Gyroscopic Motion
Conservation of Angular Momentum
in Complex Motions of a Gyroscope
and a Spinning Top

Physics 109, Class Period 12
Experiment Number 10 in the
Physics 121 Lab Manual (page 57)

Gyroscope Precession

Outline
• History of the Gyroscope
• Description of the Experiment
• Class Questions
• Assignment

History
• First discovered in 1817 by Johann
  Bohnenberger
• Actual invention and name attributed to
  Leon Foucault in 1852
  – He was trying to measure the rotation of the
    Earth
  – Friction limited trials to 8-10 minutes, not long
    enough
  – Foucault noted for something else --
Foucault Pendulum

• Plane of swing remains fixed while the earth rotates.

• Returns to original orientation in two days.

More History

• First marine gyroscopes developed between 1905 and 1908 in Germany.
• In 1910 American Elmer Sperry developed his own design.
• Shortly thereafter the Sperry Gyroscope Company was providing aircraft and ships with gyroscope stabilizers.
• Today, the Hubble Space Telescope uses gyroscopes for stabilization.

Description of the Experiment—Gyroscope Motion

• Conservation of angular momentum
  – Gyroscope
  – Spinning top
• We will examine:
  – Fixed orientations
  – Precession
  – Nutation
Key to Understanding:
• Finding the directions in which angular momentum is conserved.

Nutation
• Motion along $\theta$ of the gyroscope spin axis
• Spin and precession are not coupled.
• There are three cases of nutation
  – Case 1 -- Cycloid Pattern
  – Case 2 -- Sinusoidal Pattern
  – Case 3 -- Curly Pattern

Nutation Patterns:
• Cycloid pattern
• Sinusoidal pattern
• Curly pattern

Class Problems
• Problems based on homework
• Flywheel at rest
• Flywheel spinning
Given the mass of the disk, the rotation speed of the disk, the radius of the disk and the precession rate of the gyroscope, what is the expression for \(d\), the shaft length?

- Hints: \(L = I\omega\) \(\Omega = mgd/L\) \(I = mr^2/2\)
- A. \(d = 2g/\omega\Omega r^2\)
- B. \(d = \omega\Omega r^2/2g\)
- C. \(d = r^2/2g\omega\Omega\)
- D. None of the above.

We cannot use the component method to solve for the angle between two vectors, given that the dot product is twice the cross product. We must use:

- A. \(AB\cos\theta = 2AB\sin\theta\) C.
- B. \(AB\sin\theta = 2AB\cos\theta\)
- C. Both of these
- D. Neither of these

A perfectly balanced gyroscope, spins in the direction shown. A mass, \(m\), is added to the end of the shaft. What happens?

A. The gyroscope falls over.
B. The gyroscope precesses about the vertical axis. C.
C. Nothing.
D. Not enough information to tell.

If a lump of clay strikes a rotating disk with velocity, \(v\), and sticks a distance \(b\) from the center, what is true?

- A. Initial angular momentum = \(I\omega\)
- B. Initial angular momentum = \(I\omega\), \(-mvb\) C.
- C. Initial angular momentum = \(-mvb\)
- D. None of the above
If, instead of a 22 g clay lump moving with a velocity of 1.3 m/s opposite the rotation, we just drop the lump on the rotating disk, what would be the mass of clay that we drop in order to reduce the rotation rate by the same amount?

- A. 500 g.
- B. 1 kg.
- C. 1.5 kg.
- D. 2 kg.
- E. More than 2 kg. C.

Gyroscope flywheel is at rest

Which is the torque (due to gravity) vector? B.

From the previous slide--

- What Happens?
  - A. Nothing
  - B. Gyroscope falls C.
  - C. Gyroscope precesses
  - D. Neither

Now the gyroscope flywheel is spinning-

Which is the principal angular momentum vector? D.
The flywheel is spinning-

- What happens?
  - A. Nothing
  - B. Gyroscope falls
  - C. Gyroscope precesses C.
  - D. Neither

Which is the torque (due to gravity) vector? B.

The top of the flywheel is coming toward us. Which direction is the precession?

A. Clockwise   B. Counterclockwise C.
C. Neither

Assignment

- Read Chapter 15 before 13 November
- Complete Diagnostic Test, turn in by next Monday, 12 November
- Do problems in chapter 15, 1,3,5,7,11,13 due 19 November
- Look over the next lab, “Harmonic Oscillators”, Lab 11