

CLASSICAL MECHANICS

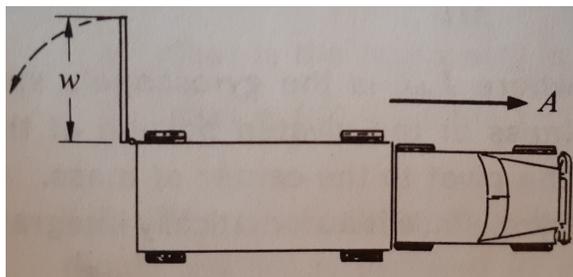
DR. KUEHN, WISCONSIN LUTHERAN COLLEGE

HOMEWORK 11

First-pass presentations on Monday, Nov. 15, 2020.

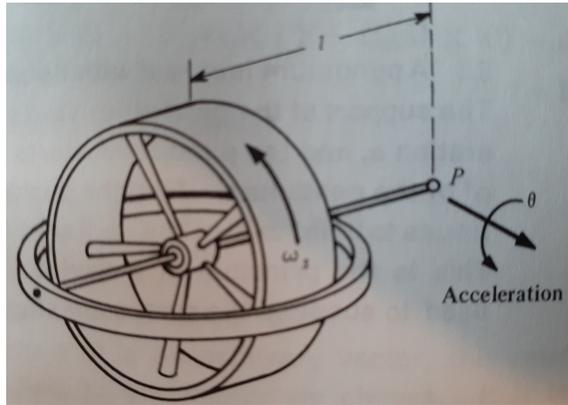
Full written solutions due Friday, Nov. 19, 2020.

- (1) **Accelerating truck:** A truck at rest has one door fully open, as shown. The truck accelerates forward at a constant rate A , and the door begins to swing shut. The door is uniform and solid, has mass M , height h , and width w . Neglect air resistance.



- (a) Find the instantaneous angular velocity of the door about its hinges when it has swung through 90 degrees.
- (b) Find the horizontal force on the door when it has swung through 90 degrees.

- (2) **Gyroscope guidance:** Many applications for gyroscopes have been found in navigational systems. For instance, gyroscopes can be used to measure acceleration. Consider a gyroscope spinning at high speed ω_s . The gyroscope is attached to a vehicle, such as a rocket, by a universal pivot, P .

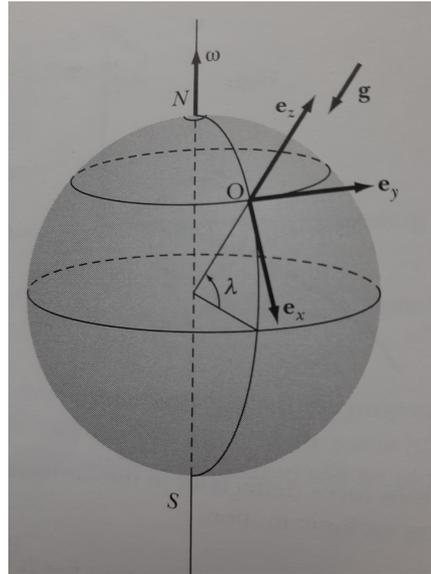


If the vehicle accelerates in the direction perpendicular to the spin axis at rate a , then the gyroscope will precess about the acceleration axis, as shown in the sketch. The total angle of precession, θ , is measured. Show that if the system starts from rest, the final velocity of the vehicle is given by

$$v = \frac{I_s \omega_s}{Ml} \theta$$

where $I_s \omega_s$ is the gyroscope's spin angular momentum, M is the total mass of the pivoted portion of the gyroscope, and l is the distance from the pivot to the center of mass. (Such a system is called an integrating gyro, since it automatically integrates the acceleration to give the velocity.)

- (3) **Coriolis force:** A (vertical) plumb line is suspended from a tower of height h located in the northern hemisphere at latitude λ , as shown below. A small m is dropped from the tower which falls freely toward Earth's surface. Earth, of course, is spinning at angular frequency ω , so the mass does not fall straight downward as measured by an observer on Earth's surface.



- Find a general formula for the horizontal deflection from the plumb line caused by the Coriolis force.
- How big of an effect would this be for a mass dropped from the top of the tallest building in Milwaukee?
- Where on Earth would this effect be most pronounced?
- Would the effect be different in southern latitudes?

- (4) **Pendulum on a rotating platform:** A pendulum is rigidly fixed to an axle held by two supports so that it can only swing in a plane perpendicular to the axle. The pendulum consists of a mass M attached to a massless rod of length l . The supports are mounted on a platform which rotates with constant angular velocity Ω . Find the pendulum's frequency (assuming the amplitude is small).

