4	**The only correct answer is C (The forces act on the same object.)** A is not correct because the motion of the chair is not relevant B is not correct because forces forming a Newtons' third law pair act in opposite directions D is not correct because forces forming a Newtons' third law pair have the same magnitude	1

8	**The correct answer is A (The ball bearing is moving downwards when the student starts the stopwatch)** B is incorrect because time would be greater giving a lower value C is incorrect because time would be greater giving a lower value D is incorrect because time would be greater giving a lower value	1

5	**The only correct answer is B ($\overrightarrow{W} + \overrightarrow{T_1} + \overrightarrow{T_2} = 0$)** A is not correct because the vector sum of $T_1 + T_2$ is in the opposite direction to W C is not correct because T_2 should not be subtracted from T_1 D is not correct because T_2 should not be subtracted from T_1	1

D is incorrect because the displacement should be doubled

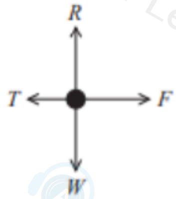
2	**C is the correct answer** A is incorrect because it takes no account of the k.e. B is incorrect because the energy dissipated would be greater than the original energy D is incorrect because the energy dissipated could not be negative	(1)

3	**D is the correct answer** A is incorrect because the acceleration is not positive B is incorrect because the acceleration is decreasing C is incorrect because the acceleration is constant	(1)

10	**The only correct answer is B $\left(\frac{W}{2\sin\theta}\right)$** A is not correct because $W = 2\sin\theta \times$ tension C is not correct because $T\cos\theta$ is the horizontal component of tension T D is not correct because $T\cos\theta$ is the horizontal component of tension T	1

9	**C is the correct answer** A is not the correct answer as every column is wrong. B is not the correct answer as the P and Q columns are the wrong way round. D is not the correct answer as the Q and R columns are the wrong way round.	(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	**D**  	**1**
	Incorrect Answers: A – Tension and friction the wrong way round but the relative sizes are correct B – Tension and friction the wrong way round and the relative sizes are incorrect C – Tension and friction the correct way round but the relative sizes are incorrect	

10	**C is the correct answer** A is incorrect because time is not speed/distance B is incorrect because time is not speed/distance D is incorrect because the powers of ten are incorrect	**(1)**

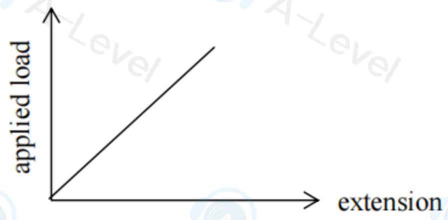
Question Number	Acceptable Answer		Additional Guidance	Mark
16(a)	Use of $\rho = \frac{m}{V}$ Calculates cross sectional area of pipe Use of volume in 1 second = cross section area × speed Speed = 37.1 (m s^{-1}) (to at least 3 significant figures)	**(1)** **(1)** **(1)** **(1)**	Example calculation $V = \frac{300\text{ kg}}{1030\text{ kg m}^{-3}} = 0.291\text{ m}^3$ $A = \pi \times (0.050\text{ m})^2 = 7.85 \times 10^{-3}\text{ m}^2$ $v = \frac{0.291\text{ m}^3\text{ s}^{-1}}{7.85 \times 10^{-3}\text{ m}^2} = 37.10\text{ m s}^{-1}$	**4**
16(b)	Pump applies a (forward/upward/rightwards) force to the water By Newton's third law, water applies an (equal and) opposite/backward/downward/leftward force to the pump **OR** Pump applies a (forward/upward/rightwards) force to the pipe By Newton's third law, pipe applies an (equal and) opposite/backward/downward/leftward force to the pump	**(1)** **(1)** **(1)** **(1)**	MP2 dependent on MP1 MP2 dependent on MP1 If no other marks scored, allow **1** mark for the direction of the water is to the right, so by Newton's third law the force of the water on the pump is to the left	**2**

16(c)	When pump is turned on there is a resultant force backwards/leftwards on the boat, (so the speed decreases) As speed decreases, drag force decreases Until resultant force = zero (when speed becomes constant) **Or** Until drag force + force from pump = forward force from engine (when speed becomes constant) **Or** Resultant force = zero when speed is constant	**(1)** **(1)** **(1)**		**3**

(Total for Question 16 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
13(a)	Low speed **Or** laminar flow **Or** an absence of turbulent flow **(1)**	Ignore small sphere	1
13(b)	Use of $W = mg$ **(1)** Use of $U + D = W$ **(1)** Use of $F = 6\pi\eta rv$ **(1)** $F = (-)\ 2.5 \times 10^{-5}$ N **(1)** Comparison of calculated value of drag with calculated value for F and corresponding conclusion **(1)**	Example calculation $W = 9.1 \times 10^{-4}\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 8.93 \times 10^{-3}\text{N}$ $\text{Drag} = 8.93 \times 10^{-3}\ \text{N} - 1.1 \times 10^{-3}\ \text{N} = 7.83 \times 10^{-3}\ \text{N}$ $F = 6\pi \times 8.9 \times 10^{-4}\ \text{Pa s} \times \frac{6.0 \times 10^{-3}\ \text{m}}{2} \times 0.50\ \text{m s}^{-1}$ $F = 2.52 \times 10^{-5}\ \text{N}$ $7.83 \times 10^{-3}\ \text{N} \neq 2.52 \times 10^{-5}\ \text{N}$, so no.	5

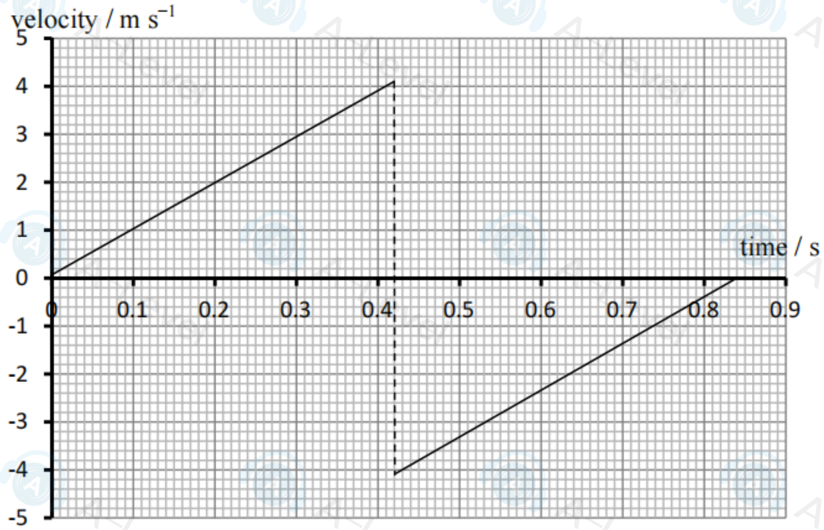
(Total for Question 13 = 6 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>17(a)</td><td>Diameter (of the wire)
Original length (of the wire)</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td>17(b)(i)</td><td>Straight line through origin

</td><td>(1)</td><td>1</td></tr>
<tr><td>17(b)(ii)</td><td>Use the gradient
$$\text{Young modulus} = \text{gradient} \times \frac{\text{original length}}{\text{cross sectional area}}$$
(Symbols used must be defined)</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td>17(c)</td><td>Max 4
Can only score from 2 of the table rows, and just 1 mark for each cell.
<table>
<tr><th>Advantage of first experiment</th><th>Explanation dependent on the advantage</th></tr>
<tr><td>Use of micrometer (not if to measure diameter)</td><td>Can measure extension/length/position with:
Or micrometer has:
Or less (percentage) uncertainty
Or better precision/resolution
Or the metre rule only measures to 1 mm while the micrometer measures to the nearest 0.01 mm</td></tr>
<tr><td>Use of control/reference /second wire</td><td>Avoids the effect of:
temperature changes
Or sag in the support</td></tr>
<tr><td>There is no pulley</td><td>Measurement of tension/force more accurate/reliable
Or Friction would reduce the tension/force in the wire.</td></tr>
</table></td><td>(1)
(1)
(1)
(1)
(1)
(1)</td><td>4</td></tr>
<tr><td></td><td>Total for question 17</td><td></td><td>9</td></tr>
</table>

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) The uncertainty was less (with the laboratory strobe) MP2 dependent on MP1	**(1)** **(1)**	**2**
14(b)(i)	(allow *a* for *g* throughout) $s = (ut+)\frac{1}{2}gt^2$ **and** *g* is constant 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)** **(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 $g = 10.0\text{ m s}^{-2}$ (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) <u>Example of calculation</u> $\frac{\Delta h}{\Delta t^2} = \frac{0.30}{0.060} = 5.00$ $g = 5.00\text{ m s}^{-2} \times 2 = 10.00\text{ m s}^{-2}$	**(1)** **(1)**	**2**
	Total for question 14		**6**

Question Number	Answer		Mark
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) The uncertainty was less (with the laboratory strobe) MP2 dependent on MP1	**(1)** **(1)**	**2**
14(b)(i)	(allow *a* for *g* throughout) $s = (ut+)\frac{1}{2}gt^2$ **and** *g* is constant 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)** **(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 $g = 10.0\ \mathrm{m\ s^{-2}}$ (allow answers in the range $9.8\ \mathrm{m\ s^{-2}}$ to $10.1\ \mathrm{m\ s^{-2}}$) (dependent on MP1) (answer must be consistent with their calculation) <u>Example of calculation</u> $\frac{\Delta h}{\Delta t^2} = \frac{0.30}{0.060} = 5.00$ $g = 5.00\ \mathrm{m\ s^{-2}} \times 2 = 10.00\ \mathrm{m\ s^{-2}}$	**(1)** **(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) <u>Example of calculation</u> $v = 0 + (9.81\ \mathrm{N\ kg^{-1}})(0.42\ \mathrm{s}) = 4.12\ \mathrm{m\ s^{-1}}$  		
	Total for question 13		**5**

Question Number	Acceptable Answer		Additional Guidance	Mark
17(a)	Corresponding force and extension read from graph	(1)	Allow a tolerance of ±½ a small square	
	Use of $\Delta F = k\Delta x$	(1)		
	$k = 2760\ \mathrm{N\ m^{-1}}$	(1)	Allow a value of k between 2650 and 2850	
	Comparison with 2700 ($\mathrm{N\ m^{-1}}$) and consistent conclusion	(1)	<u>Example calculation</u> $k = \frac{80\ \mathrm{N}}{29 \times 10^{-3}\ \mathrm{m}} = 2760\ \mathrm{N\ m^{-1}}$ $2760\ \mathrm{N\ m^{-1}} \approx 2700\ \mathrm{N\ m^{-1}}$ so this is string Y	4

Question Number	Acceptable Answer		Additional Guidance	Mark
17(a)	Corresponding force and extension read from graph Use of $\Delta F = k\Delta x$ $k = 2760\ \text{N m}^{-1}$ Comparison with 2700 (N m^{-1}) and consistent conclusion	(1) (1) (1) (1)	Allow a tolerance of ±½ a small square Allow a value of *k* between 2650 and 2850 Example calculation $k = \frac{80\ \text{N}}{29 \times 10^{-3}\ \text{m}} = 2760\ \text{N m}^{-1}$ $2760\ \text{N m}^{-1} \approx 2700\ \text{N m}^{-1}$ so this is string Y	4
17(b)	Calculates cross-sectional area of string Use of $\sigma = \frac{F}{A}$ Use of $\varepsilon = \frac{\Delta x}{x}$ Use of $E = \frac{\sigma}{\varepsilon}$ $E = 6.0$ GPa	(1) (1) (1) (1) (1)	Example calculation $A = \pi \times (0.85 \times 10^{-3}\ \text{m})^2 = 2.27 \times 10^{-6}\ \text{m}^2$ $\sigma = \frac{36\ \text{N}}{2.27 \times 10^{-6}\ \text{m}^2} = 15.9 \times 10^6\ \text{Pa}$ $\varepsilon = \frac{0.002\ \text{m}}{0.750\ \text{m}} = 0.00267$ $E = \frac{15.9 \times 10^6\ \text{Pa}}{0.00267} = 5.96 \times 10^9\ \text{Pa}$	5

(Total for Question 17 = 9 marks)