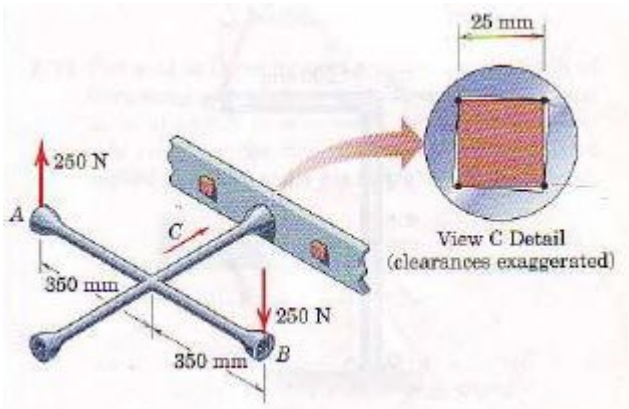
Equilibrium of non-parallel forces – Tutorial

1. A wrench is used to tighten a square-headed bolt. 250N forces are applied to the wrench, as shown.



   (a) Calculate the total torque applied to the bolt. *(175Nm)*

   (b) Calculate the size of the forces exerted on the four contact points on the 25mm square bolt-head.

   Assume the forces are perpendicular to the flats of the bolt-head.
   (3.5kN)

2. A uniform ladder 5.0m long, weighing 160N, rests against a frictionless, vertical wall with its lower end 3.0m from the wall.

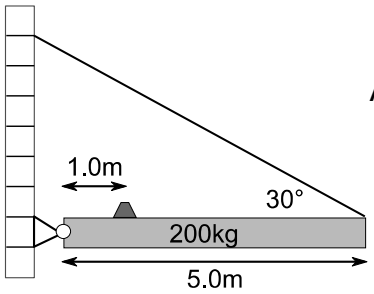
   (a) Calculate the horizontal frictional force from the ground. *(60N)*

   A man weighing 740N climbs slowly up the ladder.

   (b) Calculate the horizontal frictional force from the ground when the man has climbed:
   (i) halfway along the ladder *(337.5N)*
   (ii) 1.0m along the ladder. *(171N)*

   (c) The maximum frictional force that the ground can exert on the ladder is 360N. How far along the ladder can the man climb before the ladder starts to slip? *(2.7m)*

3. A uniform steel beam, 5.0m long, mass 200kg, is hinged to a wall and held horizontal by a steel cable connected to the end, at an angle of 30° as shown. An object of mass 60kg, resting on top of the beam, is placed a distance 1.0m from the hinge.

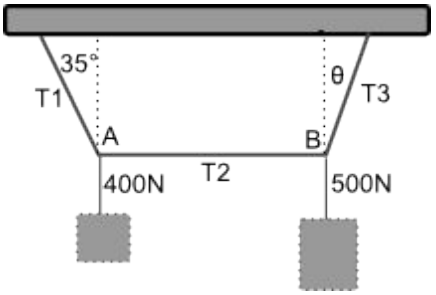


   (a) Draw a free-body diagram for the beam.

   (b) Calculate the tension in the cable. *(2.2x10^{3}N)*

   (c) Calculate the horizontal and vertical components of the force that the wall exerts on the beam. *(1.9x10^{3}N, 1.5x10^{3}N)*

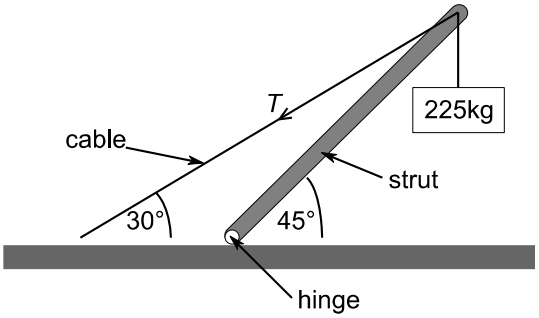
4. The system of two weights hanging from a rope is in equilibrium with the rope in the centre exactly horizontal.



   (a) By considering the equilibrium of point A, calculate tension T1, tension T2.
   (488N, 280N)

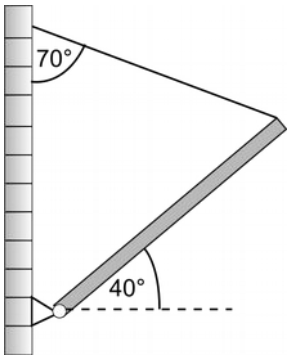
   (b) By considering the equilibrium of point B, calculate angle θ and T3. *(29°, 573N)*

5. A mass of 225 kg hangs from the end of a uniform strut whose mass is 45.0 kg. The system is in equilibrium.



   Calculate:
   (i) the tension, *T*, in the cable, *(6.63kN)*
   (ii) the horizontal and vertical force components exerted on the strut by the hinge. *(5.74kN, 5.96kN)*

6. A uniform trap door, weight 200N, is held at 40° to the horizontal by a rope at 70° to vertical.



   Calculate the tension in the rope.
   (hint: you do not need to know length of trapdoor: you could call it L)

   (88.5N)