Question Number	Answer		Mark
1(a)	Vertical and equally spaced parallel lines (minimum 3, ignore any at edges which are curved) Arrows downwards	**(1)** **(1)**	**2**
1(b)	Identifies an upward electric force Which is equal to the weight **Or** which balances the weight **Or** the resultant force on the drop is zero	**(1)** **(1)**	**2**
1(c)	See $F=VQ/d$ Equates electric force and weight $Q/m = 49 \times 10^{-6}$ (C kg^{-1}) <u>Example of calculation</u> $F = EQ = \frac{VQ}{d} = mg$ $\frac{Q}{m} = \frac{gd}{V}$ $\frac{Q}{m} = \frac{9.81\text{m s}^{-2} \times 2.5\times10^{-2}\text{ m}}{5000\text{ V}} = 4.9 \times 10^{-5}$ (C kg^{-1})	**(1)** **(1)** **(1)**	**3**
1(d)	Uses $\frac{Q}{m}$ to find Q (ecf value from (c)) ($Q = 4.9 \times 10^{-18}$ C) Use of $F = \frac{kQ_1Q_2}{r^2}$ $F = 4.5 \times 10^{-20}$ N (using show that value from (c) gives 4.64×10^{-20} N) <u>Example of calculation</u> $F = \frac{8.99\times10^{9}\text{ N m}^2\text{C}^{-2}(4.9\times10^{-5}\text{ C kg}^{-1}\times 1.0\times10^{-13}\text{ kg})^2}{(2.2\times10^{-3}\text{ m})^2} = 4.46 \times 10^{-20}$ N	**(1)** **(1)** **(1)**	**3**
1(e)	As V increases the electric/upwards force increases **Or** EQ > mg There is a resultant force Drops (initially) accelerate upwards	**(1)** **(1)** **(1)**	**3**
	Total for question		**13**

Question Number	Answer		Mark
2(a)	**sing Equation** F – kg m s^{-2} Q – A s ε_0 – $A^2\,kg^{-1}\,m^{-3}\,s^4$ **Or using the unit of F m^{-1}** C – A s J – kg $m^2\,s^{-2}$ ε_0 – $A^2\,kg^{-1}\,m^{-3}$ s	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1**	3
2(b)	**Diagram mark for parallel plate**: a minimum of 3 parallel equispaced lines touching plates (ignore edge effect) **Diagram mark for point charge**: minimum of 4 equispaced radial lines touching charged point Direction of fields correct for both diagrams consistent with charges labelled Parallel plate **-** field strength same at all points Point charge **-** field strength decreases with (increasing)distance from point **Or** obeys inverse square law	**(1)** **(1)** **(1)** **(1)** **(1)**	5

2(c)	Use of $F_E = kQ_1Q_2/r^2$ Use of $W = mg$ Resolve vertically $T\cos\theta = mg$ **and** Resolve horizontally $T\sin\theta = F_E$ Attempt to combine components to give tan θ ($\tan\theta = F_E/mg$) $\theta = 41^\circ$ to 42° $T = 0.035$ N **Or** Use of $F_E = kQ_1Q_2/r^2$ Use of $W = mg$ Use of Pythagoras to find tension force Tan $\theta = F_E/mg$ **Or** $\cos\theta = mg/T$ **Or** $\sin\theta = F_E/T$ $\theta = 41^\circ$ to 42° $T = 0.035$ N (if they halve the separation or halve the electric force they can still get MP1 and so could score MP1,2, 3 & 4) <u>Example of calculation</u> Weight of sphere = 0.0027 kg × 9.81 N kg^{-1} = 0.026 N Electric force $F_E = kQ_1Q_2/r^2$ $= 8.99 \times 10^9$ N m^2 C^{-2} × (4.0 × 10^{-7} C)^2 / 0.25^2 m^2 = 0.023 N Vertically $T\cos\theta = mg$ Horizontally $T\sin\theta = F_E$ Tan $\theta = F_E$/mg = 0.023 N/ 0.026 N $\theta = 41^\circ$ sub into vertical equation $T = mg/\cos\theta$ = 0.026 N /cos 41 $T = 0.034$ N	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **6**
	Total for question		**14**

Question Number	Answer		Mark
3(a)	(Electric field strength (at a point in a field) is) the force per unit charge (accept force per coulomb of charge) Acting on a (small) positive charge.	**(1)** **(1)**	**2**
3(b)(i)	Use of $E = kQ/r^2$ Electric field due to $Q_1 = 4.1(1) \times 10^6$ (N C^{-1}) Use of 11.9 cm to find field due to Q_2 **Or** Use of $E = kQ/r^2$ Use of $E1 / E2 = Q1\ r22 / Q2\ r12$ $E_1 / E_2 = 1$ <u>Example of calculation</u> Electric field due to Q_1 $= (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \times (3 \times 10^{-6} \text{ C}) / (8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6 \text{ N C}^{-1}$ Electric field due to Q_2 $= (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \times (6.5 \times 10^{-6} \text{ C}) / (11.9 \times 10^{-2})^2 = 4.13 \times 10^6 \text{ N C}^{-1}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
3(b)(ii)	(Force on charge is) zero/negligible/approx zero (Allow values less than 0.1 N)	**(1)**	**1**
3(b)(iii)	At midpoint repulsive force due to Q_2 > repulsive force due to Q_1 **Or** the <u>resultant</u> field/force is repulsive <u>Work</u> must be done against the repulsive force/field to move the charge to this position.	**(1)** **(1)**	**2**
	Total for question		**8**

Question Number	Answer		Mark
4(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
4(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	
4(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
4(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ $Q = (1.20 \times 10^{-14}\text{ kg} \times 9.81\text{m s}^{-2} \times 0.02\text{ m}) / (5100\text{ V})$ $Q = 4.62 \times 10^{-19}$ C	**(1)** **(1)** **(1)** **(1)**	**4**
4(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62×10^{-19} C / 1.6×10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

Question Number	Answer		Mark
5(a)	Repulsive force (due to two positive/like charges) An explicit statement relating force/repulsion to acceleration (allow F = ma) [candidates might start with the acceleration needing a force, this is acceptable]	**(1)** **(1)**	**2**
5(b)	At least four straight evenly spaced radial lines starting from the circle. Arrow pointing away from centre	**(1)** **(1)**	**2**
	Total for question		**4**

Question Number	Answer		Mark
6(a)	Use of $v = 2\pi r/t$ **Or** $v = r\omega$ **and** $T = 2\pi/\omega$ $t = 1.5 \times 10^3$ s [24.6 minutes] <u>Example of calculation</u> $t = 2\pi r/v$ $t = (2\pi \times 61\text{ m}) / 0.26\text{ m s}^{-1}$ $t = 1473$ s	**(1)** **(1)**	 **2**
6(b)	Use of $F = mv^2/r$ $F = 11$ N <u>Example of calculation</u> $F = 9.7 \times 10^3\text{ kg} \times (0.26\text{ m s}^{-1})^2 / 61\text{ m}$ $F = 10.7$ N	**(1)** **(1)**	 **2**
6(c)(i)	Three arrows all pointing to the centre of the circle (accept free hand and lines of varying length)	**(1)**	
***6(c)(ii**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Maximum at C / bottom **and** Minimum at A / top At C contact/reaction force (R) greater than weight (accept $R - W = mv^2/r$ or $R = W + mv^2/r$) At A contact/reaction force is less than the weight. (accept $W - R = mv^2/r$ or $R = W - mv^2/r$) Any statement that centripetal force / acceleration is provided by weight/reaction **Or** centripetal force is the resultant force This is a qwc question so a bald statement of the equations can score the marks but to get full marks there must be clear explanation in words.	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question		**9**