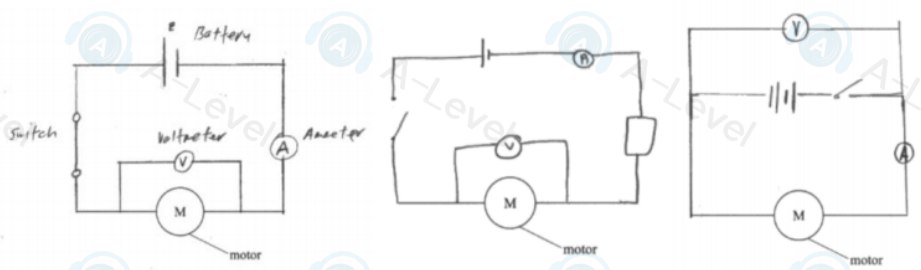
2(a)	• Diagram includes battery (accept cell), switch, ammeter and voltmeter • Ammeter in series and voltmeter in parallel with motor (Accept voltmeter in parallel with the battery if no other resistance components are added) <u>Examples of suitable diagrams</u>  	**(1)** **(1)**	**2**
2(b)(i)	• Clamp/fix the metre rule in position • Ensure the metre rule is vertical using a set square • Place the metre rule close to the mass **Or** read the height from bottom of the mass **Or** attach a marker to the mass • Take measurements perpendicular to the scale, e.g. using set square	**(1)** **(1)** **(1)** **(1)**	**4**
2(b)(ii)	• Random error will cause variation/anomalies in the values (accept suitable examples of random error e.g. reaction time, parallax error when measuring height) • (Repeat readings) allow a mean to be calculated to give a (more) accurate value	**(1)** **(1)**	**2**
2(c)	**EITHER** • power input = VI **Or** power of motor = VI • useful power output = mgh / t **Or** power of lifting mass = mgh / t (accept power of lifting mass = Fv **and** $F = mg$ and $v = h/t$) • efficiency = power of lifting mass / power of motor **Or** efficiency = $(mgh / t) / (VI)$ (accept efficiency = useful power output / power input, if quantities defined) MP3 dependent on MP1 **and** MP2 **OR** • energy input = VIt **Or** energy transferred to motor = VIt • useful energy output = mgh **Or** energy transferred to lifting mass = mgh (accept energy transferred to lifting mass = Fh **and** $F = mg$) • efficiency = energy transferred to lifting mass / energy transferred to motor **Or** efficiency = $(mgh) / (VIt)$ (accept efficiency = useful energy output / energy input, if quantities defined) MP3 dependent on MP1 **and** MP2	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
2(a)	• Measure x with a metre rule • Ensure the moveable rod is perpendicular to the fixed rods (e.g. use a set-square) **Or** measure x on both 30 cm rods and calculate the average **Or** measure to the centre of the moveable rod **Or** align the metre rule near to the 30 cm rod **Or** measure x while looking perpendicularly at the metre rule • Check for zero error on ohmmeter **Or** choose appropriate range on ohmmeter **Or** repeat R readings and calculate mean R for same value of x • Minimise contact resistance (e.g. ensure rods are clean)	**(1)** **(1)** **(1)** **(1)**	**4**

2(b)	**Max 1 of** • (When x = 0 m) the ohmmeter will measure the resistance of the (moveable) copper rod • Zero error in ohmmeter • The connecting leads have a resistance	**(1)** **(1)** **(1)**	**1**

2(c)	**EITHER** • Use of $A = \pi r^2$ (accept $A = \pi d^2 / 4$) • Use of $l = 2x + 0.05$ m • Use of $R = \rho l/A$ (with a pair of values from the line of best fit) • $\rho = 1.7 \times 10^{-8}\ \Omega$ m Accept use of x = 0 (l = 0.05 m) for MP2 and correct calculated value for MP4 **OR** • Use of $A = \pi r^2$ (accept $A = \pi d^2 / 4$) • Calculates gradient • Use of gradient = $2\rho/A$ • $\rho = 1.7 \times 10^{-8}\ \Omega$ m Example of calculation $A = \pi r^2 = \pi \times (0.0015\ \text{m})^2 = 7.1 \times 10^{-6}\ \text{m}^2$ $l = 2x + 0.05 = (2 \times 0.25\ \text{m}) + 0.05\ \text{m} = 0.55\ \text{m}$ $\rho = RA/l = (1.3 \times 10^{-3}\ \Omega \times 7.1 \times 10^{-6}\ \text{m}^2) / 0.55\ \text{m} = 1.68 \times 10^{-8}\ \Omega\ \text{m}$ OR $A = \pi r^2 = \pi \times (0.0015\ \text{m})^2 = 7.1 \times 10^{-6}\ \text{m}^2$ Gradient = $(1.55 \times 10^{-3}\ \Omega - 0.35 \times 10^{-3}\ \Omega)/(0.3\ \text{m} - 0.05\ \text{m}) = 4.8 \times 10^{-3}\ \Omega\ \text{m}^{-1}$ ρ = gradient × $A/2 = 1.70 \times 10^{-8}\ \Omega$ m	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**4**
2(d)	• As the cross-sectional area decreases the resistance (per unit length of track) increases • The system will estimate the position of the train is further away than it actually is **Or** the train is actually closer than the system estimates it to be MP2 dependent on MP1	**(1)** **(1)**	**2**

1(a)(i)	• 0.001 kg (accept 1 g)	**(1)**	**1**
1(a)(ii)	• Use of percentage uncertainty = (half) resolution / measurement × 100% • Percentage uncertainty = 0.024% (e.c.f. from 1(a)(i)) Use of full resolution scores 1 mark only, if percentage uncertainty is correct. Example of calculation Percentage uncertainty = 0.0005 kg / 2.070 kg × 100% = 0.024%	**(1)** **(1)**	**2**

1(b)	**EITHER** • Check for zero error • (Correct the value) to eliminate <u>systematic error</u> MP2 dependent on MP1 **OR** • Repeat measurement in different places and calculate a mean • To reduce the effects of <u>random error</u> MP2 dependent on MP1 **OR** • Do not use excessive force when tightening the jaws • As this could introduce a <u>random error</u> MP2 dependent on MP1	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**2**
1(c)(i)	• Use of $\rho = \frac{m}{V}$ • Density = 0.777 ($g\,cm^{-3}$) rounded to 3 s.f. <u>Example of calculation</u> Density = $\frac{2070\ g}{21\ cm \times 4.27\ cm \times 29.7\ cm} = 0.777\ (g\,cm^{-3})$	**(1)** **(1)**	**2**
1(c)(ii)	**EITHER** • The measurements (of thickness and mass) are larger • So, the <u>percentage</u> uncertainty is smaller (for the same uncertainty) MP2 dependent on MP1 **OR** • For a single sheet, the measurements (of thickness and mass) are smaller **Or** for a single sheet, the measurement (of thickness and mass) is too small • So, the <u>percentage</u> uncertainty is larger (for the same uncertainty) MP2 dependent on MP1	**(1)** **(1)** **(1)** **(1)**	**2**
3(a)	Clamp the metre rule in position **Or** Ensure the metre rule is vertical using a set square [allow spirit level] **Or** Place metre rule close to the tube Check the zero of the metre rule is level with the bottom of the transducer **Or** Check the zero of the metre rule is level with the surface of the water **Or** Measure to the surface of the water and to the bottom of the transducer and subtract the values Accept any valid method to determine *s* View (the metre rule) perpendicularly **Or** Use a set square to take the measurement from the metre rule	**(1)** **(1)** **(1)**	**3**

3(b)	Calculates time t = number of divisions × time per division	**(1)**	
	Use of $v = \frac{s}{t}$ Do not accept use of $v = f\lambda$	**(1)**	
	Uses $2 \times s$ **Or** Uses $\frac{1}{2} \times t$	**(1)**	
	$v = 331$ (m s^{-1}) Bald answer scores 0	**(1)**	**4**
	Example of calculation $t = 6$ divisions × 0.5 ms per division = 3 ms $v = \frac{s}{t} = \frac{2 \times 0.497\ \text{m}}{3 \times 10^{-3}\ \text{s}} = 331.3\ \text{m s}^{-1}$		
3(c)(i)	Calculation of mean	**(1)**	
	Mean $v = 341$ m s^{-1} 3 sig fig only	**(1)**	**2**
	Example of calculation Mean value of $v = \frac{(335 + 347 + 339 + 342)\ \text{m s}^{-1}}{4} = \frac{1363\ \text{m s}^{-1}}{4} = 340.8 = 341\ \text{m s}^{-1}$		
3(c)(ii)	Calculates half range for uncertainty Accept furthest from the mean	**(1)**	
	Correct value of percentage uncertainty using calculated mean (e.c.f. 3(c)(i))	**(1)**	**2**
	Example of calculation Uncertainty = half range = $\frac{(347 - 335)\ \text{m s}^{-1}}{2} = 6\ \text{m s}^{-1}$ Percentage uncertainty = $\frac{6\ \text{m s}^{-1}}{341\ \text{m s}^{-1}} \times 100 = 1.8\%$		

3(d)	**EITHER**		
	Upper limit = 1502 (m s^{-1})	**(1)**	
	Conclusion consistent with comparing calculated limit and given value	**(1)**	
	Example of calculation Upper limit = 1444 m s^{-1} × 1.04 = 1502 (m s^{-1}) The upper limit is above 1481 m s^{-1} so the student's value is consistent		
	OR		
	Percentage difference = 2.5 %	**(1)**	
	Conclusion consistent with comparing calculated percentage difference with 4%	**(1)**	**2**

1(b)(i)	**EITHER** Check (and correct for) zero error	**(1)**		
	To eliminate <u>systematic</u> error	**(1)**	MP2 must be linked to a relevant technique for measuring length	
	OR Repeat in different places and calculate a mean	**(1)**	Do not accept "repeat in different orientations".	**2**
	To reduce (the effect of) <u>random</u> error	**(1)**	MP2 must be linked to a relevant technique for measuring length	
1(b)(ii)	**EITHER** Use Pythagoras' theorem to calculate the length of the other side of the triangle	**(1)**	e.g. $length = \sqrt{a^2 + b^2}$	
	Measure the length of the other side of the triangle to check they are the same	**(1)**		
	OR Measure the length of the other side of the triangle	**(1)**		**2**
	Use the cosine rule to calculate the angle (to check if it is 90°)	**(1)**	e.g. $length = \sqrt{a^2 + b^2 - 2ab\,cos\theta}$ Do not accept "use sine rule", as the sine rule requires 2 angles.	

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