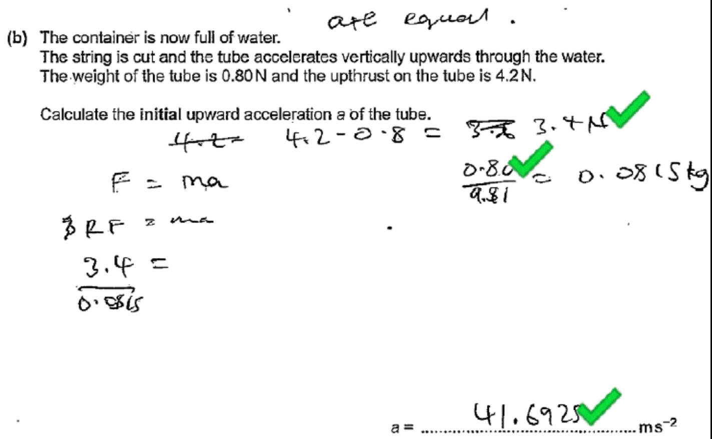
Mark scheme – Forces in Dynamics

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			C	1	
			Total	**1**	
3			B	1	
			Total	**1**	
4			A	1	
			Total	**1**	
5			**D**	**1**	
			Total	**1**	
6			**D**	**1**	
			Total	**1**	
7			B	1	
			Total	**1**	
8			**D**	**1**	**Examiner's Comments** Most candidates did not realise that both the suspended mass and the trolley are moving with acceleration a. The resultant force along for this composite object is W and the total mass is (M + W/g), giving D as the acceleration.
			Total	**1**	
9			C	1	

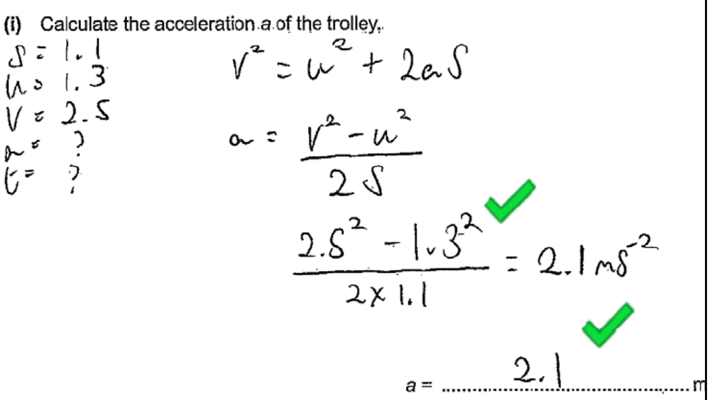
			Total	**1**	
1 0			A	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
1 1			C	1	
			Total	**1**	
1 2			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**	
1 3			B	1	
			Total	**1**	
1 4	a		(resultant force =) 4.2 − 0.8 **or** 3.4 (N) (*m* =) 0.8/9.81 **or** 0.0815 … (kg) ($a = \frac{3.4}{(0.8/9.81)}$) a = 42 (m s^{-2})	**C1** **C1** **A1**	**Allow** 0.082 (kg) **Not** 0.08 (kg) **Allow** 2 marks for F = 3.4 (N), m = 0.08 (kg) and hence a = 42.5 or **43** (m s^{-2}) **<u>Examiner's Comments</u>** The majority of the candidates scored full marks. Most answers showed good structure and reasoning. The data is given to two significant figures (SF). Answers given to more significant figures were condoned. However, if the answer was given to one SF, then this would have been penalised once only in the entire paper.

					Exemplar 9  (b) The container is now full of water. The string is cut and the tube accelerates vertically upwards through the water. The weight of the tube is 0.80 N and the upthrust on the tube is 4.2 N. Calculate the **initial** upward acceleration a of the tube. This exemplar illustrates a decent solution from a grade C candidate. The physics is very easy to follow – resultant force determined, mass calculated from the weight and then the final value for the acceleration. As mentioned earlier, the answer is not given to two SF, but this was allowed in this specific question.
	b		There is (an increasing) friction / drag (acting on the tube)	**B1**	**Allow** (water) resistance / resistive force **Allow** upthrust decreases as tube comes out of water AW **Not** 'drag **and** upthrust', unless the upthrust is qualified asabove
			Total	**4**	
15	a		There is no contact force between the astronaut and the (floor of the) space station (so no method of measuring / experiencing weight)	B1	**Allow** astronaut and the space station have same acceleration (towards Earth) / floor is falling (beneath astronaut) **<u>Examiner's Comments</u>** **Misconception** Experiencing weightlessness is not the same as being in freefall There was a lack of understanding of the nature of feeling weightless. The sensation of 'weightlessness' is a lack of the physiological sensation of 'weight'. The skeletal and muscular systems are no longer in a state of stress. This sensation is caused by a lack of contact forces as a result of the ISS and the astronaut experiencing the same acceleration. Common incorrect responses included: • the astronaut is weightless because he is falling • there is no resultant force on the astronaut • gravity is too weak to have any effect on the astronaut • the ISS orbits in a vacuum where there is no gravity.
	b	i	M = 5.97 x 10^{24}(kg) **or** ISS orbital radius R = 6.78 x 10^6(m) **or** $g \propto 1/r^2$	C1 C1	

			(gr^2 = constant so) g x (6.78 x 10^6)^2 = 9.81 x (6.37 x 10^6)^2 g = 8.66 (N kg^{-1})	A1	**or** g (= GM/R^2) = 6.67 x 10^{-11} x 5.97 x 10^{24} / (6.78 x 10^6)^2 **Allow** rounding of final answer to 2 SF i.e. 8.7 (N kg^{-1}) **Examiner's Comments** The simplest method here was to use the fact that g is inversely proportional to r^2, so gr^2 = constant. If this was not used, a value for the mass of the Sun had to be calculated, which introduced a further step. Candidates who omitted this calculation and used a memorised value of the Sun's mass instead were unable to gain full marks, because they invariably knew it to 1 s.f. only, whereas 3 were required. Errors occurred when candidates used the incorrect distance in the formula for g. Common errors included: • forgetting to square the radius • using the Earth's radius rather than the orbital radius of the satellite • calculating (6.37 × 10^6 + 4.1 × 10^5) incorrectly.
		ii	$2\pi r/T = v$ **or** T = 2 × 3.14 × 6.78 × 10^6 / 7.7 × 10^3 T = 5.5 × 10^3 s (= 92 min)	M1 A1	**ECF** incorrect value of R from **b(i)**
	c		$\frac{1}{2}M\overline{c^2}$ ($\frac{1}{2}N_A m\overline{c^2}$) = $\frac{3}{2}RT$ c^2 = 3 × 8.31 × 293 / 2.9 × 10^{-2} = 2.52 × 10^5 $\sqrt{c^2}$ = 500 (m s^{-1}) (= 7.7 × 10^3 / 15)	C1 C1 A1 A0	**or** $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ **or** $c^2 = 3kT/m$ **or** c^2 = 3 ×1.38 x 10^{-23} × 6.02 x 10^{23} x 293/2.9 × 10^{-2} = 2.52 × 10^5 **not** (7.7 × 10^3 / 15) = 510 (m s^{-1}) **Examiner's Comments** The success in this question depended on understanding the meaning of the term m in the formula $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ given in the Data, Formulae and Relationship booklet. A significant number of candidates took m to be the mass of one mole (the molar mass, M) whereas m is actually the mass of one molecule. Candidates who used the formula $\frac{1}{2}M\overline{c^2} = \frac{3}{2}RT$ were usually more successful because the molar mass had been given in the question stem.
	d		power reaching cells (= IA) = 1.4 × 10^3 × 2500 = 3.5 × 10^6 W power absorbed = 0.07 × 3.5 × 10^6 = 2.45 × 10^5 W cells in Sun for (92 – 35 =) 57 minutes average power = 57/92 × 2.45 × 10^5 = 1.5 × 10^5 (W)	C1 C1 C1 A1	mark given for multiplication by 0.07 at any stage of calculation (90 – 35 =) 55 minutes using T = 90 minutes **ECF** value of T from **b(ii)** 55/90 × 2.45 × 10^5 = 1.5 × 10^5 (W) using T = 90 minutes **Examiner's Comments**

					Although this question looked daunting, it was actually quite linear and many candidates who attempted it were able to gain two or three marks even if they did not eventually get to the correct response. Candidates who set out their reasoning and working clearly were more liable to gain these compensatory marks.
			Total	**13**	
16	a		arrow down through centre of ball labeled weight **or** W **or** mg **or** 1.2 N	**B1**	zero if any other arrows or forces present **Examiner's Comments** There were some carelessly drawn arrows on the diagram but otherwise this was done well. There were some arrows labelled *centripetal force.*
	b	i	(horizontally) mv^2/r **(or** $mr\omega^2$) = T sin θ **and** (vertically) W **or** mg = T cos θ (tan θ = v^2/rg **or** rw^2/g) tan θ = 0.045 × 4 × 9.87 × 2.2 / 9.81 **or** 0.48 / 1.2 (= 0.40) θ = 22°	**M1** **A1** **A0**	**accept** figures in place of algebra, r = 0.045 m v = 0.42 m s^{-1} ω = 3π rad s^{-1}; $r\omega^2$ = 4.0 m s^{-2} ; W = 1.2 N and m = 0.12 kg and $mr\omega^2$ = 0.48 N **accept** labelled triangle of forces diagram **N.B.** this is a *show that Q* ; sufficient calculation must be present to indicate that the candidate has not worked back from the answer
		ii	k = (mg / x_0 = 1.2 / 0.050) = 24 (N m^{-1}) (T = mg / cos θ = kx giving) x = 1.2 / 24 cos 22 x = 0.054 (m)	**C1** **C1** **A1**	**or** solution by ratios **Examiner's Comments** About half of the candidates completed the angle calculation successfully with a slightly smaller number finding the correct extension of the string.
	c		($y = ½gt^2$ =) 0.18 = 0.5 × 9.81 × t^2 giving t = 0.19 (s) (x = vt =) 0.42 × 0.19 = 0.08 (m) distance = $\sqrt{(r^2 + x^2)}$ = √(0.0020 + 0.0064) = 0.092 (m)	**C1** **C1** **C1** **A1**	**alt:** projectile motion: x = vt, $y = ½gt^2$ $y = ½g(x / v)^2$ **ecf (b)i** for v; $x^2 = 2yv^2/g$ = 2 × 0.18 × 0.42^2/9.81 **Examiner's Comments** About half of the candidates found the time for the ball to fall to the bench. Most then managed to find the horizontal distance from the point of release, but half forgot that the point of reference in the question was the centre of rotation so failing to complete the calculation.
	d		T increases **or** string stretches **or** angle θ increases to provide / create a larger centripetal force	**M1** **A1**	**allow** mv^2/r **or** $mr\omega^2$ in place of *centripetal force* causality must be implied to gain the A mark **Examiner's Comments**

					About half of the candidates appreciated that the tension in the string increased or that the angle of the string to the vertical increased. Most answers gave the impression that the *centripetal force* was a *real* force rather than its provision being necessary for the ball to follow a circular path
			Total	**12**	
17			C	1	
			Total	**1**	
18			**C**	1	
			Total	**1**	
19			D	1	
			Total	**1**	
20			**D**	1	**Examiner's Comments** This question showed that candidates had generally forgotten that the resultant force does not have to be in the direction of travel, hence all three statements could be correct, giving option D. This question provided opportunities for middle-grade candidates.
			Total	**1**	
21			D	1	
			Total	**1**	
22			D	1	
			Total	**1**	
23			A	1	
			Total	**1**	
24			**C**	1	
			Total	**1**	
25			**D**	1	
			Total	**1**	

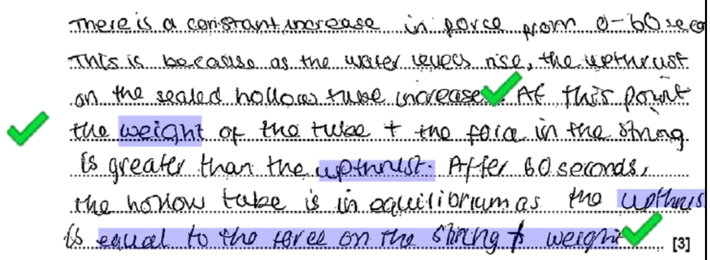
26			**B**	1	
			Total	**1**	
27			A	1	
			Total	**1**	
28			**B**	1	**Examiner's Comments** This question proved particularly straightforward and accessible to nearly all candidates.
			Total	**1**	
29			C	1	
			Total	**1**	
30		i	($v^2 = u^2 + 2as$) $2.5^2 = 1.3^2 + 2 \times 1.10 \times a$ (Any subject) a = 2.1 (m s^{-2})	C1 A1	**Allow** other methods **Allow** this mark for t = 0.58 (s) **Note** answer to 3 SF is 2.07 (m s^{-2}) **<u>Examiner's Comments</u>** Most candidates demonstrated excellent understanding and application of equations of motion. The solutions were often well represented, calculations done correctly and the answer written to the correct number of significant figures (SF). A variety of routes were possible, but the most popular method was using the equation $v^2 = u^2 + 2as$. **Exemplar 5**  This exemplar from a grade E candidate shows flawless technique. The known and unknown quantities are written on the left-hand side. The equation is clear, as is the substitution and the final answer for the acceleration.
		ii	$ma = mg \sin\theta$ **or** $a = g \sin\theta$ **or** 2.07 = 9.81 × $\sin\theta$	C1	**Allow** 2.1 (m s^{-1}) **Allow** g = 9.8 **Note** using $\tan^{-1}$(2.07/9.81) is **wrong physics**.

			θ = 12°	**A1**	Possible ECF from **(b)(i)** **Allow** g = 10 here; it gives the same answer to 2 SF **Allow** 1 mark for 78°
			Total	**2**	
31			(After 0.75 s) gradient decreases with time Indicating velocity is decreasing / deceleration	M1 A1	**Examiner's Comments** In part (b) some candidates were vague in their responses, for example, stating that the gradient changes rather than stating that the gradient decreases. In part (c) most candidates were able to draw a reasonable tangent. Parts (d) and (e) were harder to answer. Part (d) required the correct time interval to be applied by interpreting the braking time and not including the thinking time. In part (e), high achieving candidates applied the halving of the initial speed to the effect this had on the thinking distance, the thinking time, the braking distance and the braking time.
			Total	**2**	
32			Weight, drag, upthrust (correct direction and labelled)	B1	
			Correct relative length (upthrust must be longer than sum of other two forces)	B1	
			Total	**2**	
33	a		Arrow vertical down and an arrow opposite to the frictional force. Both arrows labelled correctly.	M1 A1	**Allow** weight / mg / W for the downward arrow and tension / T / 'force in rod' / 'force in tow bar' /'driving force' for the 'upward' arrow
	b		(W_s =) 1100 × 9.81 × sin 10° **or** 1100 × 9.81 × cos 80° (W_s = 1874 N or 1900 N)	C1 A0	**Allow** g instead of value
	c		force = 1900 + 300 force = 2200 (N)	 A1	**Allow** 1870 + 300 = 2170 (N)
	d		(distance =) 120 / sin 10° **or** 691 (m) (work done =) 2200 × 691 work done = 1.5 × 10^6 (J)	C1 C1 A1	**Allow** ECF from **(c)** **Allow** ECF from an incorrect attempt at first mark.
	e		(A =) π × 0.006^2 **or** 1.1 × 10^{-4} (m^2)	C1 C1	**Allow** ECF from **(c)** **Allow** x (=FL/EA) = $\frac{2174\times0.5}{2.0\times10^{11}\times1.1\times10^{-4}}$

			(stress =) $\frac{2200}{\pi \times 0.006^2}$ and $2.0 \times 10^{11} = \frac{\text{stress}}{\text{strain}}$ $x = 4.8 \times 10^{-5}$ (m)	A1	**Allow** 2 marks for 1.2×10^{-5}; 1.2×10^{-2} m used as radius **Allow** answer between 4.7 and 5.1×10^{-5} (m)
			Total	**10**	
34			Doubling the depth is too much / d is not (directly) proportional to h Qualifying statement using evidence from graph e.g. decreasing gradient, use of numbers to show not proportional, comment about non-zero intercept etc	**B1** **B1**	**Examiner's Comments** Candidates generally had the right idea on this item yet lacked clear enough language to express themselves adequately. Many had some success by referring specifically to data from the graph or the shape of the trendline to support their assertions. Less convincing attempts included those that suggested that there was square root relationship presumably with Newton's equations of motion in mind, without any justification for doing so from the graph. Centres are reminded that situations with changing accelerations are not expected to be solved algebraically at A2 level.
			Total	**2**	
35	a		weight × $y = Fx$ $(AL\rho g) \times y = Fx$ $y = \left(\frac{F}{AL\rho g}\right)x$	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	$\left(\frac{F}{AL\rho g}\right) = 1.5$ $\frac{6.8}{6.4 \times 10^{-5} \times 0.90 \times \rho \times 9.81} = 1.5$ $\rho = 8.0 \times 10^3$ (kg m^{-3})	C1 C1 A1	**Allow** ECF from **(i)** **Allow** 8×10^3 (1 SF answer) **Note** must be consistent with gradient value from **(i)**
			Total	**7**	
36		i	Earth	B1	**Allow** planet / ground **Examiner's Comments** This question was poorly answered, with only the very top candidates realising that it was the Earth experiencing the force W in the opposite direction. 'Ground' instead of the Earth was allowed by examiners – but such answers were extremely rare. Newton's third law remains enigmatic to many candidates. The most popular incorrect answers were 'ball' and 'table'.
		ii	The forces are not of the same type / The forces act on the same object	B1	**Allow** The forces do not act on different objects

					Examiner's Comments Examiners were looking for the idea that in Newton's third law, the pair of forces were of the same type and had to act on two separate objects. The force W is a **gravitational** force and N is the normal contact force is an **electrostatic** force between the base of the ball and the top of the table. The variety of incorrect answers demonstrated the lack of comprehension of this law. The two exemplars below show answers from a top-end candidate and a candidate securing a middle-grade. **Exemplar 4** According to a student, $W = N$ is a consequence of Newton's third law of motion. State why this is incorrect. W and N are not the same type of forces and this is not a consequence of Newton's third law of motion. [1] In this exemplar from a top-end candidate, the response is half of the total response, but it was given 1 mark by the examiners. Some candidates went a step further by mentioning that W is a gravitational force and N is an electrostatic force. **Exemplar 5** According to a student, $W = N$ is a consequence of Newton's third law of motion. State why this is incorrect. There was no force applied on the ball to cause a equal and opposite force. [1] This illustrates a strange response from a low-grade candidate. It shows poor understanding of this important law. There is nothing worthy here for credit.
			Total	**2**	
3 7			**D**	1	
			Total	**2**	
3 8	a	i	weight; (tractive) force up slope; drag; (normal) reaction		
		i		B1	
		i	All forces in correct direction and correctly labelled.		
		ii	14.4 + (85 × 9.81 × sin θ) = 41.7	C1	**ecf** from **(a)(ii)**
		ii	θ = 1.9 °	A1	
	b		any three from: • drag reduces velocity **or** increases time to cross **or** some kinetic energy of cyclist goes to heat.	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.

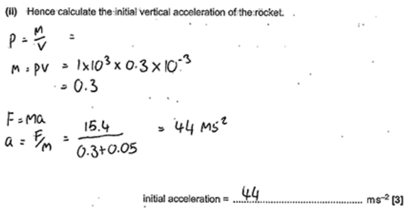
			• longer crossing time results in cyclist at lower point on other side of gap. • moment on bicycle • rotation lowers height of front wheel. Conclusion based on argument(s). The maximum gap width is smaller.	B1	conclusion based on argument(s). So no change in maximum gap width.
			Total	**7**	
39			(Clockwise moments = anticlockwise moments) 7 x 10^n x *F* = 30 x 10^n x 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**	
40			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

			• F = upthrust − weight / $F = U - W$ (Any subject)		Archimedes principle. Many candidates gave explanation without mentioning any 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 sec. 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.)
			Total	**3**	
4	1		(1 C =) (1) A s	C1	**Allow** alternative methods
			(1 J =) (1) kg m s^{-2} × m or (1) N = (1) kg m s^{-2}	C1	
			$V = \frac{\frac{\text{kg ms}^{-2} \times \text{m}}{\text{As}}}{} = \frac{\text{kgm}^2\text{s}^{-2}}{\text{As}}$ $\text{kg m}^2\text{A}^{-1}\text{s}^{-3}$	M1 A0	**Note** this mark is for clear substitution and working **Examiner's Comments**

					Some candidates were not clear on what was meant by base units. Most realised that the quantity of electric charge is measured in As. Weaker candidates had difficulty deriving work done.
			Total	**3**	
42			resultant force = $(7.0^2 + 5.0^2 - 2 \times 7.0 \times 5.0 \times \cos 40)^{1/2}$	C1	**Allow**: resultant force = $[(7.0 - 5.0 \times \cos 40)^2 + (5.0 \times \sin 40)^2]^{1/2}$
			resultant force = 4.51 (N)	C1	**Allow** full marks for a correct scale drawing to determine the resultant force; resultant force = 4.5 ± 0.1 N
			acceleration = 4.51 / 0.320 = 14 ($m\ s^{-2}$)	A1	**Allow** full marks for resolving into horizontal and vertical components and combining correctly.
			Total	**3**	
43	a		pV/T = constant	B1	
			$(1.0 \times 10^5 V)/290 = (1.0 \times 10^3 \times 1.0 \times 10^6)/230$	B1	
			$V = 1.26 \times 10^4$ (m^3)	B1	
	b	i	$n = pV/RT = 1.0 \times 10^5 \times 1.26 \times 10^4/(8.31 \times 290)$	B1	**ecf**
		i	$n = 5.2 \times 10^5$	B1	**allow** 5.4×10^5 using 1.3×10^4
		ii	$4.0 \times 10^{-3} \times 5.2 \times 10^5 = 2.1 \times 10^3$ (kg)	B1	**ecf (i)**
	c		(internal energy ∝ T) E = 1900 × 230/290 = 1500 (MJ)	B1	
	d		$U = \rho Vg = 1.3 \times 1.26 \times 10^4 \times 9.81 = 1.61 \times 10^5$	C1	**or** $1.3 \times 1.3 \times 10^4 \times 9.81 =$
			Ma = U − Mg	C1	1.66×10^5
			$27 M = 1.6 \times 10^5 - Mg$ giving $M = 4.3 \times 10^3$ kg	A1	$M = 4.6 \times 10^3$ kg
			Total	**10**	
44			Gradient determined from Fig. 22 and gradient = 16	C1	**Allow** ± 0.5 for the value of the gradient **Not** u^2/x value using the line or a data point because the gradient is not determined **Allow** this mark even if gradient = *a*
			gradient = 2*a* (*F* = *ma*); *F* = 920 × 8.0	C1	
			F = 7.4 **x** 10^3 (N)	A1	Possible ECF for this A1 mark if the gradient is determined but its value is outside the range 15.5 to 16.5 and the second C1 mark has also been scored **Note**: The answer to 3 SF is 7360 (N) **Note**: *F* = 920 **x** 16 = 14720 (N) can score the first C1 mark

					Examiner's Comments The majority of the candidates gained one mark for correctly calculating the gradient of the line using a large triangle. The reading of the coordinates was generally quite good. A pleasing number of candidates also realised that the gradient was equal to 2*a* and they then went on to correctly determine the braking force to be 7.4 kN. About a quarter of the candidates gained full marks. In spite of the equation $u^2 = 2ax$ and the hint of working out the gradient first, many candidates incorrectly assumed the gradient was equal to the deceleration of the car. A small number of candidates attempted to substitute values off the line into the equation $u^2 = 2ax$; they unfortunately missed the point of the whole question.
			Total	**3**	
45	a		pV = constant (or $p_1V_1 = p_2V_2$) $p_{final} = 2.4 \times 10^5 \times 1.2/1.5$ $= 1.9(2) \times 10^5$ (Pa)	C1 C1 A1	<u>Alternative method:</u> $p = nRT/V$ (p must be the subject) **Allow** use of $p = NkT/V$ (with $N = 7.2 \times 10^{22}$ and $k = 1.38 \times 10^{-23}$) Substitute $p = 0.12 \times 8.31 \times 290 / 1.5 \times 10^{-3}$ ECF from 1a for incorrect n and/or T $p = 1.9(3) \times 10^5$ (Pa) <u>**Examiner's Comments**</u> Questions 1(a) and 1(b) took the ideal gas equation and applied it to an unfamiliar situation, that of a toy rocket. Most candidates answered these questions well, remembering to convert the temperature from 17°C to 290K.
	b	i	$\Delta p = (2.4 – 1.0) - 10^5 = 1.4 \times 10^5$ (Pa) upwards force $(= \Delta pA) = (2.4 – 1.0) \times 10^5 \times 1.1 \times 10^{-4} = 15$ (N)	C1 C1 A0	<u>Alternative method:</u> Downwards force (from trapped air) = $pA = 2.4 \times 10^5 \times 1.1 \times 10^{-4} = 26.4$ (N) **and** upwards force (from atmosphere) = $pA = 1.0 \times 10^5 \times 1.1 \times 10^{-4} = 11.0$ (N) So total upwards force = 26.4 – 11.0 = 15.4 (N) **Ignore** any attempt to calculate weight **Special case: Allow** 1/2 for the use of $\Delta p = 2.4 \times 10^5$ (Pa) giving upwards force = 26.4 (N) <u>**Examiner's Comments**</u> Most candidates realised that a difference in air pressure between the inside and outside of the bottle would force the water downwards, producing an upwards force on the bottle which could be calculated using p = F/A.
		ii	$m = 0.3 + 0.05$ (= 0.35) (kg)	C1 C1 A1	$0.050 + (10^3 \times 0.3 \times 10^{-3})$ <u>Alternative approach</u>: $a = (15.4/m) - g$

			(Resultant force = upwards force – $W = ma$) 15.4 – (0.35 x 9.81) = 0.35a **or** a = 12/0.35 a = 34 (m s^{-2})		ECF for incorrect value of m **No** ECF ci (since we are told that upwards force = 15(.4)(N)) Upwards force = 15 (N) gives a = 33 (m s^{-2}) **<u>Examiner's Comments</u>** This question, although a simple F = ma problem, challenged many candidates. **Exemplar 1**



					Exemplar 1 shows the most common incorrect response. The correct value for mass (m = 0.35kg) has been used, but the value for the upwards force (15.4N) rather than the resultant force (15.4 – mg) has been used for F.
	c		• (initial) upward force unchanged • (initial) downwards force/weight increases • (initial) resultant force decreases • (initial) acceleration decreases • (initial) <u>rate of</u> change in momentum of rocket decreases • time taken to expel water increases • valid conclusion that the maximum height depends on more than one factor	B1 x 3	**Maximum 3** marks from 7 marking points: **Ignore** comments which assume an increase in pressure **Ignore** heavier **Allow** net or unbalanced or total for resultant **Allow** fuel for water e.g. the height depends on the bottle's velocity and its height when all the water has been expelled / the height depends on both the acceleration and the time taken to expel the water **<u>Examiner's Comments</u>** This question involved several factors and a conclusion was not required; hence the word 'discuss'. Candidates who performed well on this question realised that the weight of the rocket would increase, reducing the resultant force, and m would increase in the formula F = ma. These would both give a reduced initial acceleration and imply a smaller height. However, the time taken to expel the water would increase, meaning that the rocket would accelerate for longer. One common misconception was that the larger volume of water in the bottle would increase the pressure of the trapped air. However, as a pump was used to determine the pressure before lift-off, this argument was not given credit.
			Total	**11**	

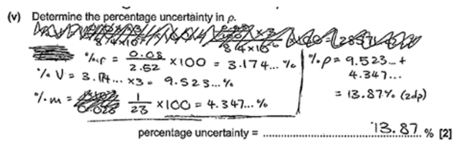
4 6			$mv^2/r = mg$ or $v^2/r = g$ $v^2 = 9.81 \times 0.25$ $v = 1.6$ (m s^{-1})	**C1** **C1** **A1**	**Allow:** $v^2/r = a$ <u>and</u> $a = g$ or $mv^2/r = ma$ <u>and</u> $a = g$ **Allow:** any subject **Allow:** any subject **Note:** qualified 2.21 (ms^{-1}) scores 2 marks. **<u>Examiner's Comments</u>** This question was answered well by those above the mean result. When the machine is switched off, the clothes are still in circular motion and at point B, the resultant force is still the weight of the clothes plus the normal contact force. This means at the critical speed when the clothes fall off at point B, the centripetal force will equal the weight of the clothes, since the question states that the normal contact force is zero.
			Total	**3**	
4 7			$\pi \times \frac{(32\times10^{-3})^2}{4} \times 100 \times 10^{-3}$ or 8.04×10^{-5} $\frac{7.0}{9.81}$ or 0.714 8900 (kg m^{-3})	C1 C1 A1	**Ignore** POT 8881 2200 scores two marks **<u>Examiner's Comments</u>** In part (a), most candidates answered this well although a significant minority confused the calculation of the volume. Answers such as 2√5 did not score in (b)(i); it is expected that decimal fractions should be used. In (b)(ii) high achieving candidates labelled the forces and correctly indicated the direction of the forces. Some candidates omitted to use the scale for their final response. In part (c), many candidates were confused in determining which forces and distances should be used.
			Total	**3**	
4 8		i	An arrow from trolley to ramp along the string (for the tension) and a downwards arrow from the trolley (for the weight).	B1	**Allow** arrows in correct directions anywhere on Fig. 21 **Not** arrow for the tension parallel to the ramp **Not** arrow perpendicular to the ramp for the weight **Not** two arrow heads in opposite directions along the string for the tension **Examiner's Comments** Most of the candidates answered this question well with two clearly drawn arrows for the weight of the trolley and the tension in the string. The most frequent mistake was to draw the tension arrow parallel to the ramp.

		ii	($s = \frac{1}{2}at^2$); $0.80 = \frac{1}{2} \times 3.0 \times t^2$ (Any subject)	C1	
		ii	$t = 0.73$ (s)	A1	**Note**: Apply SF penalty if 0.7 s is on the answer line or the final answer **Allow** 1 mark for 0.40 (s); 9.8 m s^{-2} used instead of 3.0 m s^{-2} **Allow** full credit for alternative methods, e.g: $v^2 = 2 \times 0.80 \times 3.0$; $v = 2.19$ (m s^{-1}) $t = \frac{2.19}{3.0}$ **C1** $t = 0.73$ (s) **A1** **Examiner's Comments** Candidates answered this question extremely well. The correct equation was identified, values substituted correctly and the final answer written to two significant figures. Some low-scoring candidates attempted to use the equation $x = vt$ or struggled with rearranging the equation $s = \frac{1}{2}at^2$. A disappointing number of candidates lost a mark for writing the answer to one significant figure on the answer line after correctly calculating the time t to be 0.73 s.
			Total	**3**	
49			Maximum of two from: (thinking) time is the same (braking) time is halved / 1.25 s total time is 2 s **AND** maximum of two from: (thinking) distance / displacement travelled (before braking) halved / 7.5 m (braking) distance / displacement quarters / 6.25 m total distance / displacement = 13.75 m	B1 ×3	
			Total	**3**	
50	a	i	$\pi \times \frac{(2.9\times10^{-2})^2}{4}$ or $\pi \times (1.45 \times 10^{-2})^2$ 6.605×10^{-4} m² ≈ 6.6×10^{-4}	M1 A0	

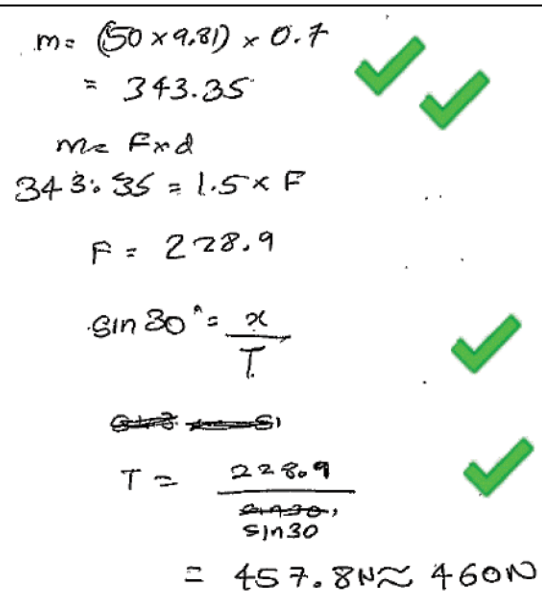
		ii	V = 6.6 × 10^{-4} × 12.0 or 7.92 × 10^{-5} (m^3) m = 400 × 7.92 × 10^{-5} or 0.03168 kg W = 0.31 (N)	C1 C1 A1	**Ignore** POT
	b		$V = \frac{0.31}{1000 \times 9.81}$ or 3.16×10^{-5} $y = \frac{3.16 \times 10^{-5}}{6.6 \times 10^{-4}}$ y = 0.048 (m)	C1 C1 A1	Mass of water displaced = $\frac{0.31}{9.81} = 0.316$ $y = \frac{0.316}{1000 \times 6.6 \times 10^{-4}}$
	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**	
5 1			m = 650/g **or** m = 650/9.81 (= 66.3 kg) ($F = mr\omega^2$ gives) d = 0.050 / $m\omega^2$ = 0.050 / 66.3 x (3.5 × 10^{-3} $)^2$ d = 62 (m)	C1 C1 A1	**Not** m = 650 kg or m = 65 kg **or** ($F = mv^2/r$ and $v = 2\Pi r/T$ gives) d = 0.050 x (30 x 60)^2 / (4π^2 x 66.3)
			Total	**3**	
5 2			Δtime = 1.75 – 0.75 OR 3.25 - 0.75 Using **(c)**: $F = 950 \times \frac{20-12}{1.75-0.75}$ or Using graph: $F = 950 \times \frac{20-0}{3.25-0.75}$ or $F = \frac{950 \times 20}{3.25-0.75}$ 7600 (N)	C1 C1 A1	**Allow** use of **(c)** and **(a)** **Allow** a= 8.0 m s^{-2} for $v^2=u^2+2as$ or $s=ut+ ½at^2$ methods **Not** ECF for incorrect time **Ignore** sign
			Total	**3**	
5 3		i	The upthrust is equal to the weight of the fluid / liquid / water / air displaced	B1	**Examiner's Comments** About one in every seven candidates omitted this question and only about a third of the candidates gave an acceptable statement of Archimedes' principle. It was clear from the answers that most candidates had not revised this topic. There were

					countless guesses, with many famous laws incorrectly linked to this principle.
		ii	(upthrust =) 9.0 − 7.8 (N) or (mass =) 9.0/9.8(1)	C1	**Note**: This C1 mark for determining the upthrust (1.2 N) or the mass (0.92 kg) of the cylinder
		ii	$V = \frac{(1.2/9.81)}{1000}$ or $V = 1.2(23) \times 10^{-4}$ (m^3) $\rho = \frac{(9.0/9.81)}{1.223 \times 10^{-4}}$	C1	
		ii	$\rho = 7.5 \times 10^3$ (kg m^{-3})	A1	**Allow** full credit for alternative methods, e.g: $\rho = \left(\frac{9.0}{1.2}\right) \times 1000 = 7.5 \times 10^3$ (kg m^{-3}) **Examiner's Comments** This proved to be a discriminating question that favoured those candidates who could apply, rather than just rote learn, Archimedes' principle. About a third of the candidates scored nothing in this question but many candidates did score one mark for determining the upthrust of 1.2 N. Most candidates stopped at this point. The top-end candidates correctly determined the volume of the displaced water and then went on to successfully calculate the density of the metal.
			Total	**4**	
54	a	i	(Vernier) Calliper or micrometer (screw gauge)	B1	**Not** rule(r) **Examiner's Comments** This question was well answered with most candidates stating either Vernier calliper or a micrometer screw gauge.
		ii	2.52 ± 0.08	B1 B1	**Allow** (2.52-2.43 =) 0.09 or (2.59-2.52 =) 0.07 **Examiner's Comments** Most candidates correctly calculated the mean diameter of the ball. A much smaller proportion of the candidates determined the absolute uncertainty in the diameter correctly. In this case, the range was 0.16 cm, so the absolute uncertainty was 0.08 cm. Examiners allowed the maximum value minus average value or average value minus minimum value. **AfL** When measurements are repeated the absolute uncertainty is given by: Absolute uncertainty = ½ x range = ½ x (maximum value – minimum value)

		iii	Volume = $\frac{4}{3} \times \pi \times (1.26 \times 10^{-2})^3$ = 8.379×10^{-6} 8.4×10^{-6} m^2	M1 A0	$\frac{1}{6} \times \pi \times (2.52 \times 10^{-2})^3$ or $\frac{4}{3} \times \pi \times \left(\frac{2.52 \times 10^{-2}}{2}\right)^3$ **Examiner's Comments** This was another "show" question. Many candidates find dealing with standard form terms in their calculator difficult. Candidates needed to show clearly the conversion of the diameter in cm to radius in m. There was some evidence of candidate just adding a 10^{-6} power to their answer.
		iv	$\frac{0.023}{8.4 \times 10^{-6}}$ or 2738 2700 (kg m^{-3}) or 2.7 x 103 (kg m^{-3})	C1 A1	**Note** 2745 if using calculator value from **(iii)** **Note** must be two significant figures **Allow** one mark for 2.7 x 106 (kg m^{-3}) **Examiner's Comments** In this question, most candidates were able to determine the density correctly although, a few candidates did not change the mass in gram to kilogram. A large number of candidates did not give their answer to an appropriate number of significant figures; the common answer being 2738 kg m^{-3}. In this case, the mass was given to two significant figures and the volume was calculated from data give to three significant figures, thus the final answer should be given to the same number of significant figures as the least significant data, i.e. to two significant figures.
		v	$\frac{1}{23}$ or $\frac{0.08}{2.52}$ or $\frac{0.24}{2.52}$ or 4.3% or 3.2% or 9.5% 14% (13.8%)	C1 A1	**Allow ECF** from **(ii)** – 3.6% or 10.7% for Δd = 0.09 **Allow** maximum/minimum methods **Note** 13% for Δd = 0.07 or 15% for Δd = 0.09 [ECF 5.5% for Δd = 0.01] **Examiner's Comments** The majority of candidates were able to determine the percentage uncertainty in the mass correctly. Fewer candidates realised that the percentage uncertainty in the volume was three times the percentage uncertainty in the diameter. Candidates who did well, clearly showed their working. Some candidates tried to use a maximum/minimum method. This was a more complex method and more difficult for candidates to gain the correct answer. In this case, the maximum mass needed to be divided by the minimum volume or the minimum mass needed to be divided by the maximum volume

					AfL How to use percentage uncertainties. **Exemplar 5**  The candidate's answer is logically structured showing the percentage uncertainty in the mass and volume and then adding them together so gaining both marks. An answer of 14% would have been acceptable.
	b		Extension = 0.096 – 0.078 or 0.018 m Weight = 0.023 x 9.81 or 0.22563 13 (N m^{-1})	C1 C1 A1	**Allow ECF** for incorrect mass conversion from **(iv)** **Allow** 12.6 (N m^{-1}) or 12.5 (N m^{-1}) **Examiner's Comments** The majority of the candidates clearly showed their working and calculated the force constant correctly. Some incorrectly used the energy stored equation.
	c	i	Apparent weight = 0.01 x 13 (= 0.13 N) (Upthrust = 0.226 - 0.13) = 0.10 (N)	C1 A1	**Allow ECF** from **(b)** **Allow** 0.008 x 12.5 **Allow** 0.1 (N) (1sf) **Examiner's Comments** In this question, many candidates calculated the apparent weight and then incorrectly assumed that this was the upthrust. Other errors included using the incorrect values for length to determine the extension. Some candidates correctly determined the upthrust by determining the change in extension.
		ii	$\rho = \frac{0.10}{9.81 \times 8.4 \times 10^{-6}}$ 1200 (kg m^{-3})	C1 A1	**Allow ECF** from **(i)** **Examiner's Comments** Candidates generally found this last question challenging. Some candidates who did less well, attempted to use the equation for liquid pressure. Candidates who did well again clearly showed their reasoning.
			Total	**15**	
5 5			(weight of plank =) 50 × 9.81 or 490.5 OR uses a distance of 0.7m to calculate	**C1**	

			clockwise moment		
			(anticlockwise moment =) $T\sin30° \times 1.5$ OR 0.75T	C1	**Allow** $T\cos60° \times 1.5$
			(clockwise moment =) 490.5 × 0.7 = 343 (N m)	C1	**Allow** 344,
			$T\sin30° \times 1.5 = 343$ OR $T\sin30° = 229$	C1	
			$T = 457.8$ (N)	A0	**Allow 458.6**, **<u>Examiner's Comments</u>** 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**	
56		i	($v^2 = u^2 + 2as$) $(2.4 \times 10^6)^2 = (7.2 \times 10^6)^2 + 2 \times a \times 1.2 \times 10^{-2}$	C1	**Allow** other correct methods
		i	$a = (-)\ 1.9 \times 10^{15}$ (m s^{-2})	A1	**Allow** 1 mark for 1.9×10^{13}; distance left in cm **Note** answer to 3 s.f. is 1.92×10^{15} (m s^{-2}) **Ignore** sign
		ii	$E = F/Q$ and $F = ma$	C1	
		ii	$E = \dfrac{1.67\times10^{-27}\times1.92\times10^{15}}{1.60\times10^{-19}}$	C1	Possible ECF from **(i)**
		ii	$E = 2.0 \times 10^7$ (N C^{-1})	A1	**Allow** 2 marks for 1.1×10^4; mass of electron used **Allow** 1 s.f. answer
			Total	**4**	
57		i	250 × 60 = 15000 J	C1	
		i	energy = $\dfrac{15000}{0.65}$ = 2.3×10^4 (J)	A1	

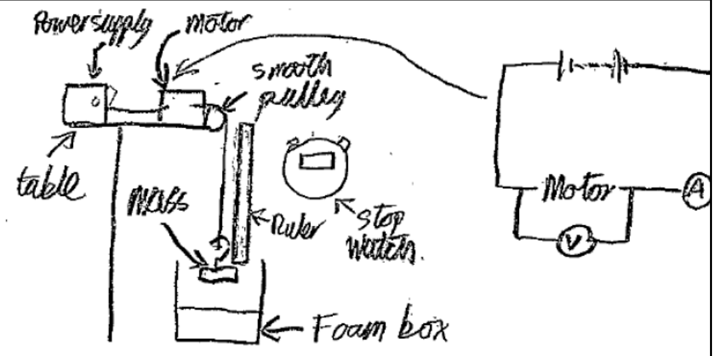
		ii	drag force = 0.4 × 6.0^2 = 14.4 N	C1	
		ii	forward force = power / velocity = 250/6.0 = 41.7 N	C1	
		ii	acceleration = $\frac{41.7 - 14.4}{85}$ = 0.32 m s^{-2}	A1	
			Total	**5**	
58		i	4.4 – 4.6 (N)	B1	
		ii	Weight of cylinder 3.5 cm vertically (judge by eye) Correct closed triangle drawn including 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**	
59		i	R (= ρ*L*/A) = 1.8 × 10^{-8} × 1500/1.1 × 10^{-4} R = 0.25 (Ω)	C1 A1	
		ii	$E = \sigma/\varepsilon = T/A\varepsilon$ (so $T = EA\mathcal{E}$) T = 1.2 x 10^{10} x 1.1 x 10^{-4} x 0.013 T = 1.7 x 104 (N) or 17 (kN)	C1 C1 A1	**or** calculation of σ =1.56 x 10^8 (Nm^{-2}) **or** T = 1.56 x 10^8 x 1.1 x 10^{-4}
			Total	**5**	
60		i	(horizontal component of *F* =) *F* × cos20° *F* cos20° × 1.30 = 0.30 × 40 × 9.81 *F* = 96.4 (N)	M1 M1 A1	**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
		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**	
61		i	weight / W / mg **and** downward arrow upthrust / U **and** upward arrow drag / D / friction **and** upward arrow	**B1** **B1** **B1**	**Allow** labels used in **(c)(i)** throughout **Ignore** arrow sizes. **Allow** '(water) resistance' for drag **Examiner's Comments**

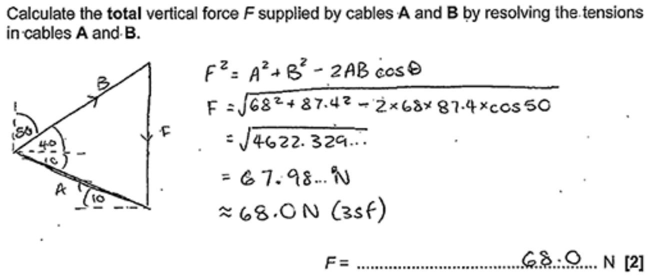
					The forces referred to by name in module 3 of the specification are weight, drag, upthrust. tension, normal contact force and friction. Candidates should be aware that the three relevant forces in this example are upthrust, weight and drag (with friction as an acceptable alternative). A wide range of other options were provided by candidates, such as gravity, buoyancy, lift, pressure, impulse and air resistance, none of which were acceptable.
		ii	Resultant force decreases (with time or as cylinder descends) Upthrust remains constant / drag decreases (as speed decreases) / resultant force is upwards / At lowest point, drag is zero At lowest point, resultant force is upwards	**B1** **B1** **B1**	**Allow** 'At lowest point, upthrust > weight' **Note:** Any incorrect answer from the list will not score this point **Not** 'resultant force = 0' **Note:** Resultant force is <u>always</u> upwards' scores B1×2 **Examiner's Comments** Examiners would like to see an improvement in the understanding of the forces acting on objects in motion as this item on resultant forces was not answered well. A large proportion of candidates misunderstood the scenario, believing it to be a terminal velocity problem. This meant that many responses included the notion that the block would speed up and eventually have zero resultant force acting upon it. In this case, that would mean that the block would continue at constant velocity downwards rather than return to the surface. This item prompted the candidates by asking about the resultant force at the lowest point of the motion, which tying in with the ideas in previous parts of the question about density and floatation, should have hinted that the resultant force at the lowest point was upwards. Those candidates that did realise this often contradicted themselves to ensure an upwards resultant at the bottom of the motion. Typically, this was by stating, incorrectly, that the upthrust or the drag increased, at which point only one mark was possible.
			Total	**6**	
62		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	$T = 3.6 \times 10^3$ (N)	A1	**Note** answer to 3 s.f. is 3.57×10^3 (N)
		ii	$\sigma = \frac{3.6\times10^3}{\pi\times0.015^2}$	C1	Possible ECF from part **(i)**

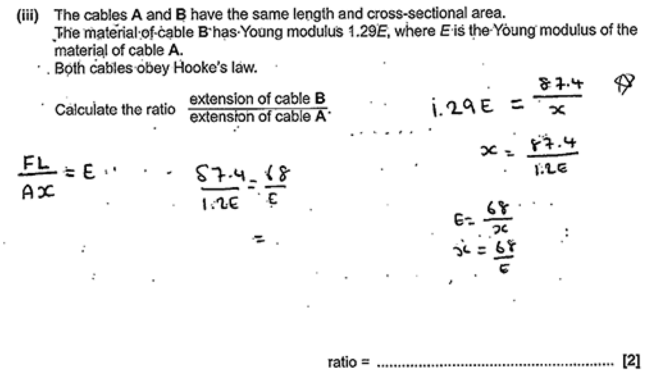
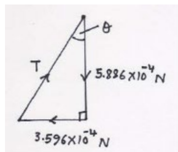
		ii	σ = 5.1 × 10^3 (kPa)	A1	**Allow** 1 mark for 5.1 × 10^6; POT error **Note** using 3.57 × 10^3 N gives 5.05 × 10^3 (kPa)
		iii	The clockwise moment increases and therefore *T* increases.	B1	
			Total	**6**	
63	a	i	1. *either* resultant force *F* = *ma* – *R* *or* resultant force decreases as *R* increases	B1	**allow** for points 2 and 3 *when F* = *R* appearing only once
		i	2. acceleration *a* decreases to zero when *F* = *R*	B1	
		i	3. velocity rises from zero to a terminal / maximum value when *F* = *R*	B1	
		ii	**1** initial acceleration is 40/120 = 0.33 (m s^{-2})	B1	
		ii	**2** from the graph *Rv* = 200 (W) so *R* = 40 N	C1	**or** forward force = 40 N so *R* = 40 N for constant
		ii	and terminal velocity *v* is 5 (m s^{-1})	A1	speed / zero acceleration
	b		p.e. / second = mgvsin θ = 120 × 9.81 × 5 × sin θ	C1	**allow** force downhill F = mgsin θ, extra power = Fv
			extra power= 200 (W)	C1	
			so sin θ = 1/29.4 giving × = 29 m	A1	
			Total	**9**	
64		i	Both forces shown in correct direction and arrows of same length.	B1	
		ii	Zero.	B1	
		iii	(Conservation of momentum) $u_x = v_x + v_z$	C1	
		iii	(Conservation of kinetic energy) $u^2_x = v^2_x + v^2_z$	C1	
		iii	Shows $v_x = 0$ by substitution	C1	
		iii	$v_z = u_x$ by substitution of $v_x = 0$	A1	
			Total	**6**	
65	a	i	t = 0 to 1.5 s, constant force (of 30 N) causes constant acceleration	B1	or reference to N2
		i	t = 1.5 to 4.0 s zero (resultant) force so constant speed	B1	or reference to N1
		ii	acceleration = 30/65 = 0.46 (m s^{-2})	M1	

		ii	speed v at 1.5 s = at = 0.46 × 1.5 = 0.69 (m s^{-1})	A1	ecf acceleration value
		ii	distance = ½at² + vt' = 0.23 × 1.5² + 0.69 × 2.5	C1	ecf acceleration and speed values
		ii	s = 2.24 m	A1	
	b		power lost in circuit = 30² × 0.11	C1	Apply ecf rule as appropriate
			= 99(w)	C1	
			mechanical power = 640 × 0.70 = 448 (W)	C1	allow 3 marks for 53%
			electrical power input = 28 × 30 = 840 (W)	C1	
			input power to motor = 741 (W)	C1	
			efficiency = 448 / 741 = 0.60 or 60%	A1	
			Total	**12**	
6 6		i	(stress =) $\frac{7.5}{8.2\times10^{-7}}$ **or** 9.15×10^{6} (Pa) (strain =) $\frac{7.5}{8.2\times10^{-7}\times2.0\times10^{11}}$ **or** 4.57×10^{-5} $x = 2.8 \times 10^{-5}$ (m) **OR** $E = \frac{FL}{Ax}$ $2.0 \times 10^{11} = \frac{7.5\times0.62}{8.2\times10^{-7}\times x}$ $x = 2.8 \times 10^{-5}$ (m)	C1 C1 A1 C1 C1 A1	**Allow** full credit for alternative methods **Note** answer is 2.84×10^{-5} to 3 SF **Note** answer is 2.84×10^{-5} to 3 SF **Special case:** 1 mark for 2.8×10^{-4} (m) or 2.9×10^{-6} (m); 7.5g or $7.5g^{-1}$ (g = 9.81) used instead of 7.5
		ii	acceleration at **Y** / deceleration at **Z** At **Y** (tension is) greater / (T) > 7.5 (N) At **Z** (tension is) less / (T) < 7.5 (N)	B1 B1 B1	**Allow** increasing velocity / increasing speed at **Y** **Allow** decreasing velocity / decreasing speed **/** negative acceleration at **Z** / slowing down **Ignore** 'downward acceleration' at **Z** **Ignore** drag throughout **Allow** (T) > weight **Allow** (T) < weight
			Total	**6**	
6 7			**Level 3 (5–6 marks)** Clear diagrams and procedure and measurements **and** analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)**	**B1 × 6** **6**	**Indicative scientific points may include:** **Diagram and procedure** • labelled diagram • correct circuit diagram • description of procedure • use of cushion in case load falls • repeats experiment.

			A diagram, some procedure, some measurements and some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited procedure and limited measurements **or** limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**Measurements** • use of balance to measure load • use of ruler to measure height • use stopwatch to measure time • use of ammeter to measure current • use of voltmeter to measure p.d. **Analysis** • equation to determine input power/energy (IV/IVt) • equation to determine output power/energy (mgh/t or mgh) • equation to determine efficiency • use of gradient of appropriate graph **<u>Examiner's Comments</u>** This question is assessing candidates' abilities to plan an investigation. The question is set to help candidates e.g. "lift light loads" should have given the hint of gravitational potential energy. The stem of the question indicates that a suitable diagram should be drawn. Many candidates did not label their diagrams, or the diagrams were not workable. It was expected that there would be a workable circuit diagram with appropriate measuring instruments to determine the input power or energy; correct circuit symbols should be used. There also needed to be a diagram indicting how the useful power or energy could be determined. See Exemplar 1. When answering planning questions, candidates should identify the measurements that need to be taken and indicate appropriate measuring instruments. Candidates also needed to explain how the data would be analysed. This required them to give the appropriate equations using their measurements to determine the input power/energy, the output power/energy and the efficiency. Good candidates suggested the plotting of an appropriate graph and explained how the efficiency could be determined from the gradient. **Exemplar 1**

					 This candidate has drawn two diagrams – one diagram indicating clearly how the motor is connected to a cell with an ammeter and voltmeter which could be used to determine the input power. The left-hand diagram is an arrangement of the apparatus which indicates the basic set up and included a foam box for the mass to fall into if the experiment does not work properly. This candidate has also underlined key words from the question.
			Total	**6**	
6 8		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 × sin50°/sin50° **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	$68 = m \times 9.81$ $m = 6.9$ (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 **Examiner's Comments** 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 **Examiner's Comments** 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

					 (iii) The cables A and B have the same length and cross-sectional area. The material of cable B has Young modulus 1.29E, where E is the Young modulus of the material of cable A. Both cables obey Hooke's law. Calculate the ratio $\frac{\text{extension of cable B}}{\text{extension of cable A}}$. ratio = ... [2] 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**	
6 9		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	$F = \frac{(4.0\times10^{-9})^2}{4\pi\varepsilon_0\times0.02^2} = 3.596....\times10^{-4}$ (N)	C1	Correct use of $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$
		ii	weight $W = 6.0\times10^{-5}\times9.81 = 5.886\times10^{-4}$ (N)	C1	
		ii	$\tan\theta = \frac{3.596\times10^{-4}}{5.886\times10^{-4}}$	C1	
		ii	angle $\theta = 31°$	A1	
			Total	**6**	
7 0		i	Tangent drawn at t = 4.0 s Attempt at calculating the gradient v calculated from gradient and between 9.50 - 10.50 (m s^{-1}) **OR** s = 20 (m) and $s = ½at^2$ 20 = ½ a × 4.0^2 **or** a = 2.5 (m s^{-2}) v = 2.5 × 4.0 **or** v^2 = 2 × 2.5 × 20 v = 10 (m s^{-1})	C1 C1 A1 C1 C1 C1 A0	**Allow** other correct methods **Note** working required for this mark
		ii	change in momentum = 1200 x 10 or 12000 (kg m s^{-1}) rate of change of momentum = 3000 unit: kg m s^{-2} or N	C1 A1 B1 C1	**Allow** ECF from **(i)** **Allow** 2850 - 3150 **Allow** newton

			OR F = 1200 X 2.5 rate of change of momentum = 3000 unit: kg m s^{-2} or N	A1 B1	**Allow** ECF from **(i)** **Allow** newton
			Total	**6**	
7 1		i	(For circular motion) there must (always) be a resultant force towards the centre The resultant force is not always vertical/sometimes has a horizontal component This can only be provided by friction/cannot be provided by R and W / R and W are always vertical/only F is horizontal	B1 x 2	any 2 from 3 marking points **Allow** F provides the horizontal (component of the) centripetal force
		ii	Sine wave with period 30 min and amplitude 0.050 (N) Correct phase, i.e. <u>negative</u> sine wave	B1 B1	Must start at the origin
		iii	F = 0.050 cos 40° F = 0.038 (N)	C1 A1	**Allow** alternative methods e.g. triangle of forces **Allow ECF** from graph if used
			Total	**6**	
7 2		i	$(E=)\frac{4000}{0.080}$ $(F=)\frac{4000}{0.080}\times 1.6\times 10^{-19}$ $(a=)\frac{8.0\times10^{-15}}{9.11\times10^{-31}}$ **or** 8.78×10^{15} $a = 8.8 \times 10^{15}$	C1 C1 C1 A0	$E = 5.0 \times 10^{4}$ (V m^{-1}) $F = 8.0 \times 10^{-15}$ (N) **Allow** this mark if the working is shown. If only value is given, then the answer must be 3SF or more **<u>Examiner's Comments</u>** This question asks for a calculation to show the value of the vertical acceleration in an electric field. The magnitude of the electric field strength first needs to be calculated, followed by the acceleration from Newton's second law. Candidates are reminded that a **show** question needs to be answered in detail and that each stage should be clear. Roughly equal numbers of candidates scored full marks or zero on this question.
		ii	$(t=)\frac{0.12}{6.0\times10^{7}}$ ($t = 2.0 \times 10^{-9}$ s)	M1 A0	**<u>Examiner's Comments</u>** As with the previous question, there is the need to make sure that the calculation leading to the given answer is clearly set out.
		iii	(x =) ½ × $8.78 \times 10^{15} \times (2.0 \times 10^{-9})^2$ $x = 1.8 \times 10^{-2}$ (m)	C1 A1	**Allow** $a = 8.8 \times 10^{15}$ **<u>Examiner's Comments</u>** Most candidates appreciated the need to use an equation of motion in their solution, but a significant number of candidates

					used an initial horizontal velocity in the expression, leading to an incorrect answer. There were also an unusually large number who gave no response. Candidates should appreciate that if they have been given show questions, then it is likely that these values will be used in alter questions. **Misconception** Many candidates included an initial vertical velocity – it may be helpful to think of this process as analogous to that of projectile motion.
			Total	**6**	
73		i	tension = 850 kg × 9.81 = 8300 N	B1	
		ii	work done = *mgh* = 850 × 9.81 × 12	C1	
		ii	work done = 100 kJ	C1	
		ii	output power = 100 × 10^3 / 40 (=2501 W)	C1	
		ii	input power (= 2501 / 0.6) = 4200 (W)	A1	
		iii	Suggestion to reduce heat losses through friction in moving parts e.g. oil, bearings	B1	
		iii	Use a stiffer / stronger cable to reduce energy loss through stretching	B1	
			Total	**7**	
74		i	(*F* = *ma* =) 190 × 10^3 = 2.1 × 10^5 a *a* = 0.90 (m s^{-2})	M1 A0	a = 0.905 to 3 SF
		ii	($v^2 = u^2 + 2as$ gives) 36 = 2 × 0.90 × s s = 20 (m)	C1 A1	**Allow** any valid suvat approach; **allow ECF** from (i) **Note** using a = 1 gives s = 18(m)
		iii	**1** *P* = *F*v One correct calculation e.g. F = 100 × 10^3 and v = 42 gives *P* = 4.2 ×10^6 (W) *F*v = constant **2** (*P* = VI = 4.2MW so) 4.2 × 10^6 = 25 × 10^3 × *I* *I* = 170 (A)	B1 B1 B1 C1 A1	Equation must be seen (not inferred from working) **Allow** any corresponding values of F and v; working must be shown. No credit for finding area below curve **Allow** *F* is proportional to 1/v or graph is hyperbolic *or* correct calculation of *Fv* at <u>two</u> points (or more) **Allow** *P* = 4MW or **ECF from (iii)1** Expect answers between 160 - 170 (A)
			Total	**8**	
75		i	*a* = *F* / *m* / *a* = 8700 / 2300	C1	

		i	a = 3.8	A1	**Note** answer is 3.78 to 3 s.f.
		ii	$D_{thinking}$ = u × t = 22 × 0.97 = 21.3 (m)	C1	Allow 21.34
		ii	$D_{braking} = u^2 / 2a$ or $22^2 / (2 \times 3.8) = 64.0$ (m)	C1	Allow 63.98
		ii	stopping distance = $D_{thinking}$ + $D_{braking}$ or 21.3 + 64.0	C1	Allow ecf
		ii	stopping distance = 85.3 (m)	A0	Allow 85.32
		iii	22 × 3600 / 1600 (= 49.5 mph)	B1	
		iv	Thinking distance for truck longer than in chart	B1	
		iv	Suggested reason e.g. tired	B1	Allow any relevant factor
		iv	Braking distance for truck longer than in chart	B1	
		iv	Suggested reason e.g. truck more massive than a car, truck's brakes are poor quality	B1	Ignore reference to road conditions
			Total	**10**	
76		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 $t = \frac{310}{8.5} = 3$ $a = (-)\frac{17^2}{2\times310} = (-)\frac{289}{620}$ OR $a = \frac{17}{36.5}$ 0.47 (m s^{-2}) **3** 1.9 × 10^5 × 0.47	**C1** **A1** **C1** **C1** **A1** **C1**	**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** **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**

			89000(N)	**A1**	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.
		iii	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**	