

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is A ($\frac{Fx}{y} + F$) B is not correct because $W = \frac{Fx}{y} + F$ C is not correct because $W = \frac{Fx}{y} + F$ D is not correct because $W = \frac{Fx}{y} + F$	1

Q2.

Question Number	Answer	Mark
	C is the only correct answer A is incorrect because moments must balance about the centre of mass. B is incorrect because moments must balance about the left support. D is incorrect because the total reaction must be equal to the weight.	1

Q3.

Question Number	Answer	Mark
	B is the correct answer A is incorrect because the CW moment of the force could balance the ACW moment of the weight C is incorrect because the CW moment of the force could balance the ACW moment of the weight D is incorrect because the CW moment of the force could balance the ACW moment of the weight	1

Q4.

Question Number	Answer	Mark
	B is the correct answer A is not correct as they are the units for force. C is not correct as they are the units for momentum. D is not correct as they are the units for power.	(1)

Q5.

Question Number	Answer	Mark
(a)	Use of appropriate trigonometry (1) Use of moment of force = Fx (1) Moment = 110 N m (1) <u>Example calculation</u> $580 \text{ N} \times 0.21 \text{ m} \times \cos(24^\circ) = 111 \text{ N m}$	3
(b)	The horizontal/perpendicular distance between W and the pivot decreases Or The component of W perpendicular to the lever decreases Or $\cos(\theta)$ decreases (from 1 to zero) (1) So the <u>moment</u> (of W about the pivot) decreases and F decreases (to zero) (1)	2
Total for question		5

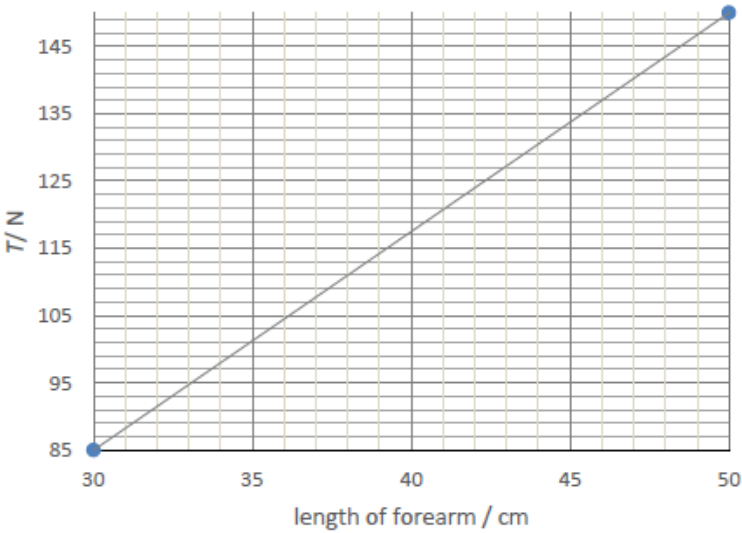
Q6.

Question Number	Answer	Additional Guidance	Mark
(a)	Because there is no (resultant) moment. (1)		1
(b)	Use of moment of force = Fx to determine clockwise moment (1) Use of appropriate trigonometry to determine vertical distance on wall between horizontal bar and supporting bar (1) Use of principle of moments (1) $F = 85 \text{ N}$ (1)	<u>Example of calculation</u> Moment of weight about bottom of supporting bar $= 34 \text{ N} \times 0.28 \text{ m}$ $= 9.52 \text{ N m}$ Vertical distance from P to F = $\frac{0.16 \text{ m}}{\tan(55^\circ)} = 0.112 \text{ m}$ $F \times 0.112 \text{ m} = 9.52 \text{ N m}$ $F = \frac{9.52 \text{ N m}}{0.112 \text{ m}} = 85 \text{ N}$	4
Total for question			5

Q7.

Question Number	Answer	Mark
(a)	Moments due to force on wheel and force on handle must be equal (magnitude about any point) (1) Moment is force times (perpendicular) distance [accept "$F x$" but no other symbols unless in question or defined by candidate] (1) [Accept for MP1 and MP2 Force $\times$ (perpendicular) distance must be same for both moments] Handle is further from centre of gravity than wheel (so less force for equal moment) [NB independent mark] (1)	3
(b)	Uses weight = 400 N (1) Or Uses x and $(1.5 - x)$ (1) Use of moment = Fx about a stated point (1) [accept pivot point clearly indicated on diagram] (1) Use of principle of moments (1) $x = 0.3 \text{ m}$ <u>Example calculation</u> Weight = $320 + 80 = 400 \text{ N}$ Taking moments about line of action of 320 N force $400 \text{ N} \times x = 80 \text{ N} \times 1.5 \text{ m}$ $x = 120 \text{ Nm} \div 400 \text{ N} = 0.30 \text{ m}$	4
Total for question		7

Q8.

Question Number	Answer	Mark
(a)	- Estimate of length of forearm 30 – 50 (cm) (1) - Use of trig to determine the perpendicular component of the tension Or see $T\sin 70$ Or see $T\cos 20$ (1) - Use of moment = Fx with a corresponding force and distance (1) - Use of the principle of moments (1) - Value for T in range 85 N to 150 N ($l = 30$ cm, $T = 85$ N and $l = 50$ cm, $T = 150$ N) (1) <u>Example of calculation</u> (for $l = 0.40$ m) $(0.04 \text{ m} \times T \times \sin 70) = (0.31 \text{ m} \times 4.5 \text{ N}) + (0.20 \text{ m} \times 15 \text{ N})$ $T = 117 \text{ N}$ 	5

(b)	- The forearm is not uniform/symmetrical (1) - The centre of gravity is not in the middle (1)	2
Total for question		7

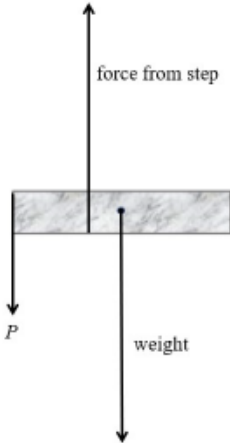
Q9.

Question Number	Answer	Mark
(a)	• Use of $\Sigma F = 0$, seen or implied (1) • $F = 11 \text{ N}$ (1) • Use of moment of force $= Fx$ (with any corresponding force and known distance from an end, A or midpoint) (1) • Use of the principle of moments (1) • $x = 0.86 \text{ m}$ (1) 5 <u>Example of calculation</u> $F_A + F_B = 8.5 \text{ N} + 14 \text{ N} = 22.5 \text{ N}$ $F_A = F_B$ $2F = 22.5 \text{ N}$ $F = 11.25 \text{ N}$ if moments taken from the left end $(11.25 \text{ N} \times 0.15 \text{ m}) + (11.25 \text{ N} \times x) = (8.5 \text{ N} \times 0.35 \text{ m}) + (14 \text{ N} \times 0.60 \text{ m})$ $x = 0.861 \text{ m}$ if moments taken from midpoint $(11.25 \text{ N} \times 0.45 \text{ m}) = (11.25 \text{ N} \times x) + (8.5 \text{ N} \times 0.25 \text{ m})$ $x = 0.261 \text{ m}$ so distance $= 0.261 \text{ m} + 0.6 \text{ m} = 0.861 \text{ m}$ if moments taken from A $(8.5 \text{ N} \times 0.20 \text{ m}) + (14 \text{ N} \times 0.45 \text{ m}) = (11.25 \text{ N} \times x)$ $x = 0.711 \text{ m}$ so distance $= 0.711 + 0.15 \text{ m} = 0.861 \text{ m}$	
(b)	The moment (of B) must be the same (1) For a smaller distance (from the left end of the shelf), the (normal contact) force must increase (1) 2	
	Total for question	7

Q10.

Question Number	Answer	Mark
(a)	Resultant force is zero (1)	2
	Resultant moment (about any point) is zero (1)	
(b)	Use of Moment of force = Fx (1)	6
	Use of principle of moments with dish in original position (1)	
	Uses total weight = weight of rice + weight of dish to determine weight of one portion of rice (1)	
	Use of principle of moments with dish in new position	
	Or	
	Calculates clockwise moment with 3 portions of rice in new position and calculates anticlockwise moment of weight of beam (1)	
	Dish contains 8.2 portions of rice (1)	
	Comparison with 3 portions and consistent conclusion (1)	
	<u>Example calculation</u>	
	Moment of weight of beam = $3.1 \text{ N} \times 0.08 \text{ m} = 0.248 \text{ N m}$	
	$0.248 \text{ N m} = (\text{weight of dish and rice}) \times 0.25 \text{ m}$	
	Weight of dish and rice = $\frac{0.248 \text{ N m}}{0.25 \text{ m}} = 0.992 \text{ N}$	
	Weight of one portion of rice = $0.992 \text{ N} - 0.64 \text{ N} = 0.352 \text{ N}$	
	$0.248 \text{ N m} = (\text{portions} \times 0.352 \text{ N} + 0.64 \text{ N}) \times 0.07 \text{ m}$	
	Number of portions = $\frac{\frac{0.248 \text{ N m}}{0.07} - 0.64 \text{ N}}{0.352 \text{ N}} = 8.247$	
	The dish contains 8.2 portions, not 3 portions of rice	
Total for question		8

Q11.

Question Number	Answer	Mark
(a)(i)	Zero resultant/net force (in any direction) (1) Zero (turning) moment (about any point) (1)	2
(a)(ii)	The point through/at which the weight of the object may be taken to act (1)	1
(b)(i)	Downward arrow at centre of gravity labelled "weight" Or " W " Or " mg " (1) Upward arrow between CoG. and P labelled "force from step" (1) 	2
(b)(ii)	Use of moment of a force = $F \times$ (1) Applies principle of moments (1) $P = 52 \text{ N}$ (1) <u>Example of calculation</u> Taking moments about the right hand edge of the step: $0.40 \text{ m} \times P = 0.05 \text{ m} \times 4.15 \times 10^2 \text{ N} = 20.8 \text{ N m}$ $P = 20.8 \text{ N m} \div 0.40 \text{ m} = 51.9 \text{ N}$	3
Total for question		8

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	Total clockwise moment = total anticlockwise moment Or Resultant moment = zero Or Sum of all moments = zero (1)		1

(b)(i)	Use of trigonometry to determine appropriate component of piston force Or Use of trigonometry to determine perpendicular distance from pivot to line of action of piston force (1) Use of trigonometry to determine appropriate component of weight Or Use of trigonometry to determine perpendicular distance from pivot to line of action of weight (1) Use of moment = Fx (1) Use of principle of moments (1) Minimum force = 22 N (1)	<u>Example calculation</u> Moment of F_{piston} about pivot = $160 \text{ N} \times \sin 18^\circ \times 0.37 \text{ m} = 18.3 \text{ Nm}$ Moment of weight about pivot = $95 \text{ N} \times \cos 42^\circ \times 0.70 \text{ m} = 49.4 \text{ Nm}$ $18.3 \text{ Nm} + F \times 1.40 \text{ m} = 49.4 \text{ Nm}$ $F = \frac{49.4 \text{ N m} - 18.3 \text{ N m}}{1.40 \text{ m}} = 22.2 \text{ N}$	5
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(b)(ii)	(each force applied by the student must cause) the same moment (about the pivot) (1) (When the force is vertical) The component of the force perpendicular to the rail must be the same Or (When the force is vertical) The perpendicular distance from the (line of action of the) force to the pivot is less Or If the same (magnitude) force is applied vertically, the moment of the force (about the pivot) is less (1) (So when the force is vertical) the force needed is greater (1)	MP3 dependent on MP1 or MP2	3
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Q13.

Question Number	Answer	Additional Guidance	Mark
(a)	In equilibrium, total clockwise moment = total anticlockwise moment Or In equilibrium, sum of all moments (about any point) = 0 Or In equilibrium, resultant moment (about any point) = 0 (1)	Clockwise moment = anticlockwise moment is insufficient.	1
(b)(i)	The weight causes a clockwise moment (about the pivot) (1) So the direction (of the moment provided by the motor) is anticlockwise (dependent on MP1) (1)		2
(b)(ii)	The motor needs to provide a smaller moment (1) So a smaller force is needed (which moves through the same distance) (1) So the work done decreases (dependent on MP1 or MP2) (1)		3

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	Determines distance from pivot to centre of gravity of section of bridge (1) Use of Moment of force = Fx (1) Use of principle of moments (1) Moment produced by motor = $8.4 \times 10^7 \text{ N m}$ (1)	<u>Example calculation</u> Distance from pivot to centre of gravity of section $= 33 \text{ m} - \frac{33 \text{ m} + 12 \text{ m}}{2}$ $= 10.5 \text{ m}$ $4.0 \times 10^6 \text{ N} \times 11 \text{ m} + \text{moment produced by motor}$ $= 1.2 \times 10^7 \text{ N} \times 10.5 \text{ m} + 71 \times 10^3 \text{ N} \times 28 \text{ m}$ Moment produced by motor = $8.40 \times 10^7 \text{ N m}$	4
	Total for question		10

Q14.

Question Number	Answer	Mark
(a)	Use of $\Delta W = F \Delta x$ or $\Delta E_{grav} = mg\Delta h$ (1) Use of $P = W / t$ (1) Use of efficiency = useful power output / total power input Or Use of efficiency = useful energy output / total energy input (1) Total power input = 2.0×10^4 W (1) <u>Example of calculation</u> $\Delta W = 4.4 \times 10^4 \times 15 \text{ m} = 6.6 \times 10^5 \text{ J}$ Output power = $6.6 \times 10^5 \text{ J} \div 70 \text{ s} = 9.4 \times 10^3 \text{ W}$ Efficiency = $\frac{9.4 \times 10^3 \text{ W}}{\text{Total power input}} = 0.47$ Total power input = $\frac{9.4 \times 10^3 \text{ W}}{0.47} = 2.0 \times 10^4 \text{ W}$	4
(b)(i)	Total clockwise must balance total anticlockwise moment (about tower) Or Net/resultant/total moment (about tower) must be zero. (1) Total anticlockwise moment is due to counterweight and Total clockwise moment is due to sum of moment from beam and load (1) Increasing the distance of the load increases the (cw) moment (distance of CoG remains the same) (1) Distance of counterweight needs to be increased [dependent on MP3] (1)	4

(b)(ii)	Use of moment = $F x$ (1)	5
	Position of centre of mass of beam identified (1)	
	Use of principle of moments (1)	
	Maximum distance of load = 15 m	
	Or, for load at 22 m ...	
	CW moment = $1.18 \times 10^6 \text{ Nm}$ and max ASW moment = $8.8 \times 10^5 \text{ Nm}$	
	Or	
	Required distance of counterweight = 11 m	
	Or	
	Required counterweight = $1.5 \times 10^5 \text{ N}$	
	Or	
	Maximum load = $3.0 \times 10^4 \text{ N}$	
	Or	
	Required distance to CoG = 2.9 m	
	Or	
	Required weight of beam = $1.3 \times 10^4 \text{ N}$	
	Or	
	Resultant moment = $3.0 \times 10^5 \text{ Nm}$ (cw) (1)	
	Valid conclusion by comparison of relevant student values (1)	
	<u>Example of calculation</u> For equilibrium: $3.0 \times 10^4 \text{ N} \times 7.0 \text{ m} + 4.4 \times 10^4 \text{ N} \times x = 1.1 \times 10^5 \text{ N} \times 8.0 \text{ m}$ where x is the maximum distance of the load from the tower. $x = (8.8 \times 10^5 \text{ Nm} - 2.1 \times 10^5 \text{ Nm}) \div 4.4 \times 10^4 \text{ N}$ $= 6.7 \times 10^5 \text{ Nm} \div 4.4 \times 10^4 \text{ N} = 15.2 \text{ m}$ $15.2 \text{ m} < 22.0 \text{ m}$ so crane would topple if load moved to end of beam	
	Total for question	

Q15.

Question Number	Answer	Mark
(a)	No resultant force (1)	2
	No resultant moment (about any point) (1)	
(b)	The point at which the weight of an object is considered to act (1)	1
(c)(i)	Use of $W = mg$ (1)	5
	Horizontal distance from edge of door to centre of gravity identified as $\frac{w}{2}$ (1)	
	Use of moment of force = Fx (1)	
	Use of clockwise moment = anticlockwise moment (1)	
	Horizontal component of force of hinge Y on door = 37.5 (N) (1)	
	OR	
	Use of $W = mg$ (1)	
	Use of $\tan \theta$ with dimensions of door (1)	
	Use of vertical component of force of hinge Y on door = $W/2$ (1)	
	Use of $\tan \theta$ with vertical and horizontal components of force of hinge Y on door (1)	
	Horizontal component of force of hinge Y on door = 37.5 (N) (1)	
	<u>Example of calculation</u>	
	$W = 14.4 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 141 \text{ N}$	
	$141 \text{ N} \times \frac{0.85 \text{ m}}{2} = F_{\text{horizontal}} \times 1.60 \text{ m}$	
	$F_{\text{horizontal}} = \frac{60.0 \text{ N m}}{1.60 \text{ m}} = 37.5 \text{ N}$	

(c)(ii)	Use of appropriate trigonometry to determine θ (1) $\theta = 28^\circ$ (allow ecf from (c)(i)) (show that answer gives 30°) (1) Use of Pythagoras' theorem to determine F Or Use of appropriate trigonometry to determine F (1) $F = 80 \text{ N}$ (allow ecf from (c)(i)) (show that answer gives 81 N) (1) <u>Example of calculation</u> $\theta = \tan^{-1} \left(\frac{37.5}{\left(\frac{141}{2}\right)} \right) = 28.0^\circ$ $F = \sqrt{(37.5 \text{ N})^2 + \left(\frac{141 \text{ N}}{2}\right)^2} = 80.0 \text{ N}$	4
(c)(iii)	Moment of weight of door (about X) remains the same. Or $mg \times \frac{w}{2} = F_{\text{horizontal}} \times L$ (and m, g and w remain the same). (1) (So) horizontal (component of) force increases (when L decreases). (1) Vertical (component of) force remains the same. Or Each hinge still holds half the weight of the door. (1) (So) F increases and θ increases. (1)	4
Total for question		16