Module 4.1 – Equilibrium of force system

Equilibrium of system of coplanar forces: Condition of equilibrium for concurrent forces, parallel forces and non-concurrent, non-parallel force system (general force system), Free body diagram.

Equilibrium

- A system comprising a number of rigid bodies is said to be under static equilibrium if the system as well as any part thereof does not move.
- When the net effect or the resultant of all the forces (and couples) acting on a system is zero, the system is said to be in equilibrium

- The necessary and sufficient conditions for a rigid body to be in static equilibrium are,

$$\sum F_x = 0, \quad \sum F_y = 0, \quad \sum F_z = 0$$

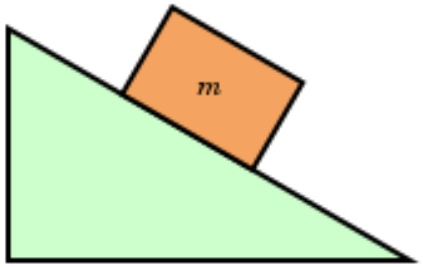
$$\sum M_x = 0, \quad \sum M_y = 0, \quad \sum M_z = 0$$

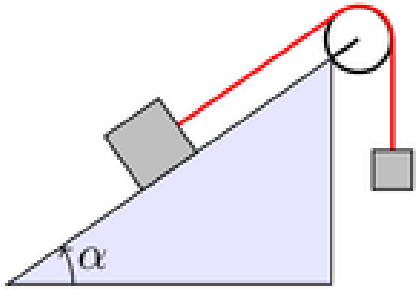
Free-body Diagram (FBD).

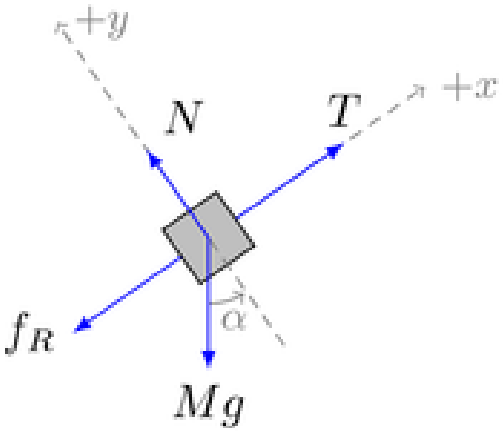
- A carefully prepared drawing or sketch that shows a “body of interest” separated from all interacting bodies is known as a free-body diagram (FBD).
- It is important that all forces acting on the body of interest be shown.
- The actual procedure for drawing a free-body diagram consists of three essential steps:-
  - ❑ Decide which body or combination of bodies is to be isolated and analysed.
  - ❑ Prepare a drawing or sketch of the outline of the isolated body selected.
  - ❑ Represent all forces, known and unknown, that are applied by other bodies to the isolated body with vectors in their correct positions.

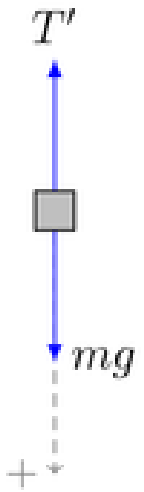
Examples of FBD

A block on a ramp

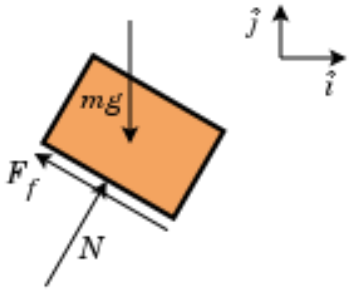






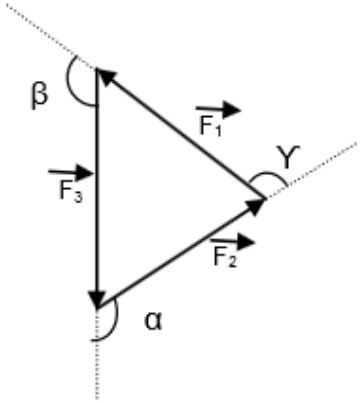


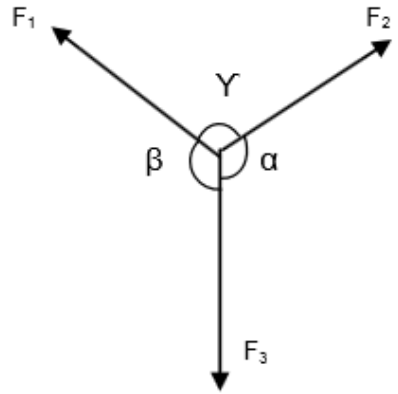
Free body diagram of just the block



Lami's Theorem

- Lami's theorem states that, if three concurrent forces act on a body keeping it in Equilibrium, then each force is proportional to the sine of the angle between the other two forces.
- Let F1, F2, F3 be the 3 concurrent forces in equilibrium as shown in fig.
- Since the forces are vectors, we can move them to form a triangle as shown in fig.

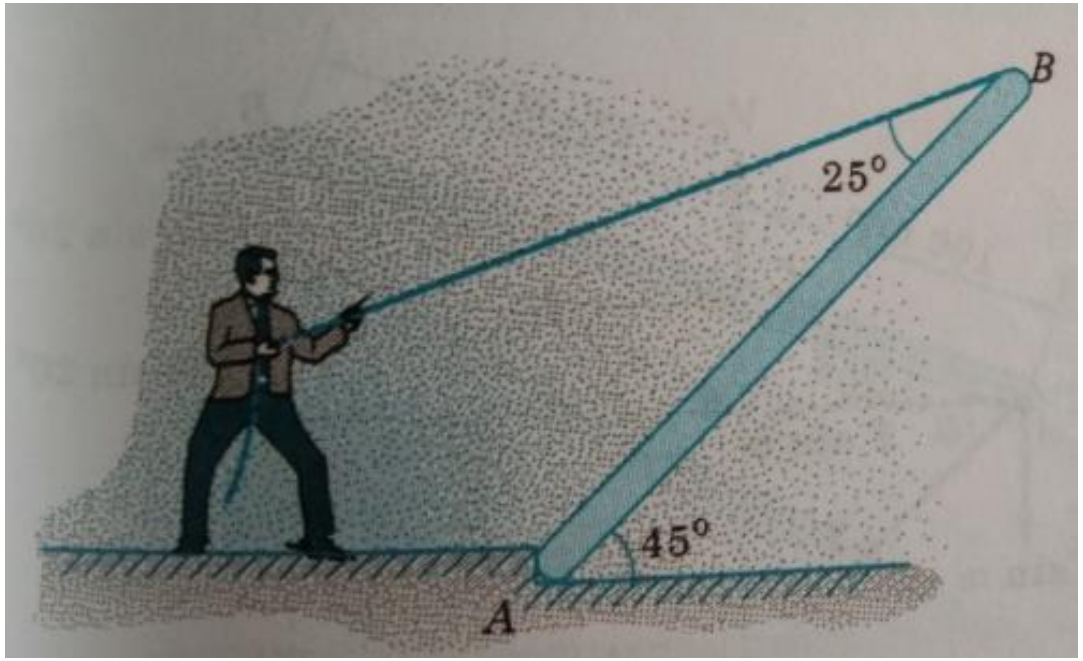




$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

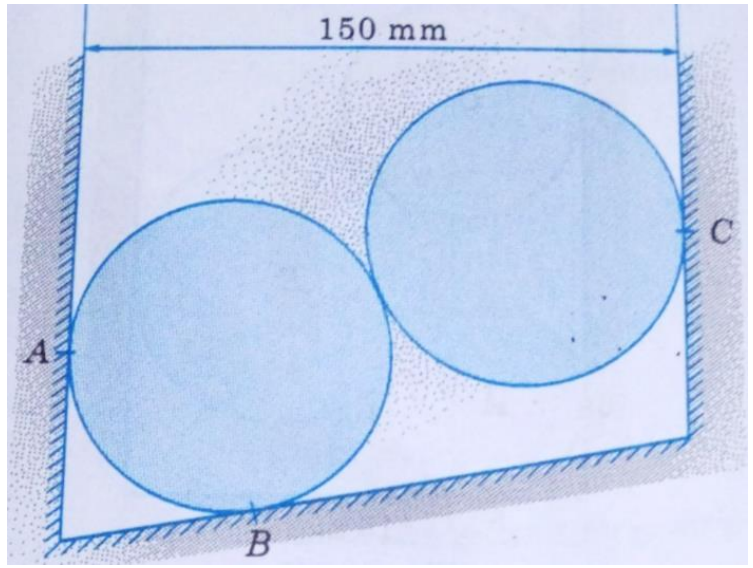
Problem No. 1

A man raises a 10 Kg joist of length 4 m by pulling on a rope. Find the tension T in the rope and the reaction at A.



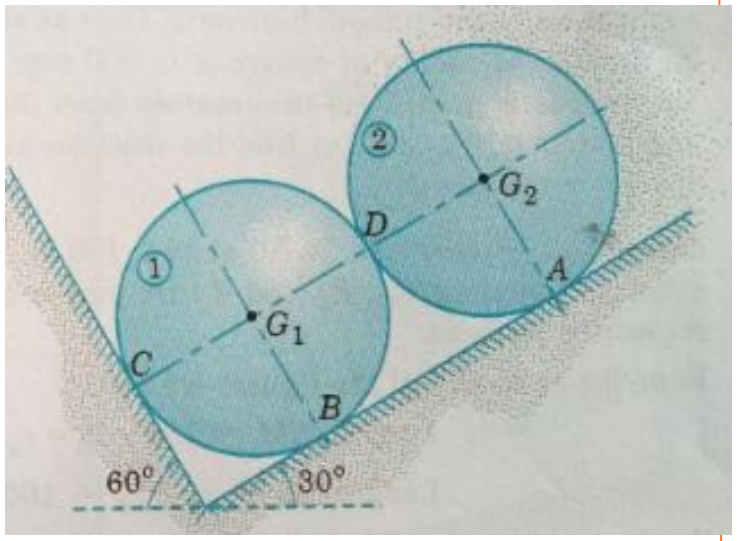
Problem No. 2

Two cylinders each of diameter 100 mm and each weighing 200 N are placed as shown in figure. Assuming that all the contact surfaces are smooth find the reactions at A, B and C.



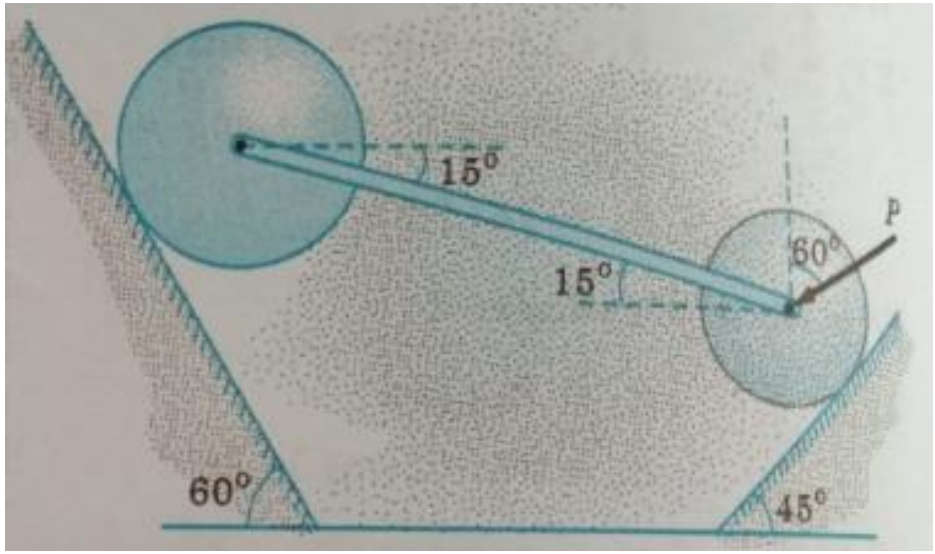
Problem No. 3

Two homogeneous cylinders of identical weight of 5000 N and radius of 0.4 m are resting against inclined wall and sloping ground as shown in figure. Assuming all surfaces are smooth, find reactions at A, B, C, and D.



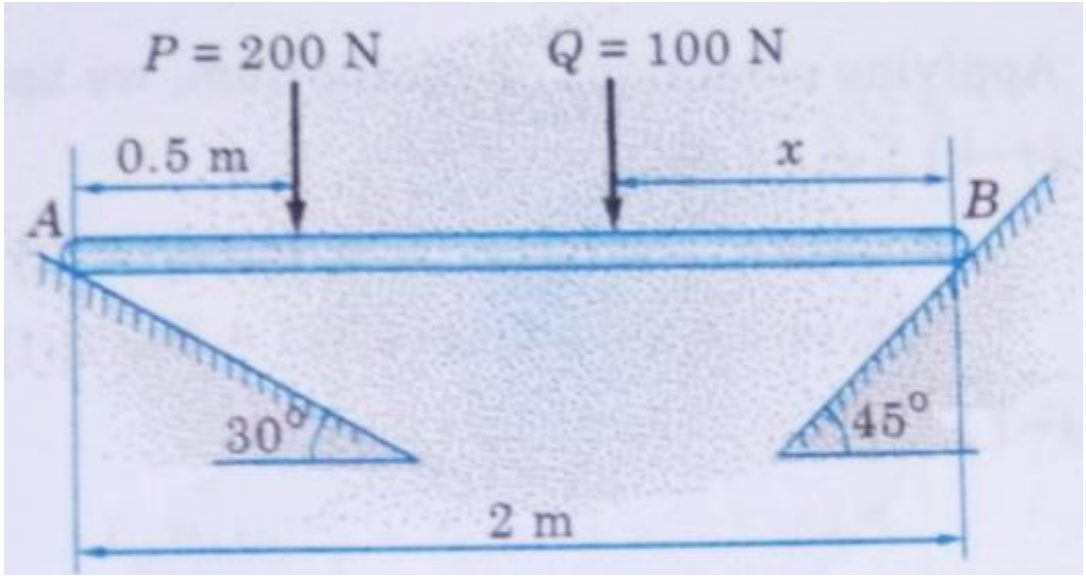
Problem No. 4

Two cylinders, A of weight 4000 N and B of weight 2000 N rest on smooth inclines as shown in figure. They are connected by a bar of negligible weight hinged to each cylinder at its geometric center by smooth pins. Find the force P to be applied such that it will hold the system in the given position.



Problem No. 5

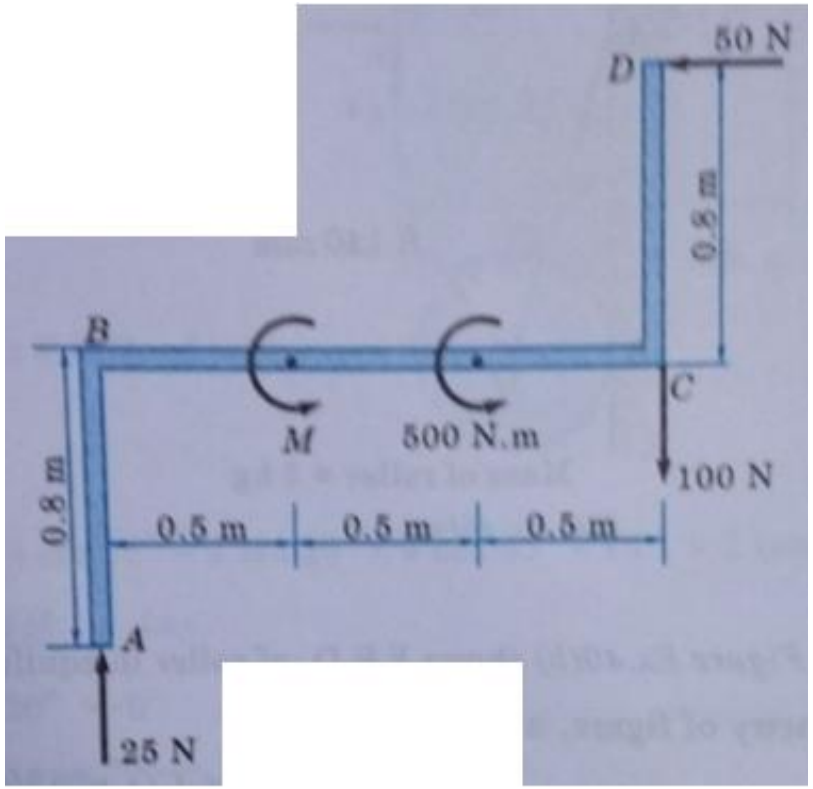
A bar 2 m long and of negligible weight rests in horizontal position on two smooth inclined planes. Determine the distance x at which the load Q = 100 N should be placed from point B to keep the bar horizontal.



Problem No. 6

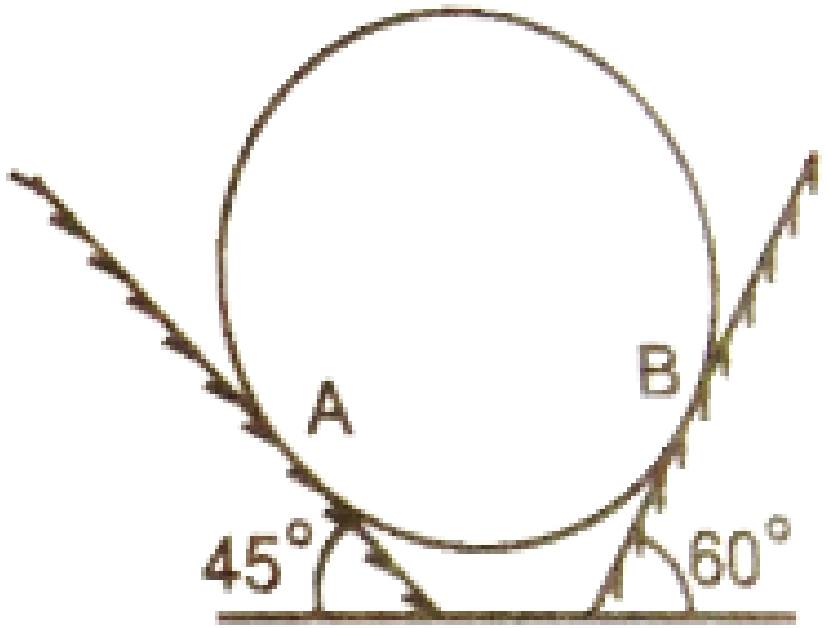
A bracket is subjected to forces and couples as shown in figure. Find the values of M and its direction if resultant is to pass through

(a) Point A
(b) Point B
(c) Point C
(d) Point D



Problem No. 7

A cylinder of 1500 N weight is resting in an unsymmetrical smooth grove as shown in figure. Determine the reactions at the points of contacts.



Problem no. 8

Three smooth spheres rest against two inclined smooth planes as shown. Determine

a) The reaction force at contact points when $\theta = 30^{\circ}$

b) The minimum angle θ for which the spheres remain in equilibrium.

Take for sphere 1 weight = 500 N and radius = 0.2 m

for spheres 2 and 3 weight = 1000 N and radius = 0.4 m