[APP02] Verification of Malus' law with a smartphone

1.Objectives：

To measure the illuminance with the smartphone and verify the law of Malus.

2. Introduction：

(1) 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 1. we say it is "unpolarized".

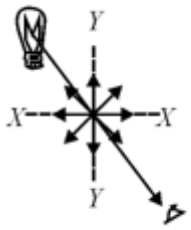

Figure 1

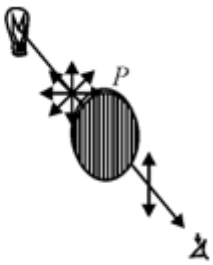

Figure 2

(2) Law of Malus:

If unpolarized light is incident on a linear polarizer, P, the transmitted light is then linearly polarized. The polarization plane of the transmitted light will be aligned along only one single direction as Figure 2, indicated by the nature of the polarizer.

Let the transmitted polarized light pass through an Analyzer A and then we can identify the direction of

polarization, as Figure 3. Here, the Analyzer A and Polarizer P are the same devices labeled differently for different use. If the intensity of the transmitted light passing through P is I_m and if the angle between the direction of the electric field of the linearly polarized light transmitted through P and the transmission axis of the analyzer A is θ, then, through the analyzer A, the electrical filed of the transmitted light is E_θ and the transmitted intensity is I_θ, as Figure 4.

$$E_\theta = E_m \cos\theta$$

$$\because \quad I_\theta \sim E_\theta^2$$

$$I_m \sim E_m^2$$

$$\therefore \quad I_\theta = I_m \cdot \cos^2 \theta$$

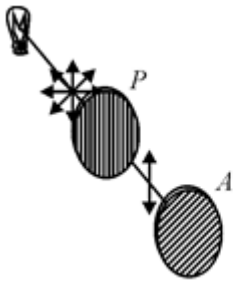

Figure 3

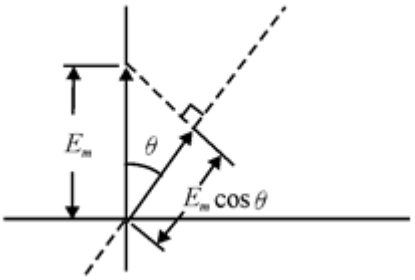

Figure 4

3. Materials：

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

4. Procedure：

1. First of all, you have to find out where the light sensor is inside the smartphone. Open the APP and use a finger to block the sensor to find a point where the illuminance reading was zero. This position is where the light sensor is located.

Figure5

2. Setup instruments as shown in Figure 6.

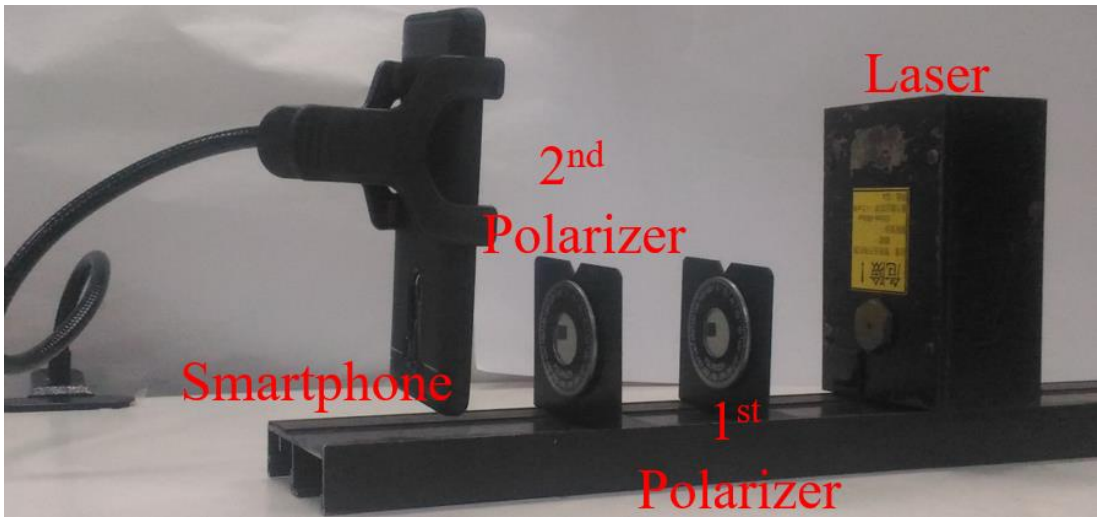

Figure6

3. Set the first polarizer to 0° and rotate the second one until the illuminance readout is maximum.
4. Record the illuminance value. Rotate the second polarizer every 10 degree and repeat the step until the angle difference between the first polarizer and the second one is around 90˚.
5. Create $\cos^2\theta$ vs. illuminance chart in Excel and calculate R-squared value.

5. Questions：

(1) How to use 2 polarizers to increase or decrease the illuminance of light?

(2) Use your experimental results to verify the law of Malus and discuss errors.

(3) Is the illuminance of light minimal when two polarizers are perpendicular to each other? Please explain.