Massachusetts Institute of Technology
Department of Mechanical Engineering

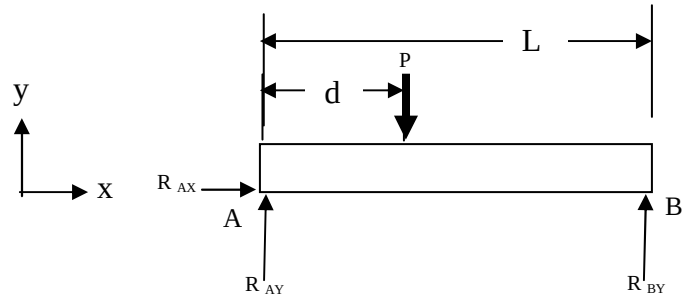
2.001 Mechanics and Materials I
Spring 2002

Equilibrium, Free Body Diagram, Friction and Problem Solving Comments

The main areas addressed are: (1) Equilibrium, (2) Free Body Diagrams, (3) Friction & (4) Problem Solving

1. Equilibrium

a) When performing equilibrium, always write the general equation – don't do the work in your head. As problems increase in complexity and difficulty, they will come back to haunt you. When doing Moment Equilibrium, make sure you indicate clearly the point around which you are taking moments. For example:



$\circlearrowleft_{+} \Sigma M_A = 0$ ***OR*** $\circlearrowleft_{+} \Sigma M_B = 0$

$-(P \cdot d) + (R_{BY} \cdot L) = 0$ $\qquad [P \cdot (L-d)] - (R_{AY} \cdot L) = 0$

b) In your equilibrium equations, the signs of the forces should be consistent with the coordinate system which you define.

c) When summing moments, indicate which direction you assume to be positive immediately in front of the summation sign.

2. Free-Body Diagrams

a) Definition: *A free body diagram is a sketch that shows a body "free" from its surroundings with* ***all*** *the forces and moments that act on the body.* In other words, "Isolate" the body. For example, with the inclined plane- friction experiment, many students showed the inclined plane in the free body diagram of the block.

b) **Question:** How do I determine what kind of reactions a given support provides?
Answer: Determine which translational and rotational motion that the support prevents. For each motion that is prevented, the support produces force (for translational motion) or moment (for rotational motion) in the direction of the prevented motion. For example, if the support prevents translation in the x-direction, it provides a reaction force in the x-direction. Likewise, if it prevents rotation about the z-axis, it provides a reaction moment about the z-axis. There are some nice diagrams of different supports in the textbook section of the Equilibrium module of the 2.001 I-Campus website.

c) The locations of the forces and moments are important, therefore a free body diagram should also include the necessary dimensions of the body and the locations at which the forces and moments act on that body.

d) All internal forces and moments must cancel when you "reassemble" the free-body diagrams you have drawn. In other words, the forces and moments you draw on one member must be equal, but in the opposite direction from that member which it mates with.

Friction:

F *is not always equal to* fN. In particular, the static friction force is only equal to the product of the coefficient of friction and the normal force ***when the motion is impending***. The value fN is the maximum friction force that can be developed in a static situation.

In general, the coefficient of **static** friction will not be the same as the coefficient of dynamic friction.

Problem Solving:

When you write up a solution to your equilibrium problems, it should not only document your algebra, but also your thought process. Right now, many of you may be able to look at the problem, and immediately see the answer, but problems will become more complex.

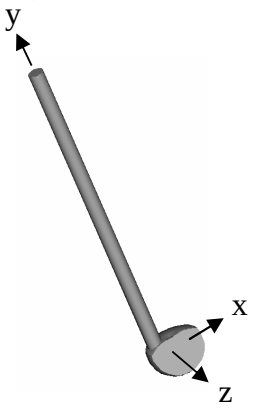
The idea here is that someone (you, a classmate, a grader, or a senior engineer) should be able to read your work at a later point and understand how you solved the problem.

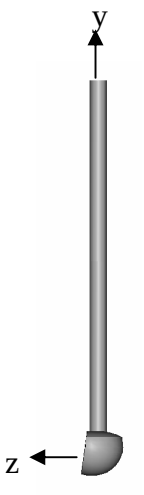
It is good practice to solve problems symbolically and to substitute the numerical values as a last step. The reason for this is two-fold: 1) it is much easier to catch your own algebra mistakes when the problem is solved symbolically. 2) When you solve the problem symbolically, you can determine the effect of various quantities in the problem on the solution (thereby gaining insight into the problem).

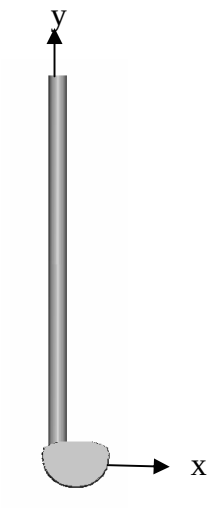
Isometeric View vs. 2-D Views

With the golf club problem, many of you had difficulty thinking of the golf club in 2-D, from two different directions. These views are to help you understand translating 3-D objects into two 2-D representations.

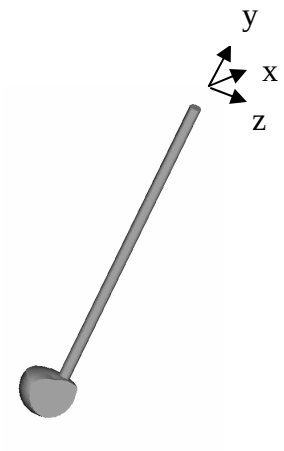
Examples: Left-handed golf club

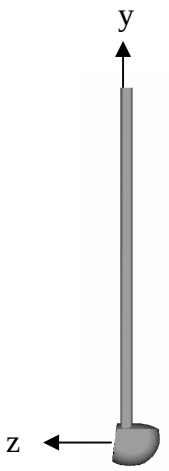






Right-handed golf club





Simple Cube with a cut-out