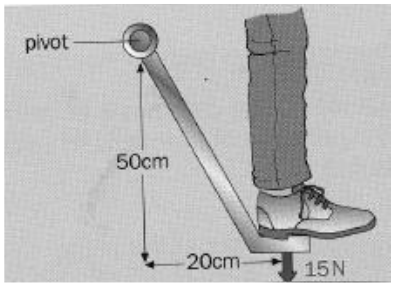
Moments

Exercise A

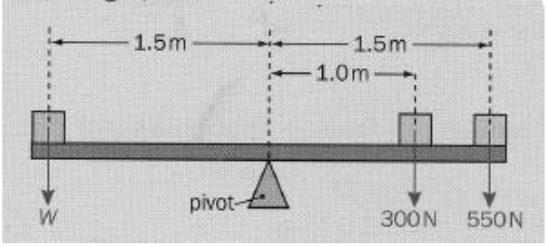
1. Calculate the moment of the pushing force on the pedal in the diagram.



2.

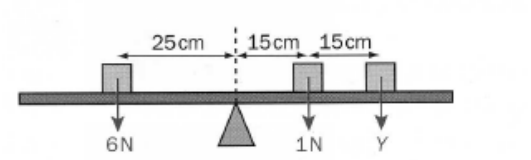
(a)

The seesaw in the diagram is balanced. Use the principle of moments to calculate the weight, *W*.



(b)

The diagram shows a rule balanced at its centre of gravity. What is the missing value Y?



3.

A uniform metre rule is balanced horizontally on a knife-edge at its 350 mm mark, by placing a 3.0 N weight on the rule at its 10 mm mark.

a Sketch the arrangement and calculate the weight of the rule.

b Calculate the support force on the rule from the knife-edge.

4.

A metre rule of weight 1.0 N is pivoted on a knife-edge at its centre of mass, supporting a weight of 5.0 N and an unknown weight W as shown in Figure 3. To balance the rule horizontally with the unknown weight on the 250 mm mark of the rule, the position of the 5.0 N weight needs to be at the 810 mm mark.

Figure 3

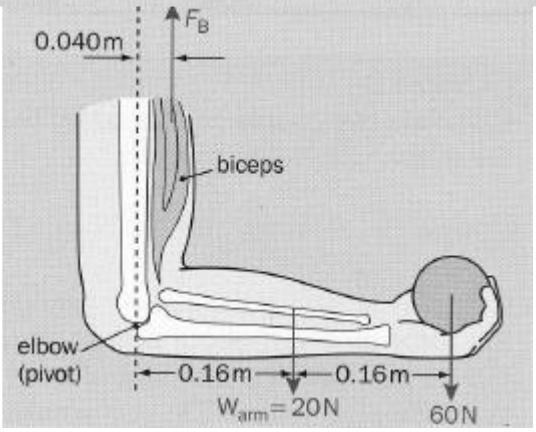
a Calculate the unknown weight.

b Calculate the support force on the rule from the knife-edge.

5.

The diagram shows the forces acting on your forearm when you hold a weight with your arm horizontal. Your elbow joint acts as a pivot:

The clockwise moments produced by the weight of your arm and the weight in your hand must be balanced by an anti-clockwise moment from your biceps muscle.
Use the principle of moments to calculate the force exerted by your biceps, F_B.



6.

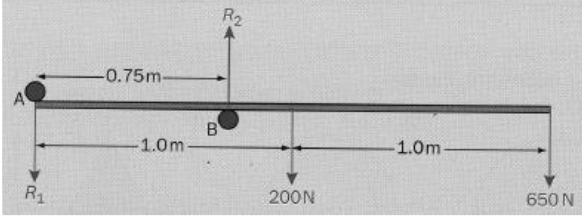
A uniform beam XY of weight 1200 N and of length 5.0 m is supported horizontally on a concrete pillar at each end. A person of weight 500 N sits on the beam at a distance of 1.5 m from end X.

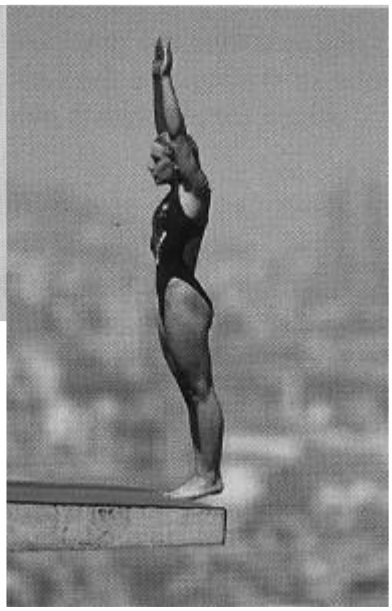
a Sketch a free body force diagram of the beam.

b Calculate the support force on the beam from each pillar.

7.

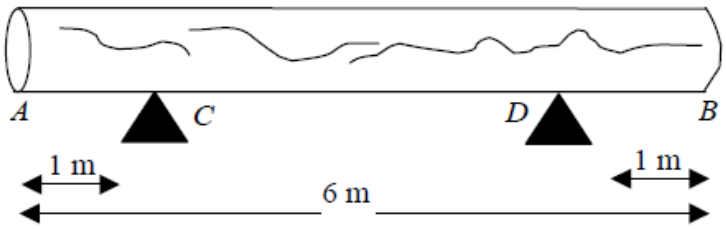
A diver weighing 650 N stands at the end of a uniform 2.0 m long diving board of weight 200 N. What are the reaction forces at the supports A and B, if the board is balanced as shown in the diagram?





8.

Figure 4



A large log AB is 6 m long. It rests in a horizontal position on two smooth supports C and D, where $AC = 1$ m and $BD = 1$ m, as shown in Figure 4. David needs an estimate of the weight of the log, but the log is too heavy to lift off both supports. When David applies a force of magnitude 1500 N vertically upwards to the log at A, the log is about to tilt about D.

(a) State the value of the reaction on the log at C for this case.

Assuming the log as a uniform rod,

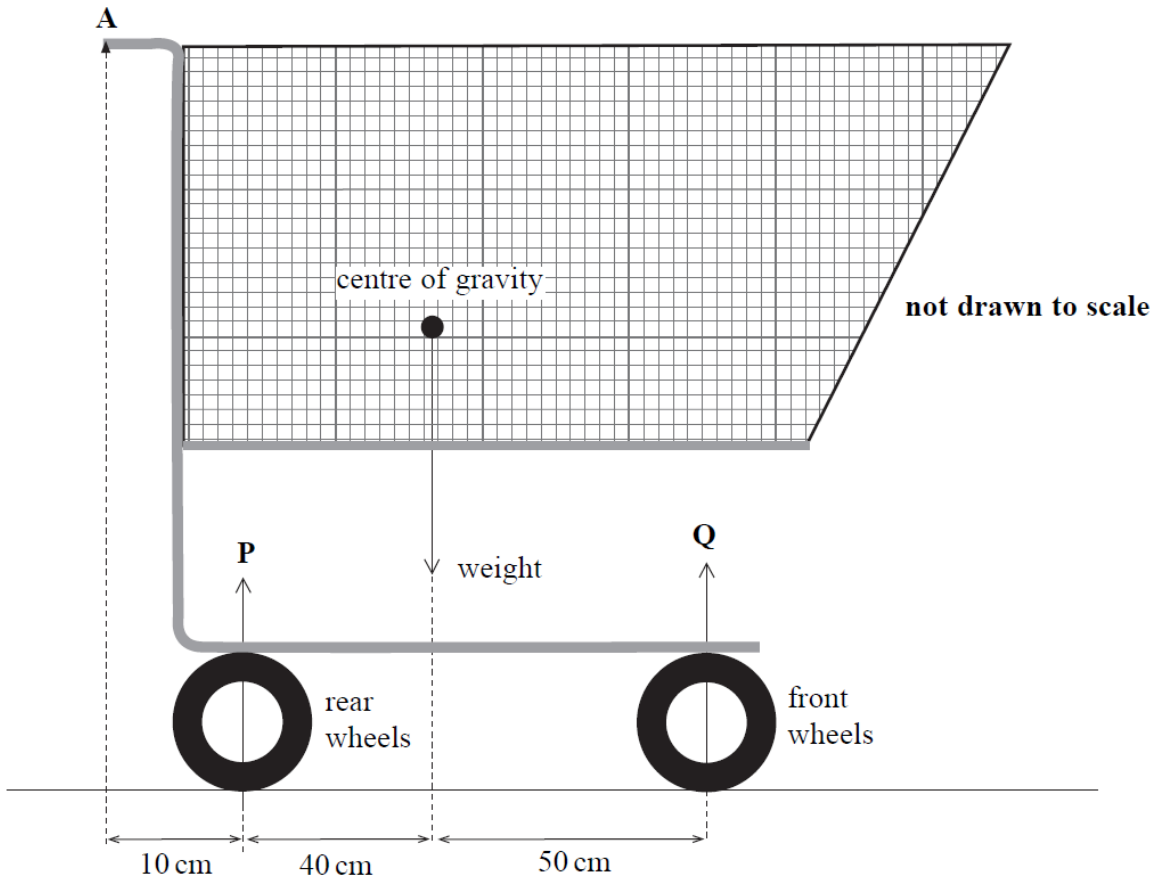
(b) estimate the weight of the log.

Exercise B

1.

Figure 2 shows a supermarket trolley.

Figure 2



The weight of the trolley and its contents is 160 N.

(a) Explain what is meant by centre of gravity.

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(2 marks)

(b) **P** and **Q** are the resultant forces that the ground exerts on the rear wheels and front wheels respectively. Calculate the magnitude of

(i) force **P**,

.....

.....

.....

(ii) force **Q**.

.....

.....

(3 marks)

(c) Calculate the minimum force that needs to be applied vertically at **A** to lift the front wheels off the ground.

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.....

.....

(2 marks)

(d) State and explain, without calculation, how the minimum force that needs to be applied vertically at **A** to lift the rear wheels off the ground compares to the force you calculated in part (c).

You may be awarded marks for the quality of written communication in your answer.

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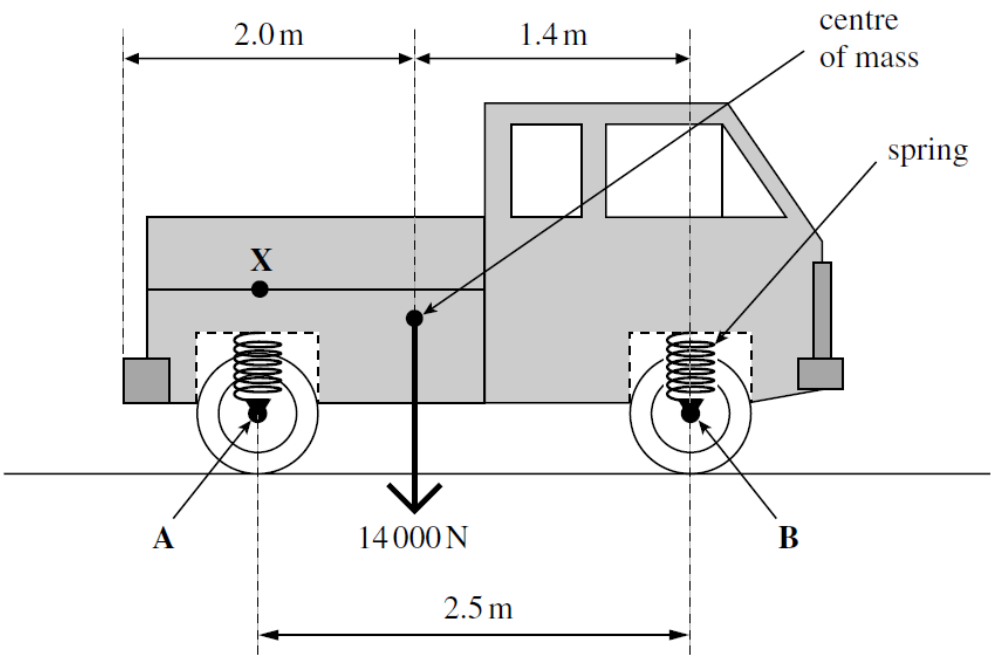
(3 marks)

2.

Heavy duty coil springs are used in vehicle suspensions. The pick-up truck shown in **Figure 2** has a weight of 14 000 N and length of 4.5 m. When carrying no load, the centre of mass is 2.0 m from the rear end. The part of the vehicle shown shaded in grey is supported by four identical springs, one near each wheel.

Figure 2



(a) (i) Define the moment of a force about a point.

.....

.....

.....

.....

(2 marks)

(a) (ii) State and explain which pair of springs, front or rear, will be compressed the most.

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.....

.....

.....

(2 marks)

(a) (iii) By taking moments about axle **B**, calculate the force exerted on the truck by each rear spring.

answer = ... N
(4 marks)

(b) The spring constant for each of these springs is $100\,000\,\text{N m}^{-1}$.

Calculate the distance that each of these rear springs is compressed by this vehicle as shown in **Figure 2**.

answer = ... m
(2 marks)

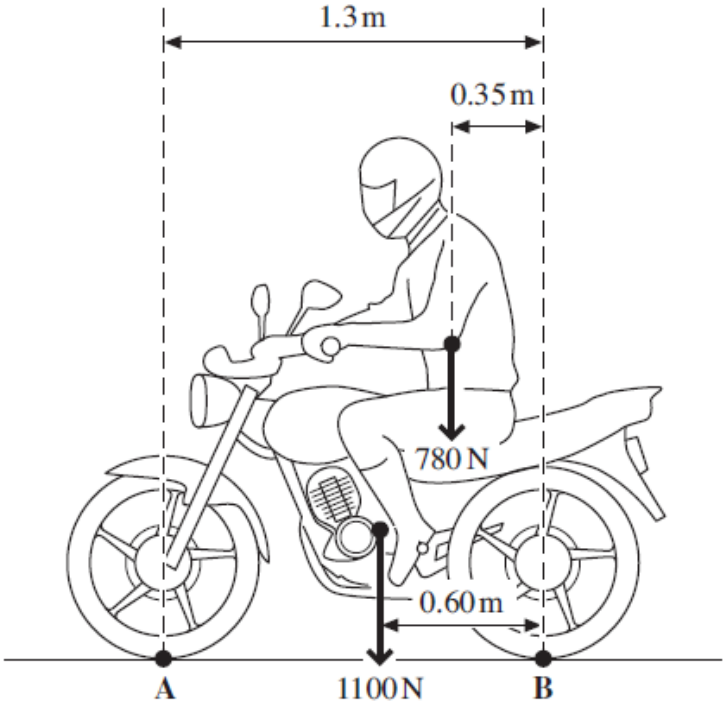
(c) The springs must not be compressed by more than an additional 0.065 m. Calculate the maximum load that could be placed at point **X**, which is directly above the centre of the rear axle **A**, as shown in **Figure 2**.

answer = ... N
(2 marks)

3.

Figure 1 shows a motorcycle and rider. The motorcycle is in contact with the road at **A** and **B**.

Figure 1



The motorcycle has a weight of 1100 N and the rider's weight is 780 N.

(a) State the Principle of Moments.

.....

.....

.....

(2 marks)

(b) Calculate the moment of the rider's weight about **B**. Give an appropriate unit.

answer = ...

(2 marks)

(c) By taking the moments about **B**, calculate the vertical force that the road exerts on the front tyre at **A**. State your answer to an appropriate number of significant figures.

answer = ... N

(4 marks)

(d) Calculate the vertical force that the road exerts on the rear tyre at **B**.

answer = ... N

(1 mark)

(e) The maximum power of the motorcycle is 7.5 kW and it has a maximum speed of 26 $m\,s^{-1}$, when travelling on a level road.

Calculate the total horizontal resistive force for this speed.

answer = ... N

(2 marks)

4.

(a) (i) Define the moment of a force.

.....[1]

(ii) State the principle of moments.

.....

.....[2]

(b) Fig. 5.1 shows a pillar (lying horizontally) made of two uniform sections X and Y each of cross-sectional area 3.5×10^{-2} m^2. The sections are made from two different materials. The weights of X and Y are shown acting through the centre of gravity of each section.

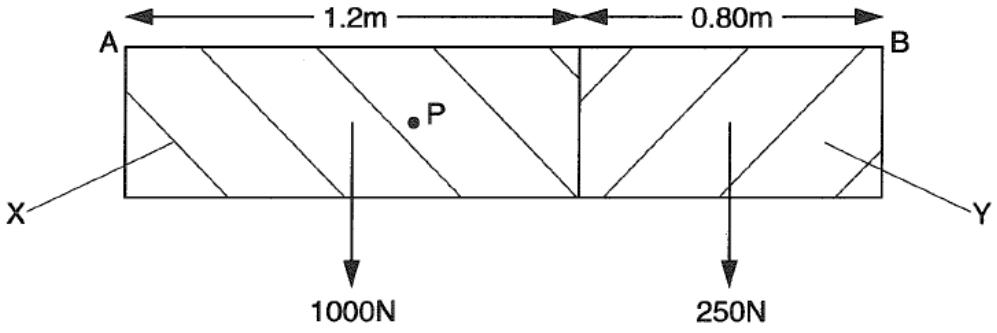


Fig. 5.1

Show that the average density of the pillar is about 1800 kg m^{-3}.

[3]

(c) The pillar in **(b)** will balance horizontally when supported vertically below the point P.

(i) Show, using the principle of moments, that the point P is 1.2 m from the end B.

[3]

(ii) State the significance of the point P.

.....[1]

5.

(a) (i) Explain what the *centre of gravity* of a body means.

.....

.....

(ii) Define *moment of a force* about a point.

.....

.....

[3]

(b) Fig. 2.1 shows an arrangement used to determine the approximate centre of gravity of a man. A uniform plank, of mass of 5.0 kg and length 2.00 m, is supported on a pivot at one end A while the other end B is supported on scales. The man lies horizontally on the plank with his feet level with end A. The man is 1.80 m tall and has a mass of 75 kg. The scales read 44 kg.

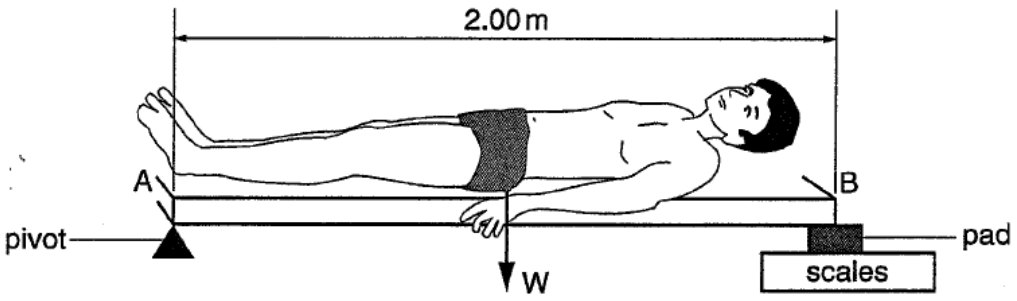


Fig. 2.1

The weight W, of the plank is shown.

(i) On Fig. 2.1 draw and label three other forces acting on the plank. [3]

(ii) Use the principle of moments to calculate the distance of the centre of gravity of the man from end A.

distance = ... m [4]

6.

(a) State the **two** conditions necessary for a system to be in equilibrium.

1. .....

.....

2. .....

.....[2]

(b) Fig. 2.1 shows a painter's plank resting on two supports **A** and **B**.

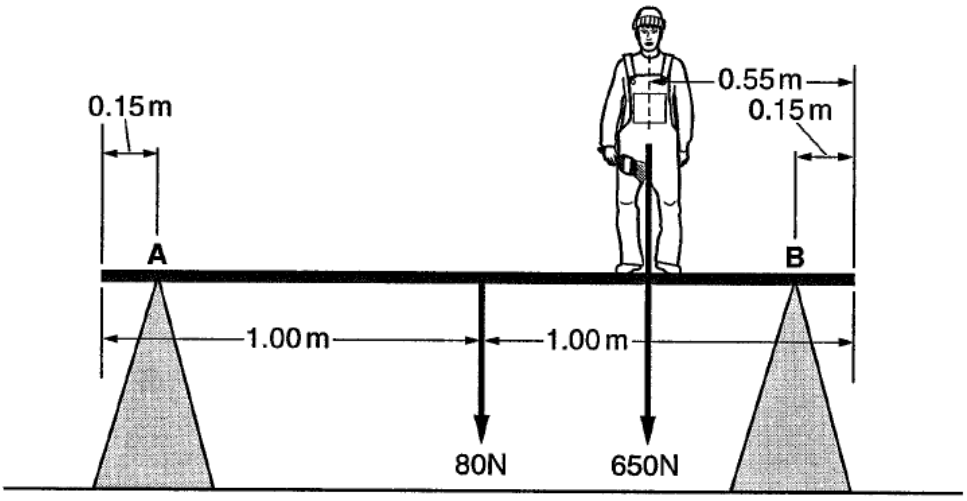


Fig. 2.1

The plank is uniform, has a weight 80 N and length 2.00 m. A painter of weight 650 N stands 0.55 m from one end.

(i) Show that the force acting on the plank at the support **B** is approximately 540 N by taking moments of all the forces about the support at **A**.

[3]

(ii) Calculate the force acting on the plank at support **A**.

force at **A** = ... N [2]

(iii) Describe and explain what happens to the forces on the plank at **A** and **B** if the painter moves towards the support at **A**. Quantitative values are not required.

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.....

.....[3]

7.

(a) **(i)** Define *pressure*.

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.....[1]

(ii) Define *moment of a force*.

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.....[1]

(b) Fig. 3.1 shows a device used for compressing materials.

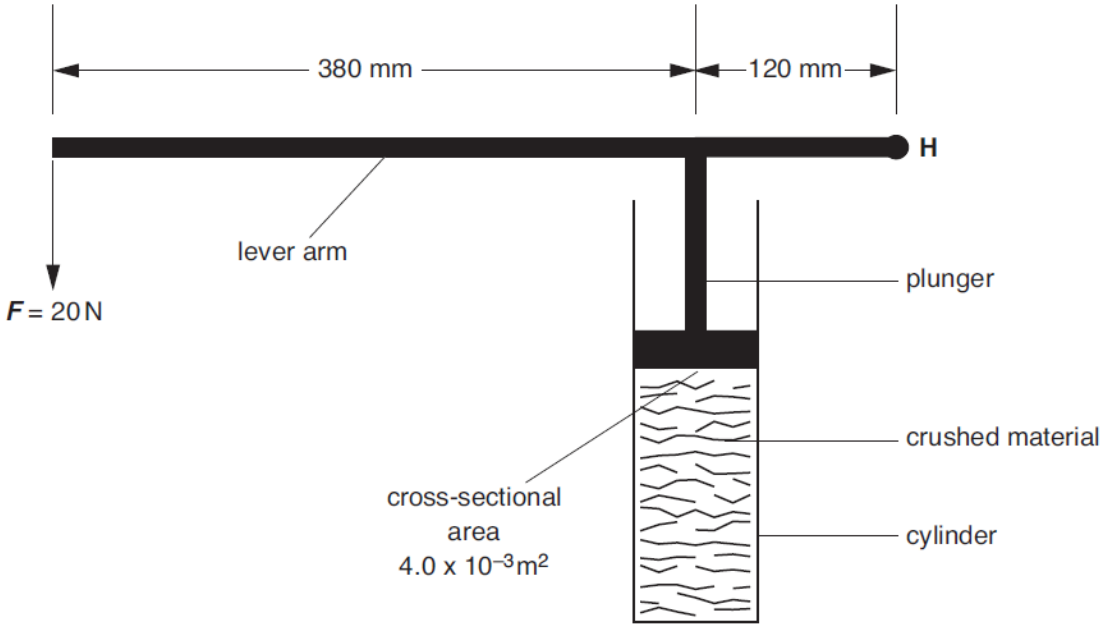

Fig. 3.1

A vertical force ***F*** of 20 N is applied at one end of a lever system. The lever is pivoted about a hinge **H**. The plunger compresses the material in the cylinder.

(i) Two forces acting on the lever arm are its weight and the force ***F***. On Fig. 3.1, draw and label **two** other forces acting on the lever arm. [2]

(ii) By taking moments about **H**, show that the force acting on the plunger is 83 N. The weight of the lever arm may be neglected.

[2]

(c) **(i)** The cross-sectional area of the plunger is $4.0 \times 10^{-3} m^2$. Calculate the pressure exerted by the plunger on the material in the cylinder.

pressure = ... Pa [2]

(ii) State **two** methods of increasing the pressure exerted by the plunger.

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.....[2]