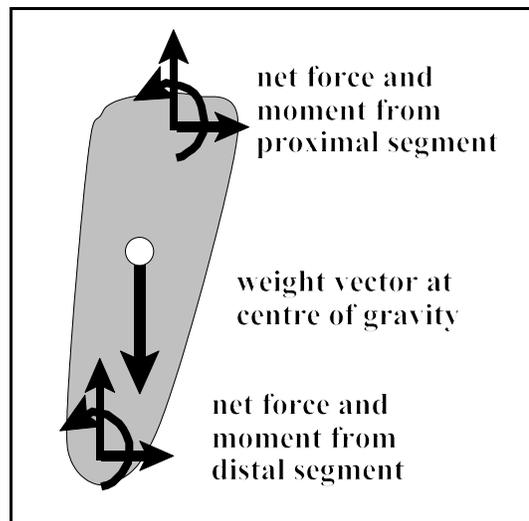


Free-body Diagrams

Rules to construct a valid free-body diagram (FBD).

The following rules must be applied accurately.

- Rule 1.** Select the appropriate body or body segment, keeping in mind the unknowns you want to compute. That is, make sure the free-body includes at least one of the unknowns.
- Rule 2.** Draw all **known** forces or moments of force at their respective points of application (e.g., weight vector, measured external forces, etc.). Note that the weight vector is placed at the centre of gravity of the free-body.
- Rule 3.** Draw all **unknown** forces and moments that directly contact the free-body. These include points of detachment from other parts of the body and points of contact with the environment. Wherever the free-body is separated from other parts of the body, replace the excluded parts of the body with an unknown force (two components) and a moment of force (see figure below).
- Rule 4.** Do NOT include **internal** forces which originate and terminate within the free-body (e.g., muscle or joint forces of internal joints).



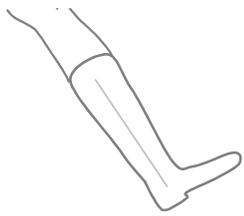
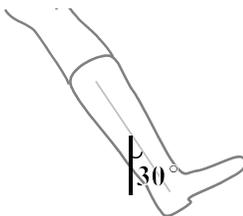
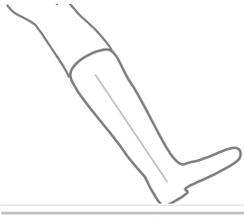
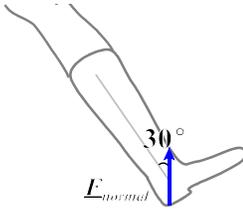
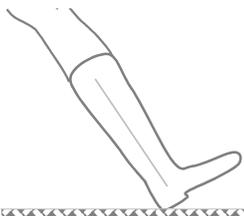
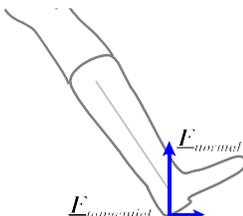
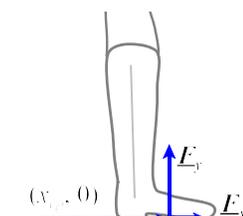
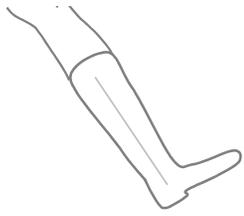
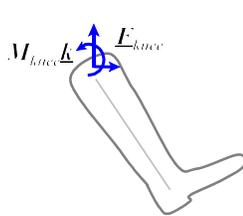
Free-body diagram of a human segment

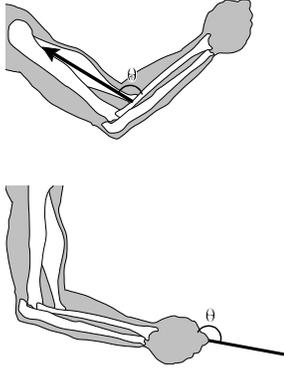
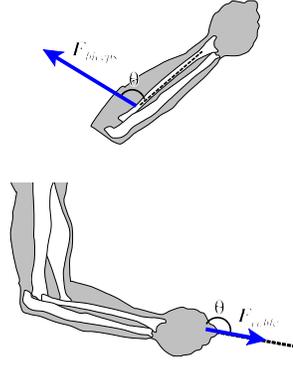
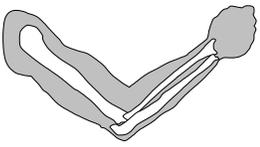
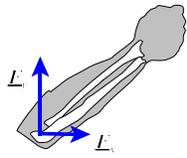
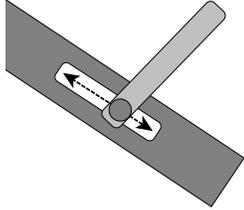
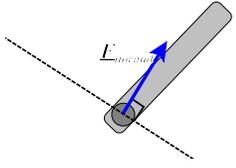
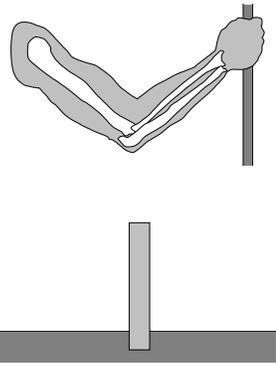
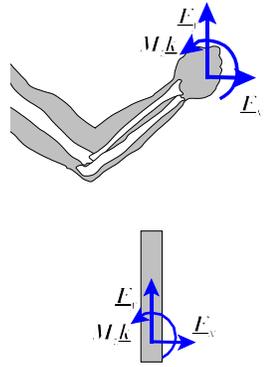
Steps for Solving Mechanics Problems

In the following chapters you will be learning how to solve different types of biomechanics problems. It is useful to develop a method that will consistently lead you to the correct solution in a clear and consistent fashion. The following steps if employed faithfully have been found to achieve this goal.

- Step 1.** Draw a **free-body diagram** (FBD) of the body (or bodies) of interest.
- Step 2.** Select and draw an appropriate **axis system** that defines the positive directions and slopes of the axes (e.g., X-Y, polar, normal-tangential, radial-transverse). Usually a right-handed axis is selected.
- Step 3.** For each free-body diagram write out the **equations of motion** or **principles** that apply to the problem. These are based upon the six fundamental laws or their corollaries.
- Step 4.** **Expand the equations** using information based on the FBD.
- Step 5.** **Solve the equations** for the unknowns (Note, this can only be done if the number of unknowns is less than or equal to the number of equations).
- Step 6.** **Write out the solutions** with the directions and signs (+/-) based on the axes selected in step 2 and with appropriate accuracies and SI units.
- Step 7.** **Check** your calculations by recomputing the solutions.

Number of Unknowns for Various Types of Connections

| Type of connection | Space diagram | Number of unknowns | Diagram of unknowns |
|---------------------------------------|---|---|---|
| Distal end of free-ended limb |  | 0 |  |
| Frictionless (icy) surface or rollers |  | 1 = force in normal direction to surface |  |
| Point loading on a rough surface |  | 2 = normal force from surface and tangential force (frictional) parallel to surface |  |
| Rough surface |  | 3 = ground reaction force and its horizontal centre of pressure |  |
| Separation at a joint (e.g., knee) |  | 3 = net force (x and y components) and net moment of force |  |

| | | | |
|--|---|--|---|
| <p>Single muscle or ligament with known line of action</p> <p>Cable or thin rod</p> |  | <p>1 = magnitude of force (tension in tendon) along the line of action, cable or rod</p> |  |
| <p>Frictionless hinge or pin-connected joint</p> |  | <p>2 = two components of force, no moment of force</p> |  |
| <p>Frictionless slot</p> |  | <p>1 = normal force to slot, no moment of force</p> |  |
| <p>Segment tied to or gripping an external structure or surface</p> <p>Cantilever beam</p> |  | <p>3 = two force components and the moment of force</p> |  |