[APP01] Brewster's angle measurement with a smartphone

1.Objectives：

(1) To introduce the polarization of reflected light and law of polarization.

(2) To measure the illuminance with the smartphone.

2. Introduction：

(1) Polarization phenomena and law of polarization:

When light passes into a surface of glass, part of the incident is reflected and rest of it is refracted. Following varying incident angle, the intensity of the reflected light will vary and so does the level of polarization. Polarization is light wave oscillating only in one plane perpendicular to the direction of wave propagation. We can use one polarizer to detect polarization if a beam of polarized light strikes such a linear polarizer, as Figure 1.

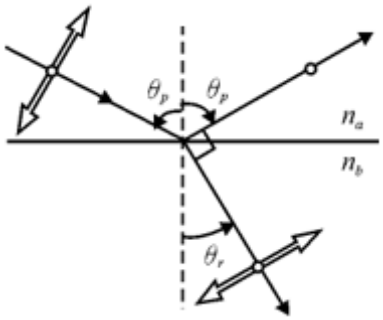

Figure 1

When the incident angle reaches certain θ_p with $\theta_p+\theta_r=90^\circ$, the reflected light will only have horizontal polarization parallel to the medium interface. If at this moment we let the reflected light passing through a polarizer and project its transmitted light on a cardboard, we will find that the polarized reflected light will vary, when we rotate the polarizer, from strong to weaken until it is vanished as Figure 2 (a). Such an angle θ_p is called Brewster's angle. According to Snell's law, $n=\tan\theta_p$, the refractive index of glass could be found. As Figure 2 (b), most of the transmitted light is vertically polarized and the horizontal component is negligible.

Figure 2

(2) Unpolarized light:

Light is a transverse electromagnetic wave. A transverse wave is characterized by its wave oscillation in a direction that is perpendicular to the direction the wave is traveling in space. In the case of light, both the electric and magnetic fields oscillate in directions that are perpendicular to the direction the light is traveling.

The oscillation plane of electrical field is called the plane of polarization, which is perpendicular to the wave-propagating direction of light. However, in natural light, the amplitudes of electrical fields all vary randomly in time and therefore no fixed state of polarization is observed, as Figure 3. we say it is "unpolarized".

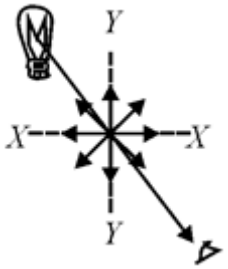

Figure 3

3. Materials：

Platform、Laser、Lens、Ray table、Semi circular lenses of acrylic and glass、Polarizer.

4. Procedure：

1. Setup instruments as shown in Figure 4. The lower side of the bracket is placed facing the laser.
2. Place the lens and the polarizer between the laser and the ray table. Adjust the lens until the laser source becomes polarized line light source.

3. Adjust the positions of the laser source, the lens and the ray table so that the laser ray is aligned with 0˚ on the ray table as shown in Figure 5.

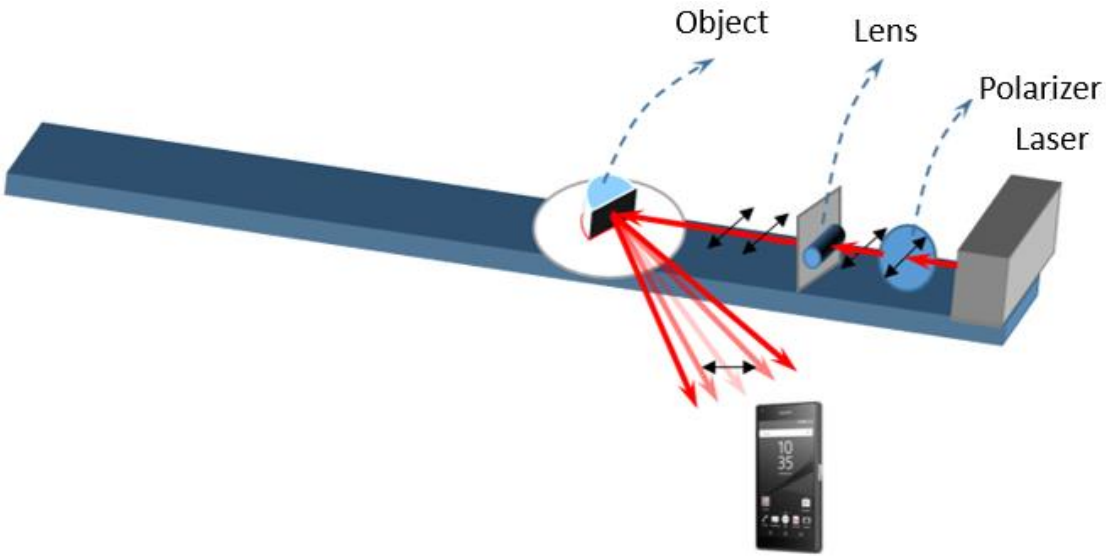

Figure 4

4. Place the object to be measured on the ray table as shown in Figure 6. Place it in the center of the ray table with the flat side just on the 90˚ line and facing the laser source.

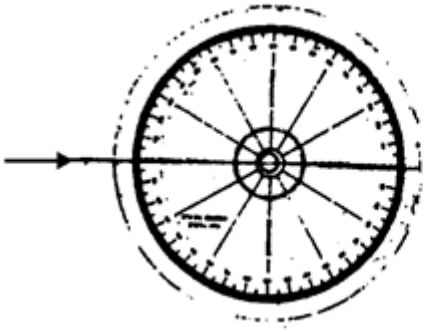

Figure 5

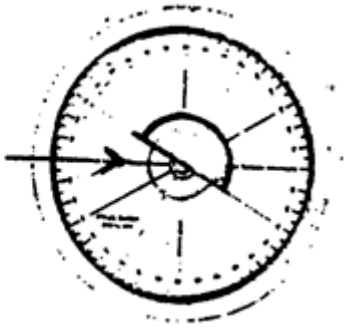

Figure 6

5. Rotate the ray table until the incident angle is equal to 20˚. Place the detector back and forth along the edge of the ray table, and the APP would record the maximum illuminance around.
6. Change the incident angle to 30°、40°、50°、60°、70° and 80°, then repeat step5.
7. Use Excel to create order-3 polynomial fitting. When the first derivative of the function is zero, one solution of that equation is Brewster's angle
8. Replace the object with different material, then repeat step 4 to 7
9. When the angle of incidence θ_p is Brewster's angle, the angle of refraction θ_r=90˚-θ_p. According to Snell's law, we have

$$n_1 \cdot \sin\theta_p = n_2 \cdot \sin\theta_r \quad \cdot \quad \tan\theta_p = \frac{n_2}{n_1} = n \tag{1}$$

where n is the refractive index of the object.

5. Questions：

(1) Where would polarized light occur when you observe the nature environment through a polarizer?

(2) If there is no scale on the analyzer, how can we determine the direction of the polarization of the light passing through the analyzer?

(3) Please show the relative position of the light sensor on the smartphone used in your experiment and the model of the smartphone.