4. Forces, Density and Pressure

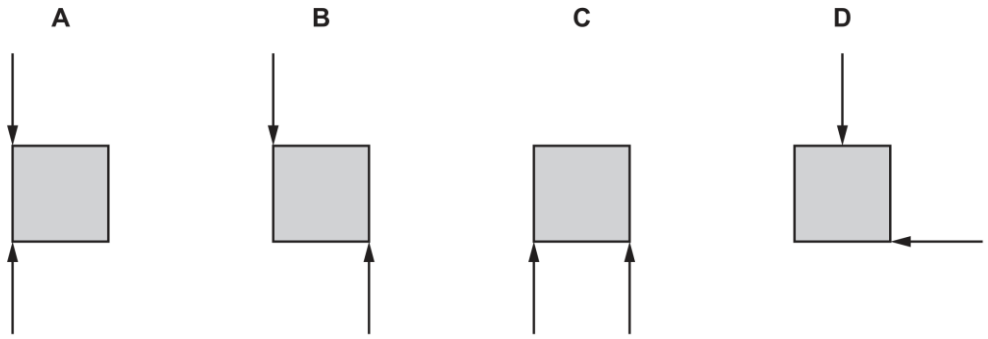
4.2 Equilibrium of forces

Paper 1

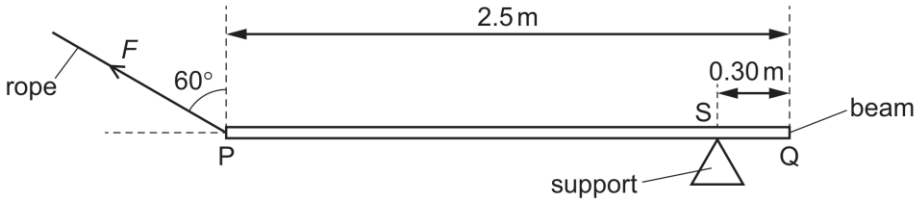
Question Paper

1 An isolated object of negligible weight is acted on by two coplanar forces of the same magnitude.

In which diagram is the object in equilibrium?



2 A uniform beam PQ rests horizontally on a support at point S.

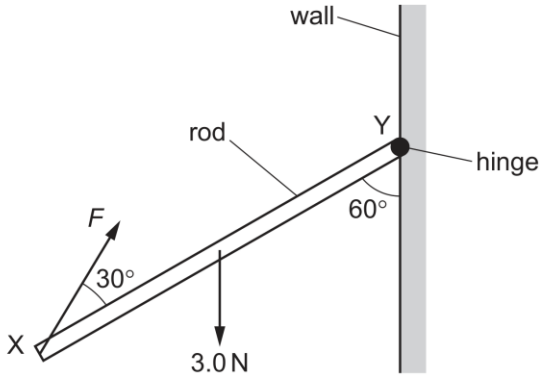


A rope is attached at one end of the beam. The rope is at an angle of 60° to the vertical and exerts a force *F*, in newtons, on the beam.

What is the moment, in N m, of the force *F* about the point S?

A 1.1*F* **B** 1.3*F* **C** 1.9*F* **D** 2.2*F*

3 The diagram shows a uniform rod, XY, that is freely hinged to a vertical wall at end Y. The rod is at an angle of 60° to the wall.



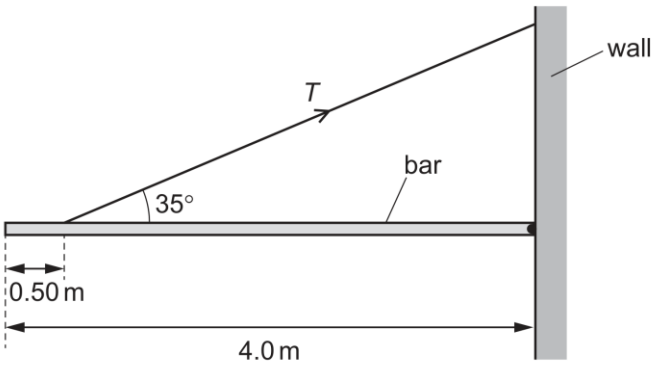
not to scale

A force *F* acts at an angle of 30° to the rod at end X. The rod has a weight of 3.0 N and is in equilibrium.

What is the magnitude of force *F*?

A 0.87 N **B** 1.5 N **C** 2.6 N **D** 5.2 N

4 A uniform bar of weight 200 N and length 4.0 m is freely hinged on a wall at one end. The bar is horizontal and is held in equilibrium by a cable attached at a distance of 0.50 m from the other end. The cable is at an angle of 35° to the horizontal.



What is the tension *T* in the cable?

A 140 N **B** 170 N **C** 200 N **D** 400 N

5 Which single condition **must** apply for an object to be in equilibrium?

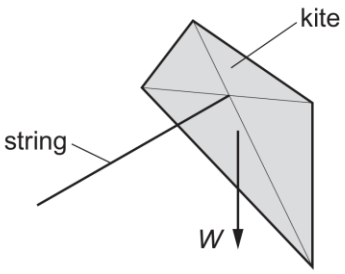
A The object has a constant non-zero acceleration.

B The object is stationary.

C There are no forces acting on the object.

D The resultant force acting on the object is zero.

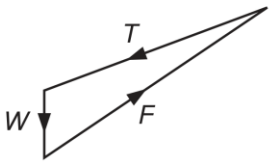
6 A kite is in equilibrium at the end of a string, as shown.



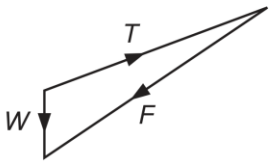
The kite has three forces acting on it: the weight *W*, the tension *T* in the string, and the force *F* from the wind.

Which vector diagram represents the forces acting on the kite?

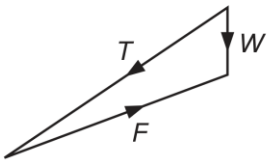
A



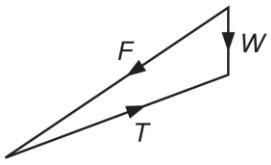
B



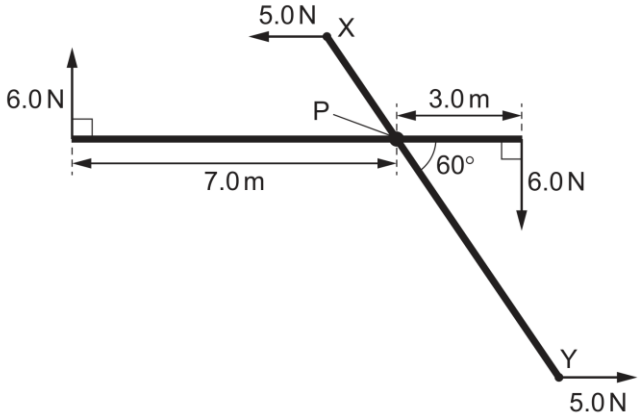
C



D



7 Four forces act about a point P, as shown.

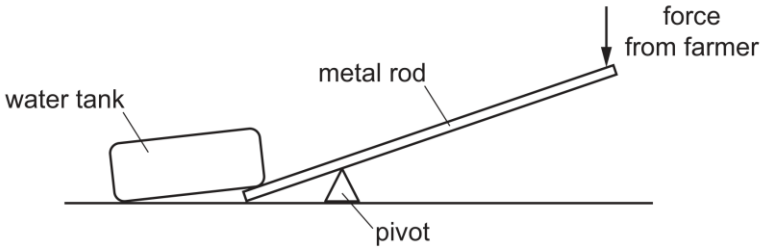


The forces act in the same plane and produce no resultant moment about point P.

What is the length XY?

A 6.9 m **B** 12 m **C** 14 m **D** 24 m

8 A farmer is trying to lift the corner of a large water tank. She uses a metal rod as a lever.



The vertical force from the farmer is constant and is always applied to the end of the rod.

Which change **must** increase the upward force on the water tank?

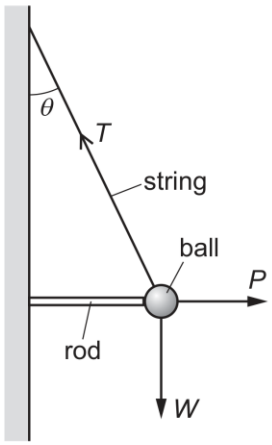
A using a longer rod and moving the pivot closer to the tank

B using a longer rod and moving the pivot further away from the tank

C using a shorter rod and moving the pivot closer to the tank

D using a shorter rod and moving the pivot further away from the tank

9 The diagram shows a ball of weight W hanging in equilibrium from a string.



The string is at an angle θ to the vertical. The tension in the string is T. The ball is held away from the wall by a horizontal force P from a metal rod.

Which relationship between the magnitudes of T, P and W is correct?

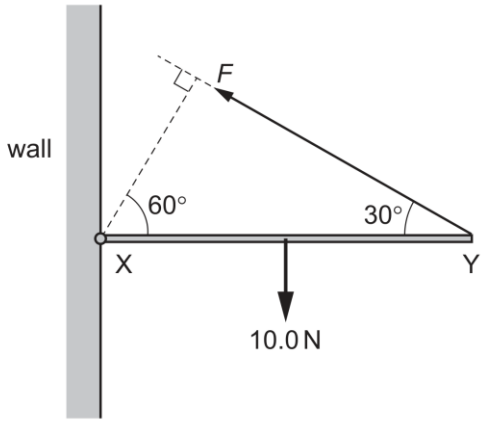
A $P = T\cos\theta$ and $W = T\sin\theta$

B $T = P + W$

C $T^2 = P^2 + W^2$

D $W = P\tan\theta$ and $W = T\cos\theta$

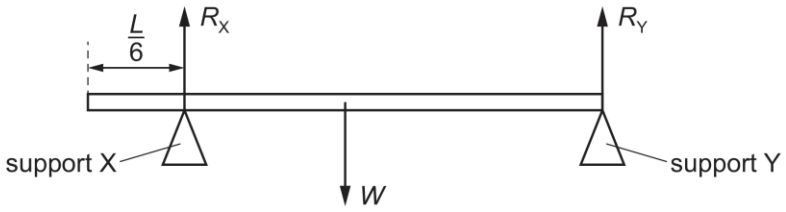
10 A uniform rod XY of weight 10.0 N is freely hinged to a wall at X. It is held horizontal by a force F acting from Y at an angle of 30° to the horizontal, as shown.



What is the value of F?

A 5.0 N **B** 8.7 N **C** 10 N **D** 20 N

11 A uniform bar of length L and weight W rests horizontally on two supports X and Y.



Support X exerts a vertical force R_X at a distance of $\frac{L}{6}$ from one end of the bar.

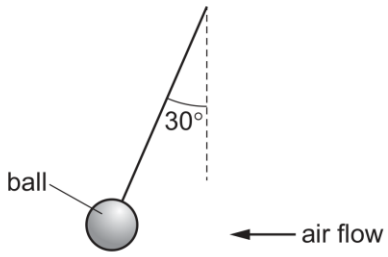
Support Y exerts a vertical force R_Y at the other end of the bar.

The bar is in equilibrium.

What is the ratio $\frac{R_X}{R_Y}$?

A $\frac{3}{2}$ **B** $\frac{2}{3}$ **C** $\frac{3}{5}$ **D** $\frac{2}{5}$

12 The diagram shows an experiment to determine the force exerted on a ball by a horizontal air flow.



The ball is suspended by a light string and weighs 0.15 N.

The deflection of the string from vertical is 30°. The ball is in equilibrium.

What is the force on the ball from the air flow?

A 0.075 N **B** 0.087 N **C** 0.26 N **D** 0.30 N

13 When **must** an object be in equilibrium?

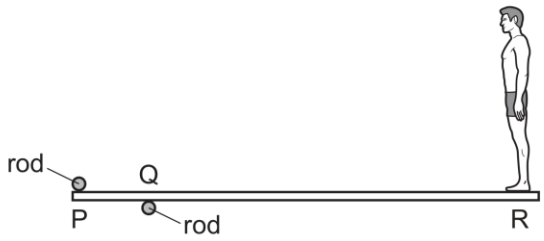
A when no resultant force acts on the object

B when no resultant force and no resultant torque act on the object

C when no resultant torque acts on the object

D when the upward force on the object is equal and opposite to its weight

14 A uniform diving board is held by two fixed rods at points P and Q. A person stands at end R of the diving board, as shown.

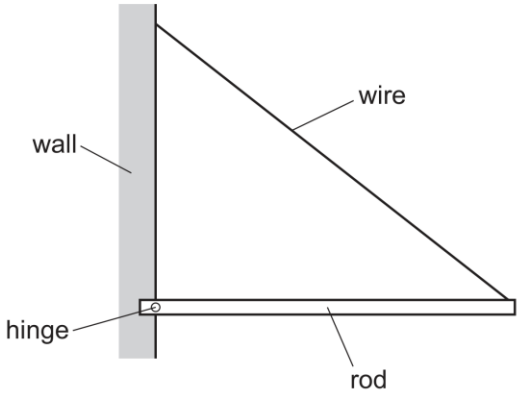


The forces exerted by the rods on the board are vertical. The board remains in equilibrium as the person slowly moves towards point Q from end R.

Which row describes the changes to the magnitudes of the forces exerted by the rods on the board?

	force at P	force at Q
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

15 A uniform rod is attached by a hinge at one end to a wall. The other end of the rod is supported by a wire so that the rod is horizontal and in equilibrium.

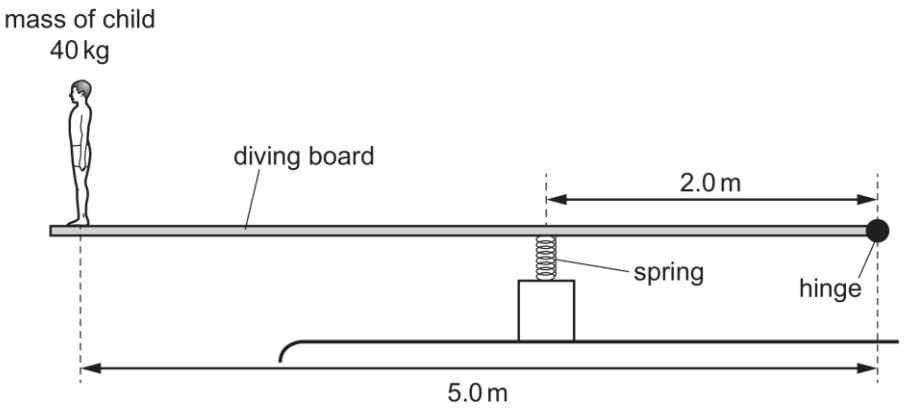


Which arrow shows the direction of the force on the rod from the hinge?

A **B** **C** **D**



16 A diving board of length 5.0 m is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.



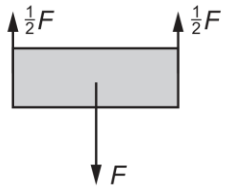
What is the extra compression of the spring caused by the child standing on the end of the board?

A 1.0 cm **B** 1.6 cm **C** 9.8 cm **D** 16 cm

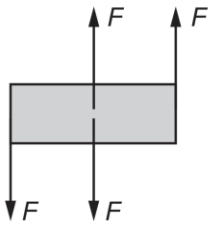
17 Forces are applied to a rigid object. The forces all act in the same plane.

In which diagram is the object in equilibrium?

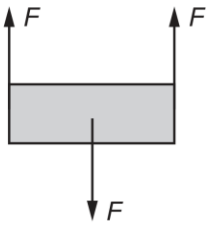
A



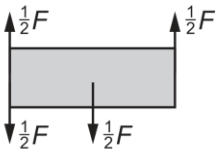
B



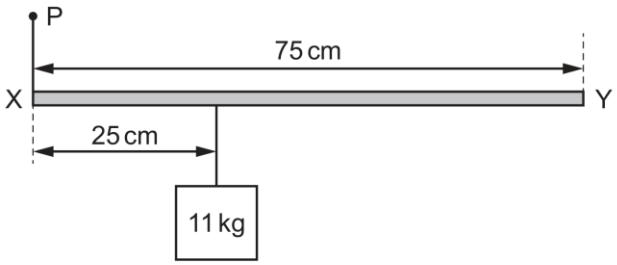
C



D



18 A rigid rod XY has negligible mass and length 75 cm. The rod is suspended from a fixed point P by a string attached to end X. An object of mass 11 kg is suspended by a string that is attached to the rod at a distance of 25 cm from end X, as shown.

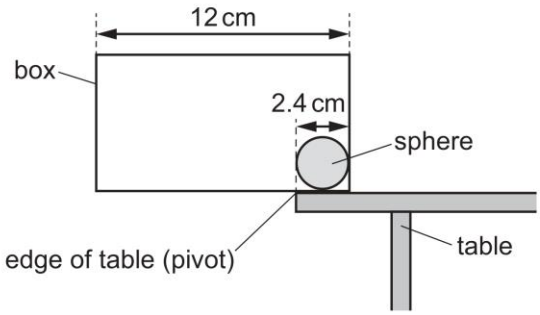


Which vertically upward force acting on end Y of the rod would hold the rod horizontally in equilibrium?

A 3.7 N **B** 33 N **C** 36 N **D** 320 N

19 A box of length 12 cm and weight 0.43 N is placed on a horizontal table, with the greater part of its length overhanging the edge of the table. The edge of the table acts as a pivot. The centre of gravity of the box is at its geometric centre.

To balance the box, a uniform sphere of diameter 2.4 cm is placed inside the box, touching one end, as shown.

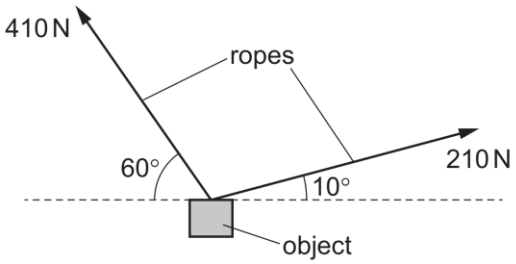


Assume that the forces acting on the box are in the plane of the diagram.

What is the minimum mass of the sphere that is needed to maintain the system in equilibrium?

A 0.066 kg **B** 0.13 kg **C** 0.22 kg **D** 1.3 kg

20 An object is suspended by two ropes. One rope has a tension of 410 N at an angle of 60° to the horizontal. The other rope has a tension of 210 N at an angle of 10° to the horizontal.



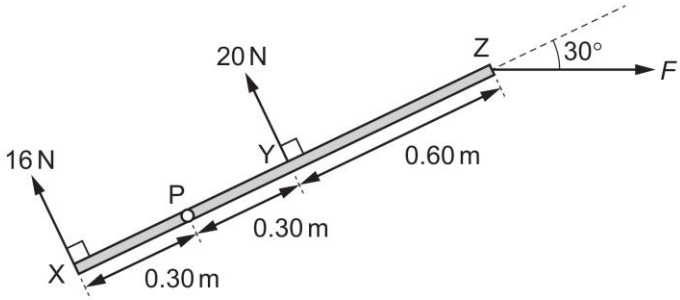
The object is in equilibrium.

What is the mass of the object?

A 40 kg **B** 42 kg **C** 390 kg **D** 410 kg

21 A uniform rigid bar XZ with negligible mass is 1.20 m long. The bar is pivoted at point P. Three coplanar forces act on the bar as shown. Forces of 16 N and 20 N act perpendicularly to the bar at points X and Y respectively. Force *F* acts at point Z at an angle of 30° to the axis of the bar.

The distances along the bar of the pivot and of the forces are shown.

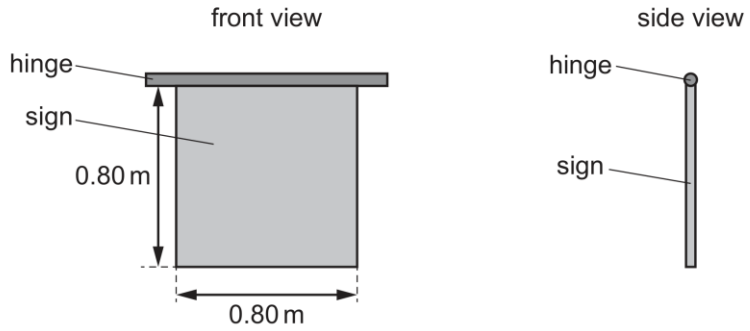


The bar experiences a resultant moment about P of 6.0 N m in a clockwise direction.

What is the magnitude of *F*?

A 9.2 N **B** 11 N **C** 16 N **D** 24 N

22 A uniform square sign of weight 40 N is suspended vertically from its top edge by a horizontal hinge, as shown.



The hinge is not frictionless. When the sign is displaced from the vertical by an external force and then released, it does not return to the vertical position.

The maximum torque exerted by the hinge on the sign is 6.0 N m. The sign is displaced by 90° so that it is horizontal and then gradually released.

At which angle to the vertical does the sign hang after release?

A 11° **B** 22° **C** 68° **D** 79°

23 A statement about the principle of moments with some words omitted is shown.

> 'For an object in a state of rotational equilibrium, the sum of the clockwise moments about any point is equal to the sum of the anticlockwise moments about ..... .'

Which words correctly complete the statement?

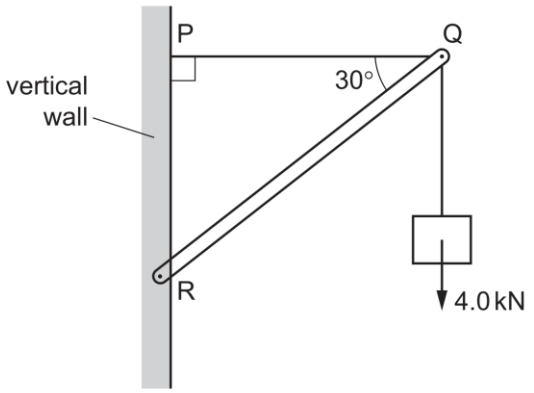
A any point

B the centre of gravity of the object

C the pivot

D the same point

24 A beam QR is held in position by a wire PQ. The structure is used to form a crane supporting a stationary load of 4.0 kN, as shown.



What is the force exerted by the beam QR on point Q?

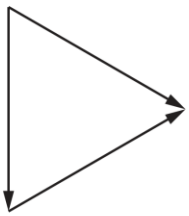
A 4.0 kN **B** 4.6 kN **C** 6.9 kN **D** 8.0 kN

25 Four combinations of vectors are shown, each representing all the forces acting on an object. The forces all act in the same plane.

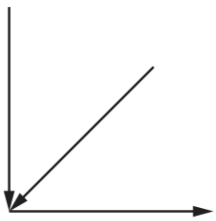
The object is in equilibrium.

Which combination of vectors could represent the forces acting on the object?

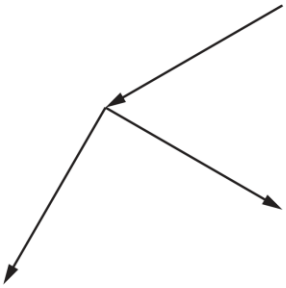
A



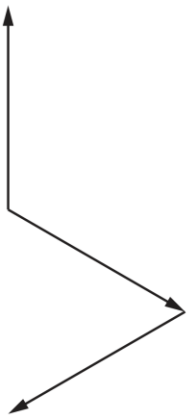
B



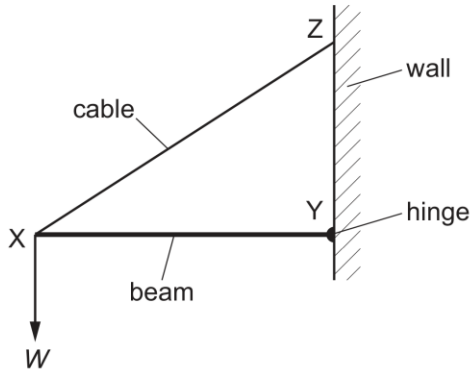
C



D



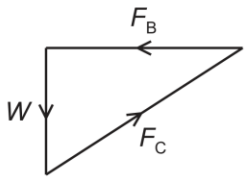
26 A thin horizontal beam XY is freely hinged at point Y to a vertical wall. The beam is held stationary by a cable XZ which is attached to the wall at point Z.



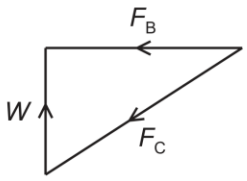
The beam supports a weight W at point X. The forces in the cable and the beam are F_C and F_B respectively.

Which vector triangle represents the forces acting on point X?

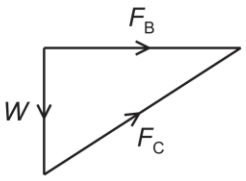
A



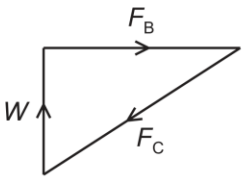
B



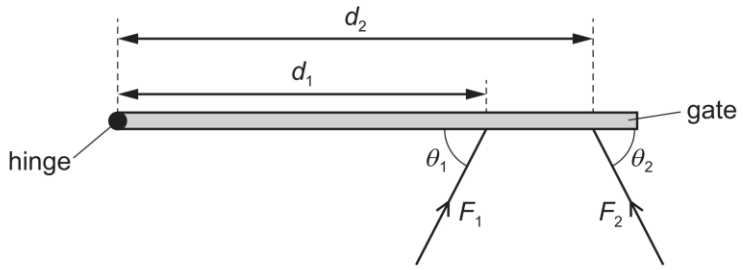
C



D



27 Two people push a vertical gate to open it. The forces exerted by the people on the gate are shown.



One person is distance d_1 from the gate's hinge and pushes with horizontal force F_1 at angle θ_1 to the gate.

The other person is at distance d_2 from the hinge and pushes with horizontal force F_2 at an angle θ_2 to the gate.

What is the total moment about the hinge due to forces F_1 and F_2?

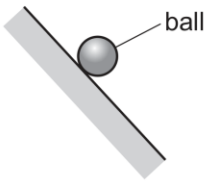
A $(d_1 \times F_1 \cos \theta_1) + (d_2 \times F_2 \cos \theta_2)$

B $(d_1 \times F_1 \sin \theta_1) + (d_2 \times F_2 \sin \theta_2)$

C $(d_1 \times F_1 \cos \theta_1) - (d_2 \times F_2 \cos \theta_2)$

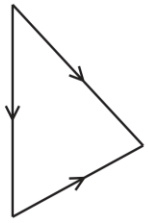
D $(d_1 \times F_1 \sin \theta_1) - (d_2 \times F_2 \sin \theta_2)$

28 A ball is rolling down a slope at a constant speed. The three forces acting on the ball are its weight, the contact force normal to the slope and friction.

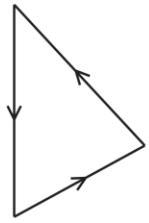


Which diagram could represent these three forces?

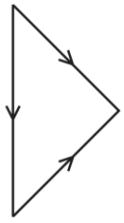
A



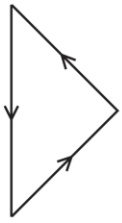
B



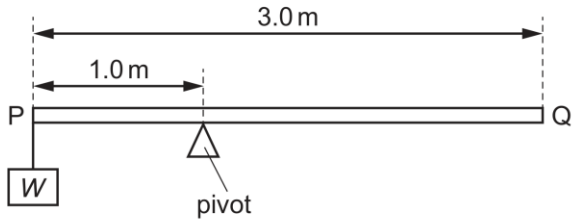
C



D



29 The diagram shows a uniform beam PQ. The length of the beam is 3.0 m and its weight is 50 N. The beam is supported on a pivot 1.0 m from end P. A load of weight *W* is hung from end P. The beam is in equilibrium.



What is the value of *W*?

A 25 N **B** 50 N **C** 75 N **D** 100 N

30 In a high-wire circus act, a man of mass 85 kg is standing at rest at the midpoint of the wire.

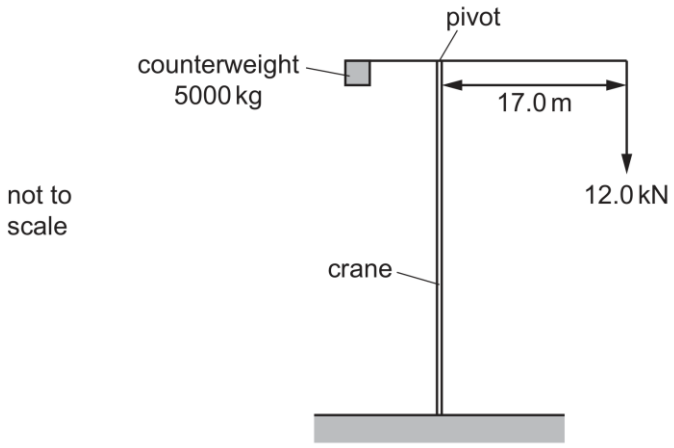


The wire on either side of the man is at an angle of 20° to the horizontal.

What is the tension *T* in the wire?

A 0.44 kN **B** 0.89 kN **C** 1.2 kN **D** 2.4 kN

31 A crane uses a counterweight to stop it from toppling over when lifting a load, as shown.



The counterweight has a mass of 5000 kg. The crane is required to lift a load of 12.0 kN and the horizontal distance from the pivot to the load is 17.0 m.

How far from the pivot should the centre of gravity of the counterweight be positioned in order to keep the crane in equilibrium?

A 0.0408 m **B** 0.240 m **C** 4.16 m **D** 40.8 m

32 Three parallel forces act on an object. As a result of these forces, the object is in equilibrium.

What **must** be correct for these forces?

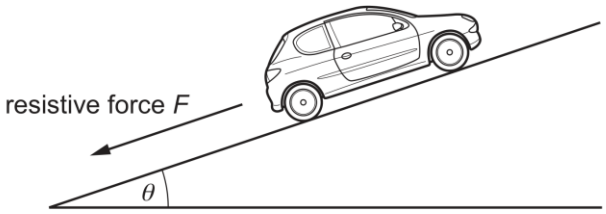
A They all act along the same line.

B They all have the same magnitude.

C They do **not** all act along the same line.

D They do **not** all have the same magnitude.

33 A car of mass *m* travels at constant speed up a slope at an angle θ to the horizontal, as shown in the diagram. Air resistance and friction provide a resistive force *F.* The acceleration of free fall is *g*.



What is the force needed to propel the car at this constant speed?

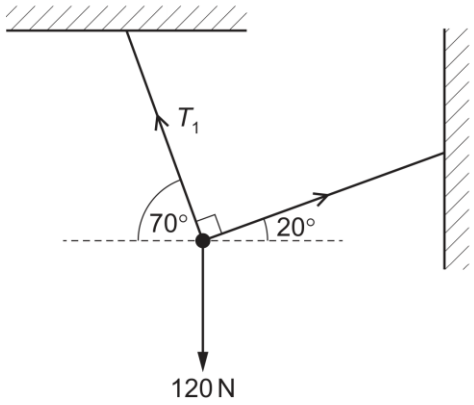
A $mg \cos \theta$

B $mg \sin \theta$

C $mg \cos \theta + F$

D $mg \sin \theta + F$

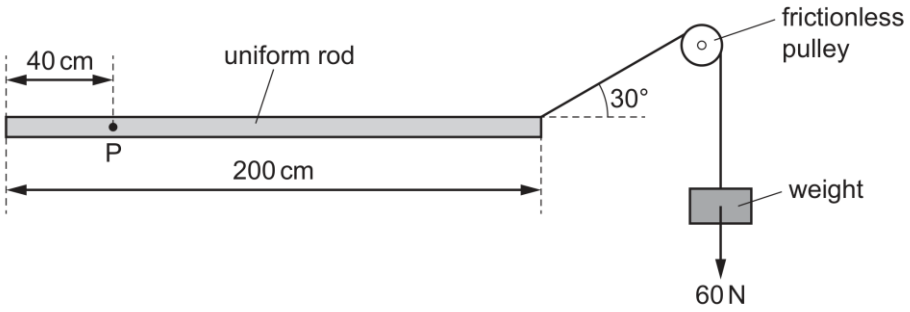
34 An object of weight 120 N is supported in equilibrium by two strings as shown.



What is the tension T_1 in the left-hand string?

A 41 N **B** 77 N **C** 113 N **D** 128 N

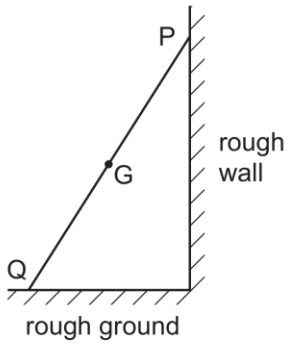
35 A uniform rod of length 200 cm is freely pivoted at point P. The rod is held horizontally in equilibrium by a 60 N weight that is attached to the rod by a string passing over a frictionless pulley.



What is the weight of the rod?

A 30 N **B** 60 N **C** 80 N **D** 140 N

36 A ladder rests in equilibrium on rough ground against a rough wall.



The weight *W* of the ladder acts through the centre of gravity G. Forces also act on the ladder at P and at Q. These forces are *P* and *Q* respectively.

Which vector triangle represents the forces on the ladder?

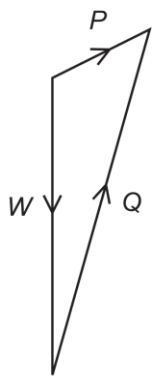
A



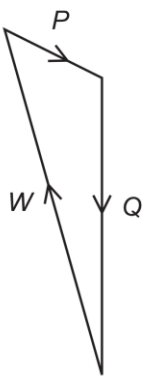
B



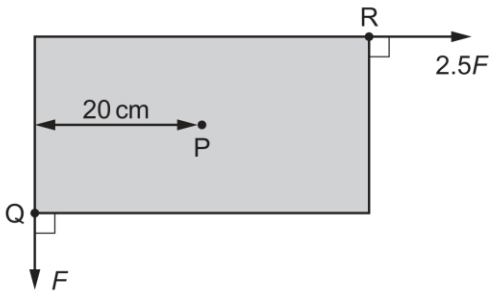
C



D



37 A uniform rectangular board is supported by a frictionless pivot at its centre point P.



Two forces act in the plane of the board. Force F acts at corner Q and force $2.5F$ acts at corner R. The perpendicular distance between the line of action of force F and point P is 20 cm. The board is in equilibrium.

What is the area of the board?

A 160 cm^2 **B** 320 cm^2 **C** 640 cm^2 **D** 1600 cm^2