neki razdalji od stevea, ki~~ kaže po eni uri 7000 sunkov na minuto, po štirih urah pa 2000 sunkov na minuto. Koliko sunkov na sekundo je pokazal stevec na začetku opazovanja?

$$N = N_0 e^{-\lambda t}, \quad \frac{N_0}{2} = N_0 e^{-\lambda t_0} \Rightarrow \ln 2 = \lambda t_0 \Rightarrow \lambda = \frac{\ln 2}{t_0}$$

$$\frac{dN}{dt} = N_0 \lambda e^{-\lambda t}$$

$$\alpha = f \cdot \frac{dN}{dt} = f \cdot N_0 \lambda e^{-\lambda t} \Rightarrow$$

$$\alpha = \alpha_0 e^{-\lambda t} \quad \alpha_0 = f \cdot N_0 \cdot \lambda$$

$t = 0$	$\alpha_0 = ?$
$t_1 = 1^h = 60 \text{ min}$	$\alpha_1 = \frac{7000}{60} \text{ s}^{-1}$
$t_2 = 4^h = 240 \text{ min}$	$\alpha_2 = \frac{2000}{60} \text{ s}^{-1}$



$$\left. \begin{aligned} \alpha_1 &= \alpha_0 e^{-\lambda t_1} \\ \alpha_2 &= \alpha_0 e^{-\lambda t_2} \end{aligned} \right\} \Rightarrow \alpha_0, \lambda$$

$$\frac{\alpha_1}{\alpha_2} = e^{-\lambda(t_1 - t_2)} \Rightarrow \ln \frac{\alpha_1}{\alpha_2} = \lambda(t_2 - t_1) \Rightarrow$$

$$\Rightarrow \lambda = \ln \left(\frac{\alpha_1}{\alpha_2} \right) / (t_2 - t_1) = \underline{\underline{1.16 \cdot 10^{-4} \text{ s}^{-1}}}$$

$$t_0 = 5975,4 \text{ s} \text{ (mp. čas)}$$

$$\underline{\underline{\alpha_0 = \alpha_1 e^{\lambda t_1} = 177 \text{ s}^{-1}}}$$

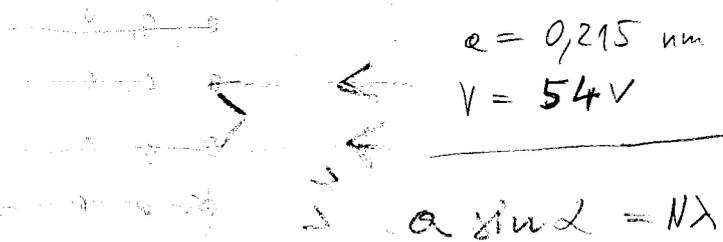
$$\tau = 8620$$

$$N = N_0 e^{-t/\tau}$$

$$177 \cdot 60 = 10620 \text{ min}^{-1}$$

10620 /min

3. Curek počasnih elektronov, ki jih pospešimo z napetostjo 54 V usmerimo pravokotno na površino kristala v kateri so kristalne ravnine v razmiku 0,215 nm. Pod katerim kotom glede na normalo na površino kristala se pojavi prvi ojačani curek odbitih elektronov?



$$N=1: \quad a \sin \alpha = \frac{1}{a} \cdot \frac{h}{\sqrt{2m e_0 V}}$$



$\alpha = 31^\circ$

fof: $W = cP$
 $P = \frac{h\nu}{c} = \frac{h}{\lambda}$

deli: $\lambda = \frac{h}{mv}$

$$\frac{1}{2}mv^2 = e_0 V = \frac{(mv)^2}{2m}$$

$$\lambda = \frac{h}{\sqrt{2m e_0 V}}$$

$$= 1,67 \cdot 10^{-10} \text{ m}$$

6. Točkasti izvor svetlobe z močjo 10 W emitira monokromatsko svetlobo valovne dolžine 0,55 μm. Poznano je, da človeško oko se lahko zazna svetlobni tok približno 60 fotonov v sekundi. Pri kateri maksimalni oddaljenosti človek se zazna omenjeni izvir svetlobe, če je premer njegove zenice 3 mm

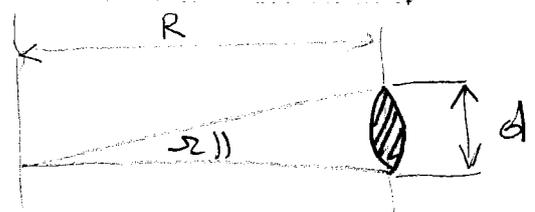
in kako zaradi sipanja svetlobe ne postane? ←

$$P_0 = 10 \text{ W}, d = 3 \cdot 10^{-3} \text{ m}$$

$$\lambda = 0,55 \mu\text{m}$$

$$n_m = \left(\frac{N}{t}\right)_{min} = 60/s$$

$$W = h\nu = \frac{hc}{\lambda}$$



$$\Omega = \frac{S}{R^2} = \frac{\pi d^2}{4R^2}$$

$$P = P_0 \frac{\Omega}{4\pi} = n \left(\frac{hc}{\lambda} \right)$$

$$\frac{P_0 \pi d^2}{16\pi R^2} = n_m \cdot h \frac{c}{\lambda} \Rightarrow R = \frac{d}{4} \sqrt{\frac{P_0 \lambda}{n_m \cdot h \cdot c}} = \underline{\underline{5,1 \cdot 10^5 \text{ m}}}$$

$$\frac{3 \cdot 10^{-3}}{4} \sqrt{\frac{10 \cdot 0,55 \cdot 10^{-6}}{60 \cdot 6,62 \cdot 10^{-34} \cdot 3 \cdot 10^8}}$$

$$h = 6,62 \cdot 10^{-34} \text{ Js}$$

A-L izpit IPP 1 z veljavno dolžino 0,025 nm

3. Pri opazovanju Comptonovega pojava v magnetnem polju z gostoto $2 \cdot 10^{-3}$ T se je sipal foton pod kotom 90° glede na vpadni žarek. Kakšen je radij kroga, ki ga opiše elektron v ravni pravokotni na magnetno polje? Računaj relativistično!

$B = 2 \cdot 10^{-3} \text{ T}$
 $\lambda = 0,025 \text{ nm}$
 $\vartheta = 90^\circ$
 $r = ?$

izena mag. polje

$v = \text{konst.}$

$\frac{d(m_{\text{fe}} v)}{dt} = e v B$

$P = m_{\text{fe}} v$

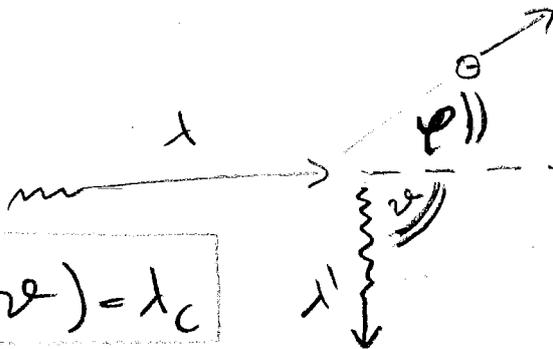
$m_{\text{fe}} a = e v B$

$a = \frac{v^2}{r} \Rightarrow$

$m_{\text{fe}} \frac{v^2}{r} = e v B$

$m_{\text{fe}} v = e r B$

$\lambda_c = \frac{h c}{m_e c^2} = 0,0024 \text{ nm}$



$\lambda' - \lambda = \lambda_c (1 - \cos \vartheta) = \lambda_c$

$\lambda' - \lambda = \lambda_c$

ohranitev gibalne količine:

x os: $\frac{h}{\lambda} = m_{\text{fe}} v \cos \varphi$

y os: $\frac{h}{\lambda'} = m_{\text{fe}} v \sin \varphi$

$\left(\frac{h}{\lambda}\right)^2 + \left(\frac{h}{\lambda'}\right)^2 = m_{\text{fe}}^2 v^2$

$m_{\text{fe}} v = e r B$

toraj:

$\lambda' - \lambda = \lambda_c \Rightarrow \lambda' = \lambda + \lambda_c = 0,0274 \text{ nm} = 2,74 \cdot 10^{-11} \text{ m}$

$\frac{1}{\lambda^2} + \frac{1}{\lambda'^2} = \left(\frac{e r B}{h}\right)^2 \Rightarrow r = \frac{h}{e B} \sqrt{\frac{1}{\lambda^2} + \frac{1}{\lambda'^2}} = 11,2 \text{ cm}$

$r = \frac{6,62 \cdot 10^{-34} \cdot 10^{11}}{1,6 \cdot 10^{-19} \cdot 2 \cdot 10^{-3}} \sqrt{\frac{1}{(2,74)^2} + \frac{1}{(2,5)^2}} = \frac{6,62}{3,2} \cdot 10^{-11} \cdot \sqrt{\dots} =$
 $= 0,112 \text{ m}$

V pospeševalniku dobimo protone s kinetično energijo 6000 MeV. Za koliko se hitrost protonov razlikuje od hitrosti svetlobe?

$$T = 6000 \text{ MeV}$$

$$m_p \cdot c_0^2 = 938 \text{ MeV}$$

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

$$\gamma = \left(\sqrt{1 - \frac{v^2}{c_0^2}} \right)^{-1}$$

$$W = T + W_0 = mc_0^2 \gamma = W_0 \left(\sqrt{1 - \frac{v^2}{c_0^2}} \right)^{-1}$$

$$\sqrt{1 - \frac{v^2}{c_0^2}} = \frac{W_0}{T + W_0}$$

$$1 - \frac{v^2}{c_0^2} = \frac{W_0^2}{(T + W_0)^2}$$

$$1 - \frac{W_0^2}{(T + W_0)^2} = \frac{v^2}{c_0^2}$$

$$\frac{T^2 + 2W_0T}{(T + W_0)^2} = \frac{v^2}{c_0^2}$$

$$\frac{v}{c_0} = \frac{\sqrt{T^2 + 2W_0T}}{T + W_0} = \underline{\underline{0,990}} = \underline{\underline{2,97 \cdot 10^8 \frac{m}{s}}}$$

$$\underline{\underline{\Delta v = c_0 - v = 2,75 \cdot 10^6 \frac{m}{s}}}$$

4. Katodo fotocelice osvetljujemo s svetlobo valovne dolžine 500 nm. Površina osvetljenega dela katode je 1 cm^2 . Kolikšna je gostota vpadnega svetlobnega toka, če je nasičeni električni tok skozi fotocelico enak 10 mA? Upoštevajte, da v povprečju le vsak deseti foton izbiije elektron.

$$\begin{aligned} \lambda &= 500 \text{ nm} \\ S &= 10^{-4} \text{ m}^2 \\ I_e &= 10 \text{ mA} \\ \eta &= 0,1 \end{aligned}$$

$$j_\nu = \frac{P}{S} = \frac{N \cdot h\nu \cdot (S \cdot dt)}{S \cdot dt} = \frac{dN}{dt} \frac{h\nu}{S}$$

$$I_e = \frac{de}{dt} = \eta \frac{dN}{dt} \cdot e_0$$

↓

$$\nu = \frac{c}{\lambda}$$

$$j_\nu = \frac{I_e}{\eta \cdot e_0} \cdot \frac{h \cdot c}{S \cdot \lambda} = \underline{\underline{2,48 \cdot 10^3 \text{ W/m}^2}}$$

3. Vzorec izdvojenega čistega polonija (${}_{84}\text{Po}^{210}$) ima maso 1 g. Kolikšen je pod normalnimi pogoji ($T = 273 \text{ K}$, $p = 10^5 \text{ N/m}^2$) volumen helija, ki je nastal iz α delcev, ki jih je emitiral vzorec polonija v toku prvega leta? Predpostavimo, da se vsi α delci pretvorijo v helij. Polonij emitira α delce z razpolovnim časom 138,4 dni.

1593

$$\tilde{m}_0 = 10^{-3} \text{ kg}$$

$$T = 273 \text{ K}$$

$$p = 10^5 \text{ N/m}^2$$

$$M_{\text{He}} = 4 \text{ g/mol}$$

$$t_{1/2} = 138.4 \text{ dni}$$

$$t = 1 \text{ leto (365 dni)}$$

$$V = ?$$

$$pV = \frac{\Delta m}{M} RT$$

$$V = \frac{\Delta m}{M} \cdot \frac{RT}{p}$$

$$N = N_0 e^{-\lambda t}$$

$$\frac{1}{2} = e^{-\lambda t_{1/2}} \rightarrow \ln \frac{1}{2} = -\lambda t_{1/2}$$

$$\ln 2 = \lambda t_{1/2} \Rightarrow \lambda = \ln 2 / t_{1/2}$$

$$N = N_0 e^{-\frac{\ln 2 t}{t_{1/2}}}$$

$$\Delta N = (N_0 - N) = N_0 \left(1 - e^{-\frac{\ln 2 t}{t_{1/2}}} \right)$$

$${}_{84}\text{Po}^{210}: \Delta \tilde{m} = \tilde{m}_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$\alpha, \text{He} \quad \Delta m = \frac{4}{210} \cdot \tilde{m}_0 \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$V = \frac{4 \cdot \tilde{m}_0 RT}{210 \cdot M p} \cdot \left[1 - \exp\left(-\frac{\ln 2 \cdot t}{t_{1/2}}\right) \right]$$

$$= \frac{4 \cdot 10^{-3} \cdot 8314 \cdot 273}{210 \cdot 4 \cdot 10^5} \cdot (0.83927) =$$

$$= 80,7 \cdot 10^{-6} \text{ m}^3$$

$$= \underline{\underline{80,7 \text{ cm}^3}}$$

Kolobovnj 20/31

8. Kolikšen je radij, po katerem se giblje proton s kinetično energijo 4 GeV v $\vec{A} \parallel \vec{M}$ prečnem homogenem magnetnem polju z gostoto 1 T?

Str. (krajša) str. 59

$$G = 10^9$$

$$W = T + W_0$$

$$W^2 = c^2 P^2 + W_0^2$$

$$(T + W_0)^2 = c^2 P^2 + W_0^2$$

$$T^2 + 2TW_0 + W_0^2 = c^2 P^2 + W_0^2$$

$$T^2 + 2TW_0 = c^2 P^2$$

$$P = \sqrt{2Tm + \frac{T^2}{c_0^2}}$$

$$\left. \begin{aligned} W_0 &= m c_0^2 \\ \frac{2TW_0}{c^2} &= 2Tm \end{aligned} \right\}$$

$$\frac{d(m\gamma v)}{dt} = F \quad \text{če } v = \text{konst.}$$

$$\left. \begin{aligned} m \frac{v^2}{r} &= e v B \\ m v &= e r B \end{aligned} \right\}$$

klonično

$$m\gamma \underline{a} = e \underline{v} \times \underline{B}$$

\Downarrow

$$P = m\gamma v = e r B$$

relativistično

$$\gamma = \left(1 - \frac{v^2}{c_0^2}\right)^{-1/2}$$

$$e r B = \sqrt{2Tm + \frac{T^2}{c_0^2}}$$

$$r = \frac{T}{e c_0 B} \sqrt{\frac{2 c_0^2 m}{T} + 1}$$

$$\underline{r} = \frac{T}{e c_0 B} \sqrt{1 + \frac{2W_0}{T}} = \underline{16 m}$$

$$\frac{4 \cdot 10^9 \cdot 1.6 \cdot 10^{-19}}{1.6 \cdot 10^{19} \cdot 3 \cdot 10^8} \sqrt{1 + \frac{2 \cdot 1.67 \cdot 10^{-27} \cdot 9 \cdot 10^{16}}{4 \cdot 10^9 \cdot 1.6 \cdot 10^{-19}}} =$$

$$\frac{4}{3} \cdot 10 \cdot \sqrt{1 + \frac{3.34 \cdot 9 \cdot 10^{-11}}{6.4 \cdot 10^{-10}}} = \underline{16.16 m}$$

$$\tilde{m} = m_0 \gamma$$

$$T = m c^2 - m_0 c^2 \quad m = m_0 \gamma$$

$$T = m_0 \gamma c^2 - m_0 c^2$$

$$\frac{T}{m_0 c^2} + 1 = \gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2}$$

$$1 - \frac{v^2}{c_0^2} = \frac{1}{\left(1 + \frac{T}{m_0 c^2}\right)^2}$$

$$\frac{v^2}{c_0^2} = 1 - \frac{1}{\left(1 + \frac{T}{m_0 c^2}\right)^2}$$

$$v = c_0 \sqrt{1 - \left(1 + \frac{T}{m_0 c^2}\right)^{-2}}$$

p. 102 + 2446

4. Ob času $t = 0$ imamo tolikšno količino polonija (${}_{84}\text{Po}^{210}$), da razpade vsako sekundo $1,85 \cdot 10^8$ njegovih jeder? Koliko gramov polonija nam bo še ostalo čez 100 dni? Razpolovni čas ${}_{84}\text{Po}^{210}$ je 138,4 dni. $N_A = 6 \cdot 10^{26} \text{ mol}^{-1}$, $M_{\text{Po}} = 210 \text{ g/mol}$

$$t = 0, A = \lambda N_0 = 1,85 \cdot 10^8 \text{ s}^{-1} = \frac{dN}{dt}$$

$$t_x = 100 \text{ dni}, m_{\text{Po}} = ?$$

$$t_{1/2} = 138,4 \text{ dni}$$

$$\lambda \cdot N_0 = \left(\frac{\ln 2}{t_{1/2}} \right) \cdot N_0 = A(0)$$

$$N_0 = \frac{A(0) \cdot t_{1/2}}{\ln 2} = \frac{1,85 \cdot 10^8 \cdot 138,4 \cdot 24 \cdot 3600}{\ln 2} = 3,18 \cdot 10^{15}$$

$$N_x = N_0 \cdot \exp\left(-\frac{\ln 2 \cdot t_x}{t_{1/2}}\right) = \frac{A(0) \cdot t_{1/2}}{\ln 2} \exp\left(-\frac{\ln 2 \cdot t_x}{t_{1/2}}\right) \approx 1,55 \cdot 10^{15}$$

$$m_{\text{Po}} = N_x \cdot m_1 = N_x \cdot \frac{m_1 \cdot N_A}{N_A} = \frac{M_{\text{Po}}}{N_A} \cdot N_x = \frac{M_{\text{Po}}}{N_A} \cdot \frac{A \cdot t_{1/2}}{\ln 2} \exp\left(-\frac{\ln 2 \cdot t_x}{t_{1/2}}\right)$$

$$m_{\text{Po}} = \frac{M_{\text{Po}}}{N_A} \cdot \frac{A \cdot t_{1/2}}{\ln 2} \cdot \exp\left[-\frac{\ln 2 \cdot t_x}{t_{1/2}}\right] = 6,77 \cdot 10^{-7} \text{ g}$$

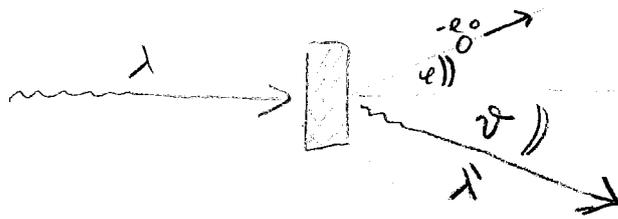
$$\frac{210 \cdot 1,85 \cdot 10^8 \cdot \text{s}^{-1} \cdot 138,4 \cdot 86,4 \cdot 10^3 \text{ s}}{6 \cdot 10^{26} \cdot \ln 2} \cdot \exp\left[-\frac{\ln 2 \cdot 100}{138,4}\right]$$

$$\frac{210 \cdot 1,85 \cdot 138,4 \cdot 86,4 \cdot 10^{11}}{6 \cdot 10^{26} \cdot \ln 2} \cdot 0,606 = 6,77 \cdot 10^{-7} \text{ g} = 6,77 \cdot 10^{-7} \text{ g}$$

X-žarek z valovno dolžino 0.1 nm se sipa na slabo vezanik elektronskih atomov v kristalni mreži. Žarek se sipa pod kotom 60° glede na vpadno smer. Za koliko se spremeni frekvenca sipanih X-žarkov glede na vpadne X-žarke?

Comptonova sipanja

fotoni: $W^2 = c^2 P^2 + W_0^2 \Rightarrow W = cP \Rightarrow P = \frac{W}{c_0} = \frac{h\nu}{c_0} = \frac{h}{\lambda}$ $c_0 = \nu\lambda$



$$W = h\nu = h \frac{c_0}{\lambda}$$

$$W = m_e c_0^2 + T$$

$$W^2 = c_0^2 P^2 + W_0^2, \quad W_0 = m_e c_0^2$$

ohranitev energije: $hc_0/\lambda + W_0 = hc_0/\lambda' + W$ (1)

ohranitev giba. kol. x-os: $h/\lambda = (h/\lambda') \cos \theta + P \cos \varphi$ (2)

ohranitev giba. kol. y-os: $(h/\lambda') \sin \theta = P \sin \varphi$ (3)

(1) $c_0 \left(\frac{h}{\lambda} - \frac{h}{\lambda'} \right) + W_0 = W$ } kvadriraj $\Rightarrow \left[c_0 \left(\frac{h}{\lambda} - \frac{h}{\lambda'} \right) + W_0 \right]^2 = W^2$ (A)

(2) $h/\lambda - (h/\lambda') \cos \theta = P \cos \varphi$
 (3) $(h/\lambda') \sin \theta = P \sin \varphi$ } kvadriraj $\Rightarrow \left[\frac{h}{\lambda} - \frac{h}{\lambda'} \cos \theta \right]^2 = P^2 \cos^2 \varphi$
 $(h/\lambda')^2 \sin^2 \theta = P^2 \sin^2 \varphi$ } $\cdot c_0^2$

$$c_0^2 \left(\frac{h}{\lambda} \right)^2 - 2c_0^2 \left(\frac{h}{\lambda} \right) \left(\frac{h}{\lambda'} \right) \cos \theta + c_0^2 \left(\frac{h}{\lambda'} \right)^2 = c_0^2 P^2$$
 (B)

od (A) odštejemo (B), upoštevamo $W^2 = c_0^2 P^2 + W_0^2$ in $\left(\frac{1}{\lambda} - \frac{1}{\lambda'} \right) \rightarrow \frac{\lambda' - \lambda}{\lambda \lambda'}$

$$\lambda' - \lambda = \lambda_c (1 - \cos \theta)$$

$$\lambda_c = \frac{hc_0}{W_0} = 0,024 \text{ \AA}$$

$$= 0,0024 \text{ nm}$$

Comptonova sipanja

Na zglajeno aluminijervo ploščico z odbojnostjo 0,81 pravokotno usmerimo svetlobni tok 0,0638 W. Ploščica se nahaja v vakuumu. Izračunaj silo s katero deluje svetlobni curek na ploščico?

fotoni: $W^2 = c^2 G^2 + W_0^2 > 0$

$$W = c G_{\nu} = h\nu$$

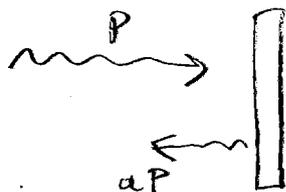
$$P = 0,0638 \text{ W}$$

$$a = 0,81$$

$$F = ?$$

$$\Rightarrow G_{\nu} = \frac{h\nu}{c_0} = \frac{h}{\lambda} = \frac{1}{\lambda} \cdot h$$

$$\lambda = \frac{2h}{\lambda}$$



$$P_{ab.} = (1-a)P$$

število abs. fotonov: $\frac{P_{ab.} \cdot t}{h\nu} = \frac{(1-a)P \cdot t}{h\nu}$

število odbitih fotonov: $\frac{aPt}{h\nu} = \frac{a \cdot P \cdot t}{h \cdot \nu}$

odbiti fotoni:

$$G_{\nu} = \frac{h\nu}{c_0}$$

$$G_{\nu} = -\frac{h\nu}{c_0}$$

absorbirani fotoni:

$$G_{\nu} = \frac{h\nu}{c_0}$$

$$G_{\nu} = 0$$

skupna gib. količina odbitih fotonov pred odbojem

$$\frac{a \cdot P \cdot t}{h \cdot \nu} \cdot \frac{h\nu}{c_0} = \frac{aPt}{c_0} \quad \text{in po odboju} \quad -\frac{aPt}{c_0}$$

skupna gib. količina abs. fotonov pred absorpcijo

$$\frac{(1-a)P \cdot t}{h \cdot \nu} \cdot \frac{h\nu}{c_0} = \frac{(1-a)P \cdot t}{c_0} \quad \text{in po absorpciji} \quad 0$$

SPREMEMBA SKUPNE GIB. KOLIČINE: $\Delta G = -\frac{aPt}{c_0} - \frac{aPt}{c_0} - \frac{(1-a)Pt}{c_0} =$

$$= \frac{-(1+a)Pt}{c_0} = \underline{F' \cdot t} \Rightarrow F' = \frac{-(1+a)P}{c_0}$$

Sila cureka na površje F je nasprotna invelo sile površje F' na

curek $\Rightarrow F = -F' = (1+a)P/c_0 = 3,86 \cdot 10^{-10} \text{ N}$

4. Foton z valovno dolžino $\lambda = 0,03 \text{ nm}$ se Comptonso sipa pod kotom 90° glede na njegovo prvotno smer. Poiščite spremembo valovne dolžine fotona in kinetično energijo elektrona po sipanju?

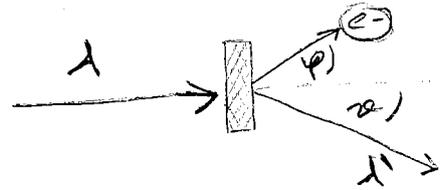
$$\lambda = 0,03 \text{ nm}$$

$$\vartheta = 90^\circ$$

$$\Delta\lambda = \lambda' - \lambda = \lambda_c \cdot (1 - \cos\vartheta) = 0,0024 \text{ nm}$$

\uparrow
 90°

$$\lambda' = 0,0324 \text{ nm}$$



dr. energiji:

$$\frac{hc}{\lambda} + W_0 = \frac{hc}{\lambda'} + W_0 + T$$

$$T = hc \left(\frac{1}{\lambda} - \frac{1}{\lambda'} \right) = \frac{h \cdot c \cdot \Delta\lambda}{\lambda \cdot \lambda'} = 0,49 \cdot 10^{-15} \text{ J} = 3,065 \text{ keV}$$

3. Foton z valovno dolžino $\lambda = 0,02 \text{ nm}$ se Comptonso sipa pod kotom 90° glede na njegovo prvotno smer. Poiščite spremembo valovne dolžine fotona in gibalno količino elektrona po sipanju?

$$\lambda = 0,02 \text{ nm}$$

$$\vartheta = 90^\circ$$

$$\Delta\lambda = \lambda' - \lambda = \lambda_c (1 - \cos\vartheta) = 0,0024 \text{ nm}, \quad \lambda' = 0,0224 \text{ nm}$$

\uparrow
 90°

dr. energiji:

$$\frac{hc}{\lambda} + W_0 = \frac{hc}{\lambda'} + W_0 + T \Rightarrow T = \frac{h \cdot c \cdot \Delta\lambda}{\lambda \cdot \lambda'} = 6,65 \text{ eV}$$

$$W^2 = c^2 P^2 + W_0^2$$

$$W^2 = (T + W_0)^2$$

$$0 = T^2 + 2TW_0 - c^2 P^2$$

$$P = \frac{1}{c} \sqrt{T^2 + 2 \cdot T \cdot W_0} = 4,41 \cdot 10^{-23} \text{ kg m s}^{-1}$$

6. Elektron se giblje v homogenem električnem polju z jakostjo 2 kV/m. $F_{\vec{v}}$
 Kolikšna je njegova kinetična energija po 1,5 μ s, če je elektron v začetku miroval? Računaj relativistično!

$$P^{\mu} = (m\gamma c_0, m\gamma \vec{v}) = \left(\frac{W}{c_0}, m\gamma \vec{v} \right)$$

$$T = W - W_0 = mc_0^2 (\gamma - 1)$$

$$\frac{d(m\gamma v)}{dt} = eE$$

$$m\gamma v = eEt$$

$$\frac{mv}{\sqrt{1 - (v/c)^2}} = eEt / mc$$

$$\frac{v/c}{\sqrt{1 - (v/c)^2}} = \frac{eE}{mc} \cdot t = \alpha t$$

$$\frac{v}{c} = \frac{\alpha t}{\sqrt{\alpha^2 t^2 + 1}} = \underline{\underline{0.8691}}$$

$$\Rightarrow \gamma = \frac{1}{\sqrt{1 - (v/c)^2}} = \underline{\underline{2.0218}}$$

$$T = W - W_0 = mc_0^2 (\gamma - 1) = 1.022 \cdot mc_0^2 = 0,523 \text{ MeV}$$

$$= \underline{\underline{8.37 \cdot 10^{-13} \text{ J}}}$$

$$m_e = 9,1 \cdot 10^{-31} \text{ kg}$$

$$t = 1,5 \mu\text{s}$$

$$E = 2 \text{ kV/m}$$

$$W_{\frac{1}{2}}(t = 1,5 \mu\text{s}) = ?$$

$$e = 1,6 \cdot 10^{-19} \text{ AS}$$

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

$$\alpha = \frac{eE}{mc} = \frac{1,6 \cdot 10^{-19} \cdot 2 \cdot 10^3}{9,1 \cdot 10^{-31} \cdot 3 \cdot 10^8} = \frac{16 \cdot 2 \cdot 10^{-17}}{27,3} = 1,172 \cdot 10^6$$

$$\alpha^2 t^2 = 3,0915$$

$$0,83 \cdot 10^{-13}$$

t,

4. Kolikšna je kinetična energija protona, ki kroži v prečnem homogenem magnetnem polju z gostoto 1,2 T po radiju 15 m?
 Računaj relativistično!

1893

$$B = 1,2 \text{ T}$$

$$R = 15 \text{ m}$$

$$T = ?$$

$$m_p c^2 = 938 \text{ MeV}$$

$$m_p = 1,672 \cdot 10^{-27} \text{ kg}$$

$$\frac{d(m_p \vec{v})}{dt} = e_0 \vec{v} \times \vec{B}$$

$$m_p a = e_0 v B$$

$$m_p \frac{v^2}{R} = e_0 v B \quad | \quad P = m_p v a = e_0 R B$$

$$\left. \begin{aligned} W^2 &= (T + W_0)^2 \\ W^2 &= c^2 p^2 + W_0^2 \end{aligned} \right\}$$

$$0 = -c^2 p^2 + T^2 + 2TW_0$$

$$T^2 + 2TW_0 - e_0^2 R^2 B^2 c^2 = 0$$

$$T = \frac{-2W_0 + \sqrt{4W_0^2 + 4e_0^2 R^2 B^2 c^2}}{2}$$

$$T = -W_0 + W_0 \sqrt{1 + \frac{e_0^2 R^2 B^2 c^2}{W_0^2}}$$

$$T = W_0 \left[\sqrt{1 + \frac{e_0^2 R^2 B^2 c^2}{W_0^2}} - 1 \right] = \underline{\underline{4,54 \text{ GeV}}}$$

$$\frac{(15)^2 (1,2)^2 9 \cdot 10^{16}}{(938) \cdot 10^{12}} =$$

1. Aktivnost nekega izvora, ki seva delce α z energijo 5 MeV v vse smeri enakomerno, je $7 \cdot 10^9$ razpadov v sekundi. Izvor je na oddaljenosti 0.5 m od površine kože, ki jo obsevamo z izvorom. Obsevalna površina je 20 cm^2 . Koliko časa moramo obsevati omenjeni del kože, da le ta prejme 10 J/m^2 . Predpostavi, da se aktivnost izvora med obsevanjem spremeni zanemarljivo malo.

A-L

1993

$$A_0 = 7 \cdot 10^9 \text{ s}^{-1}$$

$$r = 0.5 \text{ m}$$

$$S_0 = 20 \cdot 10^{-4} \text{ m}^2$$

$$j_t = 10 \text{ J/m}^2, W_\alpha = 5 \text{ MeV}$$

$$\tilde{N} = N_0 e^{-\lambda t}$$

$$A = -\frac{d\tilde{N}}{dt} = +\lambda N_0 e^{-\lambda t} = \lambda \tilde{N}(t)$$

↓

$$N \approx A_0 \cdot t$$

$$j_t = \frac{N \cdot W_\alpha \cdot S_0}{4\pi r^2} \cdot \frac{1}{S_0} = \frac{A_0 \cdot t \cdot W_\alpha}{4\pi r^2}$$

↓

$$t = \frac{j_t \cdot 4\pi r^2}{A_0 \cdot W_\alpha} = \frac{10 \cdot 4\pi \cdot 0.25}{7 \cdot 10^9 \cdot 5 \cdot 10^6 \cdot 1.6 \cdot 10^{-13}} =$$

$$= \underline{\underline{5610 \text{ s}}}$$

5610

1. Z izvorom delcev α obsevamo do enake doze dva enaka tumorja A in B, ki se nahajata 5cm (A), oziroma 7.5 cm (B) pod kožo. Tumor A moramo obsevati 20 minut. Koliko časa je potrebno obsevati tumor B? Razpolovna globina za delce α je 10 cm. Predpostavi, da se aktivnost izvora med obsevanjem spremeni zanemarljivo malo, absorpcijo delcev α v zraku pa zanemarimo.

$$\begin{aligned}
 x_A &= 0.05 \text{ m} \\
 x_B &= 0.075 \text{ m} \\
 t_A &= 1200 \text{ s} \\
 x_{1/2} &= 0.1 \text{ m} \\
 \hline
 t_B &= ?
 \end{aligned}$$

absorpcija:

$$N = N_0 e^{-\mu x}$$

$$\frac{1}{2} = \frac{N}{N_0} = e^{-\mu x_{1/2}}$$

$$\ln 2 = \mu x_{1/2}$$

$$N = N_0 e^{-\frac{\ln 2 \cdot x}{x_{1/2}}}$$

$$\tilde{N} = N_0 e^{-\lambda t}$$

$$A = -\frac{d\tilde{N}}{dt} = \lambda N_0 e^{-\lambda t} = \lambda \tilde{N}(t)$$

$$\Downarrow$$

$$N \cong A_0 \cdot t$$

$$D = \frac{N \cdot W_\alpha}{m} = \frac{N_0 e^{-\frac{\ln 2 \cdot x}{x_{1/2}}} \cdot W_\alpha}{m} \propto \frac{A_0 \cdot t \cdot e^{-\frac{\ln 2 \cdot x}{x_{1/2}}} \cdot W_\alpha}{m}$$

$$D_A = D_B$$

$$t_A e^{-\frac{\ln 2 \cdot x_A}{x_{1/2}}} = t_B e^{-\frac{\ln 2 \cdot x_B}{x_{1/2}}}$$

$$t_B = t_A \cdot e^{\frac{\ln 2}{x_{1/2}} (x_B - x_A)} = \underline{\underline{1427 \text{ s}}}$$

45. Elektron se giblje v homogenem električnem polju z jakostjo 1.75 kV/m. Kolikšna je njegova hitrost po 1 μ s, če elektron v začetku miruje? Kolikšno pot preteče elektron v tem času? Kolikšna je tedaj njegova kinetična energija? (5ht/54)

Ugovor?

X S

$$E = 1.75 \text{ kV/m}$$

$$m_e c^2 = 0.51 \text{ MeV}$$

$$t = 1 \mu\text{s}$$

$$\vec{F}' = \left(\frac{e\mu \vec{E} \cdot \vec{v}}{c_0}, e\mu (\vec{E} + \vec{v} \times \vec{B}) \right)$$

$$P' = (e\mu c_0, e\mu \vec{v}) = \left(\frac{W}{c_0}, \underbrace{e\mu \vec{v}}_{\vec{P}} \right)$$

$$dt = \mu d\tau$$

$$W = e\mu c_0^2$$

$$\vec{F}' = \frac{dP'}{d\tau} = \mu \left(\frac{dW}{c_0 dt}, \frac{d\vec{P}}{dt} \right) = \left(\frac{e\mu \vec{E} \cdot \vec{v}}{c_0}, e\mu (\vec{E} + \vec{v} \times \vec{B}) \right)$$

1 komponenta:

$$\frac{dW}{dt} = e \cdot \vec{E} \cdot \vec{v} \Rightarrow dW = e \vec{E} \cdot \frac{d\vec{r}}{dt} dt = e \vec{E} d\vec{r}$$

$$\Delta W = \int e \vec{E} d\vec{r} = - \underline{eU(r_1, r_2)} \quad \left. \vphantom{\Delta W} \right\} \text{OHRANITEV POLNE ENERGIJE}$$

2 komponenta:

$$\mu \frac{d\vec{P}}{dt} = e\mu (\vec{E} + \vec{v} \times \vec{B}) = e\mu \vec{E} \Rightarrow \frac{d\vec{P}}{dt} = e \vec{E} = \frac{d(m\mu v)}{dt}$$

$$m\mu v = e E t$$

$$s = \int_0^t v dt = c \int_0^t \frac{\alpha t}{\sqrt{\alpha^2 t^2 + 1}} dt = \frac{c}{2\alpha^2} \int_0^{\alpha^2 t^2 + 1} \frac{\alpha du}{\sqrt{u}} = \dots$$

$$\alpha^2 t^2 + 1 = u \Rightarrow 2\alpha^2 t dt = du \Rightarrow dt = \frac{du}{2\alpha^2 t}$$

$$\frac{m v}{\sqrt{1 - \frac{v^2}{c^2}}} = e E t / mc$$

$$\frac{v/c}{\sqrt{1 - (v/c)^2}} = \frac{e E}{mc} t = \alpha t$$

$$\Delta W = \int e E ds = \underline{e E s} = T = W - W_0 = m_e c^2 (\gamma - 1)$$

$$\frac{v}{c} = \frac{\alpha t}{\sqrt{\alpha^2 t^2 + 1}}$$

2. naloga in dodatki naredi iz tega !!

5. Aktivnost radioaktivnega izvora, ki seva delce α z energijo 5 MeV, je $7 \cdot 10^3$ razpadov v sekundi. Izračunaj, koliko časa mora ostati ta izvir v tumorju, da bo le ta prejel dozo 20 J/kg. Upoštevaj, da se ¹⁸⁸² aktivnost radioaktivnega izvora med obsevanjem tumorja spremeni zanemarljivo malo, vsi delci α pa se absorbirajo v tumorju. Masa tumorja je 1 kg.

$$A = 7 \cdot 10^3 \text{ s}^{-1}$$

$$W_{\alpha} = 5 \text{ MeV}$$

$$D = 20 \text{ J/kg}$$

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

$$N = N_0 e^{-\lambda t}$$

$$A = -\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$$

$$D = \frac{\Delta N \cdot W_{\alpha}}{m} \approx \frac{A \cdot t \cdot W_{\alpha}}{m}$$

↓

$$t = \frac{D \cdot m}{A \cdot W_{\alpha}} = \underline{\underline{3571 \text{ s}}} \approx \underline{\underline{1 \text{ h}}}$$

$$1 \text{ e.u.m.} = 1,66 \cdot 10^{-27}$$

1892

1. Kolikšno električno napetost mora preleteti v začetku mirujoče He jedro, da po prihodu v prečno homogeno magnetno polje z gostoto 1 T začelo krožiti po krožnem tiru s polmerom 15 m?

4.8.

$$(u_{pe} = 4,002603)$$

$$B = 1 \text{ T}, \quad e = 2e_0$$

$$r = 15 \text{ m}$$

$$m = 6,644 \cdot 10^{-27} \text{ kg}$$

$$P = m \gamma v$$

$$\frac{dP}{dt} = \frac{d}{dt} (m \gamma v) = e v B$$

$$|\vec{v}| = e a t \Rightarrow \frac{dv}{dt} = a \Rightarrow \frac{d}{dt} (m \gamma v) = m \gamma a = e v B$$

$$a = \frac{v^2}{r}$$

$$T = e \cdot U$$

$$W = T + W_0, \quad W_0 = m_0 c^2$$

$$W^2 = c^2 p^2 + W_0^2$$

$$0 = c^2 p^2 - T^2 - 2T W_0$$

$$p^2 = 2T m + \frac{T^2}{c^2}$$

$$P = m \gamma v = e r B$$

$$P^2 = e^2 r^2 B^2$$

$$2T m + \frac{T^2}{c^2} = e^2 r^2 B^2$$

$$e = 2e_0$$

$$T^2 + 2m c^2 T - r^2 e^2 B^2 c^2 = 0$$

$$T = \frac{-2m c^2 \pm \sqrt{4m^2 c^4 - 4r^2 e^2 B^2 c^2}}{2} \Rightarrow$$

$$e U = 2e_0 U = T = \frac{1}{2} \left(-2m c^2 + 2m c^2 \sqrt{1 + \frac{r^2 e^2 B^2}{m c^2}} \right)$$

$$U = \frac{m \cdot c^2}{2 \cdot e_0} \cdot \left(\sqrt{1 + \frac{r^2 \cdot 4e_0^2 \cdot B^2}{m^2 \cdot c^2}} - 1 \right) = 3 \cdot 10^9 \text{ V}$$



7

$N = \frac{1}{2}$

kolonij strani
elektrons

vojnaš miru viti

Str 46/51

AT.3

Kolikšno napetost mora preleteti proton, da bo prihode v homogeno magnetno polje z gostoto 1 T krošiti po radiju 16 m. (μ_0, e, v) \Rightarrow ($\frac{W}{e}, P$)

$m_p c^2 = 938 \text{ MeV}$

$\frac{dW}{dt} = e E v$

$dW = (e E v) dt$

$dW = \int e E dr$

$dW = - \int e E dr$

$dW = -e [W_2 - W_1]$

$T_2 - T_1 = -e U(r_2) + e U(r_1)$

$T_2 + e U(r_2) = T_1 + e U(r_1)$

$\Delta T = e \Delta U$

$T = e U$

splošno:

$\vec{F}^{\mu} = (e \gamma \vec{E} \cdot \vec{v} / c_0, \gamma e (\vec{E} + \vec{v} \times \vec{B}))$

$\vec{F}^{\mu} = \frac{dP^{\mu}}{d\tau} = \gamma \left(\frac{1}{c_0} \frac{dW}{dt}, \frac{d\vec{P}}{dt} \right)$

$dt = \gamma d\tau, \quad P^{\mu} = \left(\frac{W}{c_0}, \vec{P} \right)$

splošno:

$\vec{F}^{\mu} = (e \gamma \vec{E} \cdot \vec{v} / c_0, \gamma e (\vec{E} + \vec{v} \times \vec{B}))$

$\vec{F}^{\mu} = \frac{dP^{\mu}}{d\tau} = \gamma \left(\frac{1}{c_0} \frac{dW}{dt}, \frac{d\vec{P}}{dt} \right)$

$dt = \gamma d\tau$

$P^{\mu} = \left(\frac{W}{c_0}, \vec{P} \right)$

$E = - \frac{dU}{dr}$

$P = m \gamma v$

$W_0 = m c_0^2$

$\gamma = \left(1 - \frac{v^2}{c_0^2} \right)^{-1/2}$

$W = T + W_0$
 $W^2 = c^2 P^2 + W_0^2 \Rightarrow P^2 = \frac{W^2 - W_0^2}{c^2} = \frac{T^2}{c^2}$

$\frac{dP}{dt} = m \gamma a = e v B$

$R = \frac{v^2}{r}$

$P = m \gamma v = r r B$

$e^2 r^2 B^2 = P^2$

$r^2 e^2 B^2 = \frac{T^2}{c_0^2} \quad / \cdot c_0^2$

$T^2 + 2 m c^2 T - r^2 e^2 B^2 c^2 = 0$

$T = \frac{-2 m c^2 \pm \sqrt{4 m^2 c^4 + 4 r^2 e^2 B^2 c^2}}{2}$

$T = \left(-2 m c^2 + 2 m c^2 \sqrt{1 + \frac{r^2 e^2 B^2 c^2}{m^2 c^4}} \right) / 2$

$e U = -m c^2 + m c^2 \sqrt{1 + \frac{r^2 e^2 B^2 c^2}{m^2 c^4}}$

$U = \frac{m c^2}{e} \left(\sqrt{1 + \frac{r^2 e^2 B^2 c^2}{m^2 c^4}} - 1 \right)$

$U = 3.95 \cdot 10^8 \text{ V}$

pr. 08.11.2014

6. Pri premočrtnem in skoraj neoviranem gibanju skozi stevec napravijo mezioni π pot 1,20 m. Mezioni se gibljejo skozi stevec s hitrostjo $2,85 \cdot 10^8$ m/s. Kolikšen del mezonov razpade v števcu, če je njihov razpolovni čas $1,7 \cdot 10^{-8}$ s?

$$v = 2,85 \cdot 10^8 \text{ m/s}$$

$$x = 1,2 \text{ m}$$

$$t_{1/2} = 1,7 \cdot 10^{-8} \text{ s}$$

$$N = N_0 e^{-\frac{\ln 2 \cdot t}{t_{1/2}}}$$

$$\frac{N}{N_0} = e^{-\lambda t_{1/2}} \Rightarrow \ln 2 = \lambda t_{1/2} \Rightarrow \lambda = \frac{\ln 2}{t_{1/2}}$$

$$t'_{1/2} = \gamma \cdot t_{1/2}$$

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

$$t = \frac{x}{v}, \quad \frac{N_0 - N}{N_0} = 1 - e^{-\frac{v \cdot \ln 2}{v \cdot \gamma \cdot t_{1/2}}} = \underline{\underline{0,052}} \quad \checkmark$$

$$\gamma = 3,2$$

mezon π (pion)

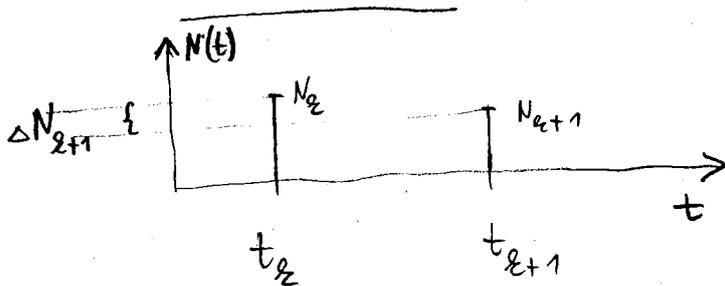
274 x masi elektrona

~~378 s~~
 Pri radioaktivnem razpadu izotopa broma (${}_{35}\text{Br}^{78}$) je v časovnem intervalu 60 sekund verjetnost razpada 0,1042. Kakšen je razpolovni čas tega izotopa broma?

$$\Delta t = 60 \text{ s}$$

$$P = 0,1042$$

$$t_{1/2} = ?$$



$$dN = -N \lambda dt \Rightarrow N_{2+1} = N_2 e^{-\lambda \Delta t}$$

$$N = N_0 e^{-\lambda t}$$

$$\frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}}$$

$$\ln 2 = \lambda t_{1/2} \Rightarrow t_{1/2} = \frac{\ln 2}{\lambda}$$

$$t_{1/2} = \frac{\ln 2}{\lambda}$$

$$\Delta t = t_{2+1} - t_2$$

$$\Delta N_{2+1} = N_2 - N_{2+1}$$

$$P = \frac{N_2 - N_{2+1}}{N_2} = 1 - \frac{N_{2+1}}{N_2} = 1 - e^{-\lambda \Delta t}$$

$$e^{-\lambda \Delta t} = 1 - P \Rightarrow$$

$$\Rightarrow \lambda \Delta t = \ln \left[\frac{1}{1 - P} \right] \Rightarrow \lambda = \frac{1}{\Delta t} \ln \left[\frac{1}{1 - P} \right]$$

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2 \cdot \Delta t}{\ln \left[\frac{1}{1 - P} \right]} = \underline{\underline{378 \text{ s}}}$$

378 s

${}_{35}\text{Br}^{78} \rightarrow \text{A} \approx \text{normalno sterilno}$
 \downarrow
 $\text{Z} \approx \text{umirajo sterilno}$

V pospeševalniku dobimo protone s kinetično energijo 6000 MeV. Za koliko se hitrost protonov razlikuje od hitrosti svetlobe?

$$T = 6000 \text{ MeV}$$

$$m_p \cdot c_0^2 = 938 \text{ MeV}$$

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

$$\gamma = \left(\sqrt{1 - \frac{v^2}{c_0^2}} \right)^{-1}$$

$$W = T + W_0 = mc_0^2 \gamma = W_0 \left(\sqrt{1 - \frac{v^2}{c_0^2}} \right)^{-1}$$

$$\sqrt{1 - \frac{v^2}{c_0^2}} = \frac{W_0}{T + W_0}$$

$$1 - \frac{v^2}{c_0^2} = \frac{W_0^2}{(T + W_0)^2}$$

$$1 - \frac{W_0^2}{(T + W_0)^2} = \frac{v^2}{c_0^2}$$

$$\frac{T^2 + 2W_0T}{(T + W_0)^2} = \frac{v^2}{c_0^2}$$

$$\frac{v}{c_0} = \frac{\sqrt{T^2 + 2W_0T}}{T + W_0} = \underline{\underline{0,990}} = \underline{\underline{2,97 \cdot 10^8 \frac{m}{s}}}$$

$$\underline{\underline{\Delta v = c_0 - v = 2,75 \cdot 10^6 \frac{m}{s}}}$$