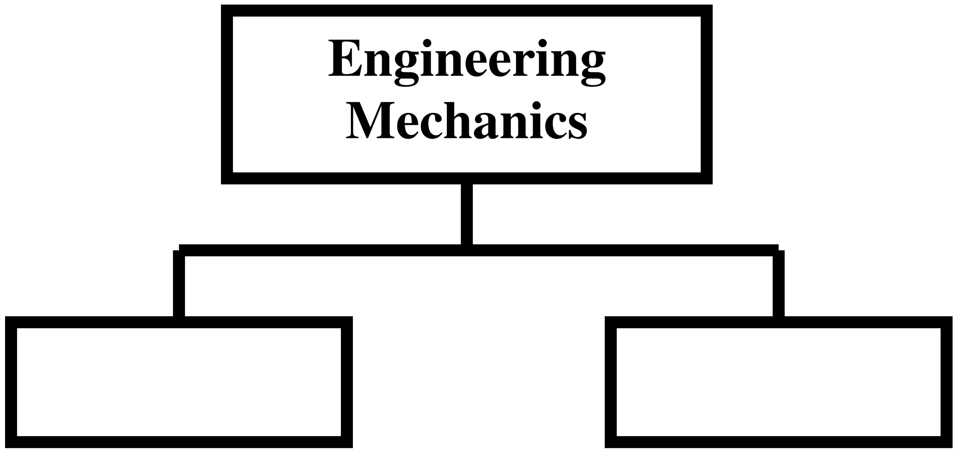
Lecture 1: Introduction



Engineering mechanics is the physical science which studies the ________________ __________. The subject is usually divided into two parts namely _______________ _________

Statics. This branch of mechanics studies ___________________________________ __________________________________. Examples of static systems include an aeroplane at cruising speed, a hovering helicopter, a floating ship, etc.

Dynamics. This branch of mechanics studies the motion of bodies, ie. a system where a body is acted upon by an unbalanced resultant force which may be a function of time. Examples of dynamic systems are a grandfather clock pendulum, a mass-spring system, an accelerating/decelerating vehicle, etc.

Basic terminologies

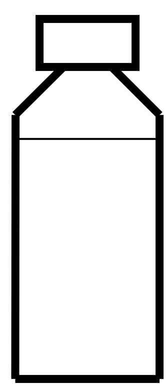
- Scalar quantity. A scalar quantity _________________________________. Mass, time, volume, distance, speed and energy are examples of scalar quantities.
- Vector quantity. A vector quantity consists of __________________________. Weight, displacement, velocity, acceleration, force and moment are examples of vector quantities.

- Force. Force is the ____.
  The effects of force acting on a body depend on the magnitude, direction and the point of application of the force. The resultant effects can be the motion (translation, rotation) or changes in shape (bending, denting, breaking, and destruction) of the body.
- Centre of gravity (centre of mass, centroid). The centre of gravity of a body is defined as ____
  ____.
- Moment. When a force is not acting through the centre of gravity of a body, it generates a moment. The effect of the resultant moment is the ___________
  ____.

Free body diagrams

A free body diagram shows ______________________________________ ____. This is a very powerful tool to help us determine the forces acting on the structures and its members.

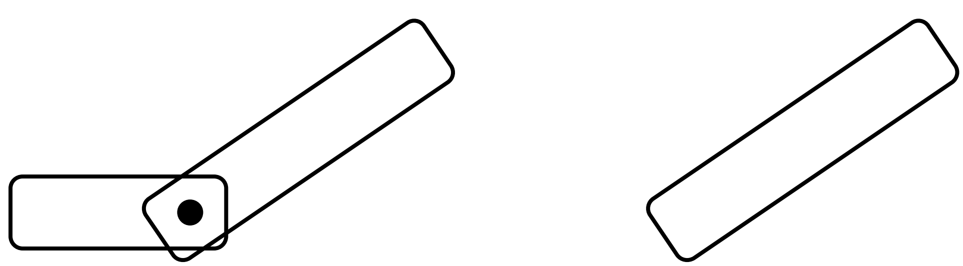
Here is an example of a free body diagram.



The weight of the water acts downward in the direction of the gravity, neglecting the weight of the bottle. The fingers exert horizontal forces on the cap of the bottle and the friction between the fingers and the cap provide the upward forces to counteract the weight of the water.

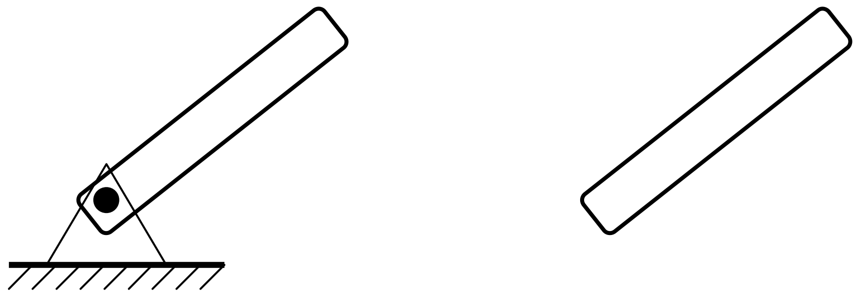
Here are some basic terminologies which are required in order to successfully create free body diagrams.

- Rigid body. A rigid body is assumed to ________________________________ ____ when acted upon by a force.
- Bars. A bar is a solid member which forms a part of the structure. _________ ____can be supported by bars.
- Cables. ___________________________________ can be supported by cables. Without tension, a cable is said to carry zero load.
- Structures or Trusses. When several members are joined at their ends to form a __________________________________, it is called a structure or a truss.
- Light. When a bar is considered light, ______________________________.
- Smooth surface or contact. ____ at the contact between two smooth surfaces.
- Rough surface. Friction is present at the contact between rough surfaces. Its direction is __________________________ to the surfaces.
- Pin joints. Usually a simplified structure consists of a number of members pin jointed together. As the connected members are _________________________ at the pin joint, only ______________ are resisted but not _______________.

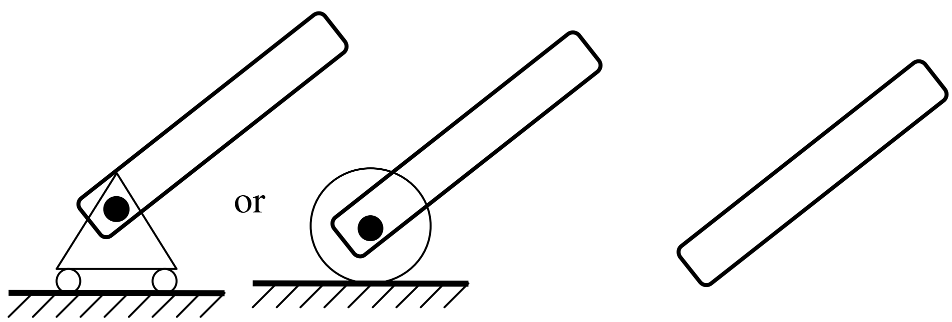


- Supports. Structures cannot be suspended in mid-air and therefore must be connected to the ground or wall by means of supports. There are several types of supports as shown below.

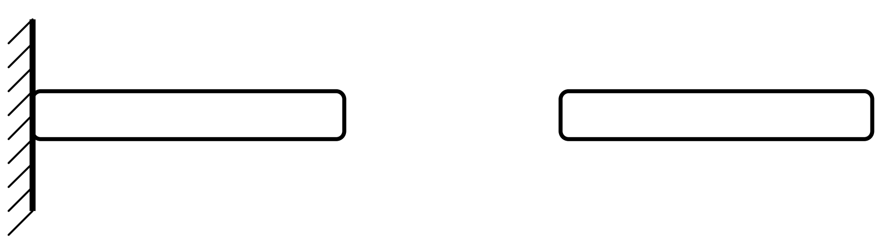
1. ______________________________. This type of support resists movement of the connected member but allows rotation about the pin joint.



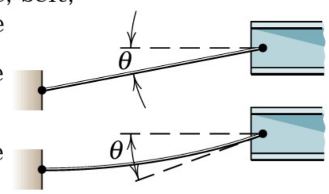
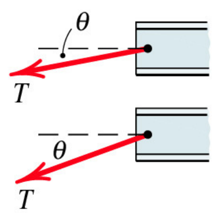
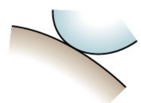
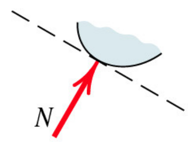
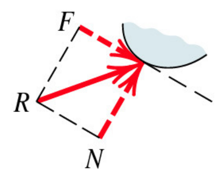
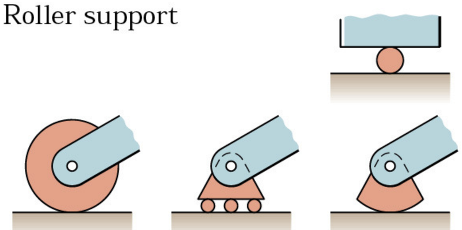
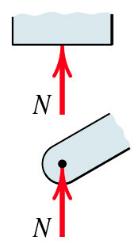
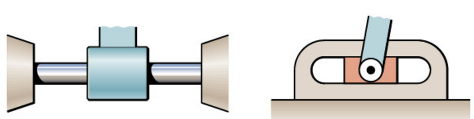
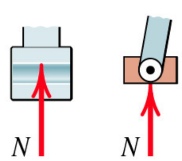
2. ________________________. This type of support allows for movement in the direction parallel to the surface. Hence, the reaction force on the member is always perpendicular to the surface. Moment is never present.

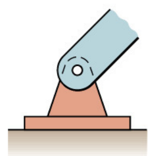
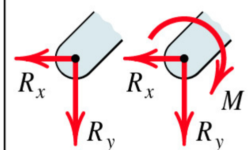
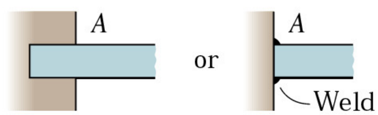
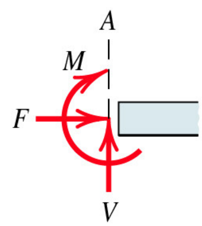
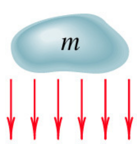
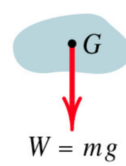
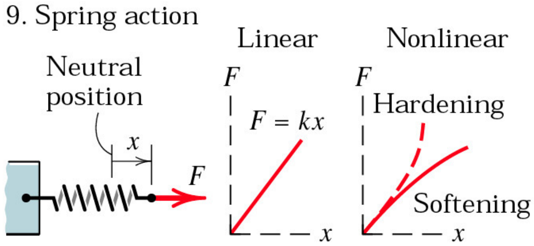
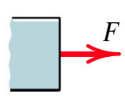


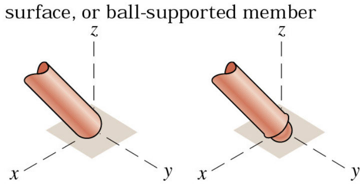
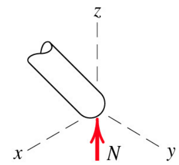
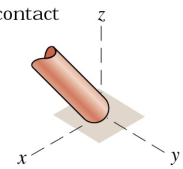
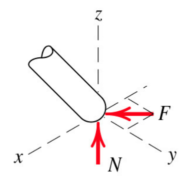
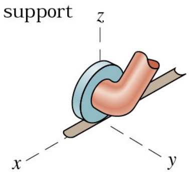
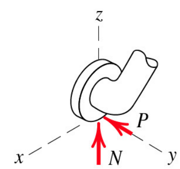
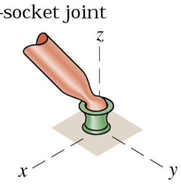
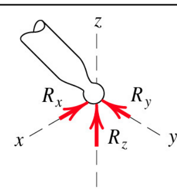
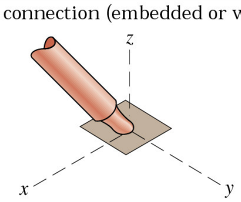
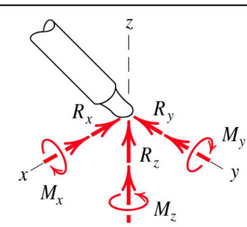
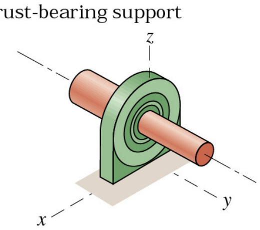
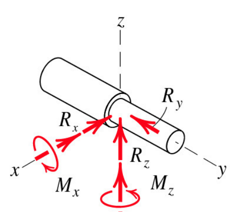
3. ____________________________. This type of support completely resists the movement of the connected member, therefore both forces and moment are present in the free body diagram.

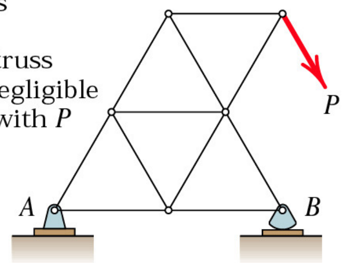
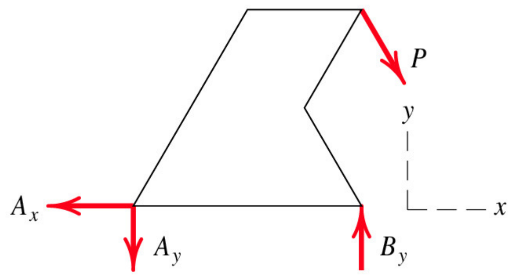
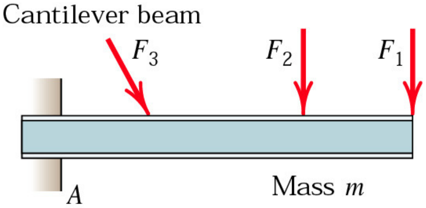
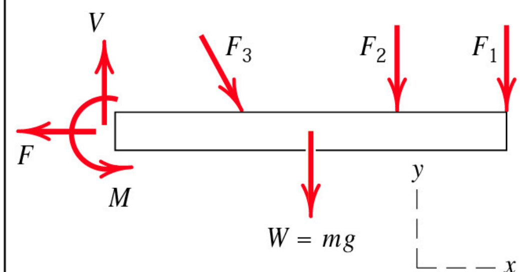
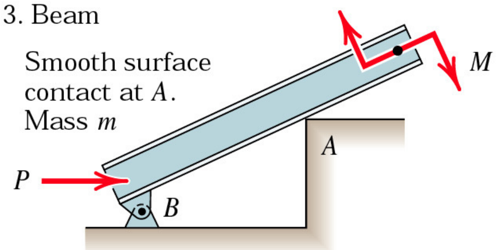
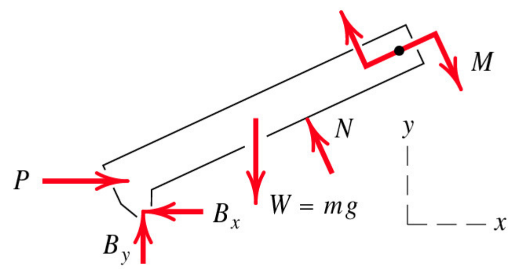
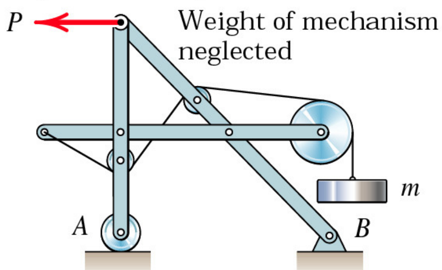
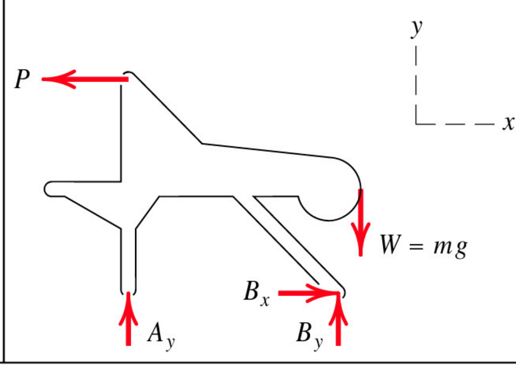


The following tables are taken from *Meriam* pages 105-106 and 109.

MODELING THE ACTION OF FORCES IN TWO-DIMENSIONAL ANALYSIS	
Type of Contact and Force Origin	Action on Body to Be Isolated
1. Flexible cable, belt, chain, or rope Weight of cable negligible Weight of cable not negligible 	 Force exerted by a flexible cable is always a tension away from the body in the direction of the cable.
2. Smooth surfaces 	 Contact force is compressive and is normal to the surface.
3. Rough surfaces 	 Rough surfaces are capable of supporting a tangential component F (frictional force) as well as a normal component N of the resultant contact force R.
4. Roller support 	 Roller, rocker, or ball support transmits a compressive force normal to the supporting surface.
5. Freely sliding guide 	 Collar or slider free to move along smooth guides; can support force normal to guide only.

MODELING THE ACTION OF FORCES IN TWO-DIMENSIONAL ANALYSIS (*cont.*)	
Type of Contact and Force Origin	**Action on Body to Be Isolated**
6. Pin connection 	 A freely hinged pin connection is capable of supporting a force in any direction in the plane normal to the axis; usually shown as two components R_x and R_y. A pin not free to turn may also support a couple M.
7. Built-in or fixed support 	 A built-in or fixed support is capable of supporting an axial force F, a transverse force V (shear force), and a couple M (bending moment) to prevent rotation.
8. Gravitational attraction 	 The resultant of gravitational attraction on all elements of a body of mass m is the weight $W = mg$ and acts toward the center of the earth through the center mass G.
9. Spring action 	 Spring force is tensile if spring is stretched and compressive if compressed. For a linearly elastic spring the stiffness k is the force required to deform the spring a unit distance.

MODELING THE ACTION OF FORCES IN THREE-DIMENSIONAL ANALYSIS	
Type of Contact and Force Origin	Action on Body to Be Isolated
1. Member in contact with smooth surface, or ball-supported member 	 Force must be normal to the surface and directed toward the member.
2. Member in contact with rough surface 	 The possibility exists for a force F tangent to the surface (friction force) to act on the member, as well as a normal force N.
3. Roller or wheel support with lateral constraint 	 A lateral force P exerted by the guide on the wheel can exist, in addition to the normal force N.
4. Ball-and-socket joint 	 A ball-and-socket joint free to pivot about the center of the ball can support a force **R** with all three components.
5. Fixed connection (embedded or welded) 	 In addition to three components of force, a fixed connection can support a couple **M** represented by its three components.
6. Thrust-bearing support 	 Thrust bearing is capable of supporting axial force R_y as well as radial forces R_x and R_z. Couples M_x and M_z must, in some cases, be assumed zero in order to provide statical determinacy.

SAMPLE FREE-BODY DIAGRAMS	
Mechanical System	**Free-Body Diagram of Isolated Body**
1. Plane truss Weight of truss assumed negligible compared with P 	
2. Cantilever beam 	
3. Beam Smooth surface contact at A. Mass m 	
4. Rigid system of interconnected bodies analyzed as a single unit Weight of mechanism neglected 	

Lecture1: Exercises

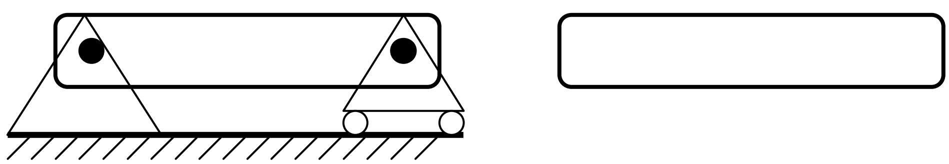
1. Mass is a scalar quantity, whereas weight is a vector quantity. Explain why the weight is a vector quantity.

2. Determine the weight of a 70kg man when he is (a) on Earth and (b) on a planet where the gravitational pull is 20 times greater than that on Earth. (Hint: Acceleration due to the Earth gravity is 9.81 m/s^2)

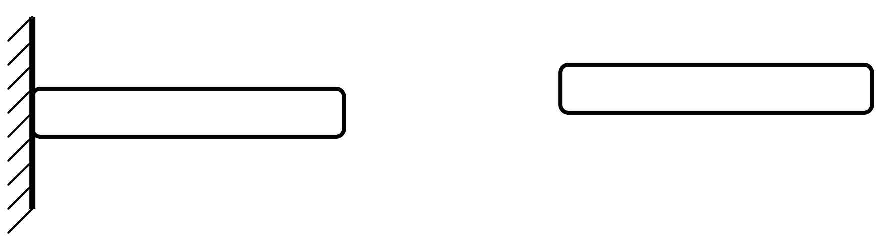
3. A car travels in a straight line towards the east for 20km then makes a turn so that it heads northward for a further 15km. Determine the total distance that the car has traveled, and the displacement at the end of the journey.

4. Draw free body diagrams for the bars in the following systems. Note that all bars used here are not considered light.

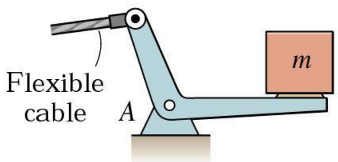
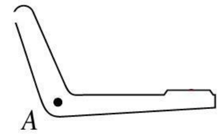
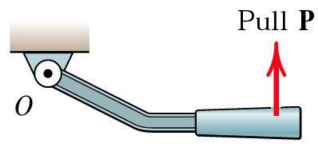
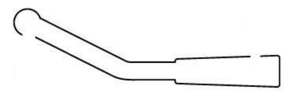
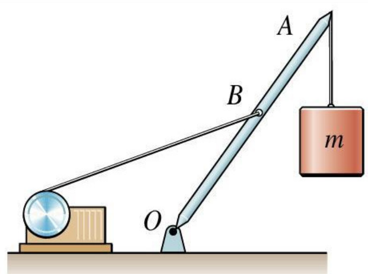
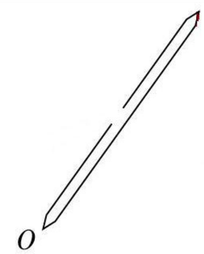
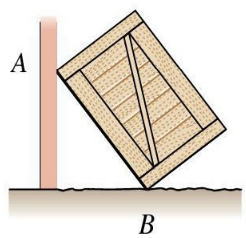
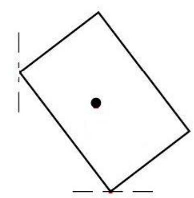
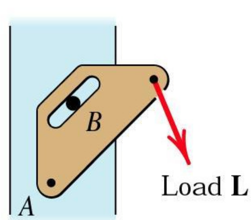
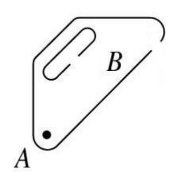
4(a)

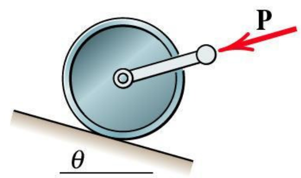
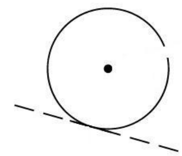
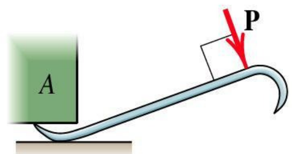
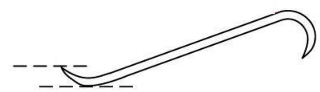
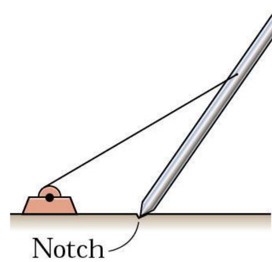
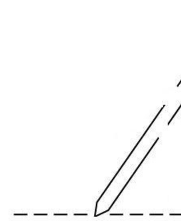
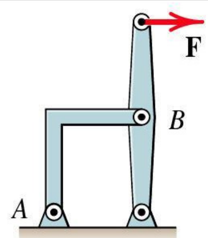
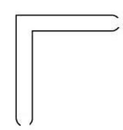
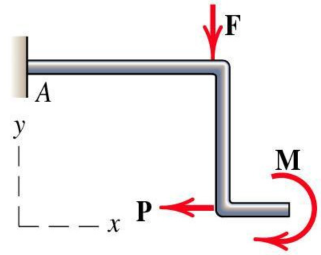
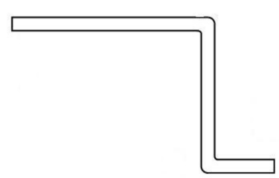


4(b)

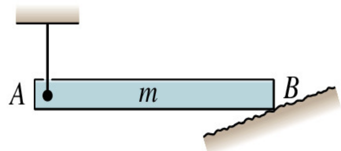


(5) Draw free body diagrams of the following systems.

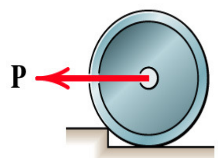
	Body	**Free body diagram**
1. Bell crank supporting mass m with pin support at A.		
2. Control lever applying torque to shaft at O.		
3. Boom OA, of negligible mass compared with mass m. Boom hinged at O and supported by hoisting cable at B.		
4. Uniform crate of mass m leaning against smooth vertical 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.		

	Body	**Free body diagram**
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.		
4. Supporting angle bracket for frame; Pin joints.		
5. Bent rod welded to support at A and subjected to two forces and couple.		

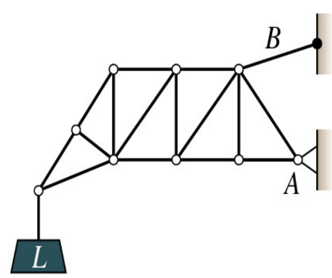
1. Uniform horizontal bar of mass m suspended by vertical cable at A and supported by rough inclined surface at B.



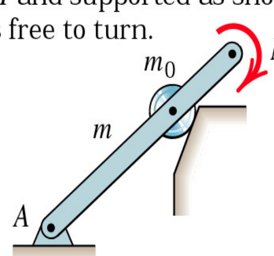
2. Wheel of mass m on verge of being rolled over curb by pull $\mathbf{P}$.



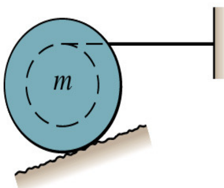
3. Loaded truss supported by pin joint at A and by cable at B.



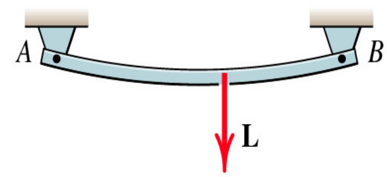
4. Uniform bar of mass m and roller of mass m_0 taken together. Subjected to couple M and supported as shown. Roller is free to turn.



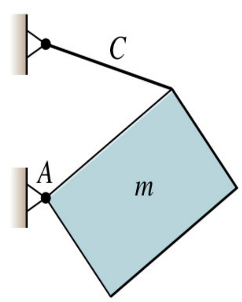
5. Uniform grooved wheel of mass m supported by a rough surface and by action of horizontal cable.



6. Bar, initially horizontal but deflected under load $\mathbf{L}$. Pinned to rigid support at each end.



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



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