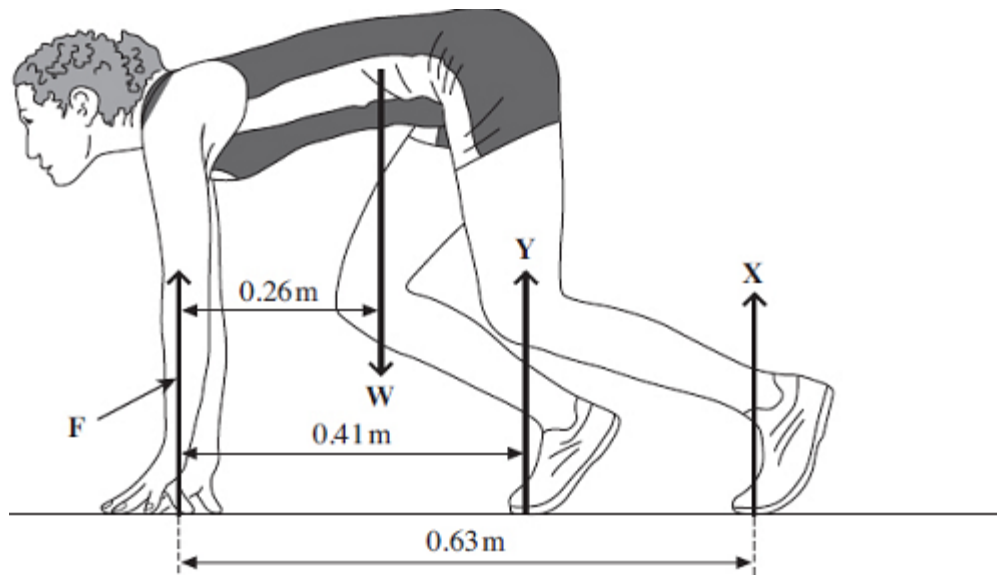


1

A sprinter is shown before a race, stationary in the 'set' position, as shown in the figure below. Force **F** is the resultant force on the sprinter's finger tips. The reaction force, **Y**, on her forward foot is 180 N and her weight, **W**, is 520 N. **X** is the vertical reaction force on her back foot.



- (a) (i) Calculate the moment of the sprinter's weight, **W**, about her finger tips. Give an appropriate unit.

answer = _____ unit _____

(2)

- (ii) By taking moments about her finger tips, calculate the force on her back foot, marked **X**.

answer = _____ N

(3)

- (iii) Calculate the force **F**.

answer = _____ N

(1)

- (b) The sprinter starts running and reaches a horizontal velocity of 9.3 ms^{-1} in a distance of 35 m.

- (i) Calculate her average acceleration over this distance.

answer = _____ m s^{-2}

(2)

- (ii) Calculate the resultant force necessary to produce this acceleration.

answer = _____ N

(2)

(Total 10 marks)

2

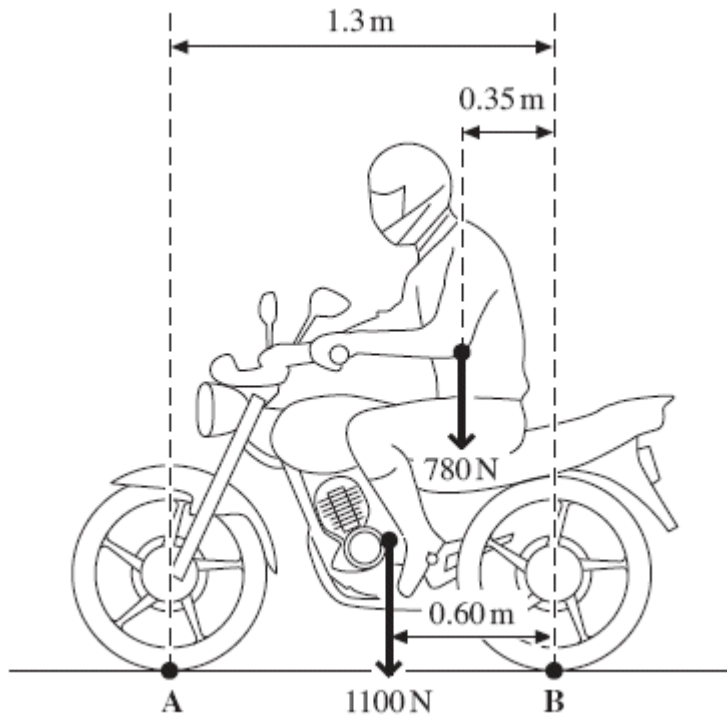
Which line, **A** to **D**, in the table shows correctly whether the moment of a force, and momentum, are scalar or vector quantities?

	moment of force	momentum
A	scalar	scalar
B	scalar	vector
C	vector	scalar
D	vector	vector

(Total 1 mark)

3

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



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

(a) State the Principle of Moments.

(2)

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

answer = _____

(2)

- (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)

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

answer = _____ N

(1)

- (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.

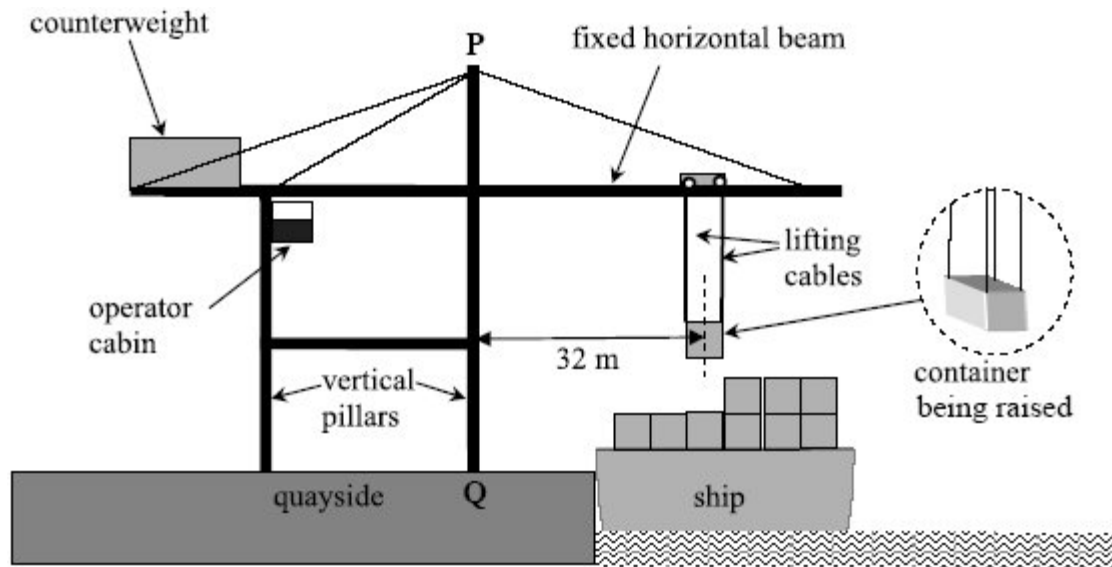
answer = _____ N

(2)

(Total 11 marks)

4

The diagram below shows a dockside crane that is used to lift a container of mass 22000 kg from a cargo ship onto the quayside. The container is lifted by four identical 'lifting' cables attached to the top corners of the container.



- (a) When the container is being raised, its centre of mass is at a horizontal distance 32 m from the nearest vertical pillar **PQ** of the crane's supporting frame.

- (i) Assume the tension in each of the four lifting cables is the same. Calculate the tension in each cable when the container is lifted at constant velocity.

answer _____ N

(2)

- (ii) Calculate the moment of the container's weight about the point **Q** on the quayside, stating an appropriate unit.

answer _____

(3)

- (iii) Describe and explain one feature of the crane that prevents it from toppling over when it is lifting a container.

(2)

- (b) Each cable has an area of cross-section of $3.8 \times 10^{-4} \text{ m}^2$.

- (i) Calculate the tensile stress in each cable, stating an appropriate unit.

answer _____

(3)

- (ii) Just before the container shown in the diagram above was raised from the ship, the length of each lifting cable was 25 m. Show that each cable extended by 17 mm when the container was raised from the ship.

Young modulus of steel = $2.1 \times 10^{11} \text{ Pa}$

(2)

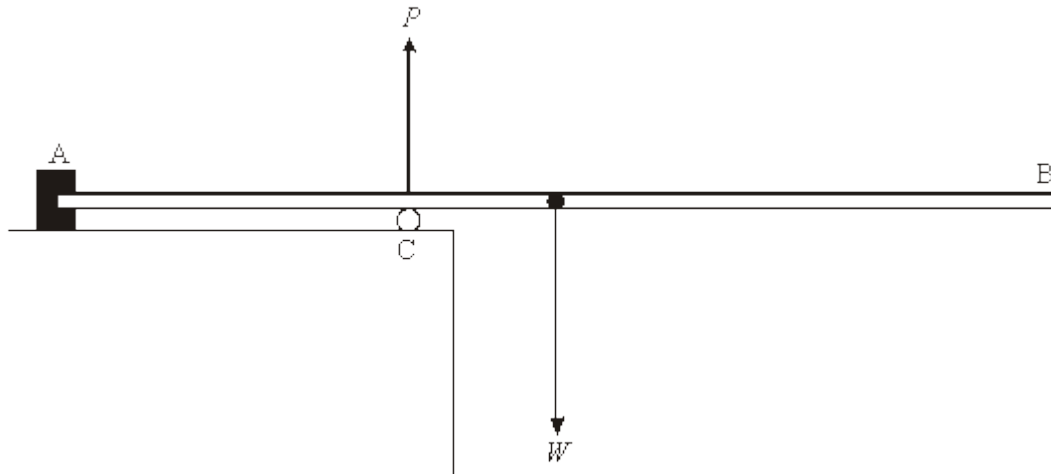
(Total 12 marks)

5

- (a) Define the moment of a force.

(2)

- (b) The diagram shows a uniform diving board of weight, W , that is fixed at A. The diving board is supported by a cylinder at C, that exerts an upward force, P , on the board.



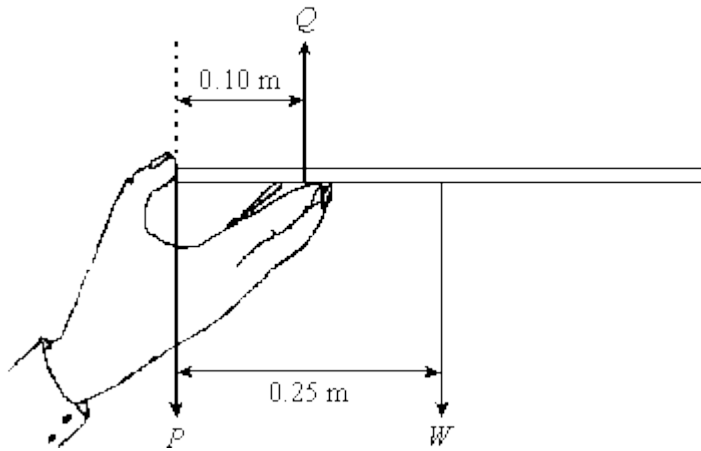
- (i) By considering moments about A, explain why the force P must be greater than the weight of the board, W .

- (ii) State and explain what would be the effect on the force P of a girl walking along the board from A to B.

(4)
(Total 6 marks)

6

A waiter holds a tray horizontally in one hand between fingers and thumb as shown in the diagram.



P , Q and W are the three forces acting on the tray.

- (a) (i) State **two** relationships between the forces that must be satisfied if the tray is to remain horizontal and in equilibrium.

- (ii) If the mass of the tray is 0.12 kg, calculate the magnitude of the force W .

- (iii) Calculate the magnitudes of forces P and Q .

- (b) The waiter places a glass on the tray. State and explain where the glass should be positioned on the tray if the force, P , is to have the same value as in part (a).

(2)

(Total 8 marks)

7

- (a) The torque of a couple is given by

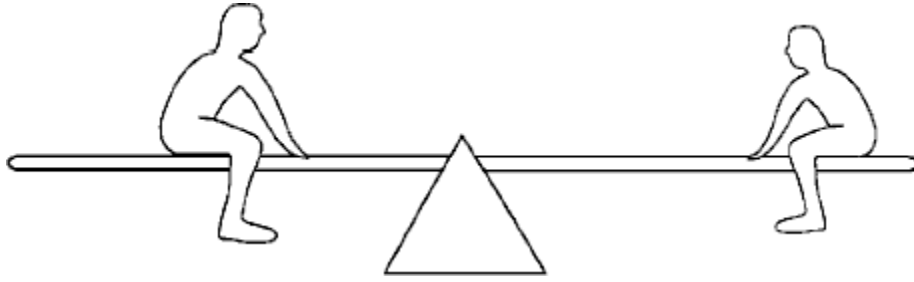
$$\text{torque} = Fs.$$

- (i) With the aid of a diagram explain what is meant by a couple. Label F and s on your diagram.

- (ii) State the unit for the torque of a couple.

(4)

- (b) The see-saw shown in the diagram consists of a uniform beam freely pivoted at the centre of the beam. Two children sit opposite each other so that the see-saw is in equilibrium.

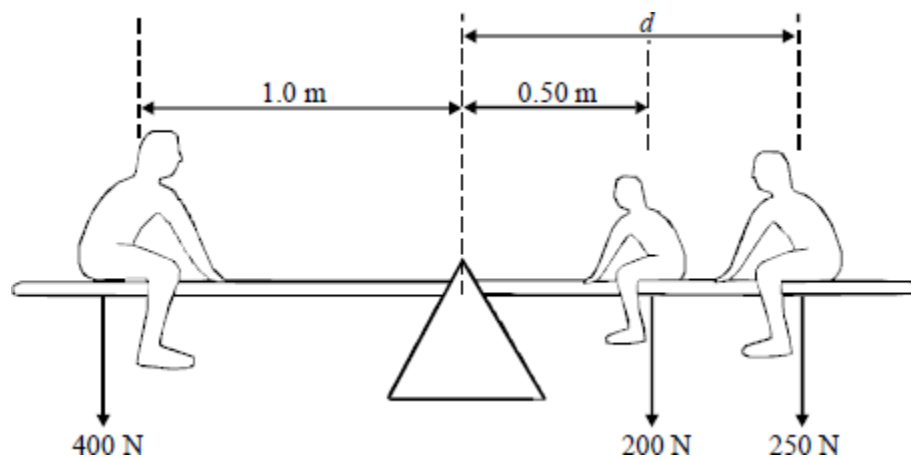


Explain why

- (i) the see-saw is in equilibrium,

- (ii) the weight of the beam does not affect equilibrium.

- (c) The diagram shows the see-saw with three children of weights 400 N, 250 N and 200 N sitting so that the see-saw is in equilibrium.



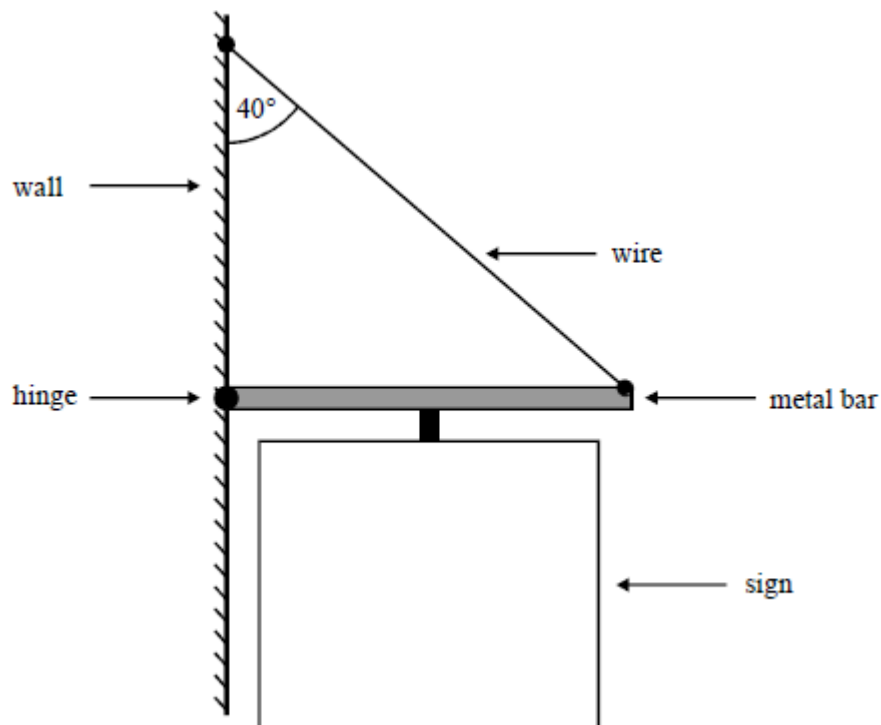
Calculate the distance, d .

(2)

(Total 9 marks)

8

A public house sign is fixed to a vertical wall as shown in the diagram.



A uniform metal bar 0.75 m long is fixed to the wall by a hinged joint that allows free movement in the vertical plane only. The wire is fixed to the wall directly above the hinge and to the free end of the horizontal metal bar. The wire makes an angle of 40° with the wall. A single support holds the sign and is mounted at the mid point of the metal bar so that the weight of the sign acts through that point.

- (a) (i) Draw on the diagram three arrows showing the forces acting on the metal bar, given that the system is in equilibrium. Label the arrows A, B and C.

- (ii) State the origin of the forces.

A _____

B _____

C _____

(5)

- (b) The combined mass of the metal bar and sign is 12 kg and the mass of the wire is negligible. By taking moments about the hinged end of the bar, or otherwise, calculate the tension in the wire.

(4)

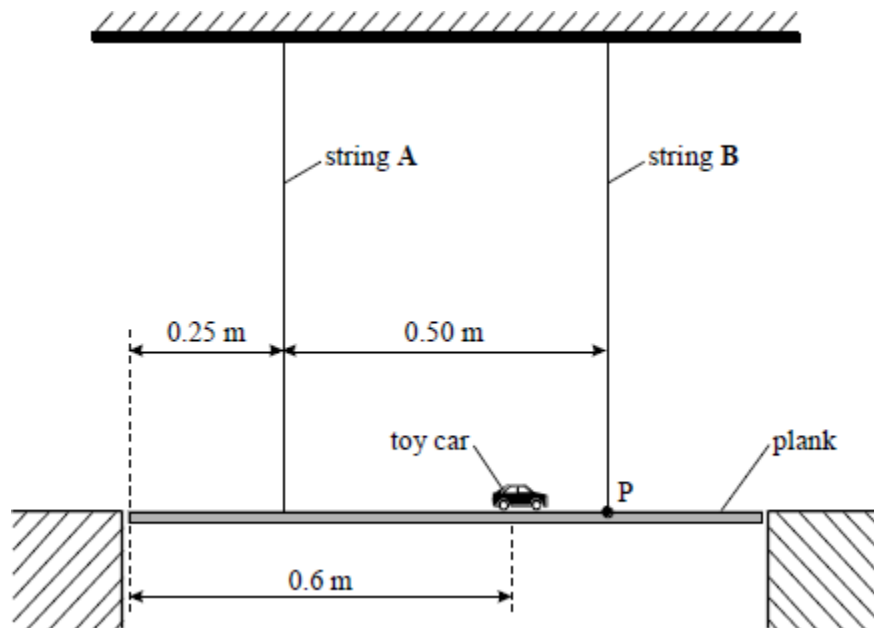
(Total 9 marks)

9

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

(2)

- (b) The diagram below shows a model bridge consisting of a uniform plank of wood. The plank is 1.0 m long and weighs 10 N. A toy car of weight 5 N is placed on it. The bridge is suspended from a rigid support by two strings and is in equilibrium. The plank does not touch the shaded blocks.



- (i) Show and label the forces acting on the bridge.

(2)

- (ii) By taking moments about point **P**, calculate the tension in string **A**.

(3)

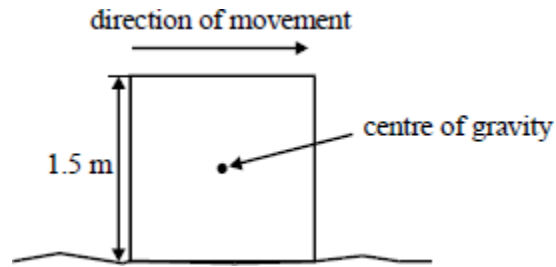
- (iii) Calculate the tension in string **B**.

(1)

(Total 8 marks)

10

A uniform square block is sliding with uniform speed along a rough surface as shown in the diagram.



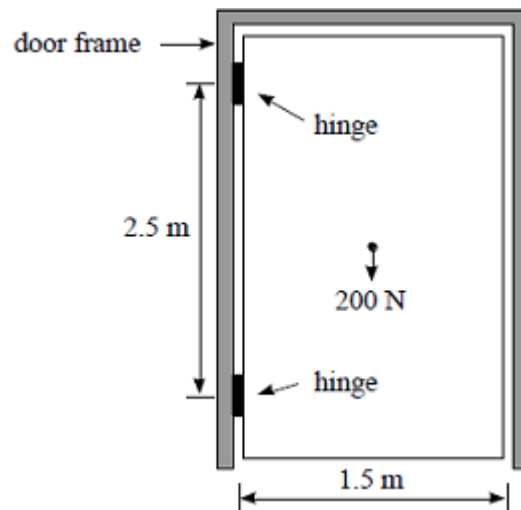
The force used to move the block is 200 N. The moment of the frictional force acting on the block about the centre of gravity of the block is

- A 150 N m, clockwise
- B 150 N m, anticlockwise
- C 300 N m, clockwise
- D 300 N m, anticlockwise

(Total 1 mark)

11

The diagram shows a uniform door hanging from two hinges 2.5 m apart.



The moment of the couple that the hinges exert on the door is

- A 150 N m
- B 200 N m
- C 250 N m
- D 500 N m

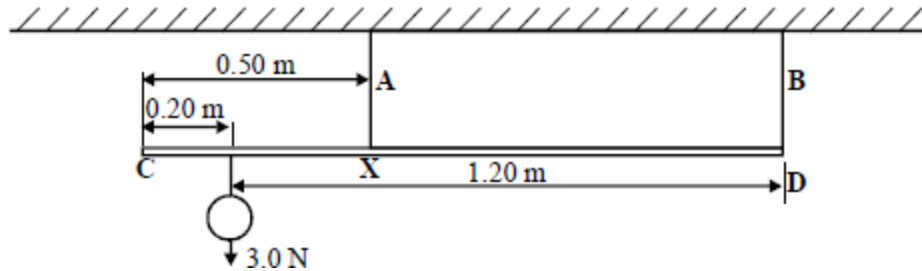
(Total 1 mark)

12

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

(2)

- (b) The system shown in the diagram below is in equilibrium. The uniform rod, **CD**, has a weight of 15 N and is suspended by two lengths of string, **A** and **B**. A ball of weight 3.0 N is attached to the rod in the position shown.



- (i) Accurately draw an arrow onto the diagram to represent the weight of the rod. You need not represent the magnitude of the weight.
- (ii) **X** is the point at which string **A** is attached to the rod. By taking moments about point **X**, determine the tension in string **B**.
- (iii) Determine the tension in string **A**.

(2)

(2)

(1)

(Total 7 marks)

Mark schemes

1

(a) (i) (moment = 520×0.26) = 140 (135.2) ✓

Nm ✓

2

(ii) **180 x 0.41** and **0.63 X** seen ✓

$135.2 = 180 \times 0.41 + 0.63 X$ ✓ ecf from (a)(i)

$(X = (135.2 - 73.8) / 0.63)$

= 97 ✓ (N) (97.46) allow 105 from use of 140Nm ecf from (a)(i)

3

(iii) $(520 - (180 + 97.46))$

= 240 ✓ (242.5 N) ecf (or from correct moments calculation)

1

(b) (i) ($v^2 = u^2 + 2as$)

$9.3^2 = 2 \times a \times 35$ OR $9.3^2 = 70a$ OR $a = v^2/2s$

OR $9.3^2/70$ ✓

OR correct alternative approach

1.2 (1.2356) ✓ (m s^{-2})

2

(ii) ($m = W/g$) = $520/9.81$ (= 53.0) ✓ (kg)

$F = ma = 53 \times 3 \times 1.2356 = 65$ (N) (65.49) ✓

accept use of 1.2 giving 64(63.6) , allow $53 \times 124 = 65.7$

2

[10]

2

D

[1]

3

(a) (sum of) clockwise moments (about a point) =(sum of) anticlockwise moments **(1)**

(for a system) in equilibrium **(1)**

accept balanced not stationary

2

(b) $(780 \times 0.35 =)$ 270 (Nm) **(1)** (273)

Nm (1) or newton metre(s) accept Newton metre(s)

(not J, nm or nM, Nms, etc)

2

(c) $(b) + (1100 \times 0.60)$ **(1)**

$(=) F_A \times 1.3$ **(1)** ($F_A = 660 + 273/1.3$ gets both marks)

$(= 933/1.3) = 720$ (N) **(1)** (717.7 or 715 for use of 930)
ecf (b)

2 sf only (1)

independent mark

4

(d) $(780 + 1100 - (c)) = 1200$ **(1)** (1162 N)

ecf (c)

1

(e) $\left(F = \frac{P}{v} \right) = \frac{7.5(\times 10^3)}{26}$ **(1)**

must be arranged in this form

$= 290$ (N) **(1)** (288.46)

2

[11]

4

(a) (i) weight of container ($= mg = 22000 \times 9.8(1) = 2.16 \times 10^5$ (N) **(1)**

tension ($= \frac{1}{4} mg$) = (5.39) 5.4×10^4 (N) or divide a weight by 4 **(1)**

(ii) moment ($= \text{force} \times \text{distance}$) = 22000×32 **(1)** ecf weight in (a) (i)

$= 6.9$ or 7.0×10^6 **(1)** N m or correct base units **(1)** not J, nm, NM

(iii) the counterweight **(1)**

provides a (sufficiently large) anticlockwise moment (about Q)
or moment in opposite direction (to that of the container to
prevent the crane toppling clockwise) **(1)**

or

left hand pillar pulls (down) **(1)**
and provides anticlockwise moment

or

the centre of mass of the crane('s frame and the counterweight)
is between the two pillars **(1)**

which prevents the crane toppling **clockwise**/to right **(1)**

7

(b) (i) (tensile) stress ($= \frac{\text{tension}}{\text{csa}} = \frac{5.4 \times 10^4}{3.8 \times 10^{-4}}$ ecf (a) (i) **(1)**

$= 1.4(2) \times 10^8$ **(1)** Pa (or N m⁻²) **(1)**

$$(ii) \text{ extension} = \frac{\text{length} \times \text{stress}}{E} \text{ or } \frac{FL}{EA} \quad (1)$$

$$= \frac{25 \times 1.4 \times 10^8}{2.1 \times 10^{11}} \text{ and } (= 1.7 \times 10^{-2} \text{ m}) = 17 \text{ (mm)} \quad (1)$$

5

[12]

5

- (a) product of the force and the **perpendicular distance (1)**
reference to a point/pivot **(1)**

2

- (b) (i) since W is at a greater distance from A **(1)**
then W must be less than P if moments are to be equal **(1)**
- (ii) P must increase **(1)**
since moment of girl's weight increases as she moves from A to B **(1)**
correct statement about how P changes
(e.g. P minimum at A , maximum at B , or P increases in a linear fashion) **(1)**

max 4

[6]

6

- (a) (i) resultant force acting on tray is zero [or $P + W = Q$] **(1)**
resultant torque is zero
[or correct moments equation
or anticlockwise moments = clockwise moments] **(1)**
- (ii) $W = 0.12 \times 9.81 = 1.2 \text{ N}$ **(1)** (1.18N)
- (iii) (taking moments about P gives)
 $Q \times 0.1 = 0.12 \times 9.81 \times 0.25$ **(1)**
 $Q = 2.9 \text{ N}$ (2.94 N) **(1)**
 $P = 2.9 - 1.2 = 1.7 \text{ N}$ **(1)** (or $2.94 - 1.18 = 1.76 \text{ N}$)
(allow C.E. for values of W and Q)

6

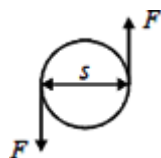
- (b) placed at Q **(1)**
no additional turning moment about Q **(1)**

2

[8]

7

- (a) (i)



two forces opposing **(1)**
forces parallel **(1)**
 s correct **(1)**

- (ii) N m **(1)**

(4)

- (b) (i) anticlockwise moments = clockwise moments **(1)**

- (ii) weight of beam acts at centre **(1)**
this is through the pivot **(1)**

(3)

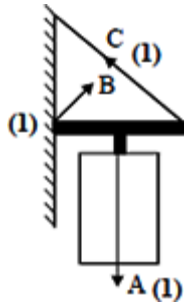
- (c) (equating moments gives) $400 \times 1.0 = 200 \times 0.50 + 250 \times d$ **(1)**
 $\therefore 400 - 100 = 250 \times d$ and $d = 1.2 \text{ m}$ **(1)**

(2)

[9]

8

- (a) (i)

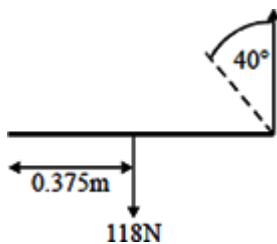


n.b. B must make an appreciable angle with wall and bar

- (ii) A weight of sign and bar (accept gravity) **(1)**
B reaction of wall **(1)**
C tension in wire **(1)**

max 5

- (b)



use of mg **(1)**

clockwise moments 118×0.375 **(1)**

= anticlockwise moments ($T \cos 40^\circ$ **(1)**) $\times 0.750$ **(1)**

$T = 77 \text{ N}$ **(1)**

max 4

[9]

9

- (a) force $\times$ distance

B1

perpendicular distance (from force) to pivot

B1

(2)

(b) (i) both string tension directions labelled and correct

B1

both weight force directions labelled and correct;

B1

(2)

(ii) statement or use of sum of moments = zero

B1

$$5 \times 0.15 + 10 \times 0.25 = T_A \times 0.5$$

$$T_A = 2(0.75 + 2.5) = 3.25 \times 2 = 6.5 \text{ N}$$

A1

(3)

(iii) $T_B = 15 - 6.5 = 8.5 \text{ N}$ (e.c.f.)

A1

(1)

[8]

10

A

[1]

11

A

[1]

12

(a) force $\times$ distance from the point

C1

force $\times$ perpendicular distance of the force from the point

A1

(2)

(b) (i) arrow drawn from mid-point of rod

M1

vertically down

A1

(2)

(ii) correct moments equation

C1

2.3 N

A1

(2)

(iii) 15.7 N (18 – (ii))

B1

(1)

[7]