Architecture Engineering Department

Engineering mechanics

Lecture 5:

EQUILIBRIUM OF A RIGID BODY & FREE-BODY DIAGRAMS

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1. Equilibrium

INTRODUCTION

In the previous lecturer, we have discussed the various methods of finding out resultant force, when a particle is acted upon by a number of forces. This resultant force will produce the same effect as produced by all the given forces. A little consideration will show, that if the resultant of a number of forces, acting on a particle is zero, the particle will be in equilibrium. Such a set of forces, whose resultant is zero, are called equilibrium forces. The force, which brings the set of forces in equilibrium is called an equilibrant. As a matter of fact, the equilibrant is equal to the resultant force in magnitude, but opposite in direction.

1. Equilibrium

PRINCIPLES OF EQUILIBRIUM

Though there are many principles of equilibrium, yet the following three are important from the subject point of view :

1. Two force principle. As per this principle, if a body in equilibrium is acted upon by two forces, then they must be equal, opposite and collinear.
2. Three force principle. As per this principle, if a body in equilibrium is acted upon by three forces, then the resultant of any two forces must be equal, opposite and collinear with the third force.
3. Four force principle. As per this principle, if a body in equilibrium is acted upon by four forces, then the resultant of any two forces must be equal, opposite and collinear with the resultant of the other two forces.

1. Equilibrium

1-For Coplanar forces system

a-concurrent coplanar forces system

$Rx=0$, $Ry=0$, $R=0$

b-non-concurrent coplanar forces system

$Rx=0$, $Ry=0$, $R=0$, $\Sigma M=0$

2-Non coplanar forces system:

a-concurrent non-coplanar forces system

$Rx=0$, $Ry=0$, $R=0$, $\Sigma M=0$

b-non-concurrent non-coplanar forces system

$Rx=0$, $Ry=0$, $R=0$, $\Sigma M=0$

1. Equilibrium

METHODS FOR THE EQUILIBRIUM OF COPLANAR FORCES

Though there are many methods of studying the equilibrium of forces, yet the following are important from the subject point of view :

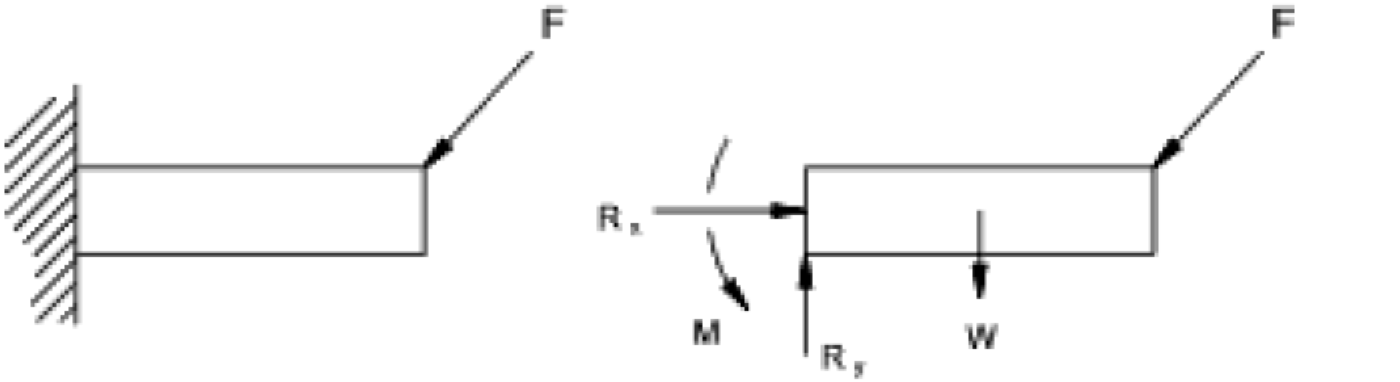
1. Analytical method.
2. Graphical method.

ANALYTICAL METHOD FOR THE EQUILIBRIUM OF COPLANAR FORCES

The equilibrium of coplanar forces may be studied, analytically, by Lami's theorem as discussed below :

1. Free Body Diagram

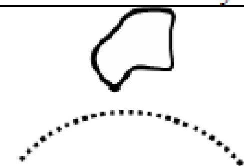
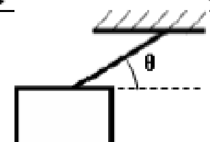
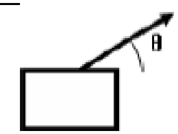
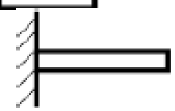
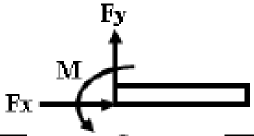
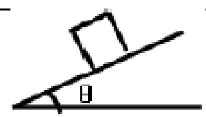
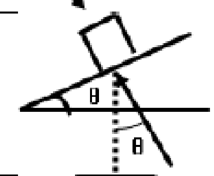
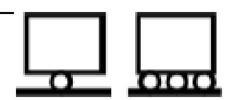
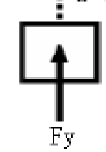
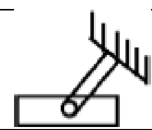
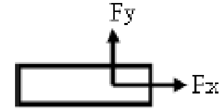
Free body diagram : is a sketch to show all the forces and reactions acting on the body For example: The free body diagram includes external forces applied to the body and external reaction forces resulting from the method of supporting the body



Free Body Diagram

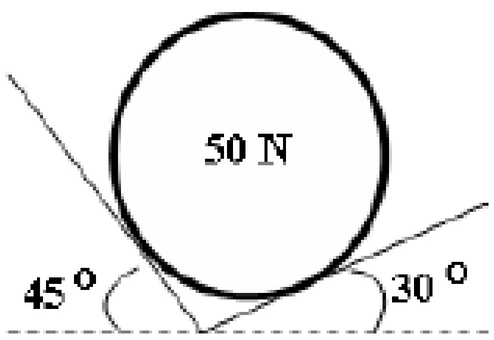
1. Free Body Diagram

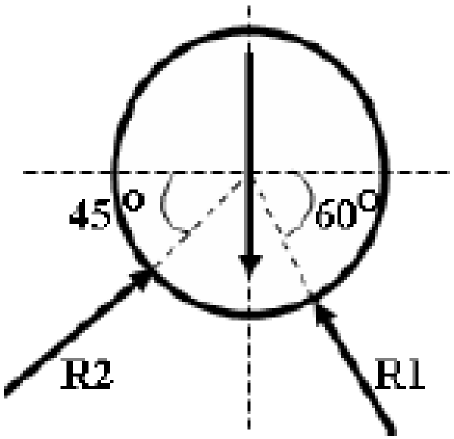
Free – body diagram and the mechanical effects

The name of the body	The effect of the body	Free-body diagram
Earth		
Flexible cables And ropes		
Cantilever beam		
Smooth surface		
Rollers , balls cylinders		
Smooth pins		

1. Free Body Diagram

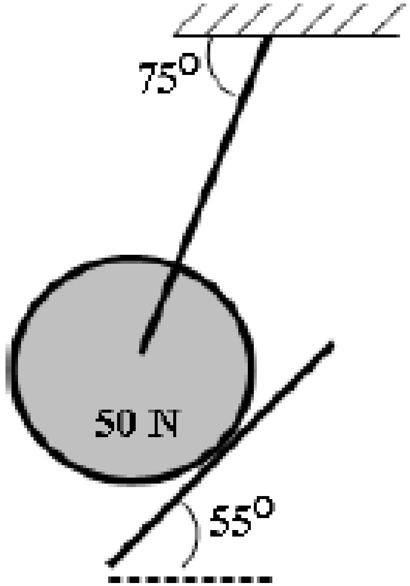
Ex1:Draw Free – body diagram for the 50 N sphere shown in fig.

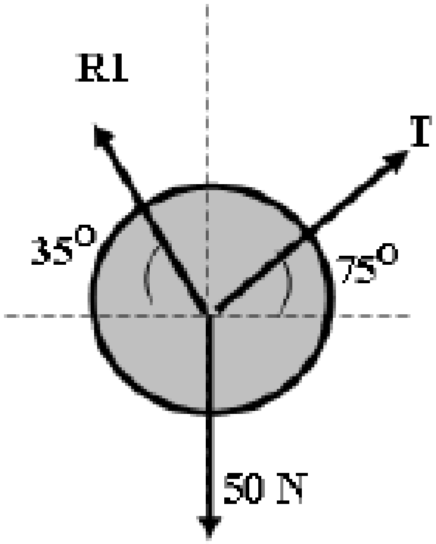




1. Free Body Diagram

Ex2:Draw Free – body diagram for the 50 N sphere shown in fig.

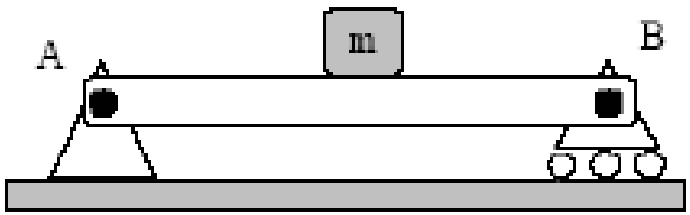




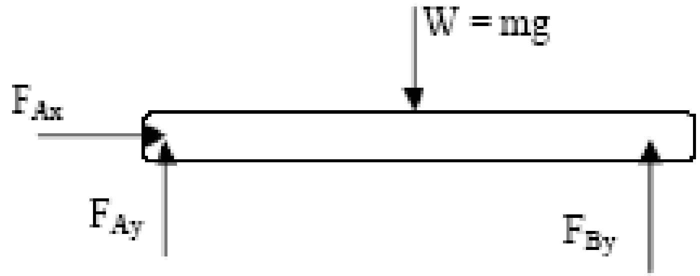
1. Free Body Diagram

Examples

Mass at mid-point on beam (length L)



Free body diagram



x-component forces
$F_{Ax} = 0$

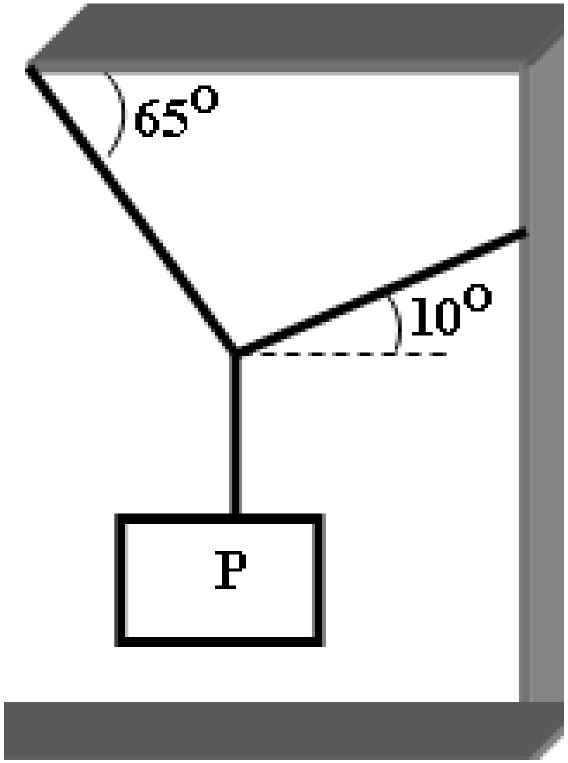
y-component forces
$F_{Ay} + F_{By} - W = 0$

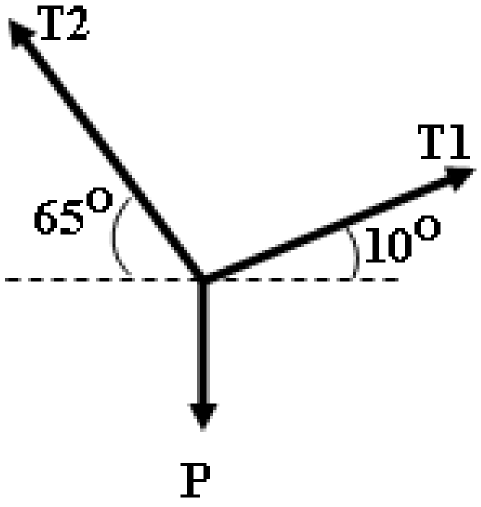
moments about mid-point (or use A or B)
$-\frac{1}{2}L\ F_{Ay} + \frac{1}{2}L\ F_{By} = 0$

Final result
$F_{Ax} = 0,$ $F_{Ay} = F_{By} = \frac{1}{2}\ W = \frac{1}{2}\ mg$

1. Free Body Diagram

Example: Draw Free body diagram for the ropes system shown in fig





1. Free Body Diagram

Example : **Draw Free body diagram for simple structure with a cable shown in fig**