Ch.3 Equilibrium

A body is in equilibrium, the resultant of all forces (force + couple) acting on it is zero.

$$\vec{R} = \sum \vec{F} = 0 \qquad \vec{M} = \sum \vec{M} = 0$$

3/2 System isolation and the free-body diagram

Before applying the equilibrium conditions, it must be cleared which body or system are analyzed, and which forces act on the body.

Free-Body Diagram (FBD) ☆

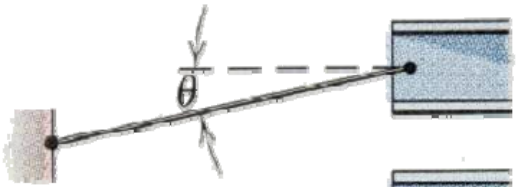
- The isolated system treated as a single body
- All forces acting on body are shown

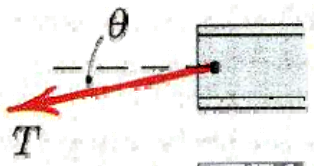
Modeling the action of forces(1)

Type of contact	Action on body to be isolated

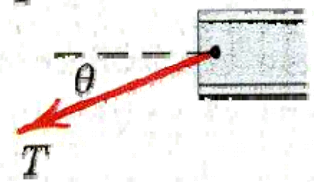
1. Flexible cable, belt, chain or rope

Weight negligible

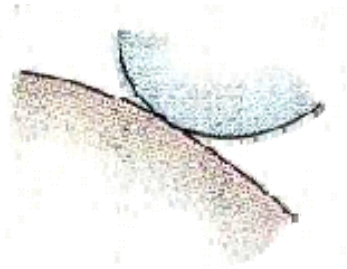


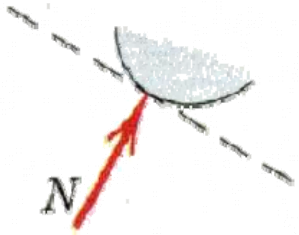


Weight not negligible



2. Smooth surfaces

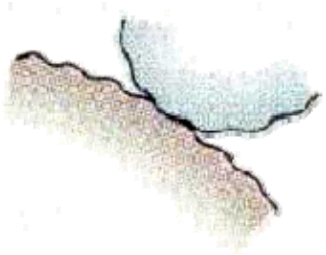


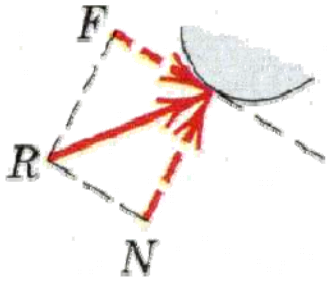


Modeling the action of forces(2)

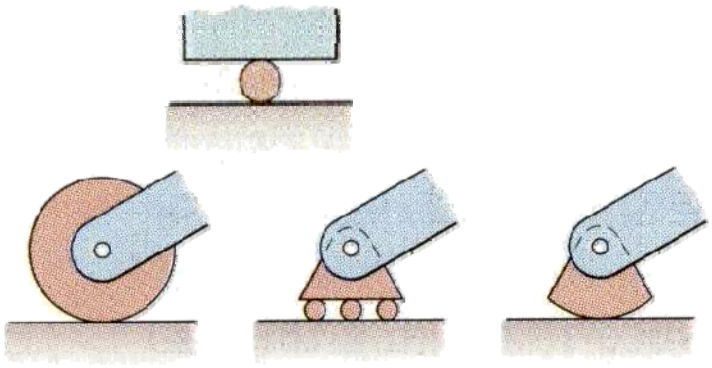
Type of contact	Action on body to be isolated

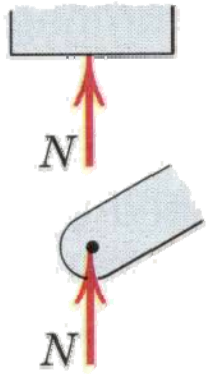
3. Rough surfaces





4. Roller support

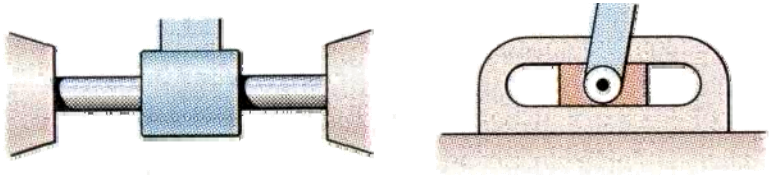


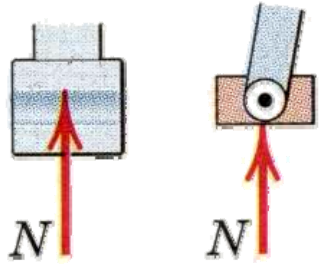


Modeling the action of forces(3)

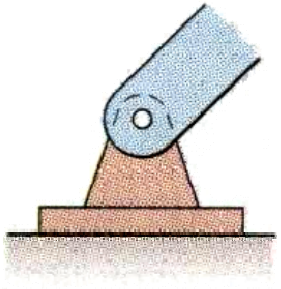
Type of contact	Action on body to be isolated

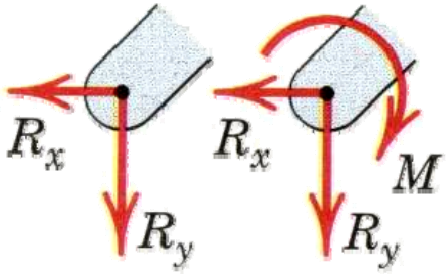
5. Freely sliding guide





6. Pin connection



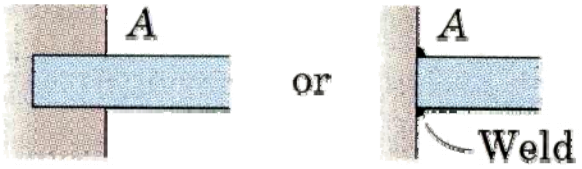


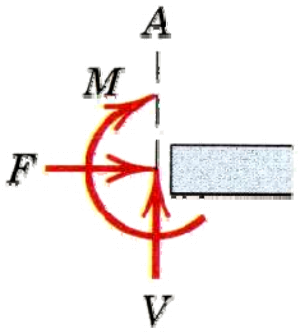
Free to turn Not free

Modeling the action of forces(4)

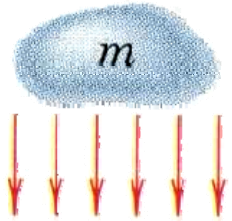
Type of contact	Action on body to be isolated

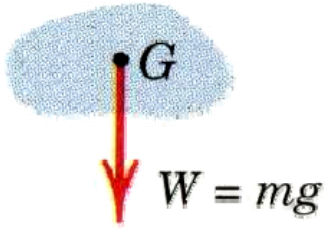
7. Built-in or fixed support



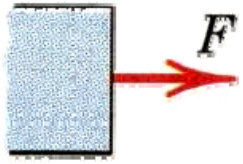


8. Gravitational attraction



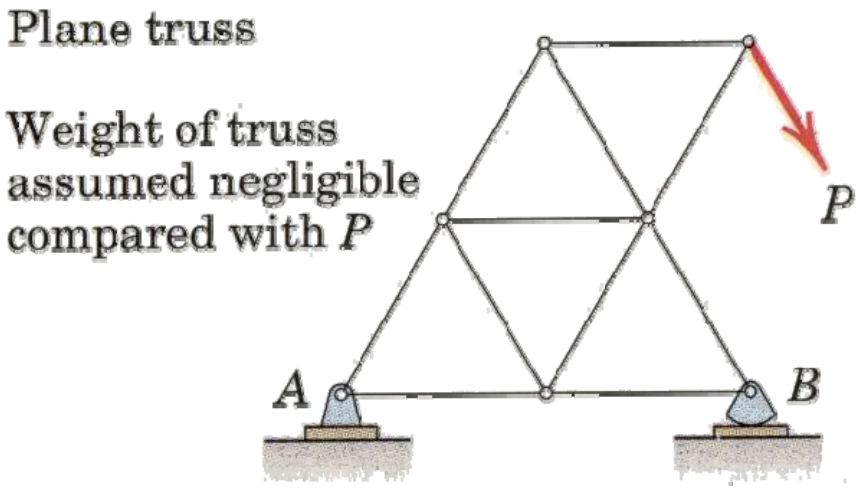


9. Spring action

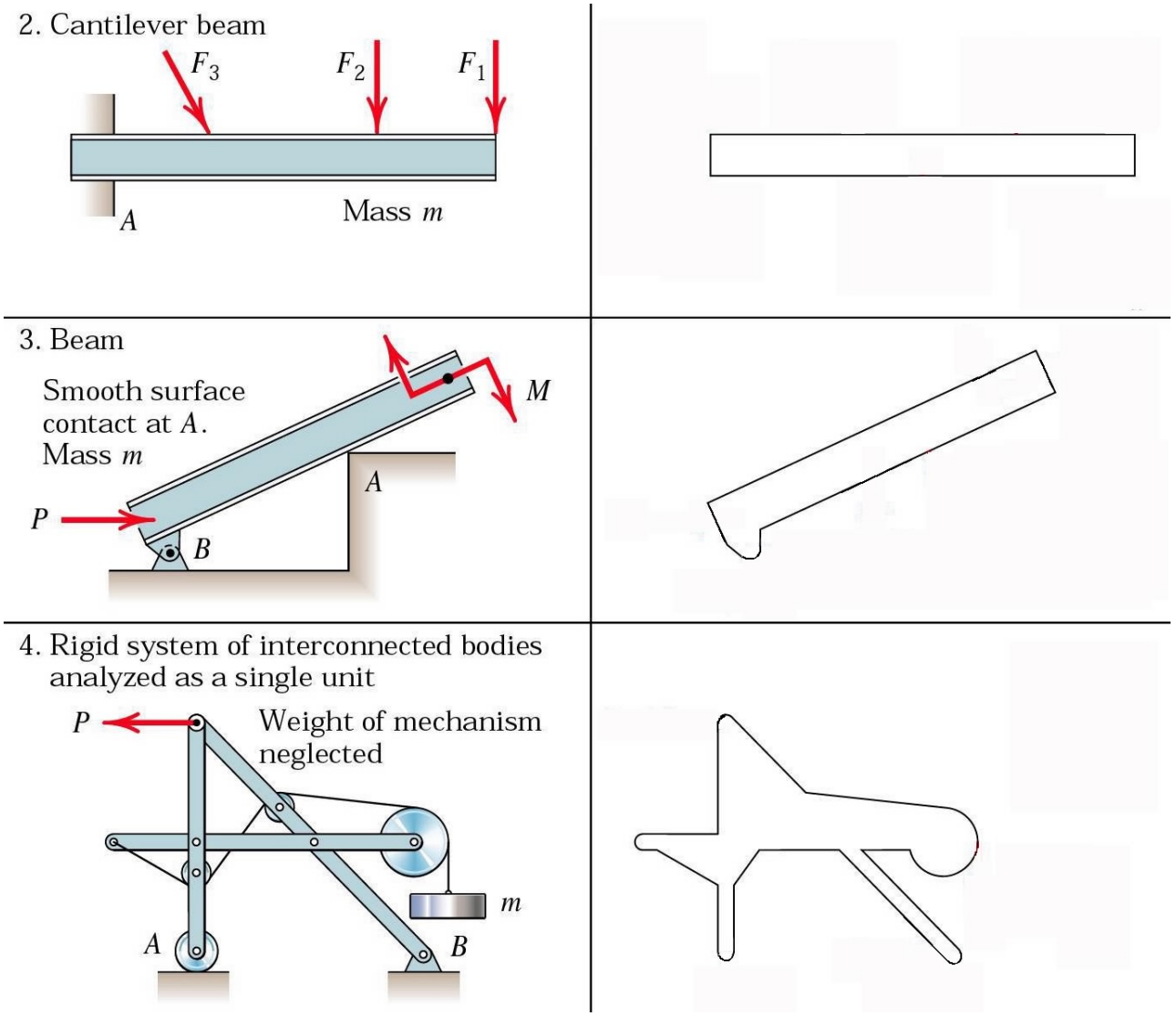


Construction of FBD

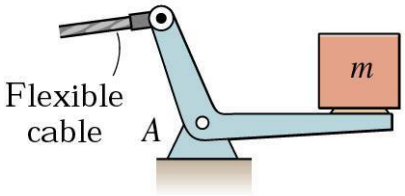
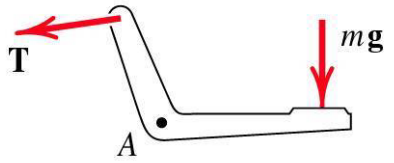
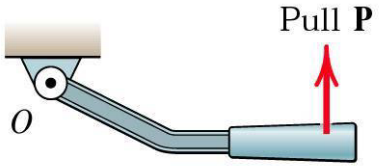
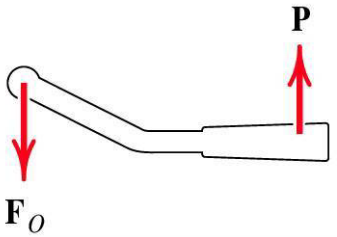
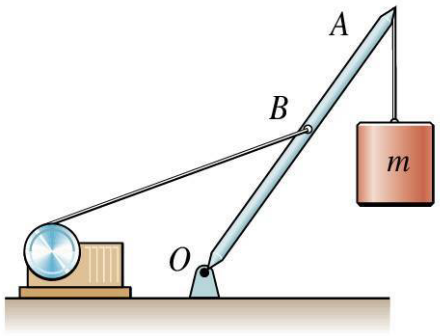
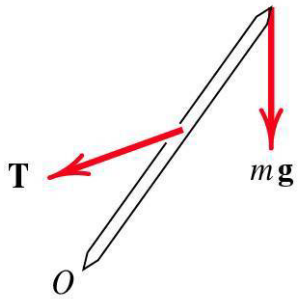
1. Choose a body to be isolated
2. Draw “complete external boundary” of the isolated body
3. Add all forces and moments
4. Indicate a coordinate system



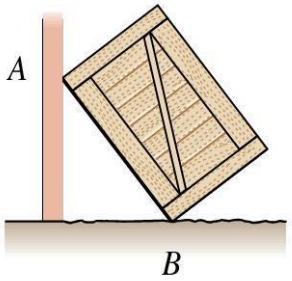
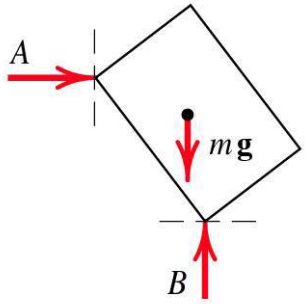
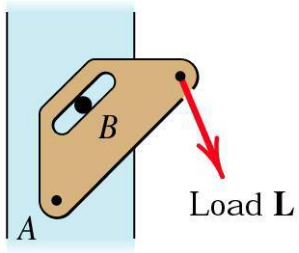
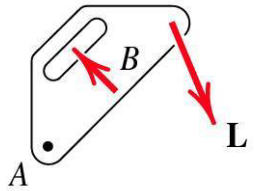
Examples of FBD



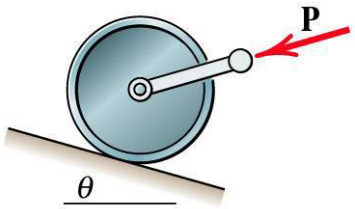
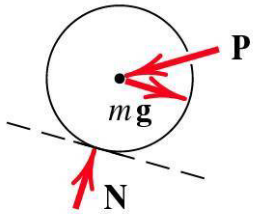
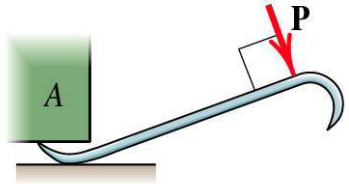
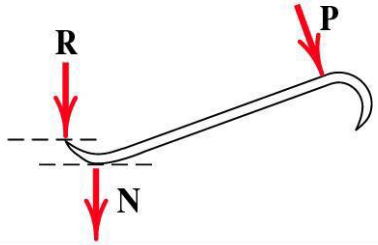
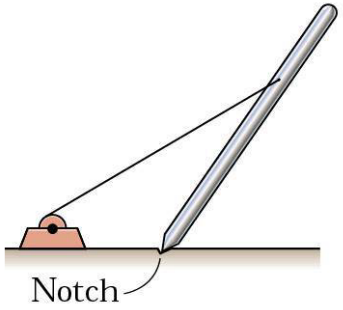
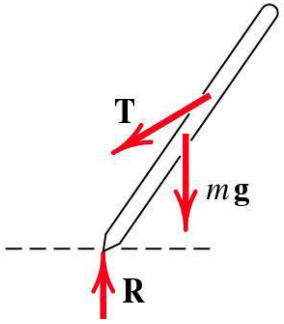
FBD problem(1)

	Body	Incomplete *FBD*
1. Bell crank supporting mass m with pin support at A.		
2. Control lever applying torque to shaft at O.		
3. Boom OA, of negligible mass compared with mass m. Boom hinged at O and supported by hoisting cable at B.		

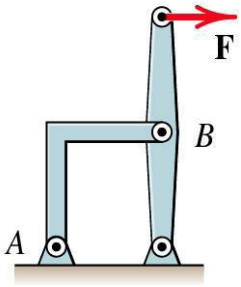
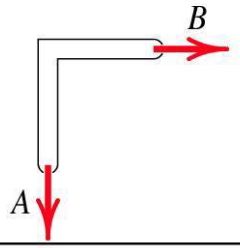
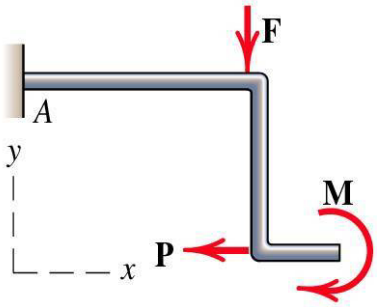
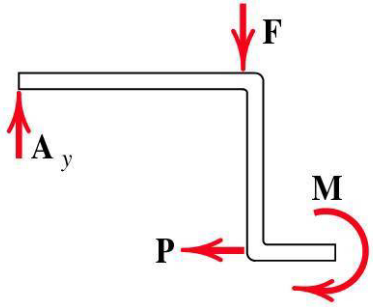
FBD problem(2)

	Body	Incomplete *FBD*
4. Uniform crate of mass m leaning against smooth vertical wall and supported on a rough horizontal surface.		
5. Loaded bracket supported by pin connection at A and fixed pin in smooth slot at B.		

FBD problem(3)

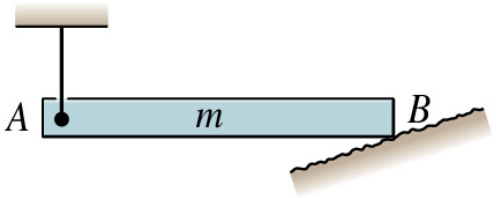
	Body	Wrong or Incomplete *FBD*
1. Lawn roller of mass m being pushed up incline θ.		
2. Prybar lifting body A having smooth horizontal surface. Bar rests on horizontal rough surface.		
3. Uniform pole of mass m being hoisted into position by winch. Horizontal supporting surface notched to prevent slipping of pole.		

FBD problem(4)

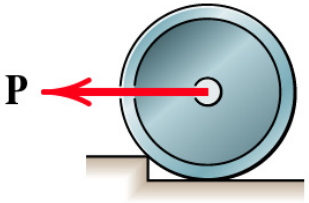
	Body	Wrong or Incomplete *FBD*
4. Supporting angle bracket for frame; Pin joints.		
5. Bent rod welded to support at *A* and subjected to two forces and couple.		

FBD problem(5)

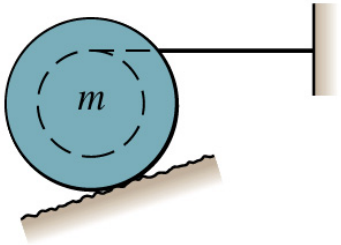
1. Uniform horizontal bar of mass m suspended by vertical cable at A and supported by rough inclined surface at B.



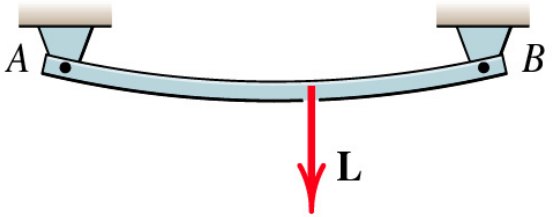
2. Wheel of mass m on verge of being rolled over curb by pull **P**.



5. Uniform grooved wheel of mass m supported by a rough surface and by action of horizontal cable.

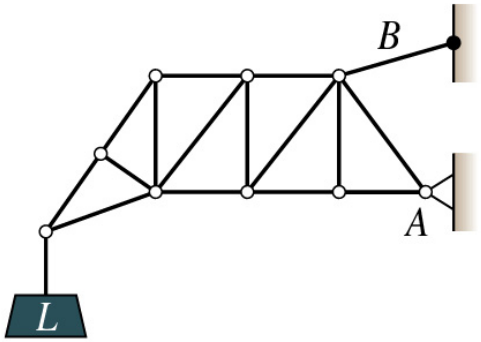


6. Bar, initially horizontal but deflected under load **L**. Pinned to rigid support at each end.

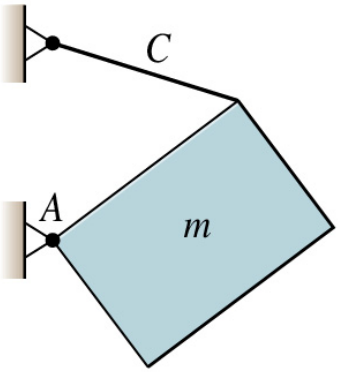


FBD problem(6)

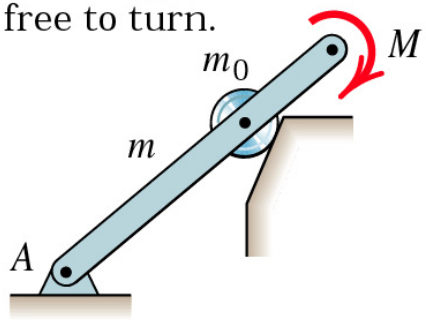
3. Loaded truss supported by pin joint at A and by cable at B.



7. Uniform heavy plate of mass m supported in vertical plane by cable C and hinge A.



4. Uniform bar of mass m and roller of mass m_0 taken together. Subjected to couple M and supported as shown. Roller is free to turn.



8. Entire frame, pulleys, and contacting cable to be isolated as a single unit.