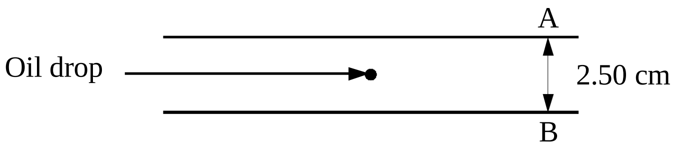
Questions on Electric Fields MS

1. The diagram shows a positively charged oil drop held at rest between two parallel conducting plates A and B.



The oil drop has a mass 9.79 x 10^{-15} kg. The potential difference between the plates is 5000 V and plate B is at a potential of 0 V. Is plate A positive or negative?

Negative (1)

Draw a labelled free-body force diagram which shows the forces acting on the oil drop. (You may ignore upthrust).

qE/electric force

mg / gravitational force / weight (2)

(3 marks)

Calculate the electric field strength between the plates.

E = $\frac{\mathbf{5000V}}{\mathbf{2.50} x \mathbf{10^{-2}} m}$ **(1)**

Electric field strength = **2 x 10^5 V m^{-1} [OR N c^{-1}] (1)**

(2 marks)

Calculate the magnitude of the charge Q on the oil drop.

Mg = qE: use of equation (1)

Charge = **4.8 x 10^{-19} C (1)**

How many electrons would have to be removed from a neutral oil drop for it to acquire this charge?

3 (1)

(3 marks)
[Total 8 marks]

2. Calculation of potential difference:

Use of $E = V/d$ [d in m or cm] **(1)**

V = 90 kV **(1)**

Calculation of maximum kinetic energy:

Use of × 1.6 × 10^{-19} [in $E = qV$ e.c.f. value of V] 1.4 × 10^{-14} (J) **(1)**

[e.c.f. their V × 1.6 × 10^{-19}] **(1)**

4

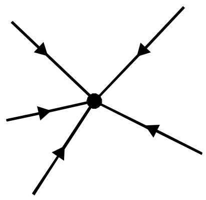
Maximum speed of one of these electrons:

Use of k.e. = ½ $m\upsilon^2$ with m = 9.1×10^{-31} kg **(1)**

[Full e.c.f. their k.e. possible; make sure v is speed term]

= 1.8×10^8 m s^{-1} [u.e. but only once] **(1)**

Diagram:



2

At least 3 radial lines touching object **(1)**

Direction towards electron **(1)**

2

Expression for electric potential V:

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{1.6 \times 10^{-19}}{r} \quad \text{OR} \quad \frac{e}{4\pi\varepsilon_0}r \quad \text{OR} \quad \frac{1.44 \times 10^{-9}}{r}$$

[not k unless defined] $\left[\textit{Not } \frac{Q}{4\pi\,\varepsilon_0\,r} \text{ unless } Q \text{ defined} \right]$

[With or without "–" sign] **(1)**

1

[9]

3. Alpha particle: diagram

Curving path between plates 1

Towards 0 V plate 1

Emerging from plates and carrying on straight 1

Calculation

$$\text{Electric field} = \frac{2000 \text{ V}}{10 \times (10^{-3}) \text{ m}}$$

Substitution 1

Force = EQ

$$= \left(\frac{2000}{10 \times 10^{-3}}\right) \text{Vm}^{-1} \times (2) \times 1.6 \times 10^{-19} \text{ C}$$

Substitution [ecf their E] 1

= 6.4×10^{-14} N

Correct answer 1

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4. Diagram

Electric pattern:

Straight, parallel, reasonably perpendicular to plates and equispaced [Minimum 3 lines] **(1)**
Correct direction labelled on one line [Downwards arrow] **(1)** 2
Equipotential lines:
Any two correct equipotentials with any labelling to identify potentials (rather than field lines) **(1)** 1
[Arrows on electric field lines – none on equipotential being sufficient labelling]

Force

$E = \dfrac{3000V}{25 \times (10^{-3})\text{m}}$ [Correct substitution] **(1)**

Use of $F = Ee$ even if value of "e" is incorrect **(1)**
$F = 120 \times (10^3)$ V m^{-1} $\times 1.6 \times 10^{-19}$ C
$= 1.9\ (2) \times 10^{-14}$ (N) **(1)** 3

Graph

Straight horizontal line [Even if extending beyond 25 mm] **(1)**
Value of F marked [e.c.f. their value] provided graph begins on force axis and is marked at this point **(1)** 2

Speed
Use **(1)**

eV = ½ mv^2 v^2 = 2 eV/m	$v^2 = 2\left(\dfrac{F}{m}\right)s$	Fd = ½ mv^2 $v^2 = 2Fd/m$

Substitution **(1)**

$V^2 = \dfrac{2 \times 1.6 \times 10^{-19}(\text{C}) \times 3000(\text{V})}{9.11 \times 10^{-31}\text{kg}}$

$= 2\ \dfrac{(1.92 \times 10^{-14}\text{ N})}{9.11 \times 10^{-31}\text{kg}} \times 25\ 10^{-3}$ m

$= \dfrac{2 \times 1.92 \times 10^{-14}\text{ N} \times 25 \times 10^{-3}\text{ m}}{9.11 \times 10^{-31}\text{kg}}$

Answer: $V = 3.2 \times 10^7$ ms^{-1} **(1)** 3

[If F= 2×10^{-14} N, then V= 3.3×10^7 ms^{-1}]

[11]

5. Explanation

Electrons are transferred from / move from/ rubbed off the rod to the duster **(1)**
Same amount of charge on each/duster becomes negative **(1)** 2

Polystyrene

Polystyrene is an insulator / non conductor [NOT bad or poor conductor] **(1)**
Prevents loss of charge/rod discharging/prevents conduction or charge low from metal plate **(1)** 2

Reading on balance

Quality of written communication **(1)** 1

Any three from:

- Reading increases **(1)**
- There is a (mutual) force of repulsion/like charges repel/rods (they) repel **(1)**
- Because by Coulomb's law/inverse square law/ $\frac{kQ_1Q_2}{r^2}$ / $\frac{1}{r^2}$ as r decreases force must increase **(1)**
- Reading increases at a greater rate/more rapidly [but accept if say "much more"] as distance reduces/when closer **(1)** Max 3

[8]

6. (a) Direction of field lines

Downwards **(1)** 1

(b) (i) Calculation of force

Use of *V/d* i.e. 250 V/0.05 m [if 5 used mark still awarded] **(1)**

Use of $\frac{V}{d}$ e [Mark is for correct use of 1.6×10^{-19} C] **(1)**

$= 8.0 \times 10^{-16}$ N **(1)** 3

(ii) Direction and explanation

(Vertically) upwards / towards AB **(1)**

No (component of) force in the horizontal direction OR because **(1)** 2
(the force) does no work in the horizontal direction

(c) Calculation of p.d.

Use of $\Delta E_K = ½ mv^2$ / ½ 9.11×10^{-31} (kg) $\times (1.3 \times 10^7)^2$ **(1)**

Use of Ve / $V \times 1.6 \times 10^{-19}$ (C) **(1)**

= 480 V **(1)** 3

(d) Beam of electrons

Diagram showing:

Spreading out from one point **(1)**
fastest electrons labelled **(1)**

2

[11]

7. (a) Electron speed

Substitution of electronic charge and 5000V in eV **(1)**
Substitution of electron mass in ½ mv^2 **(1)**

Correct answer [4.2 (4.19) $\times 10^7$ (m s^{-1}), no ue] to at least 2 sf **(1)** 3

[Bald answer scores zero, reverse working can score 2/3 only]

Example of answer:
$v^2 = (2 \times 1.6 \times 10^{-19}\text{C} \times 5000 \text{ V})/(9.11 \times 10^{-31} \text{ kg}) = 1.76 \times 10^{15}$
$v = 4.19 \times 10^7 \text{ m s}^{-1}$

(b) (i) Value of E

Correct answer [2.80×10^4 V m^{-1}/N C^{-1} or 2.80×10^2 V cm^{-1}] **(1)** 1

Example of answer:
$E = V/d = 1400 \text{ V} / 5.0 \times 10^{-2}$
$= 28\,000 \text{ V m}^{-1}$

(ii) Value of force F
Correct answer [4.5×10^{-15} N, ecf for their E] **(1)** 1

Example of answer:
$F = Ee = 2.80 \times 10^4 \text{ V m}^{-1} \times 1.6 \times 10^{-19} \text{ C}$
$= 4.48 \times 10^{-15}\text{N}$

(c) Calculation of h 4
See a = their F / 9.11×10^{-31} kg **(1)**
[$\rightarrow a = 4.9 \times 10^{15} \text{ m s}^{-2}$]

See $t = 12 (\times 10^{-2}) \text{ m} / 4 \times 10^7 \text{ m s}^{-1}$ (or use $4.2 \times 10^7 \text{ m s}^{-1}$) **(1)**
[$t = d/v$, with d = plate length; 12 cm]
[$\rightarrow t = 3.0 \times 10^{-9}$ s, or 2.86×10^{-9} s]

See substitution of a and t values [**arrived at by above methods**] into ½ at^2 **(1)**

Correct answer [h = 0.020 m – 0.022 m] **(1)**

[Full ecf for their value of F **if** methods for a and t correct **and** their $h \leq 5.0$cm]

Example of answer:
$h = ½\, a\, t^2$
$= ½ \times 4.9 \times 10^{15} \text{ m s}^{-2} \times (2.86 \times 10^{-9} \text{ s})^2$
$= 2.0 \times 10^{-2}$ m

(d) (i) Path A of electron beam
Less curved than original **(1)** 1

(ii) Path B of electron beam
More curved than original, curve starting as beam enters field [started by H of the Horizontal plate label] **(1)** 1

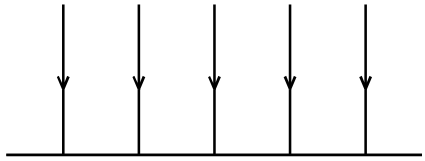
[For **both** curves:
- ignore any curvature beyond plates after exit
- new path must be same as original up to plates]

[No marks if lines not identified, OK if either one is labelled]

[11]

8. Draw diagrams to represent

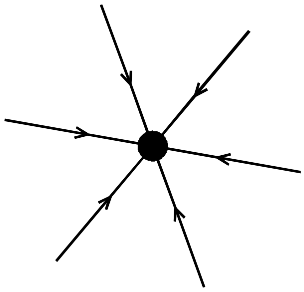
(i) the gravitational field near the surface of the Earth,



Direction

Lines: at least 3 parallel perpendicular equally spaced

(ii) the electric field in the region of an isolated negative. point charge.



Direction

Lines: at least 3 radial equally spaced

(4 marks)

How does the electric field strength *E* vary with distance *r* from the point charge?

E $\propto \frac{1}{r^2}$ **(1)**

(1 mark)

Give an example of a region in which you would expect to find a uniform electric field.

Between charged parallel plates (1).

(1 mark)
[Total 6 marks]

9. <u>Cathode Ray Tube</u>

Electron emission

- Heating effect (due to current) **(1)**
- (Surface) electrons (break free) because of energy gain **(1)** 2

[Thermionic emission scores both marks]

<u>Electron motion towards anode</u>

The electrons are attracted to/accelerated by the positive anode **(1)** 1

<u>Energy</u>

Electron energy = $(10 \times 10^3\ \text{V})\ (1.6 \times 10^{-19}\ \text{C})$

$= 1.6 \times 10^{-15}$ J

Correct use of 1.6×10^{-19} OR use of 10×10^3 **(1)**
Answer **(1)** 2

<u>Number of electrons per second</u>

Number each second = $\frac{1.5 \times 10^{-3}\ \text{A}}{1.6 \times 10^{-19}\ \text{J}}$

$9.4 \times 10^{15} s^{-1}$

Correct conversion mA →A
Answer **(1)** 2

Rate

Energy each second = $(9.4 \times 10^{15}\ s^{-1})\ (1.6 \times 10^{-15}\ J)$ **(1)**

= $15\ Js^{-1}$ (W) / $14.4\ Js^{-1}$ **(1)** 2

[ecf their energy]

[9]

10. Evenly distributed spray:

The drops repel [i.e. something repels] **(1)**
1

Explanation:

Electrons/negative charge move upwards from Earth on to object **(1)**

as positive/drops induce negative on object **(1)**

negatives attract positive/drops [not "neutralised"] **(1)**
3

Positive builds up on object OR no electrons move upwards from Earth **(1)**

OR negative can no longer flow

Positive repels approaching drops **(1)**
2

[6]

11. How electron gun creates beam of electrons

Any four from:

1. hot filament **(1)**
2. thermionic emission / electrons have enough energy to leave **(1)**
3. anode and cathode / ± electrodes [identified] **(1)**
4. E–field **OR** force direction **OR** cause of acceleration **(1)**
5. collimation [eg gap in anode identified as causing beam] **(1)**
6. need for vacuum **(1)** Max 4

Speed of electrons

(eV =) ½ mv^2 **(1)**

Use of eV [ie substituted or rearranged] **(1)**

Answer [$1.09 \times 10^7\ m\ s^{-1}$] **(1)**

$1.6 \times 10^{-19} \times 340\ (J) = ½ \times 9.11 \times 10^{-31}\ (kg) \times v^2$

$v = 1.09 \times 10^7\ m\ s^{-1}$ 3

Definition of term electric field

Region/area/space in which **charge** experiences **force (1)** 1
ertical acceleration of electrons due to field
[Bald answer =0]

Use of equation $E = V/d$ **(1)**

$E = V/d$ = 2500 V ÷ 0.09 m = 28 (kV m^{-1})

Rearranged equation $E = F/q$ or substitution into it **(1)**

$F = Eq$ = 28 000 × 1.6 × 10^{-19} (N) 4.4 × 10^{-15} (N)

Equation $F = ma$ seen or substitution into it **(1)**

$A = F/m = \dfrac{4.4 \times 10^{-15}(N)}{9.11 \times 10^{-31}(hg)}$

= 4.9 × 10^{15} (m s^{-2}) **(1)** 4

[at least 2 sig fig needed] [No u.e.] [Reverse calculation max 3]

[12]

12. Electric field

$\dfrac{100\,(\text{V})}{300 \times 10^{-6}\,(\text{m})}$ **(1)**

= 3.3 × 10^{5} V m^{-1} **(1)** 2

Force

$F = Eq$ = 3.3 × 1.6 × 10^{-19} (N)

= 5.3 × 10^{-14} N [Allow e.c.f] **(1)** 2

Why force has this direction

Vertical line ↑ **(1)**

Attracted to positive plate
OR in terms of field direction } **(1)** 2

How much energy hole gains

$W = F \times d$ = 5.3 × 10^{-14} × 2.8 × 10^{-10} (J) **(1)**

= 1.5 × 10^{-23} J [Allow e.c.f] **(1)** 2

[8]

13. Forces acting on molecule, shown on diagram A:

Forces not collinear and sense correct **(1)** 1

Explanation of why molecules align with field:

Forces not in same line **(1)**

Hence turning effect [OR torque] 2

Field lines shown on diagram B:

At least three lines drawn equidistant**(1)**

Direction correct **(1)** 2

Calculations of electric field strength:

$E = \dfrac{V}{d} = \dfrac{1.5\text{V}}{1.0 \times 10^{-5}\,\text{m}}$ **(1)**

= 1.5 × 10^{5} V m^{-1} **(1)** 2

[7]

14. Credit to be given for all good, relevant Physics

Examples of mark scoring points [each relevant formula is also worth 1 mark]:

Between plates field is uniform

Acceleration is constant

Energy gained = 2000e

All ions have same F or same energy

From hole to detector is zero field/force

Ion travels at constant speed

g negligible

time proportional to 1 /velocity

time proportional to 1 /mass

in a vacuum there are no collisions or friction forces

[Max 7]