A01-433E-Y01

Gyroscope experiment (photoelectric)

I. Experiment purpose

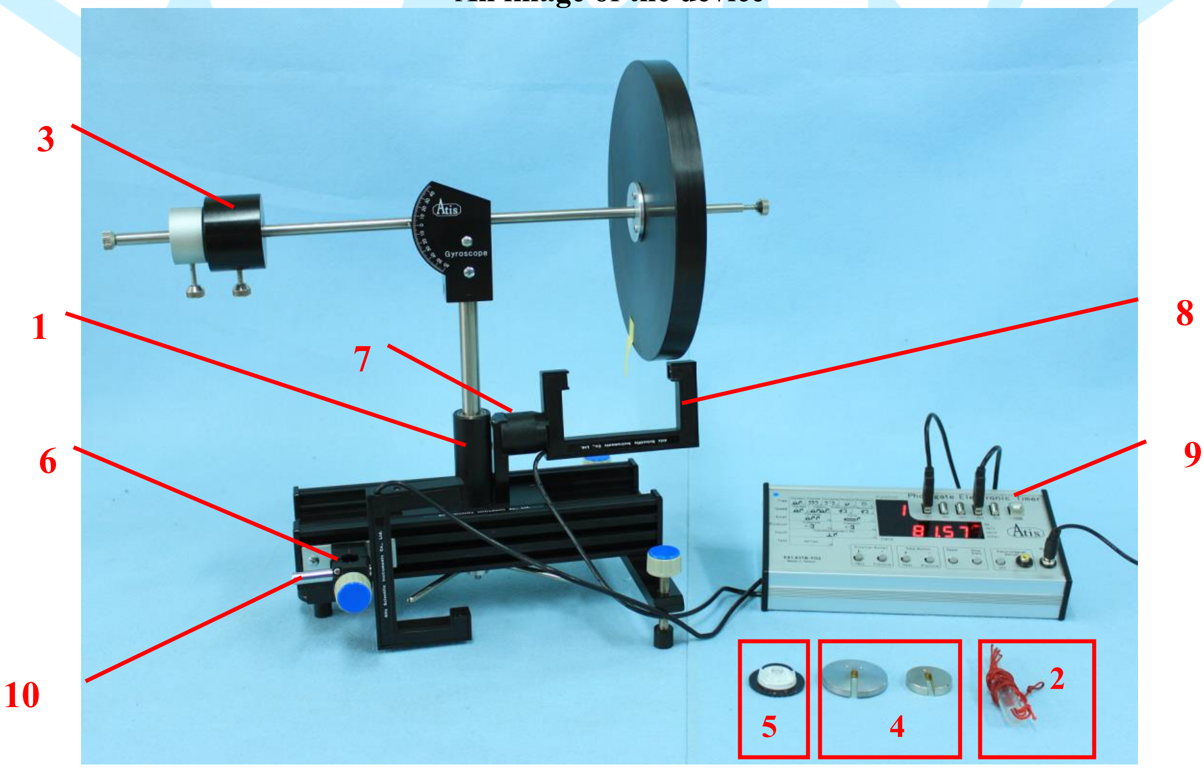
We can understand the relation to **angular momentum** and **torque** and observe the gyroscope **precession** and **nutation** phenomenon. We use the rotation of the gyroscope and the angle of the precession to get the **rotational inertia** of the gyroscope.

II. Experiment device

Experiment list

No.	Name	Qty.	No.	Name	Qty.
1	Gyroscope (three-point adjustment feet, support axis and crossbar, angle meter, and gyroscope plate)	1	2	String with holder	1
3	Balance weight（900g、150g）	2	4	Additional weight（100g、50g）	2
5	Level meter	1	6	fixed joint	1
7	Magnetic photogate joint	1	8	photogate sensor	2
9	Dynamic data capture (attached power supply DC12V)	1	10	Iron rod (3.7cm*1) (6.7cm*1)	1

An image of the device



III. Theory

We use gyroscope in aerospace and navigation to decide the status and speed that is the most convenient and practical device. Basic on the two feature that gyroscope is applied in a main part of meter on an airplane: one is **inertia or rigidity** and the other is **precession.** These two is built on **conservation of angular momentum**. According to Newton's second law of motion we know: the sum of torque that works on one particle is equal to the changed rate of time of angular momentum of this particle. As below formula:

$$\vec{\tau} = \frac{d\vec{l}}{dt}$$

We can see the gyroscope as composing of particle and these particles combine tightly. Thereby, when the gyroscope is spinning, these particles are also spinning. Therefore, we can change the angular momentum of particle system (gyroscope) as

$$\vec{L} = \vec{l}_1 + \vec{l}_2 + \vec{l}_3 + \dots + \vec{l}_m = \sum_{i=1}^{m} \vec{l}_i$$

the pure applied torque $\vec{\tau}$ of particle system is :

$$\vec{\tau} = \sum_{i=1}^{m} \frac{d\vec{l}_i}{dt} = \frac{d\vec{L}}{dt}$$

the angular momentum of the gyroscope $\vec{L}$ we can write as $I\vec{\omega}$. I is a scalar from the moment of inertia on gyroscope turntable. $\vec{\omega}$ is a vector that has the same direction as angular momentum as Image 1 below:

$$\vec{L} = \vec{r} \times \vec{P} = m(\vec{r} \times \vec{v}) = I\vec{w}$$

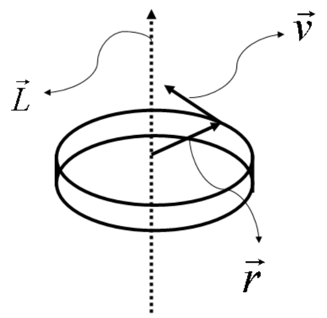


Image 1

To understand the basic of feature, we can discuss the **precession** and **nutation** of gyroscope as Image 2. We assume that the distance from the centroid position in gyroscope system to support point is $\vec{r}$. The gravity of the gyroscope is $\vec{W} = m\vec{g}$. Thereby, we can find that these two c will create a pure torque $\vec{\tau} = \vec{\gamma} \times \vec{W} = \vec{\gamma} \times m\vec{g}$. As Image 3, the centroid and the support point of the gyroscope are the same, and the gravity of the gyroscope is still $\vec{W} = m\vec{g}$. However, the support point and the centroid are $\vec{\gamma} = 0$, so we can find that the gravity of the gyroscope to pure torque of the system is zero.

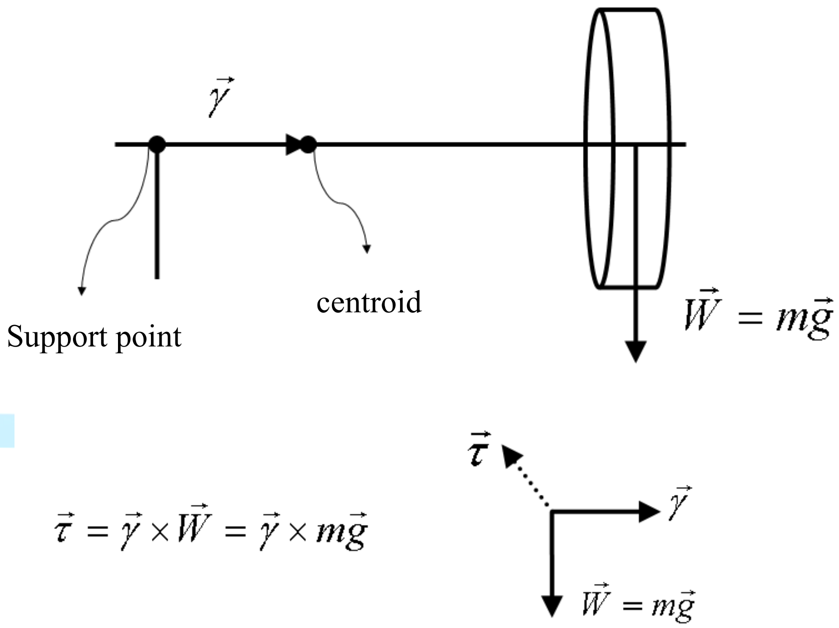


Image 2

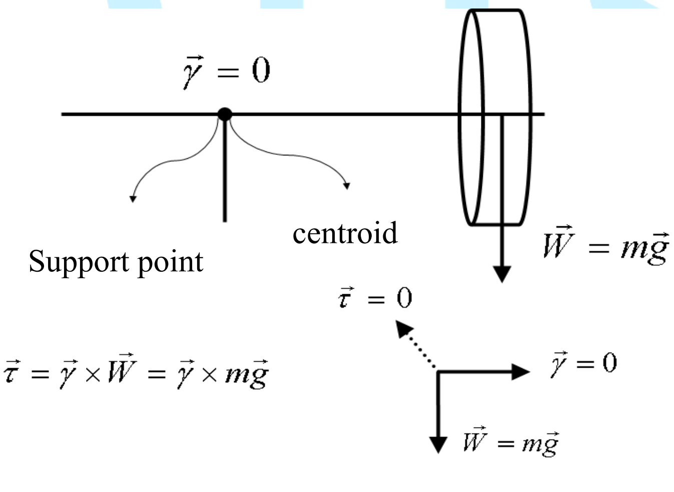


Image 3

Then, we know from upper describe. The gravity of the gyroscope creates pure torque ($\vec{\tau}$) and the changed direction ($d\vec{L}$) of the angular momentum in the gyroscope during a unit of time should be the same.

$$\frac{d\vec{L}}{dt} = \vec{\tau} = \vec{\gamma} \times \vec{W} = \vec{\gamma} \times m\vec{g}$$

$$\frac{d\vec{L}}{dt}=\frac{d\vec{L}(t+\Delta t)-d\vec{L}(t)}{dt}$$

As image 4, we can find that the direction of torque from the gravity to the support point is -x. During t time, the direction of the angular momentum is +y, when the gyroscope spins, and the different of the next moment (Δt) to the direction of the angular momentum from the gyroscope spin will have the same direction as the torque (-x). Thereby we can know that during the unit of time the direction of the Angular momentum in the gyroscope spin will deflect from +y to -x in -xy surface gradually. According to the rule, gyroscope must have precession to one direction (clockwise or counterclockwise) in order.

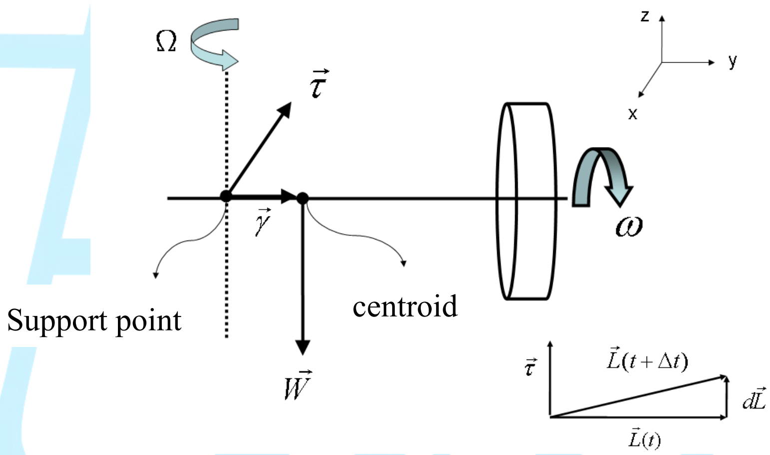


Image 4

during the experiment, we can use the angular momentum in the gyroscope spin and the angular velocity of precession in the gyroscope to get the moment of inertia in the gyroscope as Image 5.

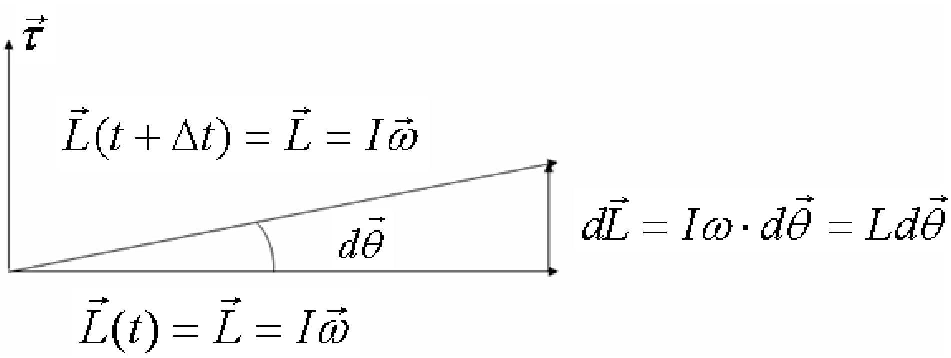


Image 5

$$\frac{d\vec{L}}{dt} = \vec{\tau}$$

$$d\vec{L} = I\omega \cdot d\vec{\theta} = Ld\vec{\theta}$$

$$\frac{d\vec{L}}{dt} = \vec{\tau} = I\omega \cdot \frac{d\vec{\theta}}{dt} \Rightarrow I\omega \cdot \vec{\Omega} = \vec{\tau}$$

$$\vec{\Omega} = \frac{\vec{\tau}}{I\omega}$$

When the torque is unchanged, the angular velocity of the precession is inverse ratio to the angular velocity of the gyroscope spin. It means that the angular velocity will slow down when the gyroscope spins. The precession of the rotating angular velocity is fast. This will be like play a gyroscope. When the gyroscope is going to stop, the gyroscope will create precession unstably, and this speed of the precession will be faster and faster until the gyroscope stops.

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