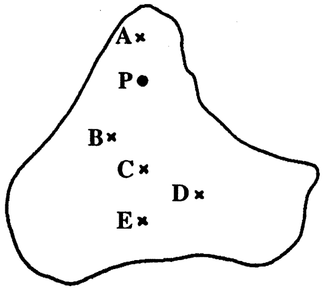
TOPIC 5 Turning Effect of Forces

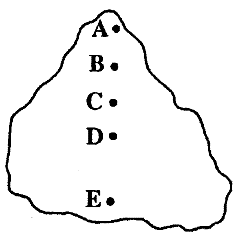
1 The diagram shows a vertical piece of card pivoted freely at **P**. Which labelled point is most likely to be at the centre of mass?



N91/I/4

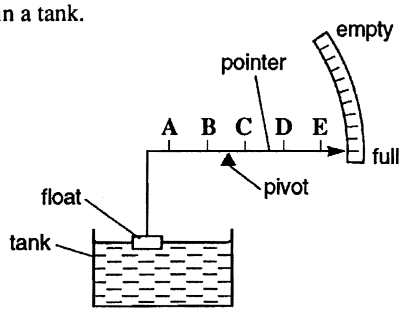
2 A pin is stuck through a lamina at position **B**. The lamina is allowed to swing freely and comes to rest as shown.

Which position is most likely to be the centre of mass of the lamina?



J92/I/3

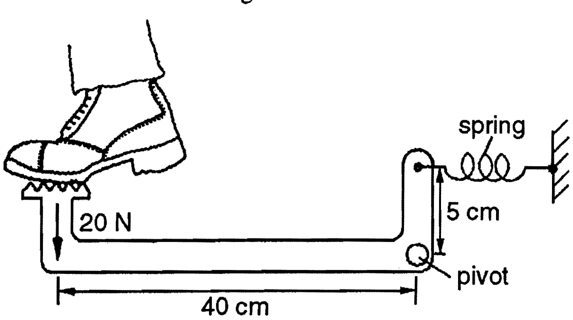
3 The diagram shows a gauge which measures the amount of liquid in a tank.



At which position should the pivot be placed so that the pointer moves the greatest distance as the tank is emptied?

J92/I/6

4 A driver's foot presses on a pedal in a car with a force of 20 N as shown in the diagram.

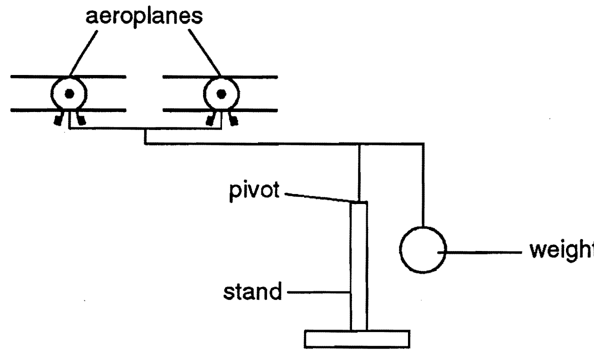


With what force is the spring pulled?

A 2.5 N
B 10 N
C 100 N
D 160 N
E 800 N

N92/I/6

5 The diagram shows a balancing toy pivoted on a stand. If the toy is tilted slightly, it does not overbalance but returns to its original position.

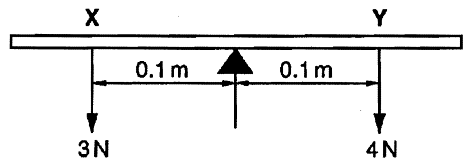


This is because the centre of mass of the toy is

A between the aeroplanes.
B below the pivot.
C exactly at the pivot.
D inside the weight.

J94/I/4

6 The diagram shows a uniform beam pivoted at its centre. Forces of 3 N and 4 N act in the directions shown.



What is the size and position of the **upward** force which will prevent the beam from turning?

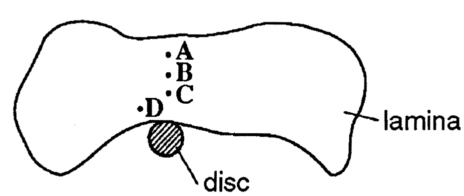
	size	position
A	1 N	**X**
B	1 N	**Y**
C	7 N	**X**
D	7 N	**Y**

J94/I/7

7 The centre of mass of the lamina in the diagram is at **B**.

A disc is then attached as shown.

Which letter shows a possible position of the centre of mass of the lamina-disc combination?



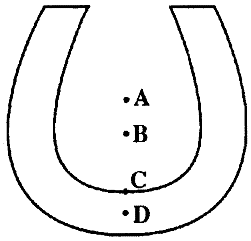
N94/I/4

8 Why does a racing car have a low centre of mass?

A to balance the acceleration of the tyres
B to help the car accelerate uniformly when the race starts
C to improve the grip of the tyres
D to keep the car stable N95/I/3

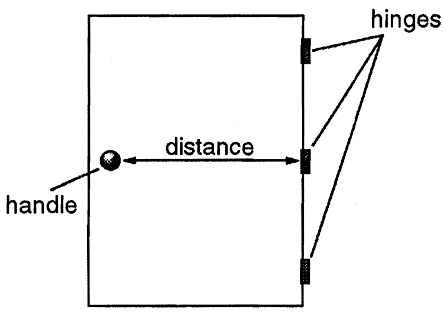
9 A horseshoe-shape is cut from a uniformly thick piece of cardboard as shown.

Which letter is at the centre of mass of the piece of cardboard?



J93/I/4 ; J96/I/4

10 A door requires a minimum moment of 32.5 N m in order to open it.



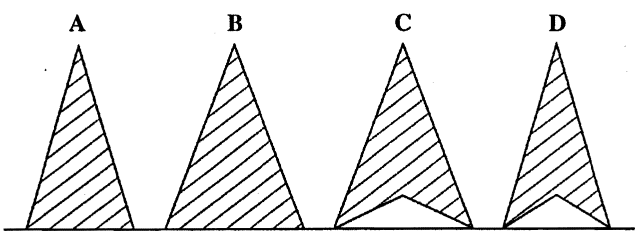
What is the minimum distance of the handle from the hinges, if the door is to be pulled open with a force at the handle not greater than 50 N?

A 0.33 m **B** 0.65 m **C** 0.77 m **D** 1.54 m
J96/I/7

11 Why is it better to use a long spanner rather than a short one to tighten a nut on a bolt?

A Less force needs to be exerted by the user.
B Less friction is present.
C Less turning effect is required on the spanner.
D Less work is done by the user. J97/I/7

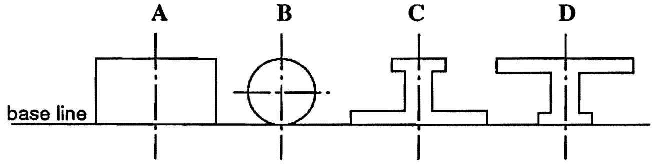
12 The diagrams show cross-sections of four solid objects. Which object is most stable?



N97/I/5

13 The diagram shows four shapes, cut from the same piece of card.

Which shape has its centre of mass nearest to the base line?



N98/I/4

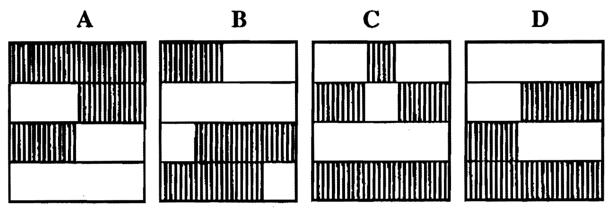
14 If a nut and bolt are difficult to undo, it may be easier to turn the nut by using a longer spanner.

This is because the longer spanner gives

A a larger turning moment.
B a smaller turning moment.
C less friction.
D more friction. N98/I/6

15 Books are placed in four bookcases as shown.

Which bookcase is **most** likely to fall forward if pulled a little?



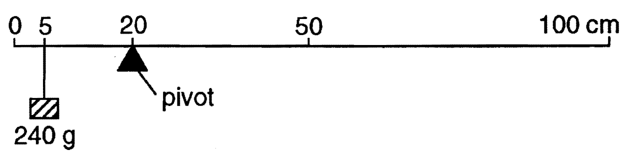
J91/I/4; J99/I/3

16 A spanner is used to loosen a nut. The turning effect depends on the force applied and the perpendicular distance from the force to the nut.

Which name is given to the turning effect?

A moment
B pivot
C pressure
D resultant J99/I/5

17 The diagram shows a metre rule pivoted off-centre but kept in equilibrium by a suspended mass of 240 g.

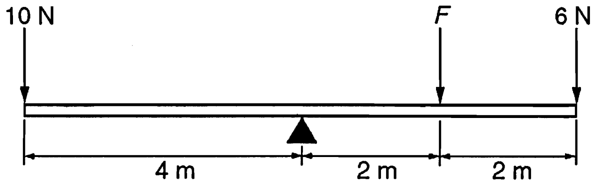


The centre of mass of the rule is at the 50 cm mark.

What is the mass of the rule?

A 12 g
B 24 g
C 45 g
D 120 g N99/I/7

18 A pivoted uniform bar is in equilibrium under the action of the forces shown.



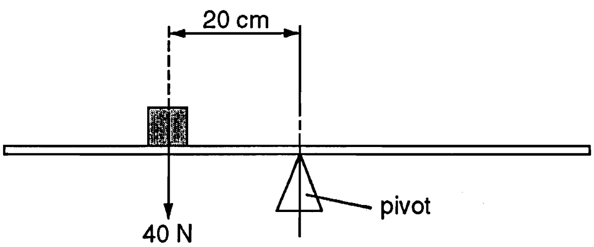
What is the magnitude of the force *F*?

A 2 N
B 4 N
C 8 N
D 14 N

J2000/I/7

19 A uniform beam is pivoted at its midpoint. An object is placed on the beam as shown.

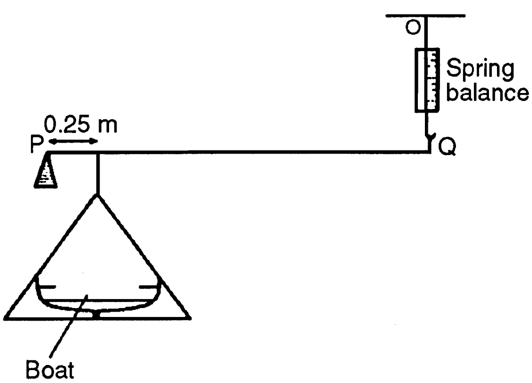
Which force will re-balance the system?



A 20 N acting downwards, 40 cm to the right of the midpoint
B 20 N acting upwards, 40 cm to the right of the midpoint
C 50 N acting downwards, 10 cm to the right of the midpoint
D 50 N acting upwards, 10 cm to the left of the midpoint

N2000/I/7

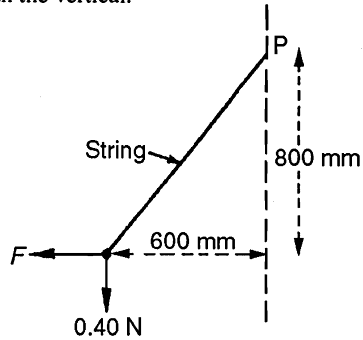
20



The diagram shows a *uniform* plank PQ which is supported at P and has length 4.0 m and weight 70 N. A small boat is suspended as shown from a point which is 0.25 m from the end P of the plank. The other end, Q, of the plank is supported by a spring balance fixed to the point O, so that the plank is horizontal. The spring balance reads 110 N. Calculate the weight of the boat. The weight of the sling holding the boat may be neglected.

J79/I/3

21 A small pendulum bob, weight 0.40 N, is suspended by a string from a point P. The bob is drawn aside by a horizontal force *F*, as shown in the diagram, so that the string makes an angle with the vertical.



The bob remains at rest in this position.

(a) By considering moments of forces about P, calculate the magnitude of the force *F*.

(b) A third force *T*, the tension in the string, acts on the bob. Why does the action of this force have no effect on your calculation?

N79/I/3

22 *(a)* State the relation which must be satisfied by the moments of the forces acting on a body which is balanced, and at rest, on a fulcrum.

(b) The apparatus shown in Fig. 1 was set up and used in an attempt to test the Principle of Moments. Describe the procedure you would follow, and list the measurements you would make.

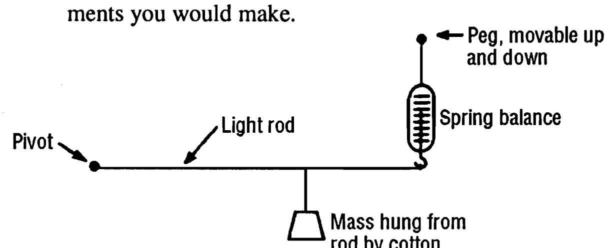


Fig. 1

Explain why in another experiment using a heavy rod instead of a light one, the weight of the rod must be taken into account.

(c)

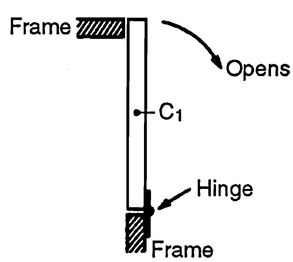


Fig. 2 (i)

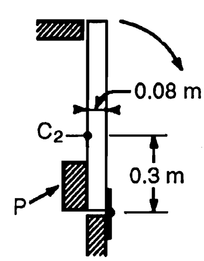


Fig. 2 (ii)

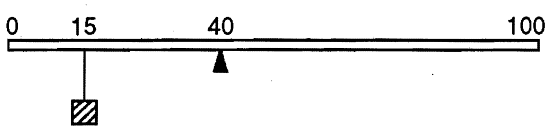
Fig. 2 (i) shows a section through a vertical locker door with a horizontal hinge along its lower edge. C_1 is the position of the centre of gravity of the door, and the door opens in the direction indicated. Fig 2 (ii) shows the door with a piece of wood, P, attached to it so that the door is less liable to fall open; the position of the centre of gravity of the door and the wood is C_2. Explain why the door is now less likely to fall open.

The total mass of the door and the wood is 6.0 kg, and the force of gravity may be taken to be 10 N/kg. Using the dimensions given in Fig. 2 (ii), calculate the turning moment holding the door closed when it is in the vertical position.

The hinge allows the door to turn until it is horizontal. Calculate the turning moment acting on the door when it is in this position. J80/II/7

23 What is meant by the *centre of gravity* of an object?

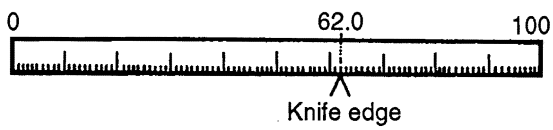
A metre rule is supported on a knife edge placed at the 40 cm graduation. It is found that the metre rule balances horizontally when a mass which has a weight of 0.45 N is suspended at the 15 cm graduation, as shown in the, diagram.



Calculate the *moment*, about the knife edge in this balanced condition, of the force due to the mass of the rule.

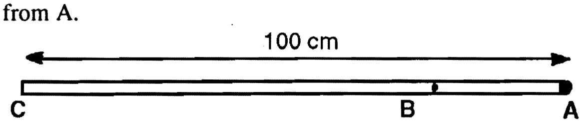
If the weight of the rule is 0.90 N, calculate the position of its centre of gravity. N80/II/7

24 A knife edge is placed at the 62.0 cm mark of the *uniform* metre rule shown in the diagram. In order to balance the rule horizontally, a weight of 0.24 N is hung from one end. Show this weight on the diagram and also mark the weight W of the rule acting in the correct position.



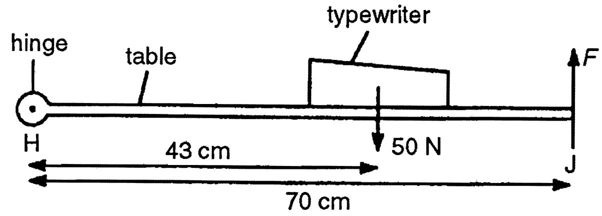
Calculate the weight W of the rule. J81/I/1

25 AC represents a trap door of width 100 cm which is hinged at A. The weight of the trap door is 30 N and its centre of gravity is 45 cm from A. An object is placed on the trap door so that its weight of 40 N acts through B which is 25 cm from A.



Show on the diagram these two forces and add a force applied vertically at C which just lifts the door. Calculate the magnitude of this force at C. J82/I/5

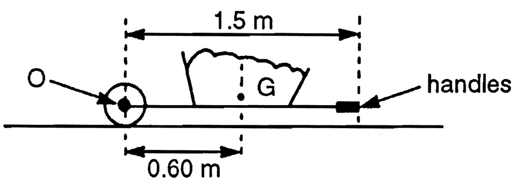
26 The diagram represents a table top, of weight 45 N, which is hinged at H. The centre of gravity of the table top is 30 cm from the axis of the hinge and the table top can be supported in a horizontal position by a vertical force F directed through J as shown. The distance HJ is 70 cm.



A typewriter of weight 50 N is placed on the table top so that its weight acts through a point which is 43 cm from the axis of the hinge, as indicated in the diagram. Calculate the magnitude of the force F required to hold the table in a horizontal position. N82/I/4

27 Explain the terms *centre of gravity* and *moment of a force*.

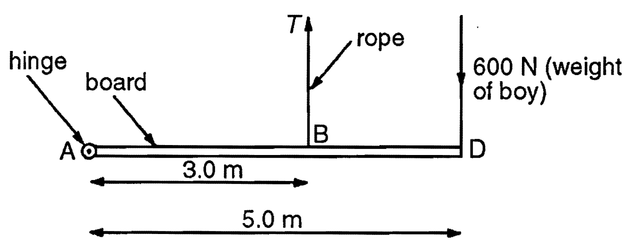
The diagram (simplified, not to scale) illustrates a loaded wheelbarrow. The wheelbarrow and its load have an effective mass of 50.0 kg, the centre of gravity being 0.60 m distant horizontally from the axle O of the wheel.



Calculate the *minimum* upward force F_1, at the handles, which will support the load. Give *one* reason why, in practice, the force needed may be larger than this minimum. Explain an advantage that would be gained by constructing the wheelbarrow so that the centre of gravity is much closer to the axle of the wheel. [Take the weight of 1 kg as 10 N.)

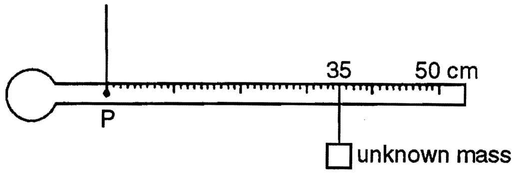
A resultant horizontal force F_2, exerted on the wheel-barrow, produces a horizontal acceleration of the barrow of 1.4 m/s^2. What is the magnitude of F_2? J83/II/7

28 The board shown in the diagram is hinged at A and supported by a vertical rope at B, 3.0 m from A. A boy of weight 600 N stands at the end D of the board, which is 5.0 m from the hinge. Neglecting the weight of the board, calculate the tension T in the rope.



If the board were uniform and of weight 48 N, calculate the tension in the rope. N83/I/1

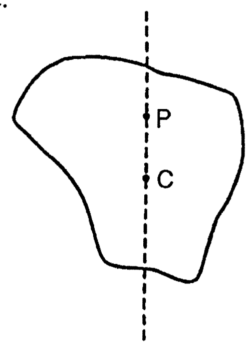
29 A non-uniform rod, with a centimetre scale marked on it, is suspended at a point P near one end. It is used to determine an unknown mass. The rod balances in a horizontal position when the unknown mass is hung 35.0 cm from P, as shown in the diagram.



The rod also balances horizontally when a 140 g mass is hung 20.0 cm from P, the unknown mass having first been removed.

By taking moments about P, calculate the value of the unknown mass. J84/I/1

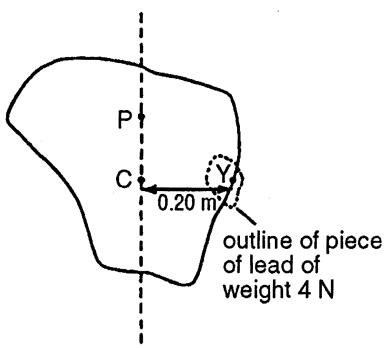
30 The diagram represents an irregularly shaped flat metal sheet freely pivoted at P on a horizontal pivot so that the plane of the sheet is vertical. The centre of gravity of the sheet is marked C.



(a) State why C is vertically below P.

(b) How would you attempt to check that C is the centre of gravity of the sheet?

A piece of lead is now fixed to the sheet so that its weight 4 N acts at Y. The distance CY is 0.20 m.



(c) The loaded sheet is held steady in its original position.

Calculate the turning effect about P of the weight of the lead.

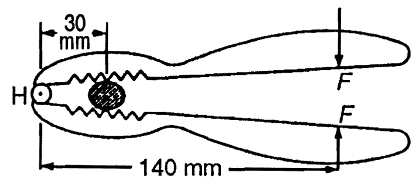
(d) The loaded sheet is now released.

(i) Describe the subsequent motion of the sheet until it finally stops moving.

(ii) Given that the weight of the lead is about the same as that of the sheet, draw a diagram to indicate a possible stable position of the loaded sheet.

N84/II/1

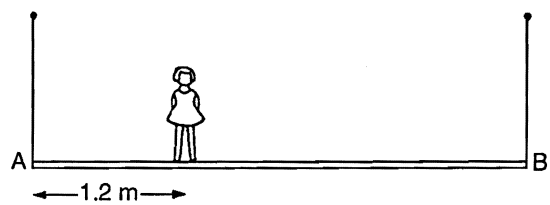
31 The diagram above shows a nut between the jaws of a nutcracker. Forces F are applied to the handles, at points 140 mm from the hinge H. The contact between the nutcracker and nut is effectively 30 mm from H. By taking moments about H estimate the force applied to the nut when $F = 120$ N. Given that each jaw touches the nut over an area of 4.0×10^{-5} m^2 find the pressure exerted on the nut.



The serrations on the jaws increase the pressure applied for a given force. Why is this?

Suggest one advantage and one disadvantage of constructing a nutcracker with handles twice as long. J85/I/2

32 A uniform plank AB of length 4.0 m and weight 500 N is suspended by a vertical rope at each end. A girl of weight 300 N stands in the position shown, 1.2 m from the end A.



By taking moments about A, calculate the tension in the rope supporting the end B.

Would you expect the tension in the rope at A to be larger or smaller than that in the rope at B? State a reason for your answer. N85/I/2

33 *(b)*

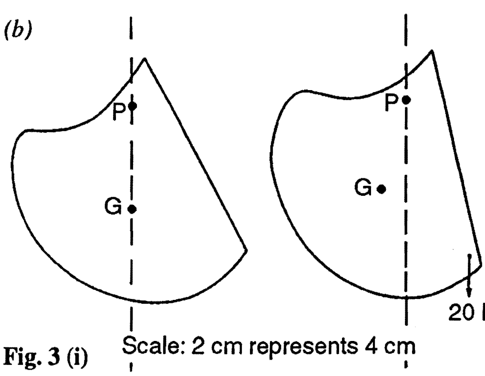


Fig. 3 (i) **Fig. 3 (ii)**

Fig. 3 (i) shows, to scale, the rest position of a sheet of metal, centre of gravity G, freely pivoted at P.

Indicate by an arrow on the diagram the line of action of the weight of the sheet.

Fig. 3 (ii) shows, on the same scale, the rest position of the same sheet when it has a small weight of 20 N attached to it and is pivoted about the same point. By taking and recording the necessary measurements from Fig. 3 (ii), calculate the weight of the sheet.

(c) Fig. 4 below shows a reclining seat.

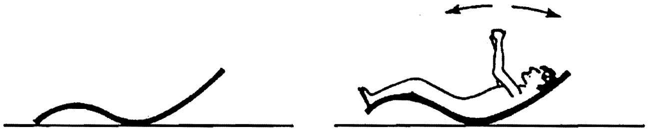
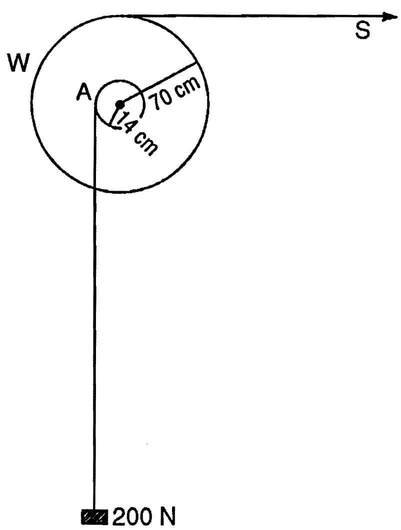


Fig. 4

A boy lying in the seat discovers that he can balance in the position shown, and can rock himself forwards or backwards simply by moving his arms as shown by the arrows. Explain this. J86/II/8*(b, c)*

34 In the diagram the axle A is fixed into the wheel W, so that they rotate together, mounted in bearings which are not shown.



A load of 200 N hangs on a rope wound around the axle which has a radius 14 cm. A string S is wound around the wheel of radius 70 cm.

(a) Write down the moment of the weight of the load about the centre of the axle and hence calculate the force in the string S which produces an equal and opposite moment.

(b) The string is pulled with a force of 50 N and the load rises through a vertical distance of 6.0 m at a slow, steady speed.

Calculate

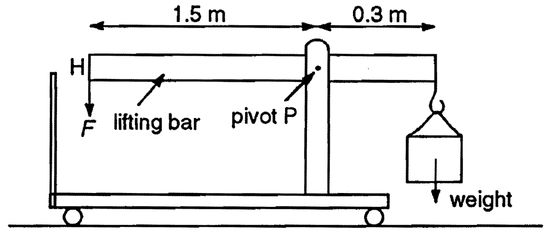
(i) the length of the string which unwinds from the wheel,

*(ii) the work done on the load,

*(iii) the work done by the force pulling the string.

(c) Account for the difference in the answers to (ii) and (iii) above. N86/II/2

35 The diagram shows the essential features of a trolley used for lifting and transporting heavy buckets in a factory. The force to lift a bucket is derived from the downward force the operator exerts at the handle H at the end of the lifting bar. The centre of gravity of the lifting bar is at P.



(a) By taking moments, calculate the force *F* necessary to hold steady, in the position shown, a bucket and contents of total mass 60 kg. (Take the weight of 1 kg to be 10 N.)

(b) Calculate the work done in lifting the mass of 60 kg through a vertical height of 0.12 m.

(c) Calculate the power needed to complete this lifting operation in 4.0 s.

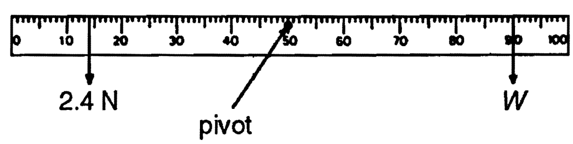
Suggest a reason why the power actually developed by the operator during the 4.0 s must be greater than your calculated value.

(d) State, with a reason in each case, why the device is designed so that the bar PH is 1.5 m long rather than

(i) 0.3 m,

(ii) about 5.0 m. J87/II/1

36 A uniform metre rule balances horizontally on a pivot at its mid-point when a weight of 2.4 N is suspended from the 14.0 cm mark and a weight *W* is suspended from the 90.0 cm mark as shown in the diagram. Calculate *W*.



Why do you **not** need to know the weight of the rule in order to calculate *W*?

The 2.4 N weight is replaced by a 4 N weight. Indicate on the diagram how the ruler would begin to move and explain your answer. N87/I/3

37 *(c)* The diagrams illustrate both the rest position (Fig. 5.1) and the displaced position (Fig. 5.2) of a weighted toy. G is its centre of gravity. Explain briefly why the toy returns to its rest position when displaced and released. [3]

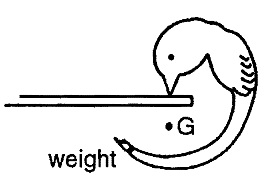


Fig. 5.1

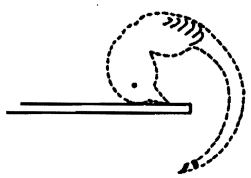
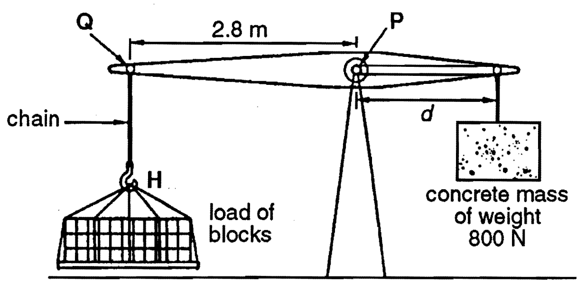


Fig. 5.2 J88/II/7*(c)*

38 *(a)* The diagram below shows the essential features of a simple crane used for lifting blocks which are attached to the hook **H**.



(i) With no blocks suspended from **H**, the crane arm balances horizontally when the position of the concrete mass is adjusted so that *d* is 0.6 m. Calculate the moment of the weight of the concrete mass about the pivot **P**. [2]

(ii) A mechanism on the right-hand side moves the concrete mass away from the pivot **P** until the blocks are lifted from ground. Calculate the weight of the blocks just lifted off the ground when $d = 1.7$ m. [3]

(iii) An electric motor is fitted at **Q** which, by shortening the chain, increases the height to which the blocks can be raised. State with a reason whether or not raising the height of the blocks increases the moment of the weight of the blocks. [2]

What would be the effect of the weight of this electric motor on the operation of the crane? Explain the effect in terms of the moment of the weight of the electric motor. [3]

N88/II/7*(a)*

39 Fig. 6.1 shows a cross-section through a child's toy called a Tumbling Kelly. The toy consists of a thin plastic egg-shaped shell with a layer of lead fixed in the bottom. When the toy is knocked over as shown in Fig. 6.2, it always rolls back to the upright position.

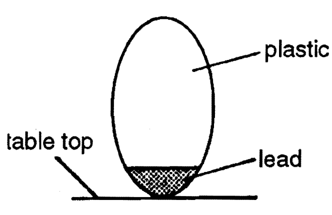


Fig. 6.1

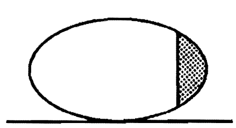


Fig. 6.2

(a) On Fig. 6.1, use small crosses to mark the positions of the centre of mass of

(i) the plastic shell; label the cross **P**,

(ii) the lead; label the cross **L**. [2]

(b) (i) On Fig. 6.2, mark and label the external forces acting on the toy.

(ii) Explain why the toy returns to the upright position. [3]

(c) What are the properties of plastic and lead which makes them suitable materials for use in a Tumbling Kelly? [2]

J90/II/1

40 *(a)* Explain what is meant by the moment of a force. Write down a unit in which it can be measured. [3]

(b) Fig. 7 shows an electrically operated railway-crossing barrier. The barrier is pivoted at **P** and, in order to make it easier to raise the arm of the barrier, the weight of the arm is balanced by the counter-weight **M**.

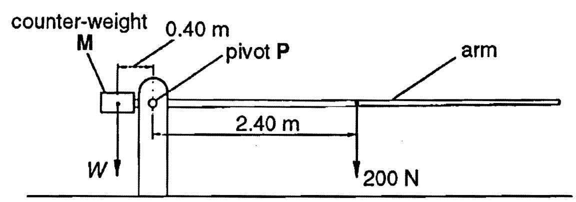


Fig. 7

The weight of the arm is 200 N and its centre of mass is 2.40 m from **P**. The centre of mass of **M** is 0.40 m from **P**. Calculate *W*, the weight of **M**, assuming that it just balances the weight of the arm. Show clearly how you arrived at your answer. [4]

N90/II/2

41 *(a)* State what is meant by the *moment of a force about a point* and state how it is calculated. [2]

(c) Fig. 8.1 shows a uniform metre rule, freely pivoted at a point 20 cm from end **P**.

The rule is kept horizontal by means of a 120 g mass suspended 5.0 cm from end **P**.

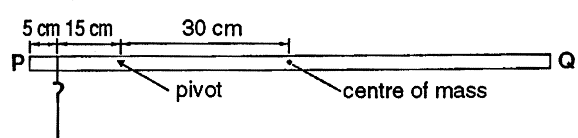


Fig. 8.1

(i) Write down the size of the vertical force acting 5.0 cm from **P**.

(ii) Use the principle of moments to help you determine the mass of the metre rule. [3]

(d) The threaded stopper of some gas cylinders is tightened and loosened by means of a long bar fitted with two pegs as shown in Fig. 8.2. The pegs fit into two holes drilled part way into the top of the stopper.

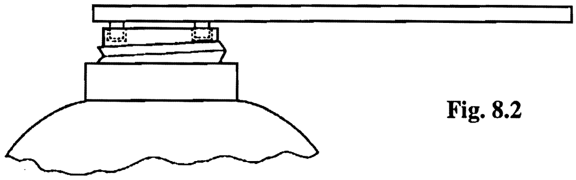
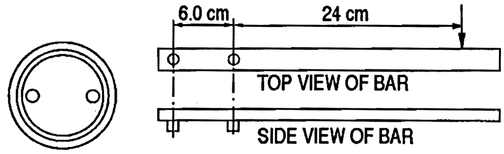


Fig. 8.2



TOP VIEW OF STOPPER

Fig. 8.3

(i) Copy the diagram of the top view of the bar given in Fig. 8.3. On your diagram draw arrows to represent **all** the horizontal forces acting on the bar when it is being used to turn the stopper in a clockwise direction.

(ii) Explain why it is important to make the distance between the holes in the stopper as big as possible.

(iii) In one case the distance between the pegs is 6.0 cm. The minimum force to unscrew the stopper is 450 N when the force is applied 24 cm from the nearer peg. Determine the size of the force exerted on each peg. ($g = 10$ m/s^2) [6]

J91/II/9 *(a, c, d)*

42 Fig. 9 shows a plank of mass 5.0 kg and length 3.00 m resting horizontally on two trestles, **P** and **Q**, which are a distance of 2.50 m apart. When a student of mass 60.0 kg walks along the plank from one trestle to the other, the plank sags.

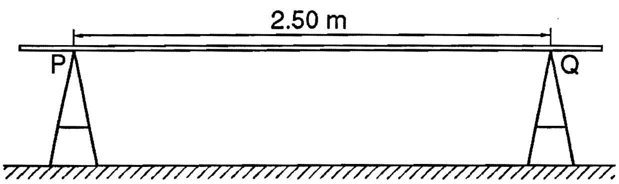


Fig. 9

(a) Explain why the sag increases as the student walks towards the middle of the plank.

(b) Calculate the downwards force exerted on each trestle when the student is a distance of

(i) 0.50 m from trestle **P**,

(ii) 1.25 m from trestle **P**.

($g = 10.0$ N/kg) [6] N91/II/2

43 Fig. 10 shows an oval disc freely pivotted at **P**. The bottom of the disc is pulled to the right by the tension in the thread **ST**.

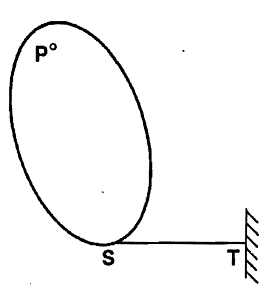


Fig. 10

(a) On Fig. 10

(i) mark the position of the centre of mass of the disc with a cross, x,

(ii) show the direction of the force exerted by the thread on the disc,

(iii) draw an arrow to show the force exerted by gravity on the disc. [3]

(b) (i) State the point of application of the force exerted by the thread on the disc.

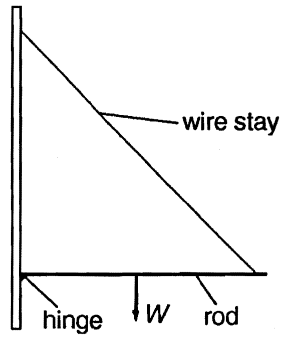
(ii) There is a third external force acting on the disc. State the point of application of this force. [1]

(c) The thread **ST** is now cut. State what, if anything, now happens to the disc. [2]

N92/II/1

44 Figure 11 shows a hinged, uniform rod held in a horizontal position by a wire stay. The rod is 1.2 m long and has a mass of 1.2 kg. The force of gravity acting on a mass of 1 kg is 10 N.

Fig. 11



(a) Calculate

(i) W, the weight of the rod,

(ii) the moment of W about the hinge. [3]

(b) Given that the diagram is drawn to scale, determine the tension in the wire. [3]

N93/II/2

45 Figure 12.1 shows a long, rigid, curved pole balanced at its midpoint **M** on a taut horizontal wire. One end of the pole is pushed upwards slightly by means of a vertical force ***F***, as shown in Fig. 12.2.

The cross, labelled **C**, shows the position of the centre of mass of the pole in each diagram.

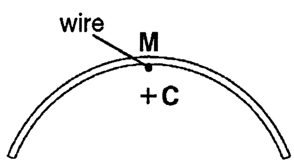


Fig. 12.1

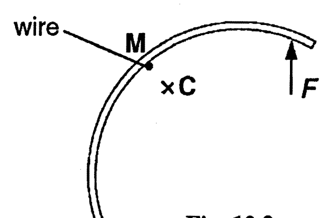


Fig. 12.2

(a) (i) **On Fig. 12.1**, draw an arrow to show the direction of weight of the pole with the arrow starting the point at which the weight acts.

(ii) In Fig. 12.2, the pole is balanced by force ***F*** and two more forces. **On Fig. 12.2**, draw arrows to show the positions and directions of these two forces. [3]

(b) Force ***F*** is now taken away. State and explain what will happen to the pole as soon as force ***F*** is taken away. [2]
J95/II/2

46 *(b)* Fig. 13 shows a cross-section through the centre of a triangular prism. **G** shows the position of the centre of mass of the prism.

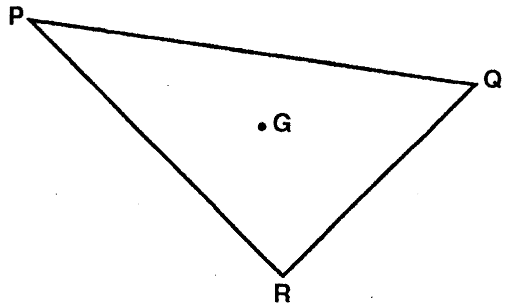


Fig. 13

The prism is laid on one of its rectangular faces on a horizontal table. On which side, **PQ** or **QR** or **RP**, should the prism be placed for maximum stability? State your reasons for your answer. [2]
N96/II/2*(b)*

47 Fig. 14 shows an empty wheelbarrow which weighs 80 N. The operator pulls upwards on the handles with a force of 20 N to keep the handles horizontal. The point marked M is the centre of mass of the wheelbarrow.

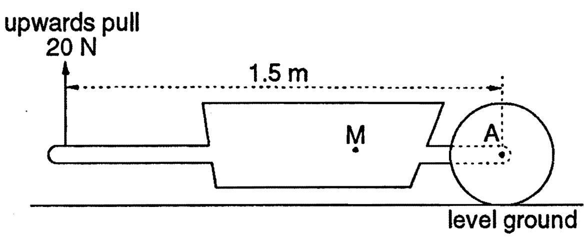


Fig. 14

(a) On Fig. 14, draw arrows to show the other two vertical forces that act on the wheelbarrow. [2]

(b) Determine

(i) the moment of the 20 N force about the centre of the wheel A,

moment =.....................................

(ii) the distance between points A and M.

distance AM = ... [3]
J98/II/2

ANSWERS

1. **C**	2. **D**	3. **A**	4. **D**	5. **C**
6. **B**	7. **C**	8. **D**	9. **B**	10. **B**
11. **A**	12. **B**	13. **C**	14. **A**	15. **A**
16. **A**	17. **D**	18. **C**	19. **A**	

20. 1200 N
21. *(a)* 0.3 N
22. *(c)* 4.8 Nm ; 18 Nm
23. 11.25 Nm ; 52.5 cm
24. 0.76 N
25. 23.5 N
26. 50 N
27. 200 N ; $F_2 = 70$ N
28. 1000 N ; 1040 N
29. 80 g
30. *(c)* 0.8 Nm *(b)* 50 N
31. 560 N ; 1.4×10^7 Pa
32. 340 N
33. *(b)* 50 N
34. *(a)* 40 N
(b) (i) 30 m (ii) 1200 J
(iii) 1500 J
35. *(a)* 120 N *(b)* 72 J
(c) 18 W
38. *(a)* (i) 480 Nm (ii) 486 N
40. *(b)* 1200 N
41. *(c)* (i) 1.2 N (ii) 60 g
(d) (iii) 1800 N; 2250 N
42. *(b)* (i) 145 N ; 505 N
(ii) 325 N
43. *(b)* (i) **S** (ii) **P**
44. *(a)* (i) 12 N (ii) 7.2 Nm
(b) 8.75 N
46. *(b)* Side **PQ** ; The centre of mass is lowest in this position.
47. *(b)* (i) 30 Nm (ii) 0.375 m