Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	**Method 1** $d = 8.5 - 3.2$ (= 5.3(cm)) ($F = kd$ so) $F = 0.62 \times 5.30$ (= 3.3 (N)) $a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$ a = 17(m s^{-2}) **Method 2** ($F = kd$ so) $F = 0.62 \times 8.50$ (= 5.27(N)) $F_R = (0.62 \times 8.50) - (0.20 \times 9.81)$ (= 3.3 (N)) $a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$ **Method 3** ($F = kd$ so) $F = 0.62 \times 8.5$ (= 5.27(N)) $\left(a = \frac{F}{m} \text{ so}\right) a = \frac{5.27}{0.20}$ = 26 (m s^{-2}) $a_{initial}$ = 26.35 – 9.81 = 17 (m s^{-2})	C1 C1 A1 (C1) (C1) (A1) (C1) (C1) (A1)	**Mark whichever method leads to the most marks** d = 5.3cm does not need to be calculated explicitly but seeing 5.3 implies first C1 mark F = 3.3N does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** k = 0.61 (N cm^{-1}) leading to F = 3.2 (N)... ... and a = 16 (m s^{-2}) F = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** k = 0.61 (N cm^{-1}) leading to F = 5.19 (N) F = 3.3(N) does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** k = 0.61 (N cm^{-1}) leading to F = 3.2 (N)... ... and a = 16 (m s^{-2}) F = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** k = 0.61 (N cm^{-1}) leading to F = 5.19 (N) Note: a= 26 (ms^{-2}) is an intermediate calculation for $a_{initial}$ in this method only and is **not** the A1 mark **Allow** k = 0.61 leading to F = 5.19 and a = 16 **<u>Examiner's Comments</u>** There are two measurements for extension given here: an extension of 3.2cm under a load of (0.2 × 9.81) N and an extension of 8.5cm under a force of F + (0.2 × 9.81)

					The easiest way to approach the question is to recognise that the extension due to *F* alone must be (8.5 – 3.2) = 5.3cm. *F* = *kx* then becomes *F* = 0.62 × 5.3 (since *k* is given in N cm^{-1}) and so we can use *F* = *ma* with *m* = 0.2kg to find the acceleration *a*. However, other valid methods were also given credit.
		ii	Use of $a = (-)\omega^2 x$ Use of $f = \frac{\omega}{2\pi}$ *f* = 2.8 (Hz) **<u>Alternative method:</u>** (*a = F / m = kx/ m* and *a = (-) (−)ω²x* gives) $\omega^2 = \frac{k}{m}$ $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $= \frac{1}{2\pi}\sqrt{\frac{0.62 \times 100}{0.2}}$ *f* = 2.8 (Hz)	C1 C1 A1 (C1) (C1) (A1)	The two C1 marks are independent and XP in one does not imply XP in the other **Not** just formula alone Expect *a* = 17 but **allow** ECF of *a* from **(b)(i)** **Allow** any value for *x* **Not** just formula alone Use of $a = (-)(2\pi f)^2 x$ scores both C1 marks **Allow** *f* = 2.9 (Hz) **Allow** $T = 2\pi\sqrt{\frac{m}{k}}$ $f = \frac{1}{T}$ **Allow** *f* = 2.9 (Hz) **<u>Examiner's Comments</u>** The answer to this question is frequency = 2.8Hz, since ω depends only on *k* and *m* ($\omega^2 = k/m$). However, most candidates used the formula $a = (-)\omega^2 x$ together with appropriate values for *a* and *x*.
	b	i	(motion of magnet M causes) a change of flux (linkage) in coil Y (inducing an e.m.f.) there is an (induced) <u>current</u> in (or through) coil X alternating current / field / flux in coil X interacts with the field of magnet L (causing an alternating force)	B1 B1 B1	**Allow** field (lines of M) cuts (turns of) coil Y **Allow** the coil or Y or solenoid for coil Y **Allow** the coils or the wire(s) or X for coil X **Ignore** (induced) e.m.f. **Not** changing or varying or oscillating for alternating **Allow** current / field / flux in coil X

					interacts with field of magnet L **to** cause an alternating force **Allow** changing direction for alternating **Allow** combines for interacts **Allow** cuts across for interacts with **<u>Examiner's Comments</u>** Clarity in explanation was important here, as there are two magnets, M and L, plus two coils, X and Y. It is a change in flux linkage in coil *Y* which leads to an induced alternating current in coil *X*. This current creates an alternating magnetic field in coil *X* which interacts with the field of magnet *L* to create an alternating force on L. **Assessment for learning** Many explanations were too generalised: 'Faraday's Law states that there must be an induced emf which is proportional to the rate of change of flux linkage' or 'Fleming's left hand rule states there must be a force on the magnet' were often seen. Candidates should be encouraged to write in less general terms and to focus their answer on the specific question.
		ii	frequency of magnet L (always) equals (forcing/driving) frequency of vibration generator / magnet M resonance occurs at / close to 2.5 Hz amplitude is maximum at resonance	B1 B1 B1	**Allow** frequency of magnet increases with frequency of vibration generator May be seen from a **labelled** graph of amplitude against frequency **Allow** resonance occurs when forcing / driving frequency = natural frequency May be seen from a labelled graph of amplitude against frequency **<u>Examiner's Comments</u>** Many candidates did not realise that this was a question about resonance, presumably because of the unfamiliar context of the question.

					Common problems in 4(c)(ii) • not answering every part of the question: most candidates forgot to describe how the frequency varied as well as the amplitude • not realising that the vibration generator is driving the oscillation of L, and that this is a question about resonance • not labelling the scales on the graph of amplitude against frequency (or just using letters such as *A* and *f*) • failing to mark the resonance frequency as 2.5Hz (instead calling it f_o)
•			**Total**	**12**	
2		i	Horizontal = 43 (.3) (m s^{-1}) Vertical = 25 (m s^{-1})	B1 B1	ignore sign Allow answers in incorrect order for 1 mark MAX Allow H = 7.7 (m s^{-1}), V = −49.4 (m s^{-1}) 1 mark MAX **<u>Examiner's Comments</u>** Most candidates got this correct. Some scored a single mark for confusing sine and cosine but otherwise completing the calculation correctly. **Examination Tip** Make sure to check whether your calculator should be in degrees or radians mode. Also, practise which trigonometric function to use. If in doubt, draw a labelled right-angled triangle to help identify the correct function.
		ii	Correct application of N3L Plus ONE from: (Direction of) momentum of air has changed or direction of air flow has	B1 B1 B1	force on air is equal (and opposite) to force on model **<u>Examiner's Comments</u>** The key idea here was Newton's third

			changed There is a force on the air (from the model)		law, with credit for some supporting information.
		iii	$F = \frac{\Delta p}{\Delta t}$ F = 35 × 25 (divided by 1) F =880 (N)	C1 C1 A1	ecf candidate's vertical velocity in (i) Allow 875 Allow 870 **Examiner's Comments** Answers that clearly used F = ma with the acceleration of 25 ms^{-2} were deemed wrong Physics (as in previous series). Error Carried Forward (ECF) was clearly applied here also.
			Total	**7**	
3			**C**	1	The condition for circular motion is that the centripetal force is equal to the resultant force. In this case, the resultant force is the weight - normal contact force so W - R = m v^2 / r. The person leaves the seat when R ≤ 0. When rearranged with W = mg gives the correct answer C.
			Total	**1**	
4			**C**	1	**Examiner's Comments** For small angles, sin*θ* and tan*θ* are relatively close to each other and small. cos*θ*, however, is close to 1, which eliminates options 1 and 2. The only correct pair is option 3, making C the correct answer.
			Total	**1**	
5		i	$\left(\frac{(-)18}{2.7} =\right)$ (-) 6.7 (m s^{-2})	A1	**Ignore** sign **Examiner's Comments** This question required candidates to calculate the gradient of the sloping line. More able candidates clearly demonstrated the co-ordinates used and substituted the values into $\frac{y_2 - y_1}{x_2 - x_1}$. Candidates should be encouraged to show working since the read-offs could have helped with gaining credit in Question 1 (a) (iii) and (iv) where

					the values from the graph were used again. Some candidates incorrectly gave the answer to one significant figure (as “7”). Other candidates incorrectly wrote 6.6; this should have been rounded to 6.7.
		ii	(1200 ×6.7 =) 8000 (N)	B1	**ALLOW ECF** from **(a)(i)** **IGNORE** “-” **<u>Examiner’s Comments</u>** This question was answered well with the majority of candidates multiplying 1200 by the answer to Question 1 (a) (i).
		iii	$d = 18\times0.7+\frac{1}{2}\times18\times2.7$ OR $d = (3.4+0.7)\times\frac{1}{2}\times18$ 37 (m)	C1 A1	**ALLOW ECF** from **(a)(i)** **ALLOW** $d = 18\times0.7+18\times2.7-\frac{1}{2}\times6.7\times2.7^2$ 36.9 **ALLOW** one mark for $\left(\frac{1}{2}\times18\times2.7=\right)24(.3)$ (m) **<u>Examiner’s Comments</u>** Candidates who showed working usually gained credit. A common error was to calculate the distance travelled while braking rather than the stopping distance. **Assessment for learning** Understand the meaning of the terms thinking distance, braking distance and stopping distance.
		iv	$8000\times24(.3)$ OR $8000\times\frac{1}{2}\times18\times2.7$ 190 000 (J)	C1 A1	**ALLOW ECF** from **(a)(i)** and **(ii)** and **(iii)** **ALLOW** $\frac{1}{2}\times1200\times18^2$ **ALLOW** 194 000 / 200 000 (J) **ALLOW** one mark for (8000 ×37 =) 296000 (J) **<u>Examiner’s Comments</u>** Many candidates multiplied force (from Question 1 (a) (ii)) by the braking distance. A common error was to use the stopping distance rather than the braking distance.

					Other candidates correctly calculated the kinetic energy. One error that was occasionally observed was the incorrect use of *P* = *Fv*.
			Total	**6**	
6	a		pV=nRT mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	Not n=1 Not n=1 **Examiner's Comments** Successful candidates correctly identified the starting point for this question as the ideal gas equation, *pV = nRT.* Many candidates took the approach that *n* = 1 which was not sufficient. A more sufficient proof used the idea that the total mass of the gas was *n* × *M,* allowing cancelling of the *n* in the ideal gas equation.
	b	i	$\rho = \frac{100\,000 \times 0.029}{8.31 \times 293}$ =1.19 kg m^{-3}	M1 A0	Accept R for 8.31, T = 293.1(5) Reject 20 for T. **Examiner's Comments** The vast majority of candidates correctly substituted values into the given formula, also remembering to convert the temperature from celsius into kelvin. Good practice for "show that" questions is to calculate the quantity required to at least one more significant figure in the question. In this example, that would mean evaluating the density to 1.19 kg m^{-3}.
		ii	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	Accept all answers that round to 140 000 N, eg 140210, 141264 **Examiner's Comments** In part (b) (ii), finding the weight was a matter of finding the mass and then finding the weight, all by using data in the question.

		iii	<u>Upthrust</u> = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified "Archimedes' principle" Not water for fluid **<u>Examiner's Comments</u>** Part (b) (iii) required understanding of Archimedes' principle, rather than merely referring to it. Most candidates successfully related the principle to this context, writing about the upthrust being equal to the weight of fluid or air displaced by the gasbag. This is *always* true, regardless of the other forces that may be in play. References to displacement of water at this point were rejected. Fewer candidates completed the explanation by mentioning that the upthrust must be equal to the weight of the gas bag because we know that the gas bag is in equilibrium.
		iv	**Two** from • (Greater pressure) would increase the density/mass/weight of the helium • (increased pressure but) no change in volume therefore no more upthrust. • If the volume goes up then the upthrust will increase / ORA • Pressure only needs to be large enough to inflate the gasbag • (increased pressure difference or volume) may cause structural failure • (higher pressure means) more collisions of helium atoms with walls so more leakage of helium	B1 x 2	**<u>Examiner's Comments</u>** Most candidates scored a mark in part (b) (iv) because they referred to some sort of structural failure if the pressure increased. Others delved a bit deeper, correctly stating that an increase in mass without an increase in volume (and hence upthrust) would cause the gas bag to sink. **Misconception** Some candidates confused the ideas of mass and weight. Remember that weight = mass × gravitational field strength. **Misconception** Some candidates suggested that an increase in pressure alone would cause a change in temperature in this question, using the ideal gas equation as supporting evidence. Here, the pressure change has been caused by an increase in the number of moles of gas. As previously mentioned, candidates should take care to think

					about what is constant in such relationships and what is not.
	c		F = ([delta mass ÷ delta time] x speed =) 7.8 x 45 = 350N	C1 A1	reject 'F=ma = 7.8 x 45' score zero annotate XP **Examiner's Comments** Question 20 parts (c) and (d) group well here. Part (c) is similar in nature to previous questions about rate of change of momentum. We rejected the use of the idea *F=ma* as it is wrong physics, even though the numerical value is the same.
	d		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced. There is less drag/resistive force on the airship.	B1 B1	**Examiner's Comments** The idea of rate of momentum transfer carries on in part (d). Most candidates correctly assumed that the density of air at high altitudes is much lower than at low altitudes. Many candidates implied that this meant a reduction in drag, which is correct. Far fewer correctly described the reduction of rate of change of momentum, causing less thrust. **Assessment for learning** Candidates should take care to use technical language. In this question, responses that included ideas of 'less air to push' or 'less mass moved per second' are insufficient at A2 Level.
			Total	**14**	
7	a	i	Arrow **along** the line of the support rod labelled tension or T.	B1	Allow unlabelled single arrow along either rod Allow unlabelled arrows along both rods Allow arrow(s) up, down or both NOT any contradictory arrows **Examiner's Comments** In Question 17 (a) (i) of this question, the phrase 'tension in the rod' can mean several different things, all of which were given in the mark scheme.

		ii	11.1 sin 35 or 11.1 cos 55 seen addition of 3.9 (half the diameter of the support disc) to candidate's horizontal component of rod length Total= 10.3m	M1 M1 A0	NOT use of tan 35 or tan 55 allow 7.8/2 for 3.9 10.27 to 2 dp NB use of 11.1 cos 35 or 11.1 sin 55 arriving at 12.99 scores 1 (wrong trig) NB reject use of radians (scores 0) **<u>Examiner's Comments</u>** Many candidates approached part (ii) with some confidence, spotting that the horizontal portion of the rod was 11.1 sin(35) and that it should be added to the radius of the disc.
		iii	mg=T cos 35 T= mg ÷ cos 35 = 140 N	C1 C1 A1	Allow use of sin 55 NOT use of tan 35 or tan 55 Answer is 143.7 N to 4 sf **<u>Examiner's Comments</u>** Parts (a) (iii) and (iv) were more challenging, requiring good knowledge of both circular motion and how to calculate components of forces. Again there were several legitimate routes to the right answer, all of which were mentioned in the mark scheme. Very logical approaches were in part (a) (iii), to equate the vertical component of the tension with the weight of the sandbag.
		iv	T sin 35 = mrω^2 $\omega=\sqrt{\frac{T\sin 35}{mr}}$ =0.8(17) radian s^{-1}	M1 A1 A0	Allow use of W tan 35 or W tan 55 Allow use of cos 55 and/or mv^2/r Allow use of Pythogoras to find centripetal force (82.4...) NOT use of T tan 35 or T tan 55 Allow ω^2 subject. Allow any combination of rearrangement and substitution ECF allowed for T and r. Use of 2 s.f. values for T and r gives 0.84 m

					Examiner's Comments In part (a) (iv), the quickest approach was to equate the horizontal component of the tension with the centripetal force. The data booklet provides a convenient expression for the centripetal force in terms of the angular velocity, without the need for finding the tangential velocity.
	b	i	Use of $17=1/2\ gt^2$ =1.9 (1.86) s	C1 A1	i.e. substitution of 17 and g or 9.81 or 9.8 e.g. $s=(ut)+ ½\ at^2$ $t=\sqrt{\frac{2s}{a}}$ $=\sqrt{\frac{2 x 17}{9.81}}$ Allow any subject
		ii	Horizontal speed = rω or Horizontal distance = speed × time = 0.82 radians s^{-1} × 10.26 m × 1.86 s = 16 m (15.6 m)	C1 C1 A1	Use of data in the question stem (0.8 and 10) allowed, which gives 15.2 m. Ecf for use of candidate's value of r and ω, giving values rounding to between 14.9 and 16.0 m
		iii	Relevant variable identified Effect on speed of shoe or time of flight of shoe correctly identified Conclusion consistent with relevant physics e.g. • Shoe is lower mass yet no change in angular velocity or radius since independent of mass so no change in horizontal displacement. • Shoe is below seat so would be travelling with larger radius/speed so larger distance travelled horizontally	M1 M1 A1	e.g mass/weight, drag/air resistance, radius, height, starting condition (e.g. kicking shoe off) Assume "it" in response refers to the shoe. ignore velocity for first M1 allow correct explanation of "no effect" on speed or time by change of mass **Examiner's Comments** Question 17 (b) explored ideas about parabolic flight due to gravitation. The only force acting on the sandbag and the shoe after they have been released is the weight force, which acts vertically downwards. Many candidates realised that the vertical velocity of the sandbag when it left the swing was zero, enabling

			• Shoe might have be kicked off backwards so have lower speed so lower distance • Shoe would come from below the seat/lower than the sandbag i.e. vertical distance to fall less, thus time of flight and horizontal distance less. • Effect of air resistance hadn't been included so shoe suffers drag, decelerating horizontally so distance would be smaller		them to calculate the time for the bag to fall 17m vertically downwards (using $s = ½ gt^2$) To calculate the horizontal distance travelled required both the horizontal velocity (from $v = r\omega$) and the time of flight from part (b) (iii). There was lots of scope for applying error carried forward rules as mentioned in the mark scheme. **Misconception** In lots of questions, candidates make assumptions when trying to use formulae to justify their ideas. In this case, it was that for the same radius, the shoe must leave the seat faster than the sandbag, purely because the shoe had less mass. Often, what is constant is as important to consider as what is changing. Here, if the radius for the sandbag and the shoe are the same, then the horizontal velocity at release must be the same, since the radius and angular speed for both are the same, using $v = r\omega$.
			Total	**16**	
8		i	$a = \omega^2 r$ **and** $\omega = 2\pi / T$ **or** $a = v^2/r$ **and** $v = 2\pi r / T$ **Either** $\omega = \frac{2\pi}{5830 \times 3600}$ **or** $v = \frac{2\pi \times 6050 \times 10^3}{5830 \times 3600}$ **or** $a = \frac{4\pi^2}{(5830 \times 3600)^2} \times 6050 \times 10^3$ $a = 5.42 \times 10^{-7}$ (ms^{-2})	C1 C1 A1	**Allow** use of $T^2 = 4\pi^2 r^3/(GM)$ **and** $v = 2\pi r/T$ $\omega = 2.99 \times 10^{-7}$ (rad s^{-1}) $v = 1.81$ (ms^{-1}) $a = \omega^2 r = (2.99 \times 10^{-7})^2 \times 6050 \times 10^3$ $a = v^2/r = 1.81^2 / (6050 \times 10^3)$ **Do not allow** incorrect or omitted conversion of T **Allow** answer given to 2sf **Allow** any answer which rounds to 5.4 × 10^{-7} Do **not** penalise incorrect km conversion (giving $a = 5.42 \times 10^{-10}$) if already penalised in **(a)** **<u>Examiner's Comments</u>**

		ii			A slightly harder question, requiring the use of two formulas (either $a = \omega^2 r$ and $\omega = 2\pi / T$, or $a = v^2/r$ and $v = 2\pi r / T$). Some marks were available for calculating either *ω* or *v* correctly. **Common problems in 1(b)(i)** • omitting to convert *T* from hours to seconds, or converting *T* incorrectly • omitting to convert *r* from km to m and so incurring a POT error
•		ii	(Mass of fluid displaced = $\rho \times V$ =) 65 × 1.7 (Weight of fluid displaced = $\rho \times V \times g$ =) 65 × 1.7 × 8.87 *U* (= weight of fluid displaced) = 980 (N)	C1 C1 A1	Possible **ECF** from **(a)** but **do not allow** g = 9.81 N kg^{-1} **<u>Examiner's Comments</u>** Unfortunately, many candidates did not know how to calculate upthrust, often confusing it with the normal contact force. This may be because upthrust forms a small part of the syllabus and is therefore easily overlooked. Upthrust = weight of fluid (atmosphere) displaced by the probe. The volume of the atmosphere displaced by the probe is identical to the volume of the probe itself. **Common problems in 1(b)(ii)** • using the value *g* = 9.81 rather than the value of *g* on Venus calculated in (a) • using the mass of the *probe* instead of calculating the mass of the *atmosphere* using the formula mass = density of atmosphere × volume of probe
•		iii	Any 2 from: • Forces are balanced at **A** /there is no centripetal force at **A** / forces are unbalanced at **B** / there is a resultant **or** centripetal force at **B**	B1 × 2	**Allow** the pole for **A** and the equator for **B** throughout **Allow** weight provides the centripetal force but **do not allow** normal contact force/upthrust provides the centripetal force

			• correct balanced forces equation at **A** • correct expression of Newton's second law at **B** • calculation of centripetal force at **B** • calculation of normal contact force at **A** • calculation of normal contact force at **B** <u>therefore</u> reaction force (must be) greater on **A**	B1	**Allow** acceleration in place of force **Ignore** any statement that suggests that centripetal force is a separate or additional force e.g. $R_A = W - U$ e.g. ($mr\omega^2$**or** ma**or**) $F = W - U - R_B$ Centripetal force (= ma = 760 × 5.4 × 10^{-7}) = 4.1 × 10^{-4} (N) Possible **ECF** from **(b)(i)** R_A (= $W - U$ = (680 × 8.87) − 980) = 5760 (N) Possible **ECF** from **(a)** and **(b)(ii)** R_B (= $W - U - ma$ = 5760 − 4.1 × 10^{-4}) Possible **ECF** from **(a), (b)(i)** and **(b)(ii)** Conclusion must follow some valid and relevant reasoning in which upthrust is mentioned **Allow** reverse argument **Allow** CF is negligible therefore reaction force is same at **A** and **B** **<u>Examiner's Comments</u>** Candidates often struggle to demonstrate a clear understanding of circular motion, and this year was no exception. Most candidates understood that probe **B** on the equator was acted on by centripetal force whereas probe **A** at the pole was not. However, some thought that the centripetal force acted outwards, away from the surface. Many thought that the centripetal force was a separate force acting on probe **B** in addition to its weight. These candidates wrongly concluded that this would increase the force towards the centre, resulting in an increased normal contact force. Whereas the opposite is actually the case; part of the probe's weight must be used to provide the centripetal force, and so the normal contact force would be smaller.

					A very common mistake was to ignore the effect of upthrust acting on the probe. Although the upthrust would be the same both at the equator and at the pole, it was worth a mention. Upthrust = 980N (from b(ii)) whereas the centripetal force was only 760 × 5.42 × 10^{-7}N (from b(i)). **Assessment for learning** The author of the examination paper structures questions to support candidates in writing their responses. 1(b)(i) is a calculation of the centripetal acceleration and 1(b)(ii) is a calculation of the upthrust. These provide a logical progression to 1(b)(iii) which involves both centripetal acceleration and upthrust (and not, say, the shape of Venus or its magnetic field).
			Total	**9**	
9		i	Δp = 0.10 × 1000 × 9.81 Δp = 980 (Pa)	C1 A1	**Allow** 1 mark for 490 Pa; 5.0 cm used **Examiner's Comments** Most candidates thought that the height difference here was 0.05 m, because that is the difference between the final liquid level and the undisturbed level. The correct approach is to look at the difference between the liquid levels once the liquid has stopped moving.
		ii	$\omega^2 = \frac{2\rho g A}{m}$ **or ω^2** = 37.7 (rad^2 s^{-1}) **1** ω = 6.1 $T = \frac{2\pi}{6.1}$ *T* = 1.02 (s) Oscillation is isochronous starting **2** from (0,5)	C1 C1 C1 A0 B1	**NOT** ω = 37.7 **Alternative route**: • Substitution of expression for omega • Re-arrangement to make T subject

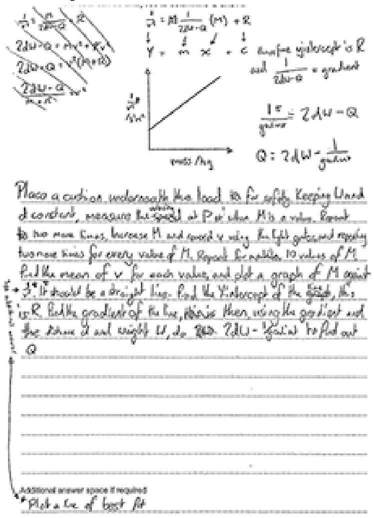
			Correct value(s) on the horizontal axis At least 2 oscillations shown **and** amplitude is decreasing The (driving) frequency is close to the natural frequency (of the system) / resonance will occur **3** (Level of) water will oscillate with large amplitude	B1 B1 B1 B1	• Evidence of evaluation to T = 1.02 (s) Period same by eye. **Note** scale must be linear and increasing Amplitude of 2nd oscillation smaller by eye. **Allow** a description of consequence such as water leaving the tube or being unable to measure the height of liquid **<u>Examiner's Comments</u>** Very few candidates made the link that the gas pressure oscillating would cause a periodic force and so this would become a resonant system. The best way to describe a resonating system in this context is that the amplitude of vibrations becomes significantly larger.
			Total	**10**	
10		i	Extension (from graph) is 6.0 (cm) Use of E = ½ kx^2 elastic potential energy = 0.90 (J)	M1 M1 A1	**Allow** Use of E = ½ Fx and F = kx **Allow** 1 SF of 0.9 (J)
		ii	(KE = ½ mv^2) 0.90 = ½ × 0.030 × v^2 v =7.7 (ms^{-1})	M1 A1	**Allow** 1 J instead of 0.90 J **Note** using 1 J gives an answer of 8.2 ms^{-1} **Note** allow possible ECF with energy approx 1 J
		iii	1.5 = ½ gt^2 t = 0.55 (s) (R = 7.7 × 0.55) R = 4.2 (m)	C1 C1 A1	**Allow** 8 ms^{-1} or 8.2 ms^{-1} instead of 7.7 ms^{-1} **i.e**. 4.4, 4.5 (m) **Possible** ECF from **(b)(ii)**
		iv	(Actual distance is smaller than calculated R) Valid explanation	M1	Examples of valid explanation include: For velocity / speed decreases

			The velocity /speed (in flight) smaller than expected **or** The initial velocity / speed will be smaller than expected	A1	• drag/air resistance For initial velocity /speed is smaller • not all the energy transfers to the ball • the cord also has KE • hysteresis (so cord heats up) **Ignore** references to efficiency and unqualified energy dissipation. **Examiner's Comments** Questions 16 (a), (b) (i) and (ii) were answered very well indeed. Most candidates recalled the experimental procedure for investigating force-extension relationships well. Question16 (b) (iii) required knowledge of independent motion. Successful candidates used the vertical motion of the object to find the time taken for it to hit the ground. After that, they used that time to find the horizontal range. Question 16 (b) (iv) was answered well by candidates that realised the distance in real life would be less and could explain why that was the case.
			Total	**10**	
11			Horizontal arrow to the left same size as F At least one horizontal magnitude given as 6700 (N) At least one vertical magnitude given as 170 000 (N)	B1 B1 B1	by eye **Allow** $280 \times 10^3 \div 42$ or 6670 (N) **Allow** 17000×9.81 or 167000 (N) **Examiner's Comments** This question was answered well, in part. Candidates found the weight of the engine with ease, broadly. The force *F*, being the value of the power divided by the velocity was less well calculated. Most candidates realised that this object was in equilibrium and so that there should be a force to the left of

					equal magnitude to force *F*. This is an example of a frictional force causing an acceleration. The friction force on the rails is to the left. By Newton's 3rd Law, the friction force on the engine from the rails must therefore be to the right. The force to the left is a drag force, causing equilibrium.
			Total	**3**	
12			**C**	1	**Examiner's Comments** The first step with this question is to calculate the resultant force, which is 0.2 N upwards (eliminating option A). As the drag force is upwards, the direction of motion must be downwards (eliminating option D). Since the resultant is opposite to the direction of travel, this object must be decelerating.
			Total	**1**	
13		i	$a = \frac{6.0}{3.0}$ 2.0	C1 A0	**Allow** any correct gradient calculation **Examiner's Comments** Candidates had to show that the acceleration was 2.0 m s^{-2} which 90% of candidates demonstrated successfully by using values from the graph and calculating a gradient value which equalled the acceleration. To be given this mark, candidates had to clearly show their working out using values taken from the graph.
		ii	680cos55 / 150 × 2.0 680cos55 – *R* = 150 × 2.0 *R* = 90 (N)	C1 C1 A1	If both components given (vertical and horizontal) it must be clear that the 390N is the horizontal component. **Examiner's Comments** Candidates performed less well on this question as it was mostly only the most successful responses that were given 3 marks for resolving the

					horizontal component of the tension in the rope to correctly calculate the horizontal resistance *R*. About 40% of candidates were given 1 mark for either correctly resolving the horizontal component of the tension to give 390 N or calculating the resultant force ($F = ma$) to give 300 N. It would have helped candidates understand the question to draw a free body force diagram to identify the forces acting on the buggy and direction and magnitude of the resultant force.
			Total	**4**	
14		i	Weight of *M* = 3.9 − (2.1 + 0.49) or 1.31 $M = \frac{1.31}{9.81}$ = 0.134 (kg) 0.13 (kg)	M1 M1 A0	**Allow** any rearrangement **Examiner's Comments** Most successful candidates stated the equilibrium of forces in the vertical direction. Some candidates incorrectly used a value of 10 N kg^{-1} rather than the value of 9.81 N kg^{-1} given on the data sheet.
		ii	1.3 × 0.1 OR 2.1 × 0.3 OR 0.49 × 0.38 1.3 × 0.1+2.1 × 0.3 + 0.49 × 0.38 = 0.9462 *d* = 0.24 (m)	C1 C1 A1	**Allow ECF** from (b)(i) **Allow** 1.28 or 1.31 for 1.3 **Allow** 1.28 or 1.31 for 1.3; 0.9442 or 0.9472 for 0.9462 **Examiner's Comments** Candidates who scored highly on this question clearly determined the individual moments. Common errors were ignoring moment due to the weight of the beam and incorrectly determining the distance for 0.49 N weight.
			Total	**5**	
15			**Level 3 (5–6 marks)** Clear diagram and procedure and measurements including explanation of the use of one light gate **and** analysis including determination of *Q* and *R*. *There is a well-developed line of*	B1 × 6	**Indicative scientific points may include**: **Diagram and procedure** • labelled diagram including light gate positioned at P

			reasoning which is clear and logically structured. The information presented is relevant and substantiated. **Level 2 (3–4 marks)** Some procedure, some measurements and some analysis. OR Limited procedure, limited measurements and detailed analysis OR Detailed procedure, detailed measurements and limited 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 and limited analysis *There is an attempt at a logical structure with a line of reasoning.The information is in the most part relevant.* **0 mark** No response or no response worthy of credit.		• card added to trolley to interrupt light beam • description of procedure • repeats experiment for each *M* • keep *d* constant • method to keep *d* constant, e.g. mark start position • method to stop trolley hitting pulley / load hitting floor e.g. cushion / sand bag • method to fix *M* to the trolley • use a release mechanism **Measurements** • use ruler to measure length of card / object interrupting light beam • use of balance to determine *M* • method to determine *W* • use of ruler to measure d. **Analysis** • v = length of card ÷ time • plot a graph of $1/v^2$ against *M* (or equivalent graph • gradient = $\frac{1}{2dW-Q}$ • *R* = y-intercept • $Q = 2dW - \frac{1}{\text{gradient}}$ <u>**Examiner's Comments**</u> The question was designed to assess candidates' practical skills. Candidates were advised to draw a 'suitable diagram', it was anticipated that they would draw a diagram with one light gate positioned at point P and a rectangular card added to the trolley to interrupt the light beam. To gain a Level 3 mark on this question candidates needed to explain both the procedure and measurements that needed to be taken. In particular candidates needed to explain how the velocity *v* was determined at P. Many candidates

					incorrectly used two light gates and determine the average speed to travel distance *d*. Appropriate measuring instruments should be specified to determine the other constants. The analysis of the data should include an appropriate graph to plot and an explanation of how *Q* and *R* could be determined from the gradient and intercept. *Q* and *R* should be the subject of the equation. **Exemplar 1**  Exemplar 1 - The candidate was awarded 4 marks as the scientific content of the response meets the Level 2 descriptors and the communication statement is also satisfied. The candidate structures the response by initially determining the graph that would need to be plotted to determine the constant *Q* and *R*. The candidate then explains how the gradient and *y*-intercept is used to determine *Q* and *R*. The candidate describes a brief procedure and includes the use of a cushion, repeating results and keeping *d* and *W* constant. To gain Level 3, the candidate needed to have included a diagram showing

					the position of the light gate and explained the measurements that would need to be taken to determine *v* from a light gate connected to a timer. **Assessment for learning** Candidates should understand how light gates attached to a timer can be used to determine velocity and acceleration. In particular, candidates should understand the distance measurements and shape of the interrupt card. Other data logging methods such as a motion sensor should also be understood. **Misconception** Many candidates incorrectly calculated the velocity *v* at P since they measured the time for the trolley to travel distance *d* and then calculated the average speed to travel distance *d*. **Assessment for learning** Candidates should be able to determine appropriate axes to plot graphs and then explain how constants can be determined from the gradient and *y*-intercept.
			Total	**6**	