5	C **Gain in gravitational potential energy** / **Power developed** **same for P and Q** / **greater for P than Q** Incorrect Answers: A – incorrect gain in GPE but correct power developed B – incorrect gain in GPE and incorrect power developed D – correct gain in GPE but incorrect power developed	1

8	**The only correct answer is B ($\frac{2}{3}v$)** A is not correct because the momentum and mass of the ball should not be multiplied together C is not correct because the mass of the ball should not be divided by the momentum of the ball D is not correct because the momentum and mass of the cricket ball should not be multiplied together	1

6	**D is the correct answer** A is not the correct answer as spurious factor of 100 and 0.68 multiplies B is not the correct answer as this gives a lower input than output C is not the correct answer as there is a spurious factor of 100	**(1)**

9	**B is the correct answer** A is incorrect because the forces do act in opposite directions C is incorrect because the forces are of the same type D is incorrect because the forces do have the same magnitude	**(1)**

5	**D is the correct answer** A is not the correct answer as the areas under the two graphs are not both zero. B is not the correct answer as the areas under the two graphs are not equal. C is not the correct answer as P is <u>at</u> the initial position.	**(1)**

3	**The correct answer is C (small, spherical, laminar)** A is incorrect because the object must be small and spherical, and there should be laminar flow B is incorrect because the object must be small and there should be laminar flow D is incorrect because the object must be spherical	1

6	**The only correct answer is A Hard**	1
	***B** is not correct because the resistance to scratching of the surface of a material does not depend on the stiffness of the material* ***C** is not correct because the resistance to scratching of the surface of a material does not depend on the strength of the material* ***D** is not correct because the resistance to scratching of the surface of a material does not depend on the toughness of the material*	

6	**The only correct answer is C** ($\frac{5000}{42\times0.63}$) A is not correct because the useful output power should not be inverted B is not correct because the useful output power should not be inverted and should be divided by 0.63 D is not correct because the useful output power should be divided by 0.63	1

9	**C is the correct answer** A is not correct because P has a smaller breaking stress than Q B is not correct because P has a smaller breaking strain than Q D is not correct because graph P has an initial gradient greater than graph Q	1

3	**The only correct answer is B** (s) A is not correct because displacement is measured in metres C is not correct because velocity is measured in metres per second D is not correct because acceleration is a vector	1

2	**2. The only correct answer is C** ***A*** *is not correct as ductile behaviour is only exhibited under a tensile force and not a compressive force* ***B*** *is not correct as hardness is a measure of a material's resistance to being scratched* ***D*** *is not correct because a stiff material would not exhibit as much compression under a compressive force*	**(1)**

3	**The only correct answer is C** A is not correct because 4 cm is the additional extension when a load of 2.5 N is added B is not correct because 8 cm is the additional extension when a load of 5.0 N is added D is not correct because 16 cm is the total extension when a load of 10.0 N is added and not the additional extension *x*.	1

3	**A** ***Fd***	1
	Incorrect Answers: (all due to incorrect variables selected from information given) B – *Ft* is the impulse on the block due to the applied force *F* C – *Fv* is the power developed by the block D – *mgd* would be the work done had the block moved a distance *d* due to the gravitational force and not the applied force *F*	

6	**The correct answer is B** $\left(\frac{(q-p)\times R}{2}\right)$ A is incorrect because work done ≠ ½ force × length C is incorrect because work done ≠ ½ force × (final + original length) D is incorrect because the factor of ½ is missing	1

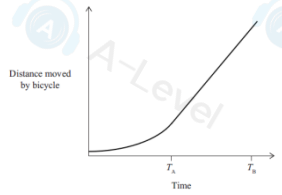
6	**The only correct answer is A** $\left(\frac{2}{3}\Delta x\right)$ B is not correct because doubling the force does not give half the extension and three times the stiffness does not give three times the extension C is not correct because doubling the force does not give half the extension D is not correct because three times the stiffness does not give three times the extension	**1**

Question Number	Answer	Mark
12(a)	Use of $(\Delta)E_{grav} = Fd$ **Or** Use of $E_k = (\Delta)E_{grav}$ **AND** Use of $v^2=u^2+2as$ with $a = -\frac{F}{m}$ (1) Gradient = $\frac{mg}{F}$ **Or** $\frac{d}{h} = \frac{mg}{F}$ (1) Example of calculation $mgh = Fd$ $\frac{d}{h} = \frac{mg}{F}$	**(2)**
12(b)	$u = \sqrt{2gh}$ (1) (Do not allow if suvat used with $a=g$) Use of $p = mv$ (1) $m_1u = (m_1 + m_2)\,v$ (either seen or used) (Do not allow if there is an m_2u term unless $u=0$) (1) Some working leading to the correct expression **AND** statement that the student is correct. (1) Example of calculation $mgh = ½\,mv^2$ $v = \sqrt{2gh}$ $m\sqrt{2gh} = 2mv$ $v = \frac{\sqrt{2gh}}{2} = \sqrt{\frac{gh}{2}}$	**(4)**
	Total for question 12	**6**

Question Number	Answer		Mark
16(a)(i)	Pull of box on man **and** pull of man on box	**(1)**	**1**
16(a)(ii)	Difference (act on) different objects **Or** opposite direction	**(1)**	
	Similarity (Same) type of force **Or** (same) line of action **Or** act for same time	**(1)**	**2**
16(b)(i)	Use of $W = mg$ See mg – 620 See Tsin35 or Tcos55 Pull of man (T) = 370 (N) Example of calculation Vertical component of the force of the man on the box = T sin35° Resultant vertical force = (85 kg × 9.81 N kg^{-1}) – 620 N – T sin35° = 0 T = 373 N	**(1)** **(1)** **(1)** **(1)**	**4**
16(b)(ii)	See 370cos35 **Or** (85g – 620)tan55 Identify that 370cos35 or (85g – 620)tan55 is the frictional force required Friction = 310 N (ecf for T from (b)(i)) **Or** Use of Pythagoras (with any vertical force and tension from part (b)(i)) Use of correct resultant vertical force with Pythagoras Friction = 310 N (ecf for T from (b)(i)) (F = 328 N using 'show that value'. Using g = 9.8 gives F = 304 N) Example of calculation Horizontal component of the force of the man on the box =(373 N)cos35° Resultant force = (373 N)(cos35°) – F = 0 F = 305.5 N	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
16(b)(iii)	Use of $F = ma$ m = 85 kg +90 kg Use of F= friction on man – friction on box Friction on man = 340 N (ecf value from b(ii)) (friction on man = 363 N using show that value) Example of calculation F = (85 kg +90 kg) × 0.200 m s^{-2} = 35 N 35 N = friction on man – 306 N Friction on man = 341 N	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question 16		**14**

Question Number	Answer		Mark
19(a)(i)	See resultant force = weight (of system) – upthrust	(1)	
	Use of $(\Sigma)F = ma$	(1)	
	$a = 4.5$ m s^{-2}	(1)	**3**
	Example of calculation (470 kg) a = (470 kg)(9.81 N kg^{-1}) – 2500 N $a = 4.49$ m s^{-2}		
19(a)(ii)	Drag increases with speed	(1)	
	(The system moves with a constant velocity when:) the resultant force = 0 **Or** when weight = upthrust + drag	(1)	**2**
19(a)(iii)	Drag force = 2100 N	(1)	**1**
	Example of calculation (470 kg)(9.81 N kg^{-1}) – 2500 N = 2111 N		
19(b)	Correct use of 2500 N divided by 10 (could be later in the calculation) (Do not credit if drag or weight of the system is being used for the calculation of d)	(1)	
	Use of $W = mg$ (Divide by 9.81)	(1)	
	Use of $\rho = m/V$ (Divide by 1030)	(1)	
	Use of $V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$	(1)	
	Diameter of floatation sphere = 0.36 m	(1)	**5**
	Example of calculation Upthrust on 1 sphere = 2500 N ÷ 10 = 250 N Mass of displaced water = 250 N ÷ 9.81 N kg^{-1} = 25.5 kg Volume of displaced water = Volume of displaced water $= \frac{25.5\text{ kg}}{1030\text{ kg m}^{-3}} = 0.0248\text{ m}^3$ $0.0248\text{ m}^3 = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$ $d = 0.362$ m		
19(c)(i)	(Strength is) the stress needed to break **Or** (High strength means) it needs a large stress to break	(1)	
	There is a large tension/upthrust/weight (on the chain) (Not force – must relate to the equipment)	(1)	**2**
19(c)(ii)	(There is an additional force from) the currents in the sea **Or** (There is an additional force from) the movement of the seawater (ignore references to the normal reaction force from the seabed and other forces that act)	(1)	**1**
	Total for question 19		**14**

Question Number	Answer		Mark
17(a)(i)	The graph is less steep **Or** The gradient is smaller	**(1)**	**(1)**
17(a)(ii)	Use of $a = \frac{v-u}{t}$ **Or** Use of a = gradient	**(1)**	
	a_2 = 0.96 to 1.3 m s^{-2}	**(1)**	**(2)**
	Example of calculation $a_2 = \frac{13.2\ \text{m s}^{-1} - 6.8\ \text{m s}^{-1}}{(10.5-4)\text{s}} = 0.98\ \text{m s}^{-2}$		
17(a)(iii)	Velocity is large(r) (in higher gears)	**(1)**	
	so force (of the engine) will be smaller.	**(1)**	**(2)**
17(b)(i)	Conversion of mph to m s^{-1}	**(1)**	
	Use of acceleration values for first and second gears only.	**(1)**	
	Use of a = $\frac{v-u}{t}$ to determine a time	**(1)**	
	total time = 13.0 to 14.0 s	**(1)**	**(4)**
	Example of calculation Velocity conversion = $\frac{60\ \text{mph} \times 1600\ \text{m}}{3600} = 26.7\ \text{m s}^{-1}$ 2.9 m s^{-2} = $\frac{18\ \text{m s}^{-1} - 0}{t_1}$ t_1 = 6.21 s 1.2 m s^{-2} = $\frac{26.7\ \text{m s}^{-1} - 18\ \text{m s}^{-1}}{t}$ t_2 = 7.22 s Total time = 6.21 s + 7.22 s = 13.4 s		
17(b)(ii)	As velocity increases the air resistance increases	**(1)**	
	(When) frictional forces are equal to the (driving) force of engine/car	**(1)**	
	There is no resultant/net/unbalanced force **and** no acceleration	**(1)**	**(3)**
	Total for question 17		**12**

Question Number	Answer	Additional Guidance	Mark
18(a)	Gradient increasing between 0 s and T_A **(1)** Straight line with positive gradient between T_A and T_B **(1)**	graph does not have to start from origin Example diagram  	**2**

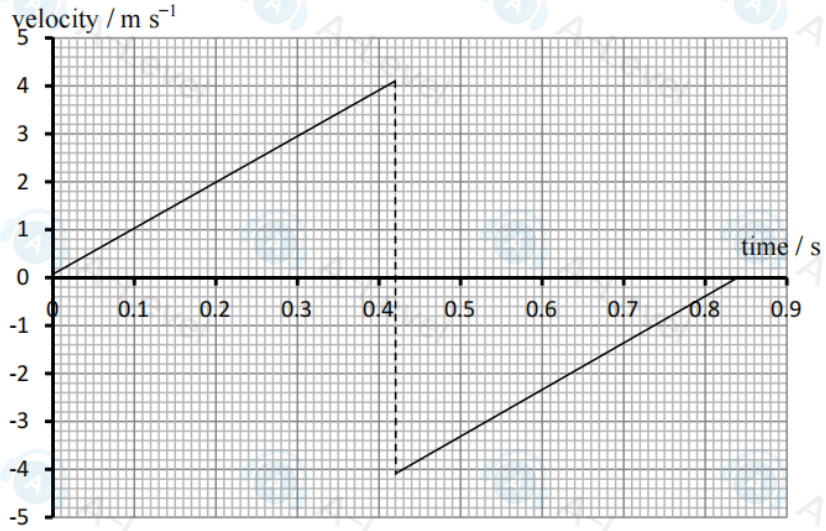
***18(b)**	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. IC points / IC mark / Max linkage mark / Max final mark 6 / 4 / 2 / 6 5 / 3 / 2 / 5 4 / 3 / 1 / 4 3 / 2 / 1 / 3 2 / 2 / 0 / 2 1 / 1 / 0 / 1 0 / 0 / 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning. Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout — 2 Answer is partially structured with some linkages and lines of reasoning — 1 Answer has no linkages between points and is unstructured — 0	**Indicative content** IC1 In stage A, the kinetic energy increases IC2 (and kinetic energy is proportional to speed squared, so) in stage A, the useful power output increases IC3 In stage B, the gravitational potential energy increases (and kinetic energy is constant) **Or** In stage B, work is done against gravity (and kinetic energy is constant) IC4 And in stage B the gradient of the slope increases so power output increases IC5 In stage C gravitational potential energy increases **and** kinetic energy decreases IC6 So in stage C the useful power output of the person is zero	**6**
	Total for question 18		**8**

	Indicative content IC1 Measure the original length (from clamp to marker) IC2 Measure distance moved by marker from original position to determine extension. **Or** Measure new length and subtract original length to determine extension IC3 Calculate weight of masses using $W = mg$ **Or** Use a newtonmeter to measure weight of masses IC4 Use diameter to calculate cross-sectional area IC5 Calculate stress using $\frac{\text{force}}{\text{area}}$ **and** calculate strain using $\frac{\text{extension}}{\text{original length}}$ (allow symbol equations if terms defined) **Or** plot a graph of stress against strain **Or** plot a graph of force against extension IC6 Calculate Young Modulus using $\frac{\text{stress}}{\text{strain}}$ (allow symbol equations if terms defined) **Or** Correctly relate gradient of (straight section of) graph to Young Modulus.	

16(b)	Calculates cross-sectional area	**(1)**	
	Use of $\sigma = \frac{F}{A}$	**(1)**	
	Use of $E = \frac{\sigma}{\varepsilon}$ **and** use of $\varepsilon = \frac{\Delta x}{x}$	**(1)**	
	$\Delta x = 4.6 \times 10^{-4}$ m	**(1)**	**4**
	Example calculation $A = \pi \times \left(\frac{0.56\times10^{-3}\text{ m}}{2}\right)^2 = 2.46 \times 10^{-7}\text{m}^2$ $\sigma = \frac{5.0\text{ N}}{2.46\times10^{-7}\text{m}^2} = 2.03 \times 10^{7}$ Pa $\varepsilon = \frac{2.03\times10^{7}\text{Pa}}{1.1\times10^{11}\text{Pa}} = 1.85 \times 10^{-4}$ $\Delta x = 1.85 \times 10^{-4} \times 2.5 = 4.61 \times 10^{-4}$ m		
	Total for question 16		**10**

14(a)	The ball fell a smaller distance (during each flash of the laboratory strobe) **Or** Each image of the ball would be smaller (using the laboratory strobe)	**(1)**	
	The uncertainty was less (with the laboratory strobe) MP2 dependent on MP1	**(1)**	**2**
14(b)(i)	(allow a for g throughout) $s = (ut+)\frac{1}{2}gt^2$ **and** g is constant	**(1)**	
	Comparison of $s = \frac{1}{2}gt^2$ $(+ut)$ with $y = mx$ $(+c)$ **Or** s is proportional to t^2 so the gradient of graph is constant	**(1)**	**2**
14(b)(ii)	Use of $s = \frac{1}{2}at^2$ and a pair of corresponding values from the graph **Or** Pair of corresponding values from the graph used to determine gradient	**(1)**	
	$g = 10.0$ m s^{-2} (allow answers in the range 9.8 m s^{-2} to 10.1 m s^{-2}) (dependent on MP1) (answer must be consistent with their calculation) Example of calculation $\frac{\Delta h}{\Delta t^2} = \frac{0.30}{0.060} = 5.00$ $g = 5.00 \text{ m s}^{-2} \times 2 = 10.00 \text{ m s}^{-2}$	**(1)**	**2**
	Total for question 14		**6**

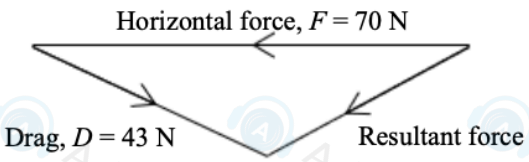
14(a)	The ball fell a smaller distance (during each flash of the laboratory strobe) **Or** Each image of the ball would be smaller (using the laboratory strobe)	**(1)**	
	The uncertainty was less (with the laboratory strobe) MP2 dependent on MP1	**(1)**	**2**
14(b)(i)	(allow a for g throughout) $s = (ut+)\frac{1}{2}gt^2$ **and** g is constant	**(1)**	
	Comparison of $s = \frac{1}{2}gt^2$ $(+ut)$ with $y = mx$ $(+c)$ **Or** s is proportional to t^2 so the gradient of graph is constant	**(1)**	**2**
14(b)(ii)	Use of $s = \frac{1}{2}at^2$ and a pair of corresponding values from the graph **Or** Pair of corresponding values from the graph used to determine gradient	**(1)**	
	$g = 10.0$ m s^{-2} (allow answers in the range 9.8 m s^{-2} to 10.1 m s^{-2}) (dependent on MP1) (answer must be consistent with their calculation) Example of calculation $\frac{\Delta h}{\Delta t^2} = \frac{0.30}{0.060} = 5.00$ $g = 5.00 \text{ m s}^{-2} \times 2 = 10.00 \text{ m s}^{-2}$	**(1)**	**2**
	Total for question 14		**6**

Question Number	Answer		Mark
13	Use of $v = u + at$	(1)	
	Axes scaled correctly (+ and – velocity and time axes scaled appropriately)	(1)	
	Line from (0, 0) to (0.42, 4.1)	(1)	
	Vertical line linking positive and negative velocity (accept use of candidate's velocity, allow 1 square tolerance)	(1)	
	Line from (0.42, −4.1) to (0.84, 0) (accept candidate's velocity)	(1)	**5**
	(accept the negative version of this graph, taking positive as upwards) Example of calculation $v = 0 + (9.81\ \text{N kg}^{-1})(0.42\ \text{s}) = 4.12\ \text{m s}^{-1}$  		
	Total for question 13		**5**

Question Number	Answer	Mark
*18(b)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. The following table shows how the marks should be awarded for structure and lines of reasoning. **Indicative content** IC1 the resultant force on the submarine is zero IC2 So tension = weight – upthrust IC3 As the submarine leaves the water, the volume / mass / weight of water displaced decreases IC4 So the upthrust on the submarine decreases IC5 and the tension in the cable increases IC6 When the submarine is out of the water the tension in the cable is equal (in magnitude) to the weight of the submarine	6
	Total for question 18	11

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Question Number	Answer	Mark
18(a)	Straight arrow at least 3.5 cm long representing horizontal force, with label *F*, horizontal force or 70 N **(1)** Vector triangle drawn with at least two sides in the triangle labelled, and horizontal force on the longest side. **(1)** All three arrows in correct relative directions (dependent on MP2) **(1)** Magnitude = 36 N (allow an answer in the range 34 N to 38 N) **(1)** Angle to horizontal = 30° **Or** 150° (allow a tolerance of ± 2°) **(1)** Example diagram  	5

Question Number	Acceptable Answer		Additional Guidance	Mark
15(a)	Compression changes from 60 nm to 97.5 nm	**(1)**	Allow compression changes from a value between 55 nm and 62 nm to a value between 95 nm and 100nm	**3**
	Use of $E_{el} = \frac{1}{2}F\Delta x$ with corresponding values of F and compression **or** Determines area under graph between 85 N and 140 N	**(1)**		
	Increase in elastic strain energy = 4.3×10^{-6} J	**(1)**	Allow an answer consistent with their allowed readings from the graph. <u>Example calculation</u> $E_{el} = \frac{1}{2}140\ \text{N} \times 97.5 \times 10^{-9}\ \text{m} = 6.83 \times 10^{-6}\ \text{J}$ $E_{el} = \frac{1}{2}85\ \text{N} \times 60 \times 10^{-9}\ \text{m} = 2.55 \times 10^{-6}\ \text{J}$ $\Delta E_{el} = 6.83 \times 10^{-6}\ \text{J} - 2.55 \times 10^{-6}\ \text{J} = 4.28 \times 10^{-6}\ \text{J}$	

Question Number	Acceptable Answer		Additional Guidance	Mark
15(a)	Compression changes from 60 nm to 97.5 nm	**(1)**	Allow compression changes from a value between 55 nm and 62 nm to a value between 95 nm and 100nm	**3**
	Use of $E_{el} = \frac{1}{2}F\Delta x$ with corresponding values of F and compression **or** Determines area under graph between 85 N and 140 N	**(1)**		
	Increase in elastic strain energy = 4.3×10^{-6} J	**(1)**	Allow an answer consistent with their allowed readings from the graph. <u>Example calculation</u> $E_{el} = \frac{1}{2}140\ \text{N} \times 97.5 \times 10^{-9}\ \text{m} = 6.83 \times 10^{-6}\ \text{J}$ $E_{el} = \frac{1}{2}85\ \text{N} \times 60 \times 10^{-9}\ \text{m} = 2.55 \times 10^{-6}\ \text{J}$ $\Delta E_{el} = 6.83 \times 10^{-6}\ \text{J} - 2.55 \times 10^{-6}\ \text{J} = 4.28 \times 10^{-6}\ \text{J}$	

15(b)	(The brick) returns to its original size / shape / length when the force / stress is removed	**(1)**		**1**

(Total for Question 15 = 4 marks)