

# OPTIC 2024 Taiwan Photonics Outreach Contest

## Operational Manual

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Name of the team: 你是電你是光你是唯一的神話

Name of the outreach kit: Phantom Roulette

Target age range: 12-20 years old

Estimated Time: 8 to 20 minutes

### Objectives:

The strobe effect is a visual phenomenon in which an object rotates at a specific speed and, when combined with a flashing light source, the observer sees an almost stationary or slow motion effect. Through our teaching aids, students will be interested in the physical phenomena behind the strobe effect, including the properties of light and the visual processing of the human eye, and be able to actively explore the movement of objects, the relationship between light and time, and through the actual operation, cultivate the spirit of experimentation and the ability to explore the principles behind things!

### Background Information:

#### 1. Stroboscopic effect

Stroboscopic effect is a special visual phenomenon that occurs when a moving object encounters a periodically flickering light source, especially when the flicker frequency of the light source is close to the frequency of the object's motion.

When a light source flickers rapidly, our eyes are unable to capture the positional changes of the object continuously, so the brain connects the images we see at different moments. If the flicker frequency is very close to the object's motion frequency, this connection may create the illusion that the object is stationary or moving slowly, and may even show a motion trajectory that is opposite to the actual direction of motion.

In factories or places where fluorescent lighting is used, sometimes the movement of objects may look strange or trembling. Since fluorescent lighting is driven by AC power, the flashing speed may be close to the frequency of the object's movement, which may cause this phenomenon.

In photography or video recording, when using a specific shutter speed to shoot a rotating object (such as a fan blade), sometimes the object will appear to be stationary or rotating in the opposite direction, which is also a manifestation of the strobe effect.

## 2. Frequency and Periodicity

Frequency refers to the number of repetitive events that occur per second, commonly measured in Hertz (Hz), with 1 Hz equating to one event per second. For example, an alternating current of 50 Hz means that the direction changes 50 times per second, and a vibrator vibrates 10 times per second, so the frequency is 10 Hz. Period refers to the time it takes to complete a cycle or vibration. Period is inversely related to frequency.

## 3. Angular frequency

The angular frequency is a physical quantity that describes periodic motion and represents the angle at which an object turns per second. It is often used to describe frequencies in circular motion or vibration systems, and it is related to linear frequencies.

The symbol for the angular frequency is usually  $\omega$  which in **radians per second** (rad/s). In equal-rate circular motion, the angular frequency represents the number of radians per second of rotation rather than the number of complete revolutions, the relationship between the angular frequency  $\omega$  and the linear frequency  $f$  is:  $\omega = 2\pi f$

## 4. Visual Suspension

Visual pause is a physiological phenomenon that refers to the short period of time, approximately 1/25 seconds, that an image of light remains on the retina after a light stimulus has ended. This phenomenon explains why we can see smooth, continuous images, even though they are composed of a series of rapidly changing still images.

## Teaching Aids

Our teaching aid hardware consists of the following components:

1. Brushless motor: Used to drive the rotor to rotate at high speeds.
2. Brushless Motor Driver Board: Used to control the rotation of the motor, adjusting the rotation speed with the duty cycle to ensure the smooth running of the rotor.
3. Development board (ESP32): mainly responsible for adjusting the motor speed and flashing frequency of the strobe light source, as well as web control.
4. Frequency Strobe Source (with input): Provides stable strobe light with adjustable frequency to realize frequency strobe effect.
5. Power supply: Provide stable power for the whole system to ensure the normal operation of all components.
6. Turntable: A flat surface that carries graphics, displays visual effects as the motor rotates, and can display different patterns to increase interest.

Software and accessories included:

1. sample\_pattern.pdf: Contains a variety of pre-set paper patterns for clear and obvious effects.
2. DiskGenerator.exe: Customizable images and GIF animations to generate fun disk patterns.

The above and the source code are available at

<https://github.com/iscodeminister/Phantom-Roulette>

## Operation procedures:

### 1. Teaching Aids Installation

- (1) Connect the power to the motor and strobe light source and turn on the power supply.
- (2) Print and fix the paper pattern of the attached file or the customized turntable pattern on the turntable.
- (3) Using a computer or cell phone, connect to the Wi-Fi (Phantom Roulette) provided with the teaching aid, open the web browser and connect to 192.168.4.1 to connect to the operating web page.

### 2. Motor and strobe frequency parameter adjustment

- (1) The motor speed can be adjusted by entering a value on the web page, or by using the up and down arrow keys on the keyboard for quick fine-tuning on the computer.
- (2) There are buttons on the web page to adjust the motor speed by  $\pm 0.001\%$  or  $\pm 0.01\%$ , or enter the value directly in the field.  
\*This value is the duty cycle, which is the ratio of the maximum speed, and the maximum speed will change according to the motor load and voltage.
- (3) The flashing frequency of the strobe light source is adjusted in the same way as the motor, you can input the customized multiplication rate, press the multiply/divide adjustment button to adjust the frequency quickly and conveniently to observe the change of the strobe.

### 3. Flash Observation

- (1) By adjusting the speed of the motor and the frequency of the strobe, students can observe changes in the strobe effect. For example, at a specific speed and frequency, the propeller image will appear stationary. Increasing the speed of the motor will cause the blades to rotate clockwise and decreasing the speed will cause the blades to rotate counterclockwise.
- (2) Use the Multiply/Divide Adjustment button for strobe frequency to observe the effect of doubling the strobe frequency.

### 4. Evaluation Criteria

- (1) Can students correctly explain the principles of the strobe effect.
- (2) Whether the student is able to manipulate the teaching aids independently and observe the expected results.
- (3) Can students come up with innovative application ideas or suggestions for improvement and apply the strobe effect to real-world scenarios.

## 5. Extra Content

- (1) Open your favorite pictures or motion pictures with the attached program and adjust the size and position of each picture.
- (2) After customization is complete, export the PDF file of the carousel, print and cut and paste the file onto the carousel.
- (3) Students can have a creative design competition to design their own turntable pattern and explain its principle.

Cost estimation of the kit:

Project	Name	quantity	price
1	Brushless Motor	1	150
2	Brushless Motor Driver Board	1	250
3	ESP32 Development Edition	1	150
4	Strobe (with input)	1	1000
5	Turntable materials (e.g. wood panels)	1	50
6	Connecting Cables and Components	1	100
7	Power Supply	1	200
Total Price			1900

## Safety Precautions

1. Flashing may trigger discomfort in people with epilepsy
2. Adult supervision is required
3. Remember to keep the motor at a complete standstill when replacing the paper.
4. Avoid bringing your head, hands and other body parts close to the turntable when the motor is rotating.
5. Pay attention to the safety of power supply to avoid the risk of electric shock.

## References

- [1]. Finlay, D.J.; Dodwell, P.C. & Caelli, T.M. (1984). "The wagon-wheel effect". *Perception*.
- [2]. Purves D, Paydarfar JA, Andrews TJ. The wagon-wheel illusion in movies and reality. *proceedings of the National Academy of Sciences of the United States of America*.
- [3]. Chu Ho Wai. (Director). (2016). *Now You See Me 2* [Film]. Summit Entertainment.