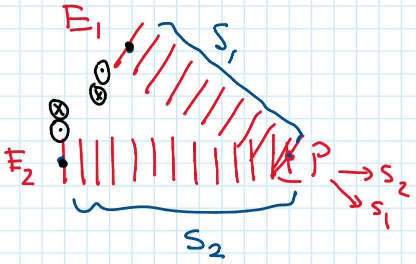
7. Bolum Girişim Interference

Wednesday, December 14, 2022 8:57 AM

Işığın Girişim

iki dalga : $\vec{E}_1 = \vec{E}_{01} \cos(kS_1 - wt + \phi_1)$

$\vec{E}_2 = \vec{E}_{02} \cos(kS_2 - wt + \phi_2)$



$\tilde{k} \cdot \vec{r} = kS_1$

$= kS_2$

$\{\lambda, f, k \overset{w = \text{aynı}}{\text{"}} \}$ $\vec{E}_p = \vec{E}_1 + \vec{E}_2$

S_1, S_2 : referans noktalarından P noktasına olan mesafe

tipik görünür ışık ⇒ $\lambda = 500\ nm$

$f = \frac{c}{\lambda} = \frac{3\times10^8}{5\times10^{-7}} \frac{1}{s} \sim 10^{15}\ Hz$ = 1 s'de 10^{15} kez titreşiyor.

İnsan gözü : video ~ 1s 24 kare ~ 30 kare 30 frame per second 30fps 60fps 120fps...

20 fps – 100 fps 20Hz – 100 Hz

dedektör ~ 1ns ~ $10^{-9}s$ ~ $10^9\ Hz$

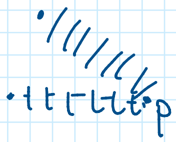
işlemci ~GHz = 10^9 Hz

$10^{15} \gg 10^9 \gg 10^2$

ışık dedektör insan

I = Intensity ≡ ışık parlaklığı $= \epsilon_0 c \langle \vec{E} \cdot \vec{E} \rangle$; $\langle \ldots \rangle$ = zaman ortalaması ($\frac{1}{100}s$; $\frac{1}{10^9}s$)

dedektör, gözün ışığı algılama süresi



$\vec{E}_p = \vec{E}_1 + \vec{E}_2$

$I_p = \epsilon_0 \epsilon \langle \vec{E}_p \cdot \vec{E}_p \rangle = \epsilon_0 c \langle \vec{E}_1 \cdot \vec{E}_1 + \vec{E}_2 \cdot \vec{E}_2 + 2 \vec{E}_1 \cdot \vec{E}_2 \rangle$

$$= \epsilon_0 c \Big[\underbrace{\langle \vec{E}_1 \cdot \vec{E}_1 \rangle}_{I_1} + \underbrace{\langle \vec{E}_2 \cdot \vec{E}_2 \rangle}_{I_2} + \underbrace{2 \langle \vec{E}_1 \cdot \vec{E}_2 \rangle}_{I_{12}\ *} \Big]$$

girişim I_{12} * ; $I_p = I_1 + I_2$ klasik

$I_1 + I_2 + I_{12}$

$$\epsilon_0 c\, 2 \langle \vec{E}_1 \cdot \vec{E}_2 \rangle = \epsilon_0 c\, 2 \langle \vec{E}_{01} \cdot \vec{E}_{02} \cos(kS_1 - wt + \phi_1) \cos(kS_2 - wt + \phi_2) \rangle$$

$kS_1 + \phi_1 = \alpha$

$kS_2 + \phi_2 = \beta$

$$= \epsilon_0 c\, 2 \langle \vec{E}_{01} \cdot \vec{E}_{02} \cos(\alpha - wt) \cos(\beta - wt) \rangle$$

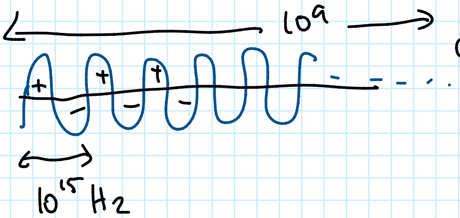
$$2\cos A\cos B = \cos(A+B)+\cos(A-B)$$

$$= \varepsilon_0 C \left\langle E_{01}\cdot E_{02}\left[\cos(\alpha+\beta-2\omega t)+\cos(\alpha-\beta)\right]\right\rangle$$

$$= \varepsilon_0 C\; E_{01} E_{02}\left[\left\langle\cos(\alpha+\beta-2\omega t)\right\rangle + \left\langle\cos(\alpha-\beta)\right\rangle\right]$$

$$\langle \dots\rangle_t = \frac{1}{\Delta t}\int_{t_1}^{t_2} \dots\, dt \quad ; \quad t_2-t_1 = 10^{-9}\,s \text{ dedektör}$$
$$= 10^{-2}\,s \text{ insan}$$

$$0 = \langle\cos(\omega t)\rangle = \langle\sin(\omega t)\rangle =$$



çok uzun zamanda toplarsa; sıfır verir.

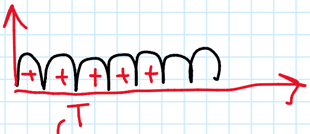
$$I_{12} = \varepsilon_0\, C\, E_{01} E_{02}\left[\underset{\Downarrow \atop 0}{\left\langle\cos(\alpha+\beta-\omega t)\right\rangle} + \left\langle\cos(\alpha-\beta)\right\rangle\right]$$

$$\cos(\alpha-\beta)$$

$$I_p = I_1 + I_2 + I_{12} \quad ; \quad \alpha-\beta = kS_1+\phi_1-(kS_2+\phi_2)$$

$$I_1 = E_{01} E_{01}\left\langle\cos^2(\alpha-\omega t)\right\rangle$$

$$I_2 = E_{02}\cdot E_{02}\left\langle\cos^2(\beta-\omega t)\right\rangle$$



$$\int_0^T \cos^2(\omega t)\,dt = \frac{1}{2}$$

$$I_p = I_1+I_2+I_{12} = \varepsilon_0 C\, E_{01}^2\,\frac{1}{2} + \varepsilon_0 C\, E_{02}^2\,\frac{1}{2} + \underbrace{\varepsilon_0 C\, E_{01}E_{02}}_{2\sqrt{I_1 I_2}}\left\langle\cos(\alpha-\beta)\right\rangle$$

$$2\sqrt{I_1 I_2}\left\langle\cos(\alpha-\beta)\right\rangle$$

$$I_1 = \frac{1}{2}\varepsilon_0 E_{01}^2 c \Rightarrow E_{01} = \sqrt{\frac{2I_1}{\varepsilon_0 c}}$$

$$I_2 = \frac{1}{2}\varepsilon_0 E_{02}^2 c \qquad E_{02} = \sqrt{\frac{2I_2}{\varepsilon_0 c}}$$

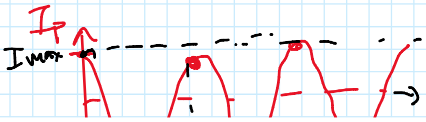
$$\alpha-\beta = \delta$$

$$\boxed{I_p = I_1 + I_2 + 2\sqrt{I_1 I_2}\left\langle\cos\delta\right\rangle}$$

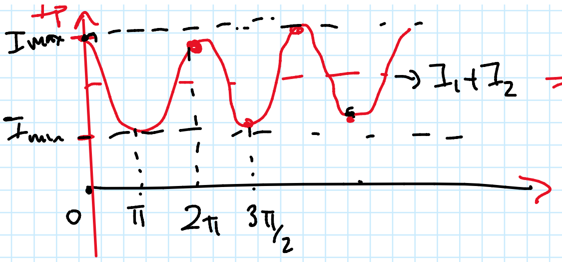
δ	$\cos\delta$
$0/2\pi$	1
$\pi/2$	0
π	−1
$3\pi/2$	0

$$I_p = I_1 + I_2 + 2\sqrt{I_1 I_2} \quad [\delta = 0] \text{ max}$$

$$I_p = I_1 + I_2 - 2\sqrt{I_1 I_2} \quad (\delta = \pi) \text{ min}$$

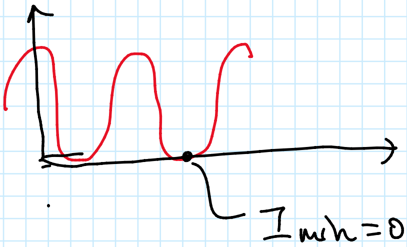


$$\rightarrow I_1 + I_2 \Rightarrow I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$



$\to I_1+I_2 \Rightarrow I_1+I_2+2\sqrt{I_1I_2}\cos\delta$

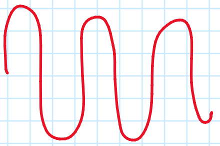
min ısık yoğunluğu ≡ tam karanlık



$I_{min}=0$ ≡ tam karanlık $\quad I_p = I_1+I_2-2\sqrt{I_1I_2}=0$

$$\varepsilon_0 c\langle E_{01} E_{01}\rangle = \varepsilon_0 c\langle E_{02} E_{02}\rangle \Leftarrow I_1=I_2=I \qquad I_p = 2I-2\sqrt{I^2}=0$$

$E_{01}=E_{02}$ (genlikleri aynı olursa)



$$\left.\begin{matrix} I_1+I_2+2\sqrt{I_1I_2} \\ I_1+I_2-2\sqrt{I_1I_2}\end{matrix}\right\} \quad I_{max}-I_{min} = 4\sqrt{I_1I_2}$$

görürebilirlik $= \dfrac{I_{max}-I_{min}}{I_{max}+I_{min}}$

$\Downarrow$

Saçak kontrastı (aydınlık - karanlık ayırt edebilme)

maksimum $\Rightarrow$ $E_{01}=E_{02}$ $\quad\Rightarrow I_1=I_2=I_0$

$$I_p = I_1+I_2+2\sqrt{I_1I_2}\cos\delta = 2I_0(1+\cos\delta) = 4I_0\cos^2\left(\frac{\delta}{2}\right)$$

$$\delta = \alpha-\beta = kS_1+\phi_1-kS_1-\phi_2 = k(S_1-S_2)+(\phi_1-\phi_2)$$

$$\delta = k\Delta S + \Delta\phi$$

pratikte farklı kaynaklardan gelen ısınlar fazları aynı olmaz.

① $\phi=\phi(t) \qquad \langle\cos\delta\rangle = \langle\cos(k\Delta S+\Delta\phi(t))\rangle = 0$

zamana bağlı veya rastgele. $\qquad I_{12}=0$

② $kS_1-kS_2 \Rightarrow \lambda$ aynı

$k_1S_1-k_2S_2 \Rightarrow \lambda$ farklı $\quad I_{12}\cong 0$

$k_1S_1 - k_2S_2 \Rightarrow \lambda$ farklı $I_{12} \cong 0$

LAZER = coherent = aynı fazda, eş zamanlı

eş fazlılık zamanı = $\tau_0 = \frac{1}{\underset{\text{frekans}}{\Delta\nu}} = \frac{1}{\text{bileşenlerin frekans aralığı}}$

$c\tau_0 = \ell$
eş fazlı olduğu uzunluk

$\ell \sim$ cm – km LASER

$\sim 1\mu m$ beyaz ışık kaynağı

ör) $E_1 = 2\cos(kS_1 - \omega t)$ kV/m
$E_2 = 5\cos(kS_2 - \omega t)$ kV/m

$k(S_1 - S_2) = k\Delta S = \underset{\sim}{\frac{\pi}{12}}$

I_{max}
I_{min} ?
✓ I_{12}
görünürlük.

$$I_{12} = \varepsilon_0 c E_{01}E_{02}\cos\delta = 2\sqrt{I_1I_2}\cos\delta$$

$$I_1 = \varepsilon_0 c E_{01}^2 = 5309 \text{ W/m}^2$$

$$I_2 = \text{''} = 33180 \text{ W/m}^2$$

$$I_{12} = 2\sqrt{5309(33180)}\cos\frac{\pi}{12} = 25640 \text{ W/m}^2$$

$I_{max} = I_1 + I_2 + I_{12} = 65034$

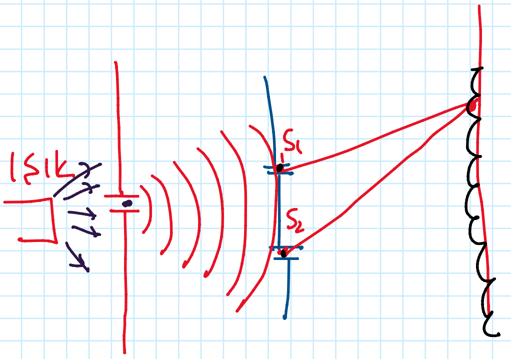
$I_{min} = I_1 + I_2 - I_{12} = 11945$

görünürlük = $\frac{I_{max} - I_{min}}{I_{max} + I_{min}} = 0.69$

= %69 görünürlük

{görünürlük max = 1 ; $I_{min} = 0$}

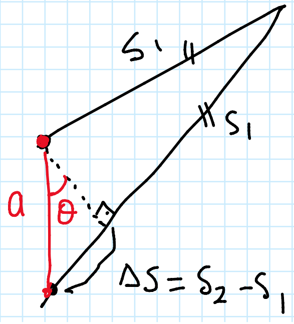
YOUNG düzeneği



S = eş faz oluşturmak için
aynı faz kaynak

$$I_P \cong I_1 + I_2 + 2\sqrt{I_1I_2}\cos\delta$$

$$\delta = k\underline{\underline{\Delta s}} + \Delta\phi$$
⇓
$\underline{\underline{0}}$ eş faz



aydınlık

$a\sin\theta = \Delta S = m\lambda$

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

kaynak

$\Delta S = S_2 - S_1$

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

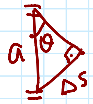
karanlık

$\cos\delta = 1$ (I max) $= \cos\delta = \cos(k\Delta S) = \cos\left(\frac{2\pi}{\lambda} m\lambda\right) = \cos(2\pi m)$

$+1$

$\cos\delta = -1$ (I min) $\cos(k\Delta S) = \cos\left[\frac{2\pi}{\lambda}(m+\frac{1}{2})\lambda\right]$

$$\cos[\pi(2m+1)] = \left.\begin{matrix}\cos\pi \\ \cos 3\pi \\ \vdots\end{matrix}\right\} = -1$$



$\Delta S = a\sin\theta = m\lambda$

$\frac{y}{\sqrt{y^2+L^2}} \simeq \frac{y}{L}$ ($\tan\theta \cong \sin\theta$)

$\Delta S = a\sin\theta$ → $m\lambda$ = aydınlık → $(m+\frac{1}{2})\lambda \equiv$ karanlık

$\frac{\lambda}{2}$ = karanlık

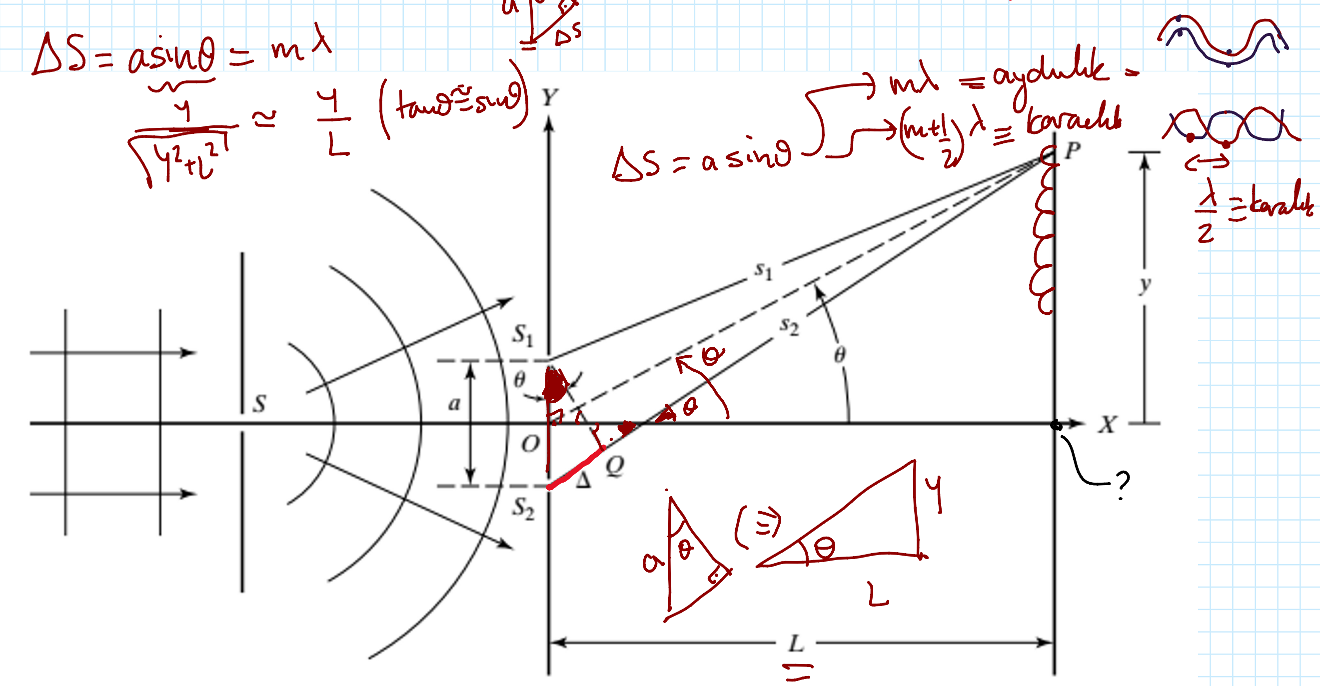
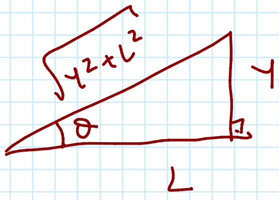


Figure 3 Schematic for Young's double-slit experiment. The holes S_1 and S_2 are usually slits, with the long dimensions extending into the page. The hole at S is not necessary if the source is a spatially coherent laser.

$a\sin\theta = a\frac{y}{L}$



$y \ll L$

$\tan\theta \simeq \sin\theta$

$\theta = \tan^{-1}\left(\frac{y}{L}\right)$

↓

$\sin\theta =$ ✓

↓

$a\sin\theta = m\lambda$

$a\frac{y}{L} = m\lambda$ (A)

$a\frac{y_m}{L} = m\lambda$ m. inci saçak

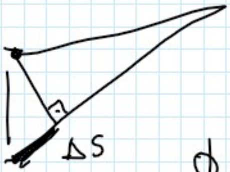
y_m = saçağın merkeze olan uzaklığı

Optik YOL FARKI $\equiv$ → $m\lambda$ (A) → $(m+\frac{1}{2})\lambda$ (K)

$I_P = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$

FARKI

$\rightarrow (m+\frac{1}{2})\lambda$ (K)



$\delta = \alpha - \beta$

$= kS_1 + \phi_1$

$- (kS_2 + \phi_2)$

$\phi_1 = \phi_2 = 0$

$I_1 = I_2 = I_0$

$I_p = 2I_0 + 2I_0(1+\cos\delta)$

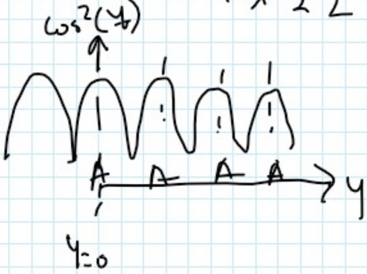
$= 4I_0 \left(\cos^2 \frac{\delta}{2}\right)$

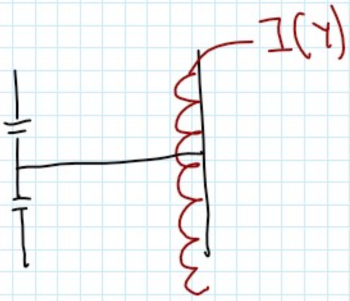
; $k = \frac{2\pi}{\lambda}$

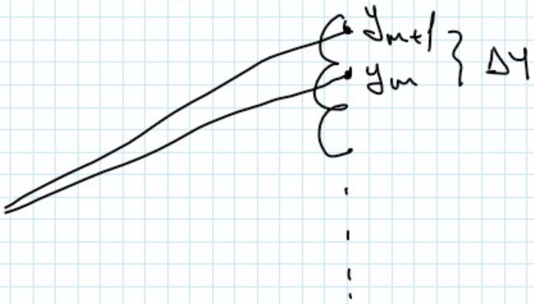
$\delta = k\Delta S + \overset{\rightarrow 0}{\Delta\phi} = k\Delta S$

$\Delta S = S_2 - S_1 = a\sin\theta = a\frac{Y}{L}$

$I(Y) = 4I_0 \cos^2\left(\frac{2\pi}{\lambda}\frac{a}{2}\frac{Y}{L}\right) = (\dots)\cos^2(\dots Y)$





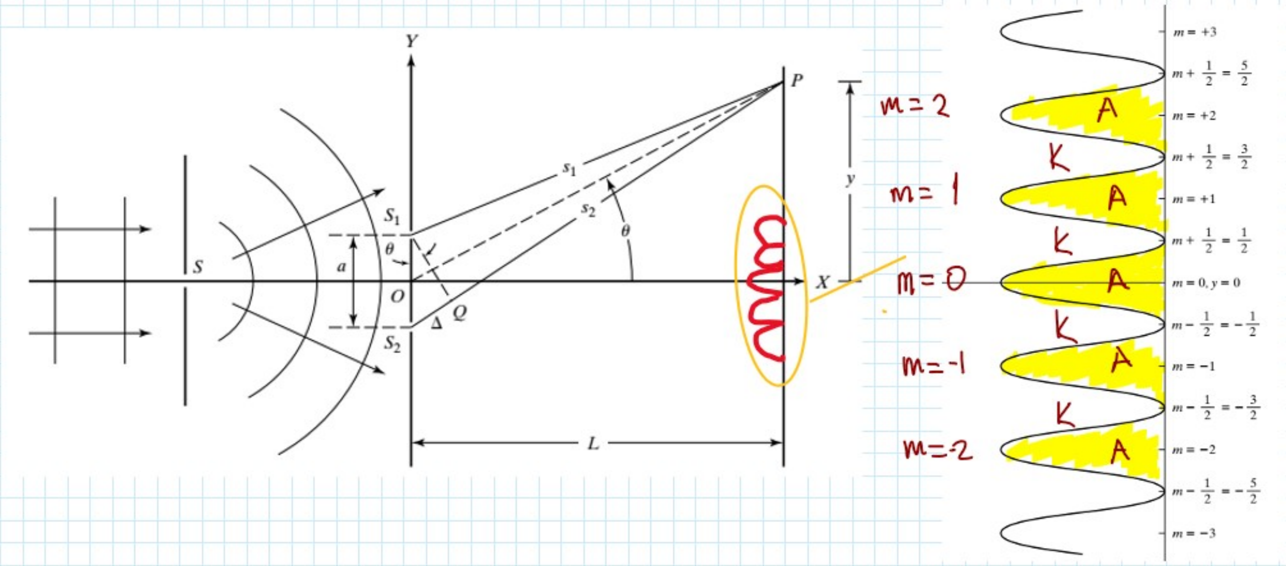


$a\frac{Y_m}{L} = m\lambda$

$a\frac{Y_{m+1}}{L}$ $(m+1)\lambda$

$\Delta Y = Y_{m+1} - Y_m$

$\Delta Y = \frac{\lambda L}{a}$



Example 2

yarık

Laser light passes through two identical and parallel slits (0.2 mm) apart. Interference fringes are seen on a screen 1 m away. Interference maxima are separated by 3.29 mm. What is the wavelength of the light? How does the ir-

$a = 0.2\,mm$

$L = 1m$

Laser light passes through two identical and parallel slits (0.2 mm) apart. Interference fringes are seen on a screen 1 m away. Interference maxima are separated by $\boxed{3.29\text{ mm}}$. What is the wavelength of the light? How does the irradiance at the screen vary, if the contribution of one slit alone is I_0?

$L = 1\text{m}$

İki aydınlık nokta arası 3.29mm olarak alınmış

λ?

$a\sin\theta = \Delta S = m\lambda$

$a\frac{y}{L} = m\lambda$

$\Delta y = y_{m+1} - y_m = 3.29\text{mm}$

$\frac{L}{a}\lambda(m+1-m) = \frac{\lambda L}{a} = 3.29\text{mm}$

$\lambda = \frac{a\Delta y}{L} = \frac{(0.2\text{mm})(3.29\text{mm})}{1000\text{mm}}$

$= 6,58 \times 10^{-4}\text{mm}$

$= 6,58 \times 10^{-7}\text{m}$

$= 658 \times 10^{-9}\text{m}$

$\lambda = 658\text{nm}$

$\frac{\text{Aydınlık saçak ışık yoğunluğu}}{\text{Işığın yoğunluğu} = I_0} = ? \quad \frac{4I_0\overbrace{\cos^2(...)}^{1}}{I_0} \approx \underline{\underline{4}}$

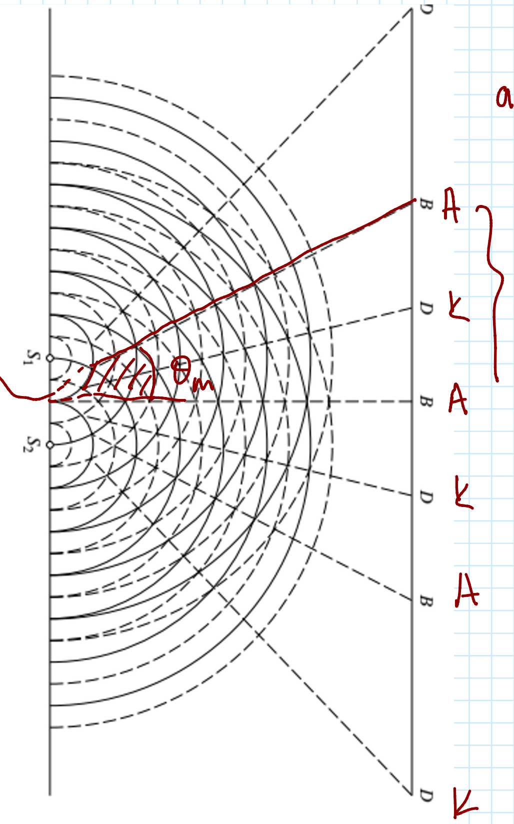


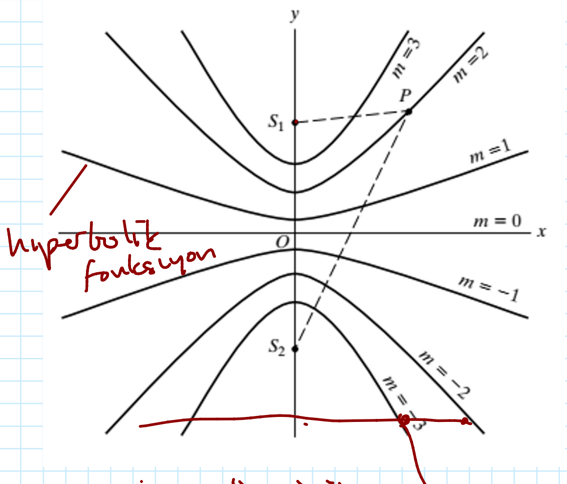
Figure 5 Alternating bright and dark interference fringes are produced by light from two coherent sources. Along directions where crests (solid circles) from S_1 intersect crests from S_2, brightness (B) results. Along directions where crests meet valleys (dashed circles), darkness (D) results.

$a\sin\theta_m = m\lambda$

$\sin\theta_1 = \frac{y_1}{L}$

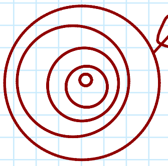
$a\frac{\textcircled{y}}{L} = m\lambda$

$\Delta y = \frac{\lambda L}{a}$



Moire örgüsü

ekran



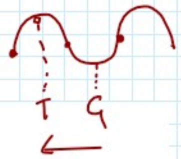
dairesel saçaklar

SANAL KAYNAKLAR ile GİRİŞİM

Lloyd Aynası yansımada faz π kayar.

Lloyd Aynası

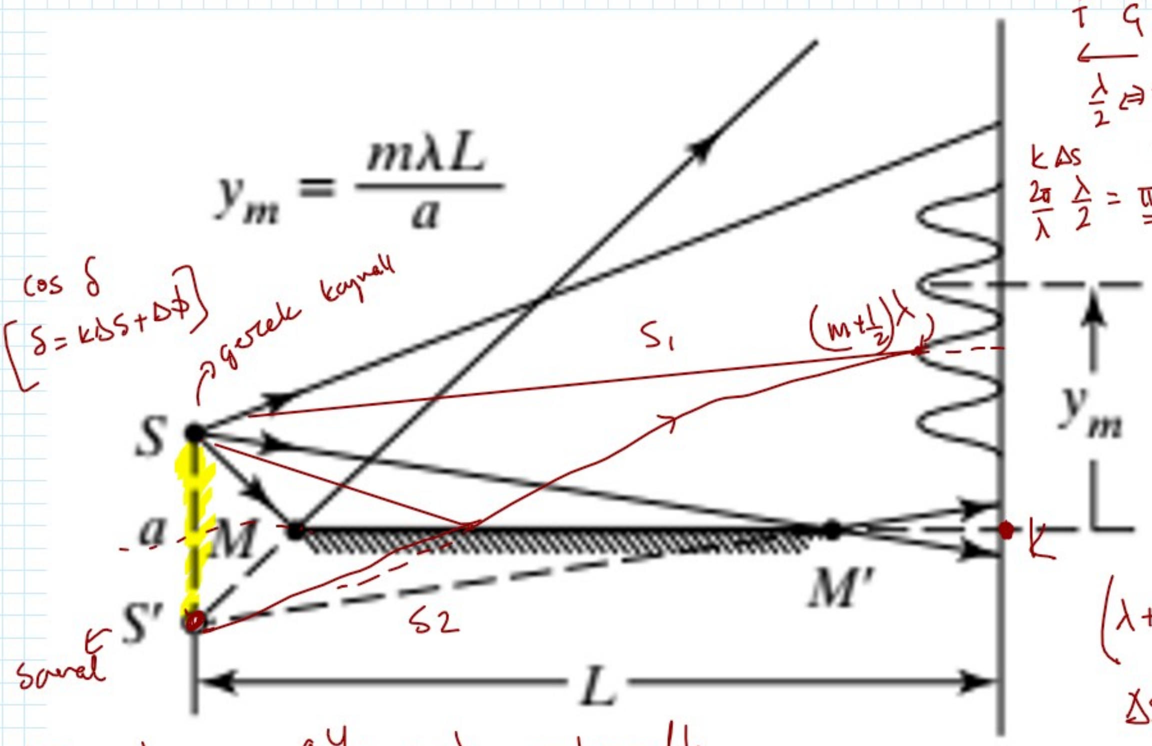
yansımada faz π kayar.

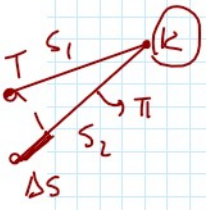


$\frac{\lambda}{2} \Rightarrow \pi$ faz farkı

$k\Delta s$

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





$\Delta s = \lambda$

$\left(\lambda + \frac{\lambda}{2}\right) = Ç$

$\Delta s = m\lambda$

↑ karanlık yerlerin numarası.

$\Delta s = m\lambda$

$\delta = \underset{2\pi}{k}\Delta s + \Delta\phi \hookrightarrow \pi$

$a\frac{y_m}{L} = m\lambda$ ≡ karanlık

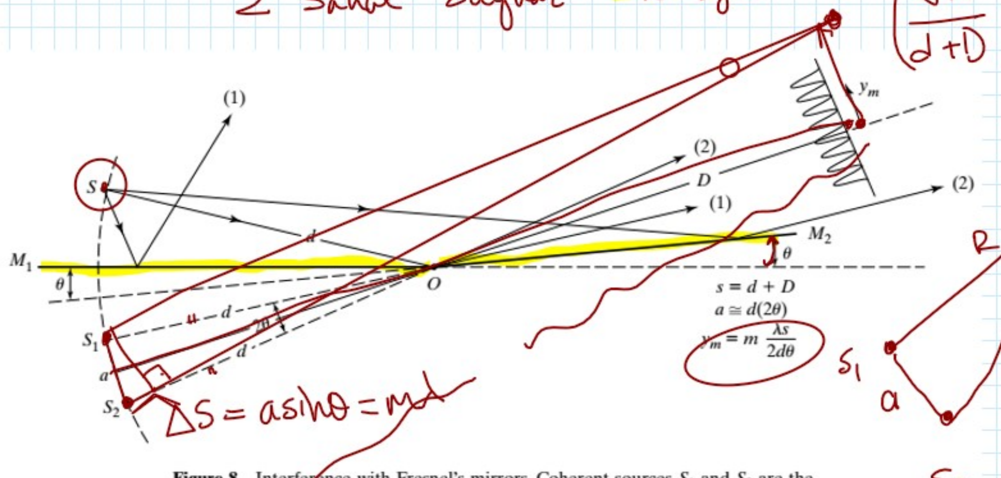
$= (m+\frac{1}{2})\lambda$ Aydınlık)

Figure 7 Interference with Lloyd's mirror. Coherent sources are the point source S and its virtual image, S'.

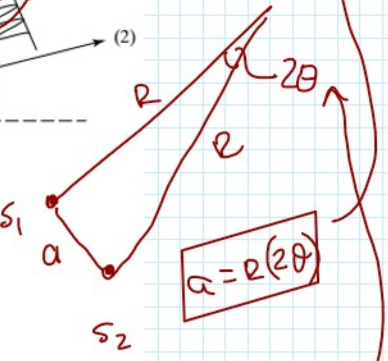
$a\frac{y}{L} = m\lambda$

2 sanal kaynak İki ayna

$\left(\frac{y_m}{d+D}\right)2\theta = m\lambda$



$\Delta S = a\sin\theta = m\lambda$



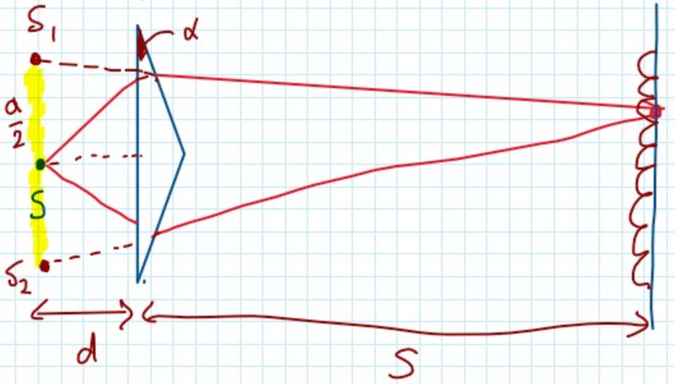
$\boxed{a = R(2\theta)}$

Figure 8 Interference with Fresnel's mirrors. Coherent sources S_1 and S_2 are the two virtual images of point source S, formed in the two plane mirrors M_1 and M_2. Direct light from S is not allowed to reach the screen.

2. ayna θ kadar dönerse S_1, S_2 arası açı 2θ olur

FRESNEL çift PRIZMA GİRİŞİM

FRESNEL çift PRIZMA GIRIŞIM



$[a < mm]$

$a \sin\theta = m\lambda$ $\qquad a = 2d\alpha(n-1)$

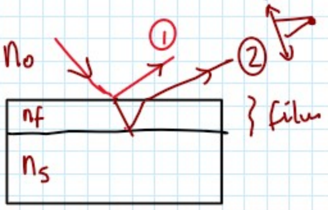
$a \frac{y_m}{L} = m\lambda$ $\qquad$ n = kırılma indisi

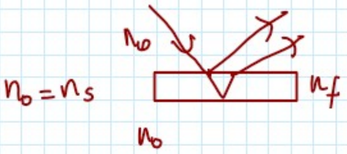
$$y_m = \frac{m\lambda L}{a} = \frac{m\lambda S}{2d\alpha(n-1)}$$

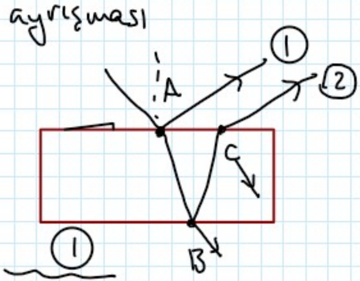
Dielektrik (yalıtkan) filmlerde girişim

ince tabaka

- sabun köpüğü
- su üstündeki ince yağ tabakası } Renk ayrışması

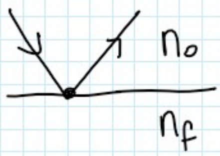






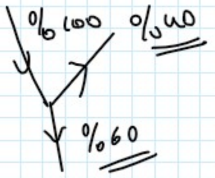
$\underset{①}{\underline{\text{* A dan yansır, kırılır}}}$

① ve ② arasındaki toplam faz farkı



$n_0 < n_f$ π ; $\frac{\lambda}{2}$ faz farkı

DIŞ yansıma



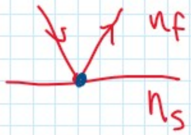
} genlik bölünmesi

Δ = faz farkı = $\Delta_s + \Delta_r$

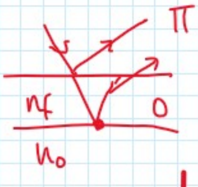
Δ_s → optik yol farkı

Δ_r → yansıma = π / = 0 !!

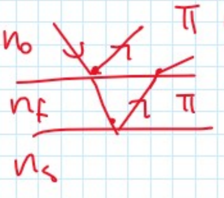
* B'den yansır
* C'den kırılır } ②



$n_f > n_s$ $\Delta r = 0$; π, $\frac{\lambda}{2}$ yok !!

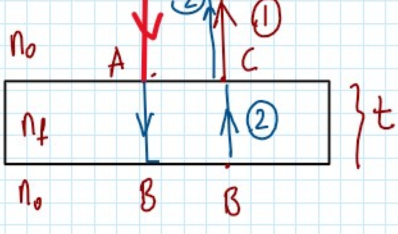


$\Delta r = \pi$



$\Delta r = 0 = 2\pi$

$n_f < n_s$



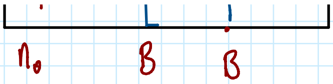
$$\Delta = \underbrace{\Delta r}_{\pi} + \underbrace{\Delta_s}_{(2nt)}$$

$\Delta_s = k_f \underline{\underline{\Delta S}} = 2t\, n_f$

fiziksel optik yol farkı

$\Delta S \; l_t \lambda_L = 2t$

$\lambda_n \;..\; \lambda_0$



$(2nt)$. Fiziksel optik yol farkı

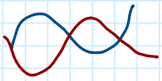
$$\lambda_f = \frac{\lambda_o}{n_f}$$

$$\Delta S \downarrow t \uparrow t = 2t$$

① + ② ⇒ karanlık / aydınlık

$$k_f = \frac{2\pi}{\lambda_f} = \frac{2\pi n_f}{\lambda_o}$$

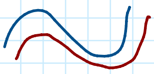
$\Delta = \pi$



K =

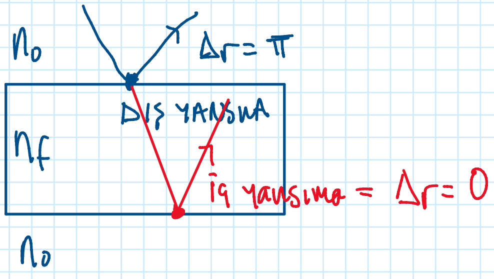
Δ = yansıma + optik yol farkı

$\Delta = 0, 2\pi$



A

$$\underset{\pi}{\text{yansıma}} \quad \underset{0}{} \qquad 2nt$$



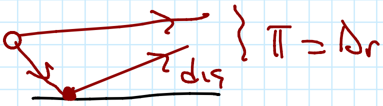
$$\left\{ \frac{\lambda}{2} + \underbrace{2nt}_{\lambda} \right\} \text{ Karanlık YIKICI}$$

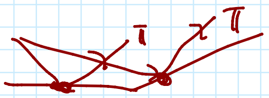
$$\left\{ \frac{\lambda}{2} + \underbrace{2nt}_{\lambda/2} \right\} \text{ Aydınlık YAPICI}$$

$\{$ iç + dış ⇒ $\Delta r = \pi$; $\lambda/2$ $\}$

$\{$ iç + iç ⇒ $\Delta r = 0$; λ
dış + dış $\Delta r = 0$; λ $\}$

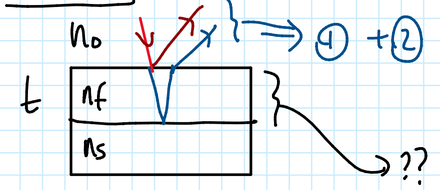
Lloyd aynası





$\Delta r = 0$

Antirefle (antireflection) tabakalar



⇒ ① + ② karanlık ≡ antirefle

$\Delta r = 0$ olsun

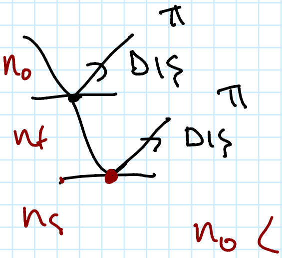
$$2n_f t = \Delta s = \frac{\lambda_o}{2} \Rightarrow$$

n_s = cam
n_f = film
n_o = hava

YIKICI

$$\underline{t} = \frac{\lambda_o}{4n_f} = \frac{\lambda_o}{n_f}\frac{1}{4} = \frac{\lambda_f}{4} = \frac{\lambda_o}{4n_f}$$

$$t = \frac{\lambda_f}{4} \Rightarrow \underbrace{\Delta r}_{0} + \underbrace{\Delta s}_{\pi} = \pi$$



} $\Delta r = 0$

$n_o < \underline{n_f} < n_s$

MgF_2

$\frac{\lambda}{4}$ =

genlik bölünmesinin TAM YIKICI

$$n_f = \sqrt{n_o n_s}$$

$1.0 < 1.38 < 1.5$

λ_f için
tam
karanlık

$= \sqrt{1.5\,(1)}$
$= 1.38$

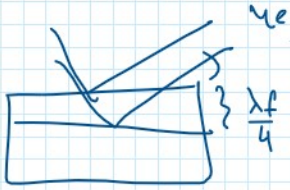
Beyaz → mor n_{mor}
→ kırmızı $n_{kırmızı}$

yeşil

$\lambda_0 = 550$ nm için
Tam yıkıcı

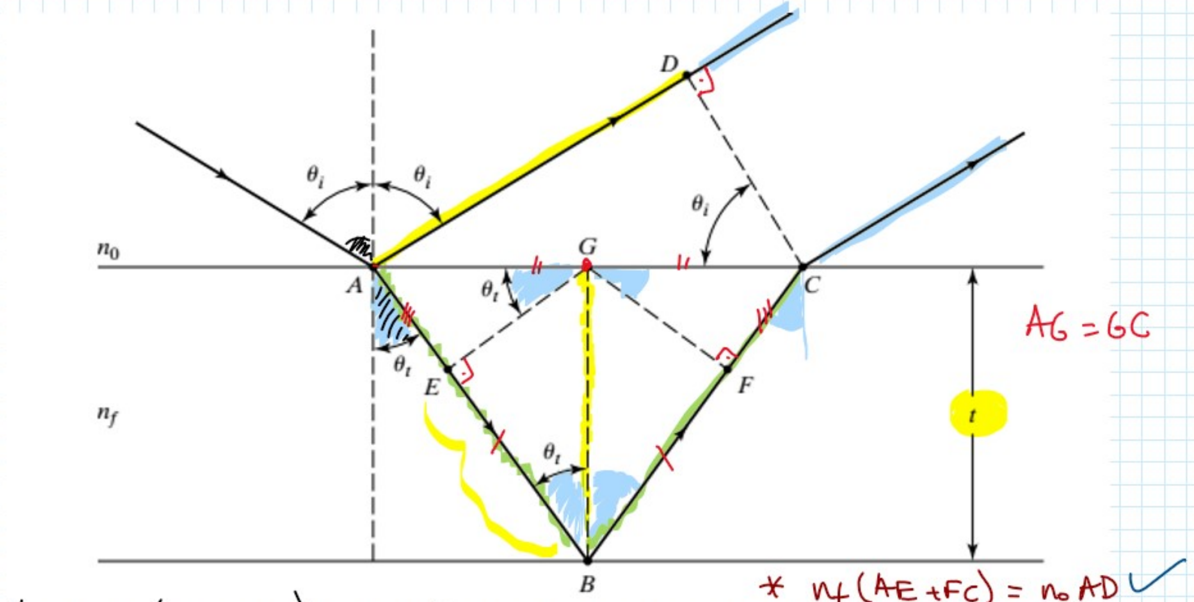
450 nm
mavi

650 nm
kırmızı



yeşil
yok

mavi + kırmızı ⇒ pembe



$*\ n_f(AE + FC) = n_0 AD$ ✓

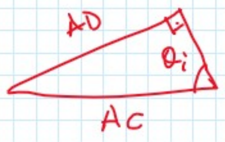
$\Delta_s = n_f(AB + BC) - n_0 AD$

$= n_f(\underline{AE} + EB + BF + \underline{FC}) - n_0 AD = n_f(EB + BF) + \underbrace{n_f(AE + FC) - n_0 AD}_{\text{SIFIR}}$

$\boxed{n_0 \sin\theta_i = n_f \sin\theta_f}$

$AE = AG \sin\theta_t = \frac{AC}{2} \sin\theta_t \Rightarrow 2AE = AC \sin\theta_t$

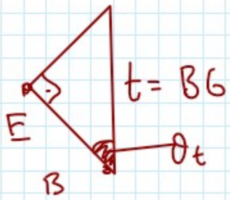
$\frac{AD}{\sin\theta_i}$



$2AE = \frac{AD}{\sin\theta_i} \sin\theta_t$

$* \boxed{n_f(AE + FC) = n_0 AD} \Leftarrow AE + FC = 2AE = AD \frac{n_0}{n_f}$

$\Delta_s = n_f(EB + BF) = 2n_f EB \qquad (EB = BF)$



$t = BG$

$EB = BG\cos\theta_t = t\cos\theta_t$

$\{\Delta_r = 0\}$

$$\boxed{\Delta_s = 2n_f\, t\cos\theta_t}$$

* → $\lambda/2$ karanlık

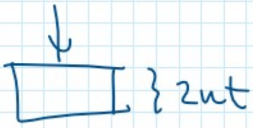
* → λ aydınlık

$$\Delta_s = 2n_f t\sqrt{(1-\sin^2\theta_t)} \quad ; \; n_f\sin\theta_t = n_0\sin\theta_i$$

$$= 2n_f t\left[1-\frac{n_0^2}{n_f^2}\sin^2\theta_i\right]^{1/2} \qquad = \frac{n_0}{n_f}\sin\theta_i$$

$$\Delta = 2t\left[n_f^2 - n_0^2\sin^2\theta_i\right]^{1/2} = \boxed{2t\sqrt{n_f^2-n_0^2\sin\theta_i^2} = 2n_f t\cos\theta_t}$$

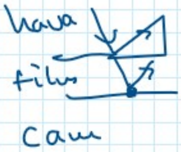
eğer $\theta_i = 0$



$$2t\sqrt{n_f^2 - 0} = \underline{\underline{2t n_f}} \checkmark$$

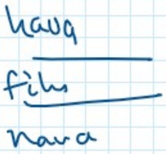
$$\Delta = \Delta_r + \Delta_s$$

$\Delta_r \downarrow 0$ (Dış + Dış), $\Delta_s \downarrow \frac{\lambda}{2}$ Karanlık



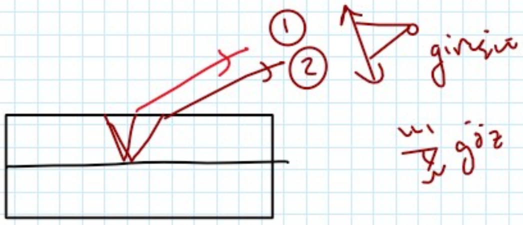
$$\Delta = \Delta_r + \Delta_s$$

$\Delta_r \downarrow \pi$ (iç + dış, $\frac{\lambda}{2}$), $\Delta_s \downarrow \lambda$ ⇒ Karanlık



$$\Delta_s + \Delta_r = \Delta = m\lambda \quad \text{Aydınlık}$$

$$= \left(m+\tfrac{1}{2}\right)\lambda \quad \text{Karanlık}$$



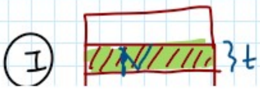
① ve ② sonsuzda birleşir

* mercek ile birleşir ⇒ girişim deseni oluşur.

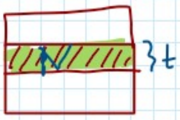
mercek yoksa

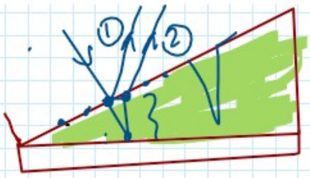
perdede / ekranda girişim gözlenmez!

FILM KALINLIĞI DEĞİŞEN DURUMLAR ⇒ "interference in wedge geometry"

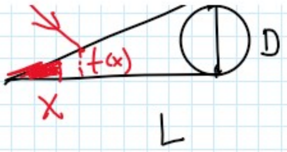


Ⅰ

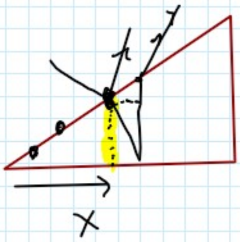




Ⅱ $\Rightarrow$



$2n_f t\cos\theta_t = \Delta_s$



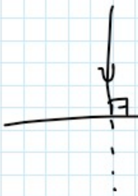
Ⅰ $\leftrightarrow$ Ⅱ

$t \to t(x)$

$\tan\alpha = \frac{t(x)}{x} = \frac{D}{L}$

$t(x) = \frac{D}{L}x$

$\underline{\underline{2n_f t(x)}}\cos\theta_t \longrightarrow 2n_f \frac{D}{L} x \;\cos\theta_t$



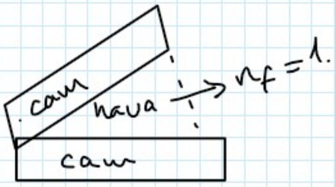
$\theta_i = 0°$

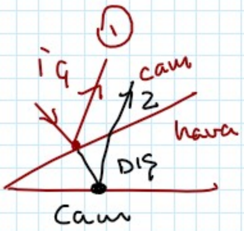
$\theta_t = 0°$

$\theta_t = 0° \Rightarrow \cos\theta_t = 1$

$\Delta_s = 2n_f t$

$\Delta r = ?$ yansımadan dolayı faz farkı ?!





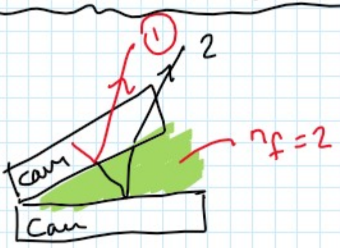
$n_{hava} = n_f < n_{cam}$

① faz kayması YOK.

② $n_{hava} = n_{film} < n_{cam}$

$\Delta r = \underline{\underline{\pi}}$ $\rightleftarrows$

① + ② $\Rightarrow \Delta r = \pi$



① DIŞ π

$n_{cam} < n_{film}$

π $\rightleftarrows$

② $n_{film} > n_{cam}$ iç $\rightleftarrows$ $\underline{\underline{0}}$

$\Delta r = \pi$

$\Delta = 2n_f \frac{D}{L} x = m\lambda$

$\theta_t = 0$

$\downarrow$

$\underline{\underline{\text{karanlık}}}$

DIK GELİYORSA $\theta_t = 0°$

$2n_f t(x) = 2nf \frac{D}{L} x = m\lambda$ (KARANLIK)

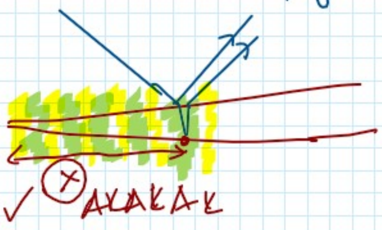
$= \left(m + \frac{1}{2}\right)\lambda$ (AYDINLIK)

$\left\{\Delta r = \pi \;;\; \frac{\lambda}{2}\right\}$

saçaklar düzgün mü?

...dikk olsun ☺.

Aydınlık olsun y.

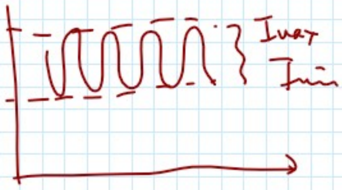


$2n_f \frac{D}{L} x$ = Aydınlık = $m\lambda$

↑ 22. saçak

$\underline{\underline{D}}$ ölçülüyor

$\frac{Dx}{L} = t(x) \Rightarrow$ 22. saçaktaki film kalınlığı



$\frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ = % görünürlük

NEWTON HALKALARI

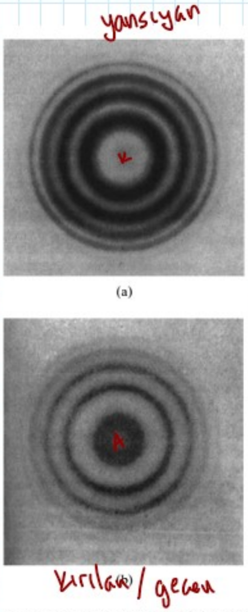
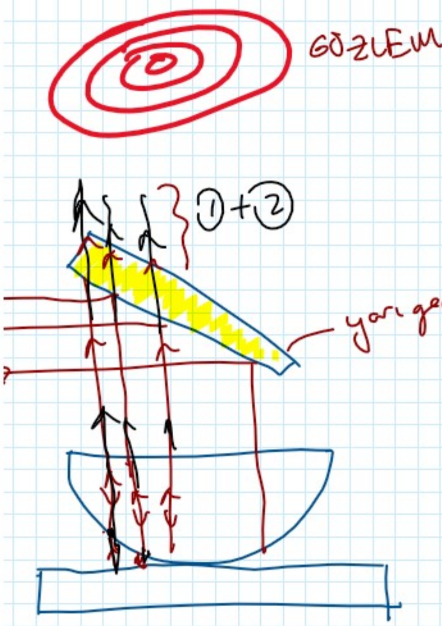
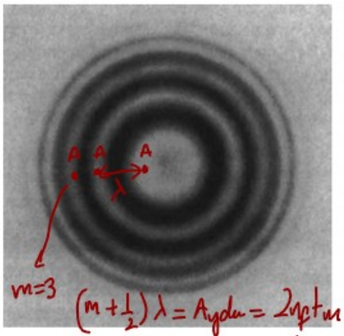


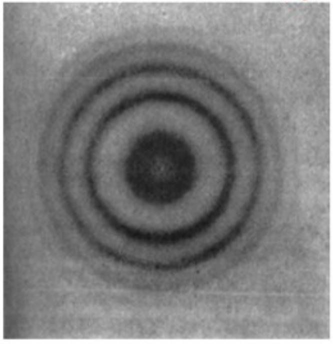
Figure 18 Newton's rings in (a) reflected light and (b) transmitted light are complementary. (From M. Cagnet, M. Francon, and J. C. Thrierr, *Atlas of Optical Phenomenon*, Plate 9, Berlin: Springer-Verlag, 1962.)





$(m+\frac{1}{2})\lambda$ = Aydınlık = $2n_f t_m$ (1.0)

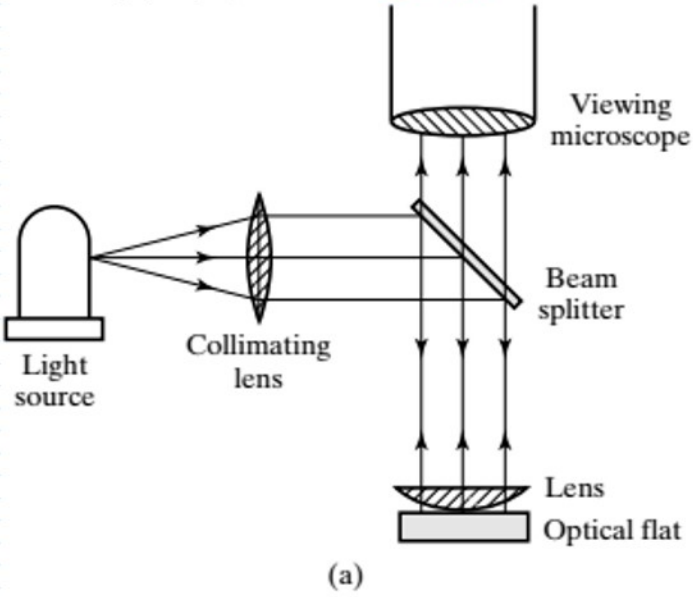
(a)



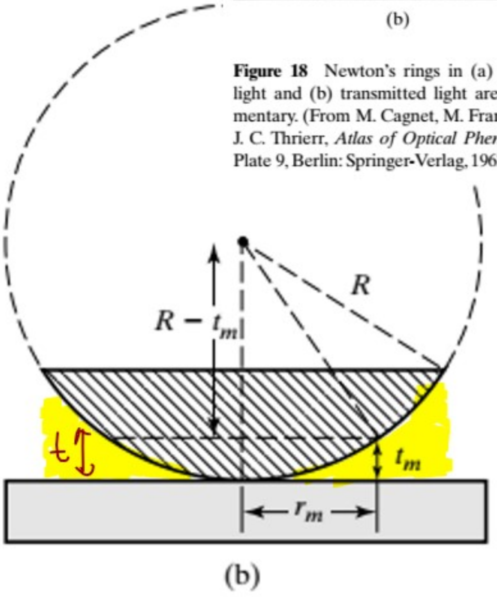
(b)

Figure 18 Newton's rings in (a) reflected light and (b) transmitted light are complementary. (From M. Cagnet, M. Francon, and J. C. Thrierr, *Atlas of Optical Phenomenon*, Plate 9, Berlin: Springer-Verlag, 1962.)

GÖZLEM



(a)



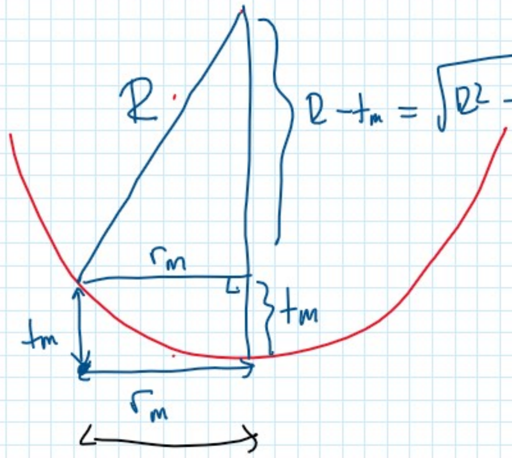
(b)

(a) (b)

$\Delta = 2n_f t \cos\theta_t \quad \theta_t = 0°$

$2n_f t_m = m\lambda$ Karanlık

$(m+\frac{1}{2})\lambda$ Aydınlık



$R - t_m = \sqrt{R^2 - r_m^2}$

$\cancel{R^2} + t_m^2 - 2Rt_m = \cancel{R^2} - r_m^2$

$t_m^2 + r_m^2 = 2R t_m$

$R = \frac{t_m^2 + r_m^2}{2t_m} \quad ; \quad \Delta_s = 2n_f t_m = m\lambda$

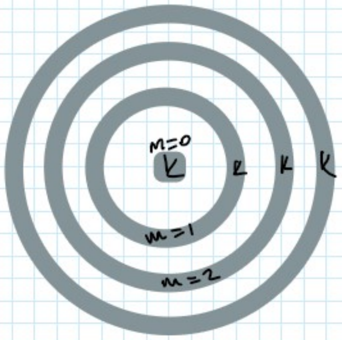
R yi ölçebiliriz

mercegin $\underline{\underline{R}}$ yarıçapı

gözlenen girişim deseni orta noktası karanlık

$(m+\frac{1}{2})\lambda \equiv$ karanlık $= 2n_f t$

$m=0 \quad \frac{\lambda}{2} \Rightarrow$ 



$2Rt_m = t_m^2 + r_m^2$

t_m çok küçük sayı

$t_m^2 \simeq 0$

$$\boxed{2Rt_m \cong r_m^2}$$

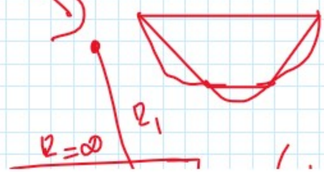
ör) $\frac{1}{8}$ Diopter değerindeki mercek yansıyan Newton saçaklar gözleniyor.

$n = 1.523 \quad \lambda = 589.3$ nm

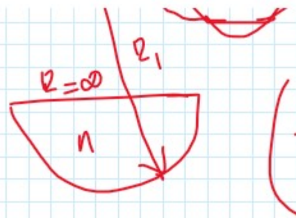
1ci ve 10cu KARANLIK halkanın yarıçapları? $r_1 = ?$ $r_{10} = ?$

$\left[\frac{1}{m}\right]$
Diyopter gözlük numarası?

$-1.75 \Rightarrow f = \frac{1}{D} \quad f = \frac{1}{-1.75} = \frac{-8}{7}$ m



D   −1.75



$$\left(\frac{1}{\underset{=}{R_1}}-\frac{1}{\underset{\infty}{R_2}}\right)(\underset{1.523}{n-1}) = \frac{1}{f} = \frac{1}{8} \qquad D=\frac{1}{8} \qquad f = 8\,m$$

$$R = 4.184\,m \checkmark$$

Karanlık saçak

$$m\lambda = 2n_f t_m \qquad \underline{\underline{r_m^2}} + \overset{0}{t_m^2} = 2Rt_m \checkmark$$

$m=1$ $\lambda = 2n_f t_1 \rightarrow t_1 = \frac{\lambda}{2} = \frac{589.3\,nm}{2}$

$m=10$ $10\lambda = 2n_f t_{10} \Rightarrow t_{10} = \frac{10\lambda}{2} = 5\times(589.3)\,nm$

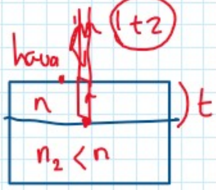
$$t_m \ll r_m \ll R \Rightarrow t_m^2 \simeq 0 \qquad r_m^2 = 2Rt_m$$

$$r_m = \sqrt{2Rt_m}$$

$$r_1 = \sqrt{2(4.184\,m)\left(\frac{589.3}{2}\right)\times10^{-9}\,m}$$

$$= 1.57\times10^{-3}\,m = 1.57\,mm$$

$$r_{10} = \sqrt{2(4.184)m\,(5\times589,3)\times10^{-9}\,m} = \underline{\underline{4.97\,mm}}$$

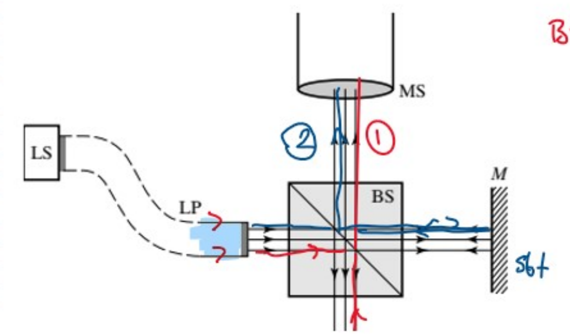


$$\underset{m\lambda?!}{2nt} + \frac{\lambda}{2}? = \Delta_s + \Delta r = m\lambda \quad \begin{matrix}\rightarrow A\\ \hookrightarrow yk?\end{matrix}$$

optik yol farkı + yansıma

$(n_1 > n_2)$ (iç) 0 — 0   π (Dış) $(n_1 < n_2)$ — $\frac{\lambda}{2}$

GIRIŞIMLE FILM KALINLIĞI ÖLÇÜMÜ

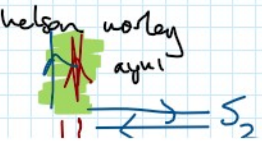


BS - Beam Splitter = ışın bölücü

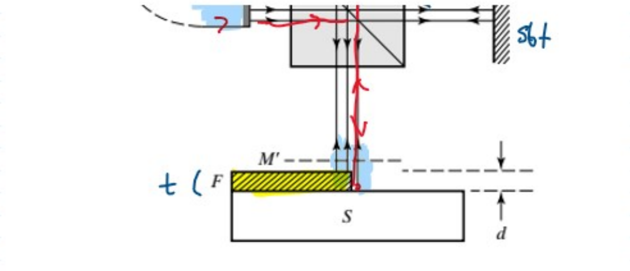
yarı geçirgen ayna

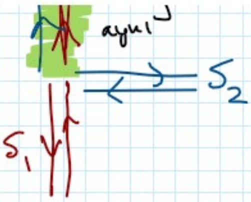
① + ② ⇒ girişim

michelson morley



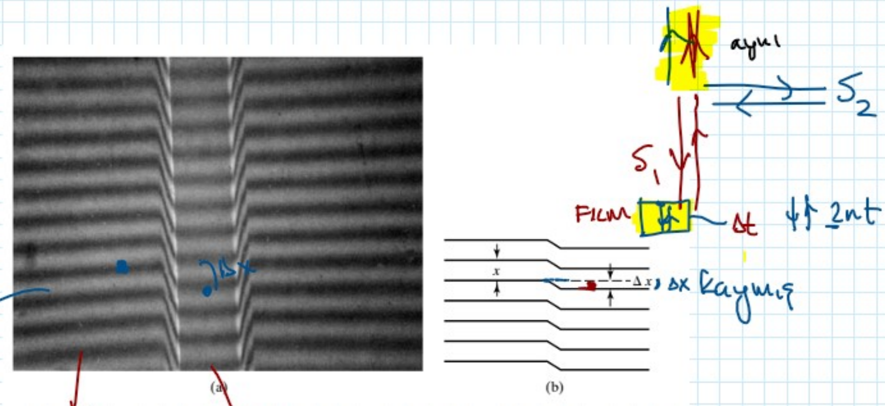
$(k\Delta S) = \delta$





$(k\Delta S) = \delta$

$S_1 - S_2 = \Delta S$



$2nt + \Delta r = m\lambda$

film yok

$\left[\Delta S = S_1 - S_2 = m\lambda\right]$ ⓘⓘ

(II) $S_2 = S_2'$

film

$\left[\Delta S' = S_1' - S_2' = m'\lambda\right]$

(I)

$\text{FILM} = \underline{2nt}$

(I) − (II) $\Rightarrow 2nt = (m' - m)\lambda$

$$\boxed{\frac{\Delta x}{x} = \Delta m = \frac{2nt}{\lambda}} = \underline{\Delta m}\,\lambda$$

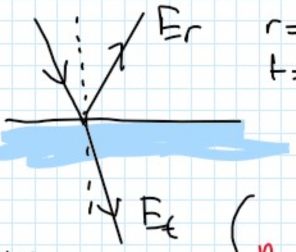
saçak kayma sayısı

⇒ saçak görüntüsü kaldığı sabit olur

ünite sonu soru sorgulu.

STOKE'S BAĞINTILARI (KATSAYILARI)

geçen (kırılan) ; yansıyan ışığın şiddetinin nasıl değiştiğini veriyor.



r = reflection
t = transmitted.

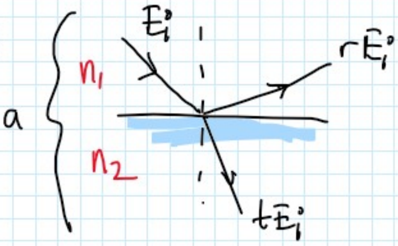
$E_r = r E_i$ r, t = sayı

$E_t = t E_i$

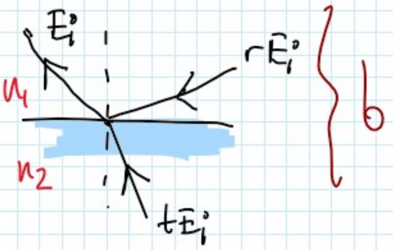
E_i = gelen

E_r : yansıyan

E_t : kırılan

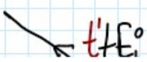


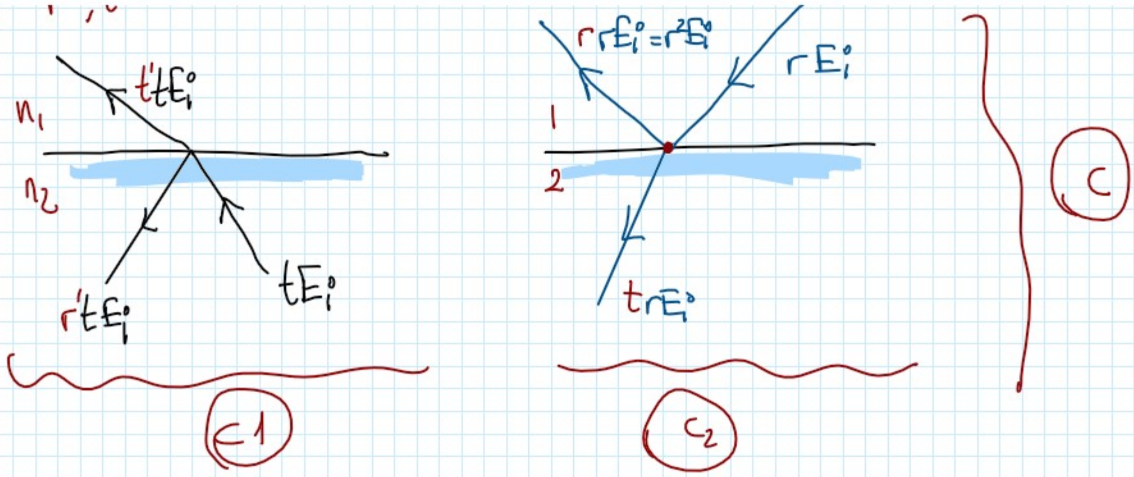
≡



$n_1 \to n_2$ r,

$n_2 \to n_1$ r′, t



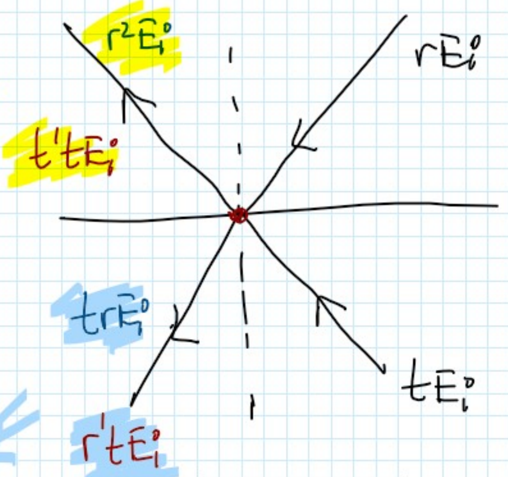


$c1 + c_2 \equiv b$

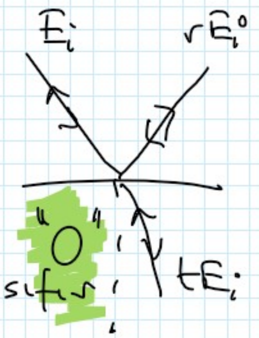
E_i^0

$E_i^0 = tt'E_i^0 + r^2 E_i^0$

$\boxed{1 = tt' + r^2}$ **



≡>

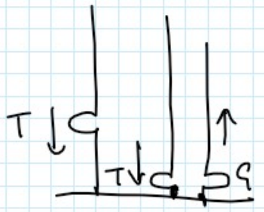


$0 = trE_i + r'tE_i$

$0 = tr + r't \Rightarrow r + r' = 0$

$\boxed{r = -r'}$ ** Dış-iç yansıma "π kayma"

? $r' = -r = re^{i\pi} = r(\cos\pi + i\sin\pi)$



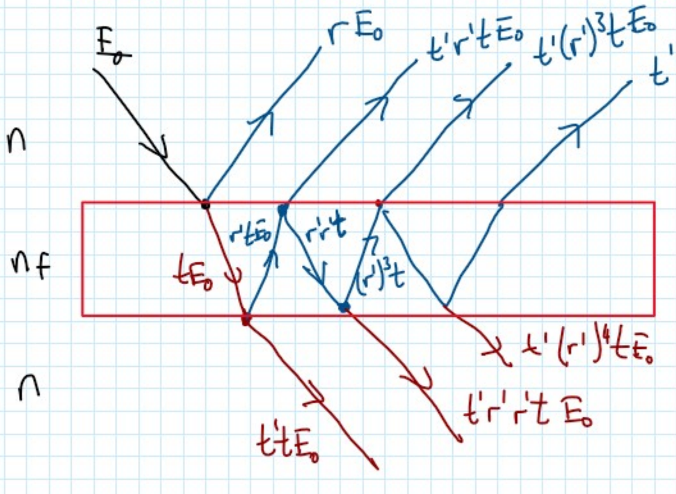
Tepe → Çukur

π faz kayması

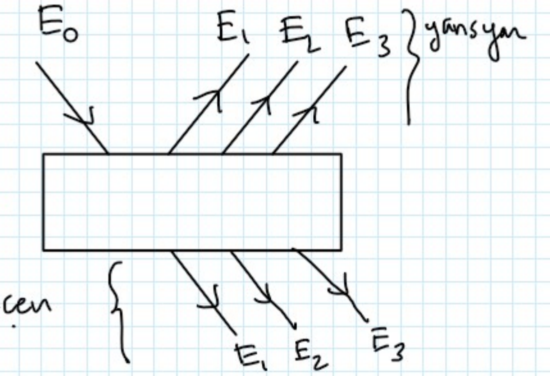
$e^{i(kx-\omega t)}\, e^{i\pi}$

faz kayması π ; $\frac{\lambda}{2}$

PARALEL PLAKADA ÇOKLU DEMET GİRİŞİMİ

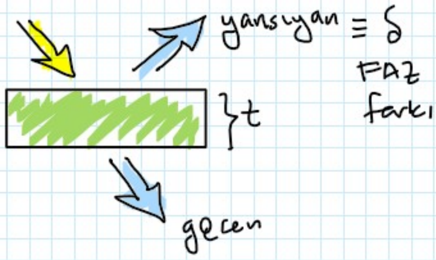


⇒



gelen ışın $\vec{E}_0 = \vec{E}_0 e^{i\omega t}$ Yansıyan + ? $E_1 = rE_0 e^{i\omega t}$

gelen ışın $\underset{\sim}{\vec{E}_0 = \vec{E}_0 e^{i\omega t}}$

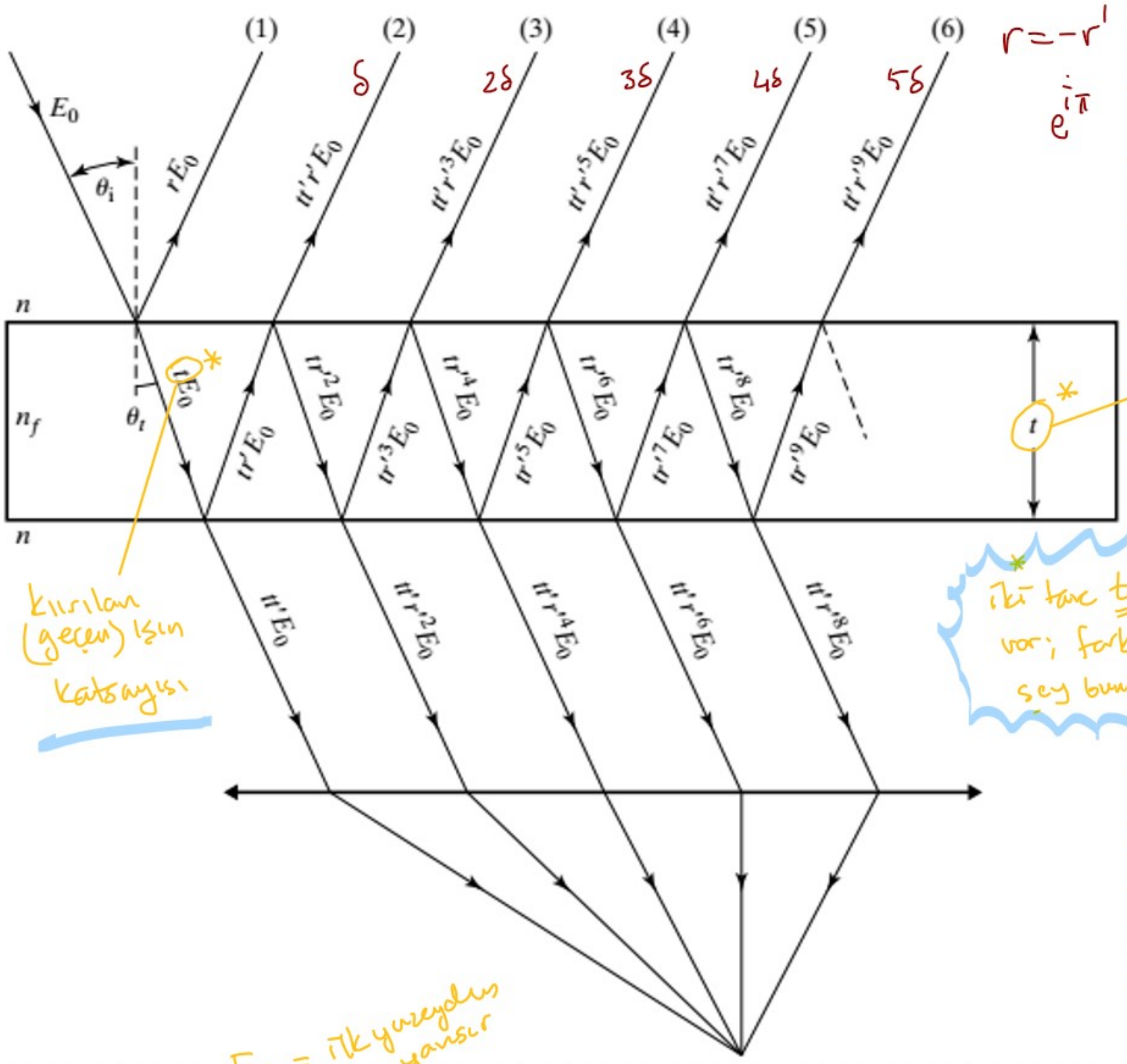


yansıyan + kırılan
$$\left.\begin{array}{l} E_1 = r E_0 e^{i\omega t} \\ E_2 = tt' E_0 e^{i(\omega t - \delta)} \\ E_3 = tt' (r') E_0 e^{i(\omega t - 2\delta)} \\ E_4 = tt' (r')^2 E_0 e^{i(\omega t - 3\delta)} \end{array}\right\}$$

$$\boxed{\delta = k\Delta_s = k 2nt\cos\theta_t}$$

$\delta = k\Delta$, where $\Delta = 2n_f t\cos\theta_t$ film kalınlığından dolayı oluşan faz farkı

$\Delta_s = 2nt\cos\theta_t$



$r = -r'$

$e^{i\pi}$

Kırılan (geçen) ışın katsayısı

* film kalınlığı

* iki tane t var; farklı şey bunlar.

$E_1 \equiv$ ilk yüzeyden yansır

$$E_R = \sum_{N=1}^{\infty} E_N = \underset{\sim}{r E_0 e^{i\omega t}} + \sum_{N=2}^{\infty} tt' E_0 (r')^{2N-3} e^{-i[\omega t - (N-1)\delta]}$$

Yansıyan ışınların toplam $\vec{E}$ alanı

$$E_R = E_0 e^{i\omega t}\left[r + tt' r' e^{i\delta} \sum_{N=2}^{\infty} (r')^{2N-4} e^{-i(N-2)\delta}\right]$$

$$\left[(r')^2 e^{-i\delta}\right]^{(N-2)}$$

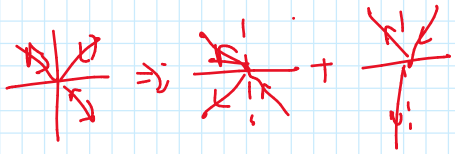
$$\left[(r')^2 \; e^{-i\delta}\right]^{(N-2)}$$

$$\sum_{N=2}^{\infty} x^{N-2} = 1+x+x^2+\cdots$$

$x = (r')^2 e^{-i\delta}$; $x<1$ $\underline{r}<1$

$$= 1+x+x^2+\cdots = \underline{\frac{1}{1-x}}$$

$$E_R = E_0 e^{i\omega t}\left(r + \frac{tt'r'e^{-i\delta}}{1-(r')^2 e^{-i\delta}}\right)$$



Stokes' bağıntıları $\Rightarrow$ $\overset{\text{dış-iç yansıma}}{\boxed{r=-r'}}$; $\boxed{tt' = 1-r^2}$

$$E_R = E_0 e^{i\omega t}\left(r + \frac{(1-r^2)(-r)\,e^{-i\delta}}{1-r^2\,e^{-i\delta}}\right) = E_0 e^{i\omega t}\left(r - \frac{(1-r^2)r\,e^{-i\delta}}{1-r^2 e^{-i\delta}}\right)$$

$$E_R = \overset{E_i}{\underbrace{E_0 e^{i\omega t}}}\left[\frac{r(1-e^{-i\delta})}{1-r^2\,e^{-i\delta}}\right] \; ; \quad \underset{\text{ışık şiddeti = parlaklığı}}{I_R} \propto E_R E_R^{*} \quad \frac{\text{Watt}}{\text{m}^2}$$

$$I_R \propto |E_R|^2 = E_0^{\,2} r^2 \left[\frac{e^{i\omega t} e^{-i\omega t}\,(1-e^{-i\delta})(1-e^{i\delta})}{(1-r^2 e^{-i\delta})(1-r^2 e^{i\delta})}\right]$$

$$2\cos\delta = e^{i\delta} + e^{-i\delta}$$

$$|E_R^2| = E_0^{\,2}\; 2r^2 \left(\frac{1-\cos\delta}{1+r^4-2r^2\cos\delta}\right)$$

Yansıma

$$\boxed{I_R = I_i\left[\frac{2r^2(1-\cos\delta)}{1+r^4-2r^2\cos\delta}\right]}$$ ışık parlaklığı

$$\frac{I_R}{I_i} = \frac{|E_R|^2}{|E_0|^2}$$ $\Rightarrow$ ışığın yansıma şiddet oranları

$I_i = I_R + I_T$

$= I_i(\underbrace{\alpha+\beta}_{1})$

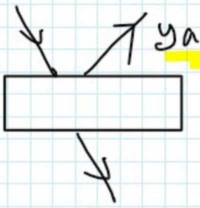
Aynı hesaplamaları E_T için yaparsak . . . .

$$(1-r^2)^2$$

ılma

$$\boxed{I_T = I_i \left[\frac{(1-r^2)^2}{1+r^4-2r^2\cos\delta} \right]}$$ kırılma (geçme)

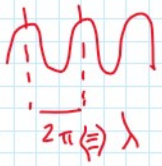
$$I_i = I_R + I_T \quad (\text{soğurma yoksa})^{*}_{*}$$



Yansıma ≡ MINIMUM olması istiyoruz diyelim $\delta = k\Delta \rightarrow \left(\frac{2\pi}{\lambda} 2nt\cos\theta_t\right)$

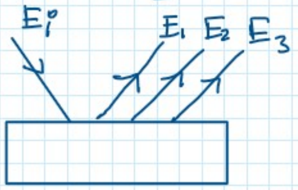
$$\left(\frac{2r^2(1-\cos\delta)}{1+r^4-2r^2\cos\delta}\right) = \min = 0 \text{ olduğu durum} \Rightarrow \boxed{\cos\delta = 1}\ {}^{*}_{*}$$

$\cos\delta = 1 \Rightarrow \{\delta = 2\pi m\}$ ve $\Delta = 2n_f t \cos\theta_t = m\lambda$



↳ yansıma MIN olursa ; geçen MAX olur. $I_i = I_T$

$I_R = 0$



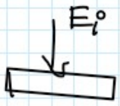
$\Big\} \rightarrow 0 \quad \underset{+}{(E_1)} + \underset{-}{(E_2 + E_3 + \cdots)} = 0$

eğer E_2 nin genliği E_1'e yakınsa $E_1 + E_2 \simeq 0$ olur.

$$\frac{E_2}{E_1} = \left|\frac{tt'r'E_0}{rE_0}\right| = \left|\frac{(1-r^2)(-r)E_0}{rE_0}\right| = (1-r^2)$$

r küçükse $\frac{E_2}{E_1} \simeq 1$

mesela geliş açısı $\theta_i = 0$ ışın cam yüzeye gönderilsin



$n = 1.5 \quad r^2 = 0.04 \Rightarrow$ %96 oranında $E_1 + E_2$ birbirini yok eder.

Bazen E_1 ve E_2 yi hesaplayarak yaklaşım yapılabilir.

Maximum Yansıma

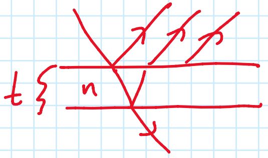
$\cos\delta = -1 \quad ; \quad \delta = \pi, 3\pi \ldots = (m + \frac{1}{2})2\pi$

$$\Delta = 2n_f t\cos\theta_t = (m + \tfrac{1}{2})\lambda$$

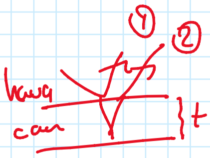
$I_R = I_i \left[\frac{4r^2}{(1+r^2)^2}\right]$ I_R max olduğunda $I_R < I_i$

$$I_T = I_i \left[\frac{(1-r^2)}{(1+r^2)}\right]^2 \qquad I_T \text{ min} \quad " \quad I_T > 0$$

Stoke ⇒ yansıma, geçme oranlarını verir.



stoke $\frac{I_R}{I_i^0}$; $\frac{I_T}{I_i}$ ⇒ % kaçı?



$\}$ (Karanlık)

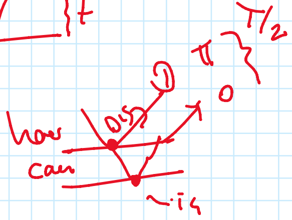
$$2nt\cos\theta_t = \Delta_s$$
✓

$$\left\{ \underline{\underline{\tilde{\Delta_s}}} + \tilde{\Delta_r} \right\}$$

$2nt\cos\theta_t$ uzunluk

$\downarrow$ $\frac{\lambda}{2}$? 0?

?? neye Stokes $r = -r'$



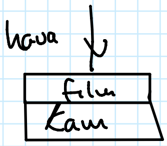
dış + iç = $\frac{\lambda}{2}$

$$\left(m+\frac{1}{2}\right)\lambda \equiv \text{Karanlık}$$

$\frac{\lambda}{2}$ $\frac{3\lambda}{2}$ .... ⇒

7.15) MgF$_2$ cam üzerine kaplanıyor.

$n = 1.38$ dik gelen 580nm ışık yansıma oluyor.

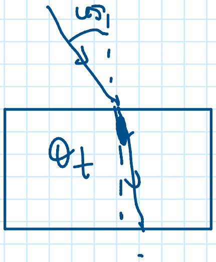


eğer 45° açı ile gelirse hangi dalga boyu yansıtılır.

$$\left(m+\frac{1}{2}\right)\lambda = 2nt \qquad \lambda = 580\text{nm} \quad m = 0 \qquad t = \frac{\lambda}{4n}$$

$$\left(m+\frac{1}{2}\right)\underline{\underline{\lambda'}} = 2n\underline{\underline{t}}\cos\theta_t$$

$$\lambda' = 498\text{nm} \; ?$$



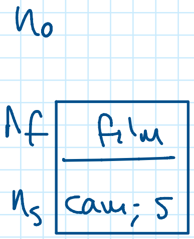
$n_1 \sin\theta_i = n_2 \sin\theta_t$

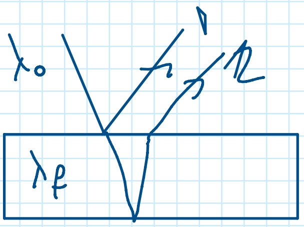
$1 \sin 45 = (1.38)\sin\theta_t \Rightarrow \theta_t \Rightarrow \cos\theta_t$

30.83°

7.16) 550nm dalgaboyunun yatsıtmanın sıfır olması için mercek üzerine kaplama yapılacak. $n_{mercek} = 1.78$

film kalınlığı? ve filmin kırılma indisi?





$$n_f = \sqrt{n_o n_s} = $$

$$= \sqrt{1(1.78)} = \underline{\underline{1.33}}$$

$\theta_t = 0°$

$$2nt = \left(\overset{0}{m}+\frac{1}{2}\right)\lambda$$

MgF$_2$ ~ 1.38

$2nt = \left(m+\frac{1}{2}\right)\lambda$

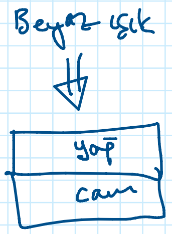
$Mg F_2 \sim 1.38$

$t = \frac{\lambda_0}{4n} = \underline{\frac{\lambda_f}{4}}$

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

$\frac{550\,nm}{4(1.33)} = \underline{\underline{103\,nm}}$

7.14)



$n_{yağ} = 1.3$

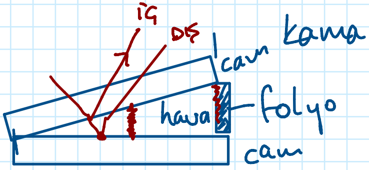
525 nm ; 675 nm <u>yok oluyor.</u>

$\left(m'+\frac{1}{2}\right)\lambda' = \left(m+\frac{1}{2}\right)\lambda = 2nt$

✗ $\left(3+\frac{1}{2}\right)525 \overset{?}{=} \left(2+\frac{1}{2}\right)675$

$t = 908.7\,nm \Leftarrow$ ✓ $\left(4+\frac{1}{2}\right)525 = \left(3+\frac{1}{2}\right)675 = 2\overset{(1.3)}{n}t$

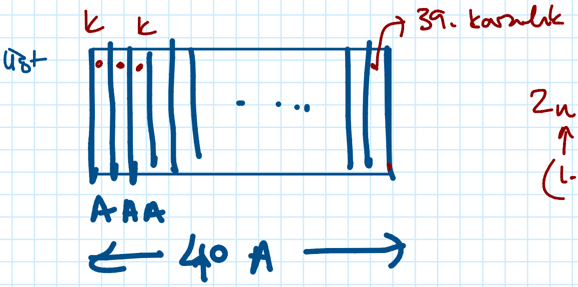
7.20)



kama = wedge

$\lambda = 589\,nm$ ışık altında 40 aydınlık saçak gözleniyor.

folyo kalınlığı ?



$2\underset{(1.0)}{n}t = 2t = \left(m+\frac{1}{2}\right)\lambda \equiv$ karanlık

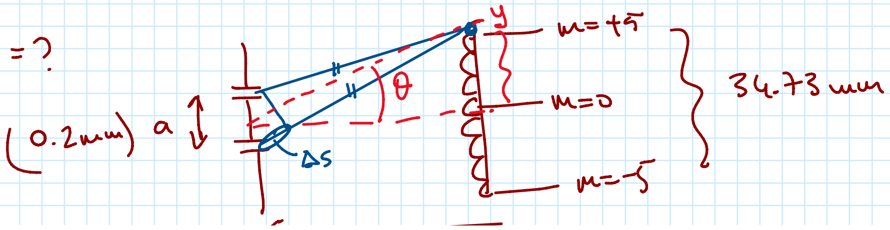
$2t = \left(39+\frac{1}{2}\right)\lambda$

$t = 1.16\times10^{-5}\,m = \underline{\underline{11.6\,\mu m}}$

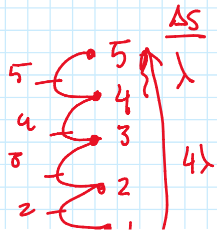
7.7 Young 0.2 mm yarık aralığı, 1.5 m perde uzaklığı

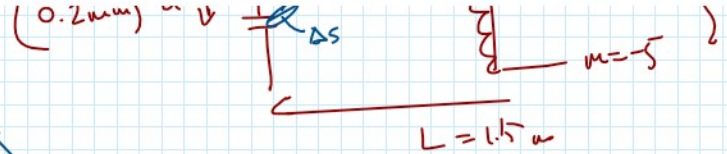
5ci min ve −5.ci minin arası mesafe 84.73 mm oluyor.

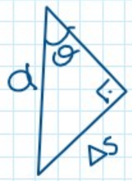
$\lambda = ?$

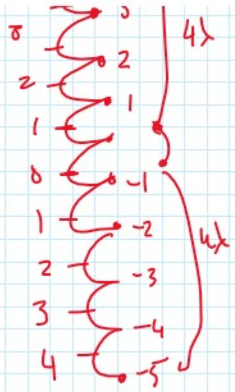


34.73 mm









$\sin\theta = \frac{\Delta s}{a} \simeq \tan\theta = \frac{y}{L}$

$\Delta S = \frac{ay}{L}$

$\downarrow$

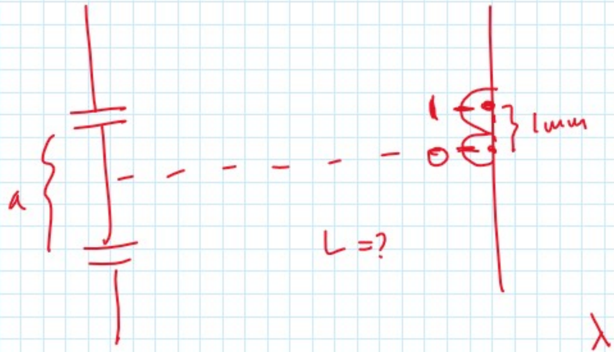
$\left(m\lambda ;\ m+\frac{1}{2}\lambda\right)$

$9\lambda = \Delta S = a\frac{y}{L}$

$\left(m-\frac{1}{2}\right)\lambda$

$$9\lambda = \frac{(0,2)\times10^{-3}\ \ 84.73\times10^{-3}}{1.5} \Rightarrow \underline{\underline{\lambda = 515\,nm}}$$

7.9)



$a = 0.5\,mm$

$\lambda = 600\,nm$

ekranda 1mm saçak aralığı var

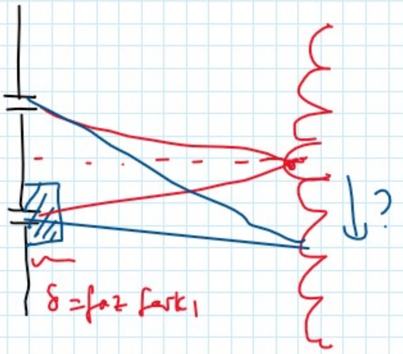
$L = ?$

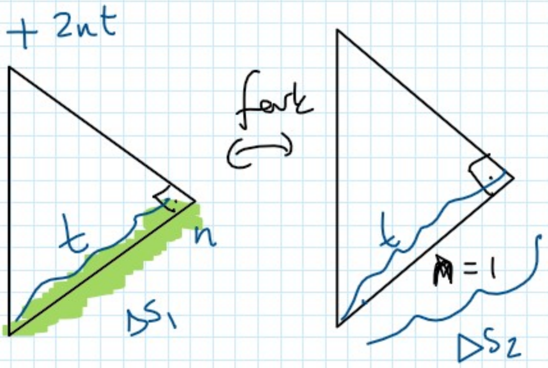
$$\lambda = \Delta s = \frac{ay}{L} = \frac{0.5\times10^{-3}\times10^{-3}}{L} = 600\times10^{-9}$$

$L = 0.83\,m$

b) deliklerden birine
100μm kalınlığında
n= 1.5 olan bir film
tabakası koyuluyr.
ekrandaki saçak yerdeğiştirmesi ne olur?

normalde $\underset{\sim}{\Delta S} = \frac{aY}{L}$





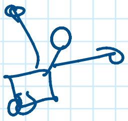
$$\Delta S_1 - \Delta S_2 = \underset{\sim\sim\sim}{nt - t} = \Delta m\lambda$$

$\underset{(\Delta S)}{nt} = m'\lambda \quad ; \quad \underset{(\Delta S)}{t} = m\lambda$

$$t(n-1) = \Delta m\,\lambda \quad \Rightarrow \quad \Delta m = \frac{t(n-1)}{\lambda} = \frac{(100\times10^{-6})(1.5-1)}{\quad -9}$$

$$t(n-1) = \Delta m \lambda \Rightarrow \Delta m = \frac{t(n-1)}{\lambda} = \frac{(100\times10^{-6})(1.5-1)}{600\times10^{-9}}$$

$= 83.3$ saçak kaymış



2023

— SON — iyi mutlu yıllar