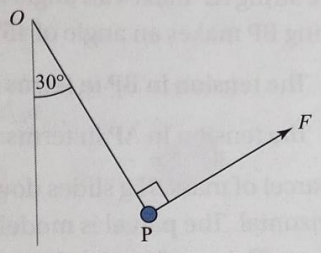
1 Four forces, **P**, **Q**, **R** and **S**, act on an object. The object is in equilibrium. $\mathbf{P} = 4\mathbf{i} + 5\mathbf{j}$, $\mathbf{Q} = \mathbf{i} - 8\mathbf{j}$ and $\mathbf{R} = 3\mathbf{i} - 12\mathbf{j}$

a Calculate **S** **[3 marks]**

b Calculate $|\mathbf{S}|$ **[2]**

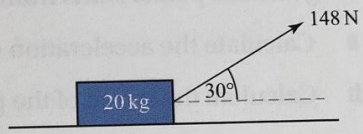
2 A particle, P, of mass 20 kg, is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point, *O*. A force, *F*, is applied to P, at right angles to the string. The system rests in equilibrium with the string at an angle of 30° to the vertical.



a Calculate the value of *F* in terms of *g* **[3]**

b Work out the tension in the string in terms of *g* **[3]**

3 A box of mass 20 kg is being pulled along a rough horizontal floor by a rope. The box is accelerating at $2\,\text{m s}^{-2}$. The tension in the rope is 148 N, and the rope makes an angle of 30° with the horizontal. The coefficient of friction between the box and the floor is μ. Modelling the rope as a light inextensible string,

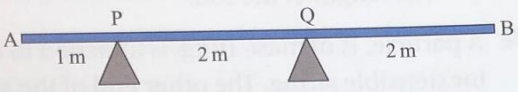


a Calculate the normal reaction between the box and the floor, **[3]**

b Calculate μ **[5]**

4 Two forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, act on a body. $\mathbf{F}_1 = \begin{pmatrix} 5 \\ -6 \end{pmatrix}$ and $\mathbf{F}_2 = \begin{pmatrix} -1 \\ -2 \end{pmatrix}$. Find the magnitude and direction of their resultant. **[6]**

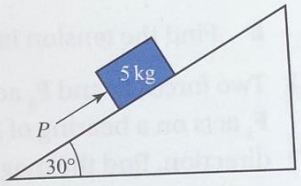
5 A uniform rod, AB, has weight 60 N and length 5 m. It rests in a horizontal position on two supports placed at P and Q, where AP = 1 m, and PQ = 2 m, as shown in the diagram. Calculate the magnitude of the force in the support



a At Q, **[3]**

b At P. **[2]**

6 A box of mass 5 kg rests in equilibrium on a rough plane. The plane is inclined at an angle of 30° to the horizontal. The coefficient of friction between the box and the plane is $\frac{\sqrt{3}}{5}$. The box is acted on by a force of *P* newtons, where *P* acts up the plane, along the line of greatest slope of the plane.



a Write an expression, in terms of *g*, for the normal reaction between the plane and the box. **[2]**

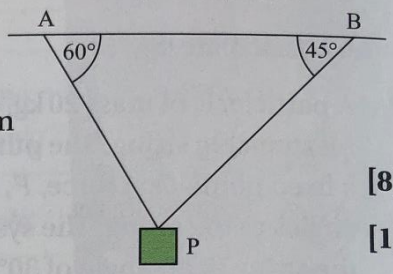
b Calculate, in terms of *g*, the range of possible values of *P* **[7]**

7 Two forces, **P** and **Q**, act on a particle. The force **P** is of magnitude 6 N and acts on a bearing of 035°. The force **Q** is of magnitude 8 N and acts on a bearing of 288°

a Draw a diagram and calculate the magnitude of the resultant of **P** and **Q** **[5]**

b Calculate the direction of the resultant of **P** and **Q** **[3]**

8 A parcel, P, of mass 5 kg, is attached to the ends of two light inextensible strings. The other ends of the strings are attached to two points, A and B, on a horizontal ceiling. The parcel hangs in equilibrium.



The string AP makes an angle of 60° with the ceiling, and the string BP makes an angle of 45° with the ceiling. Find, in exact form

a The tension in BP in terms of g **[8]**

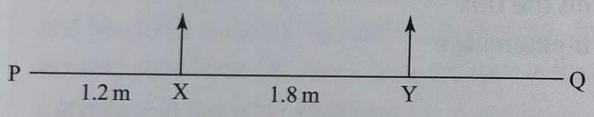
b The tension in AP in terms of g **[1]**

9 A parcel of mass 8 kg slides down a ramp which is inclined at an angle of 40° to the horizontal. The parcel is modelled as a particle and the ramp as a rough plane. The coefficient of friction between the parcel and the ramp is 0.6. The ramp is 9 metres long and the parcel starts from rest at the top of the ramp.

a Calculate the acceleration of the parcel. **[7]**

b Calculate the speed of the parcel at the bottom of the ramp. **[2]**

10

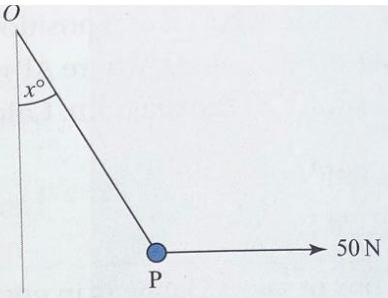


A uniform rod, PQ, has weight 200 N. It hangs in a horizontal position, supported by two light inextensible strings attached at X and Y, where PX = 1.2 m, and XY = 1.8 m as in the diagram. The tension in the string at Y is 120 N. Calculate

a The tension in the string at X, **[2]**

b The length of the rod. **[3]**

11 A particle, P, of mass 10 kg, is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point, O. A horizontal force of 50 N is applied to P, so that the system rests in equilibrium with the string at an angle of $x°$ to the vertical.



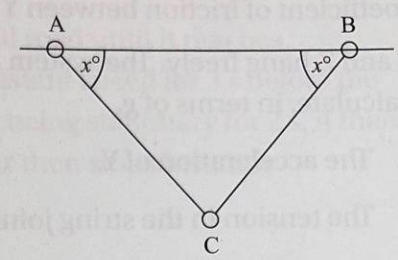
a Find the value of x **[7]**

b Find the tension in the string. **[2]**

12 Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on an object. $\mathbf{F}_1$ is of magnitude 5 N, and acts on a bearing of 041°. $\mathbf{F}_2$ acts on a bearing of 289°. Given that the resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ acts in a north-westerly direction, find the magnitude of $\mathbf{F}_2$ **[5]**

13 Two rings, A and B, each of mass 20 kg, are threaded on a rough horizontal wire. The coefficient of friction between each ring and the wire is μ. The rings are attached to the ends of a light inextensible string.

A smooth ring, C, of mass 30 kg, is threaded on the string, and hangs in equilibrium below the wire. The rings are in limiting equilibrium on the wire, on the point of slipping inwards. The angles between the strings and the wire are each $x°$, where $\tan x = \frac{3}{4}$



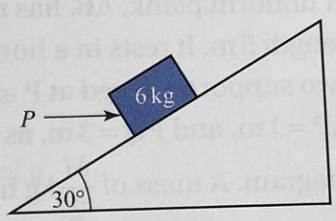
a Calculate the tension in the string in terms of g **[4]**

b Show that $\mu = \frac{4}{7}$ **[7]**

14 A box of mass 6 kg rests on a rough plane. The plane is inclined at an angle of 30° to the horizontal.

The coefficient of friction between the box and the plane is $\frac{\sqrt{3}}{2}$.

A horizontal force of P newtons acts on the parcel, and it is in limiting equilibrium, on the point of moving up the plane.



Calculate, in terms of g

a The force P **[5]**

b The normal reaction between the plane and the box, **[2]**

c The frictional force between the plane and the box. **[2]**

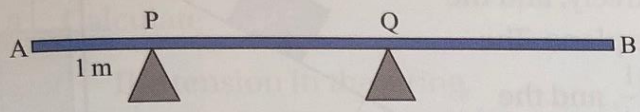
15 A particle is projected up the line of greatest slope of a rough plane with an initial velocity of 4 m s^{-1}. The plane makes an angle of 15° with the horizontal, and the coefficient of friction between the particle and the plane is $\frac{1}{10}$

a Calculate the acceleration of the particle. **[7]**

b Calculate the distance move by the particle before it comes instantaneously to rest. **[2]**

c Will the particle start to move back down the slope? Justify your answer. **[2]**

16



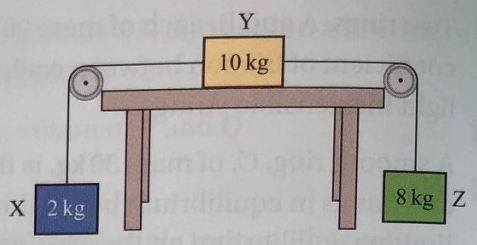
A uniform plank, AB, has mass 100 N and length 6 m. It rests in a horizontal position on two supports placed at P and Q, where AP = 1 m, as shown in the diagram. The reaction at Q is 20 N more than the reaction at P.

a Find the magnitude of the reaction at P. **[2]**

b Find the magnitude of the reaction at Q. **[1]**

c Find the distance AQ. **[3]**

17 The diagram shows three bodies, X, Y and Z, connected by two light inextensible strings, passing over smooth pulleys. Y lies on a rough horizontal table, and the coefficient of friction between Y and the table is $\frac{2}{5}$. X and Z hang freely. The system is released from rest. Calculate, in terms of g,

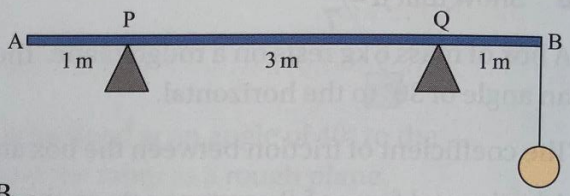


a The acceleration of Y, **[10]**

b The tension in the string joining X to Y, **[2]**

c The tension in the string joining Y to Z. **[2]**

18 A uniform plank, AB, has mass M kg and length 5 m. It rests in a horizontal position on two supports placed at P and Q, where AP = 1 m, and PQ = 3 m, as shown in the diagram. A mass of $\frac{M}{2}$ kg hangs from the rod at B.



a Find expressions, in terms of M and g, for

i The magnitude of the force in the support at Q,

ii The magnitude of the force in the support at P. **[5]**

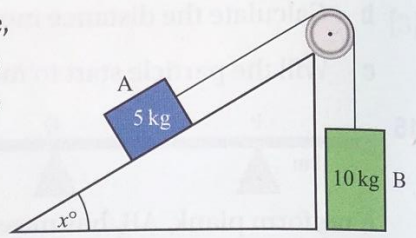
The mass at B is now replaced with a new mass of λM kg. The plank is on the point of tipping about Q.

b Find

i The value of λ

ii An expression, in terms of M and g, for the magnitude of the force in the support at Q. **[4]**

19 The diagram shows a particle, A, of mass 5 kg, on a rough plane, connected to a particle, B, of mass 10 kg, by a light inextensible string that passes over a smooth pulley. B hangs freely, and the string is parallel to the line of greatest slope of the plane. The coefficient of friction between A and the plane is $\frac{1}{4}$, and the plane is inclined at an angle of $x°$ to the horizontal, where $\sin x = \frac{3}{5}$



The particles are released from rest.

a Calculate, in terms of g, the acceleration of A. **[11]**

After B has dropped a distance of 1 metre, it hits the floor, and does not rebound.

b Calculate, in terms of g, the velocity with which B hits the floor. **[2]**

c Given that A does not hit the pulley, find the further distance travelled by A, until A is instantaneously at rest. **[4]**