University of Technology
Department of Laser & Opto-electronic Engineering
Final Examination 2011-2012
Subject :geometrical optics
Division: laser and optoelectronics
Examiner: Lec.Aseel Abdul Ameer
Class:2nd year
Time:3 hours
Date: 10/ 6 / 2012

Answer five questions only

Q1.A.By using **snells law** derive an expression for the critical angle ?

B. A small object is placed **30 cm** from the first of three lenses with focal length , in order , of **20 , 25 , 30 cm** .calculate the final image position relative to the last lens and its linear magnification relative to the original object when the middle lens is negative ?

Q2.Aglass lens **3cm** thick along the axis has one convex face of radius **5 cm** and the other , also convex , of radius **2cm** . the former face is on the left in contact with air and the other in contact with a liquid of index **1.4** . find the position of the foci , principal planes , and focal length of the system .use the matrix approach?

Q3. A positive lens of index **1.5** and focal length **50 cm** is "bent" to produce Coddington shape factor of **0.8** and **2** determine the corresponding radii of curvature?.

Q4.Derive an expression for phase and group velocity?

Q5.Derive an expression for the optical path difference between the emerging beams from single layer film that's related to constructive interference ?

Q6.A. When one mirror of a Michelson interferometer is translate by **.0114cm** , **523** fringes are observed to bass the cross hairs of the viewing telescope .calculate the wavelength of light?.

B.Draw the set up of mach–zehnder interferometer and explain its advantagc over Michelson interferometer ?

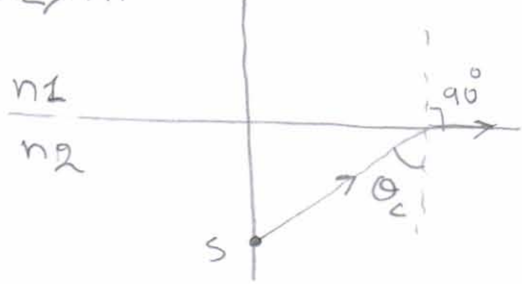
Good luck

أ.د.عبد

الاجوبة للنسخة الاولى من الاسئلة

Q1/ (A)

By using snell's law derive an expression for the critical angle?



snell's law

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

For the critical angle $\theta_1 = 90$, $\theta_2 = \theta_c$.

By using paraxial approximation the angle of incident and angle of refracting are very small and the approximation,

~~$\sin\theta \cong \tan\theta \cong \theta$ (in radians).~~

~~$n_1 \tan\theta_1 \cong n_2 \tan\theta_2$~~

$\theta_1 = 90$

$n_1 \sin 90 = n_2 \sin\theta_c$ ($\sin 90 \to 1$)

$n_1 = n_2 \sin\theta_c \Rightarrow \sin\theta_c = \frac{n_1}{n_2} \Rightarrow \theta_c = \sin^{-1}\frac{n_1}{n_2}$

OR $\theta_c = \tan^{-1}\frac{n_1}{n_2}$ where $n_2 > n_1$.

(B) $S = 30\,cm$, $f_1 = 20\,cm$, $f_2 = -25\,cm$, $f_3 = 30\,cm$

$P_T = P_1 + P_2 + P_3$.

$\frac{1}{F_T} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$, $\frac{1}{F_T} = \frac{1}{20\times10^{-2}} - \frac{1}{25\times10^{-2}} + \frac{1}{30\times10^{-2}}$

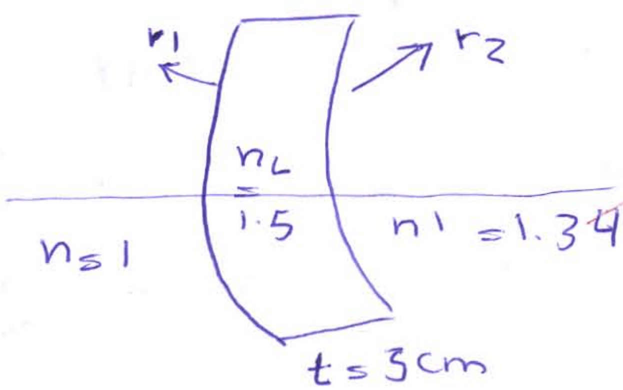
$\frac{1}{F_T} = 0.05 * 10^2 - 0.04 * 10^2 + 0.033 * 10^2$

$= (0.05 - 0.04 + 0.033) * 10^2 = 0.04333$

$= 23.078\,cm$

$\frac{1}{S} + \frac{1}{S'} = \frac{1}{F} \Rightarrow \frac{1}{S'} = \frac{1}{F} - \frac{1}{S} \Rightarrow S' = \frac{FS}{S-F} = -98.9\,cm$

Q2/



$$M = M_3 * M_2 * M_1$$

$$M_1 = \begin{bmatrix} 1 & 0 \\ \frac{n_L - n}{n R_1} & \frac{n_L}{n} \end{bmatrix}$$

$$M_2 = \begin{bmatrix} 1 & t \\ 0 & 1 \end{bmatrix}, \quad M_3 = \begin{bmatrix} 1 & 0 \\ \frac{n' - n_L}{n_L R_2} & \frac{n'}{n_L} \end{bmatrix}$$

$$M_1 = \begin{bmatrix} 1 & 0 \\ 10 & 1.5 \end{bmatrix}, \quad M_2 = \begin{bmatrix} 1 & 3\times10^{-2} \\ 0 & 1 \end{bmatrix}$$

$$M_3 = \begin{bmatrix} 1 & 0 \\ -8 & 0.893 \end{bmatrix}$$

$$M = \begin{bmatrix} 1.3 & 4.5 * 10^{-2} \\ -1.47 & 0.9795 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

$$p = \frac{D}{C} = -\frac{0.9795}{-1.47} = -0.666 \text{ m}$$

$$q = \frac{A}{C} = \frac{1.3}{-1.47} = -0.7647 \text{ m}$$

$$r = \frac{D - n_o/n_f}{C} = \frac{0.9795 - 1/1.34}{-1.47} = -0.15866 \text{ m}$$

$$s = \frac{1 - A}{C} = \frac{1 - 1.3}{-1.47} = 0.2 \text{ m}$$

$$f_1 = p - r = -0.666 + 0.158 = -0.508 \text{ m}$$

$F_2 = \frac{1}{c} = \frac{1}{-1.47} = \bar{0}.68$ m.

<u>Q3</u> $r_1 / r_2 = ?$, F =

$\frac{r_1+r_2}{r_1-r_2} = 8 \Rightarrow (r_1+r_2) = 8(r_1-r_2)$

$\frac{r_1+r_2}{r_1-r_2} = 2 \Rightarrow (r_1+r_2) = 2(r_1-r_2)$ بالطرح بالتبادل

$8(r_1-r_2) - 2(r_1-r_2) = 0 \Rightarrow 6(r_1-r_2) = 0$

$(r_1 = r_2)$

$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \Rightarrow \frac{1}{-50*10^{-2}} = (1.5-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

$1 = \bar{0}.25\left(\frac{r_2+r_1}{r_1 r_2}\right)$

$1 = \bar{0}.25 \; \frac{2r_2}{r_2^2} \Rightarrow r_2^2 = 0.5 r_2$

$r_2 = 0.5$
$r_1 = 0.5$

Q3 $n = 1.5,\ f = 50cm,\ \delta = 0.8,\ \delta = 2$

$$0.8 = \frac{r_2 + r_1}{r_2 - r_1} \Rightarrow r_2 + r_1 = 0.8 r_2 - 0.8 r_1$$

$$-0.2 r_2 = -1.8 r_1 \Rightarrow \boxed{r_2 = 9 r_1}$$

$$(n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{1}{f} \Rightarrow \frac{1}{50} = (0.5)\frac{r_2 - r_1}{r_1 r_2}$$

$$r_1 r_2 = 25 \cdot (r_2 - r_1) \Rightarrow 9 r_1^2 = 25(9r_1 - r_1)$$

$$9 r_1^2 = 25(8 r_1) \Rightarrow 9 r_1 = 25 * 8 \Rightarrow r_1 = \frac{25 * 8}{9}$$

$$\boxed{r_1 = 22.22\ cm}$$

$$\boxed{r_2 = 200\ cm}$$

$$2 = \frac{r_2 + r_1}{r_2 - r_1} \Rightarrow r_2 + r_1 = 2r_2 - 2r_1$$

$$r_1 + 2r_1 = 2r_2 - r_2$$

$$\boxed{3r_1 = r_2}$$

$$r_1 r_2 = 50 * 0.5 (r_2 - r_1)$$

$$r_1 r_2 = 25(r_2 - r_1) \Rightarrow 3r_1^2 = 25(2r_1)$$

$$3 r_1^2 = 50 r_1 \Rightarrow r_1 = \frac{50}{3} = 16.666$$

$$r_2 = 50\ cm.$$

Q4 $E_1 = 5\sin(wt - 60)$

$E_2 = 7\cos(wt + 30)$

$E_3 = 5\cos(wt + 60)$ $t = 2s$.

$E_1 = 5\sin(wt - 60 - 90) = 5\cos(wt - 150)$.

$E_o^2 = [5\sin(-150) + 7\sin(30) + 5\sin 60]^2$

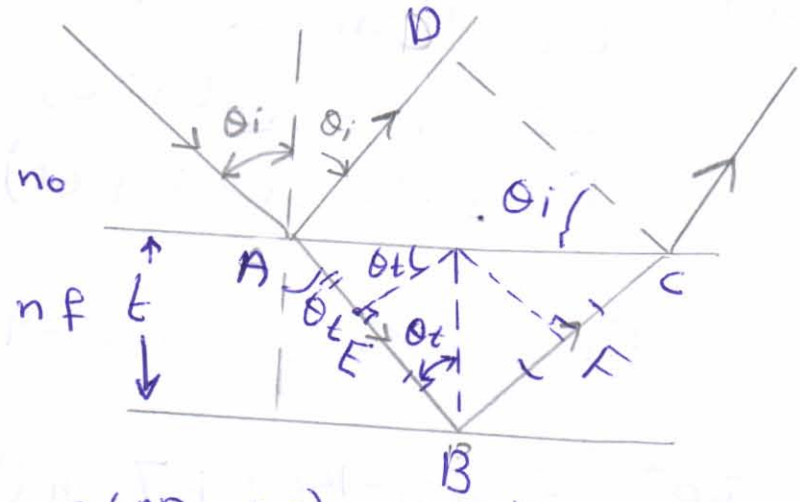
$+ [5\cos(-150) + 7\cos(30) + 5\cos 60]^2$

$= 46.31$

$\alpha = \tan^{-1} \frac{5.33}{4.23} = 51.562^\circ$

$E_R = 46.31\cos(wt + 51.562)$.

Q5 /



Δ = optical path diffrence $= n_f\,(AB + BC) - n_o(AD)$

$\Delta = [n_f(AE + FC) - n_o\,AD] + n_f\,(EB + BF)$

By snell's law $n_1 \sin\theta_i = n_2 \sin\theta_t$.

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

$AD = AC \sin\theta_i \Rightarrow AC = \frac{AD}{\sin\theta_i}$

$2\,AE = AC \sin\theta_t = AD\left(\frac{\sin\theta_t}{\sin\theta_i}\right) = AD\left(\frac{n_o}{n_f}\right)$

So that $n_o\,AD = 2 n_f\,AE = n_f\,(AE + FC)$

$\therefore \Delta = n_f(EB + BF) = 2 n_f \cdot EB$

EB is related to the film thickness t by $EB = t\cos\theta_t$

we have finally: $\Delta = 2 n_f\, t \cos\theta_t$.

For constructive interference $\Delta_p + \Delta_r = m\lambda$.

Q6 (A)

$\Delta m = 523$, $\Delta d = 0.0114$ cm

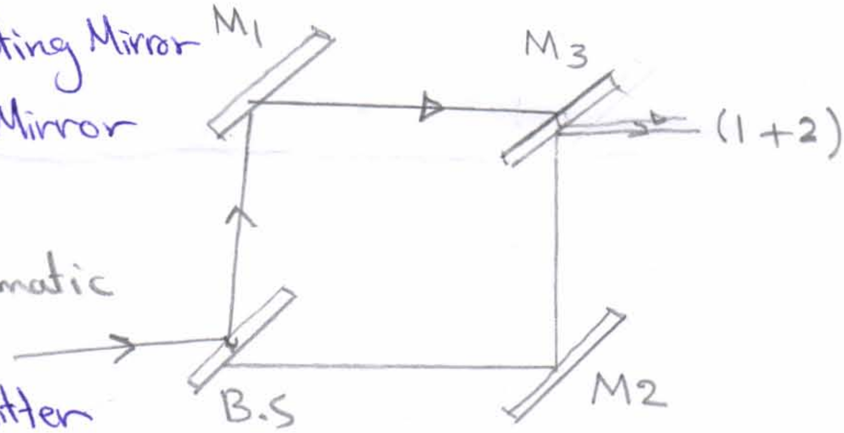
$$\lambda = \frac{2 * \Delta d}{\Delta m} = \frac{2 * 0.0114 * 10^{-2}}{523} = 4.359 * 10^{-7} m.$$

(B)

M_1, M_2, totally reflecting Mirror

M_3, semi_transparent Mirror

B.S: identical Beam splitter



an advantage of the Mach-Zehnder over the Michelson interferometer is that, by approximate small rotations of the mirrors, the fringes may be made to appear at the object being test, So that both can be viewed or photographed togather. in other fringes appear localized on the mirror and so cannot be seen in sharp focus at sam time as a test object. placed in one of arm.