Vp140 Recitation VIII

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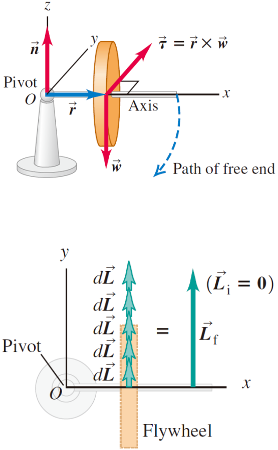
Overview

1. The Gyroscopic Effect
2. Elasticity
3. Fluid

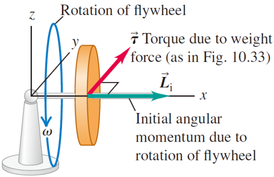
Nonrotating flywheel

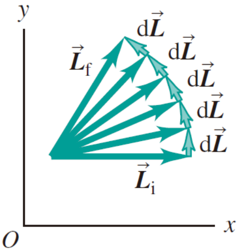
Figure



Rotating flywheel

Figure





Rotating flywheel

Formula

$$\Omega = \frac{d\phi}{dt} = \frac{|d\overrightarrow{\boldsymbol{L}}|/\overrightarrow{\boldsymbol{L}}|}{dt} = \frac{\tau_z}{L_z} = \frac{wr}{I\omega}$$

Observation

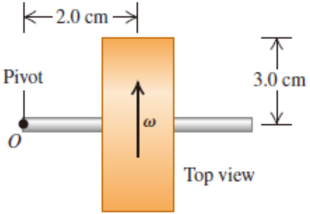
1. the angular speed of precession is inversely proportional to the angular speed of rotation (spinning) of the flywheel (in other words: a rapidly spinning gyroscope precesses slowly).
2. We have ignored the contribution to the angular momentum due to precession (this component is along the z axis). Our simplified analysis is valid for a rapidly spinning flywheel.

Exercise I

The Gyroscopic Effect

The figure shows a top view of a spinning, cylindrical gyroscope wheel. The pivot is at O, and the mass of the axle is negligible.

1. As seen from above, is the precession clockwise or counterclockwise?
2. If the gyroscope takes 4.0 s for one revolution of precession, what is the angular speed of the wheel?



Conditions for Equilibrium

Formula

$$\sum \vec{F} = 0$$

$$\sum \vec{\tau} = 0$$

How to solve problems

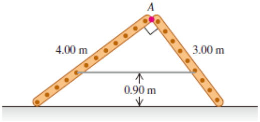
1. Sketch the situation; identify the object (do not treat it as a point!) in equilibrium.
2. Draw a free-body diagram with forces attached to the points they act onto.
3. Choose an appropriately placed coordinate system (can save calculations by eliminating torques of certain forces!).
4. Write down equilibrium conditions for forces and torques.

Exercise II

Solving problems using equilibrium

The ladders weigh 480 N and 360 N, respectively, and the center of gravity of each is at its center. Assume that the floor is freshly waxed and frictionless.

1. Find the upward force at the bottom of each ladder.
2. Find the tension in the rope.
3. Find the magnitude of the force one ladder exerts on the other at point A.
4. If an 800-N painter stands at point A, find the tension in the horizontal rope.



General Description

Hooke's Law

$$\frac{stress}{strain} = elastic\ modulus$$

Different Types

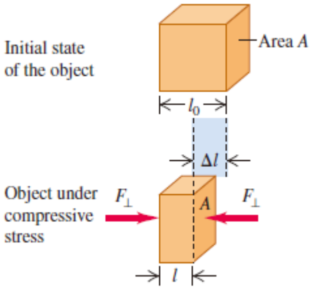
1. Tensile and Compressive Stress and Strain
2. Bulk Stress and Strain
3. Shear Stress and strain

Tensile and Compressive Stress and Strain

Formula

$$Y = \frac{\text{Tensile stress}}{\text{Tensile strain}} = \frac{F_\perp / A}{\Delta l / l_0} = \frac{F_\perp}{A}\frac{l_0}{\Delta l}$$

Figure



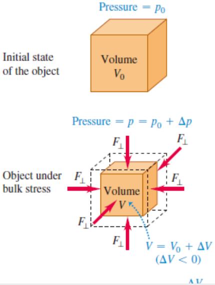
Bulk Stress and Strain

Formula

$$B = \frac{\text{Bulk stress}}{\text{Bulk strain}} = -\frac{\Delta p}{\Delta V / V_0}$$

$$k \ (compressibility) = \frac{1}{B} = -\frac{\Delta V / V_0}{\Delta p} = -\frac{1}{V_0}\frac{\Delta V}{\Delta p}$$

Figure

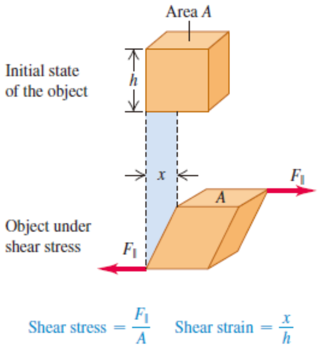


Shear stress and strain

Formula

$$S = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{F_{\parallel}/A}{x/h} = \frac{F_{\parallel}}{A}\frac{h}{x}$$

Figure

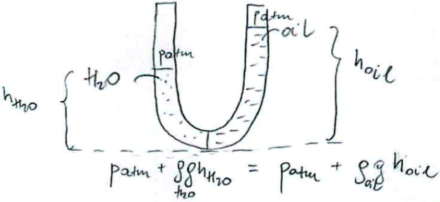


Pressure

Formula

$$p = p_0 + \varrho g h$$

U-shape tube



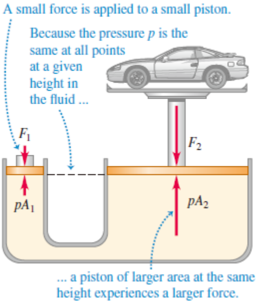
Pascal's law

Description

Pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the liquid and the walls of the container.

Application: Hydraulic lift

12.7 The hydraulic lift is an application of Pascal's law. The size of the fluid-filled container is exaggerated for clarity.

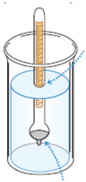


Buoyancy

Archimedes's principle

When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

Application: Hydrometer



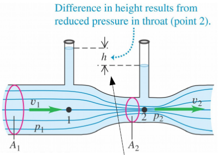
The hydrometer floats higher in denser liquids than in less dense liquids.

Bernoulli's equation

Formula

$$p + \rho g y + \frac{1}{2}\rho v^2 = \ \mathit{constant}$$

Example from lectures

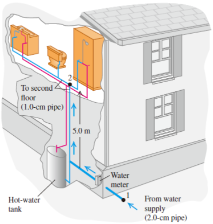


$$v_1 = \sqrt{\frac{2gh}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

Example in the textbook

Fluid

Water enters a house through a pipe with an inside diameter of 2.0 cm at an absolute pressure of 4.0×10^5 Pa (4 atm). A 1.0-cm-diameter pipe leads to the second-floor bathroom 5.0 m above. When the flow speed at the inlet pipe is 1.5 m/s, find the flow speed, pressure, and volume flow rate in the bathroom.



The End

- Office hour: Wed 8:00-10:00 (Discussion Room 326I)
- Email: *zhanghaomeng@sjtu.edu.cn*