1(a)	Value of *P* in range 5.00 to 15.00 s, with unit seen somewhere
	Evidence of repeated measurement of *P*
1(b)	Six sets of readings of *z* (different values) and *P* with correct overall trend and without help scores 5 marks, five sets scores 4 marks etc. Correct trend is *P* decreases as *z* increases.
	Range: at least one reading of $z \leqslant 10$ g **<u>and</u>** at least one reading of $z \geqslant 70$ g
	Column headings: Each column heading must contain a quantity and a unit where appropriate. The presentation of quantity and unit must conform to accepted scientific convention e.g. $1 / \sqrt{M}$ ($g^{-½}$)
	Consistency: <u>All</u> raw values of *P* must be given to the nearest 0.01 s or **<u>all</u>** to the nearest 0.1 s.
	Significant figures: <u>All</u> values of $1 / \sqrt{M}$ must be given to 3 s.f. or 4 s.f.
	Calculation: $1 / \sqrt{M}$ calculated correctly
1(c)(i)	Axes: Axes must be labelled **with the correct quantities.** Scales must be chosen so that the plotted points occupy at least half the graph grid in both the *x* and *y* directions. Scale markings are no more than 2 cm (one large square) apart. Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions).
	Plotting of points: All observations **<u>in the table</u>** must be plotted on the grid. Diameter of plotted points must be ⩽ half a small square. Points must be plotted to an accuracy of half a small square in both *x* and *y* directions.
	Quality: General trend of points must be negative. All points in the table must be plotted (at least 5) for this mark to be awarded. It must be possible to draw a straight line that is within ± 0.001 $g^{-1/2}$ on the $1 / \sqrt{M}$ axis of **<u>all</u>** plotted points.
1(c)(ii)	Line of best fit: 'Best fit' is judged by the balance of all points on the grid (at least 5 points) about the candidate's line. There must be an even distribution of points either side of the line along the full length. Lines must not be kinked or thicker than half a square. Some candidates may choose to identify an anomalous point. If they identify **one** point as anomalous (e.g. by circling or labelling) then this point is to be disregarded when judging the line of best fit. There must be at least 5 points left after the anomalous point is disregarded.

1(c)(iii)	Gradient: Gradient sign on answer line consistent with graph drawn. The hypotenuse of the triangle used should be greater than half the length of the drawn line. Both read offs must be accurate to half a small square in both the *x* and *y* directions. Method of calculation must be correct, not $\Delta x / \Delta y$.
1(c)(iii)	*y*-intercept: **Either** Intercept read directly from the graph, with read off at *x* = 0, accurate to half a small square in *y* direction. **Or** Correct read off from a point on the line is substituted into $y = mx + c$ or an equivalent expression. Read-off accurate to half a small square in both *x* and *y* directions
1(d)	Value of *a* = candidate's gradient value **and** Value of *b* = candidate's y-intercept value. The values must not be written as fractions or given to only one significant figure.
	Units for *a* and *b* correct and consistent with readings (e.g. $g^{½}s^{-1}$ for *a* and s^{-1} for *b*)

4(a)(i)	temperature = –273.15 °C
4(a)(ii)	temperature = 0 K
4(b)(i)	gas is ideal
4(b)(ii)	$pV = NkT$
	$N = 270 / (8.0 \times 10^{-21})$ $= 3.4 \times 10^{22}$
4(b)(iii)	$n = (3.4 \times 10^{22}) / (6.02 \times 10^{23})$ = 0.056 mol
4(c)	$½ m\langle c^2\rangle = (3 / 2) kT$
	$½ \times m \times 1900^2 = 1.5 \times 8.0 \times 10^{-21}$ ($m = 6.65 \times 10^{-27}$ kg)
	$m = (6.65 \times 10^{-27}) / (1.66 \times 10^{-27})$
	= 4.0 u

5(a)	work done per unit charge
	work (done) moving positive charge from infinity (to the point)
5(b)(i)	potential (due to proton) = $(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 10 \times 10^{-12})$ **or** potential (due to electron) = $(-1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 110 \times 10^{-12})$
	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(10^{-1} - 110^{-1}) \times 10^{12}] = 130\ \text{V}$
5(b)(ii)	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(30^{-1} - 90^{-1}) \times 10^{12}]$
	= (+) 32 V
5(b)(iii)	cross drawn midway between the electron and the proton
5(b)(iv)	line from (10, +130) to (110, –130)
	curve getting shallower until x = 60 pm, crossing V = 0 at (60, 0) and then getting steeper after x = 60 pm
	curve passing through (30, ±32) and (90, ±32)

6(a)	series charges: $Q_S = Q_1 = Q_2$
	series p.d.s: $V_S = V_1 + V_2$
	parallel charges: $Q_S = Q_1 + Q_2$
	parallel p.d.s: $V_S = V_1 = V_2$
6(b)(i)	$E = ½ CV^2$
	p.d.= $[(2 \times 19 \times 10^{-3}) / (470 \times 10^{-6})]^{½}$ = 9.0 V
6(b)(ii)	$E = Q^2 / 2C$ **or** $C = Q / V$
	$Q = (19 \times 10^{-3} \times 2 \times 470 \times 10^{-6})^{½}$ **or** $Q = 470 \times 10^{-6} \times 9.0$ $Q = 4.2 \times 10^{-3}$ C
6(b)(iii)	total charge unchanged
	total capacitance = $(470 + 180) \times 10^{-6}$ (F)
	$E = Q^2 / 2C = (4.23 \times 10^{-3})^2 / (2 \times 650 \times 10^{-6})$ (= 0.014 J) E = 14 mJ

1	**Defining the problem**
	vary f and measure V **or** f is the independent variable and V is the dependent variable
	keep E constant
	Methods of data collection
	labelled diagram of workable experiment including: • circuit with a.c. supply • oscilloscope connected in parallel with the resistor • workable circuit • oscilloscope and a.c. supply labelled
	labelled signal generator or variable frequency power supply connected across the terminals
	method to determine V or E from oscilloscope, e.g. multiply amplitude / height of wave by y-gain on oscilloscope
	method to determine f from oscilloscope, e.g. determine period T by multiplying number of divisions in 1 cycle or horizontal distance in 1 cycle by the time base **and** $f = 1 / T$
	Method of Analysis
	plot a graph of $\frac{1}{V}$ against f or equivalent, e.g. f against $\frac{1}{V}$ Allow logarithms e.g. lg V against lg f.
	relationship valid if a straight line is produced passing through the origin (for lg V against lg f: relationship valid if a straight line is produced with gradient = –1)
1	$\frac{1}{V}$ against f: $K = \frac{lES}{AN^2} \times \text{gradient}$ f against $\frac{1}{V}$: $K = \frac{lES}{AN^2} \times \frac{1}{\text{gradient}}$ (for lg V against lg f: $K = \frac{ElS}{AN^2} \times 10^{-y\text{-intercept}}$).
	Additional detail including safety considerations
	D1 precaution linked to hot coil or hot resistor or prevention of burns from coil or resistor, e.g. use gloves / switch off power supply when not measuring V to prevent burns from coil / resistor
	D2 keep N **and** A **and** l **and** S constant
	D3 method to keep S constant, e.g. switch off power supply between readings to prevent heating of resistor or to allow resistor to cool
	D4 method to determine A, e.g. use calipers / micrometer to measure diameter (of coil) / d **and** $A = \frac{\pi d^2}{4}$
	D5 repeat measurements of diameter d along the length of the coil / in different directions **and** determine the average value of d
	D6 method to determine the value of S, e.g. separate circuit diagram showing resistor connected to ohmmeter, or circuit diagram showing resistor connected to a power supply with an ammeter and voltmeter **and** $S = V / I$
	D7 measure l with a ruler / calipers
	D8 oscilloscope drawn connected across terminals / across signal generator **and** description to determine E
	D9 adjust y-gain for maximum amplitude **or** adjust time base for length of one wave or measure n waves and divide measured time by n
1	D10 method to keep E constant, e.g. check p.d. and alter supply **or** method to keep l constant, e.g. tape coil **or** method to keep A constant, e.g. wind wire on a cylinder

3(a)(i)	gas for which $pV \propto T$
	where T is thermodynamic temperature
3(a)(ii)	no intermolecular forces
	(so) potential energy is zero
3(b)(i)	$pV = NkT$
	$N = (2.0 \times 10^5 \times 0.26) / (1.38 \times 10^{-23} \times 290)$ $= 1.3 \times 10^{25}$
3(b)(ii)	$E_K = (3/2)\,kT$
	$E_K = (3/2) \times 1.38 \times 10^{-23} \times 290$ $= 6.0 \times 10^{-21}$ J
3(b)(iii)	internal energy = total KE + PE of molecules **or** PE = 0 so internal energy = total KE of molecules
	internal energy = $1.3 \times 10^{25} \times 6.0 \times 10^{-21}$ $= 7.8 \times 10^4$ J
3(c)	straight line with positive gradient
	line passing through the origin