

$T = 10 \text{ N}$
 $L = 50 \text{ cm}$
 $R = 1 \text{ mm}$
 $\rho = 1 \frac{\text{kg}}{\text{m}^3}$

$\psi = (A \cos kx + B \sin kx) \cos(\omega t + \phi)$ *נכנסים לנורמל* (k)

$\psi|_{x=0} = 0 \Rightarrow A = 0$

$m \frac{\partial^2 \psi}{\partial t^2} \Big|_{x=L} = -T \frac{\partial \psi}{\partial x} \Big|_{x=L}$ *נכנסים לנורמל*

$-m \omega^2 B \sin kL = -T k B \cos kL$

$\omega = v k = \sqrt{\frac{T}{\rho}} k$

$\Rightarrow m \frac{T}{\rho} k^2 B \sin kL = T k B \cos kL$

$\Downarrow k \neq 0$

$\frac{m k}{\rho} = \text{ctg} kL$

$m \rightarrow 0$

נכנסים לנורמל

$\text{ctg} kL = 0$

$k_n = \frac{(n + \frac{1}{2}) \pi}{L}$

\Rightarrow

$\lambda_n = \frac{2\pi}{k_n} = \frac{2L}{n + \frac{1}{2}}$

$$W_n = \sqrt{\frac{I}{S}} \frac{(n + \frac{1}{2}) \pi}{L} \quad (2)$$

$$S = \pi R^2 \cdot \rho = \pi \cdot 1 \text{ mm}^2 \cdot 1 \frac{\text{kg}}{\text{m}^3} = \pi \cdot 10^{-6} \frac{\text{kg}}{\text{m}}, \quad L = 0.5 \text{ m}$$

$$1 \frac{\text{kg}}{\text{m}^3} \text{ (density of steel)} \rightarrow \rho = 1 \frac{\text{kg}}{\text{m}^3}$$

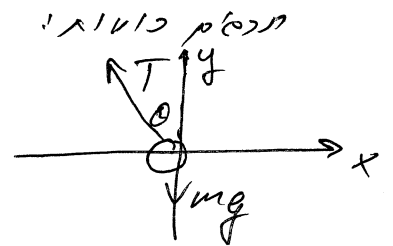
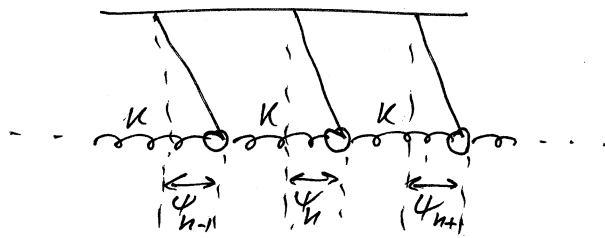
$$W_n = \sqrt{10^7 (2n + \frac{1}{2}) \pi} \cdot \frac{1}{\text{sec}}$$

$$\psi = \frac{a_0}{2} + \sum_{n=1}^{\infty} (A_n(\kappa) \cos \kappa x + B_n(\kappa) \sin(\kappa x)) \quad (3)$$

$$A_n(\kappa) = \frac{1}{L} \int_{-L}^L F(x) \cos(\kappa x) dx \quad \text{for } \kappa = \frac{n\pi}{L}$$

$$B_n(\kappa) = \frac{1}{L} \int_{-L}^L F(x) \sin(\kappa x) dx$$

(for the Fourier series). The coefficients are given by the formulas above.



y: $T \cos \theta = mg$: תנאי איזוטרופיות (1)
 $T \approx mg$
 $\sin \theta = \frac{\psi_n}{L}$

$$m \frac{\partial^2 \psi}{\partial t^2} = -T \sin \theta + k(\psi_{n+1} - \psi_n) - k(\psi_n - \psi_{n-1})$$

$$= -mg \sin \theta + k(\psi_{n+1} - \psi_n) - k(\psi_n - \psi_{n-1})$$

↓

$$(1) \frac{\partial^2 \psi_n}{\partial t^2} = -g \frac{\psi_n}{L} + \frac{k}{m} (\psi_{n+1} - 2\psi_n + \psi_{n-1})$$

$\psi_n = A \sin(\kappa n a) \cos(\omega t)$ (כ) עניין סטנדרט של תנודות סינוסיות
(א) תנודות של סדרה של תנודות סינוסיות

$$(2) \psi_{n+1} - 2\psi_n + \psi_{n-1} = A \cos \omega t (\sin(\kappa(n+1)a) - 2\sin(\kappa n a) + \sin(\kappa(n-1)a))$$

* $\sin \alpha \cdot \cos \beta = \frac{1}{2} (\sin(\alpha + \beta) + \sin(\alpha - \beta))$

$$\Rightarrow (2) = A \cos(\omega t) [2 \sin(\kappa n a) \cos(\kappa a) - 2 \sin(\kappa n a)]$$

$$= A \cos(\omega t) \sin(\kappa n a) [2 \cos(\kappa a) - 2] = \{ 2 \cos \alpha - 2 = 2 \cdot 4 \sin^2 \frac{\alpha}{2} \}$$

$$= -A \cos \omega t \sin(\kappa n a) \cdot 4 \sin^2 \left(\frac{\kappa a}{2} \right)$$

$$\Rightarrow (1) : -\omega^2 A \sin(\kappa n a) \cos(\omega t) = -\frac{g}{L} A \sin(\kappa n a) \cos(\omega t) - \frac{k}{m} (A \cos \omega t \sin(\kappa n a) \cdot 4 \sin^2 \left(\frac{\kappa a}{2} \right))$$

$$\omega^2 = \frac{g}{L} + \frac{4k}{m} \sin^2 \left(\frac{\kappa a}{2} \right)$$

(c) יקום כ' עמור עם מערכת משוואות

$$\frac{d^2 y}{dt^2} = -\omega^2 y$$

כמו כן יקום עמור עם מערכת משוואות

$$\frac{d^2 y}{dx^2} = -\kappa^2 y$$

כמו כן יקום עמור עם מערכת משוואות a ו- b

$$\sin \frac{\kappa a}{2} \rightarrow \frac{\kappa a}{2} \quad \text{ובכן}$$

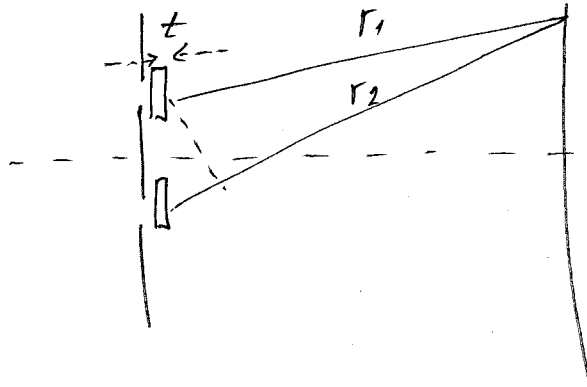
מכאן אלו ה'ז' מקבלים את התוצאה

* תוצאה יותר טובה ואת נכונה היא עמור משוואות $\frac{d^2 y}{dx^2} = -\kappa^2 y$ ו- $y(0) = 0$
המשוואות ה'ז' $x = a$ במידה להכאן ע'.

$$y(u+1) - 2y(u) + y(u-1) = a^2 \frac{d^2 y}{dx^2}$$

- עכשיו מנסה לקבל את התוצאה עם ה'ז' שפיר קצת
המשוואות קטין-זרועות וקיים את ה'ז' הנכונה.

(3)



לכיוון זווית θ

$$\delta = \kappa \Delta = \kappa(r_2 - r_1) + \kappa_2 t - \kappa_1 t = \frac{2\pi}{\lambda} d \sin \theta + \frac{2\pi}{\lambda} (n_2 - n_1) t$$

$$I(\theta) = I_m \cos^2 \left[\frac{\pi}{\lambda} (d \sin \theta + (n_2 - n_1) t) \right]$$

$n_2 - n_1 = 1$

$$\Delta \psi = \frac{2\pi}{\lambda} (n_2 - n_1) t$$

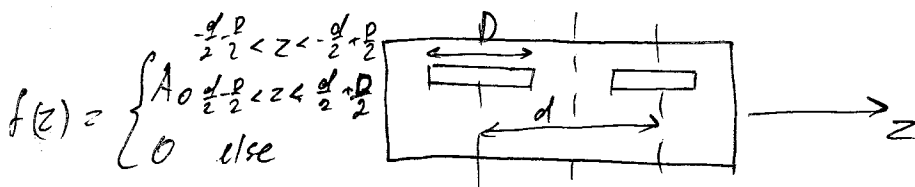
↓

$$(n_2 - n_1) t = \frac{\lambda}{2}$$

↓

$$t = \frac{\lambda}{2(n_2 - n_1)} = \frac{\lambda}{2(n_2 - 1)}$$

(ב) חזק כעין במקור: יחס אורכי הגל של שני האופקים. ככל שהאורך של החסם קטן יותר, כך האורך של האופק (המסך) קטן יותר (במילים אחרות). * את המעגל עם רגש עכבר, יש להוסיף את המרחק בין המסך והמקור.



$$F(k_2) = \int_{-\infty}^{\infty} f(z) e^{ik_2 z} dz = A_0 \int_{\frac{d-D}{2}}^{\frac{d+D}{2}} e^{ik_2 z} dz + A_0 \int_{\frac{d-D}{2}}^{\frac{d+D}{2}} e^{ik_2 z} dz =$$

$$F(k_z) = A_0 \left[\frac{1}{ik_z} e^{ik_z z} \Big|_{-\frac{d}{2} - \frac{D}{2}}^{-\frac{d}{2} + \frac{D}{2}} + \frac{1}{ik_z} e^{ik_z z} \Big|_{\frac{d}{2} - \frac{D}{2}}^{\frac{d}{2} + \frac{D}{2}} \right] =$$

$$= \frac{A_0}{ik_z} \left[e^{-ik_z \frac{d}{2}} e^{ik_z \frac{D}{2}} - e^{-ik_z d} e^{-ik_z \frac{D}{2}} + e^{ik_z \frac{d}{2}} e^{ik_z \frac{D}{2}} - e^{ik_z \frac{d}{2}} e^{-ik_z \frac{D}{2}} \right]$$

$$= \frac{A_0}{ik_z} \left[e^{+ik_z \frac{D}{2}} \left(e^{-ik_z \frac{d}{2}} + e^{ik_z \frac{d}{2}} \right) - e^{-ik_z \frac{D}{2}} \left(e^{-ik_z \frac{d}{2}} + e^{ik_z \frac{d}{2}} \right) \right]$$

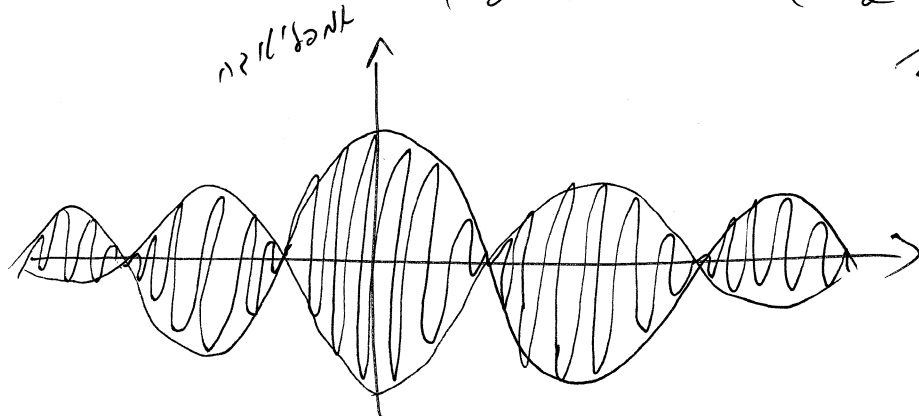
$$= ik_z \frac{D}{2} = i\alpha \quad k_z \frac{d}{2} = \beta$$

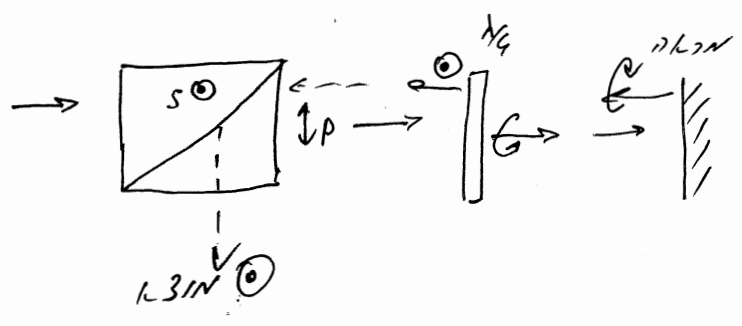
$$= A_0 \left[\frac{e^{i\alpha} - e^{-i\alpha}}{ik_z} \cdot \frac{2(e^{i\beta} + e^{-i\beta})}{2} \right] = 2A_0 \cos \beta \frac{e^{i\alpha} - e^{-i\alpha}}{ik_z}$$

$$= 4A_0 \cos \beta \frac{\sin \alpha}{k_z} = \frac{D}{D}$$

$$= 2A_0 D \cos \beta \operatorname{sinc} \alpha =$$

$$F(k_z) = 2A_0 D \cos\left(\frac{k_z d}{2}\right) \operatorname{sinc}\left(\frac{k_z D}{2}\right)$$





(4)

BS שולח : $\psi(z,t) = Ae^{i(\omega t - kz)} \hat{x} = \frac{1}{\sqrt{2}} A e^{i(\omega t - kz)} (\hat{x}' + \hat{y}')$
 $\frac{\lambda}{4}$ שולח שם קב'ס - \hat{x}', \hat{y}'

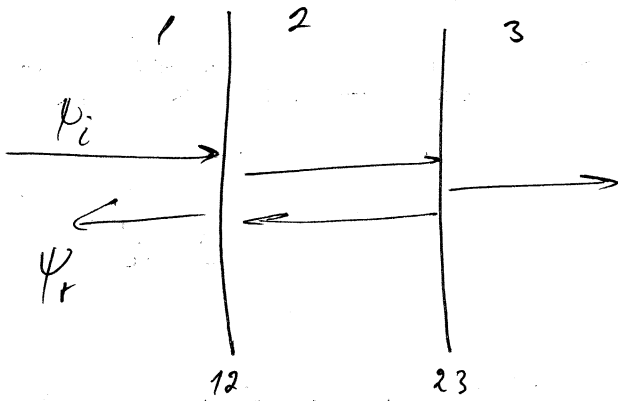
$\frac{\lambda}{4}$ שולח : $\psi(z,t) = \frac{A}{\sqrt{2}} [e^{i(\omega t - kz)} \hat{x}' + e^{i(\omega t - kz - \frac{\pi}{2})} \hat{y}']$

אטל מראה : $\psi(z,t) = \frac{A}{\sqrt{2}} [e^{i(\omega t + kz)} \hat{x}' + e^{i(\omega t + kz - \frac{\pi}{2})} \hat{y}']$

אטל מראה $\frac{\lambda}{4}$ קר'ס : $\psi(z,t) = A' [e^{i(\omega t + kz)} \hat{x}' + e^{i(\omega t + kz - \pi)} \hat{y}']$
 $= A' e^{i(\omega t + kz)} (\hat{x}' - \hat{y}') = A' e^{i(\omega t + kz)} \hat{y}$

השם המוגבל הוא במילויק ב'טוס'כנס וסבן ס' ימור PBS ל'ט' ס'ט' ל'ט'.

(1) (3)



$$\Psi_r = R_{12} A \cos(\omega t + kx) + R_{23} T_{12} T_{21} A \cos(\omega t + kx - 2k_2 L)$$

$$T_{12} T_{21} = (1 + R_{12})(1 - R_{12}) = 1 - R_{12}^2 \approx 1$$

$$R_{12}, R_{23} \ll 1, \rho v$$

↓

$$\Psi_r = R_{12} A \cos(\omega t + k_1 x) + R_{23} A \cos(\omega t + k_1 x - 2k_2 L)$$

$$R = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

$$Z_2 = \sqrt{Z_1 Z_3}$$

$$\Leftrightarrow \frac{Z_1}{Z_2} = \frac{Z_2}{Z_3}$$

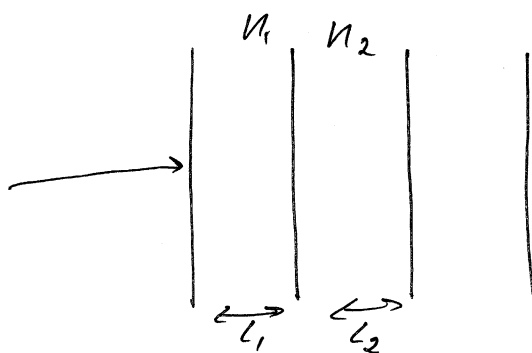
$$\Leftrightarrow R_{12} = R_{23} \text{ נחמד}$$

↓

$$\Psi_r^{tot} \approx R_{12} A [\cos(\omega t + k_1 x) + \cos(\omega t + k_1 x - 2k_2 L)]$$

$$\Psi_r^{tot} = 0$$

$$\Leftrightarrow 2k_2 L = \pi \quad \rho v$$

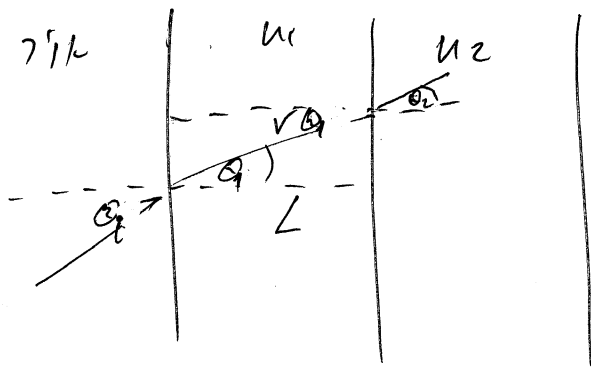


ק"ו

בדרך כלל מקום האסרה הוא קל/ולכן צריך לזכור את זה.

כך שאם $2k_1 L_1 = 2\pi$ | $2k_2 L_2 = 2\pi$ | $2k_3 L_3 = 2\pi$ | $2k_4 L_4 = 2\pi$ | $2k_5 L_5 = 2\pi$ | $2k_6 L_6 = 2\pi$ | $2k_7 L_7 = 2\pi$ | $2k_8 L_8 = 2\pi$ | $2k_9 L_9 = 2\pi$ | $2k_{10} L_{10} = 2\pi$ | $2k_{11} L_{11} = 2\pi$ | $2k_{12} L_{12} = 2\pi$ | $2k_{13} L_{13} = 2\pi$ | $2k_{14} L_{14} = 2\pi$ | $2k_{15} L_{15} = 2\pi$ | $2k_{16} L_{16} = 2\pi$ | $2k_{17} L_{17} = 2\pi$ | $2k_{18} L_{18} = 2\pi$ | $2k_{19} L_{19} = 2\pi$ | $2k_{20} L_{20} = 2\pi$ | $2k_{21} L_{21} = 2\pi$ | $2k_{22} L_{22} = 2\pi$ | $2k_{23} L_{23} = 2\pi$ | $2k_{24} L_{24} = 2\pi$ | $2k_{25} L_{25} = 2\pi$ | $2k_{26} L_{26} = 2\pi$ | $2k_{27} L_{27} = 2\pi$ | $2k_{28} L_{28} = 2\pi$ | $2k_{29} L_{29} = 2\pi$ | $2k_{30} L_{30} = 2\pi$ | $2k_{31} L_{31} = 2\pi$ | $2k_{32} L_{32} = 2\pi$ | $2k_{33} L_{33} = 2\pi$ | $2k_{34} L_{34} = 2\pi$ | $2k_{35} L_{35} = 2\pi$ | $2k_{36} L_{36} = 2\pi$ | $2k_{37} L_{37} = 2\pi$ | $2k_{38} L_{38} = 2\pi$ | $2k_{39} L_{39} = 2\pi$ | $2k_{40} L_{40} = 2\pi$ | $2k_{41} L_{41} = 2\pi$ | $2k_{42} L_{42} = 2\pi$ | $2k_{43} L_{43} = 2\pi$ | $2k_{44} L_{44} = 2\pi$ | $2k_{45} L_{45} = 2\pi$ | $2k_{46} L_{46} = 2\pi$ | $2k_{47} L_{47} = 2\pi$ | $2k_{48} L_{48} = 2\pi$ | $2k_{49} L_{49} = 2\pi$ | $2k_{50} L_{50} = 2\pi$ | $2k_{51} L_{51} = 2\pi$ | $2k_{52} L_{52} = 2\pi$ | $2k_{53} L_{53} = 2\pi$ | $2k_{54} L_{54} = 2\pi$ | $2k_{55} L_{55} = 2\pi$ | $2k_{56} L_{56} = 2\pi$ | $2k_{57} L_{57} = 2\pi$ | $2k_{58} L_{58} = 2\pi$ | $2k_{59} L_{59} = 2\pi$ | $2k_{60} L_{60} = 2\pi$ | $2k_{61} L_{61} = 2\pi$ | $2k_{62} L_{62} = 2\pi$ | $2k_{63} L_{63} = 2\pi$ | $2k_{64} L_{64} = 2\pi$ | $2k_{65} L_{65} = 2\pi$ | $2k_{66} L_{66} = 2\pi$ | $2k_{67} L_{67} = 2\pi$ | $2k_{68} L_{68} = 2\pi$ | $2k_{69} L_{69} = 2\pi$ | $2k_{70} L_{70} = 2\pi$ | $2k_{71} L_{71} = 2\pi$ | $2k_{72} L_{72} = 2\pi$ | $2k_{73} L_{73} = 2\pi$ | $2k_{74} L_{74} = 2\pi$ | $2k_{75} L_{75} = 2\pi$ | $2k_{76} L_{76} = 2\pi$ | $2k_{77} L_{77} = 2\pi$ | $2k_{78} L_{78} = 2\pi$ | $2k_{79} L_{79} = 2\pi$ | $2k_{80} L_{80} = 2\pi$ | $2k_{81} L_{81} = 2\pi$ | $2k_{82} L_{82} = 2\pi$ | $2k_{83} L_{83} = 2\pi$ | $2k_{84} L_{84} = 2\pi$ | $2k_{85} L_{85} = 2\pi$ | $2k_{86} L_{86} = 2\pi$ | $2k_{87} L_{87} = 2\pi$ | $2k_{88} L_{88} = 2\pi$ | $2k_{89} L_{89} = 2\pi$ | $2k_{90} L_{90} = 2\pi$ | $2k_{91} L_{91} = 2\pi$ | $2k_{92} L_{92} = 2\pi$ | $2k_{93} L_{93} = 2\pi$ | $2k_{94} L_{94} = 2\pi$ | $2k_{95} L_{95} = 2\pi$ | $2k_{96} L_{96} = 2\pi$ | $2k_{97} L_{97} = 2\pi$ | $2k_{98} L_{98} = 2\pi$ | $2k_{99} L_{99} = 2\pi$ | $2k_{100} L_{100} = 2\pi$

$$L_1 = \frac{\pi}{\frac{2\pi n_1}{\lambda}} = \frac{\lambda}{2n_1} = \frac{c}{2n_1 f} \quad \Leftrightarrow \quad L_1 = \frac{\pi}{k_1} \quad \left| \quad L_2 = \frac{\pi}{k_2} = \frac{\lambda}{2n_2} = \frac{c}{2n_2 f}$$



$$n_i \sin \theta_i = n_t \sin \theta_t \quad \text{for } n_1 \neq n_2$$

$$\cos \theta_t = \frac{L}{r} \Rightarrow r = \frac{L}{\cos \theta_t}$$

$$2K_1 r = 2\pi$$

$$K_1 \frac{L}{\cos \theta_t} = \pi$$

$$L_1 = \frac{\pi \cos \theta_t}{K_1} = \frac{\lambda \cos \theta_t}{2n_1} = \frac{c \cos \theta_t}{2n_1 f}$$

$$\therefore L_2 = \frac{\lambda \cos \theta_t}{2n_2} = \frac{c \cos \theta_t}{2n_2 f}$$

$$n_i \sin \theta_i = n_t \sin \theta_t \Rightarrow 1 \cdot \sin 45 = n_1 \sin \theta_1 = n_2 \sqrt{1 - \cos^2 \theta_1} \quad \text{for } n_1 \neq n_2$$

$$\frac{1}{2n_1^2} = 1 - \cos^2 \theta_1$$

$$\cos \theta_1 = \sqrt{1 - \frac{1}{2n_1^2}} \Rightarrow L_1 = \frac{c \sqrt{1 - \frac{1}{2n_1^2}}}{2n_1 f}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_2 = \frac{n_1}{n_2} \sin \theta_1 = \frac{\sin 45}{n_2}$$

$$1 - \cos^2 \theta_2 = \left(\frac{n_1}{n_2} \sin \theta_1 \right)^2$$

$$\cos^2 \theta_2 = 1 - \left(\frac{n_1}{n_2} \sin \theta_1 \right)^2 = 1 - \left(\frac{\sin 45}{n_2} \right)^2$$

$$\cos^2 \theta_2 = 1 - \frac{1}{2n_2^2}$$

$$L_2 = \frac{c \sqrt{1 - \frac{1}{2n_2^2}}}{2n_2 f}$$