Exam Answers

Chapter 1·5 - Torque & Equilibrium

Answer 1 2010:1:7

(4 marks)

The photograph shows the yacht *BMW Oracle*, which has both a length and width of 28 m.

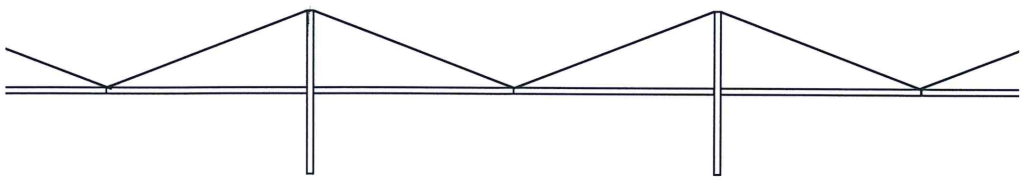
Estimate the torque, exerted by the wind blowing on the sails, that would just begin to tip the *BMW Oracle* as shown. The sail has a mass of 3.5×10^3 kg, the central hull 1.0×10^3 kg and each outrigger 0.5×10^3 kg.

Description	Marks
Torque = Force (weight]) × perpendicular distance.	1
Understand max torque is when assume angle of tilt is zero ie weight and wind direction perpendicular. (Allow an angle of up to 20° as this corresponds to diagram)	1
Take moments about left hand hull, Torque = $(1.0 + 3.5) \times 9.8 \times 10^3 \times 14 + 0.5 \times 10^3 \times 9.8 \times 28$ $= 6.3 \times 10^5 + 1.35 \times 10^5$ $= 8 \times 10^5$ Nm (allow $g = 10$ m s^{-2}) Note: Can consider all of the mass acting through c of m but this must be stated to get full marks. ie $T_{sail} = \Sigma m \times g \times r_{c\ of\ m}$ where $r_{c\ of\ m}$ is assumed in the centre since symmetrical $T_{sail} = 5.5 \times 10^3 \times 9.8 \times 14 = 7.5 \times 10^5$ Nm	1-2
	Total 4

Answer 2 2010:2:19

(9 marks)

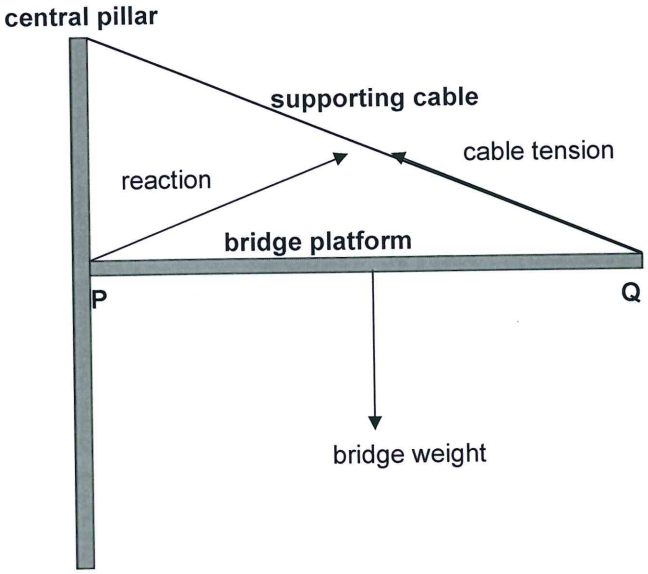
A concrete bridge structure is being built. It consists of vertical pillars that support horizontal platforms, as shown below.



Exam Answers
Chapter 1·5-Torque & Equilibrium
Answer 2: continued

(a) The section of bridge platform labelled PQ on the diagram below is in equilibrium even though three forces act on it. Draw and label these three forces on the diagram. (3 marks)

Description	Marks
Each vector drawn with arrow to indicate direction.	1-3
All three vectors should intersect at one point. 3 unlabelled forces maximum 1 mark	
Total	**3**



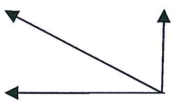
(b) Calculate the angle Φ. (1 mark)

Description	Marks
Calculate angle Φ tan Φ = 17.5/35 Φ = 26.6°	1
Total	**1**

(c) By taking moments about a suitable point calculate the vertical component of the tension. (3 marks)

Description	Marks
Take moments about point A $(50 \times 10 \times 1000 \times 9.8) + (420 \times 17.5 \times 1000 \times 9.8) = T_V \times 35$	1-2
$T_v = 76.9 \times 10^6 / 35 = 2.19 \times 10^6$ N	1
Total	**3**

(d) Using the vertical component from (c), determine the tension in the cable. If you could not calculate the vertical component, use 4.20×10^6 N. (2 marks)

Description	Marks
$\sin 26.5° = T_v / T$ $T = \frac{2.19 \times 10^6}{\sin 26.5°}$ 	1
$T = 4.91 \times 10^6$ N if use 4.20×10^6 N then $T = 9.39 \times 10^6$	1
Total	**2**

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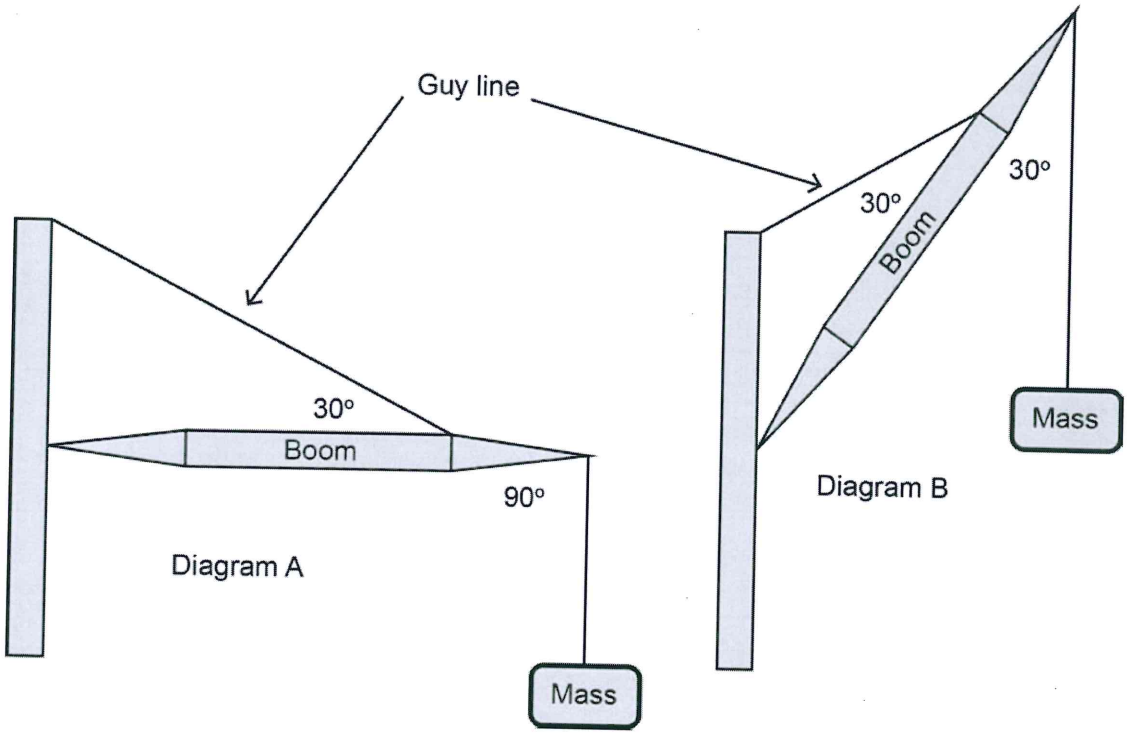
Chapter 1.5 - Torque & Equilibrium
Answer 3 2011:1:8

(4 marks)

A crane (Diagram A) lifts a mass by raising its boom (Diagram B). Explain how this affects the tension in the guy line as the crane shifts the mass from its initial position in Diagram A to its position in Diagram B.

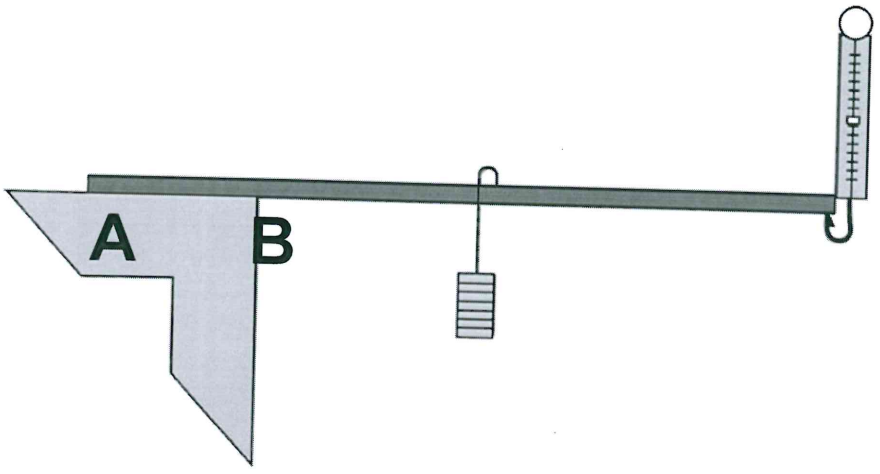


Description	Marks
The tension in Diagram B is less	1
The guy wire doesn't change its orientation to the boom ($r \times \sin 30° = \text{constant}$)	1
The mass exerts a constant force, downwards, but the θ changes (90° to 30°)	1
$\tau = rF\sin\theta = rF\sin 30°$ which is half torque, so half the tension.	1
	Total 4

Answer 4 2011:1:10

(4 marks)

A uniform 100 gram, metre-long ruler is placed on a table, with most of its length overhanging the edge. A 350 gram slotted mass is placed at the ruler's 500 mm mark, and a spring balance holds it up at one end, as shown in the diagram below.



Exam Answers
Chapter 1·5 - Torque & Equilibrium
Answer 4: continued

The ruler is just lifted using the spring balance so that it touches the table in only one place. At this point the spring balance reads 2.20 N. Indicate on the diagram the fulcrum, or pivot point, for this action and label it 'A'.

The ruler is then lowered slightly, changing the position of the fulcrum.

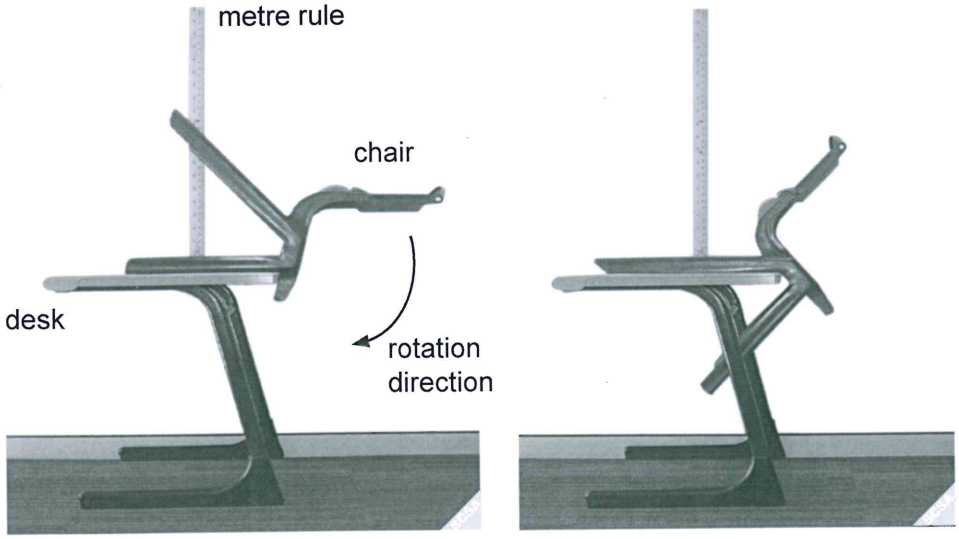
Label this new fulcrum, or pivot point, 'B'.

When the ruler is in this position, the spring balance reads 1.65 N. Determine the distance between the points 'A' and 'B'. Note that the angle that the ruler makes with the horizontal has not changed significantly and should not be considered in your calculations.

Description	Marks
Diagram labelled correctly	1
For point 'B' (radii correct) Anticlockwise torque = Clockwise torque Turning point chosen and radii determined	1
$(s - 1.00) \times 1.65 = (s - 0.50) \times (0.350+0.100) \times 9.8$	1
$s = 0.201$ m	1
	Total 4

Answer 5 2013:1:5

(8 marks)



Photograph A **Photograph B**

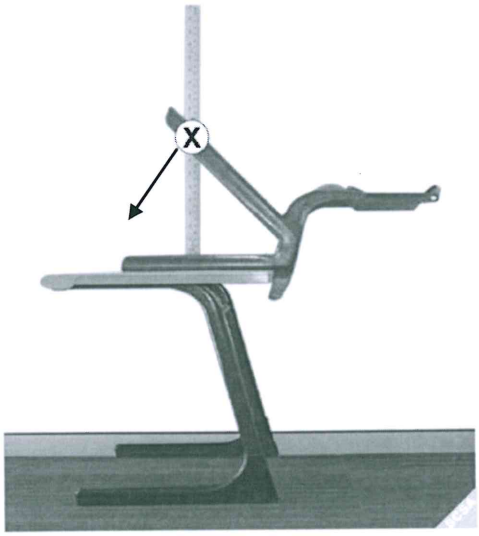
(a) The photographs above show the same chair in two different positions. A metre rule is included to provide scale. Photograph A shows the chair in the instant after the person holding it in place let go.

In Photograph A the chair will begin to rotate and fall to the floor as soon as the hand is removed, while in Photograph B the chair will stay in the position as shown. Explain why the chair will rotate in Photograph A but not in Photograph B. (3 marks)

Exam Answers
Chapter 1.5 - Torque & Equilibrium
Answer 5: continued

Description	Marks
Uses or refers to a photograph to aid explanation eg indicates centre of mass, pivot point, forces or torques.	1
Explanation involving concept of a rigid body in equilibrium – clockwise torque is unbalanced in A but not in B	1
States chair will rotate about a pivot point.	1
Total	**3**

(b) On the photograph below, indicate the direction of the force that you could apply at Point X in order to prevent the chair from rotating. Estimate the magnitude of this force, stating clearly any assumptions that you make. (5 marks)



Description	Marks
Force drawn that would result in a restoring torque (should be anticlockwise, unless part (a) is incorrect) to the chair, see above.	1
Assumptions mass of chair = 3 kg (1-10) Distance of weight force from the pivot point = 0.05 m (0.01-0.15)	1
Estimation of clockwise torque = rF = $0.05 \times 3 \times 9.8 = 1.47$ N m (includes estimate of perpendicular distance)	1
Provides a reasonable answer Type example: $F = \tau / r = 1.47 / 0.5 = 2.9$ N (no units required)	1
to one or two significant figures	1
Total	**5**

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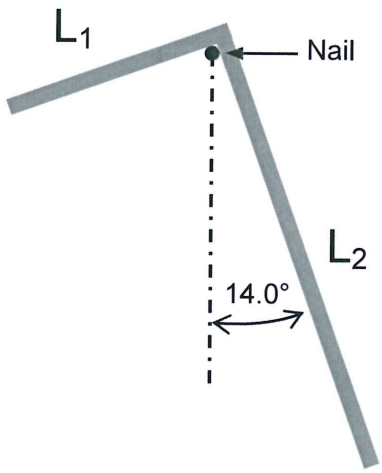
Chapter 1.5 - Torque & Equilibrium
Answer 6 2014:1:13

(6 marks)

A thin metal rod is bent into a right angle and hung on a nail from a wall, as shown in the diagram. Assume that there is no contact between the rod and wall. The longer side (L_2) is 0.800 m long and makes an angle of 14.0° to the vertical. The rod has uniform density and constant thickness. Calculate the length of the shorter side, L_1. Show **all** workings.



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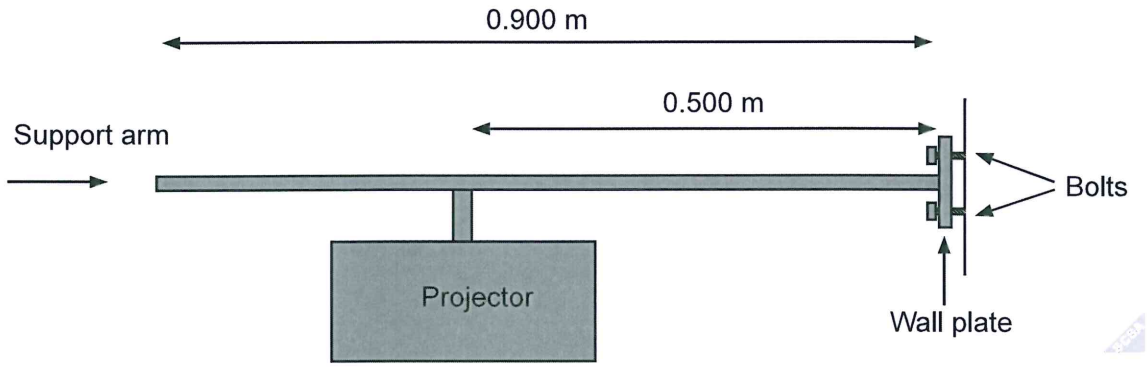
Description	Marks
Take moments about P $\Sigma\tau_{cw}=\Sigma\tau_{acw}$	1
Forces act through centre of mass which is in the middle of each length	1
Force on L_1 acts at 76° to L_1 arm	1
Uses torque=rF sin θ i.e. $L_1 M_1 g \sin 76° = L_2 M_2 g \sin 14°$	1
Recognises that M_1 is proportional to length i.e. $M_1 = kL_1$ $M_2 = kL_2 = 0.8\,k$	1
∴ $L_1 kL_1 g \sin 76° = L_2 kL_2 g \sin 14°$ ∴ $L_1^2 \sin 76° = 0.8^2 \sin 14°$ ∴ $L_1 = 0.399$ m	1
Total	**6**
Note: much of the above information may be shown on a diagram.	

Exam Answers
Chapter 1.5 - Torque & Equilibrium
Answer 7 2014:2:16

(10 marks)

The diagram below shows a data projector with a mass of 7.00 kg. The projector is mounted on its uniform horizontal support arm at a distance of 0.500 m from the wall plate. The support arm itself is 0.900 m long and has a total mass of 1.00 kg.



The assembly is held in place by bolts as shown in the diagram above. The upper bolt is 4.00 cm above the support arm and the lower bolt is 4.00 cm below the support arm. The wall plate does not touch the wall and is supported only by the bolts.

(a) Calculate the **horizontal force** in newtons exerted by the **upper bolt** used to attach this projector to the wall. Show **all** workings.
Hint: Take the bottom bolt of the wall plate as a pivot point. (4 marks)

Description	Marks
ΣACWM = ΣCWM $\tau_{Projector} + \tau_{Support\ Arm} = \tau_{Upper\ bolts}$	1
$(7 \times 9.8 \times 0.5) + (1 \times 9.8 \times 0.45) = (F_{upper} \times 0.08)$	1
$F_{upper} = 38.71 / 0.08$	1
$F_{upper} = 484$ N	1
Total	**4**

(b) Explain quantitatively the effect on the centre of mass of the projector/support arm system as the projector is moved further away from the wall. (3 marks)

Description	Marks
The projector is 7 times more massive than the arm, so as the projector is moved the centre of mass of the system is moved 7/8 the distance of the projector (or other correct calculation or equation)	3
or	
As the projector is moved, only part of the system's mass is moved, so the centre of mass moves, but not as much as the projector	2
or	
The centre of mass is moved away from the wall.	1
Total	**3**

Exam Answers
Chapter 1.5 - Torque & Equilibrium
Answer 7: continued

(c) Explain quantitatively the effect on the horizontal force exerted by the upper bolt as the projector is moved further away from the wall, assuming the system maintains its stability.

(3 marks)

Description	Marks
Some quantification attempted e.g. as the distance of the centre of mass doubles, so does the restoring horizontal force needed or states that $F_{upper} = \frac{7 \times 9.8 \times d + (1 \times 9.8 \times 0.45)}{0.08}$ $\therefore$ as d increases, F_{upper} increases.	3
or	
The bolt would need to increase the force to maintain the restoring torque	2
or	
As the projector increases its distance the torque increases	1
Total	**3**