Physic² 121:
Phundament°ls of Phy²ics I

November 17, 2006

Chapter 8

Rotational Equilibrium
and
Rotational Dynamics

Torque and Equilibrium

- First Condition of Equilibrium
  - The net external force must be zero

$$\Sigma \vec{\mathbf{F}} = 0 \text{ or}$$

$$\Sigma \vec{\mathbf{F}}_x = 0 \text{ and } \Sigma \vec{\mathbf{F}}_y = 0$$

  - This is a necessary, but not sufficient, condition to ensure that an object is in complete mechanical equilibrium
  - This is a statement of translational equilibrium

Torque and Equilibrium, cont

- To ensure mechanical equilibrium, you need to ensure rotational equilibrium as well as translational
- The Second Condition of Equilibrium states
  - The net external torque must be zero

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

Axis of Rotation

- If the object is in equilibrium, it does not matter where you put the axis of rotation for calculating the net torque
  - The location of the axis of rotation is completely arbitrary
  - Often the nature of the problem will suggest a convenient location for the axis
  - When solving a problem, you *must* specify an axis of rotation
    - Once you have chosen an axis, you must maintain that choice consistently throughout the problem

Notes About Equilibrium

- A zero net torque does not mean the absence of rotational motion
  - An object that rotates at uniform angular velocity can be under the influence of a zero net torque
    - This is analogous to the translational situation where a zero net force does not mean the object is not in motion

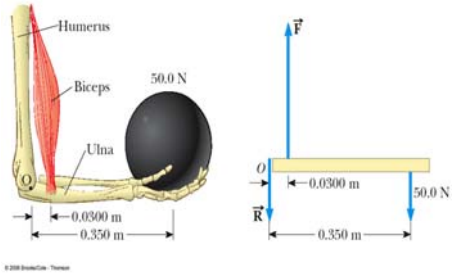
Solving Equilibrium Problems

- Draw a diagram of the system
  - Include coordinates and choose a rotation axis
- Isolate the object being analyzed and draw a free body diagram showing all the external forces acting on the object
  - For systems containing more than one object, draw a separate free body diagram for each object

Problem Solving, cont.

- Apply the Second Condition of Equilibrium
  - This will yield a single equation, often with one unknown which can be solved immediately
- Apply the First Condition of Equilibrium
  - This will give you two more equations
- Solve the resulting simultaneous equations for all of the unknowns
  - Solving by substitution is generally easiest

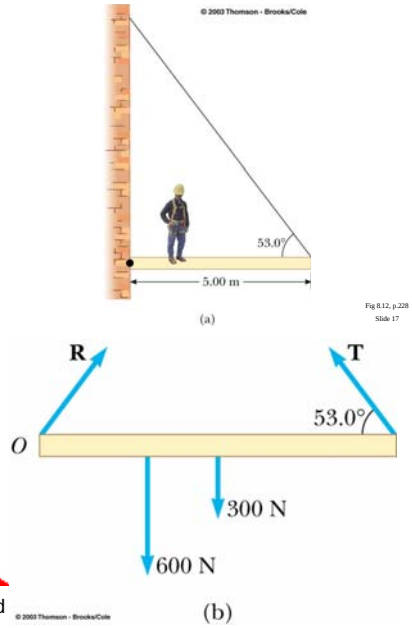
Example of a Free Body Diagram (Forearm)



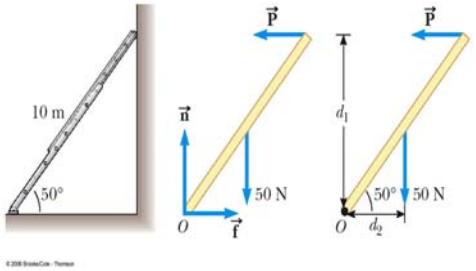
- Isolate the object to be analyzed
- Draw the free body diagram for that object
  - Include all the external forces acting on the object

Example of a Free Body Diagram (Beam)

- The free body diagram includes the directions of the forces
- The weights act through the centers of gravity of their objects



Example of a Free Body Diagram (Ladder)



- The free body diagram shows the normal force and the force of static friction acting on the ladder at the ground
- The last diagram shows the lever arms for the forces