Gyroscope Principles

Rigidity is the ability of a freely rotating mass to maintain its plane of spin when any external force is applied to it.

First Law Of Gyroscopes: If a rotating wheel is so maintained as to be free to move about any axis passing through its centre of mass, its spin axis will remain fixed in space.

Second Law Of Gyroscopes: When a torque acts on a spinning mass with an axis perpendicular to that of spin, then the latter will precess about an axis perpendicular to both aforementioned axes, at an angular velocity, Ω, = $T/I\omega$.

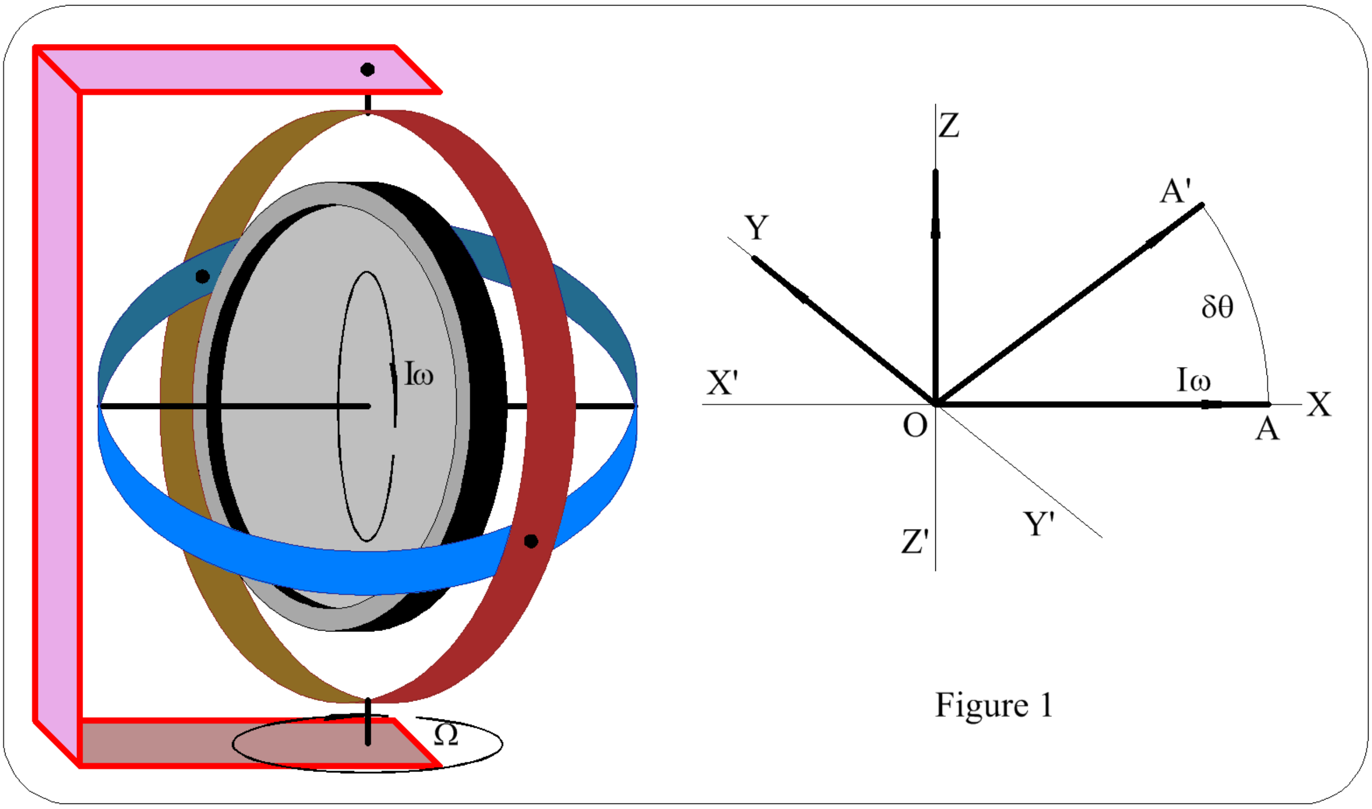

Figure 1

Referring to Figure 1:

Angular momentum of system = Ω

Angular momentum of rotor = $I\omega$ (I = moment of inertia; ω = angular velocity)

Torque = T

In time δt the spin axis moves through $\delta\theta$.

$\therefore \delta\theta = \Omega\delta t$

$AA' = OA\delta\theta$

$= OA\Omega\delta t$

$= I\omega\Omega\delta t$

Newton's second law states that torque = rate of change of precession,

$\therefore AA' / \delta t = T$

$\therefore T = I\Omega\omega$

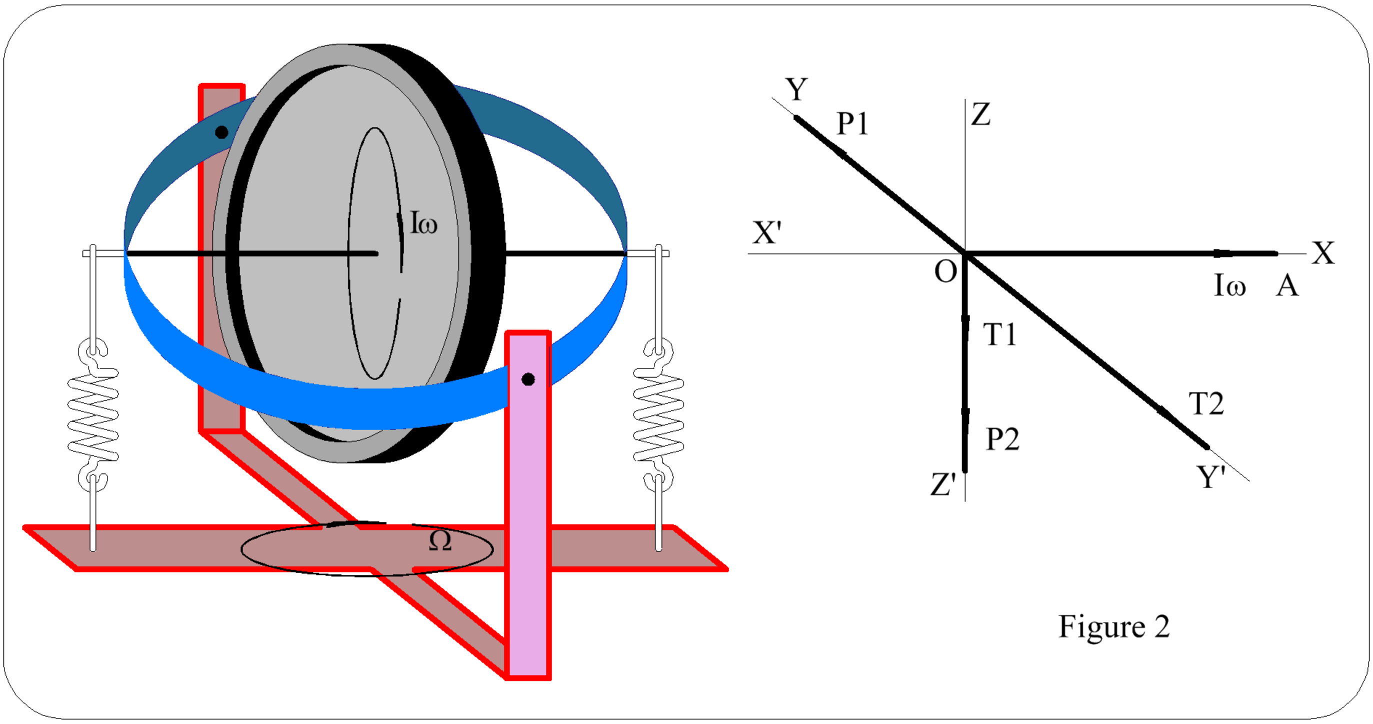

Figure 2

The Rate Gyroscope

This has only two planes of freedom. Springs limit the amount of precession & introduce a secondary torque. Refer to Figure 2.

The secondary torque produces a secondary precession which causes the gyro to precess in the direction of the application of the initial torque.

When the rate of secondary precession is equal to the rate of turning which produces the initial torque a state of equilibrium is reached & gyro displacement ceases.

The secondary precession is due to the initial deflection of the gyro when torque is applied, & the final displacement is proportional to the rate of displacement of the gyro.

The force exerted by the spring µ extension.

Extension µ angle of deflection of spin axis due to primary precession.

Let deflection = λ radians

Spring torque = kλ (k = Hooke's constant of spring)

Rate of secondary precession = spring torque / Iω

At equilibrium:

Rate of secondary precession = Rate of turning of gyro frame

ie kλ = Iω

Assuming Iω remains constant, λ µ θ

Restraint Of A Rate Gyro

1 Helical springs
2 Single side restraining spring; this gives greater o/p for the same i/p.
3 Leaf spring; less sensitive than 2 but simplifies construction.

Methods Of Damping Rate Gyro Oscillations

The use of restraining springs produces excessive oscillation of the gyro when the initial torque is removed. The methods of damping are:

1- Air dashpot damping; used only on air-driven gyros.

2- Eddy-current damping using a copper disc rotating in the field of a permanent magnet.

3- Eddy current damping using a coil moving in the field of a permanent magnet.

Apparent Wander

This is due to the earth's rotation.
Vertical axis: At the poles the gyro appears to precess at 15°/h in the opposite direction to the earth's rotation, & the rate decrease to 0°/h at the equator. If the latitude is $\phi°$ apparent wander = 15° x sinϕ / h. Horizontal axis: In this case apparent wander is 0 at the poles & maximum at the equator. Apparent wander = 15° x cosϕ / h.

Random Wander

This is due to bearing friction & might be greater than apparent wander in gyros of low quality. Those used for inertial guidance have no bearing friction; this is achieved by mounting the rotor in a fluid. When the gyro is running it is completely suspended in the gas & free of friction.

Earth Gyros

Wander is the drift of the gyro about the ZZ' axis. Topple is the drift about the YY' axis.

Methods Of Erecting Earth Gyros

A split ring commutator is supplied with opposite phases of the vehicle power supplies. Two pickoffs are positioned in the neutral gaps of the commutator & any movement from the orthogonal position causes the pickoffs to make contact with the energised commutator. The supply from the pickoffs is used to energise a torque motor which applies a force to the outer ring & precesses the inner ring or vice versa.

The Integrating Gyro

Although dissimilar in appearance & construction to the rate gyro, the principle of operation is similar. The main differences are:

1- The primary precession, though resisted, is a continuous rotation, proportional to the rate of turn of the outer case or frame.
2- The gimbal does not return to the neutral position when the applied torque is removed.

When torque is applied to the frame, or outer case, a primary precession occurs & the gimbal drum rotates. Viscosity of liquid resists this precession giving secondary precession to the frame. The resisting torque due to the liquid is very nearly proportional to the rate of primary precession which is therefore proportional to the secondary precession. The integrating gyro provides an o/p angle proportional to the rate of change of i/p.