EQUILIBRIUM

For any body to be in equilibrium the following must be true:

1) $\sum \vec{t}_{EXT} = 0$ Therefore:

For an object to be in rotational equilibrium the vector sum of the external torques that act on the body, measured about **<u>any</u>** possible point, must equal zero.

2) $\sum \vec{F}_{EXT} = 0$ Therefore:

a=0, P=Constant

For an object to be in translational equilibrium, the vector sum of all the external forces that act on the body must also equal zero.

The main type of problem that is going to be used is a **static equilibrium** problem.

***<u>Static Equilibrium</u> is achieved when P=0 and L=0, not constants.**

The same equations are used for static equilibrium problems.

$$\sum \vec{F}_{EXT} = 0 \quad \text{And} \quad \sum \vec{t}_{EXT} = 0$$

Because the equations are vector equations, when solving the problem, break them up into their scalar components:

FORCE	**TORQUES**
$\sum F_X = 0$	$\sum t_X = 0$
$\sum F_Y = 0$	$\sum t_Y = 0$
$\sum F_Z = 0$	$\sum t_Z = 0$

In class we mostly deals with bodies that lie in the *xy*-plane, so three of the equations can eliminated, leaving:

$$\sum F_X = 0,\ \sum F_Y = 0,\ \sum t_Z = 0$$

Now that having three equations, **<u>three</u>** unknowns can be solved for. But, if a problem arises in which there are **<u>four or more</u>** unknowns, this is called and INDETERMINATE. Because there are more unknowns than equations, the problem can not be solved without using principles of elasticity. This subject was not covered in class, so the problem can be discarded.

Center Of Gravity

If g = Constant at every point in an object then:

$$X_{Center\ of\ Mass} = X_{Center\ of\ Gravity}$$

This is used in static equilibrium problems to condense the forces (due to gravity) into one point. This simplifies the problem so that each point in an object does not have to figured into the equations.

Tips/Advice

1) There is a Problem Solving Tactics section on pg. 307 in the book. It gives a detailed “plan of attack” for solving static equilibrium problems. A copy of this is provided on this page.
2) The most important step is to choose the axis of rotation for the system. Choose an axis that eliminates the largest amount of unknowns. The best way to eliminate these rotational unknowns is to choose an axis perpendicular to the line of action (Rule 6).
3) Do several problems. The more practice you have with static equilibrium problems the easier it will be to solve them in the future. We have provided several of these problems, for you to try, but try solving them before you look at the answers.
4) There is no substitute for good old fashion **STUDYING**! The more studying you do the less time it will take you to approach the problems.
5) Get good nights sleep, and do not cram before the exam. Have everything done before the night before the exam.

Problem Solving Tactics from Page 307

Tactic one: Static Equilibrium Problems

Here is a list of steps for solving static equilibrium problems:

1. Draw a nice sketch of the problem.
2. Select the system to which you will apply the laws of equilibrium, drawing a closed curve around it on your sketch to fix it clearly in your mind. In some situations you can select a single object as the system; it is the object you wish to be in equilibrium (such as the rock climber in sample problem 13-6). In other situations, you might include additional objects in the system if their inclusion simplifies the calculations for the equilibrium. For example, suppose in Sample Problems 13-3 and 13-4 you select only the ladder as the system. Then in figure 13-8b you will have to account for additional unknown forces exerted on the ladder by the hands and feet of the firefighter. These additional unknowns complicate the equilibrium calculations. The system in figure 13-8 was chosen to include the firefighter so that those unknown forces are internal to the system and thus need not be found in order to solve sample problems 13-3 and 13-4.
3. Draw a free body diagram of the system. Show all the forces that act on the system, labeling them clearly and making sure that their points of application and lines of action are correctly shown.
4. Draw in the x and y axes of a coordinate system. Choose them so that at least one axis is parallel to one or more unknown force. Resolve into components the forces that do not lie along one of the axes. In all our sample problems it made sense to choose the x axis horizontal and the y axis vertical.
5. Write the two balance of forces equations, using symbols throughout.
6. Choose one or more rotational axes perpendicular to the plane of the figure and write the balance of torques equation for each axis. If you choose an axis that passes through the line of action of an unknown force, the equation will be simplified because that force will not appear in it.
7. Solve your equations algebraically for the unknowns. Some students feel more confident in substituting numbers with units in the independent equations at this stage, especially if the algebra is particularly involved. However, experienced problem solvers prefer the algebraic approach, which reveals the dependence of solutions on the various variables.
8. Finally, substitute numbers with units in you algebraic solutions, obtaining numerical values for the unknowns.
9. Look at your answer – does it make sense? Is it obviously too large or too small? Is the sign correct? Are the units appropriate?