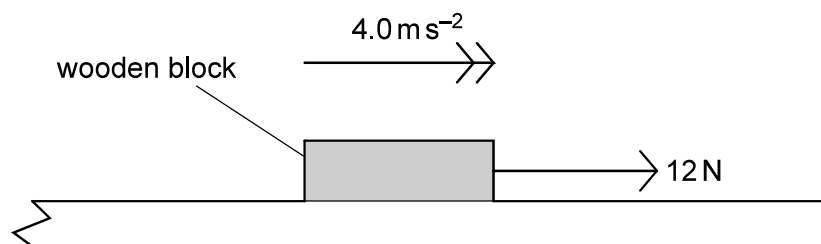


- 1 A wooden block of mass 0.60 kg is on a rough horizontal surface. A force of 12 N is applied to the block and it accelerates at 4.0 m s^{-2} .

9702/1/M/J/02/Q10



What is the magnitude of the frictional force acting on the block?

- A 2.4 N
 B 9.6 N
 C 14 N
 D 16 N
- 2 A submarine descends vertically at constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight.

9702/1/M/J/02/Q12

Which relationship between their magnitudes is correct?

- A weight < drag
 B weight = drag
 C weight < upthrust
 D weight > upthrust
- 3 A cylindrical block of wood has a cross-sectional area A and weight W . It is totally immersed in water with its axis vertical. The block experiences pressures p_t and p_b at its top and bottom surfaces respectively.

9702/1/M/J/02/Q14

Which of the following expressions is equal to the upthrust on the block?

- A $(p_b - p_t)A + W$
 B $(p_b - p_t)$
 C $(p_b - p_t)A$
 D $(p_b - p_t)A - W$
- 4 A horizontal force of 90 N is used to push a box across a horizontal floor. The frictional force on the box is 50 N .

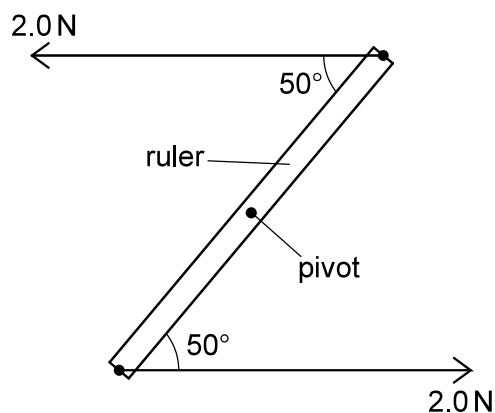
9702 01 04/Q16

What is the gain in kinetic energy of the box when it is moved through a distance of 6.0 m ?

- A 240 B 300 C 540 D 840

- 5 A ruler of length 0.30 m is pivoted at its centre. Equal and opposite forces of magnitude 2.0 N are applied to the ends of the ruler, creating a couple as shown.

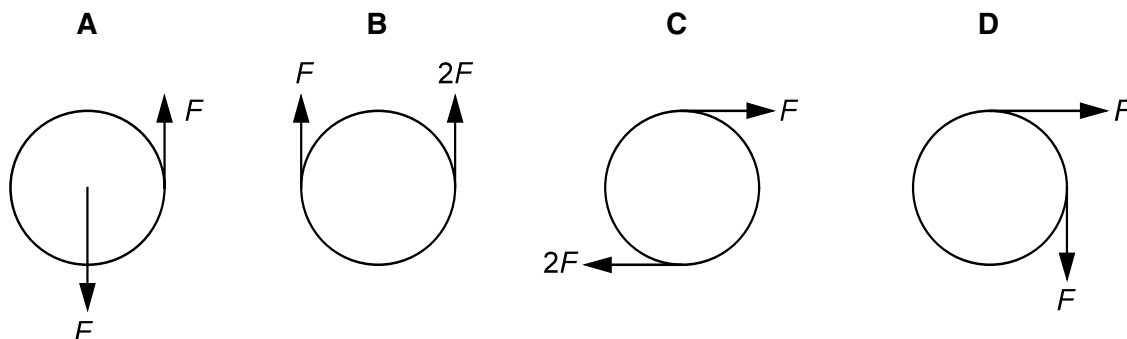
9702/1/M/J/02/Q13



What is the magnitude of the torque of the couple on the ruler when it is in the position shown?

- A** 0.23 Nm **B** 0.39 Nm **C** 0.46 Nm **D** 0.60 Nm

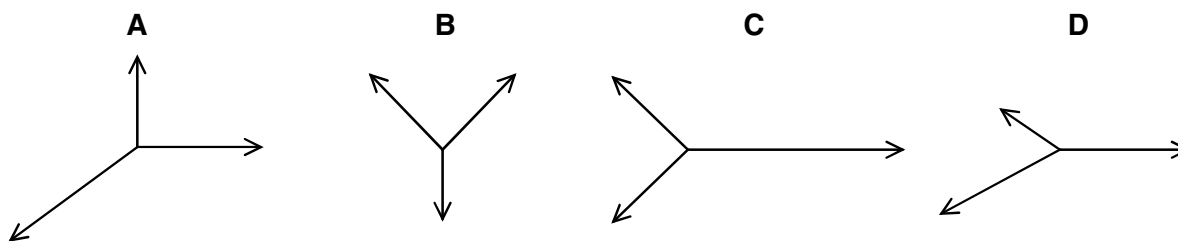
- 6 Which of the following pairs of forces, acting on a circular object, constitutes a couple? 9702/1/O/N/02/Q13



- 7 The diagrams represent systems of coplanar forces acting at a point. The lengths of the force vectors represent the magnitudes of the forces.

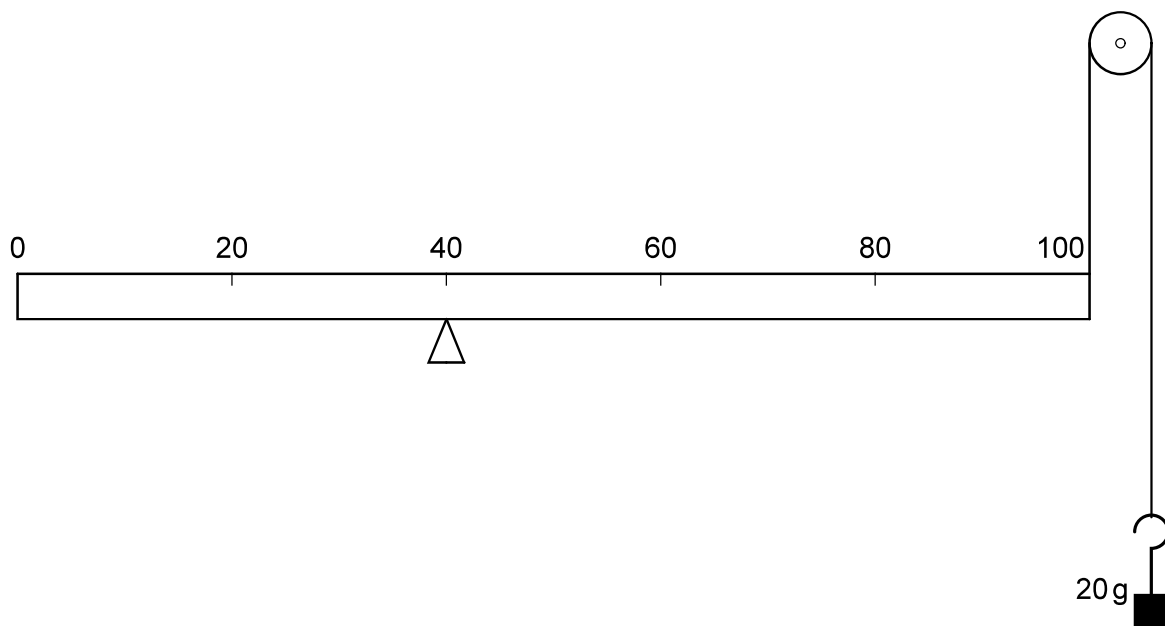
9702/1/O/N/02/Q15

Which system of forces is in equilibrium?



- 8 A uniform metre rule of mass 100 g is supported by a knife-edge at the 40 cm mark and a string at the 100 cm mark. The string passes round a frictionless pulley and carries a mass of 20 g as shown in the diagram.

9702/1/O/N/02/Q14

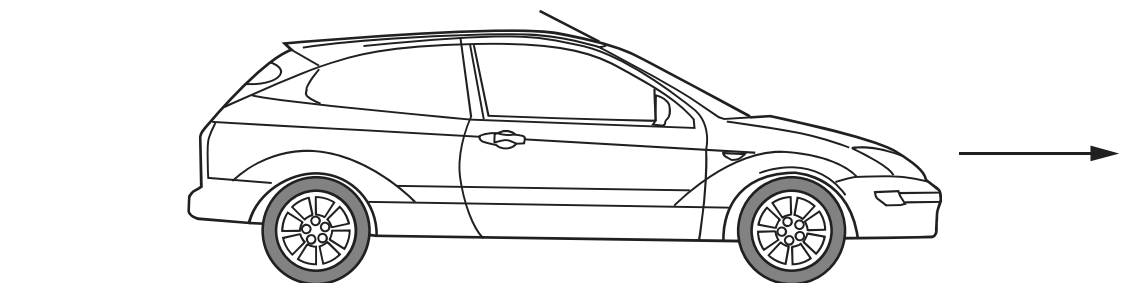


At which mark on the rule must a 50 g mass be suspended so that the rule balances?

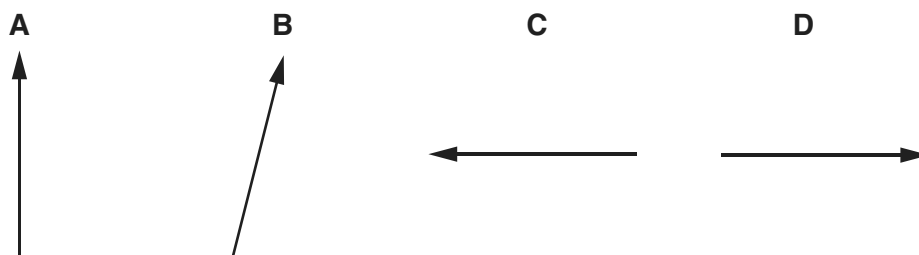
- A** 4 cm **B** 36 cm **C** 44 cm **D** 96 cm

- 9 A car with front-wheel drive accelerates in the direction shown.

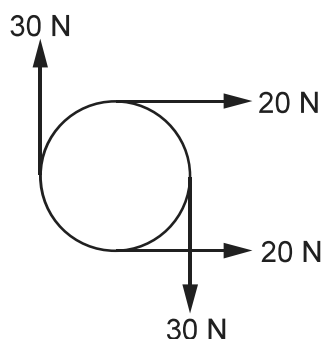
9702/01/M/J/03/Q11



Which diagram best shows the direction of the total force exerted by the road on the front wheels?



- 10 The diagram shows four forces applied to a circular object.

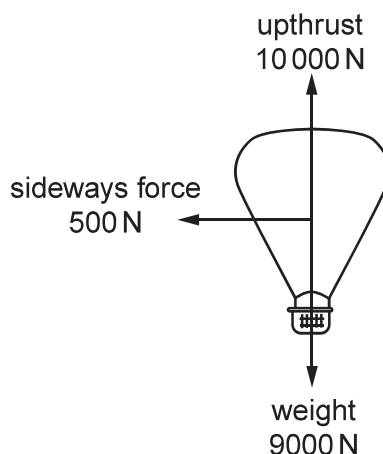


Which of the following describes the resultant force and resultant torque on the object?

	resultant force	resultant torque
A	zero	zero
B	zero	non-zero
C	non-zero	zero
D	non-zero	non-zero

- 11 A balloon is acted upon by three forces, weight, upthrust and sideways force due to the wind, as shown in the diagram.

9702/01/M/J/03/Q14



What is the vertical component of the resultant force on the balloon?

- A** 500 N **B** 1000 N **C** 10 000 N **D** 10 500 N

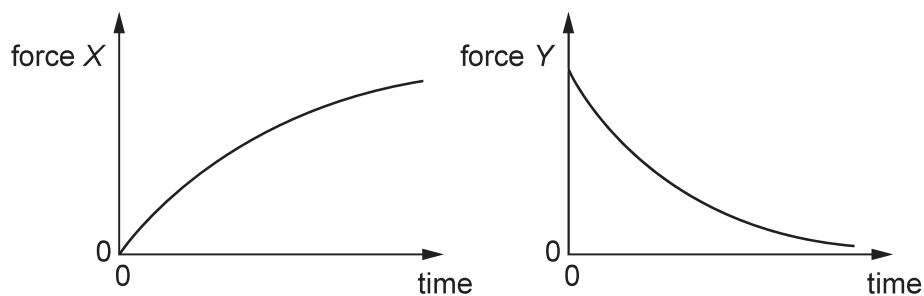
- 12 A steel wire is rotated vertically onto a horizontal metal plate. The wire is then rotated at a speed such that it is at a steady state. The wire is then rotated at a speed such that it is at a steady state. 9702 11 11/Q14

the expression for the value of $\frac{1}{u}$

- A** $\frac{1}{2^2}$ **B** $\frac{1}{2}$ **C** $\frac{1}{\sqrt{2}}$ **D** $1 - \frac{1}{\sqrt{2}}$

- 13 A ball falls from rest through air and eventually reaches a constant velocity.

For this fall, forces X and Y vary with time as shown.



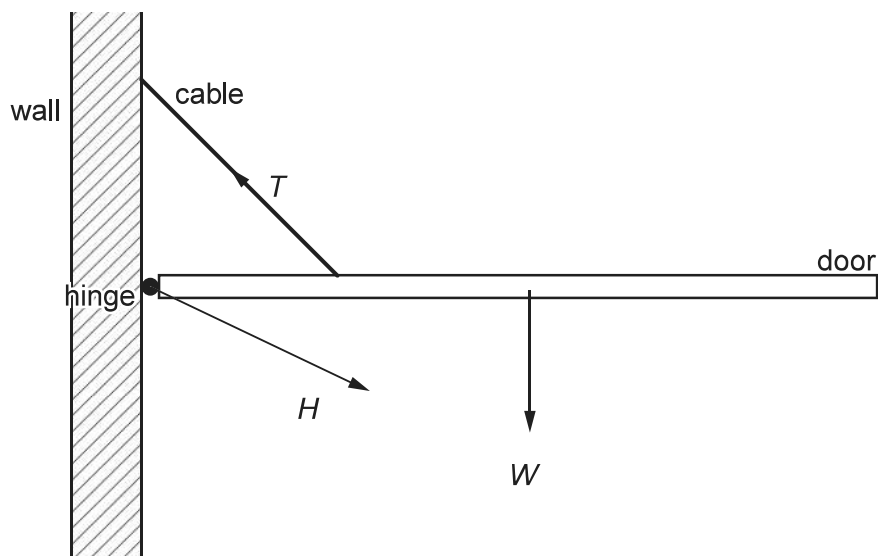
What are forces X and Y ?

	force X	force Y
A	air resistance	resultant force
B	air resistance	weight
C	upthrust	resultant force
D	upthrust	weight

- 14 A hinged door is held closed in the horizontal position by a cable.

Three forces act on the door: the weight W of the door, the tension T in the cable, and the force H at the hinge.

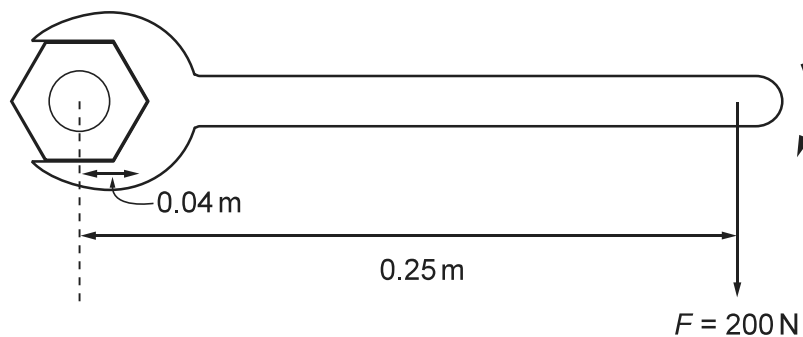
9702/01/O/N/03/Q16



Which list gives the three forces in **increasing** order of magnitude?

- A** H, T, W **B** T, H, W **C** W, H, T **D** W, T, H

- 15 A spanner is used to tighten a nut as shown.



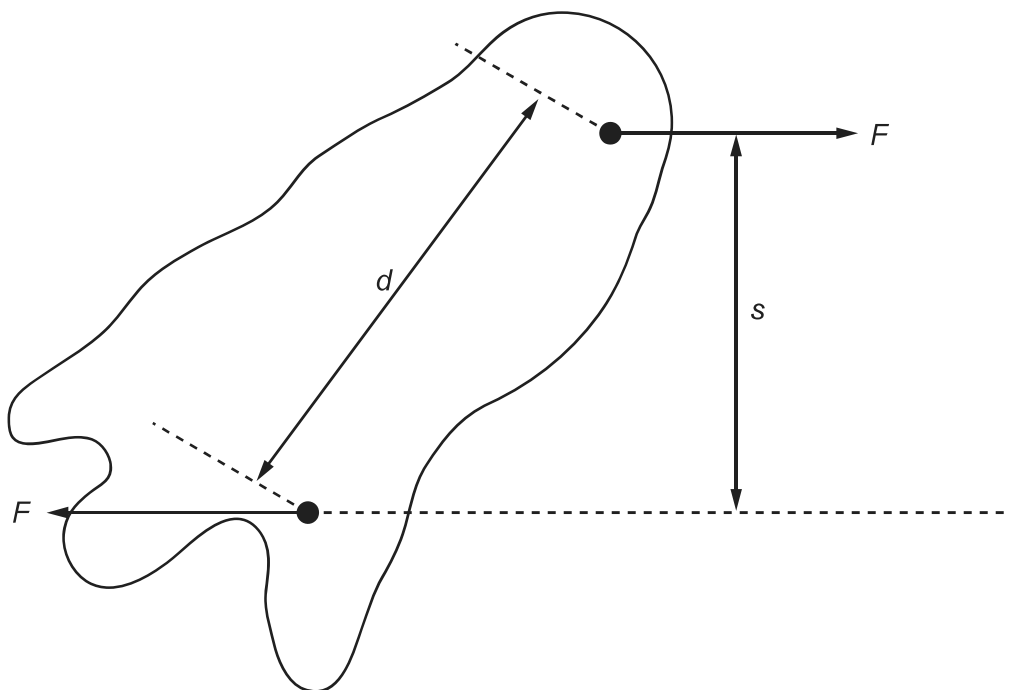
A force F is applied at right-angles to the spanner at a distance of 0.25 m from the centre of the nut. When the nut is fully tightened, the applied force is 200 N.

What is the resistive torque, in an anticlockwise direction, preventing further tightening?

- A 8 N m
- B 25 N m
- C 50 N m
- D 800 N m

- 16 Two parallel forces, each of magnitude F , act on a body as shown.

9702/01/O/N/03/Q14



What is the magnitude of the torque on the body produced by these forces?

- A Fd
- B Fs
- C $2Fd$
- D $2Fs$

- 17 A force F is applied to a freely moving object. At one instant of time, the object has velocity v and acceleration a .

9702/01/O/N/03/Q15

Which quantities **must** be in the same direction?

- A a and v only
- B a and F only
- C v and F only
- D v , F and a

- 18 A ball is at rest on a horizontal surface. The forces acting on it are:

9702 01 04/Q10

Which of the following statements are about the forces acting on the ball while it is in contact with the ground? Which statement is correct?

- A The force that the ground exerts on the ball is a reaction force to the weight of the ball.
- B The force that the ground exerts on the ball is a reaction force to the weight of the ground.
- C The force that the ground exerts on the ball is a reaction force to the weight of the ground.
- D The weight of the ball is a reaction force to the weight of the ground.

- 19 An object is immersed in a fluid. The object experiences an upthrust.

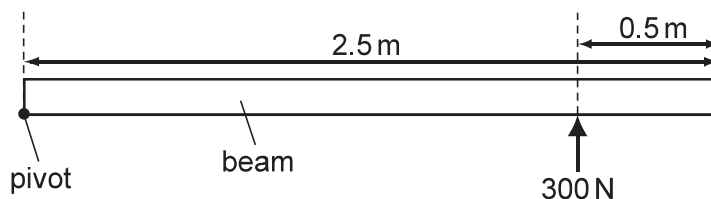
9702 01 04/Q12

Which of the following is a correct reason for the upthrust?

- A The density of the fluid increases with depth.
- B The density of the fluid increases with time.
- C The pressure in the fluid increases with depth.
- D The area of the fluid increases with depth.

- 20 A long uniform beam is pivoted at one end. A force of 300 N is applied to the other end of the beam.

9702 01 04/Q13

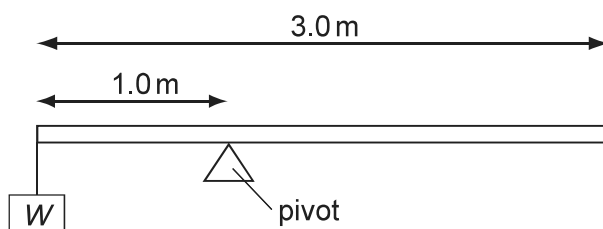


What is the weight of the beam?

- A 300
- B 480
- C 600
- D 960

- 21 A uniform beam of weight 50 N is 3.0 m long and is supported on a pivot at one end. A weight of 100 N is hung from the other end. The beam is in equilibrium. Calculate the weight of the beam.

9702 01 04/Q13

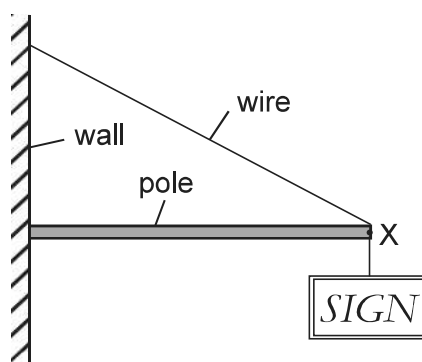


What is the weight of

- A 25 B 50 C 75 D 100

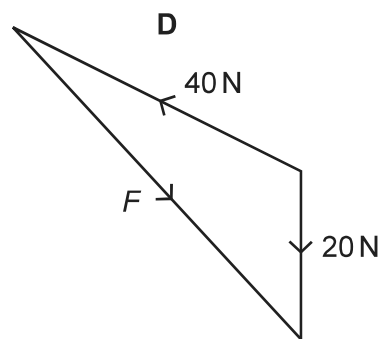
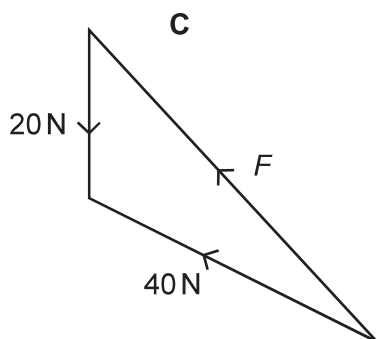
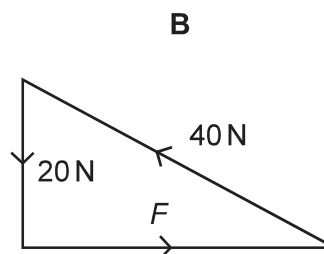
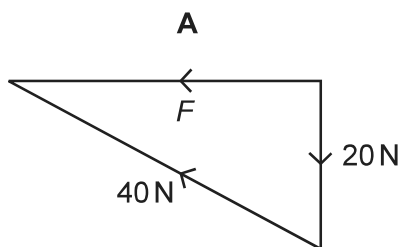
- 22 A diagram shows a sign of weight 20 N suspended from a horizontal pole attached to a wall. The pole is in equilibrium. Calculate the tension in the wire.

9702 01 04/Q14



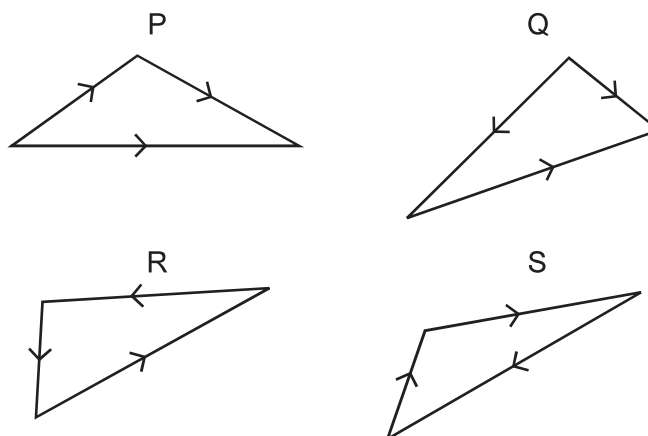
The forces exerted on the pole at point X are shown in the diagram below.

Which diagram represents the three forces acting at point X?



23 Which vector diagrams represent forces in equilibrium

9702 01 04/Q12



- A an
- B an
- C an
- D an

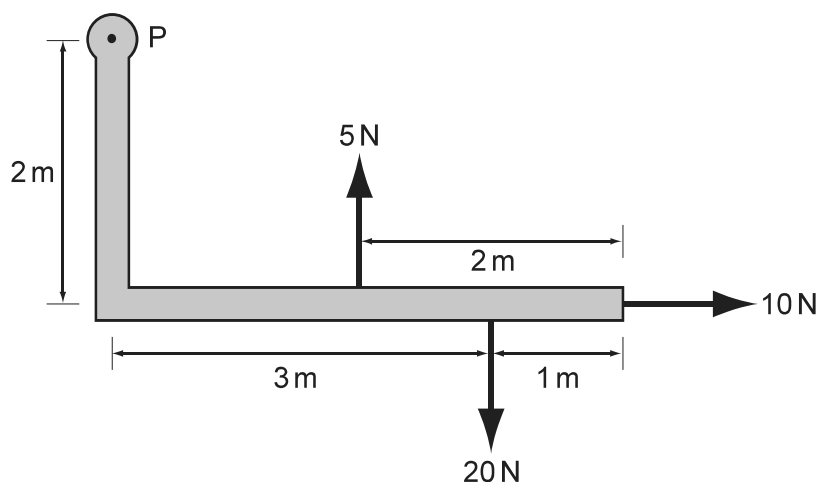
24 What is the centre of gravity of an object

9702 01 05/Q12

- A the geometric centre of the object
- B the point about which the total torque is zero
- C the point at which the weight of the object may be considered to act
- D the point through which gravity acts

25 An L-shaped rigid member is pivoted at point

9702 01 05/Q13



Three forces act on the L-shaped member as shown in the diagram

What is the magnitude of the resultant moment of these forces about point

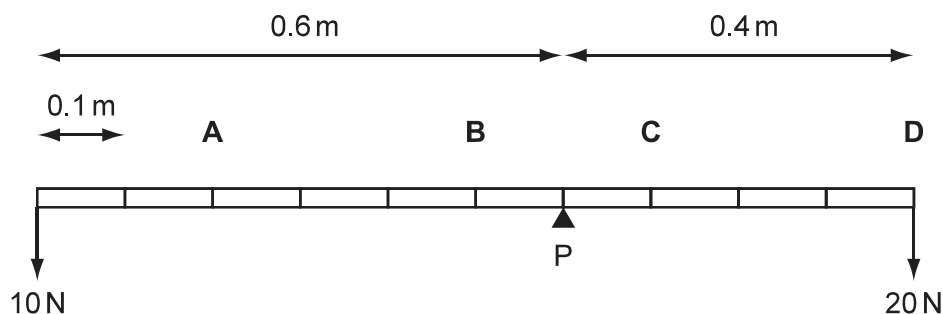
- A 30 N m
- B 35 N m
- C 50 N m
- D 90 N m

- 26 A uniform beam of length 100 is pivoted at its centre. Two forces of 10 N and 20 N are attached to its ends

9702 01 05/Q12

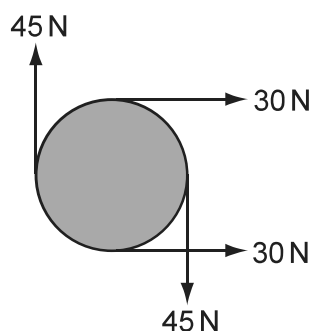
The length of the beam is marked at 0.1 m intervals

At its points on a further length of 20 N are attached to achieve equilibrium



- 27 The diagrams show four forces acting on a circular object

9702 01 05/Q13



Which of the following describes the resultant force and the resultant torque on the object?

9702 01 05

	resultant force	resultant torque
A	non zero	non zero
B	non zero	zero
C	zero	non zero
D	zero	zero

- 28 A cyclist is riding at a steady speed on a level road

9702 01 06/Q10

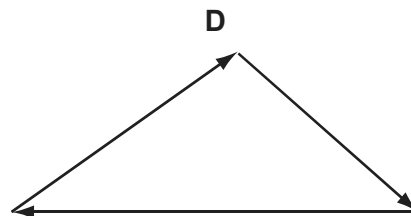
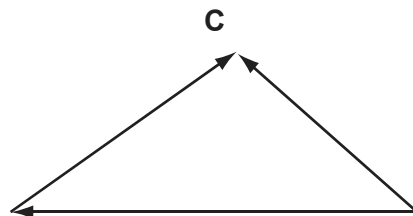
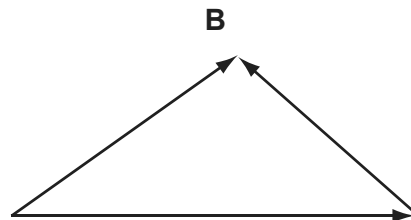
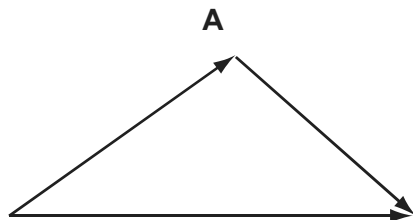
According to the constant speed motion, what is the relationship between the forces acting on the cyclist?

- A The forces exerted by the cyclist on the road are equal and opposite to the forces exerted by the road on the cyclist.
- B The forward force on the cyclist is equal to the backward force on the cyclist.
- C The tension in the chain is equal to the resistance.
- D The total air resistance and friction force is equal to the forward force.

29 The diagrams show three forces acting on a point.

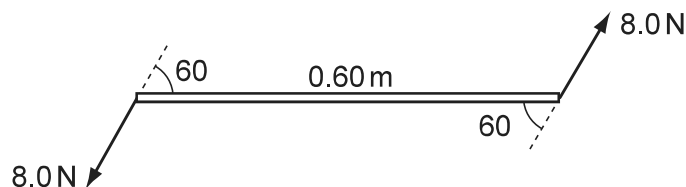
9702 01 06/Q13

Which diagram is the point in equilibrium?



30 Two 8.0 N forces act at each end of a beam of length 0.60 m. The forces are parallel and act in opposite directions. The angle between the forces and the beam is 60° .

9702 01 07/Q13

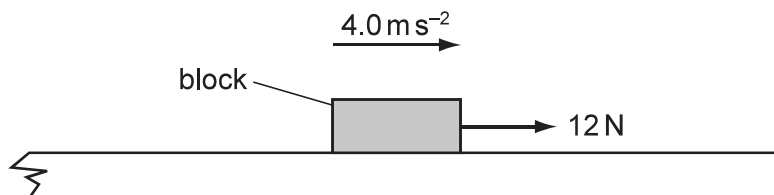


What is the torque of the couple exerted on the beam?

- A 2.4 m B 4.2 m C 4.8 m D 9.6 m

31 A block of mass 0.60 kg is on a rough horizontal surface. A force of 12 N is applied to the block and it accelerates at 4.0 m s^{-2} .

9702 01 07/Q10

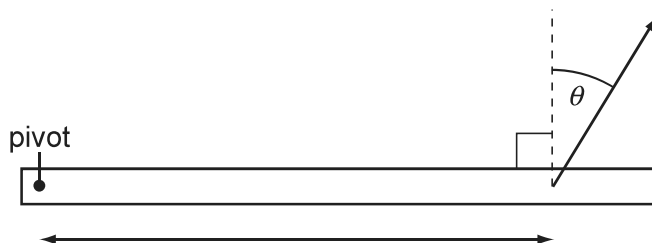


What is the magnitude of the frictional force acting on the block?

- A 2.4 B 5.3 C 6.7 D 9.6

- 32 A force is applied to a beam at a distance from a pivot. The force acts at an angle θ to a line perpendicular to the beam.

9702 01 06/Q14

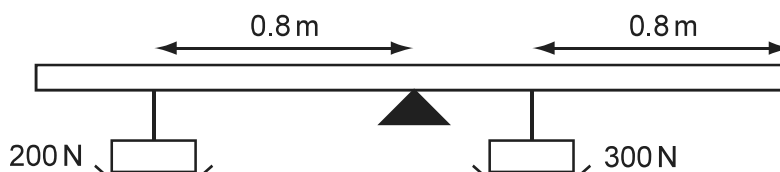


Which combination will cause the largest turning effect about the pivot?

			θ
A	large	large	large
B	large	large	small
C	small	small	large
D	small	large	small

- 33 A rigid uniform bar of length 2.4 m is in equilibrium. It is supported at its midpoint.

9702 01 06/Q15



Which are the units for the moments of the forces shown in the diagram to maintain equilibrium? A couple is a force times the perpendicular distance from the pivot to the line of action of the force.

What is the torque and its direction?

- A 40 N m clockwise
- B 40 N m anticlockwise
- C 80 N m clockwise
- D 80 N m anticlockwise

- 34 A ball is falling at terminal speed in still air. The forces acting on the ball are weight, drag, and upthrust.

9702 01 08/Q12

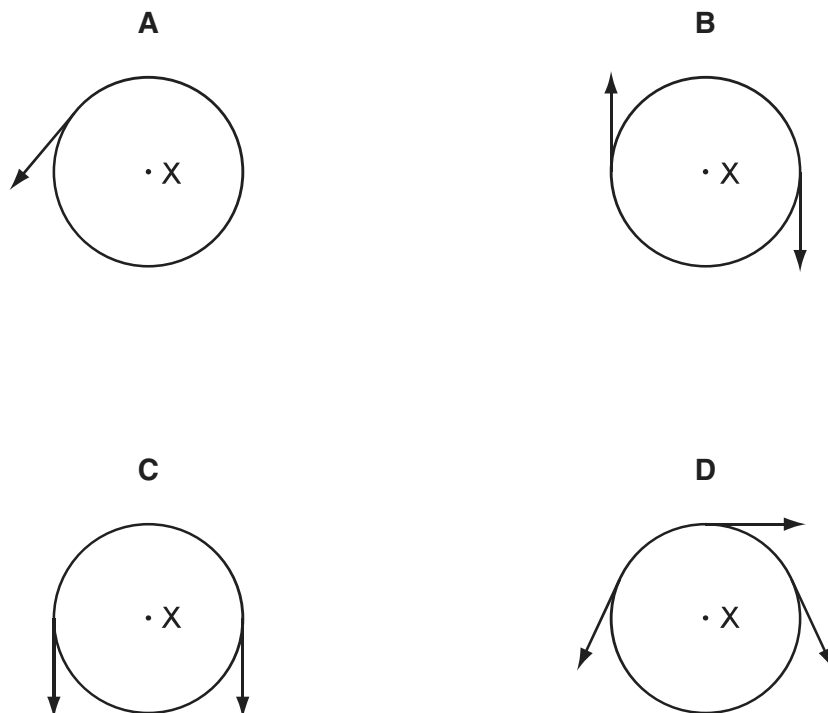
What is the order of increasing magnitude of these three forces?

- A upthrust $\rightarrow$ drag $\rightarrow$ weight
- B drag $\rightarrow$ upthrust $\rightarrow$ weight
- C drag $\rightarrow$ weight $\rightarrow$ upthrust
- D weight $\rightarrow$ upthrust $\rightarrow$ drag

- 35 A rigid circular disc of radius r has its centre at A . A number of forces of equal magnitude are applied at the edge of the disc. The forces are in the plane of the disc.

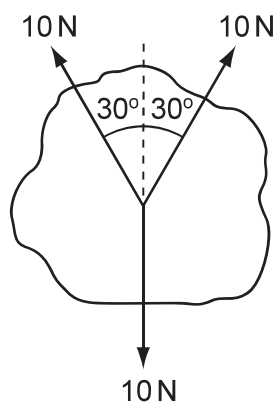
9702 01 06/Q14

In which arrangement of forces is the resultant moment about A zero?



- 36 Three coplanar forces each of magnitude 10 N act at the same point. The forces are in the same plane.

9702 01 06/Q15



What is the magnitude of the resultant force?

- A 0 B 13 C 7.3 D 10

- 37 A small object of total mass 30 g is moving at 3.0 ms^{-1} . A retarding force of 60 mN is applied to it for 0.50 s in the opposite direction to its initial motion.

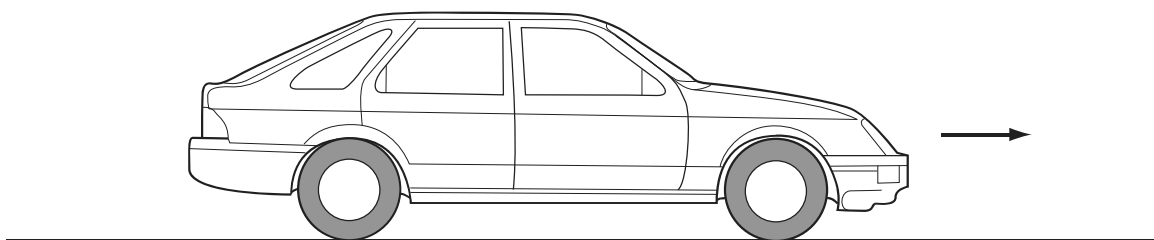
9702 12 09/Q9

What is the speed of the object at the end of the time interval?

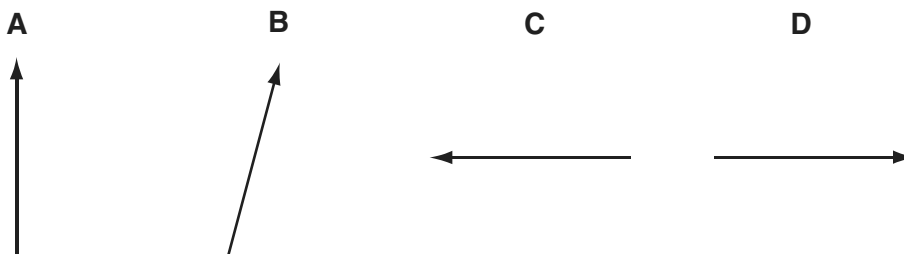
- A 1.0 ms^{-1} B 1.5 ms^{-1} C 2.0 ms^{-1} D 2.8 ms^{-1}

38 A car is accelerating in the direction shown

9702 01 07/Q11

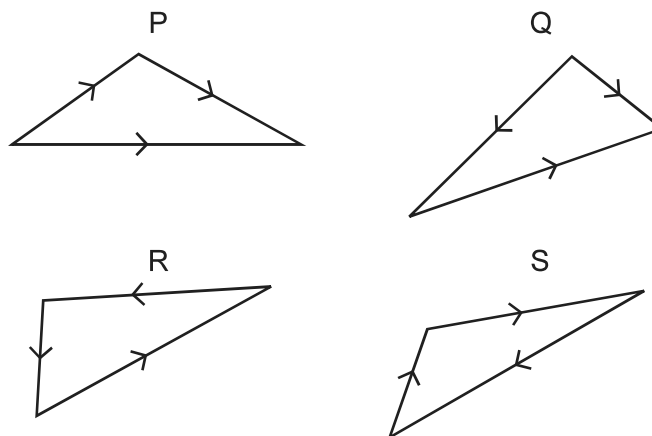


Which diagram best shows the direction of the total force exerted on the car?



39 Which vector diagrams represent forces in equilibrium?

9702 01 07/Q13

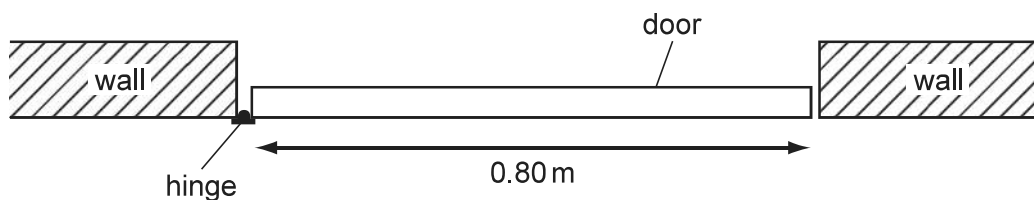


A B C D

40 The diagram shows a door which requires a moment of 12 Nm to open it.

9702 01

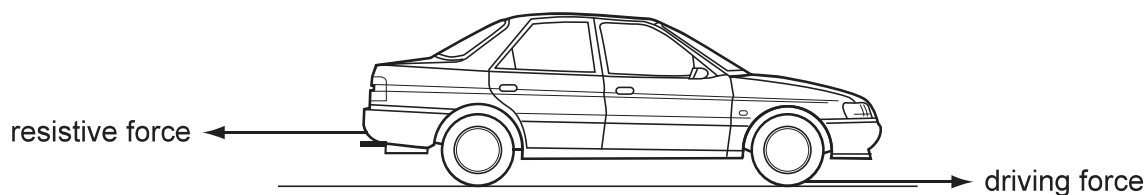
07/Q14



What is the minimum force that must be applied at the door's midpoint to ensure it opens?

A 48 B 96 C 15 D 30

- 41 A car of mass 750 kg has a resistive force of 20 N acting on it that causes a forward acceleration of 2.0 ms^{-2} 9702 01 08/Q11



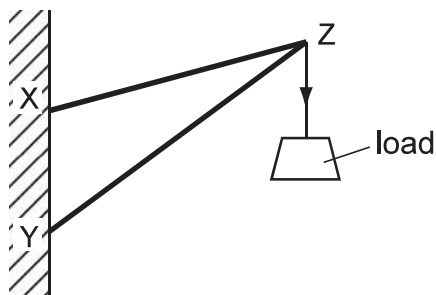
What is the resistive force acting on the car?

- A 0.5 B 15 C 20 D 35

- 42 Two rigid rods are joined together at a point and are attached to a vertical wall at two points. A load is hung from the joint. 9702 01 08/Q13

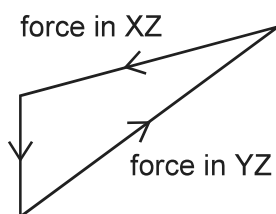
A diagram of the system is shown below.

The load is not moving.

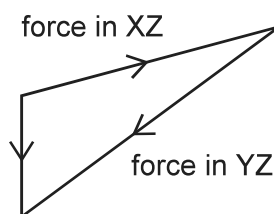


Which diagram shows the forces acting at point Z?

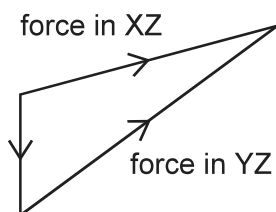
A



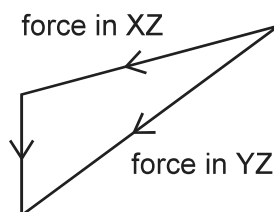
B



C



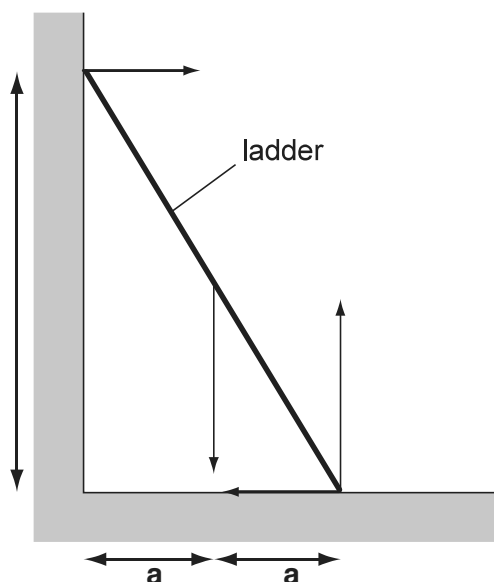
D



- 43 A uniform ladder rests against a vertical wall where there is negligible friction. The bottom of the ladder rests on rough ground where there is friction. The top of the ladder is at a height a above the ground and the foot of the ladder is at a distance $2a$ from the wall.

9702 01 08/Q14

The diagrams show the forces which act on the ladder.



Which equation is correct when taking moments?

A $W \times a = F \times 2a$

B $W \times a = F \times a$

C $W \times 2a = F \times a$

D $W \times 2a = F \times 2a$

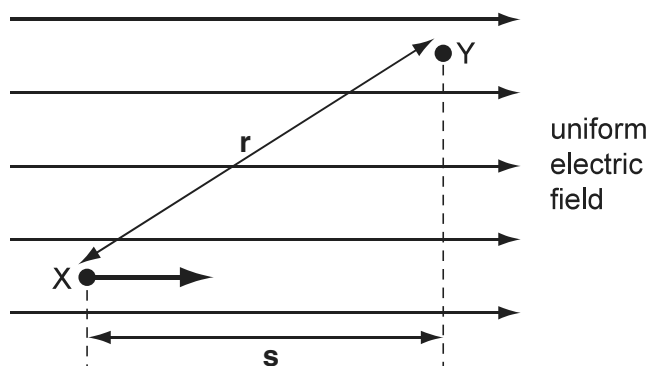
- 44 A positive charge experiences a force when placed at point Y in a uniform electric field.

9702 01

08/Q16

The charge is taken from point Y to point X.

Distances r and s are shown on the diagram.



What is the change in the potential energy of the charge?

A decreases s

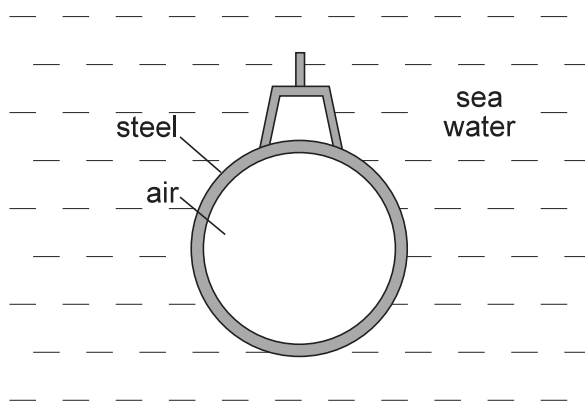
B increases s

C decreases r

D increases r

45 A submarine is in equilibrium in a fully submerged position

9702 01 08/Q15

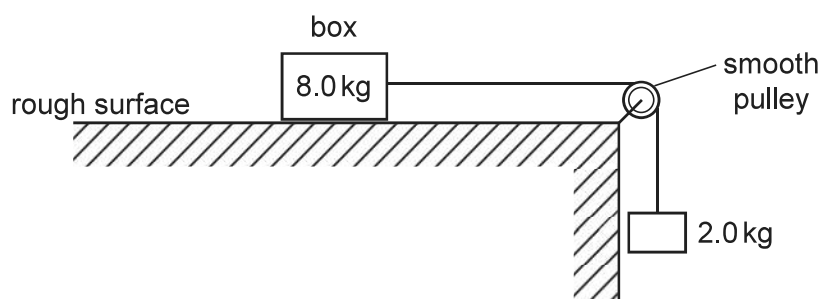


What causes the submarine to be in equilibrium?

- A The air in the submarine is less dense than sea water
- B The sea water exerts a greater upward force on the submarine than the weight of the steel
- C The submarine displaces its own volume of sea water
- D There is a difference in water pressure acting on the top and bottom of the submarine

46 A block of mass 8.0 kg rests on a horizontal rough surface. A string attached to the block passes over a smooth pulley and supports a 2.0 kg mass at its other end.

9702 01 08/Q11



When the 2.0 kg mass is released, a friction force of 6.0 N acts on it.

What is the acceleration of the 8.0 kg block?

- A 1.4 ms^{-2}
- B 1.7 ms^{-2}
- C 2.0 ms^{-2}
- D 2.5 ms^{-2}

47 An object made from two unequal masses joined by a light rod is released from rest in a uniform sea of thick air. The object remains horizontal.

9702 01 09/Q12

Which statement about the equilibrium of the system is correct?

- A It is not in equilibrium because it is accelerating
- B It is not in equilibrium because it is in motion
- C It is not in equilibrium because there is a resultant force
- D It is in equilibrium because there is no resultant force and no resultant torque

48 A mass of 100 g is placed on a horizontal surface.

9702 01 08/Q9

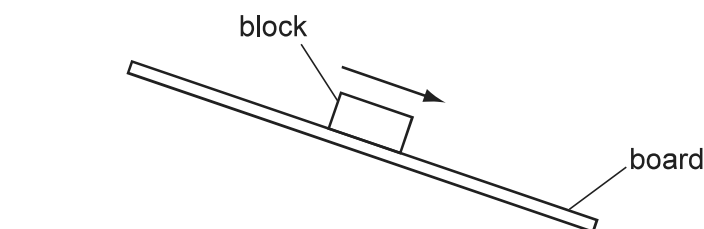
Which of the following statements are about the forces acting on the mass when it is in contact with the ground?

Which statement is correct?

- A The weight of the mass acts on the ground. It is a force of 1 N acting vertically downwards.
- B The weight of the mass acts on the ground. It is a force of 1 N acting vertically upwards.
- C The weight of the mass acts on the ground. It is a force of 1 N acting horizontally to the right.
- D The weight of the mass acts on the ground. It is a force of 1 N acting horizontally to the left.

49 A block of mass 100 g is placed on a rough horizontal surface. The surface is then raised until the block is on the verge of slipping. The surface is then lowered until the block is on the verge of slipping again. The block is then placed on the surface at constant velocity.

9702 01 08/Q12

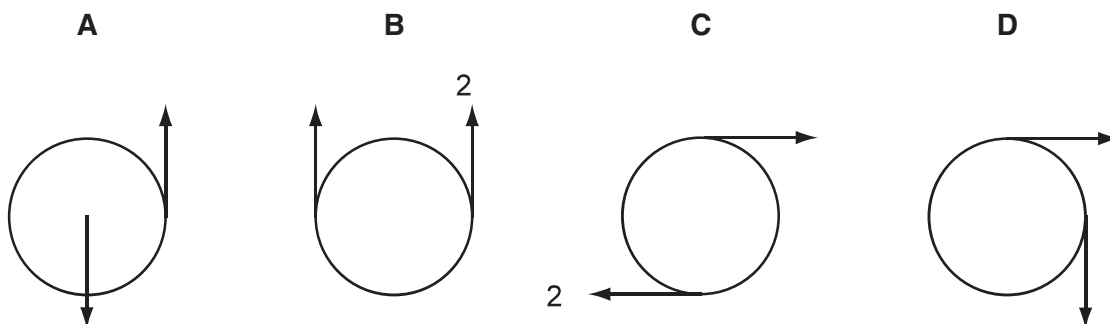


Which of the following describes the forces acting on the block when it is on the incline at constant velocity?

	frictional force on block	resultant force on block
A	acts vertically downwards	acts vertically downwards
B	acts vertically upwards	zero
C	acts horizontally to the right	acts vertically downwards
D	acts horizontally to the left	zero

50 Which pair of forces acts as a couple on the circular object?

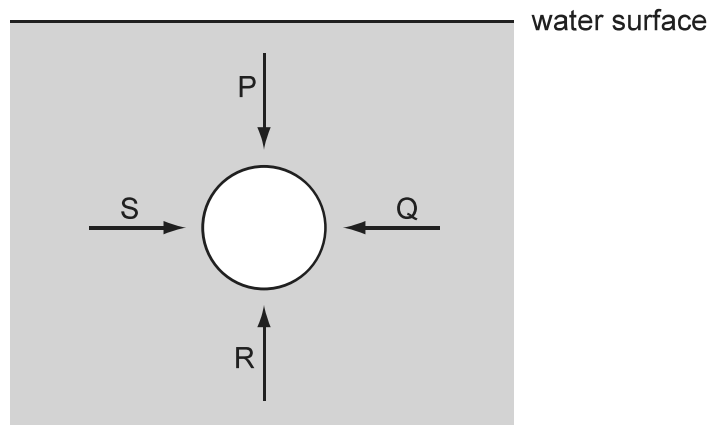
9702 01 08/Q14



51 The diagram represents a sphere under water. Four forces are acting on the sphere due to the pressure of the water.

Four forces are acting on the sphere.

9702 01 09/Q11



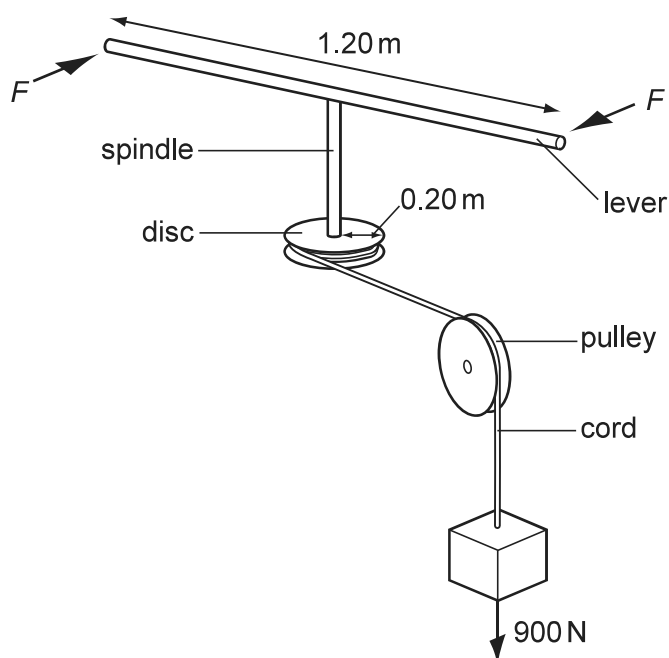
Force P acts vertically downwards on the sphere's surface and force R acts vertically upwards on the sphere's surface. Forces S and Q act horizontally on the sphere's surface.

Which information about the magnitudes of the forces is correct?

- A
- B
- C
- D

52 A string is attached at one end to the centre of a wheel 1.20 m long and at its other end to the centre of a disc of radius 0.20 m. A cord is wrapped round the disc, passes over a pulley and is attached to a 900 N weight.

9702 01 09/Q13



What is the minimum force 'F' applied to each end of the lever to lift the weight?

- A 75
- B 150
- C 300
- D 950

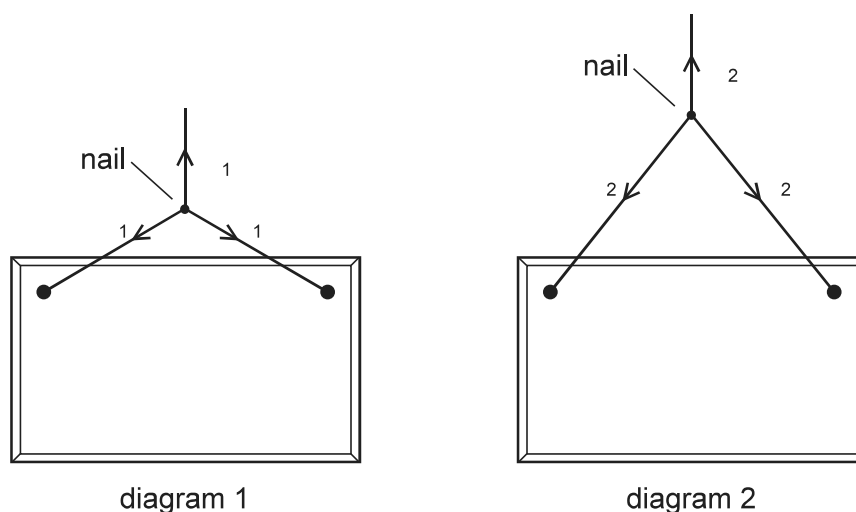
53 What is the centre of gravity of an object

9702/11 09/Q11

- A The geometrical centre of the object
- B The point at which the total torque is zero
- C The point at which the weight of the object may be considered to act
- D The point through which gravity acts

54 The diagrams show two arrangements of the same picture

9702/11 09/Q12



In both cases a string is attached to the same points on the picture and the forces exerted by the string on the nail are not necessarily equal in magnitude.

In diagram 1 the string is shorter than in diagram 2.

Which information about the magnitude of the forces is correct?

- A $F_1 < F_2$
- B $F_1 = F_2$
- C $F_1 > F_2$
- D $F_1 = 2F_2$

55 An object immersed in a fluid in a tank experiences an upthrust

9702/12 10/Q13

What is the physical reason for the upthrust?

- A The density of the object is less than that of the fluid
- B The density of the fluid increases with depth
- C The pressure in the fluid increases with depth
- D The area of contact between the object and the fluid increases with depth

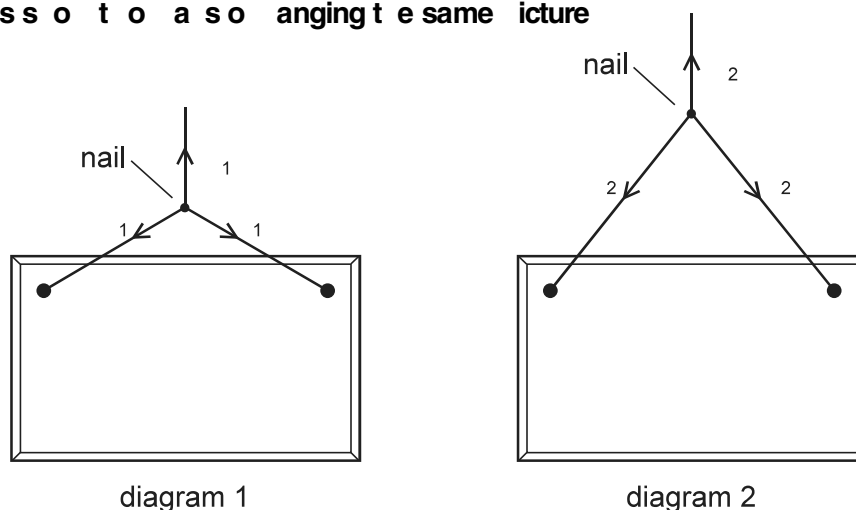
56 What is the centre of gravity of an object?

9702/12 09/Q10

- A The geometrical centre of the object
- B The point at which the total torque is zero
- C The point at which the weight of the object may be considered to act
- D The point through which gravity acts

57 The diagrams show two arrangements of the same picture.

9702/12 09/Q11



In both cases a string is attached to the same points on the picture and the forces exerted by the string on the nail are not the same.

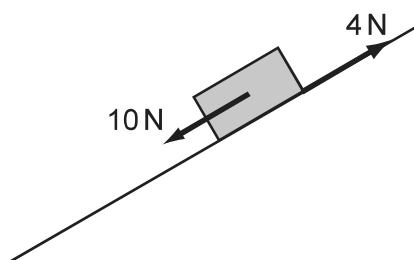
In diagram 1 the string is shorter than in diagram 2.

Which information about the magnitude of the forces is correct?

- A 1 > 2
- B 1 = 2
- C 1 < 2
- D 1 = 2

58 A brick weighing 20 N rests on an inclined plane. The weight of the brick has a component of 10 N acting down the plane. The brick also experiences a frictional force of 4 N acting up the plane.

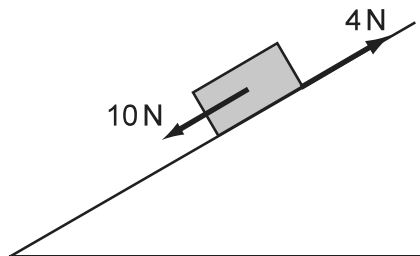
9702/11 10/Q11



What is the acceleration of the brick down the plane? Assume that the acceleration of free fall is 10 ms^{-2} .

- A 0.3 ms^{-2}
- B 0.8 ms^{-2}
- C 3.0 ms^{-2}
- D 8.0 ms^{-2}

- 59 A rectangular block rests on an inclined plane. The weight of the block has a component of 10 N parallel to the plane. The block also experiences a frictional force of 4 N.



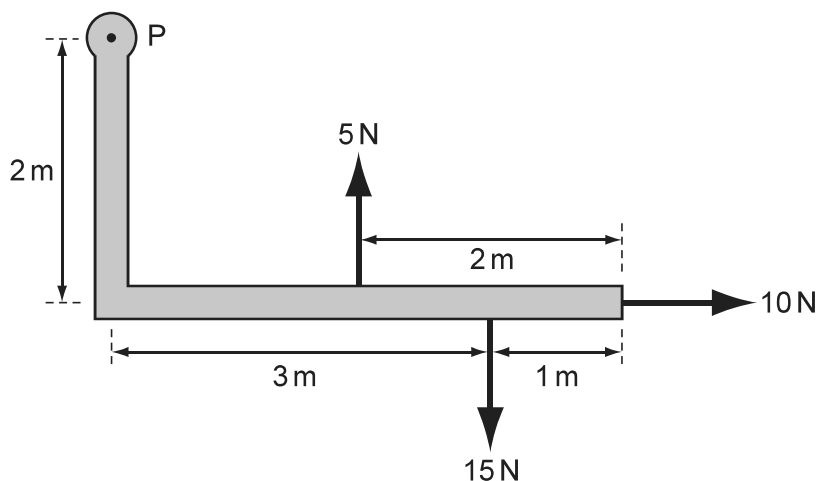
What is the acceleration of the block down the plane? Assume that the acceleration of free fall is 10 ms^{-2} .

- A 0.3 ms^{-2} B 0.8 ms^{-2} C 3.0 ms^{-2} D 8.0 ms^{-2}
- 60 An object immersed in a fluid in a tank experiences an upthrust.

What is the most likely reason for the upthrust?

- A The density of the object is less than that of the fluid.
 B The density of the fluid increases with time.
 C The pressure in the fluid increases with time.
 D The buoyant force in the fluid increases with time.

- 61 A rigid L-shaped lever arm is pivoted at point P.



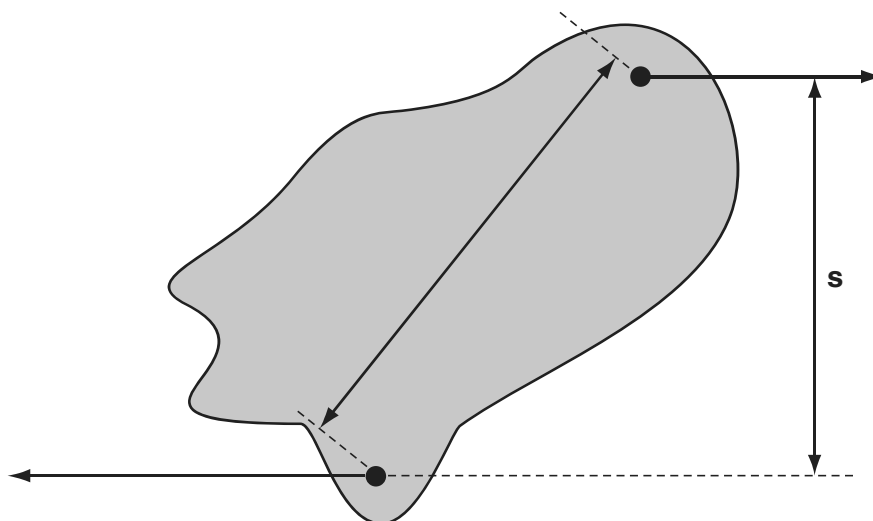
Three forces act on the lever arm as shown in the diagram.

What is the magnitude of the resultant moment of these forces about point P?

- A 15 N m B 20 N m C 35 N m D 75 N m

62 The magnitude of the torque on the body about the point

9702/11 10/Q14



What is the magnitude of the torque on the body due to these forces?

A

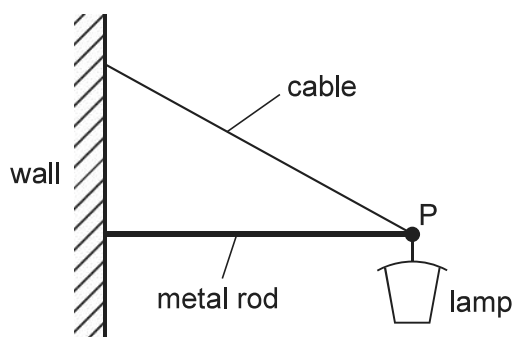
B s

C $2s$

D $2s$

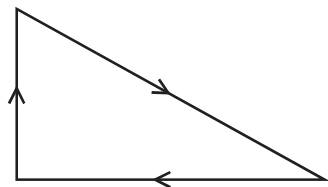
63 A street lamp is fixed to a wall by a metal rod and a cable.

9702/11 10/Q15

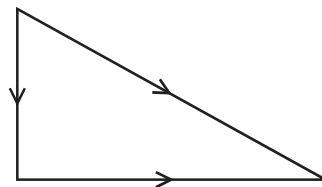


Which vector triangle represents the forces acting at point P?

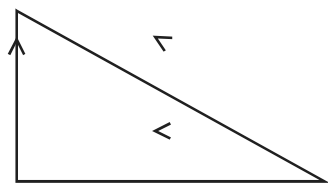
A



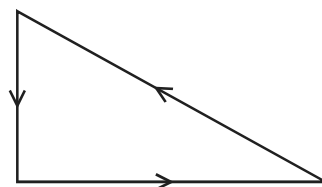
B



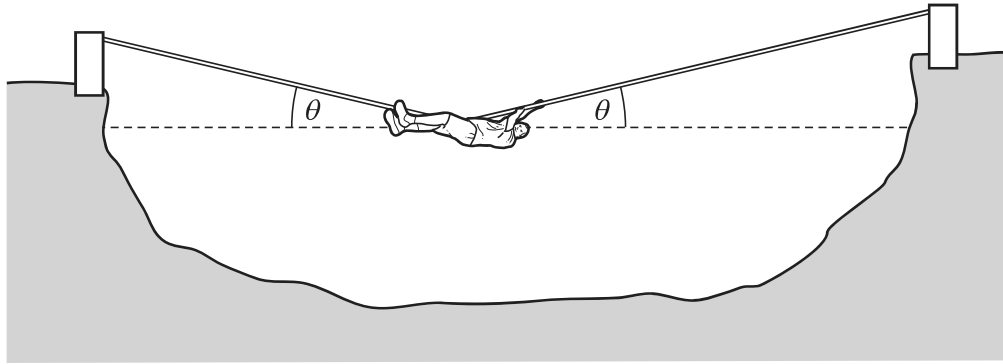
C



D



- 64 The diagram shows a rope being held at a student's hands on an adventure training course. The student is sitting on the rope.

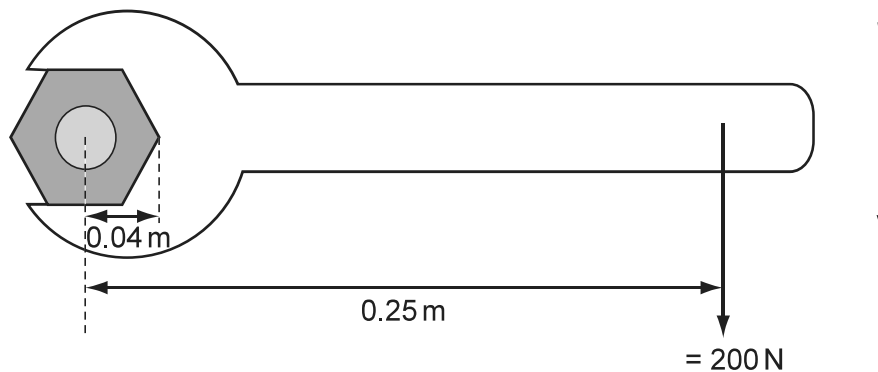


Which formula gives the tension in the rope?

- A $\frac{W}{2\cos\theta}$ B $\frac{W}{2\sin\theta}$ C $\frac{W}{\cos\theta}$ D $\frac{W}{\sin\theta}$

- 65 A spanner is used to tighten a nut as shown.

9702/12 10/Q12



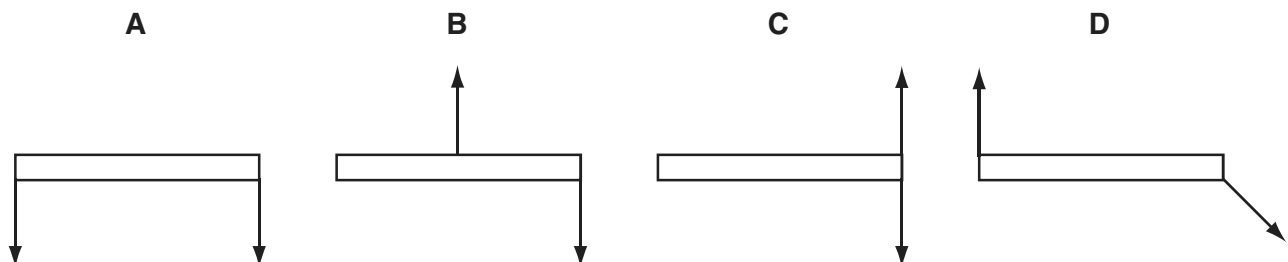
A force is applied at right angles to the spanner at a distance of 0.25 m from the centre of the nut. The force is 200 N.

What is the resisting torque in an anticlockwise direction preventing further tightening?

- A 8 N m B 42 N m C 50 N m D 1250 N m

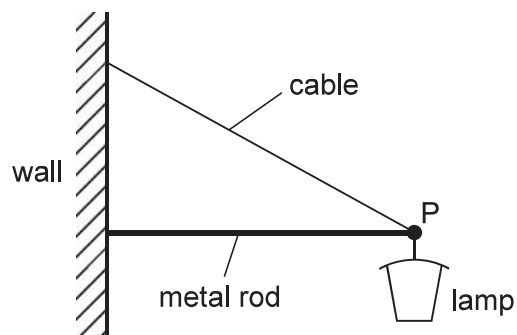
- 66 The diagrams show four forces acting on a metre rule.

Which diagram shows forces that will be a couple and a resultant force?



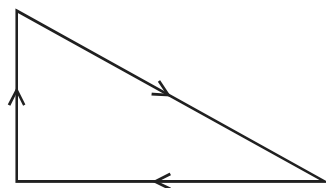
67 A street arm is fixed to a wall by a metal rod and a cable

9702/13 10/Q13

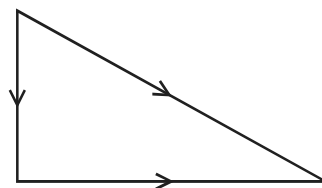


Which vector triangle represents the forces acting at point P?

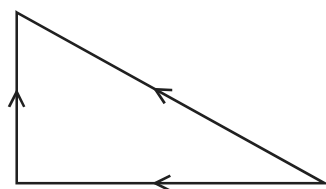
A



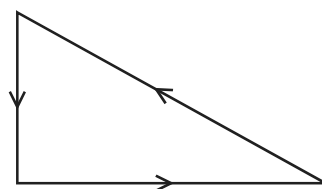
B



C

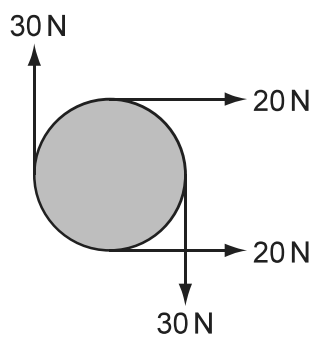


D



68 The diagram shows four forces acting on a circular object

9702/11 11/Q12

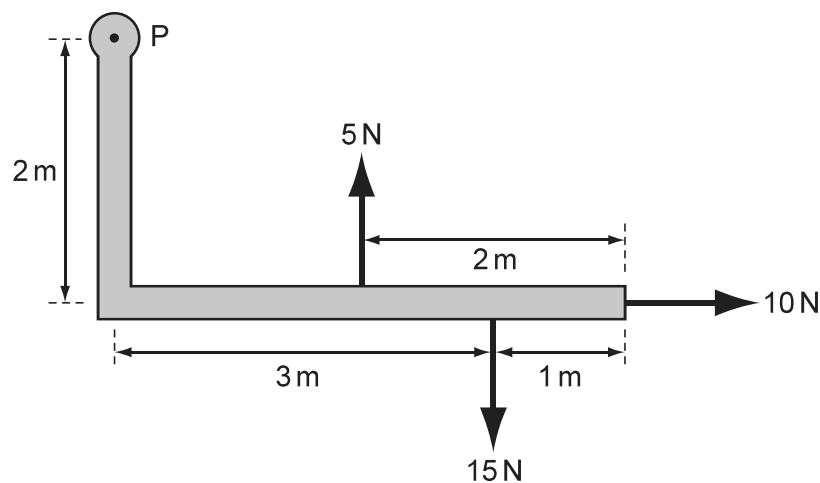


Which row describes the resultant force and resultant torque on the object?

	resultant force	resultant torque
A	zero	zero
B	zero	non zero
C	non zero	zero
D	non zero	non zero

69 A rigid L-shaped member is pivoted at point P

9702 13 10/Q14



Three forces act on the L-shaped member as shown in the diagram

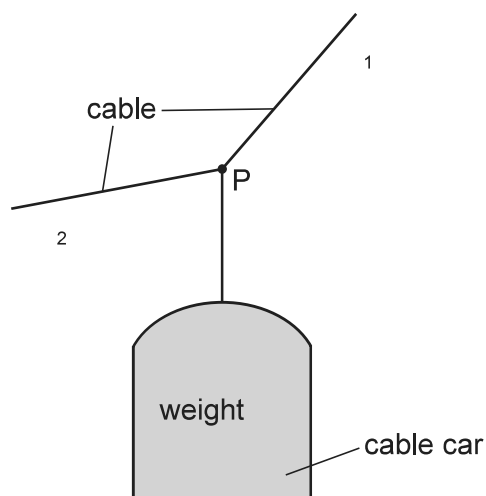
What is the magnitude of the resultant moment of these forces about point P?

- A 15 N B 20 N C 35 N D 75 N

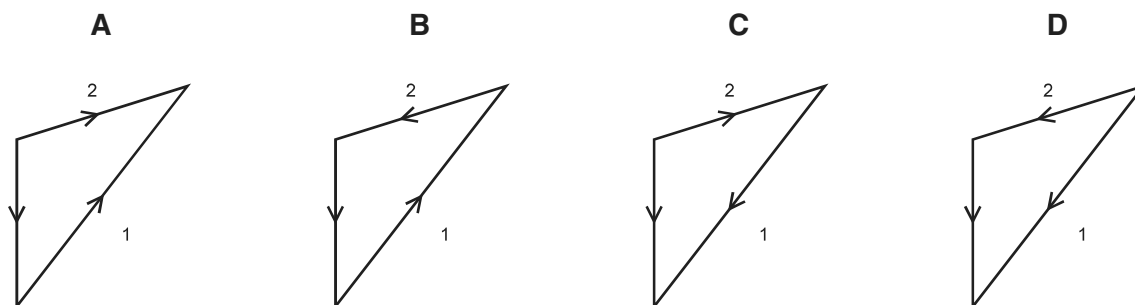
70 A cable car weighs 2000 N and hangs in equilibrium from its cables at point P

9702 11 11/Q11

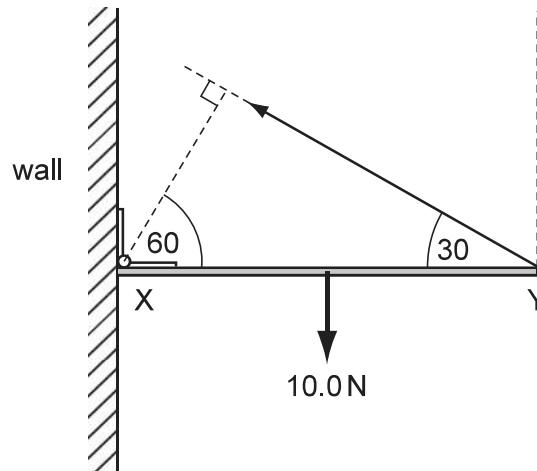
The cables are tensions T_1 and T_2 as shown



Which diagram correctly represents the forces acting at point P?



- 71 A uniform rod of weight 10.0 N is inclined to a vertical wall at this orientation. A force acting from the wall at an angle of 30° to the horizontal is shown.

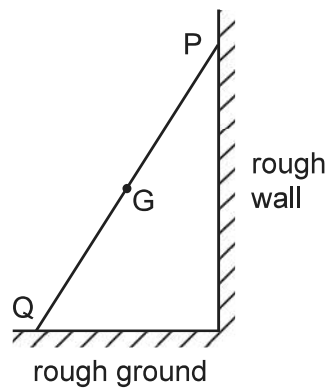


What is the value of

- A 5.0 B 8.7 C 10.0 D 20.0

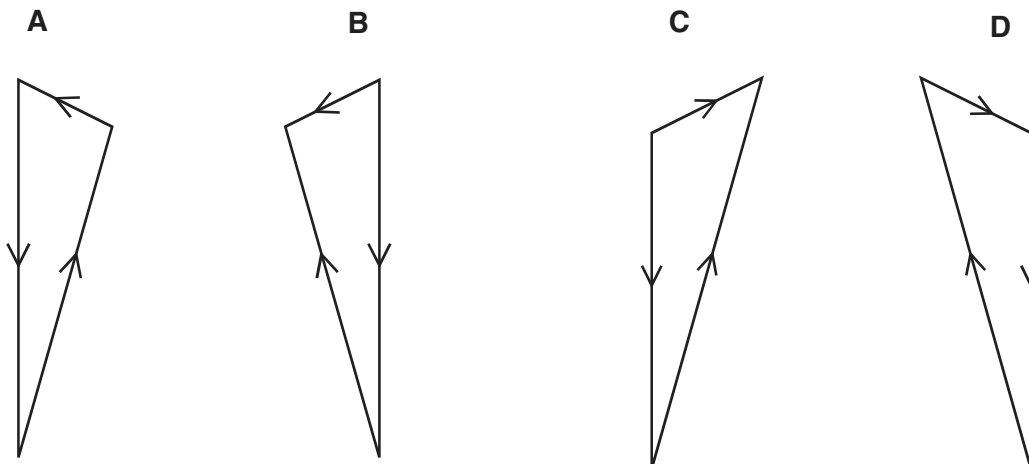
- 72 A ladder rests in equilibrium on rough ground against a rough wall.

9702/11 11/Q13



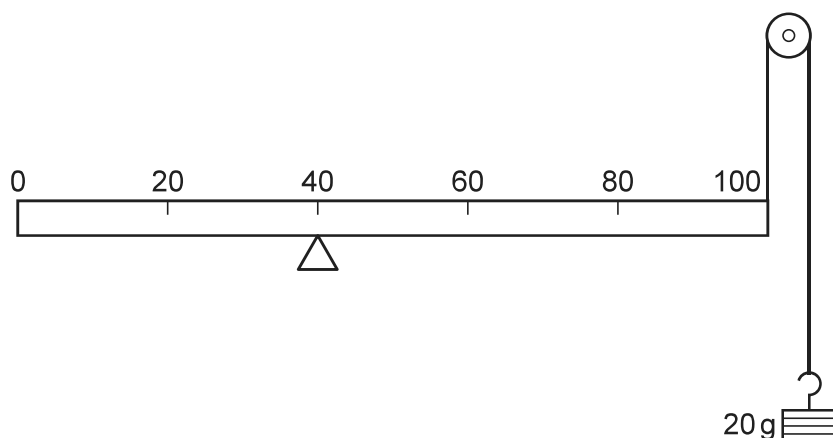
The weight acts through the centre of gravity. The forces also act on the ladder at an angle. These forces are in equilibrium.

Which vector triangle represents the forces on the ladder?



- 73 A uniform metre rule of mass 100 g is supported at a point 40 cm from the left end by a string attached to the 100 cm mark. The string passes round a frictionless pulley and carries a mass of 20 g as shown in the diagram

9702 11 11/Q13



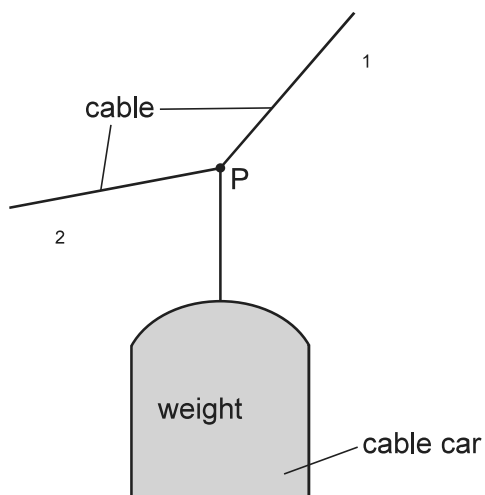
At this mark on the rule must a 50 g mass be suspended so that the rule is balanced

- A 4 cm B 36 cm C 44 cm D 64 cm

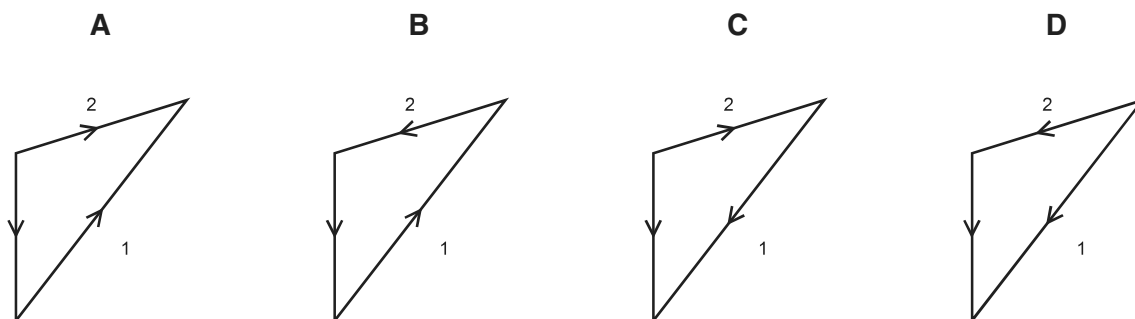
- 74 A cable car weighs 1000 N and hangs in equilibrium from its cables at point P

9702 13 11/Q13

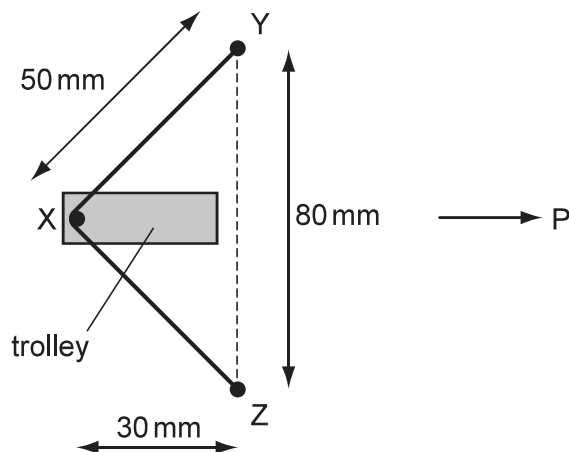
The cables are tensions T_1 and T_2 as shown



Which diagram correctly represents the forces acting at point P



75 The diagram shows a trolley on a horizontal surface. A light elastic cord is stretched between the trolley and a fixed point Y. The cord is attached to the trolley at point X. The distance XY is 50 mm. The vertical distance from X to the horizontal line through Y is 80 mm. The horizontal distance from X to the vertical line through Y is 30 mm. A horizontal force P is applied to the trolley. The tension in the elastic cord is 4 N.



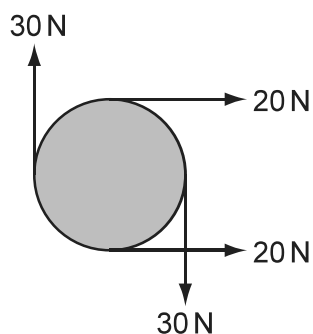
What is the acceleration of the trolley in the direction of the force P?

What is the force accelerating the trolley in the direction of the force P?

- A 2.4 B 3.2 C 4.8 D 6.4

76 The diagram shows four forces acting on a circular object.

9702/13 11/Q11

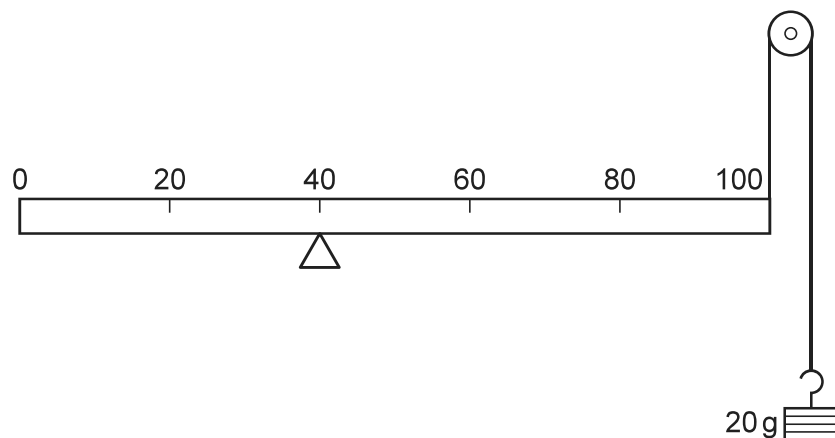


Which of the following describes the resultant force and the resultant torque on the object?

	resultant force	resultant torque
A	zero	zero
B	zero	non-zero
C	non-zero	zero
D	non-zero	non-zero

- 77 A uniform metre rule of mass 100 g is supported at its left end by a string attached to a 100 cm mark. The string passes round a frictionless pulley and carries a mass of 20 g as shown in the diagram.

9702 13 11/Q12

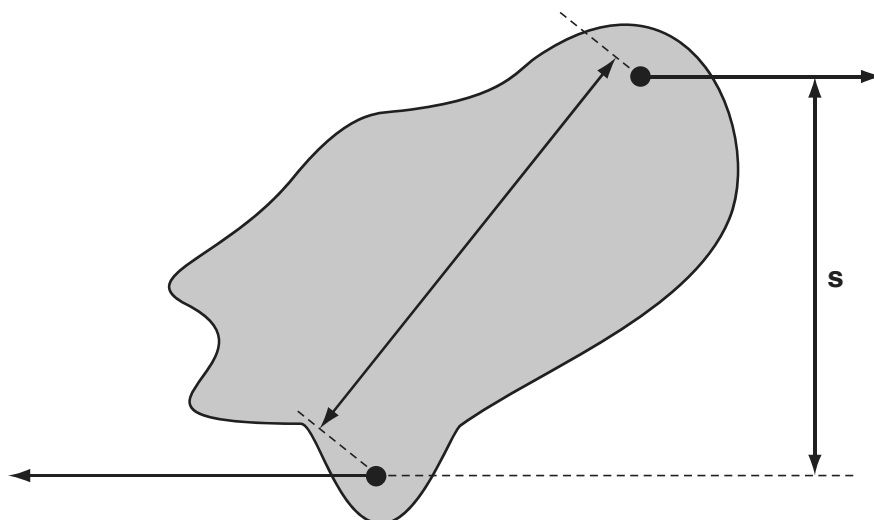


At which mark on the rule must a 50 g mass be suspended so that the rule is balanced?

- A 4 cm B 36 cm C 44 cm D 64 cm

- 78 Two forces of equal magnitude act on a body as shown.

9702 13 10/Q15



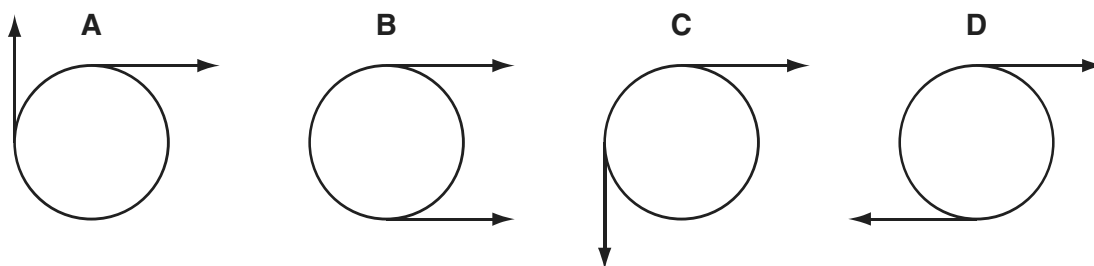
What is the magnitude of the torque on the body due to these forces?

- A B s C $2s$ D $2s$

- 79 Two coplanar forces act on the rim of a wheel. The forces are equal in magnitude.

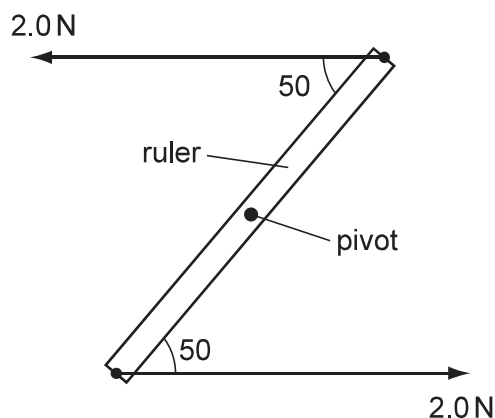
9702 12 11/Q13

Which arrangement of forces produces no couple?



- 80 A ruler of length 0.30 m is pivoted at its centre. Two forces of magnitude 2.0 N are applied to the ruler creating a couple as shown.

9702 11 11/Q14

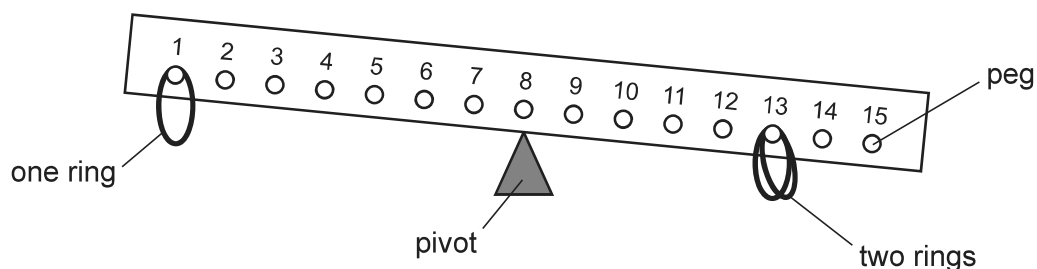


What is the magnitude of the torque of the couple on the ruler when it is in the position shown?

- A 0.23 m B 0.39 m C 0.46 m D 0.60 m

- 81 The diagram shows a balancing game.

9702 11 11/Q15



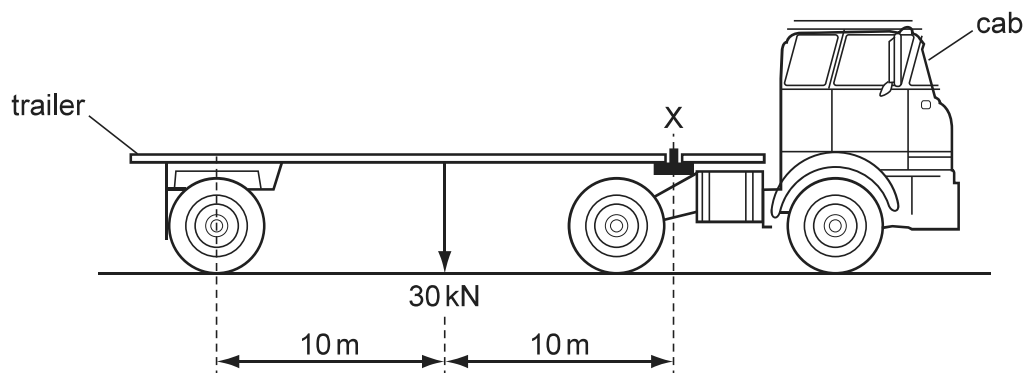
The beam is uniform and all the rings are of equal mass. Two rings are hung on peg 13 and one on peg 1.

How many more rings must be hung in order to balance the beam?

- A 2 B 3 C 5 D 6

- 82 A trailer of length 30 m is attached to a car as shown in the diagram.

9702 12 11/Q14



What is the upward force exerted by the car on the trailer at the point of attachment?

- A 3 B 15 C 30 D 60

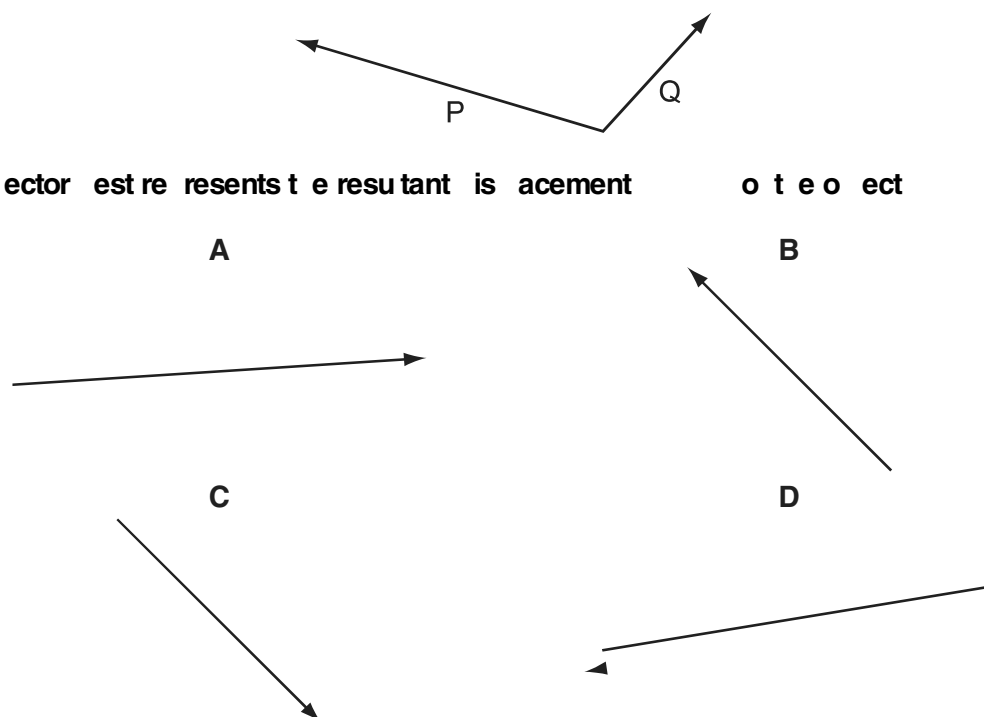
83

Two forces P and Q are represented by the vectors $\vec{P}$ and $\vec{Q}$ respectively. The resultant force R is represented by the vector $\vec{R}$.

9702 12

11/Q12

The vector $\vec{R}$ represents the resultant force. The vector $\vec{P}$ represents the force P and the vector $\vec{Q}$ represents the force Q .

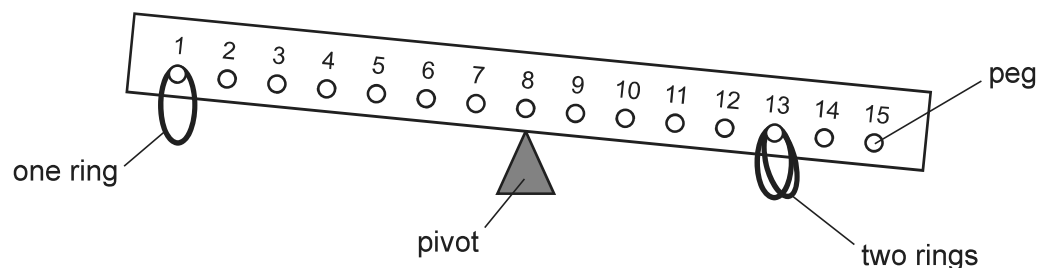


84

The diagram shows a uniform beam of length 15 cm, pivoted at the 8 cm mark. A ring is attached to the 1 cm mark and two rings are attached to the 13 cm mark. The beam is released from a horizontal position.

9702 13

11/Q13



The beam is uniform and the rings are of equal mass. The rings are hung on the 1 cm and 13 cm marks.

The beam must rotate about the pivot in order to achieve equilibrium.

A 2

B 3

C 5

D 6

85

A cylinder of cross-sectional area A and height h is totally immersed in a liquid of density ρ . The pressure at the top surface is p_1 and the pressure at the bottom surface is p_2 .

9702 11

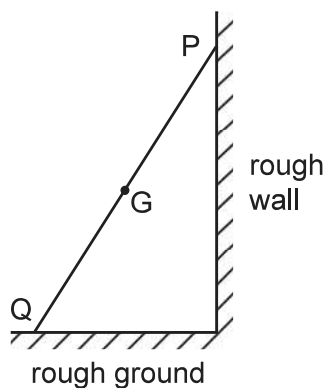
12/Q13

The pressure difference is due to the weight of the liquid.

A $\rho h A$ B ρh C $\rho h A$ D $\rho h A$

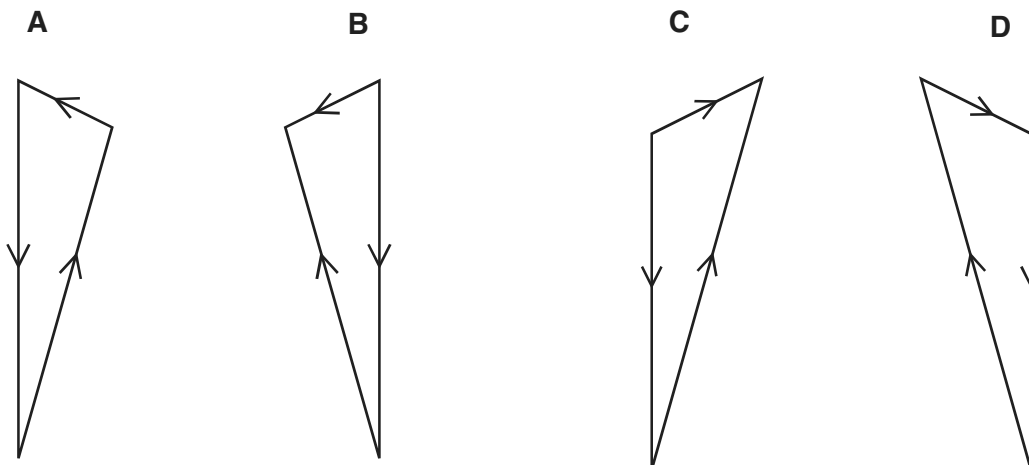
86 A ladder rests in equilibrium on rough ground against a rough wall

9702/13 11/Q14



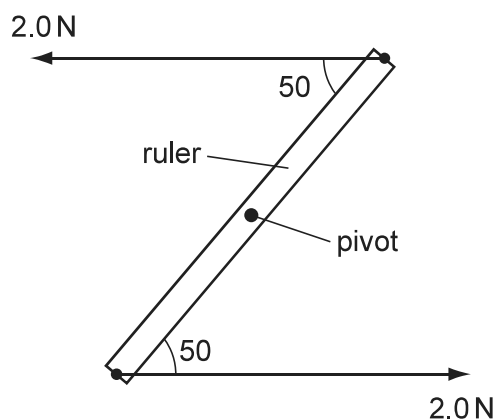
Three forces act on the ladder: the weight acting at the centre of gravity, the normal reaction from the wall, and the friction from the ground. These forces are in equilibrium.

The vector triangle represents the forces on the ladder.



87 A ruler of length 0.30 m is pivoted at its centre. Two equal and opposite forces of magnitude 2.0 N are applied at the ends so that the ruler is in equilibrium.

9702/13 11/Q15

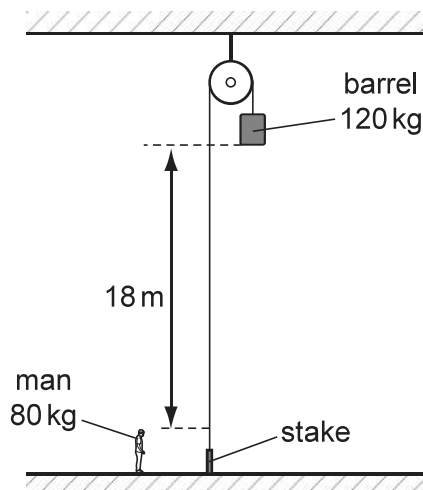


What is the magnitude of the torque of the couple on the ruler when it is in the position shown?

- A 0.23 m B 0.39 m C 0.46 m D 0.60 m

- 88 The diagram shows a barrel suspended from a frictionless pulley on a building. The barrel is 18 m above the ground. A man of mass 80 kg is standing on the ground. The barrel is 120 kg.

9702/11 12/Q12



A man stands close to the stake. The bottom of the barrel is 18 m above the man's head. The mass of the barrel is 120 kg and the mass of the man is 80 kg.

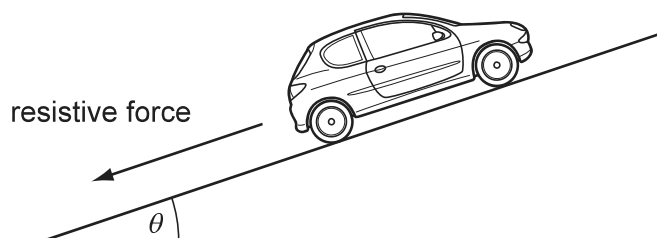
The man pulls on the rope to lift the barrel. He is pulling the rope upwards with a constant force of 1000 N.

What is the man's upward acceleration when he starts to pull the rope?

- A 6 ms^{-1} B 8 ms^{-1} C 13 ms^{-1} D 19 ms^{-1}

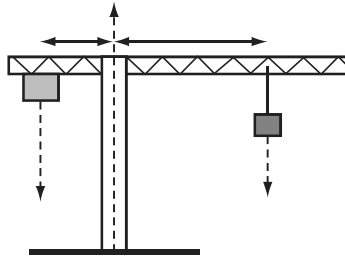
- 89 A car of mass m travels at constant speed u up a slope at an angle θ to the horizontal. The forces acting on the car are its weight, the normal reaction, the friction force and the resistive force.

9702/11 12/Q14



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

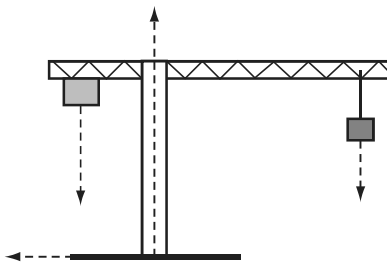
- A $mg \cos \theta$
 B $mg \sin \theta$
 C $mg \cos \theta$
 D $mg \sin \theta$



A mass m_1 is a balancing load. The position of the load is such that the system is in equilibrium. The distance from the support column to the load is x . The reaction force at the support column is R . The distance from the support column to the other mass is y . The distance does not change.

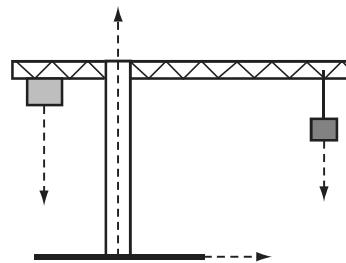
The load is moved further out so that the distance increases and the crane does not topple. Which statement is correct?

A



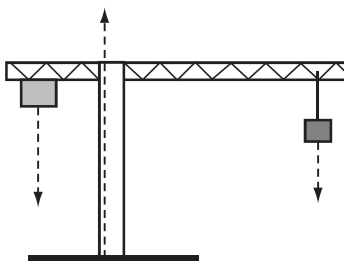
A horizontal force acts on the base of the support column towards the left.

B



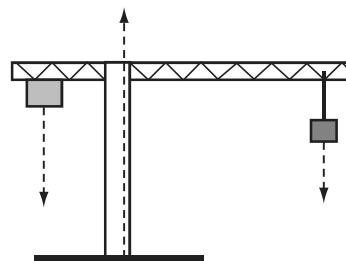
A horizontal force acts on the base of the support column towards the right.

C



The reaction force moves to the left.

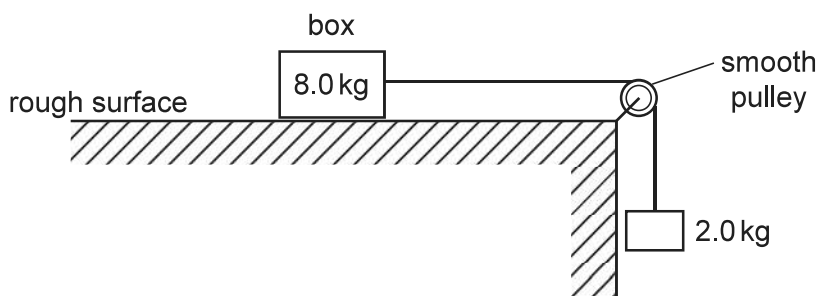
D



The reaction force moves to the right.

- 91 A box of mass 8.0 kg rests on a horizontal rough surface. A string attached to the box passes over a smooth pulley and supports a 2.0 kg mass at its other end.

9702/12/12/Q13



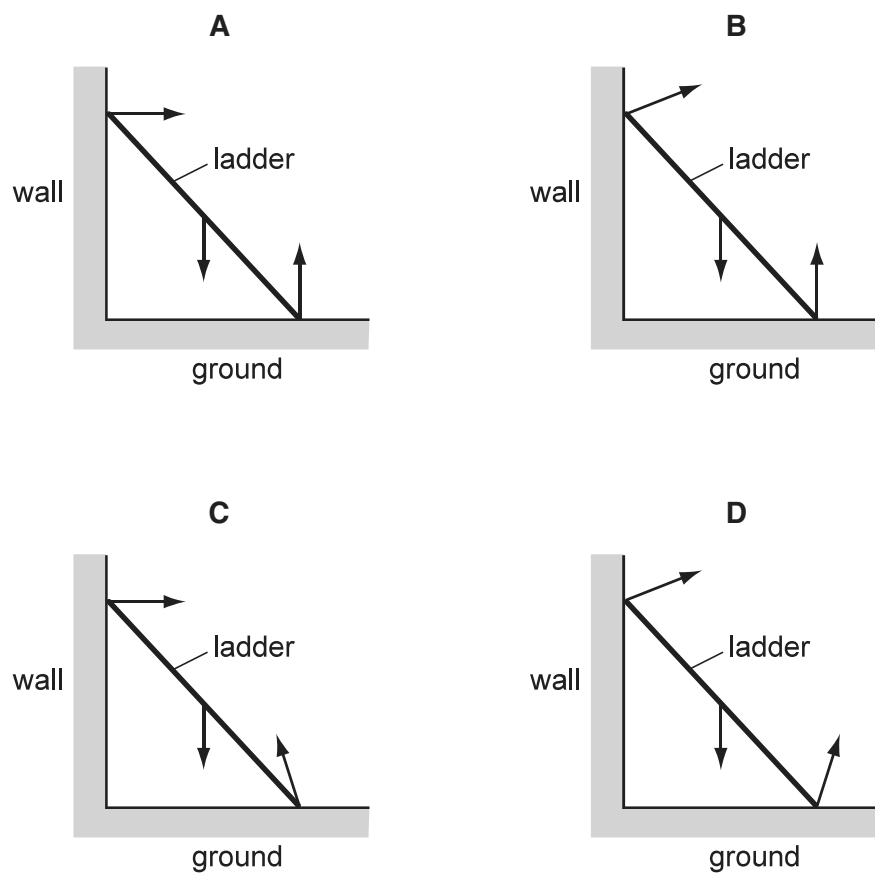
When the box is released, a frictional force of 6.0 N acts on it.

What is the acceleration of the box?

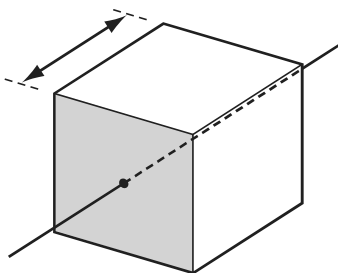
- A 1.4 ms^{-2} B 1.7 ms^{-2} C 2.0 ms^{-2} D 2.5 ms^{-2}
- 92 A ladder is positioned on a frictionless ground and is leaned against a rough wall. At the instant it is released, it begins to slide.

9702/12/12/Q14

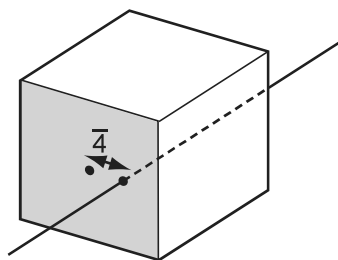
Which diagram correctly shows the directions of the forces acting on the ladder as it begins to slide?



- 93 The diagram shows a solid cube of side length a resting on a rough horizontal surface. The centre of mass is at a distance $\frac{a}{4}$ from the vertical face of the cube. The cube is in equilibrium. The reaction forces at the base of the cube are R and F . The cube is on the point of toppling.



The cube is on the point of toppling. The reaction forces at the base of the cube are R and F . The cube is in equilibrium.



The cube is on the point of toppling. The reaction forces at the base of the cube are R and F . The cube is in equilibrium.

A $\frac{1}{2}$ anticlockwise

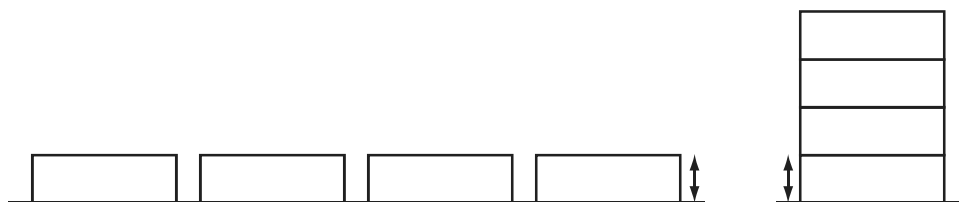
B $\frac{1}{2}$ clockwise

C $\frac{1}{4}$ anticlockwise

D $\frac{1}{4}$ clockwise

- 94 Four identical uniform blocks of mass m are stacked on a table.

9702 12 12/Q17



The blocks are stacked on a table. The reaction forces at the base of the blocks are R and F . The blocks are in equilibrium.

A 3 mg

B 6 mg

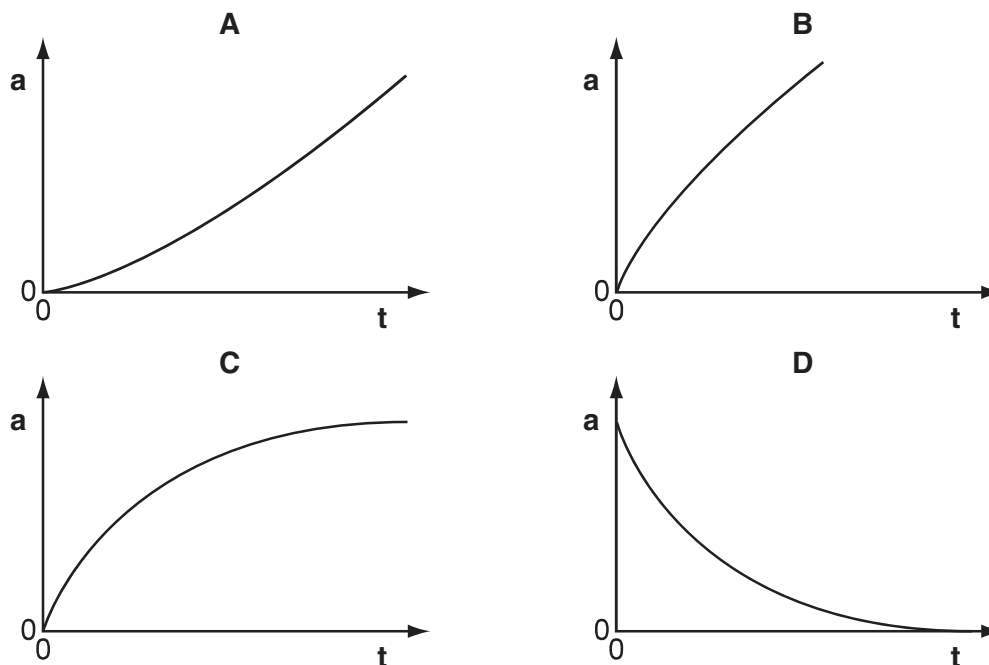
C 8 mg

D 10 mg

95 A sphere is released from rest in a viscous fluid

9702/12 12/Q16

The graph represents the variation of time to the acceleration of the sphere



96 Which equation is a correct one for the equation in the following force

9702/13 12/Q11

Which equation is the definition of force

- A Force = energy / time
- B Force = mass × acceleration
- C Force = pressure × area
- D Force = rate of change of momentum

97 Two similar spheres each of mass m are travelling towards each other

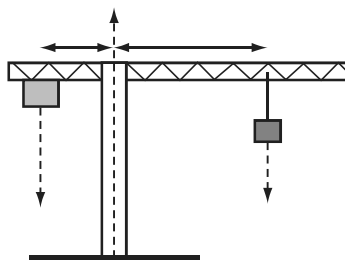
9702/13 12/Q12



The spheres have an elastic collision

Which statement is correct

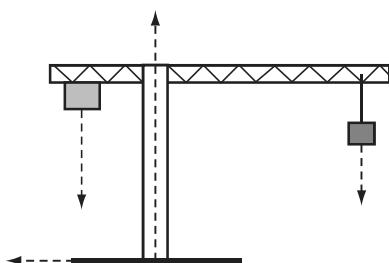
- A The spheres stick together on impact
- B The total kinetic energy after impact is $2m^2$
- C The total kinetic energy before impact is zero
- D The total momentum before impact is $2m$



A mass m is a hanging mass. The position of the mass is such that the system is in equilibrium. The distance from the support to the mass does not change.

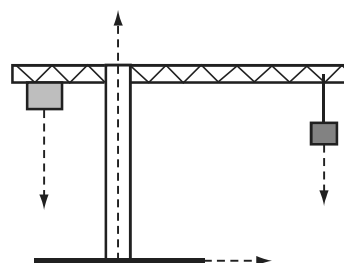
The mass is moved further out so that the distance increases and the crane does not topple. This statement is correct.

A



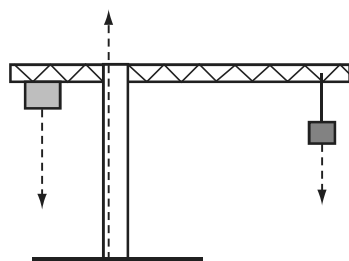
A horizontal force acts on the base of the support column towards the left.

B



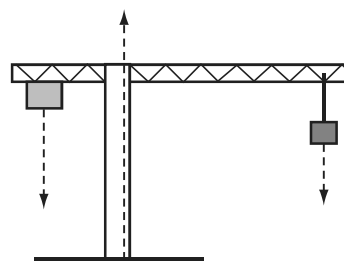
A horizontal force acts on the base of the support column towards the right.

C



The reaction force moves to the left.

D



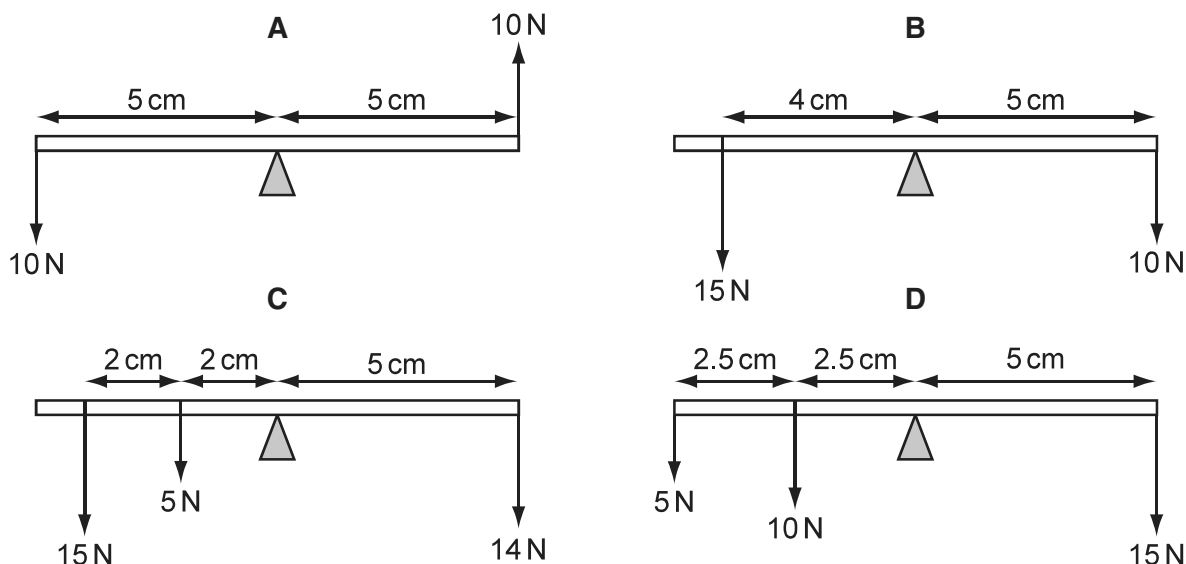
The reaction force moves to the right.

102 A rigid uniform beam is pivoted horizontally at its midpoint

9702/12 12/Q17

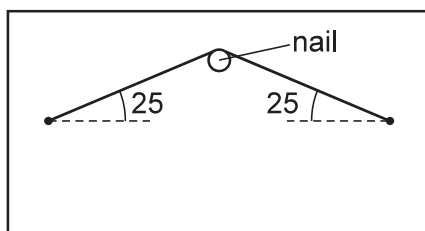
Different vertical forces are applied to different positions on the beam

Which diagram is the beam in equilibrium



103 A picture on a wall is supported by a wire connected to the wall

9702/12 12/Q18



The mass of the picture is 4.2 kg

What is the tension in the supporting wire

A 5.0

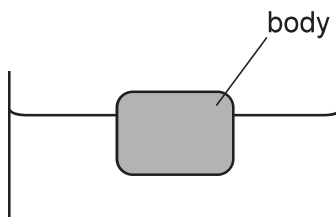
B 23

C 49

D 97

104 A stationary boat floats in water

9702/12 12/Q16



Which statement about the forces acting on the boat is correct

A The gravitational force is equal to the viscous force

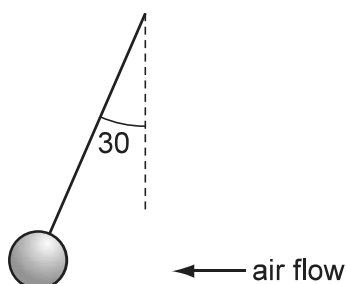
B The gravitational force is greater than the upthrust

C The upthrust is zero

D The viscous force is zero

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

9702/11 12/Q15



The mass of the ball is 0.15 kg.

The angle between the string and the vertical is 30°.

Calculate the force exerted on the ball by the air flow.

- A 0.075 B 0.087 C 0.26 D 0.30

106 A student places a 30 cm ruler on a fulcrum set at the 15 cm mark. A mass of 20 g is placed at the 7 cm mark and a 50 g mass is placed at the 23 cm mark.

9702/11 12/Q16



Calculate the mass that should be placed at the 7 cm mark to restore the balance.

- A 30 g B 40 g C 47 g D 133 g

107 A seagull is in a steady state at a constant velocity. The three forces that act on the seagull are the normal contact force C , the weight W , and a constant frictional force F .

9702/11 12/Q17

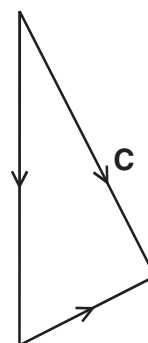
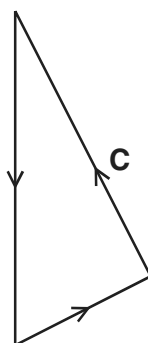
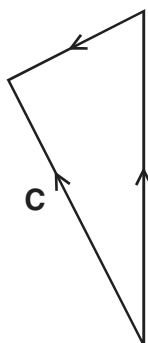
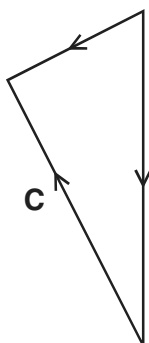
The diagram represents these forces acting on the seagull.

A

B

C

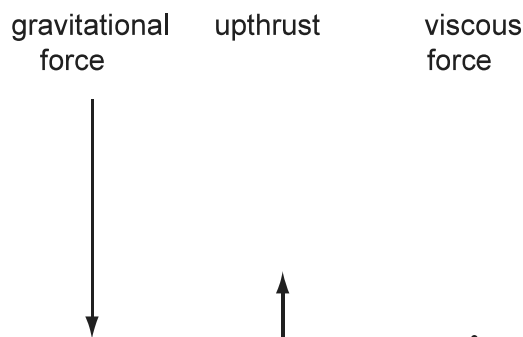
D



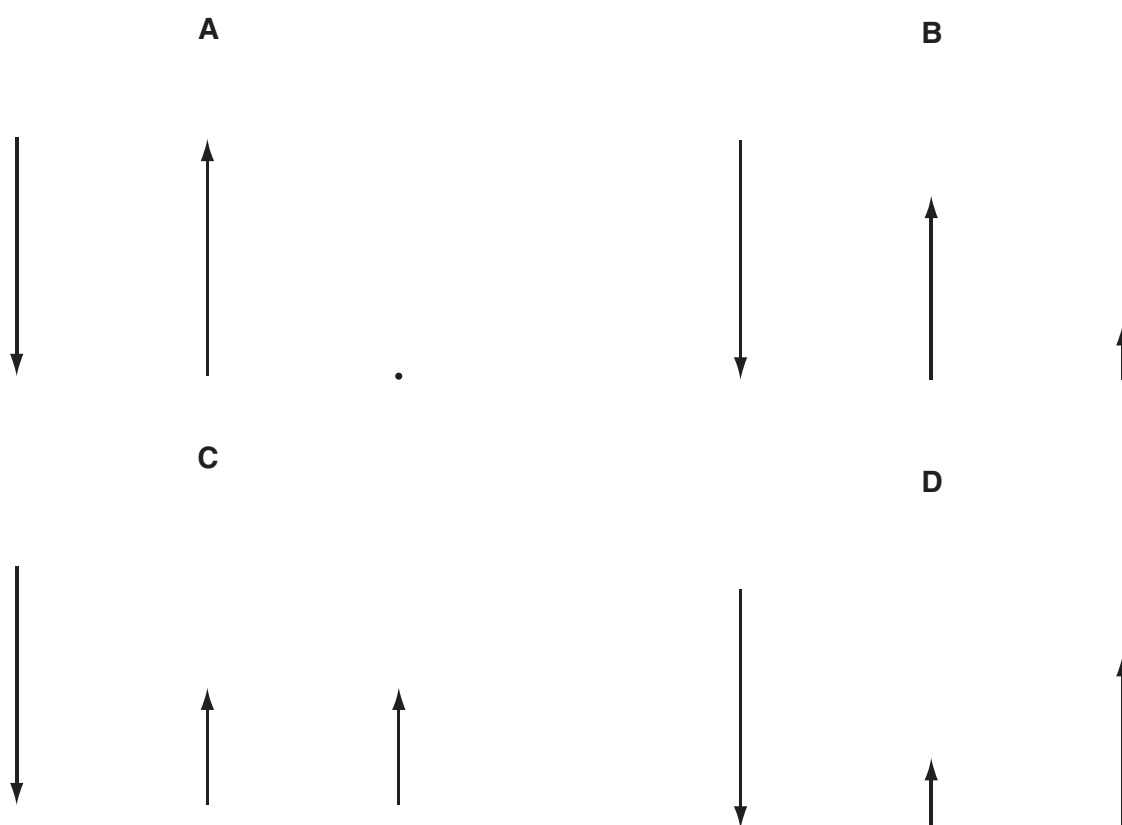
- 108 A ball is initially stationary at the base of a smooth vertical tube. As the ball starts to fall, a diagram shows the magnitudes and directions of the forces acting on the ball as it starts to fall.

9702/13

12/Q15



As the ball falls, a diagram shows the magnitudes and directions of these forces when the ball attains a terminal speed in the air of uniform density.



- 109 A car travelling at 28 ms^{-1} passes a motor car on a level road. The motor car is 22 m behind the motor car.

9702/13

12/Q18

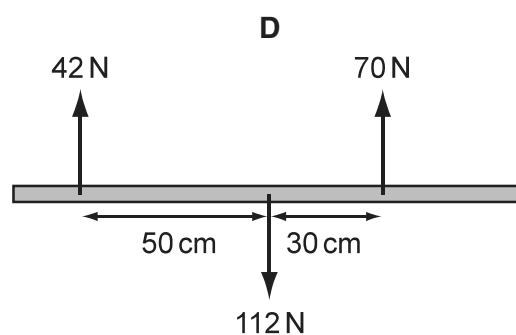
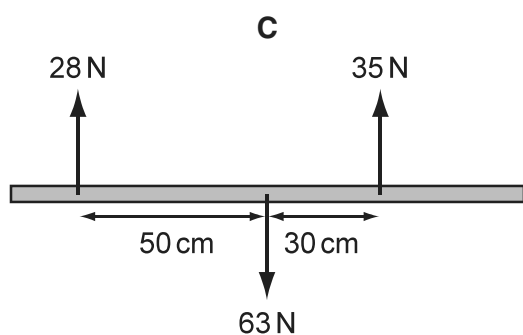
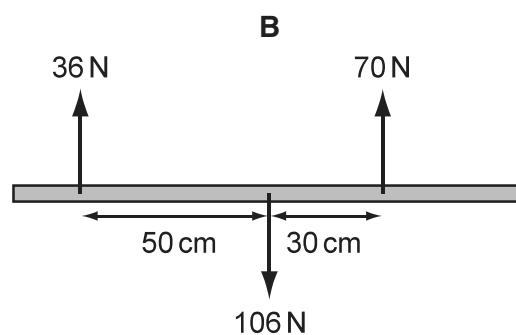
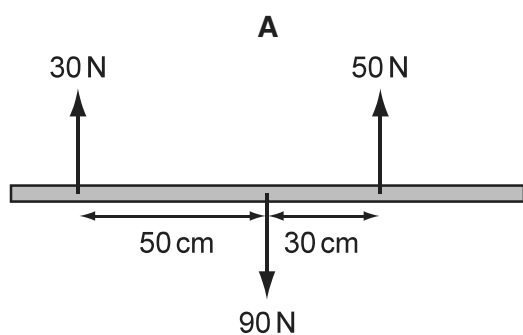
The force of gravity is considered negligible. The car at the end of the road is

- A 7.3 ms^{-1} B 19 ms^{-1} C 21 ms^{-1} D 24 ms^{-1}

110 Four beams of the same length each have three forces acting on them

9702/13 12/Q16

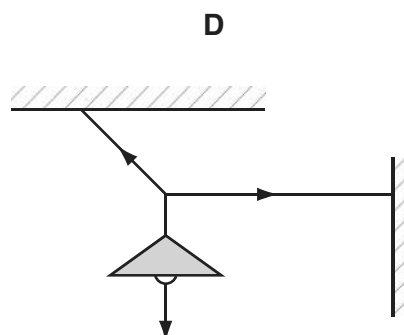
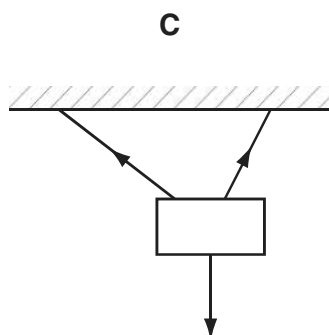
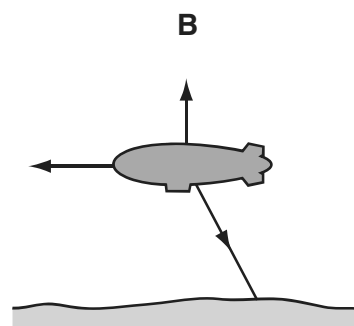
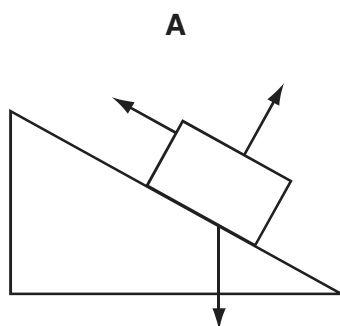
Which beam has the greatest resultant force and the greatest resultant torque acting



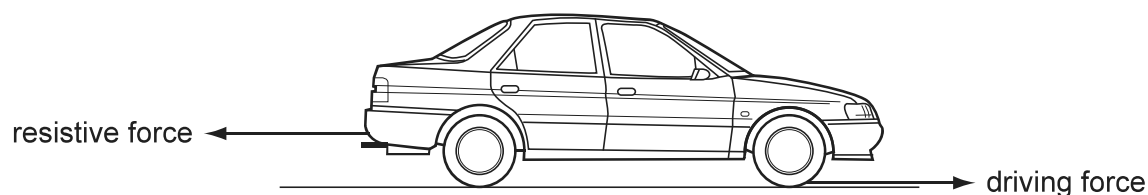
111 The diagrams show the forces acting on different objects

9702/13 12/Q17

Which object cannot be in equilibrium



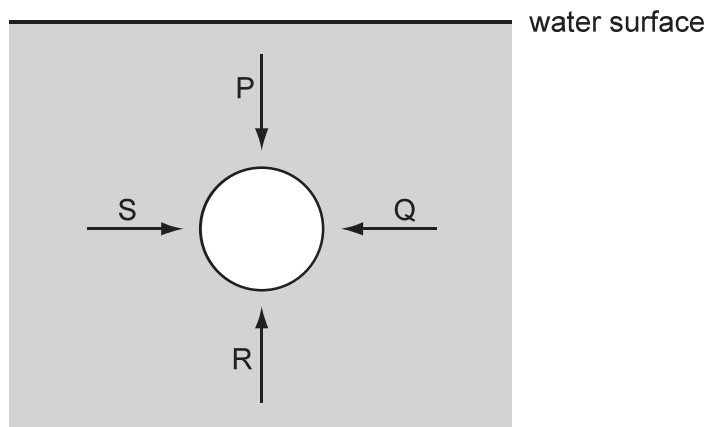
- 112 A car of mass 750 kg has a driving force of 2000 N acting on it that gives it an acceleration of 2.0 ms^{-2} 9702/11 13/Q12



What is the resistive force acting on the car?

- A 0.50 B 1.5 C 2.0 D 3.5

- 113 The diagram represents a sphere under the action of four forces. Which of the following are the forces acting on the sphere? 9702/11 13/Q15



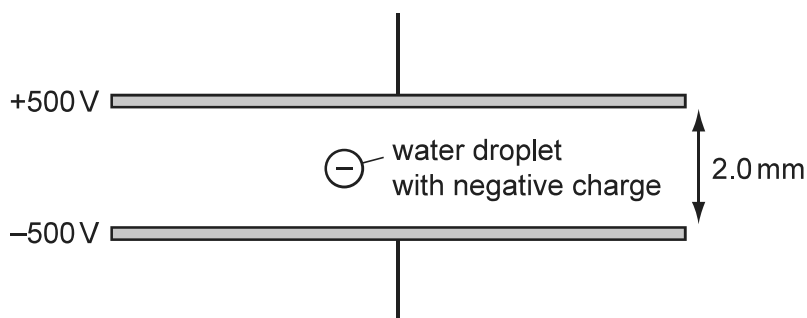
Which force acts perpendicular to the sphere's surface and acts in opposite directions to the other three forces?

Which of the following is the correct information about the magnitudes of the forces?

- A $P = Q = R = S$
 B $P = Q \neq R = S$
 C $P = R \neq Q = S$
 D $P = S \neq Q = R$

- 114 A small water droplet of mass 3.0 g carries a charge of $6.0 \times 10^{-11} \text{ C}$ and is situated in the uniform gravitational field between two parallel metal plates. The potential of the upper plate is 500 V and the potential of the lower plate is -500 V .

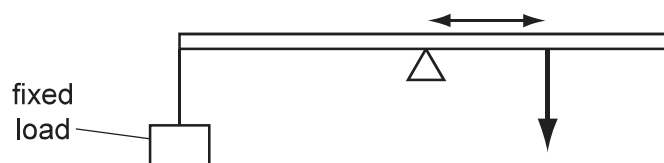
9702/11 13/Q13



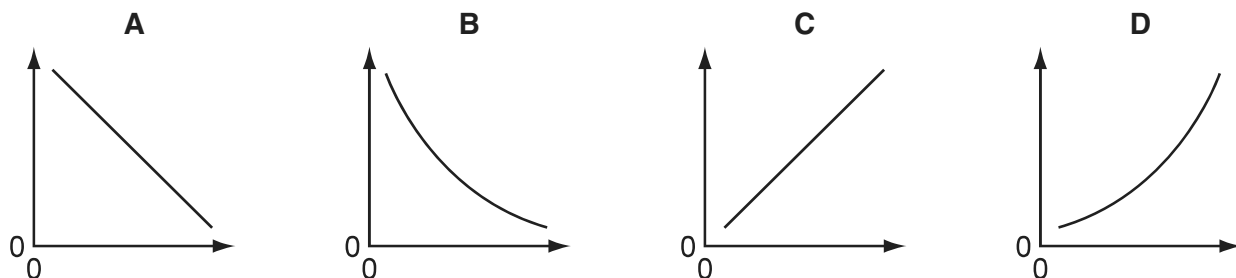
What is the motion of the droplet?

- A it accelerates downwards
 B it remains stationary
 C it accelerates upwards
 D it moves upwards at a constant velocity
- 115 A horizontal bar is supported on a pivot at its centre of gravity. A load is attached to one end of the bar and the other end is free. The bar is in equilibrium. A force is applied at a distance from the pivot.

9702/11 13/Q14



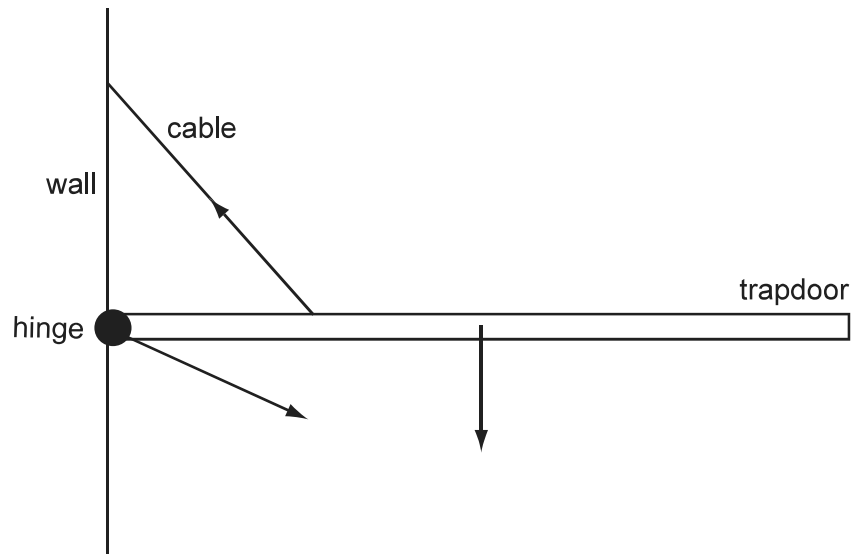
Which graph shows the variation of the force applied with the distance from the pivot?



116 A hinge trapdoor is in equilibrium in the horizontal position as shown

9702 11 13/Q16

Three forces act on the trapdoor: the weight of the door, the tension in the cable and the reaction force at the hinge.

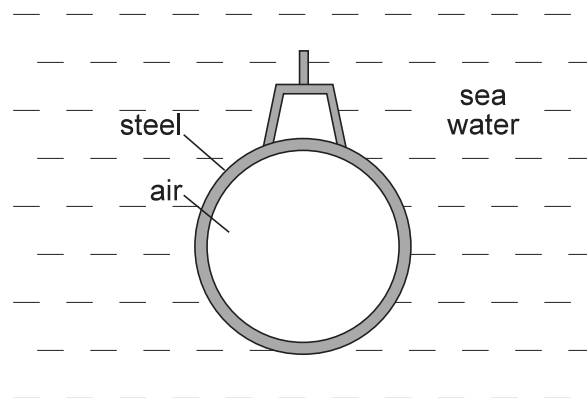


Which of the following represents the three forces in increasing order of magnitude?

- A B C D

117 A submarine is in equilibrium in a fully submerged position

9702 12 13/Q11



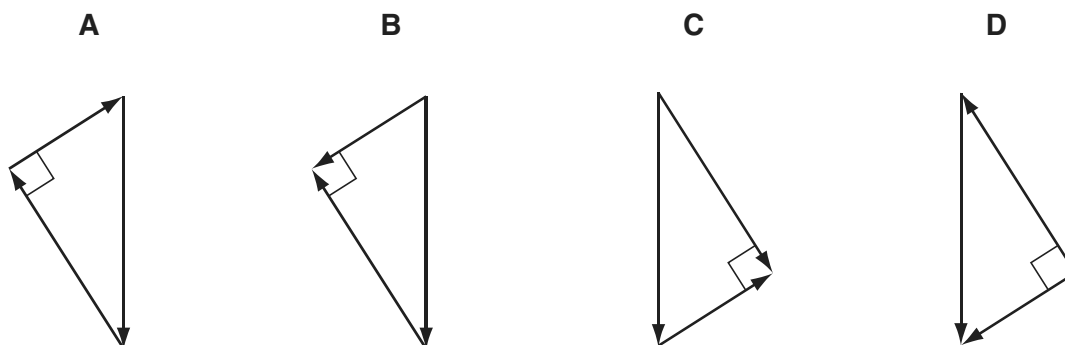
What causes the upward thrust on the submarine?

- A The air in the submarine is less dense than sea water
 B The sea water exerts a greater upward force on the submarine than the weight of the steel
 C The submarine displaces its own volume of sea water
 D There is a difference in water pressure acting on the top and on the bottom of the submarine

- 118 A piece is at rest on a surface. It is considered to have three forces acting on it to keep it in equilibrium. 9702/12 13/Q12

These are its weight, a normal reaction force and a frictional force.

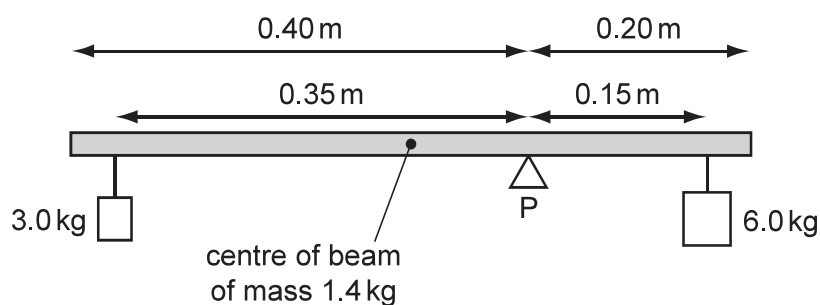
Which triangle of forces is correct?



- 119 A system of forces on a body is in equilibrium. 9702/12 13/Q13

Which statement must be correct?

- A The body does not move.
 B The momentum of the body remains unchanged.
 C The speed of the body remains unchanged.
 D The total kinetic and potential energy of the body remains unchanged.
- 120 A uniform beam of mass 1.4 kg is pivoted at its centre. The beam has a length of 0.60 m and is 0.20 m from one end. A mass of 3.0 kg and a mass of 6.0 kg are suspended 0.35 m and 0.15 m from the pivot respectively. 9702/12 13/Q14

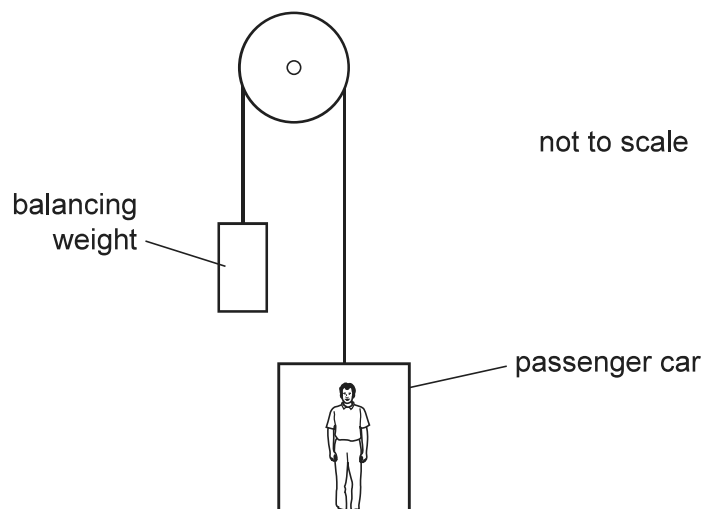


At what distance must a 1.0 kg mass be suspended from the other end to maintain the beam in equilibrium?

- A 0.010 m B 0.10 m C 0.29 m D 2.8 m

- 121 A trolley consists of a passenger car supported by a cable which runs over a light frictionless pulley to a balancing weight. The balancing weight is suspended and the passenger car rises.

9702/13 13/Q9



Some masses are shown in the table.

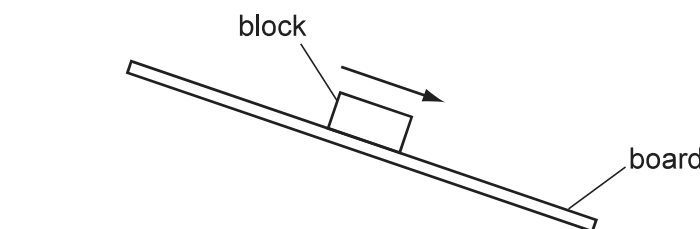
	mass g
passenger car	520
balancing weight	640
passenger	80

What is the magnitude of the acceleration of the car when carrying just one passenger and the pulley is free to rotate?

- A 0.032 ms^{-2} B 0.32 ms^{-2} C 0.61 ms^{-2} D 0.65 ms^{-2}

- 122 A wooden block rests on a rough board. The end of the board is then raised until the block slides down the board at constant velocity.

9702/13 13/Q13

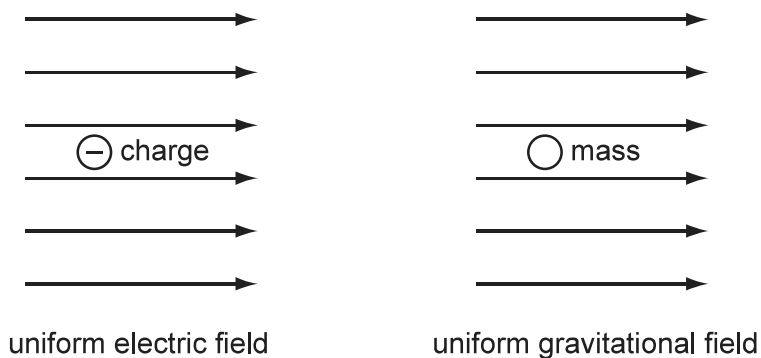


Which row describes the forces acting on the block when it is sliding at constant velocity?

	frictional force on block	resultant force on block
A	down the board	down the board
B	down the board	zero
C	up the board	down the board
D	up the board	zero

- 123 Diagrams show a negative electric charge situated in a uniform electric field and a mass situated in a uniform gravitational field

9702 13 13/Q12

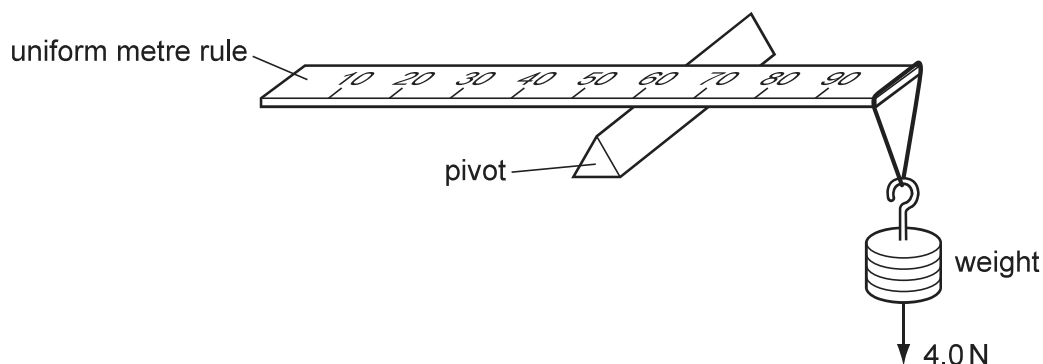


Indicate the directions of the forces acting on the charge and on the mass

	charge	mass
A		
B		
C		
D		

- 124 A uniform metre rule of weight 2.0 N is pivoted at the 60 cm mark. A 4.0 N weight is suspended from one end causing the rule to rotate about the pivot

9702 11 13/Q15



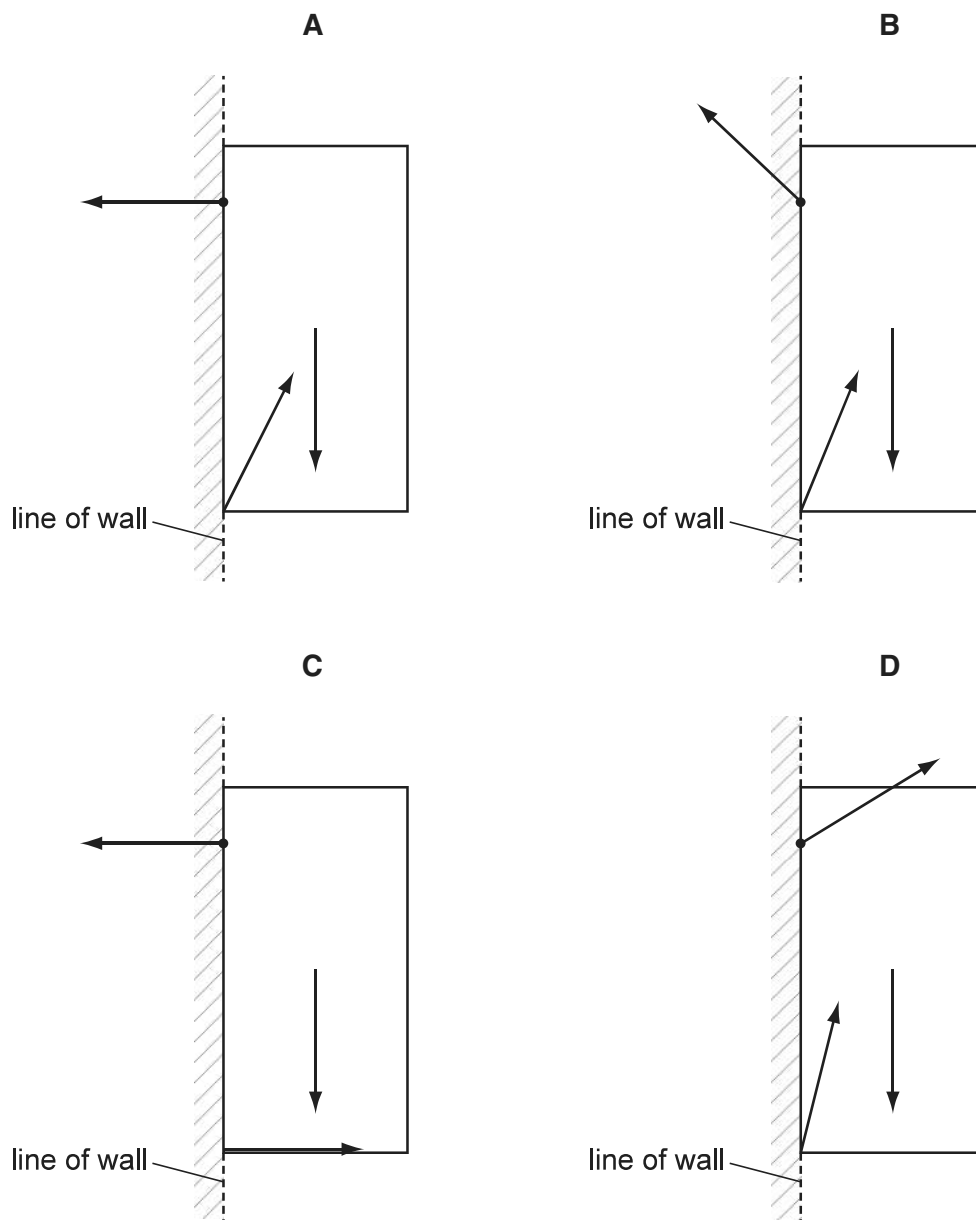
At the instant when the rule is horizontal, what is the resultant turning moment about the pivot?

- A zero B 1.4 N C 1.6 N D 1.8 N

128 A cupboard is attached to a wall by a screw.

9702/13 13/Q14

In the force diagrams of the cupboard in equilibrium, the weight of the cupboard acts downwards from the centre of the cupboard. The force that the screw exerts on the cupboard and the force that the wall exerts on the cupboard are shown in the diagrams.



129 e iagramss o t o a so anging t e same icture

9702 11 14/Q11

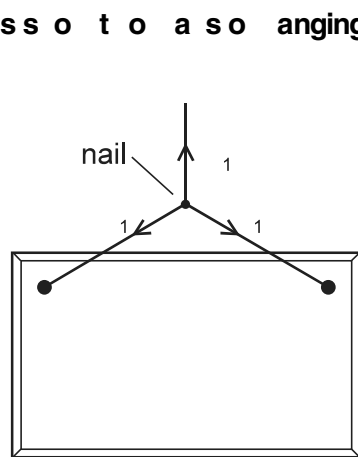


diagram 1

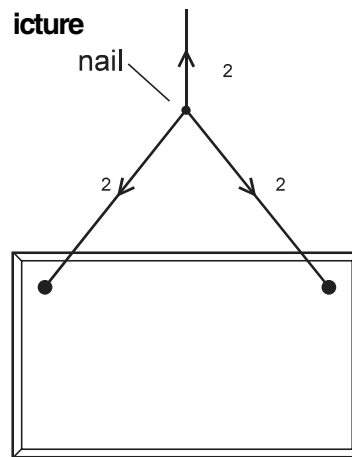


diagram 2

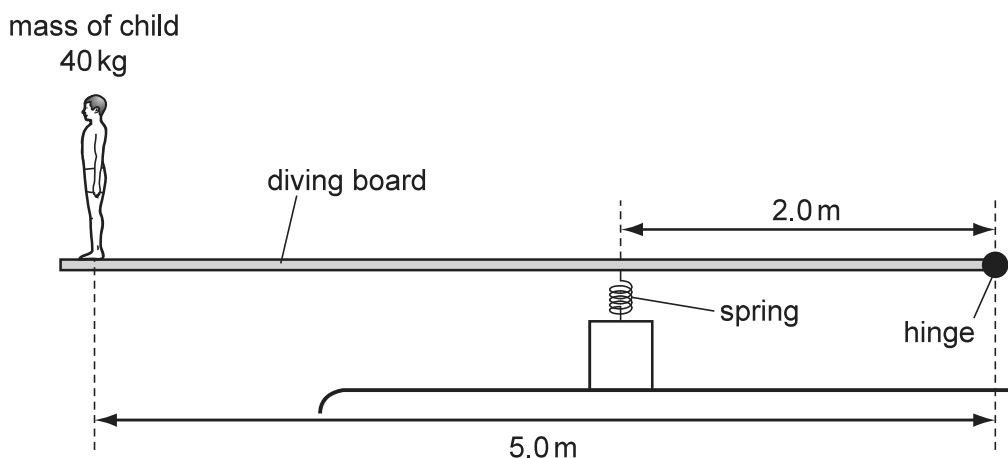
n ot cases a string is attac e to t e same oints on t e icture an oo e s mmetrica
o er a nai in a a e orces s o n are t ose t at act on t e nai

n iagram 1 t e string oo is s orter t an in iagram 2

ic in ormation a out t e magnitu e o t e orces is correct

- A 1 2 1 2
B 1 2 1 2
C 1 2 1 2
D 1 2 1 2

130 A i ing oar o engt 5.0 m is inge at one en an su orte 2.0 m rom t is en a s ring
o s ring constant 10 N m^{-1} A c i o mass 40 g stan s att e are n o t e oar 9702 13 13/Q15

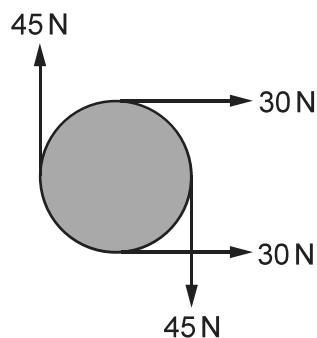


at is t e e tra com ression o t e s ring cause t e c i stan ing on t e en o t e
oar

- A 10 cm B 16 cm C 98 cm D 16 cm

131 The diagram shows four forces acting on a circular object

9702/12 14/Q13

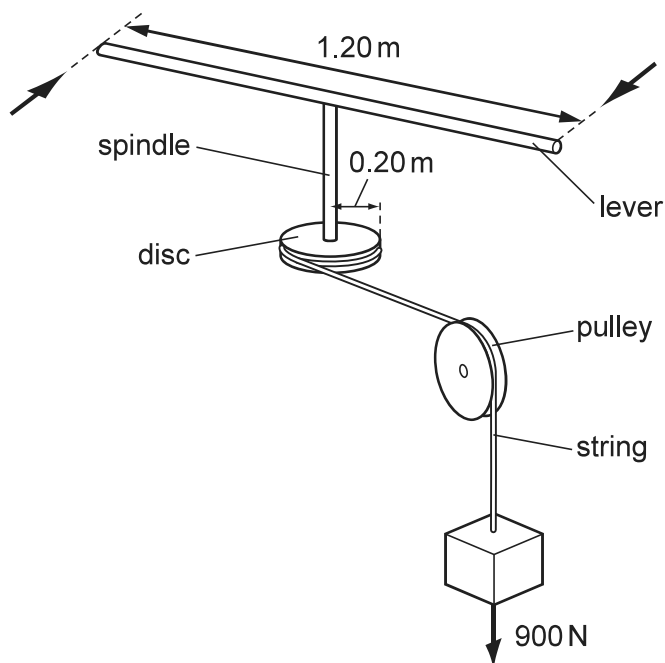


Which of the following describes the resultant force and the resultant torque on the object?

	resultant force	resultant torque
A	non zero	non zero
B	non zero	zero
C	zero	non zero
D	zero	zero

132 A string is attached at one end to the centre of a lever of length 1.20 m and at its other end to the centre of a disc of radius 0.20 m. A string is wrapped round the disc, passes over a pulley and is attached to a 900 N weight.

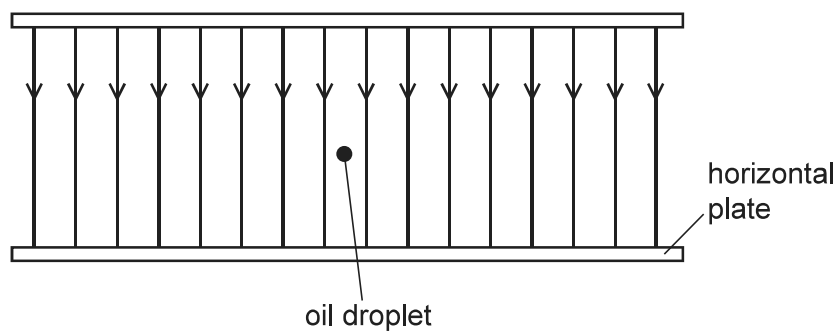
9702/11 14/Q13



What is the minimum force applied to each end of the lever to lift the weight?

- A 75 B 150 C 300 D 950

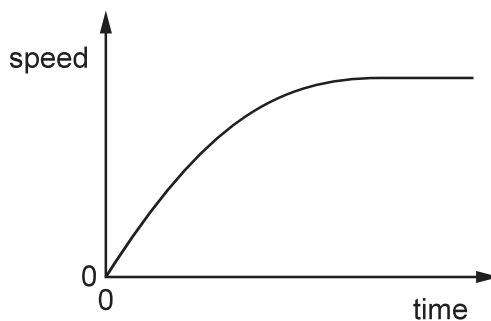
- 133 A tin of rosettes has a mass $6.9 \times 10^{-13} \text{ g}$ is at rest in an electric field of electric field strength $2.1 \times 10^7 \text{ C}^{-1} \text{ as s o n}$ 9702 12 14/Q12



The weight of the rosette acts downwards. The electric force on the rosette acts upwards.

- A $3.3 \times 10^{20} \text{ C}$
 B $3.3 \times 10^{20} \text{ C}$
 C $3.2 \times 10^{19} \text{ C}$
 D $3.2 \times 10^{19} \text{ C}$

- 134 The graph shows the variation of speed of a rain droplet falling through air 9702 12 14/Q11



Which statement is correct?

- A The acceleration decreases to produce a steady speed
 B The acceleration increases as the speed increases
 C The air resistance decreases as the speed increases
 D The resultant force increases as the speed increases

135 At what condition or conditions must the forces on an object be in equilibrium?

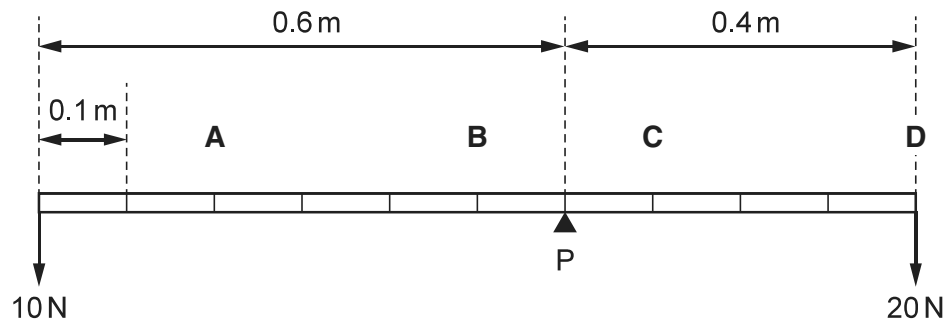
9702/13 14/Q13

- A The objects must be at rest and the resultant force on it must be zero.
- B The objects must be at rest and the resultant force on it must be zero.
- C The resultant force and the resultant torque on the object must both be zero.
- D The resultant force on the object must be zero.

136 A uniform beam is pivoted at its centre. Weights of 10 N and 20 N are attached to its ends. The length of the beam is 1.0 m. The beam is released from rest at an angle of 30° to the horizontal. The beam is released from rest at an angle of 30° to the horizontal.

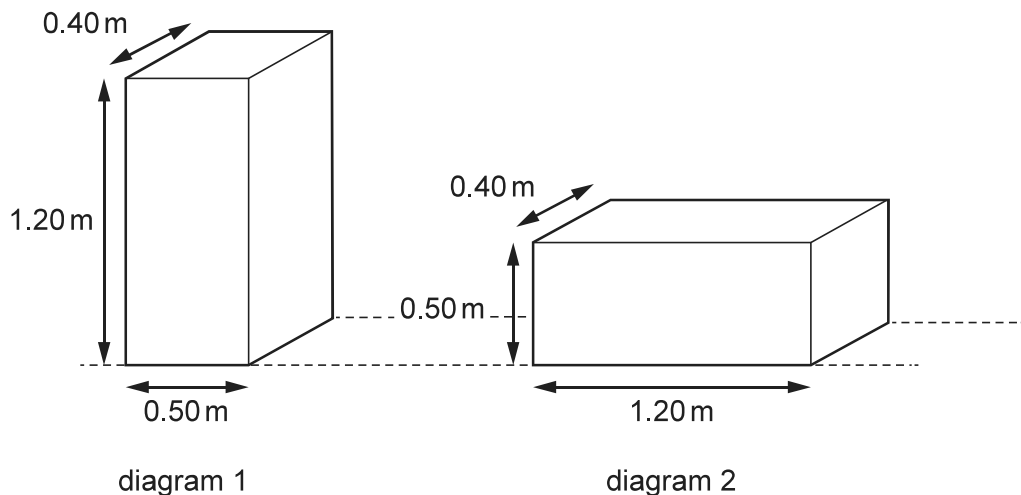
At which point is the beam in equilibrium?

9702/13 14/Q15



137 A uniform solid concrete block of dimensions 0.50 m × 1.20 m × 0.40 m and weight 4000 N rests on a flat surface. It is tilted to the position shown in diagram 2.

9702/13 14/Q14



What is the minimum energy required to rotate the block through 90° to the position shown in diagram 2?

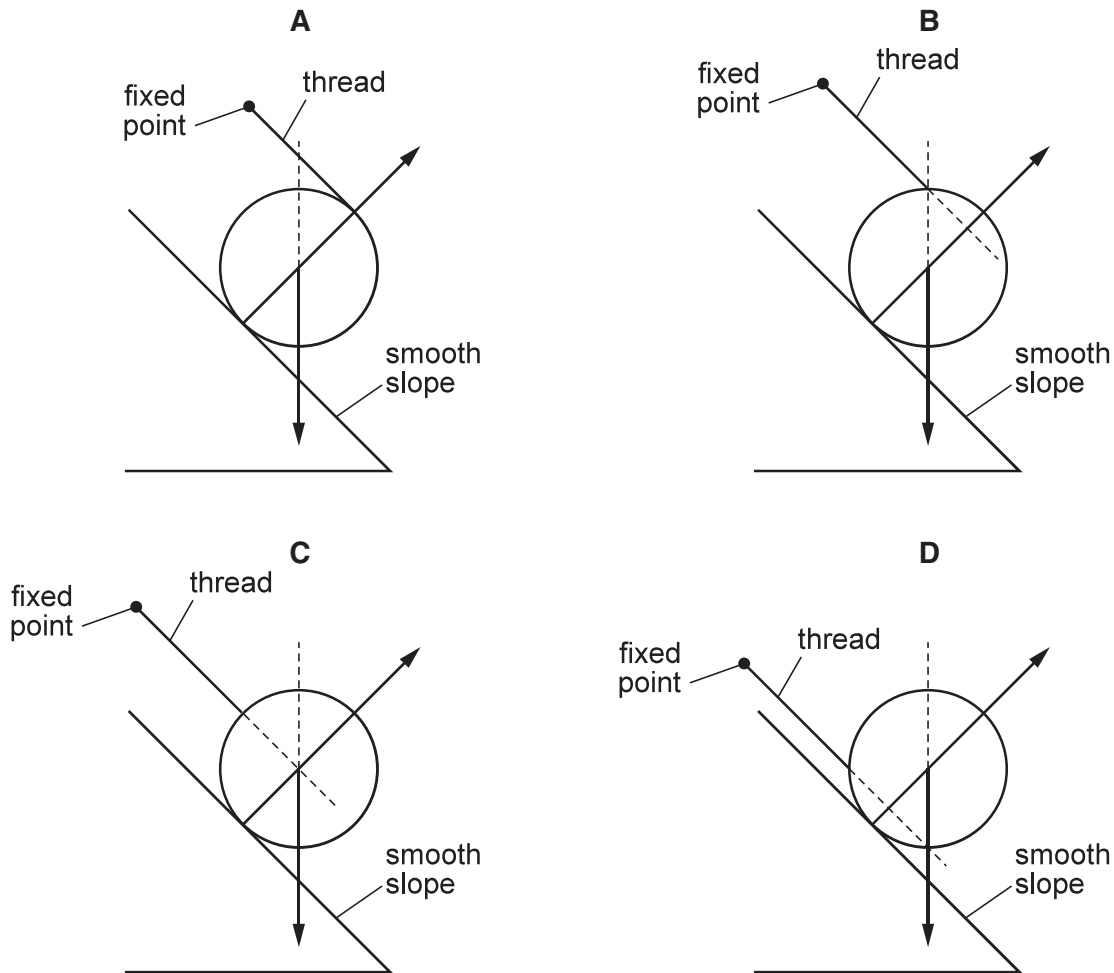
- A 200
- B 400
- C 1400
- D 2600

- 138 A cylinder is placed on a smooth surface. The contact force of the surface on the cylinder is $\vec{F}$. The reaction force to $\vec{F}$ is $\vec{R}$. The reaction force to $\vec{F}$ is $\vec{R}$.

9702/13

14/Q13

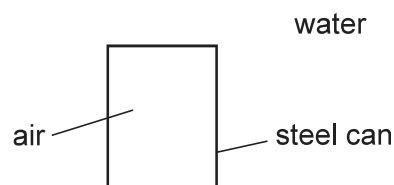
Which diagrams show the cylinder in equilibrium?



- 139 A sealed rigid steel can is situated below the surface of water.

9702/13

14/Q12



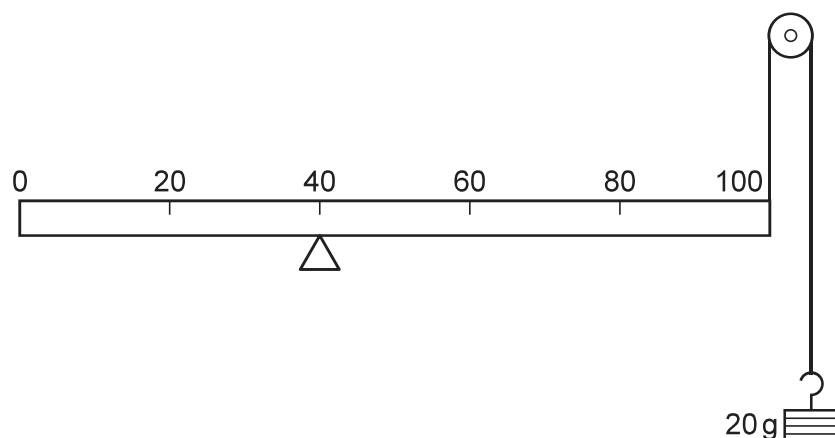
What is the origin of the upthrust that acts on the can?

- A The air pressure in the can is less than the water pressure outside the can.
 B The average density of the air and steel is less than the density of water.
 C The water pressure on the bottom of the can is greater than the water pressure on the top.
 D The weight of the can is less than the weight of the water displaced by the can.

- 140 A uniform metre rule of mass 100 g is supported at its left end at the 40 cm mark. A string at the 100 cm mark is attached to a string passes round a frictionless pulley and carries a mass of 20 g as shown in the diagram.

9702 13

14/Q14



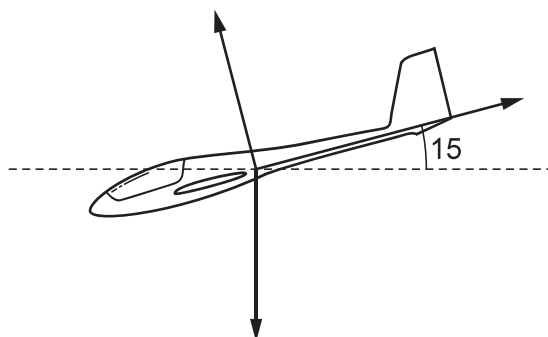
At this mark on the rule must a 50 g mass be suspended so that the rule is balanced.

- A 4 cm B 36 cm C 44 cm D 64 cm

- 141 A glider is ascending at constant speed at an angle of 15° to the horizontal. The diagram shows the forces acting on the glider.

9702 11

14/Q10



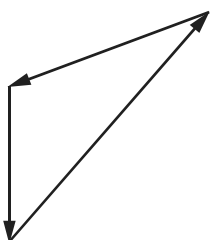
Which vector triangle could represent the forces acting on the glider?

A

B

C

D



- 142 A car is accelerating at terminal speed in still air. The forces acting on the car are up thrust, viscous drag and weight.

9702/11 14/Q11

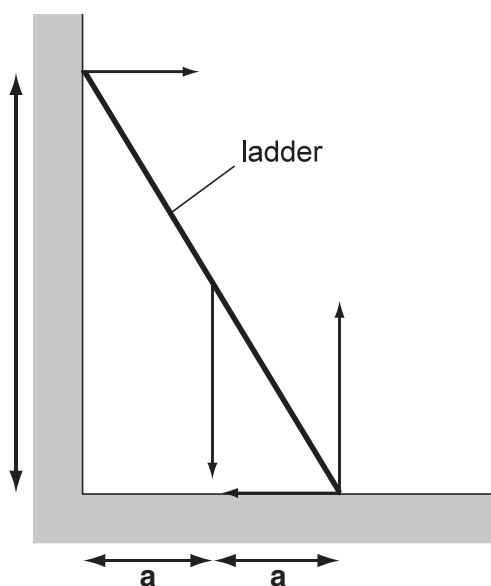
At this speed, the increasing magnitude of these three forces

- A up thrust $\rightarrow$ viscous drag $\rightarrow$ weight
- B viscous drag $\rightarrow$ up thrust $\rightarrow$ weight
- C viscous drag $\rightarrow$ weight $\rightarrow$ up thrust
- D weight $\rightarrow$ up thrust $\rightarrow$ viscous drag

- 143 A uniform ladder rests against a vertical wall where there is negligible friction. The bottom of the ladder rests on rough ground where there is friction. The top of the ladder is at a height a above the ground and the foot of the ladder is at a distance $2a$ from the wall.

9702/11 14/Q12

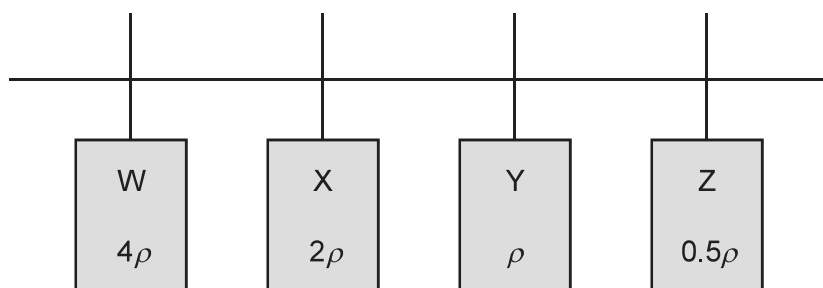
The diagrams show the forces that act on the ladder.



Which equation is correct for taking moments?

- A $a = 2a$
- B $a = a$
- C $a = 2a$
- D $a = 2a$

- 144 Four cubes of identical material are immersed in water. The cubes are at the same level and in identical orientations. The ratio of the weight of the cubes to the weight of the water displaced is
- 9702 13 15/Q14



Water has density ρ

Cube W is made of material of density 4ρ

Cube X is made of material of density 2ρ

Cube Y is made of material of density ρ

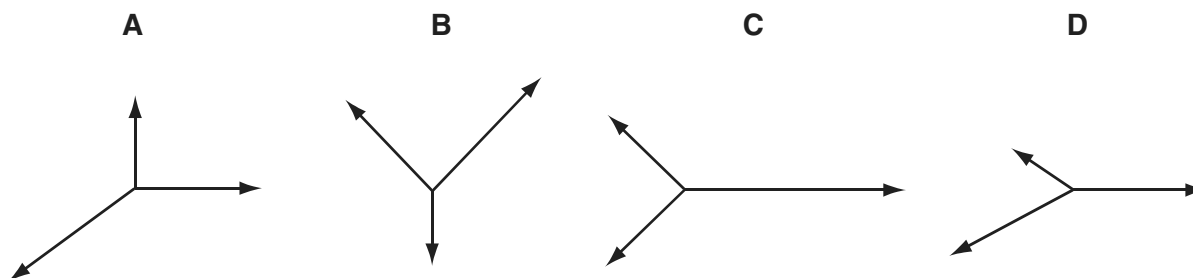
Cube Z is made of material of density 0.5ρ

Which statement is correct?

- A The upthrust on each of the cubes is the same
- B The upthrust on cube X is the same as the upthrust on cube Y
- C The upthrust on cube X is the same as the upthrust on cube Z
- D The upthrust on cube Z is zero

- 145 The diagrams represent systems of coplanar forces acting at a point. The length of the force vectors represents the magnitudes of the forces.
- 9702 13 15/Q16

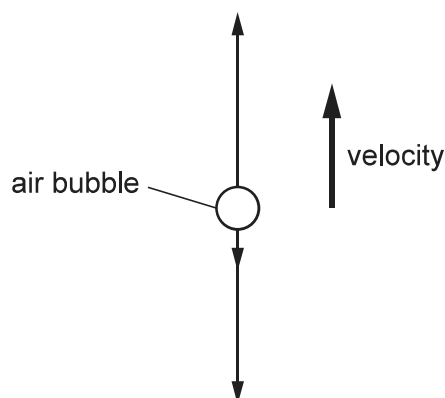
Which system of forces is in equilibrium?



- 146 What is a reasonable estimate of the average gravitational force acting on a young woman standing on the Earth?
- 9702 11 15/Q10
- A 60 B 250 C 350 D 650

- 147 An air bubble in a tank of water is rising at constant speed. The forces acting on the bubble are in equilibrium.

9702/13 15/Q15

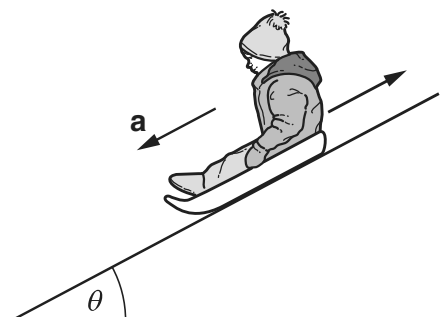


What are the three forces?

- A The weight of the bubble, the upthrust on the bubble and the drag force on the bubble.
- B The weight of the bubble, the upthrust on the bubble and the drag force on the bubble.
- C The weight of the bubble, the upthrust on the bubble and the drag force on the bubble.
- D The weight of the bubble, the upthrust on the bubble and the drag force on the bubble.

- 148 A skier is accelerating down a slope. The acceleration is at an angle θ to the horizontal.

9702/11 15/Q12



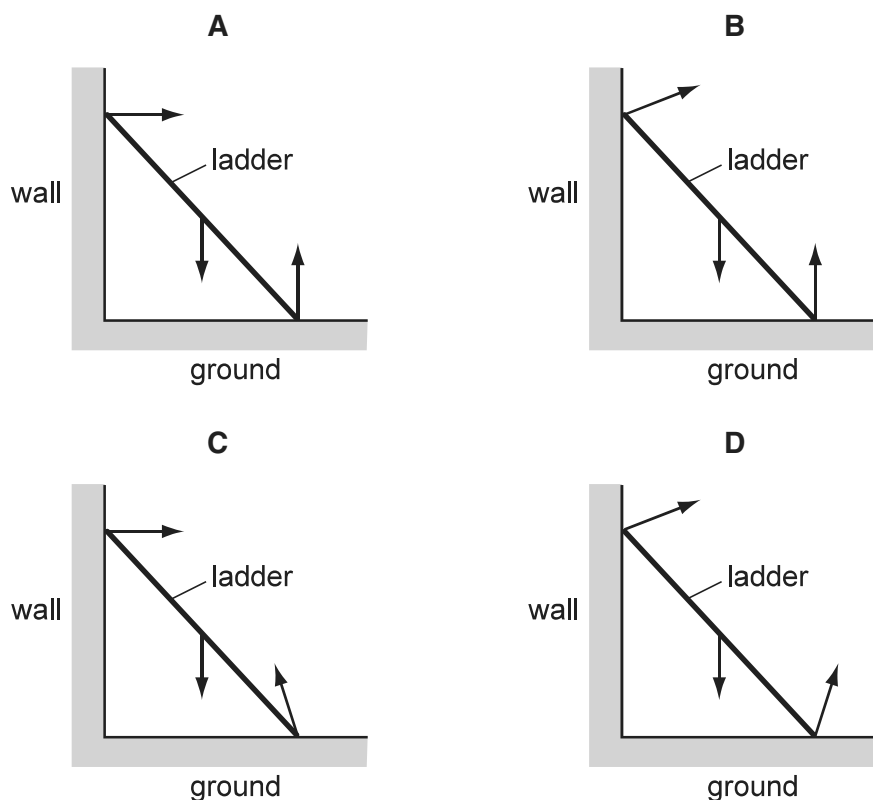
The total mass of the skier is m . The acceleration of the skier is a .

What is the friction force?

- A $mg \cos \theta - a$
- B $mg \cos \theta + a$
- C $mg \sin \theta - a$
- D $mg \sin \theta + a$

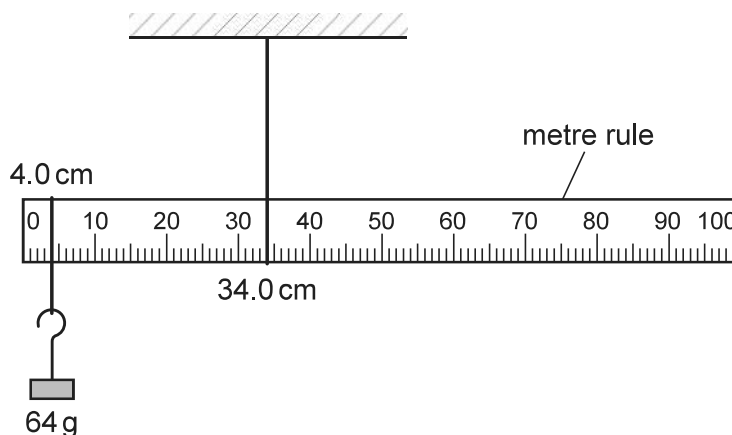
- 149 A ladder is positioned on a frictionless ground and leans against a rough wall. At the instant it is released it begins to slide. Which diagram correctly shows the directions of the forces acting on the ladder as it slides?

9702 12 15/Q14



- 150 A uniform metre rule is pivoted at the 34.0 cm mark as shown.

9702 11 15/Q15

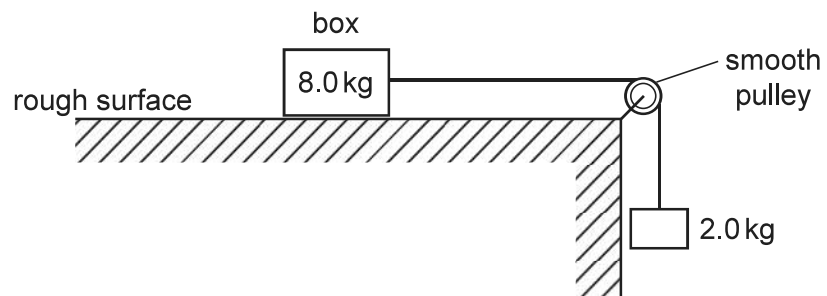


The rule balances when a 64 g mass is hung from the 4.0 cm mark. What is the mass of the metre rule?

- A 38 g B 44 g C 120 g D 136 g

- 151 A box of mass 8.0 kg rests on a horizontal rough surface. A string attached to the box passes over a smooth pulley and supports a 2.0 kg mass at its other end.

9702/11 15/Q13



When the box is released, a frictional force of 6.0 N acts on it.

What is the acceleration of the box?

- A 1.4 ms^{-2} B 1.7 ms^{-2} C 2.0 ms^{-2} D 2.6 ms^{-2}