PH 201 Electromagnetics
Assignment 02 **Due Date: April_20, 2022**

Maximum Marks: 10

Instruction:

1. **The assignment should be submitted only in teams with in the stipulated time (April 20, 2022, by 8.00pm).**
2. **Please Write down your name and Roll no. in the manner given below.**
3. **You may form a group of maximum three students. But each of you must submit it individually.**
4. **Diagrams and plots should be well labeled. Report should include the complete code developed.**
5. **The format for the file name for submitting the assignment: xx_assignmnet_02 where xx is your nine digit roll no. Please submit a single pdf file with good contrast. (for the poor contrast or the not legible, marks will be deducted)**

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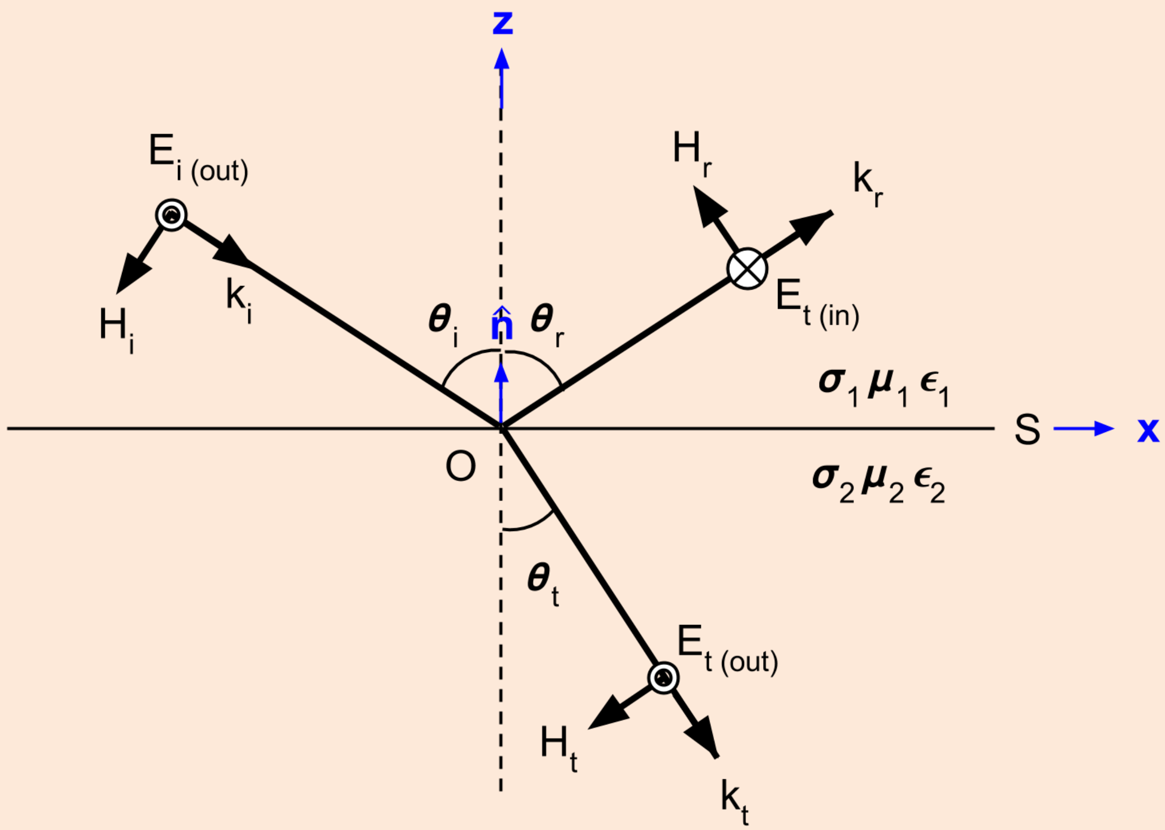
1. In this assignment, develop a computer programs for plotting all the four Fresnel's equations (ratios of the reflected and transmitted electric fields for both the polarizations as a function of angle of incidence) for dielectric-dielectric interface, taking n_1=1.33 and n_2 =2.77 and hence obtain the Brewster angle.

SOLUTION:

Theory

The ratio of the electric field of a reflected and transmitted wave to the electric field of the incident wave is determined by the Fresnel Equations (also known as the Fresnel coefficients). Because this ratio is complex, it can explain both relative amplitude and phase shifts between waves.

Diagram Depicting the Situation



Derivation of Equations

6.2-2 **Derivation of Fresnel Equations.** Derive the reflection equation (6.2-6), which is used to derive the Fresnel equation (6.2-8) for TE polarization. How would you go about obtaining the reflection coefficient if the incident light took the form of a beam rather than a plane wave?

$$\mathrm{r}_x = \frac{\eta_2 \sec\theta_2 - \eta_1 \sec\theta_1}{\eta_2 \sec\theta_2 + \eta_1 \sec\theta_1}, \qquad \mathrm{t}_x = 1 + \mathrm{r}_x, \tag{6.2-6}$$

TE Polarization

$$\mathrm{r}_y = \frac{\eta_2 \cos\theta_2 - \eta_1 \cos\theta_1}{\eta_2 \cos\theta_2 + \eta_1 \cos\theta_1}, \qquad \mathrm{t}_y = (1 + \mathrm{r}_y)\,\frac{\cos\theta_1}{\cos\theta_2}. \tag{6.2-7}$$

TM Polarization

Reflection & Transmission

$$\mathrm{r}_x = \frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2}, \qquad \mathrm{t}_x = 1 + \mathrm{r}_x, \tag{6.2-8}$$

TE Polarization

$$\mathrm{r}_y = \frac{n_1 \sec\theta_1 - n_2 \sec\theta_2}{n_1 \sec\theta_1 + n_2 \sec\theta_2}, \qquad \mathrm{t}_y = (1 + \mathrm{r}_y)\,\frac{\cos\theta_1}{\cos\theta_2}. \tag{6.2-9}$$

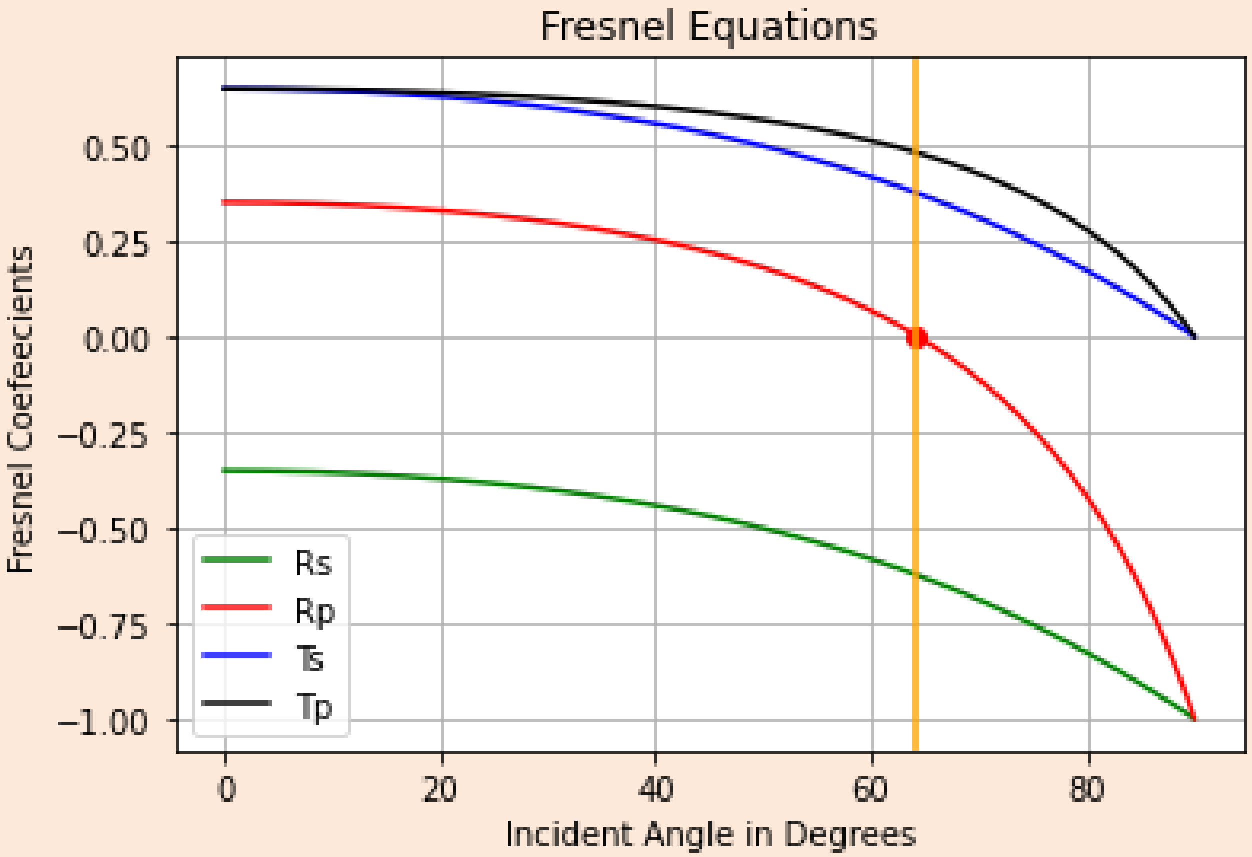
TM Polarization

Fresnel Equations

Code

```
import matplotlib.pyplot as plt
import numpy as np
import math

theta_i_deg = np.arange(0, 90.1, 0.1)
n1 = 1.33
n2 = 2.77
theta_i = theta_i_deg * (np.pi/180)
theta_t = np.arcsin(n1/n2*np.sin(theta_i))

def fresnel(n1, n2, t_i, t_t):
    r_s = (n1*np.cos(t_i)-n2*np.cos(t_t))/(n1*np.cos(t_i)+n2*np.cos(t_t))
    r_p = (n2*np.cos(t_i)-n1*np.cos(t_t))/(n2*np.cos(t_i)+n1*np.cos(t_t))
    t_s = (2*n1*np.cos(t_i))/(n1*np.cos(t_i)+n2*np.cos(t_t))
    t_p = (2*n1*np.cos(t_i))/(n2*np.cos(t_i)+n1*np.cos(t_t))
    return r_s, r_p, t_s, t_p
r_s, r_p, t_s, t_p = fresnel(n1, n2, theta_i, theta_t)
r_p_0 = 0.0
theta_i_0_deg = 0
k = n1/n2

for i in theta_i_deg:
    if math.fabs(k*np.cos(np.arcsin(k*np.sin(i*(np.pi/180)))) -
 np.cos(i*(np.pi/180))) < 0.001:
        theta_i_0_deg = i
        break
theta_i_0 = theta_i_0_deg * (np.pi/180)
theta_t_0 = np.arcsin(n1/n2*np.sin(theta_i_0))
r_s_0, r_p_0, t_s_0, t_p_0 = fresnel(n1, n2, theta_i_0, theta_t_0)

plt.plot(theta_i_deg,r_s,color='Green', label = "Rs")
plt.plot(theta_i_deg,r_p,color='Red', label = "Rp")
plt.plot(theta_i_deg,t_s,color='Blue', label = "Ts")
plt.plot(theta_i_deg,t_p,color='Black', label = "Tp")
plt.plot(theta_i_0_deg,0,'ro')
plt.axvline(x = theta_i_0_deg, color = 'Orange')
plt.grid()
plt.legend()
plt.xlabel('Incident Angle in Degrees')
plt.ylabel('Fresnel Coefeecients')
plt.title('Fresnel Equations')
plt.show()
print()
print('*********************')
print('For Brewster Angle Rp = 0, Thus on solving from the equation we get i
t as = ', theta_i_0_deg, 'Approximately, Which can be seen as the vertical O
range line in the Curve')
```

Diagram



Fresnel Equations
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Fresnel Coefeecients
0
20
40
60
80
Incident Angle in Degrees
Rs
Rp
Ts
Tp