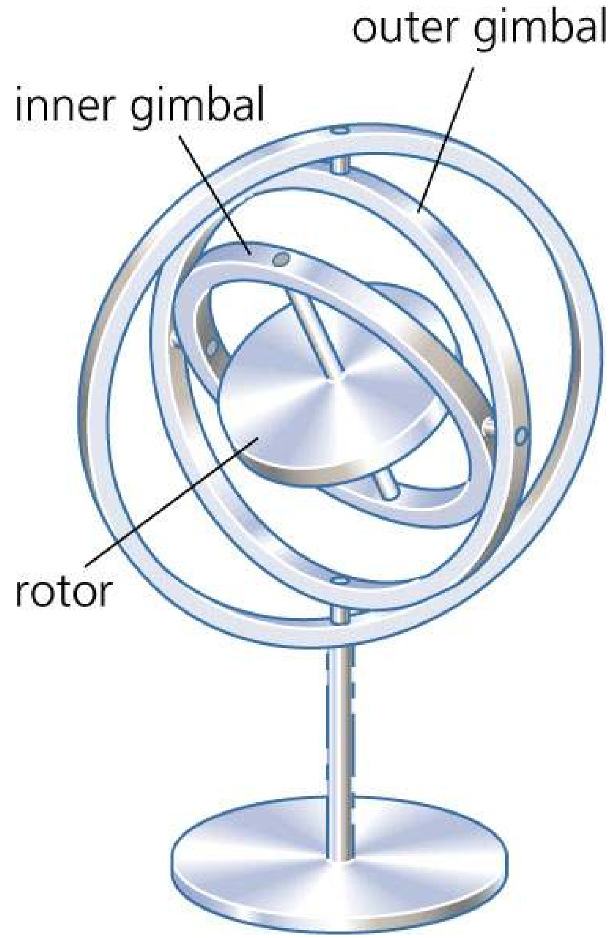
Dynamics 36212221

Ben-Gurion University of the Negev
Department of Mechanical Engineering
Oriel Shoshani

Inertial Instruments and Inertial Navigation

Gimbals

- Gimbals are essentially hinges that allow freedom of rotation about one axis. Gimbals often have superb bearings and motors to help achieve virtually frictionless behavior. Sensors in the bearings provide measurements of gimbal angles. Three gimbals allow freedom of rotation of a vehicle about three axes while a central platform remains stationary with respect to inertial space.



www.youtube.com/watch?v=VkXyWUcO9hc

Gyros

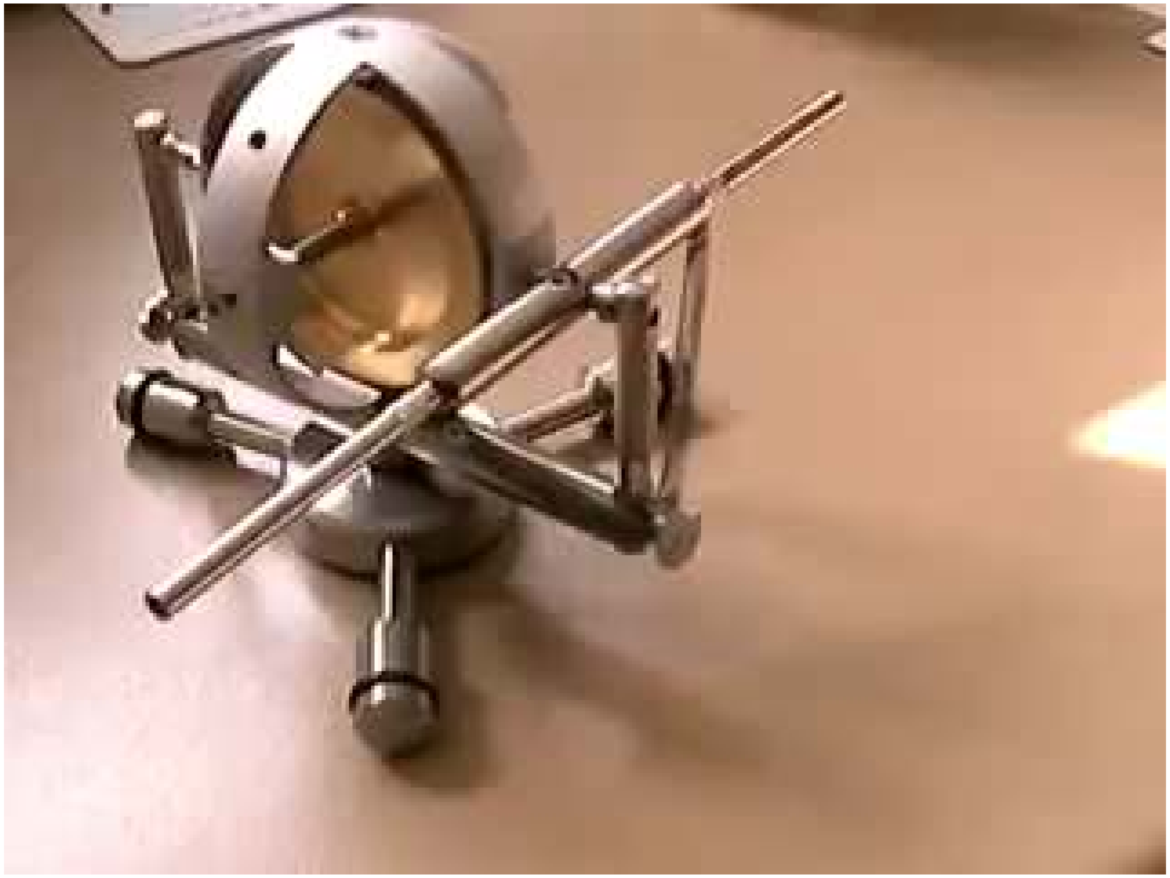
- A gyro is a spinning mass with relatively large angular momentum. We know that the rate of change of angular momentum is equal to the applied moment.

$$\Sigma \vec{M} = \dot{\vec{H}}$$

- If no torque is applied then the angular momentum vector remains stationary with respect to inertial space. Gimbals allow a vehicle to rotate freely about a gyro so the gyro spin axis can provide a single axis direction that is stationary with respect to inertial space.

www.youtube.com/watch?v=ekzwbt3hu2k

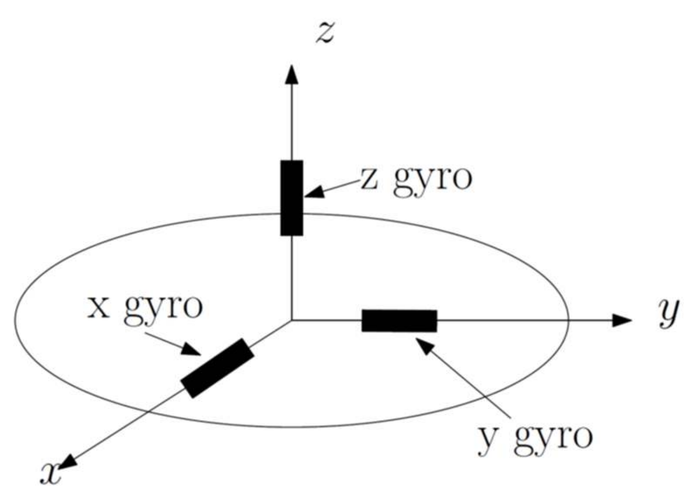
- Restraining a gyro about an axis perpendicular to the angular momentum vector provides a means for measuring angular velocity with respect to inertial space. This device is called a rate gyro and is a common sensor for aiding in rate stabilization of vehicles.



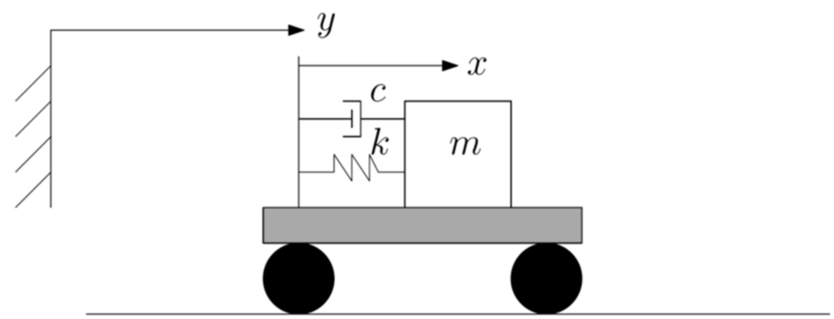
www.youtube.com/watch?v=NQSYERWASE4

Inertial Platforms

- A gyro mounted on a platform can be used as a sensor in a feedback loop to stabilize the platform with respect to inertial space. This is called an inertially stabilized platform. The inertially stabilized platform is an essential element of inertial navigation.



Accelerometers



- Accelerometer equation of motion:

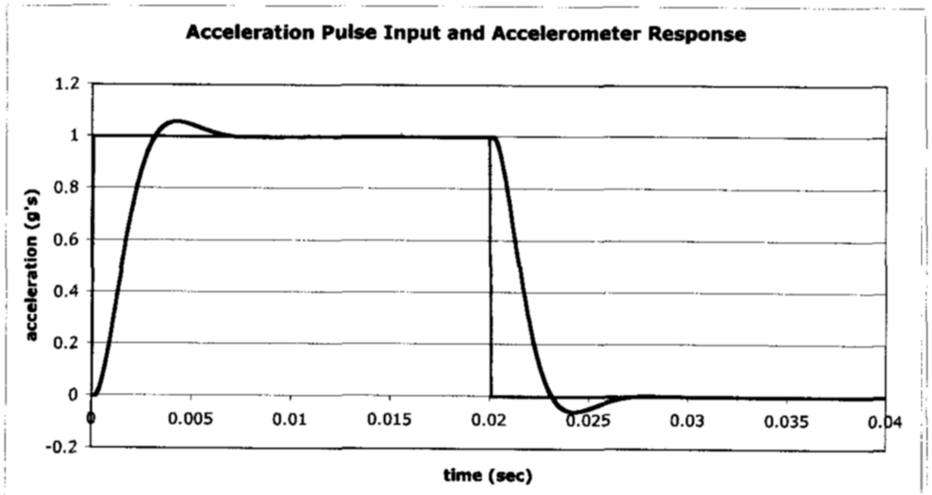
$$m\ddot{x} + c\dot{x} + kx = -m\ddot{y}$$

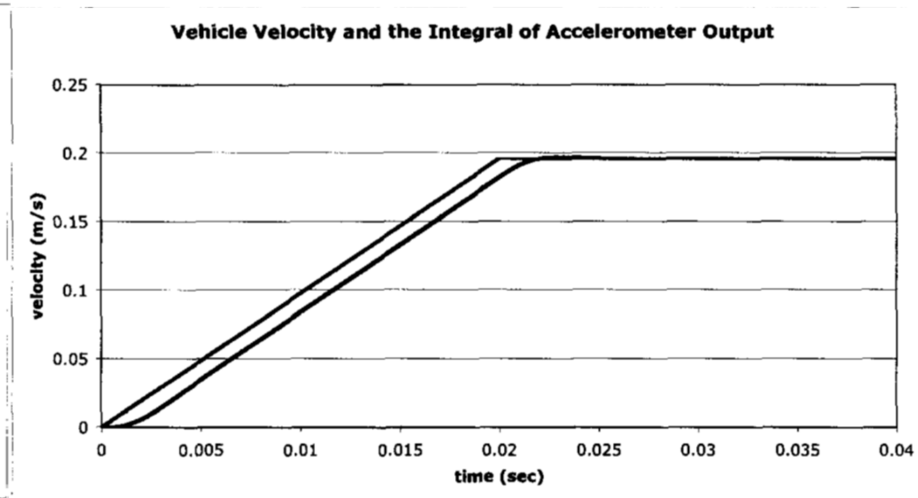
Where:

$\ddot{y}$ - vehicle acceleration

m - test mass

x - displacement of the test mass from its rest point


Acceleration Pulse Input and Accelerometer Response
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
acceleration (g's)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
time (sec)


Vehicle Velocity and the Integral of Accelerometer Output
0.25
0.2
0.15
0.1
0.05
0
velocity (m/s)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
time (sec)

Applications of Inertial Systems

Vehicles utilize inertially stabilized platforms in a number of ways:

1. Provide a reference for stabilizing and controlling vehicle attitude
2. Stabilize sensors and point them in desired directions
3. Provide a stable reference for estimating changes in vehicle velocity

The three gyros stabilize the platform orientation so that it is stationary with respect to inertial space. Each gyro is responsible for stabilization about one axis. The stable platform holds the accelerometers fixed in space so that they can sense acceleration. The three components of acceleration are then integrated to estimate the change in vehicle velocity vector.