Question Number	Answer	Mark
1(a)(i)	Two relevant precautions with reasons, e.g. Ensure that the thermometer and coil are at the same part of the beaker so that the results are not affected by differences in temperature **(1)** Stir water so that the results are not affected by differences in temperature **(1)** Check the meter for zero error by connecting a lead across its terminals so there is no systematic error in the resistance measurements **(1)** Ensure small current so no heating effect in addition to hot water which would make results inaccurate **(1)** Switch off between readings so no heating effect in addition to hot water which would make results inaccurate **(1)** Read thermometer at eye level to avoid parallax errors **(1)**	**2**
1(a)(ii)	This will ensure that the readings are simultaneous **Or** Higher sampling rate **(1)**	**1**
1(b) (i)	(The straight line) does not pass through the origin **(1)**	**1**
1 (b) (ii)	As temperature increase the (lattice) ion/atom vibrations increase **(1)** (for the same current) electrons will collide more frequently with the vibrating (lattice) ions/atoms **(1)** More energy dissipated by collisions so (for constant *I*) greater *V* required **Or** (constant *V* gives) lower *v* and, since $I = nAvq$, *I* will be lower **(1)** Since *V* increases and $R = V/I$, *R* will increase with temperature **Or** Since *I* decreases and $R = V/I$, *R* will increase with temperature **(1)**	**4**
1(c)	Use of $R = \rho l/A$ **(1)** Use of correct area in $R = \rho l/A$ **(1)** length = 0.66 m **(1)** <u>Example of calculation</u> $l = 12.4\ \Omega \times 5.19 \times 10^{-9}\ m^2 / 9.71 \times 10^{-8}\ \Omega$ m length = 0.663 m	**3**

1(d)	Use of ratio of resistors = ratio of p.d.s **Or** Use of $I = V/R$ for fixed resistor and $R = V/I$ for resistance under investigation **(1)** Resistance of resistor = 14.4 (Ω) **(1)** Temperature (from graph) = 27 °C to 29 °C **(1)** <u>Example of calculation</u> 24 Ω / R = 7.5 V / 4.5 V Resistance of resistor = 14.4 Ω Temperature (from graph) = 28 °C	**3**
	Total for question	**14**

Question Number	Answer	Mark
2(a)	Third column completed 4.04 and 3.50 **(1)** Points plotted correctly **and** straight line drawn **(1)** (ecf error in calculation for points plotted)	**2**
2(b)	Any evidence of gradient (look at graph) **(1)** Value between 0.061 and 0.066 (cm^{-1}) (ignore – sign) **(1)** **Or** value between 6.1 and 6.6 (m^{-1})	**2**
	Total for question	**4**

Question Number	Answer	Mark
3(a)(i)	$v = f\lambda$ (words or symbols not numbers) length of string = $\lambda/2$ OR wavelength = 2 x length OR node to node = $\lambda/2$	**(1)** **(1)**
3(a)(ii)	$\pi d^2/4$ OR $\pi(D3/2)^2$ OR π(D3/2)^2 (this mark is lost if there is a *length / A3) (ignore powers of ten)	**(1)**
3(a)(iii)	E4*density OR E4*7800 (ignore powers of ten) **OR** volume of 1 metre length x density	**(1)**
3(a)(iv)	5.12 (spreadsheet answers must be correct to same number dec places so do not accept 5.116 or 5.11) (correct answer on spreadsheet scores mark irrespective of what's written on next page)	**(1)**
3(a)(v)	See $T = v^2 \mu$ **OR** $\sqrt{T} = v\sqrt{\mu}$ (not just quoting given equation) T = 82 (N) (do not penalise dec places twice, 82.1 could score both marks if more than 3 dec places given in (iv)) (correct answer on spreadsheet scores both marks)	**(1)** **(1)**
3(b)	Plot a graph of $v \rightarrow \sqrt{T}$, $v^2 \rightarrow T$, $f \rightarrow \sqrt{T}$, or $f^2 \rightarrow T$ Graph should be a straight line through the origin Statement of what gradient equals (consistent with what has been plotted) (For this experiment μ is a constant. A graph using a variable μ can score max 1 mark for the correct gradient)	**(1)** **(1)** **(1)**
	Total for question	**10**

Question Number	Answer	Mark
3(a)(i)	$v = f\lambda$ (words or symbols not numbers) length of string = $\lambda/2$ OR wavelength = 2 x length OR node to node = $\lambda/2$	**(1)** **(1)**
3(a)(ii)	$\pi d^2/4$ OR $\pi(D3/2)^2$ OR π(D3/2)^2 (this mark is lost if there is a *length / A3) (ignore powers of ten)	**(1)**
3(a)(iii)	E4*density OR E4*7800 (ignore powers of ten) **OR** volume of 1 metre length x density	**(1)**
3(a)(iv)	5.12 (spreadsheet answers must be correct to same number dec places so do not accept 5.116 or 5.11) (correct answer on spreadsheet scores mark irrespective of what's written on next page)	**(1)**
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	Total for question	**10**

Question Number	Answer		Mark
4(a)	Pressure (of gas) Amount of gas **Or** mass of gas **Or** number of moles / molecules / atoms	**(1)** **(1)**	**2**
4(b)	Extending/extrapolating the line backwards The volume occupied by a gas will be zero at a particular temperature **Or** The graphs for different gases All cut the x axis at the same temp	**(1)** **(1)** **(1)** **(1)**	**2**
	Total for question		**4**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>5(a)(i)</td><td>1 velocity correct (1)
2 or 3 velocities correct (1)
4 velocities correct (1)
(no unit error)
<table><tr><td>0.66</td><td>0.</td></tr><tr><td>0.91</td><td>0.</td></tr></table></td><td>3</td></tr>
<tr><td>5(a)(ii)</td><td>A (Can be implied within the answer)
The idea that the time increments are smaller Or the idea that the velocity is (constantly) changing (1)

Or
Not B(Can be implied within the answer)
As B gives the value over the whole journey Or B does not take into account that the velocity of the battery is (constantly) changing (1)</td><td>1</td></tr>
<tr><td>5(b)</td><td><u>Source of error:</u>
(Human) reaction time Or recording the exact position of the battery at the correct time Or parallax when marking the position of the battery (1)

<u>Changes to the method:</u>
Film/video camera (1)
with a measuring tape/scale along the ramp (and watch frame by frame) (1)

Or
Motion sensor (1)
Connected to a computer/data logger (to directly plot/record distance against time) (1)

Or
Strobe (as a timer) (1)
Set with a frequency of 1 Hz (1)
(or any sensible frequency suggested with a reason)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>7</td></tr>
</table>

Question Number	Answer		Mark
6(a)	This is describing weight/force and not the mass **Or** the newton is not the unit of mass **Or** mass does not have a direction **Or** kg is the unit of mass and not force/weight	**(1)**	
	The velocity should be speed **Or** velocity would need a direction	**(1)**	
	The car would be decelerating **Or** the car should be speeding up (for an acceleration) **Or** a direction is needed **Or** the value should be negative/-2.5 m s^{-2}	**(1)**	**3**
6(b)(i)	Distance = 75 km	**(1)**	**1**
6(b)(ii)	Use of Pythagoras **Or** correctly constructed scale drawing (labels not required) Displacement = 54 km Direction = 34° East of North (accept angle indicated on diagram) (there is only 1 unit error for km in (i)and (ii)) <u>Example of calculation</u> Displacement^2 = $45^2 + 30^2$ Displacement = $\sqrt{2925}$ km Displacement = 54.1 km Direction = 33.7° (east of north) **Or** 56° (north of east)	**(1)** **(1)** **(1)**	**3**
	Total for question		**7**

<table>
<tr><th>Question Number</th><th></th><th>Mark</th></tr>
<tr><td>7 (a)</td><td>Calculation leading to v = 18.1 (m s^{-1}) (1)

(A reverse argument gives 64.8 (km h^{-1}) and scores the mark)

<u>Example of calculation</u>
v = 65 000 m / 60 × 60 s
= 18.06 m s^{-1}</td><td>1</td></tr>
<tr><td>7 (b)(i)</td><td>Use of distance = speed × time (see the calculation or use of 3 km) (1)

Use of emission = distance × reading from graph (1)

Use of difference between emissions at different speeds for 1 or 3 cars (1)

(This mark may still be awarded if the difference is between a 5 m s^{-1} for 10 minutes journey and an 18 m s^{-1} for 10 minutes journey)

CO_2 emission = 0.72 kg (1)

(allow range 0.63 kg to 0.81 kg)

<table>
<tr><th>Journey</th><th>CO_2 emission</th><th>Range</th><th>Marks</th></tr>
<tr><td>1 car 1 km</td><td>0.08 kg</td><td>0.07 to 0.09</td><td>1 (MP3)</td></tr>
<tr><td>3 cars 1 km</td><td>0.24 kg</td><td>0.21 to 0.27</td><td>1 (MP3)</td></tr>
<tr><td>1 car 3 km</td><td>0.24 kg</td><td>0.21 to 0.27</td><td>3 (MP1,2,&3)</td></tr>
<tr><td>1 car travelling for 10 minutes at 5 m s^{-1} and 18 m s^{-1}</td><td>(-) 1.164 kg</td><td>1.02 to 1.31</td><td>3 (MP1,2,&3)</td></tr>
<tr><td>3 cars travelling for 10 minutes at 5 m s^{-1} and 18 m s^{-1}</td><td>(-) 3.49 kg</td><td>3.06 to 3.93</td><td>3 (MP1,2 &3)</td></tr>
</table>

<u>Example of calculation</u>
Distance = 5 m s^{-1} × 10 × 60 s = 3000 m = 3 km
3 × 3 km × (0.26 kg km^{-1} – 0.18 kg km^{-1}) = 0.72 kg</td><td>4</td></tr>
<tr><td>7 (b)(ii)</td><td>Quantitative comparison of values 0.72 kg and 0.54 kg to indicate that the cyclist causes more CO_2 emissions
Or qualitative statement e.g. more carbon dioxide emitted when he cycles (1)
candidates answer must be consistent with their value from part (i)</td><td>1</td></tr>
<tr><td></td><td>Total for question</td><td>6</td></tr>
</table>

Question Number	Answer	Mark
8(a)	Explain the difference between scalar quantities and vector quantities. It must mention direction or give an e.g. with direction. [Vectors have direction 1 mark. Scalars don't have direction 1 mark] scalar – magnitude/size only but vector – magnitude/size and direction (1) (accept vector has direction but scalar doesn't)	1
8(b)	Comment on this statement. (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) velocity is: a vector / speed in a given direction / = displacement/time / = (total distance in a particular direction)/time [accept references to velocity being postive and negative / changing direction] (1) end and start at the same place / distance in any direction is zero / displacement = 0 (1) so it's true – (ave) vel = zero (1) (consequential on 2nd mark)	3
	Total for question	**4**

Question Number	Answer		Mark
***9(a**	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** Measure the initial length (of the spring) **Or** record position of a 'fixed point' **Or** record the position of the bottom of the spring (with no masses on the spring) Add mass/weight and record the new length/position Repeat for a range of masses/weights Reference to a precaution taken to ensure measurements were accurate e.g. use of set square, method to reduce parallax, hang spring close to rule, do not exceed proportional/elastic limit	**(1)** **(1)** **(1)** **(1)**	**4**
9(b)	Plot appropriate graph of extension/length and force/mass Calculate the gradient (of linear region) Appropriate method to find k from their graph (**Max 1** if no graph is suggested i.e. use $k = F/\Delta x$ and average k)	**(1)** **(1)** **(1)**	**3**
9(c)	k would not be constant for the spring **Or** the graph would not be a straight line **Or** the idea that Hooke's law would not be obeyed **Or** $F = k(\Delta)x$ does not apply	**(1)**	**1**
	Total for Question		**8**