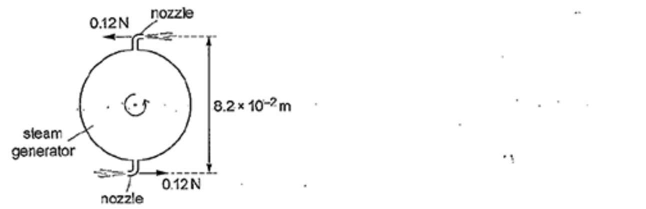
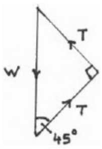
Mark scheme – Forces in Action Equilibrium

Question			Answer/Indicative content	Marks	Guidance
1			**C**	1	**Examiner's Comments** This proved to be challenging for most, except for the very top–end candidates. All the distractors were equally popular, and just over a third of the candidates got the correct answer C. Many of the scripts from the successful candidates had the term key *uniform* underlined or circled. The centre of gravity of the rod and the point of contact of the cable to the rod were the same. For equilibrium, the contact force from **X** had to pass through this same point – which only left arrow C as the correct answer.
			Total	**1**	
2			**D**	**1**	**Examiner's Comments** If this system is in equilibrium, then the moment due to tension T must equal the moment of the couple formed by the two 50 N forces. Many candidates forgot to include one of the two 50 N forces. Since the force is 50 N and the separation is 0.80 m, then the moment of the couple is 40 Nm.
			Total	**1**	
3			sum of clockwise moments (about a point / axis) = sum of anticlockwise moments (about the same point /axis)	B1	**Allow** total / Σ for 'sum'
			Total	**1**	
4			(For a system in equilibrium) the sum of the clockwise moments (about the same point) = sum of anticlockwise moments	B1	**Allow** total / ∑ / resultant for 'sum' **Allow** the sum of moments = 0
			Total	**1**	
5			Force is proportional to the product of the mass of each asteroid. **and** the force is inversely proportional to the distance squared between the centres of mass of the asteroids.	B1	
			Total	**1**	

6			(torque =) 350 x 0.0050 torque = 1.8 (N m)	C0 A1	Answer is 1.75 to 3 sf. **Allow**: 1.7 (N m)
			Total	**1**	
7			Resultant / net / total moment = 0	B1	**Allow** sum of / Σ moments = 0 **Allow** 'total torque = 0' **Allow** clockwise moment = anticlockwise moment **<u>Examiner's Comments</u>** Most candidates struggled with this opening question. Only a third of the candidates picked up a mark for 'resultant moment = 0'. A small number of candidates spoilt their answers by mentioning momentum rather than moment. A statement for the principle of moments was allowed. **Misconception** The two most popular incorrect responses for the second condition for equilibrium were: • The system has no external forces acting. • The object must be travelling with constant speed.
			Total	**1**	
8	a		When (line of force of the) weight falls to the right of the (bottom of the) wheel/AW	B1	
	b		For a body in (rotational) equilibrium the sum of the clockwise moments (about any point) is equal to the sum of the anticlockwise moments (about the same point)	B1	**Note** Accept Σ / total (AW) for sum **<u>Examiner's Comments</u>** The principle of moments only applies when an object is in equilibrium as required.
			Total	**2**	
9			B	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions. The candidates to demonstrate their knowledge and understanding of physics.

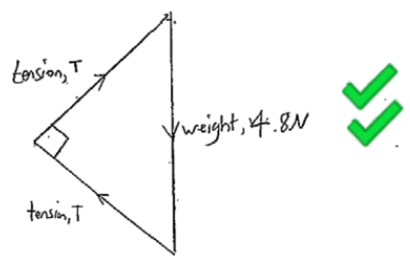
			Total	**1**	
10			D	1	
			Total	**1**	
11			**C**	**1**	
			Total	**1**	
12			B	1	
			Total	**1**	
13			**A**	**1**	
			Total	**1**	
14			D	1	
			Total	**1**	
15			A	1	
			Total	**1**	
16			D	1	
			Total	**1**	
17			**B**	1	
			Total	**1**	
18			**C**	1	
			Total	**1**	
19			**A**	1	
			Total	**1**	
20			**D**	1	**<u>Examiner's Comments</u>** This question was based on work done by a couple, and as such proved to be quite challenging. The work done by the couple is given by the expression below: work done = 2 × work done by each force = 2 × [0.12 × π × 8.2 × 10^{-2}] = 6.2 × 10^{-2} J The most popular answers turned out to be either A or C. The

					answer C was for the work done by one of the forces. This question was only accessible to the very top-end candidates. The exemplar 1 below shows an incorrect analysis that led to B being inserted into the answer box. **Exemplar 1**  The diagram below shows a rotating steam generator. The steam ejected from the nozzles provides a couple. The force at each nozzle is 0.12 N. The perpendicular distance between the nozzles is 8.2 × 10^{-2} m. What is the work done by the forces as the steam generator completes one revolution? **A** 0 J **B** 9.8 × 10^{-3} J **C** 3.1 × 10^{-2} J **D** 6.2 × 10^{-2} J Your answer B [1] The candidate has either written the equation for work done, or torque of a couple. Substitution shows that the torque has been calculated. Unfortunately, the response of 9.8 × 10^{-3} J was there as one of the options. This exemplar shows that if the starting point is incorrect, it can easily lead to what looks like a promising response.
			Total	**1**	
21	a		Triangle with at least **two** forces shown, **one** angle marked and the *W* side being longest The (force) arrows are consistently clockwise or anticlockwise 	B1 B1	**Allow**  for right angle **Ignore** 'orientation' of the triangle **Ignore** any other figures **Note** all three arrows are required
	b		2 × T^2 = 4.8^2 **or** 2*T*sin45° = 4.8 **or** *T* = 4.8 sin45° **T** = 3.39(4)(N)	B1 B1	**Note**: sin45° = cos45° **Note**: *T* must be given to at least 3 SF **<u>Examiner's Comments</u>** This question was good discriminator, where the top–end candidates could demonstrate their powers of analysis. The success in **(c)** was very much dependent on a well–annotated triangle of forces in **(b)**. Most triangle of forces were workable but lacked detail. Missing labels and incorrect direction of the force arrows were the

main misdemeanours. As expected, candidates used a range of methods to show the force in the extended spring was 3.4 N. In order of popularity, the techniques were using Pythagoras' theorem, using trigonometry, resolving forces in the vertical direction and sine (or cosine) rule. It is sensible to show the final answer to more significant figures than required in a 'show' question.

Exemplar 6

(b) Sketch a **labelled** triangle of forces diagram for the three forces acting at point
You do not need to draw this diagram to scale.



(c) Show that the tension *T* in each extended spring is 3.4 N.

$T^2 + T^2 = 4.8^2$

$2T^2 = 23.04$

$T^2 = 11.52$

$T = 3.39\ N$

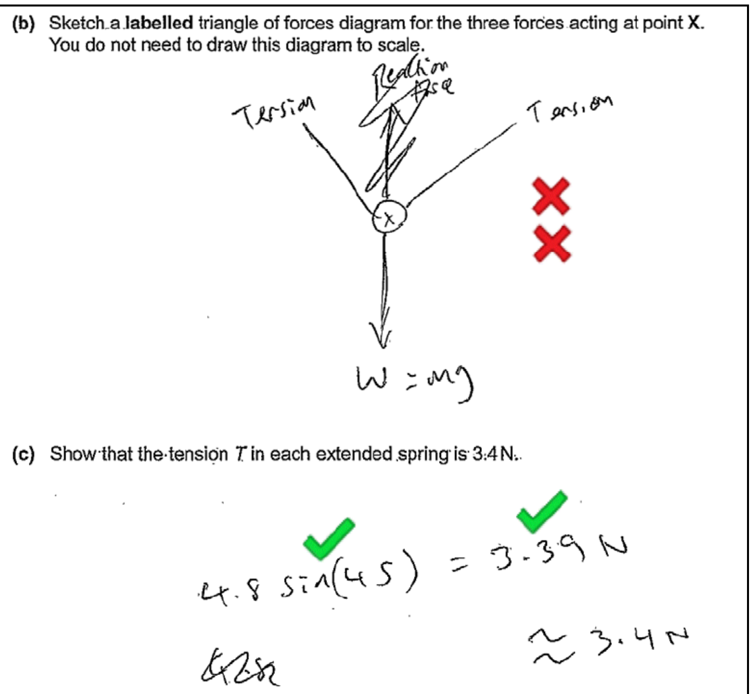
$\rightarrow 3.4N$

This exemplar illustrates a flawless answer from a top–end candidate.

The triangle of forces of perfect – all labels clear and the pivotal angle 90° between the two tensions marked. The calculation in **(c)** makes an excellent use of this triangle to show that the force is 3.39 N and hence 3.4 N.

Contrast the above excellent solution with the exemplar shown below from a grade C candidate.

Exemplar 7

					 The triangle of forces in **(b)** is simply not right. However, in **(c)**, the analysis is correct and shows another plausible method for securing the 2 marks. Again, it is good to see the penultimate value for the force given to **more** than two significant figures.
	c		$3.4 = 24x$ **or** $(x =) \frac{3.4}{24}$ **or** (*x*=) 0.14(17)(m) ($E = ½ × 24 × 0.1417^2$ **or** $E = ½ × 3.4 × 0.1417$) energy = 0.24 (J)	**C1** **A1**	**Allow** the C1 mark for $E = 3.4^2/(2 × 24)$ **Allow** 3.39(4) N No ECF from **(c)**
			Total	**6**	
22		i	Force × perpendicular distance from pivot / fulcrum	B1	
		ii	Clockwise moments = anticlockwise moments about any axis **or** zero resultant moment about any axis	B1	**Allow** alternatives such as about a given point
			Total	**2**	
23			(clockwise moment = anticlockwise moment) 2.5 × 9100 = 3.5 × *F* (Any subject) *F* = 6500 (N)	**C1** **A1**	**Examiner's Comments** Most candidates effortlessly applied the principle of moments to

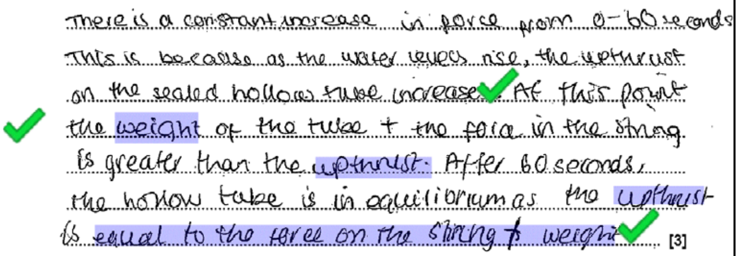
					calculate the vertical force at the pillar. A few candidates took moments about the pillar, determined the force on the platform at the wall and then calculated the force *F* at the pillar using 'net vertical force = 0'. Although this was a longer route, it was still worthy of two marks. About a quarter of the candidates scored nothing. The common errors were quoting the moment of the weight about the wall (22750 Nm) as the force *F* and using 5.0 m instead of 3.5 m in the calculations.
			Total	**2**	
24		i	arrow from rod wall junction through point where T and line of W cross.	B1	
		ii	require triangle of forces for equilibrium **or** the forces must pass through a point for equilibrium.	B1	
			Total	**2**	
25			*F x 100 or 7.0 x 16* $F = \frac{7.0 \times 16}{100} = 1.1$ (N)	C1 A1	**Ignore** POT 1.12 **Not** 1.067
			Total	**2**	
26			(The resultant of the tensions in the springs is) *W* / 4.8 (N) Direction: up(wards) / opposite to weight / opposite to *W* (because the total force in the vertical direction is zero)	**B1** **B1**	
			Total	**2**	
27			Take moments about contact point of rod and wall (because this removes the unknown forces in the calculation).	B1	
			W x *l*/2 = *F* x *l* **or** the vertical force is at a distance twice that for the weight.	B1	
			Total	**2**	
28	a		weight × *y* = *Fx* *(ALρg)* × *y* = *Fx* $y = \left(\frac{F}{AL\rho g}\right)x$	M1 M1 A0	**Allow** W or mg *Wy* = *Fx* or *mgy* = *Fx*
	b	i	Straight line of best fit drawn through the data points Gradient = 1.5	B1 B1	**Allow** gradient in the range 1.40 -1.60
		ii	$\left(\frac{F}{AL\rho g}\right) = 1.5$ $\frac{6.8}{6.4 \times 10^{-5} \times 0.90 \times \rho \times 9.81} = 1.5$	C1 C1 A1	**Allow** ECF from **(i)** **Allow** 8×10^3 (1 SF answer) **Note** must be consistent with gradient value from **(i)**

			$\rho = 8.0 \times 10^3$ (kg m^{-3})		
			Total	**7**	
29	a	i	$\pi \times \frac{(2.9\times10^{-2})^2}{4}$ or $\pi \times (1.45 \times 10^{-2})^2$ 6.605×10^{-4} m$^2 \approx 6.6 \times 10^{-4}$	M1 A0	
		ii	$V = 6.6 \times 10^{-4} \times 12.0$ or 7.92×10^{-5} (m^3) $m = 400 \times 7.92 \times 10^{-5}$ or 0.03168 kg $W = 0.31$ (N)	C1 C1 A1	**Ignore** POT
	b		$V = \frac{0.31}{1000 \times 9.81}$ or 3.16×10^{-5} $y = \frac{3.16\times10^{-5}}{6.6\times10^{-4}}$ $y = 0.048$ (m)	C1 C1 A1	Mass of water displaced = $\frac{0.31}{9.81} = 0.316$ $y = \frac{0.316}{1000\times6.6\times10^{-4}}$
	c		$y = 0.053$ m Same weight / mass displaced of oil Smaller density implies larger volume of oil displaced y is larger OR y *a* 1/p	B1 B1 B1 B1	
			Total	**11**	
30			Weight (of tube), <u>upthrust</u> (and tension / F are the forces acting on the tube) (For t < 60 s) the <u>upthrust</u> (on the tube) increases <u>One</u> detail point from: • <u>Upthrust</u> **increases** because <u>weight</u> of water displaced increases (up to 60s) **or** <u>upthrust</u> is constant (after 60s) because <u>weight</u> of water displaced is constant • Constant gradient (before 60 s) because upthrust **or** volume (of water displaced) **or** mass (of water displaced) **or** weight (of water displaced) increases at a constant <u>rate</u> • (After t = 60 s / eventually / finally the) upthrust is constant because tube is (fully) submerged / container is full (of water)	**B1** **B1** **B1**	**Allow** 'buoyancy <u>force</u>' for upthrust throughout, but not just 'buoyancy' **Not** 'mass' or 'volume' of water displaced **Not** upthrust = weight of fluid / water displaced **Allow** 'no more water is displaced after 60 (s) because tube is (fully) submerged' AW **<u>Examiner's Comments</u>** This question required understanding of upthrust and Archimedes principle. Many candidates gave explanation without mentioning any

<table>
<tr><td></td><td></td><td></td><td>• F = upthrust − weight / F = U − W (Any subject)</td><td></td><td>of the forces acting on the tube. Those candidates who read and focussed on the requirements of the question did better, but there were too many misconceptions and missed opportunities.
The most common missed opportunities and errors were:

• Not mentioning any of the two of the forces from the list of three (upthrust, tension and weight)
• Stating Archimedes principle without reference to this specific question
• Confusing mass and weight in the description of upthrust
• Confusing the tension in the string with upthrust

key
Misconception

Exemplar 8

There is a constant increase in force from 0–60 seconds. This is because as the water levels rise, the upthrust on the sealed hollow tube increases. At this point the weight of the tube + the force in the string is greater than the upthrust. After 60 seconds, the hollow tube is in equilibrium as the upthrust is equal to the force on the string + weight [3]

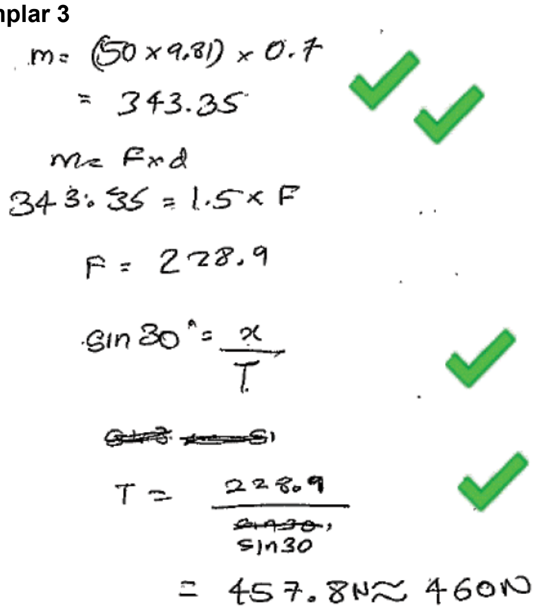
This exemplar illustrates how correct use of technical language can score full marks. Here the marks were credited for

• Identifying a minimum of two forces acting on the tube (weight and upthrust) ii
• Mentioning that upthrust increases as the water level rises ii
• Explanation that upthrust is equal to the force on the string (tension) and weight ii

(The last mark was the toughest mark to gain, so this candidate has shown good understanding of this difficult topic.)</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>3
1</td><td>a</td><td>i</td><td>weight; (tractive) force up slope; drag; (normal) reaction</td><td></td><td></td></tr>
<tr><td></td><td></td><td>i</td><td></td><td>B1</td><td></td></tr>
<tr><td></td><td></td><td>i</td><td>All forces in correct direction and correctly labelled.</td><td></td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>14.4 + (85 × 9.81 × sin θ) = 41.7</td><td>C1</td><td>ecf from (a)(ii)</td></tr>
<tr><td></td><td></td><td>ii</td><td>θ = 1.9 °</td><td>A1</td><td></td></tr>
</table>

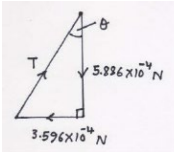
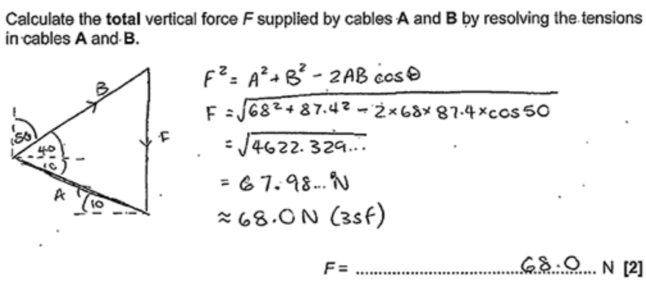
	b		any three from: • drag reduces velocity **or** increases time to cross **or** some kinetic energy of cyclist goes to heat. • longer crossing time results in cyclist at lower point on other side of gap. • moment on bicycle • rotation lowers height of front wheel.	B1 × 3	Allow argument based on: • very short crossing time (< 0.43s at speed of 6 ms^{-1} up slope). • energy changed to heat insignificant compared to KE • amount of rotation very small in short time.
					conclusion based on argument(s). So no change in maximum gap width.
			Conclusion based on argument(s). The maximum gap width is smaller.	B1	
			Total	**7**	
32	a	i	Weight (or 17.6 or 18 kN) through **D** vertically down	B1	
		i	tension along **CB**	B1	
		i	reaction from **A** passing through point where weight arrow meets tension arrow	B1	
		ii	Taking moments about **A**	C1	
		ii	1800 × 9.8 × 3.0 × cos 30 = T × 6.0 × sin 30	C1	for reversing sin and cos
		ii	T = 15(.3) kN	A1	**Allow** 2 marks for 5.1 kN
	b		Moment of weight of arm decreases	M1	
			perpendicular distance of **BC** from **A** increases	M1	
			therefore tension decreases	A1	
			Total	**9**	
33			(Clockwise moments = anticlockwise moments) $7 \times 10^n \times F = 30 \times 10^n \times 31$ *F* = 130 (N) (mass $\frac{F}{g}$) mass = 14 (kg)	C1 C1 A1	**Allow** any power of 10 for distance as long as unit consistent. **Allow** *R* = 164 (N) found by taking moments about flat head of screw/point A **Note** F to 3SF is 133 (N)

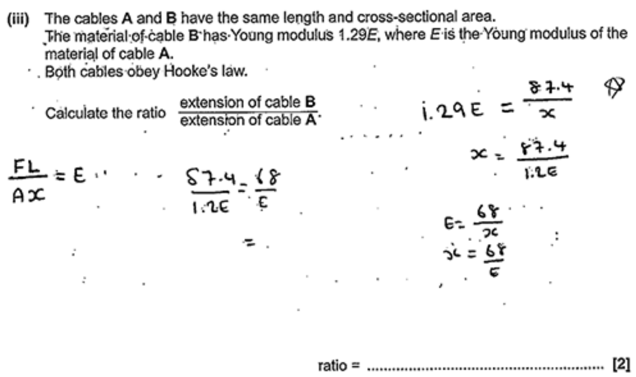
			Total	**3**	
34			Allow the object to hang freely from one of the holes around the edge of the head gasket using a nail secured in a clamp stand. (AW)	B1	
			Draw a vertical line downwards using a plumb line. (AW)	B1	
			Repeat for at least one more hole.	B1	
			Where the lines intersect is the centre of gravity.	B1	Allow another correct method.
			Total	**4**	
35			(weight of plank =) 50 × 9.81 or 490.5 OR uses a distance of 0.7m to calculate clockwise moment (anticlockwise moment =) *T*sin30° × 1.5 OR 0.75T (clockwise moment =) 490.5 × 0.7 = 343 (N m) *T*sin30° × 1.5 = 343 OR *T*sin30° = 229 *T* = 457.8 (N)	**C1** **C1** **C1** **C1** **A0**	**Allow** *T*cos60° × 1.5 **Allow** 344, **Allow 458.6**, **Examiner's Comments** This question was a "show" type question where candidates needed to show that the tension in the cable was about 460 N. Ideally in these type of questions, candidates should have shown their working logically and gained answer of 457.8 (N). Most candidates scored a mark for determining the weight of the beam. Good candidates clearly showed their working. Good candidates stated the principle of moments, indicated how the clockwise moment would be determined, indicated how the anticlockwise moment would be determined and gave an answer of 457.8 (N). To determine the anticlockwise moment candidates needed to resolve the tension *T* into its vertical component − both *T*sin30° and *T*cos60° were acceptable.

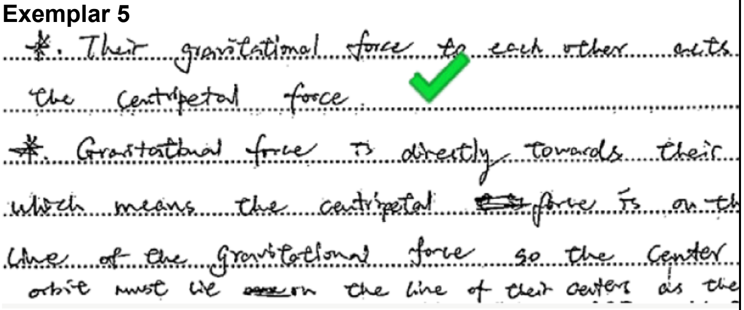
					Exemplar 3  In this exemplar the candidate has clearly shown the working to answer the question. Initially the candidate has calculated the clockwise moment by multiplying the force (mass of 50 (kg) by 9.81) by 0.7 (m). This gains two marks. The candidate's answer could have better if the candidate had written on the left-hand side "clockwise moment" rather than "m", however, it is implicit from the candidate's working the meaning of "m". The candidate has then clearly shown that the anticlockwise moment is equal to the clockwise moment and determined correctly the perpendicular force or vertical force. The candidate then correctly relates the force *T* to sin 30° and the vertical force and evaluates the answer as 457.8 N before indicating that this is approximately 460 N. Including the 457.8 is appropriate in these type of show questions.
			Total	**4**	
36	a	i	$F = QE = QV/d$ **or** $E = 5(.0) \times 10^4$ (Vm^{-1}) $F = 9.0 \times 10^{-9} \times 4000 / 8.0 \times 10^{-2}$ (= 4.5×10^{-4} N)	C1 A1	$F = 5.0 \times 10^4 \times 9.0 \times 10^{-9}$ **<u>Examiner's Comments</u>** Many lower ability candidates did not appreciate the uniform nature of the electric field between the plates and attempted to use Coulomb's Law.
		ii		B1 x 2	All correct, 2 marks; 2 correct, 1 mark 1 mark maximum if more than 3 arrows are drawn **Ignore** position of arrows **Allow** W **or** 0.030(N) (**not** gravity or g)

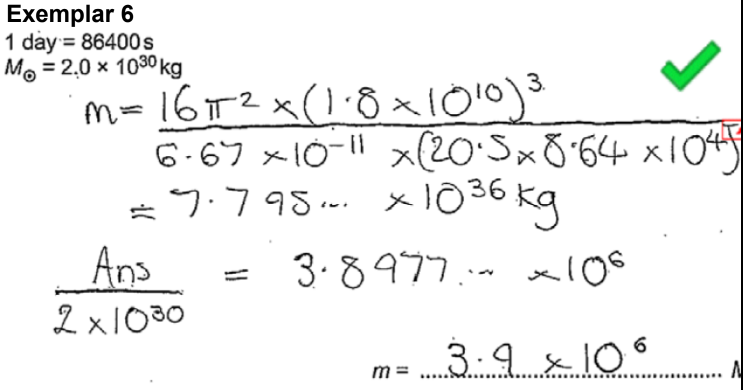
			weight; arrow vertically downwards tension; arrow upwards in direction of string electric (force); arrow horizontally to the right (not along dotted line)		**Allow** T **Allow** F **or** E or 4.5 x 10^{-4}(N) or electrostatic **Ignore** repulsion or attraction **Not** electric field / electric field strength / electromagnetic **Examiner's Comments** Most candidates scored a mark for showing the weight and tension forces accurately. Only a small proportion labelled the electric force arrow correctly and drew it as clearly perpendicular to the plates. **AfL** Do not use the word 'gravity' in place of 'weight'
		iii	$W x = F l$ 0.03 x = 4.5 x 10^{-4} x 120 **or** = 4.5 x 10^{-4} x 1.2 x = 1.8 cm **or** x = 0.018 m	M1 M1 A0	**Allow** any valid alternative approach e.g. M1 deflection angle θ = 1° M1 x = 120sinθ 1 mark for each side of the equation **Examiner's Comments** Although most candidates knew the principle of moments, many were unable to apply it correctly in this situation. More practice at this sort of question is recommended.
	b		Electric force/field (strength) increases Ball deflected further from vertical / moves to the right / touches negative plate Ball acquires the charge of the (negative) plate when it touches (Oscillates because) constantly repelled from (oppositely) charged plate	B1 B1 B1 B1	Must be clear which force is increasing Must have the idea of a repeating cycle **Examiner's Comments** The purpose of this question was to challenge the candidates to use their knowledge of electric fields in a novel practical situation. The word 'oscillate' confused many candidates, who tried to explain why the ball would perform simple harmonic motion.
	c		$I = Qf$ **or** $Q = It$ f = 3.2 x 10^{-8}/9.0 x 10^{-9} = 3.6 (Hz)	C1 A1	
			Total	**12**	
37		i	(horizontal component of F =) F × cos20° F cos20° × 1.30 = 0.30 × 40 × 9.81	M1 M1	**Allow** ECF for incorrect trig i.e. use of sine (gives F =265) or cos(20 radians) which gives F = 222 for 2 marks. **Allow ECF** for incorrect units for angle and incorrect trig sin(20 radians) which gives F = 99(.2) for 1 mark

			F = 96.4 (N)	A1	
		ii	*R* = *F* cos20° or 96(.4) × cos 20° (*R* =) 91 (N)	C1 A1	**Allow** ECF from (i) **Answer is 90.6 (N) to 3sf if 96.4 used.** **Answer is 90(.2) (N) to 3sf if 96 used**
			Total	**5**	
38		i	4.4 – 4.6 (N)	B1	
		ii	Weight of cylinder 3.5 cm vertically (judge by eye) Correct closed triangle drawn including T_A Correct directions indicated for weight and T_A and T_A = 6.4 ± 0.2 (N)	M1 M1 A1	
		iii	39 ± 1°	A1	**Allow ECF** from **(b)(ii)** for trigonometry methods
			Total	**5**	
39		i	(Clockwise moment) *T* sin 50° × 0.030	C1	
		i	(Anticlockwise moment) 260 × 0.40	C1	**Allow** N cm
		i	*T* sin 50° × 0.030 = 260 × 0.40		
		i	*T* = 4500 N	A1	**Allow** 4525 N
		ii	Perpendicular distance of weight to *P* decreases	M1	
		ii	So *T* must decrease.	A1	
			Total	**5**	
40		i	The charges repel each other (because they have like charges).	B1	
		i	Each charge is in equilibrium under the action of the three forces: downward weight, a horizontal electrical force and an upwardly inclined force due to the tension in the string.	B1	
		ii	$F = \frac{(4.0\times10^{-9})^2}{4\pi\varepsilon_0 \times 0.02^2} = 3.596....\times10^{-4}$ (N)	C1	Correct use of $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$
		ii	weight *W* = 6.0 × 10^{-5} × 9.81 = 5.886 × 10^{-4} (N)	C1	

		ii	$\tan\theta = \dfrac{3.596\times10^{-4}}{5.886\times10^{-4}}$	C1	
		ii	angle θ = 31°	A1	
			Total	**6**	
4 1		i	87.4cos50° **or** 68.0sin10° *F* = 68.0 (N)	C1 A1	**Allow** 87.4sin40° or 68.0cos80° **Allow** cosine and sine rules being used, e.g. $F^2 = 68.0^2 + 87.4^2 - 2 \times 68.0 \times 87.4 \times \cos 50°$ **or** $F = 87.4 \times \sin 50°/\sin 80°$ **or** $F = 68.0 \times \sin 50°/\sin 50°$ **Allow** 2 SF answer here **Examiner's Comments** The question has a clue for making a start on this question. Most candidates did resolve the two tensions in the cables vertically. The majority of the responses were well-structured and demonstrated excellent understanding of vectors. Although not straightforward, many candidates used the correct angle when determining the vertical components of the forces. The correct answer of 68.0 N appeared on most scripts. A small number of candidates got 1 mark for just getting one of the components correct. A very small number of candidates got the correct answer by using trigonometry and triangle of forces. This is not what was expected, but full credit was given for this alternative approach. Correct responses will always score marks, even when the candidates choose not to go along the path designed by the examiners. This different approach is illustrated in the exemplar 6 below. **Exemplar 6**  The candidate has used a triangle of forces and the cosine rule to determine the net downward. As it happens, the F in this calculation is the weight of the dolphin. However, it is numerically equal to the total upward vertical force. This concise and perfect alternative technique picked up the maximum marks.
		ii	68 = *m* × 9.81 *m* = 6.9 (kg)	C1 A1	Possible ECF from **(c)(i)** **Allow** 68 = *mg* **Note** answer to 3 SF is 6.93 (kg) **Allow** *g* = 9.8; this gives 6.94 (kg)

					Not g = 10; this gives 6.8 (kg). Only the first C1 mark can be scored **<u>Examiner's Comments</u>** Almost all candidates correctly used $W = mg$ to determine the mass of the dolphin. Full marks were frequently picked up because of error carried forward (ECF) from **(c)(i)**. There were very few cases of g = 10 m s^{-2} being used; this was penalised because g = 9.81 m s^{-2} is given in the Data, Formulae and Relationship Booklet.
		iii	$E = \frac{\text{stress}}{\text{strain}}$ (Any subject) (Tension and E increase by the same factor of 1.29) ratio = 1.0	C1 A1	**Allow** $E = \frac{\sigma}{\varepsilon}$ **or** $E = \frac{FL}{Ax}$ (Any subject) **Allow** 1 SF answer **Allow** 1:1 **<u>Examiner's Comments</u>** This question on the equation for Young modulus E was well-answered with most candidates picking up one or more marks. The extension x of a wire is given by the expression $x = \frac{FL}{EA}$, where F is the tension in the wire, L its length and A its cross-sectional area. In this question, the extension $x \propto \frac{F}{E}$. Since both F and E increase by the same factor of 1.29, this meant that the ratio is 1.00. The most frequent incorrect answers were 1.29 and 1.29^{-1} or 0.78. The majority of the candidates in the upper quartile picked up 2 marks. Exemplar 7  This exemplar shows a response from a top-grade candidate. The solution is much more elaborate and the response of 0.996 is given to 3 significant figures. A perfect solution that earned this candidate 2 marks.
			Total	**6**	
42		i	(Sum of clockwise moments = sum of anticlockwise moments) 95 × 9.81 × 1.80 / 120 × 9.81 × 1.00 / 1.60 × T sin 30°	C1	

		i	(95 × 9.81 × 1.80) + (120 × 9.81 × 1.00) = 1.60 × T sin30°	C1	
		i	T = 3.6 × 10^3 (N)	A1	**Note** answer to 3 s.f. is 3.57 × 10^3 (N)
		ii	$\sigma = \frac{3.6 \times 10^3}{\pi \times 0.015^2}$	C1	Possible ECF from part **(i)**
		ii	σ = 5.1 × 10^3 (kPa)	A1	**Allow** 1 mark for 5.1 × 10^6; POT error **Note** using 3.57 × 10^3 N gives 5.05 × 10^3 (kPa)
		iii	The clockwise moment increases and therefore T increases.	B1	
			Total	**6**	
43		i	(For circular orbit) centripetal force provided by gravitational force (of attraction) (Gravitational / centripetal) force is along line joining stars which must therefore be diameter of circle (AW)	**M1** **A1**	**Examiner's Comments** Only a minority of candidates related the gravitational force between the stars to the centripetal force required for circular motion to occur. This candidate has written the perfect answer (exemplar 5). There were two popular insufficient answers; that if the stars were not diametrically opposite they would collide and that the centre of mass of the system had to be at the centre of the orbit. **Exemplar 5** 
		ii	T = 20.5 × 86400 (= 1.77 × 10^6 s) **and** R = 1.8 × 10^{10} (m) m = 16 × π^2 × (1.8 × 10^{10})^3/G × (20.5 × 86400)^2 giving m = 4.4 × 10^{30} so m = 2.2 M⊙	**C1** **C1** **A1**	values of T **and** R scores first mark; **both** incorrect 0/3 correct substitution allowing π^2 and G m =16 × 9.87 × 1.8^3 × 10^{30}/6.67 × 10^{-11} × 1.8^2 × 10^{12} using 2R gives 35.2 × 10^{30} = 17.6 M⊙ or using T = 1 day gives 1850 × 10^{30} = 930 M⊙ **award** 2/3 **Examiner's Comments** This question tested the candidates' ability to interpret and substitute data into an elaborate formula and then evaluate it. The most common error was to write the formula with the correct substitutions but then to omit the square symbol against T. Candidates should be encouraged to consider whether their

					answers are reasonable before moving on to the next question. In the calculation (exemplar 6) shown here, is it possible that these stars could be four million times the mass of the Sun? The correct answer of 2.2 Sun masses seems very plausible and should give candidates confidence. **Exemplar 6**  1 day = 86400 s $M_{\odot} = 2.0 \times 10^{30}$ kg $m = \frac{16\pi^2 \times (1.8 \times 10^{10})^3}{6.67 \times 10^{-11} \times (20.5 \times 8.64 \times 10^4)^2}$ $\approx 7.795... \times 10^{36}$ kg $\frac{Ans}{2 \times 10^{30}} = 3.8977... \times 10^6$ m = 3.9 × 10^6
		iii	$v = 2\pi R/T = 2 \times 3.14 \times 1.8 \times 10^{10} / 1.8 \times 10^6$ (giving v = 6.3 or 6.4 × 10^4) $\Delta\lambda = (v/c)\lambda = (6.3/3) \times 10^{-4} \times 656 =$ 0.14 (nm)	C1 A1	**do not** penalise repeated error for R or T **ecf** for incorrect v, gives $\Delta\lambda = v \times 2.2 \times 10^{-6}$ $\Delta\lambda$ = 0.28 for 2R; $\Delta\lambda$ = 2.9 for 1 day and $\Delta\lambda$ = 5.7 for both incorrect **Examiner's Comments** Most of the higher performing candidates completed this problem successfully. Two common errors among the remainder were to equate the formula for central force gravitational potential energy *(GMm/r)* to kinetic energy to find a value for the speed of the stars and to rewrite incorrectly metres in powers of 10 in nanometres.
			Total	**7**	
44		i	$\frac{61000}{3600} = 16.944$ 17 ms^{-1}	M1 A0	**Note** v must be the subject **Examiner's Comments** This question was the first 'show' question of the paper. It is important that candidates show clearly their working. In this case it was expected to see 61 multiplied by 1000 and divided by 3600. Most candidates came up with an answer of 16.9.
		ii	**1** $\frac{1}{2} \times 1.9 \times 10^5 \times 17^2$ 2.7(5) × 10^7(J) **2** $0 = 17^2 + 2a \times 310$ OR $\boldsymbol{t} = \frac{310}{8.5}$ $a = (-)\frac{17^2}{2 \times 310} = (-)\frac{289}{620}$ OR $\boldsymbol{a} = \frac{17}{36.5}$ 0.47 ($m s^{-2}$)	C1 A1 C1 C1 A1	**Allow** use of 16.9 gives 2.7 × 10^7(J) **Allow** $v^2 = u^2 + 2as$ with values stated correctly **Ignore** negative sign **Allow** use of 16.9 gives 0.46 **Not** 0.5 **Allow** ECF from **(b) (ii) 1** and **(b) (ii) 2**

			3 1.9 × 10^5 × 0.47 **3** 89000(N)	C1 A1	**Allow** $\frac{2.7\times10^7}{310}$ **Allow** 1.9 × 10^5 × 0.46 **Allow** $\frac{1.9\times10^5\times17}{36.5}$ **Allow** alternatives 87100, 87400, 88000 **Examiner's Comments** Most candidates were able to correctly write down the equation for kinetic energy and substitute the numbers into it. Where mistakes were made, it was normally with candidates not squaring the speed. It was hoped that candidates would use a speed of 17 m s^{-1} from the previous part. Good candidates clearly indicated which equation they were going to use and then clearly showed the substitution of the numbers, with the acceleration as the subject of the formula. Some candidates attempted to determine the time taken for the train to stop. Often when this method was attempted, candidates incorrectly assumed that the speed of 17 m s^{-1} was the average speed and not the initial speed. A few candidates round their answer inappropriately to one significant figure. Candidates answered this question in a number of different ways. The majority of the candidates substituted in their answer to the previous part into *F* = *m a.* Other candidates either used their answer for kinetic energy and the distance travelled or determined the time for the train to stop and used force equals the rate of change of momentum.
		ii i	Component of train's <u>weight</u> acts against the motion / down the incline / same direction as braking force OR some KE transferred to GPE <u>Smaller distance</u> because larger opposing forces / net force or greater deceleration or less work done by braking force	B1 B1	**Not** gravity will slow it down **Not** down, parallel **Examiner's Comments** Candidates found this question requiring an explanation tough. There were many vague answers referring to "gravity" as opposed to the "force due to gravity" or "weight". Candidates should be encouraged to use correct scientific terms. There was also occasional reference to

					“faster” deceleration. Some candidates correctly answer this question in terms of the kinetic energy being transferred to an increase in gravitational potential energy. Few candidates were precise in discussing the component of the weight parallel to the incline.
			Total	**10**	