FIZIKALNA OPTIKA

INTERFERENCIJA

- kada se dva vala istovremeno nađu u istoj točki prostora
- KOHERENTNI IZVORI - razlika faza dva ista vala je vremenski nepromjenjiva

Rezultantni val: $E(t_0,x) = \vec{E}_1(t_0,x_1) + \vec{E}_2(t_0,x_2)$

$$= E_0\cos\left(\omega\left(t_0 - \frac{n_1x_1}{c}\right)\right) + E_0\cos\left(\omega\left(t_0 - \frac{n_2x_2}{c}\right)\right)$$

$$= \left\{2E_0\cos\left[\frac{\omega}{2c}(n_1x_1 - n_2x_2)\right]\right\}\cdot \cancel{\cos}\ \sin?\left[\omega t_0 - \frac{\omega}{2c}(n_1x_1 + n_2x_2)\right]$$

$$\Delta\phi = \frac{\omega}{c}(n_1x_1 - n_2x_2) = \frac{2\pi}{\lambda}(n_1x_1 - n_2x_2) = \frac{2\pi}{\lambda}\delta$$

↳ razlika optičkih puteva

$$E_{0,rez} = \left\{2E_0\cos\left[\frac{\omega}{2c}(n_1x_1 - n_2x_2)\right]\right\} = 2E_0\cos\left(\frac{\Delta\phi}{2}\right)$$

KONSTRUKTIVNA

$$\cos\left(\frac{\Delta\phi}{2}\right) = \pm 1 \Rightarrow \frac{\Delta\phi}{2} = m\cdot\pi$$

$$\delta_{max} = m\cdot\lambda,\ n_1 \neq n_2 \Rightarrow (n_2x_2 - n_1x_1) = \lambda m$$

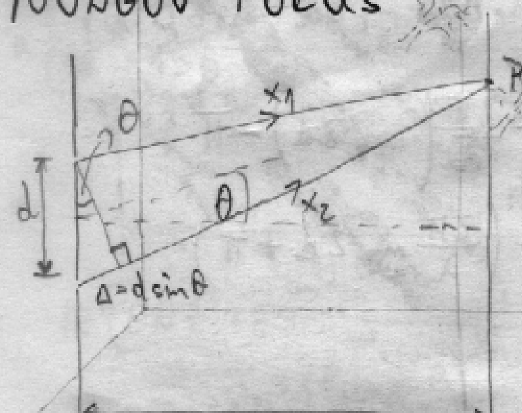
$n_1 = n_2 \Rightarrow I_0 = 4I$ - INTEZITET

DESTRUKTIVNA

$$\cos\left(\frac{\Delta\phi}{2}\right) = 0 \Rightarrow \frac{\Delta\phi}{2} = (2m+1)\frac{\pi}{2}$$

$$\delta_{min} = (2m+1)\frac{\lambda}{2}$$

YOUNGOV POKUS



$$E_p = \left\{2E_0\cos\left[\frac{\omega}{2c}(n_1x_1 - n_2x_2)\right]\right\}\cos\left[\omega t_0 - \frac{\omega}{2c}(n_1x_1 + n_2x_2)\right]$$

$n_1 = n_2 \simeq 1$

$$\delta = n\cdot|x_1 - x_2| = \Delta = d\sin\theta$$

$$d\sin\theta_{max} = m\cdot\lambda$$

$$d\sin\theta_{min} = (2m+1)\frac{\lambda}{2}$$

$$tg\,\theta = \frac{y}{D} \qquad tg\,\theta \simeq \sin\theta \simeq \theta$$

$$\frac{\Delta}{d} \simeq \frac{y}{D}$$

$$y_{maks} = m\frac{\lambda D}{d} \Rightarrow \Delta y_{maks} = \frac{\lambda D}{d}$$

$$y_{min} = (2m+1)\frac{\lambda D}{2d}$$

INTENZITET $\left[\frac{W}{m^2}\right]$

- $I_0 \propto \frac{1}{2} \cdot E_0^2$

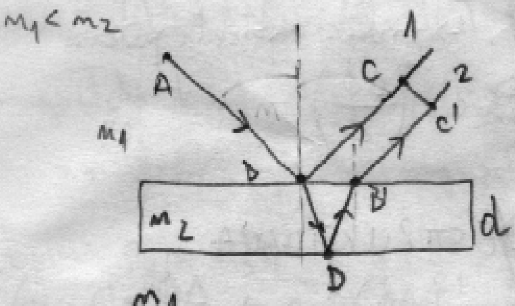
$$I \propto \left(E_{0\,rez}\right)^2 = (2E_0)^2\left[\cos\left(\frac{\Delta\phi}{2}\right)\right]^2$$

$$I_{kon} = I_0 \cos^2\left(\frac{\Delta\phi}{2}\right) = I_0 \cos^2\left(\frac{1}{2}\frac{2\pi}{\lambda}\delta\right)$$

$$= I_0 \cos^2\left[\frac{\pi}{\lambda}(n_1x_1 - n_2x_2)\right] = I_0 \cos^2\left(\frac{\pi}{\lambda}\Delta\right)$$

$$= I_0 \cos^2\left(\frac{\pi}{\lambda} d \sin\theta\right)$$

TANKI LISTIĆI



$$L_1 = n_1\overline{AB} + n_1\overline{BC}$$

$$L_2 = n_1\overline{AB} + n_2\overline{BD} + n_2\overline{DB'} + n_1\overline{B'C'}$$

$$\overline{BD} = \overline{DB'} = d$$

$$\overline{BC} \simeq \overline{B'C'}$$

$$\phi_1 = \omega t - \frac{2\pi}{\lambda}\left(n_1 \cdot \overline{AB} + n_1\overline{BC}\right) + \pi$$

$$\phi_2 = \omega t - \frac{2\pi}{\lambda}\left(n_1\overline{AB} + n_2 2d + n_1\overline{B'C'}\right)$$

$$\Delta\phi = \phi_2 - \phi_1 = -\frac{2\pi}{\lambda}\left(n_2 2d\right) - \pi$$

$$= -\left(\frac{2\pi}{\lambda}n_2 2d + \pi\right)$$

$$E_{rez} = 2E_0\cos\left(\frac{\Delta\phi}{2}\right)$$

MAX: $\frac{1}{2}\left(\frac{2\pi}{\lambda}n2d + \pi\right) = m\pi$

$$\frac{2\cancel{\pi}}{\lambda}n_2 2d = 2m\cancel{\pi} - \cancel{\pi}$$

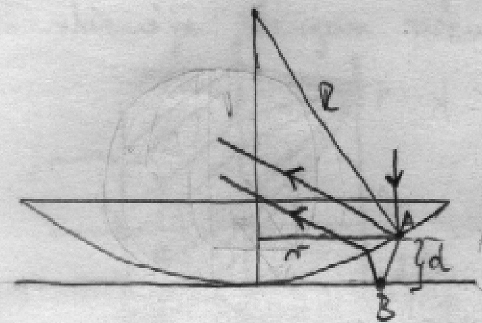
$$d = \frac{2m-1}{2n_2}\frac{\lambda}{2}$$

MIN $= \frac{1}{2}\left(\frac{2\pi}{\lambda}n2d + \pi\right) = (2m-1)\frac{\pi}{2}$

$$\frac{2\cancel{\pi}}{\lambda}n2d = (2m-2)\cancel{\pi}$$

$$d = \frac{m-1}{n_2}\frac{\lambda}{2}$$

NEWTONOVI KOLOBARI



$$|\Delta\phi| = \phi_2 - \phi_1 = \frac{2\pi}{\lambda}\cdot 2d + \pi$$
$$= \left(\frac{2\pi}{\lambda}\cdot 2d + \pi\right)$$

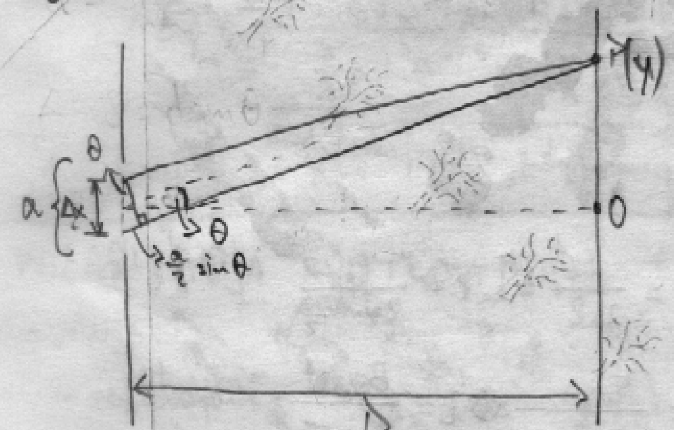
Dva puta se reflektira pa nema promjene faze.

MAX: $\frac{\Delta\phi}{2} = m\pi$ MIN: $\frac{\Delta\phi}{2} = (2m+1)\frac{\pi}{2}$

$d_{max} = \frac{1}{2}(2m-1)\frac{\lambda}{2}$ $d_{min} = \frac{1}{2}m\lambda$

$$r^2 + (R-d)^2 = R^2$$
$$d = \frac{r^2}{2R}$$
$$r_{max} = \sqrt{\frac{(2m-1)\lambda}{2}\cdot R}$$
$$r_{min} = \sqrt{R m \lambda}$$

OGIB NA PUKOTINI



$$\Delta = \Delta x \sin\theta = \delta$$
$$\frac{\Delta\phi}{2} = \frac{\pi}{\lambda}\cdot\Delta x \sin\theta$$

MIN: $\frac{\Delta\phi}{2} = \pm\frac{\pi}{2}$

$a\sin\theta_{min} = \pm 1\cdot\lambda$

$a\sin\theta_{min} = m\lambda$

INTENZITET:

$$I = I_0 \frac{\sin^2\left(\frac{\pi}{\lambda}N\Delta x\sin\theta\right)}{\sin^2\left(\frac{\pi}{\lambda}\Delta x\sin\theta\right)}, \quad N\cdot\Delta x = a, \quad \Delta x \to 0$$

$$\Rightarrow \sin\left(\frac{\pi}{\lambda}\Delta x\sin\theta\right) \simeq \frac{\pi}{\lambda}\Delta x\sin\theta = \frac{1}{N}\frac{\pi}{\lambda}a\sin\theta$$

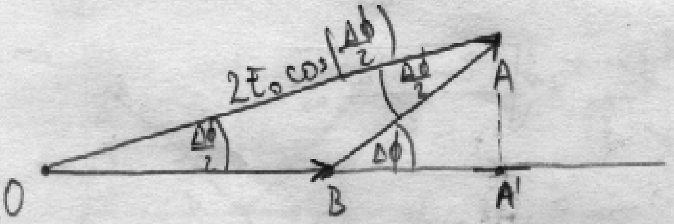
$$I \sim \frac{\sin^2\left(\frac{\pi}{\lambda}a\sin\theta\right)}{\left(\frac{\pi}{\lambda}a\sin\theta\right)^2} \Rightarrow I = I_0\frac{\sin^2 z}{z^2}$$
$$z = \frac{\pi}{\lambda}a\sin\theta$$

$$I = I_0\left(\frac{\sin z}{z}\right)^2, \quad z = \frac{\Delta\phi}{2} = \frac{\pi a}{\lambda}\sin\theta$$

$$I = 0, \quad \sin z = 0, \quad z = m\pi$$
$$\Rightarrow \frac{\pi a}{\lambda}\sin\theta = m\pi$$
$$a\sin\theta = m\lambda$$
$$a = \lambda, \quad \theta_{min,1} = 90^\circ$$

INTERFERENCIJA NA DVIJE PUKOTINE

$$E_1 = E_0 \cos(\omega t - k_1 x_1)$$
$$= E_0 \cos\phi_1$$
$$E_2 = E_0 \cos\phi_2$$
$$\Delta\phi = \phi_2 - \phi_1 = (\omega t - k_2 x_2) - (\omega t - k_1 x_1) = k_1 x_1 - k_2 x_2$$
$$k_i = \frac{2\pi}{\lambda_i} = \frac{2\pi}{\left(\frac{\lambda}{n_i}\right)} = 2\pi \frac{n_i}{\lambda}$$
$$E_2 = E_0 \cos(\phi_1 + \Delta\phi)$$



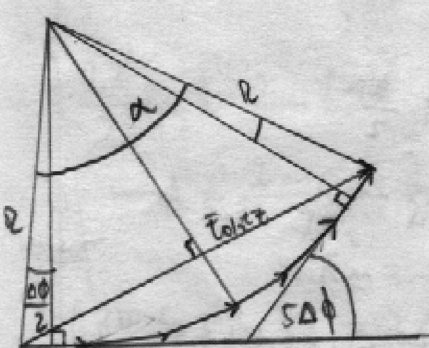
ΔOAB : $\alpha = \frac{\Delta\phi}{2}$

$$\sin\alpha = \frac{\overline{AA'}}{E_{0/rez}} = \sin\frac{\Delta\phi}{2}$$

$\Delta AA'B$ $\sin\Delta\phi = \frac{\overline{AA'}}{E_0}$

$$E_0 \sin\Delta\phi = E_{0/rez} \sin\frac{\Delta\phi}{2}$$
$$E_{0/rez} = 2E_0 \cos\frac{\Delta\phi}{2}$$

Poopćenje na 6 izvora:



$$\alpha = 6\Delta\phi$$
$$\sin\frac{\Delta\phi}{2} = \frac{E_0}{2R} \Rightarrow R = \frac{E_0}{2\sin\frac{\Delta\phi}{2}}$$
$$\sin\frac{\alpha}{2} = \frac{E_{0/rez}}{2R} \Rightarrow R = \frac{E_{0/rez}}{2\sin\frac{\alpha}{2}}$$
$$E_{0/rez} = E_0 \frac{\sin\frac{\alpha}{2}}{\sin\frac{\Delta\phi}{2}} = E_0 \frac{\sin\frac{6\Delta\phi}{2}}{\sin\frac{\Delta\phi}{2}}$$
$$I(\theta) = \frac{I_0}{36} \cdot \frac{\sin^2\frac{6\Delta\phi}{2}}{\sin^2\frac{\Delta\phi}{2}}$$

MAX: $d\sin\theta_m = m\lambda$

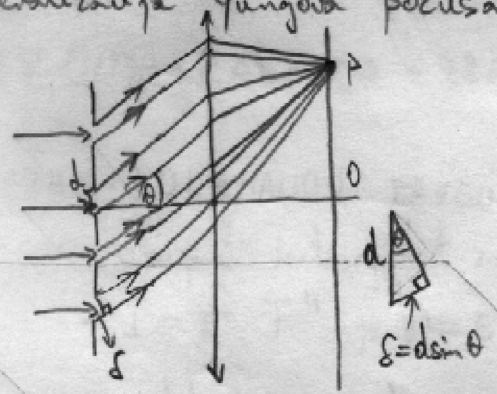
MIN: $d\sin\theta = m\frac{\lambda}{N}$ $(m \neq kN)$

SPOR. MAX: $\frac{\pi}{\lambda} d\sin\theta = \pm\frac{3\pi}{N}, \pm\frac{5\pi}{N}, \dots$

N izvora $I(\theta) = \frac{I_0}{N^2} \frac{\sin^2\frac{N\Delta\phi}{2}}{\sin^2\frac{\Delta\phi}{2}}$, $\Delta\phi = \frac{2\pi}{\lambda} d\sin\theta$

OPTIČKA REŠETKA

- generalizacija Yungova pokusa



$$E_{Olre} = E_0 \frac{\sin\frac{N\Delta\phi}{2}}{\sin\frac{\Delta\phi}{2}} \qquad I = I_0 \frac{\sin^2\frac{N\Delta\phi}{2}}{\sin^2\frac{\Delta\phi}{2}}$$

MAX: $\frac{\Delta\phi}{2} = 0, \pm\pi, \pm 2\pi, \dots = m\pi$

$$d\sin\theta_m = m\lambda$$

MIN: $d\sin\theta_{min} = m\frac{\lambda}{N}$

INTERFERENCIJA NA ŠIROKOJ PUKOTINI

$$E = 2E_0\cos\left(\frac{\Delta\phi}{2}\right) = 2E_0\cos\left(\frac{\pi}{\lambda}\sin\theta\right)$$

$$E_0 \to E_0\frac{\sin y}{y} \ ; \ y = \frac{1}{2}\cdot\frac{2\pi}{\lambda}a\sin\theta$$

Za dva izvora:

$$\cos\left(\frac{\Delta\phi}{2}\right) = \frac{\sin\left(\frac{2\Delta\phi}{2}\right)}{\sin\left(\frac{\Delta\phi}{2}\right)}$$

$$E = E_0\frac{\sin y}{y}\cdot\frac{\sin\left(\frac{2\Delta\phi}{2}\right)}{\sin\left(\frac{\Delta\phi}{2}\right)}$$

$$E = E_0 \underbrace{\frac{\sin\left(\frac{\pi}{\lambda}a\sin\theta\right)}{\frac{\pi}{\lambda}a\sin\theta}}_{\text{difrakcija}} \cdot \underbrace{\frac{\sin\left(2\frac{\pi}{\lambda}d\sin\theta\right)}{\sin\left(\frac{\pi}{\lambda}d\sin\theta\right)}}_{\text{interferencija}}$$

$$I = I_0\left(\frac{\sin\left(\frac{\pi}{\lambda}a\sin\theta\right)}{\frac{\pi}{\lambda}a\sin\theta}\right)^2\cdot\left(\frac{\sin\left(N\frac{\pi}{\lambda}d\sin\theta\right)}{\sin\left(\frac{\pi}{\lambda}d\sin\theta\right)}\right)^2$$

d - razmak među pukotinama

a - širina pukotine

POLARIZACIJA SVJETLOSTI

DOBIVANJE:

- refleksijom - okomita na ravninu refleksije
- raspršenjem
- dvolom - dvije zrake okomito polarizirane
- dikroizam

DIKROIZAM - "polaroidi"

- Malusov zakon

$$I(\theta) = I(0)\cos^2\theta$$

POLARIZACIJA REFLEKSIJOM

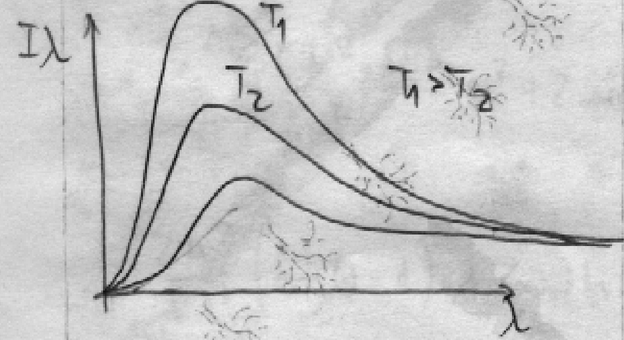
- Brewsterov kut
- $\mathrm{tg}\,\alpha_B = n$
- lomljena ⊥ reflektiranu

ZRAČENJE i ATOMI

ZAKONI ZRAČENJA – ZRAČENJE APSOLUTNO CRNOG TIJELA

STEFAN-BOLZMANOV ZAKON

- ukupni intenzitet zračenja crnog tijela ovisan je o temp.
- $I = \sigma \cdot T^4$, $\sigma = 5{,}67 \cdot 10^{8} \frac{W}{m^2 K^4}$
- spektralna gustoća zračenja : $I_\lambda = \frac{dI}{d\lambda}$



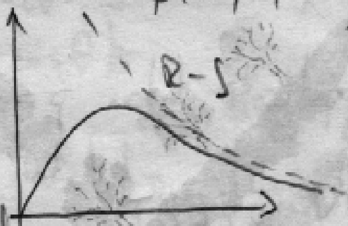
$I_\lambda = f(\lambda, T)$

Wienov zakon pomaka: $\lambda_m \cdot T = k_w$, $k_w = 0{,}0029\ m \cdot K$;

$f(\lambda, T) = \frac{A}{\lambda^5} e^{-\frac{b}{\lambda T}}$

- loše za velike λ

PLANCKOV ZAKON



Rayleigh-Jeans-ova formula

- ultraljubičasta katastrofa
- dobije se beskonačno velik intenzitet
- $f(\nu, T) = \frac{2\pi}{c^2} \nu^2 kT$
- $f(\lambda, T) = \frac{2\pi c kT}{\lambda^4}$

PLANCK:

- energija u $h\nu$ paketićima
- $E_0 = h\nu = \frac{hc}{\lambda}$ – minimalna energija, kvant energije

$$f(\lambda, T) = \frac{2\pi h c^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1}$$

$$I = \int_0^\infty f(\lambda, T)\, d\lambda = \frac{2\pi^5 k^4}{15 c^2 h^3} \cdot T^4$$ – STEFAN-BOLTZMAN

PLANCKOV IZVOD

$$\bar{E} = \sum_n E_n P_n$$

$$E_n = n h\nu$$

$P_n = P(E_n)$ - vjerojatnost da $P_n = c' \cdot e^{-\frac{E}{kT}}$
je na temp. T pobuđeno stanje E_n

$$\sum_n P_n = 1 \qquad \sum_n P_n = c' \sum_n e^{-\frac{nh\nu}{kT}}, \quad \frac{h\nu}{kt} \to x$$

$$= c' \sum_n e^{-nx}$$

$$= c'\left(1 + e^{-x} + e^{-2x} + e^{-3x} + \dots\right) =$$

$$= c' \underbrace{\left(1 + e^{-x} + (e^{-x})^2 + (e^{-x})^3\right)}_{\frac{1}{1-e^{-x}}}$$

$$c' \frac{1}{1-e^{-x}} = 1$$

$$c' = 1 - e^{-x}$$
$$= 1 - e^{-\frac{h\nu}{kT}}$$

$$\bar{E} = \sum_n E_n P_n = h\nu\left(1 - e^{-\frac{h\nu}{kT}}\right) \cdot \sum_n n \cdot e^{-\frac{nh\nu}{kT}}$$

$$= h\nu(1-e^{-x}) \sum_n n e^{-nx}$$

$$= h\nu(1-e^{-x})\left[e^{-x} + 2e^{-2x} + 3e^{-3x} + \dots\right]$$

$$= h\nu(1-e^{-x})(-1)\frac{d}{dx}\left[e^{-x} + (e^{-x})^2 + (e^{-x})^3 + \dots\right]$$

$$= -h\nu(1-e^{-x})\frac{d}{dx}(e^{-x})\left[\underbrace{1 + e^{-x} + (e^{-x})^2 + (e^{-x})^3 + \dots}_{\frac{1}{1-e^{x}}}\right]$$

$$= -h\nu(1-e^{-x})\frac{d}{dx}\left(\frac{1}{e^{x}-1}\right) = \text{SREDI} \Rightarrow h\nu\frac{1}{e^{x}-1} = h\nu\frac{1}{e^{\frac{h\nu}{kT}}-1}$$

$$\frac{8\pi}{c^3}\nu^2\cdot\left(\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}\right)=\psi(\nu,T)$$

Raighi Jenson

$$h\nu=\frac{hc}{\lambda}\ll kT$$

$$\psi(\lambda,T)=\frac{2\pi c}{\lambda^4}\cdot kT$$

Wimon

$$h\nu=\frac{hc}{\lambda}\gg kT$$

$$\psi(\lambda,T)=\frac{2\pi hc^2}{\lambda^5}\cdot e^{-\frac{hc}{\lambda kT}}$$

$$I=\int_0^\infty\psi(\lambda,T)\,d\lambda=\sigma\cdot T^4$$ STEFFAN-BOLTZMAN

FOTOEFEKT

(1) $\nu > \nu_g$ $\quad I \sim$ intenzitetu

(2) $\nu < \nu_g$, $I = 0$, $I_{int.} \to \infty$

(3) V_z - zaustavni napon

$$E_{k|maks} = \frac{m v^2_{maks}}{2} = e \cdot V_z$$

(4) valna priroda ne može objasniti kako izlaze uz mali intenzitet

EINSTEIN

- kvantna priroda svjetlosti

$E_f = h\nu = \frac{hc}{\lambda} = W + E_k$, $W = h \cdot \nu_g$ $\quad E_{k|max} = eV_z$

- čestica svjetlosti foton $p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

$$\gamma mc^2 = mc^2 + E_k$$

COMPTONOV EFEKT

- raspršenje fotona
- $\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1 - \cos\Theta)$

IZVOD

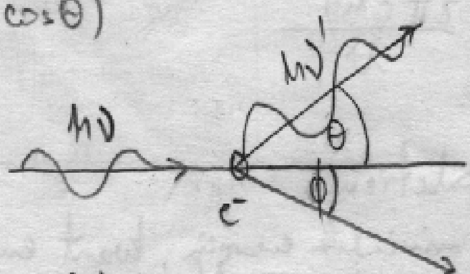
$E_f = h\nu = \frac{hc}{\lambda}$

$p_f = \frac{E}{c} = \frac{h}{\lambda}$

$p'_f = \frac{h}{\lambda'}$ - izlazni foton

$p'_{f|h} = \frac{h}{\lambda'} \cos\Theta$

$p_{f|v} = \frac{h}{\lambda'} \sin\Theta$



elektron miruje

$p'_e = \gamma m v$

$p'_{e|h} = \gamma m v \cos\phi$

$p'_{e|v} = \gamma m v \sin\phi$

ZOE $\quad \frac{hc}{\lambda} + mc^2 = \frac{hc}{\lambda'} + \gamma mc^2$

ZOKG:

horizon: $\frac{h}{\lambda} = \frac{h}{\lambda'} \cos\Theta + \gamma m v \cos\phi$

ver: $0 = \frac{h}{\lambda'} \sin\Theta + \gamma m v \sin\phi$

$$\left.\begin{aligned} \frac{h}{\lambda} - \frac{h}{\lambda'}\cos\Theta &= \gamma m v \cos\phi \,\Big|^2 \\ -\frac{h}{\lambda'}\sin\Theta &= \gamma m v \sin\phi \,\Big|^2 \end{aligned}\right\} +$$

$$\frac{h^2}{\lambda^2} - 2\frac{h^2}{\lambda\lambda'}\cos\Theta + \frac{h^2}{\lambda'^2}\cos^2\Theta + \frac{h^2}{\lambda'^2}\sin^2\Theta = \gamma^2 m^2 v^2 (\cos^2\phi + \sin^2\phi)$$

COMPTON - nastavki

$$\frac{h^2}{\lambda^2} - 2\frac{h^2}{\lambda\lambda'}\cos\theta + \frac{h^2}{\lambda'^2} = \gamma^2 m^2 v^2 \quad (*)$$

$$\text{ZOE:}\quad \frac{hc}{\lambda} + mc^2 - \frac{hc}{\lambda'} = \gamma mc^2 \quad \Big|^2$$

$$\frac{h^2c^2}{\lambda^2} + \frac{h^2c^2}{\lambda'^2} + m^2c^4 - \frac{2h^2c^2}{\lambda\lambda'} + 2mc^3h\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \gamma^2 m^2 c^4 \quad \Big| : c^2$$

$$\frac{h^2}{\lambda^2} + \frac{h^2}{\lambda'^2} - \frac{2h^2}{\lambda\lambda'} + m^2c^2 + 2mch\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \gamma^2 m^2 c^2 \quad - (*)$$

$$\frac{2h^2}{\lambda\lambda'}(\cos\theta - 1) + 2mch\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = 0 \quad \Big| \cdot \lambda\lambda'$$

$$\cancel{2}h^{\cancel{2}}(\cos\theta - 1) = -\cancel{2}mc\cancel{h}(\lambda' - \lambda)$$

$$\lambda' - \lambda = \Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$\lambda_c = \frac{h}{mc}$$ Comptonova λ elektrona (m - elektrona)

THOMPSONOV model atoma

- puding sa šljivama
- 10^{-10} m
- titraje "šljiva" oko ravnotežnog položaja emitira EM zračenje

RUTHERFORD

- α-česticama bombardirali listić zlata i gledali odbijanje
- 1911. - jezgra 10^{-14} m
  - elektroni 10^{-10} m
  - planetarni model atoma

SPEKTROSKOPIJA vodikovog atoma. BOHR

BALMERova formula: - $\lambda = (364{,}56\ \text{nm}) \cdot \frac{n^2}{n^2-4}$ $\quad n = 3,4,5,\ldots$

- $\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$ $\quad n = 3,4,5,\ldots$

- R_H - Rydbergova konstanta

BOHR

- elektron gubi energiju
- $a_{cp} = \frac{v^2}{r} \Rightarrow P = \frac{dE}{dt} = \frac{e^2 a_{cp}^2}{6\pi \varepsilon_0 c^3}$
- $\tau \sim 10^{-11}$ s elektron bi pao na jezgru

POSTULATI:

P-1. el. se giba oko jezgre samo na određenim stazama, tada ne zrači i u stacionarnom je stanju.

P-2. Dozvoljena su stanja za koja kut. kol. gib. jednaka $\frac{h}{2\pi} \Rightarrow L = r_n m v_n = n \frac{h}{2\pi}$

$L = n\hbar$ $\xrightarrow{}$ glavni kvantni broj

$$\int_0^{2\pi} p_\theta \, d\theta = nh$$

$$p_\theta \int_0^{2\pi} d\theta = nh$$

$$p_\theta = \frac{nh}{2\pi}$$

BOHR - nast.

P-3. Kada el. skoči iz više u nižu stazu emitira višak energije:

$$h\nu = E_i - E_f$$

KVANTIZACIJA ENERGIJE

P-1 $\quad F_{coul} = F_{cp} \Rightarrow \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2} = \frac{m v_n^2}{r_n}$

P-2 $\quad v_n = \frac{n\hbar}{m r_n} \Rightarrow r_n = \frac{n\hbar}{m v_n}$

P-1 ; P-2

$$\frac{1}{4\pi\varepsilon_0}\frac{e^2}{\cancel{r_n^2}} = \frac{\cancel{m} n^2\hbar^2}{m^2 \cancel{r_n^2} r_n}$$

$$r_n = \frac{4\pi\varepsilon_0 n^2\hbar^2}{me^2} \qquad n = 1,2,3,\ldots$$

$$v_n = \frac{1}{n}\frac{e^2}{4\pi\varepsilon_0\hbar} = \frac{v_1}{n}$$

$$E_n = \frac{1}{2} m v_n^2 - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

$$\boxed{E_n = -\frac{1}{n^2}\cdot\frac{me^4}{32\pi^2\varepsilon_0^2\hbar^2}}$$

$$E_1 = -13{,}58\ eV$$

energija ionizacije/vezanja

P-3 $\quad h\nu = \hbar\omega = E_i - E_f$

$E_i > E_f$ emisija fotona

$$E_i = \frac{-E_I}{n_i^2} \qquad E_f = \frac{-E_I}{n_f^2}$$

$$\nu = \frac{E_i}{h} - \frac{E_f}{h} = \frac{E_I}{h}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = \frac{E_I}{hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = \frac{me^4}{(4\pi\varepsilon_0)^2\cdot 4\pi\hbar^3 c}\left(\frac{1}{n_f} - \frac{1}{n_i}\right)$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f} - \frac{1}{n_i}\right)$$

Balmer $n_f = 2$

Lyman $n_f = 1$

Pachen $n_f = 3$

DE BROGLIEEVA HIPOTEZA

- pretpostavlja da i obične čestice imaju valni karakter

$$E = h\nu = \frac{h}{2\pi}2\pi\nu = \hbar\omega = \frac{hc}{\lambda} \Rightarrow$$

$$p = \frac{E}{c} = \frac{h}{\lambda} = \frac{h}{2\pi\left(\frac{\lambda}{2\pi}\right)} = \frac{\hbar}{\lambda/2\pi} = \hbar k$$

$$p = \frac{h}{\lambda_B} = \hbar k_B = mv$$

DE BROGLIEEV VALI

$$O_n = 2r_n\pi = n\lambda = \frac{nh}{p_n} = \frac{nh}{mv_n}$$

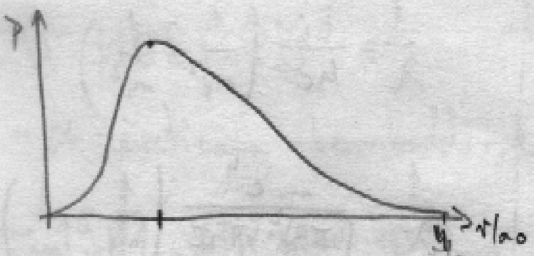
$$2\pi r_n m v_n = nh$$

$$r_n m v_n = n\frac{h}{2\pi} = n\hbar$$

KVANTNA MEHANIKA

SCHRÖDINGEROVA JDŽB.

- vjerojatnost nalaženja elektrona na nekoj energiji i vjerojatnost prijelaza



- glavni kvantni broj n $(1, 2, 3, \ldots)$
- orbitalni kvantni broj l (L) $(0, 1, 2, \ldots, n-1)$
- magnetski kvantni broj m_l (L_z) $(-l, -l+1, \ldots, l-1, l)$
  - međudjelovanje el. i mag. polje
- spin $S_z = m_s \hbar$ $\left(-\frac{1}{2}, +\frac{1}{2}\right)$

$l=0$ S $l=1$ P $l=2$ D $l=3$ F

RELACIJE NEODREĐENOSTI

Heisenberg - 1927.

- ne možemo istovremeno precizno odrediti položaj i brzinu elektrona
- gledanje fotonom koji ima kol. gib $p = \frac{h}{\lambda}$

$$\Delta x \cdot \Delta p_x \geq \hbar$$

$$\Delta p_x \gtrsim \frac{\hbar}{\Delta x}$$

PAULI - dva elektrona u atomu ne mogu imati sva četiri kvantna broja ista.

LASERI

$E_1 + h\nu = E_2$

nakon 10^{-3}-10^{-8} s

$E_2 = h\nu + E_1$ ili stimulirano

$E_2 \ (+h\nu) = 2h\nu + E_1$

- foton iste energije međudjeluje s elektronom i potakne ga da "padne" - emitira isti takav foton
- lančana reakcija