Chapter 9 Lecture Notes
Physics 2414 - Strauss

Formulas:
Stress = Force/Area = F/A
Strain = $\Delta L/L_0$
$E = FL_0/A\Delta L$ = Stress/Strain
$G = FL_0/A\Delta L$ = Stress/Strain
$B = -\Delta PV_0/\Delta V$
$F = -k\Delta L$

1. Static Equilibrium

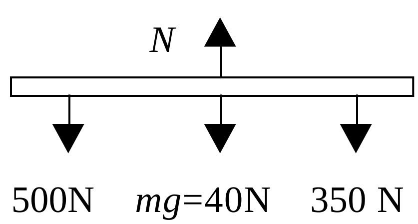
When the forces on an object are balanced so that the object does not have any acceleration or angular acceleration, we say the object is in **equilibrium.** The object is either at rest or in a state of constant velocity and/or angular velocity. So for an object to be in a state of equilibrium, the net force and the net torque must be zero. (If there were a net force or a net torque applied to the object, it would have an acceleration, or an angular acceleration, respectively.) This means that three equations must be satisfied for an object to be in equilibrium.

$\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma \tau = 0$.

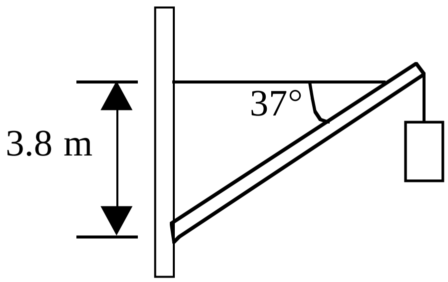
The torque can be measured relative to any axis of rotation. We must be careful to look only at the forces and torques acting *on* the object, and not any of the forces or torques exerted *by* the object.

Remember that we can consider the force of gravity acting on an object as completely acting at the point of its center of mass.

Problem: A uniform 40.0-N board supports two children weighing 500 N and 350 N. The support is under the center of gravity of the board, and the 500-N child is 1.50 m from the center. (a) What is the force which the support exerts? (b) Where should the 350 N child sit to balance the board?

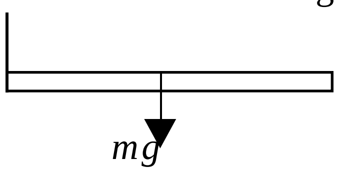


Problem: A traffic light hangs from a structure. The pole is L = 7.5 m long and has a mass of 8.0 kg. The mass of the light is 11.0 kg. Determine the tension in the horizontal cable and the vertical and horizontal components of the force on the pivot?



Problem: A 50 N weight is held in a person's hand with the forearm horizontal. The bicep muscle is attached 0.0300 m from the joint. The weight is 0.35 m from the joint. The mass of the forearm is 1.3 kg, with the center of mass located .17 m from the joint. What is the force of the humerous and the bicep on the arm.

Problem: A rod is hanging from two cords. What is the tension in the first string right after the second string is cut.



2. Balance

The rest of this chapter consists of concepts you should be familiar with which may have medical applications, such as human balance for physical therapy, and bone fracture, but are not fundamental concepts in physics. Consequently, we will cover them briefly but not in detail. Something that is not moving (or moving at a constant velocity) is said to be in equilibrium because the net vector force acting on the body is zero. If I change an object's position slightly it can do one of three things. (1) Return to its original position (called **stable** equilibrium). (2) Stay in its new position (called **neutral** equilibrium). (3) Move farther away from its original position (**unstable** equilibrium). Examples of each are (1) tipping a chair over slightly (2) sliding a chair along the floor (3) a pencil balanced on its tip. *An object will be in stable equilibrium when a line projected downward from the center of mass of the object falls within the base of the support.* This is why a person shifts their weight when carrying a heavy object.

3. Stress, Strain and Fracture

1. Definitions:

Stress = Force/Area = F/A (Pressure applied to an object)

Strain = $\Delta L/L_0$ (Percentage that something has deformed)

2. Results of Stress

- Elastic Limit: The relations below hold, and Hooke's law is valid. $F = k\Delta L$

- Plastic Limit: The relations below do not hold and the material is permantly deformed.

- Fracture: Forces exceed maximum limits derived from the relations below and material breaks.

3. <u>Types of Stress:</u>	<u>Appropriate Constant:</u>
• Tensile Stress or Compressive Stress	Young's Modulus $E = FL_0/A\Delta L$ = Stress/Strain
• Shear Stress	Shear Modulus $G = FL_0/A\Delta L$ = Stress/Strain
• All directions	Bulk Modulus $B = -\Delta P V_0/\Delta V$

For all situations, we have two definitions we need to know. The first is the stress on an object defined as the force per unit area.

Stress = F/A.

Next is the strain defined as how much the length of the object has been changed compared to its original length.

Strain = $\Delta L/L_0$.

When I exert forces on an object, there are three things that can happen. (1) The object can go back to its original form. If the object does that then I have only strained the object within its elastic limit. (2) The object can retain its new shape. If this happens, we say that I have strained the object within its plastic limit. (3) it can break. The object has been strained too much and fractures.

When (1) occurs, the material obeys Hooke's law $F = k\Delta L$. The material will retain its original shape when the forces are removed. How much it moves from its original position when the forces are on it depend on the size and shape of the body and how the force is applied. The force can be applied in three ways:

tension, compression, and shear. The change in shape for each of these three ways is determined from the elastic modulus for tension and compression, and from the shear modulus for shear. If the pressure is distributed on all parts of the object, the volume of the material changes and the bulk modulus is used. (See table 9-1 for various values).

Finally, if the stress exceeds some maximum the object will break. The maximum stress depends on whether there is a tensile, compressive, or shear force. Maximum strengths are given in table 9-2.

Problem: A nylon tennis string on a racquet is under tension of 250 N. If it has a diameter of 1.00 mm, by how much is it lengthened from its untensioned length of 30.0 cm? (Young's modulus for nylon is 5×10^9 N/m^2).

Problem: What is the maximum tension possible in a 1.00 mm diameter nylon tennis racquet string? (Tensile strength for nylon is 500×10^6 N/m^2.)