Electric Potential and Field 2 *[37 marks]*

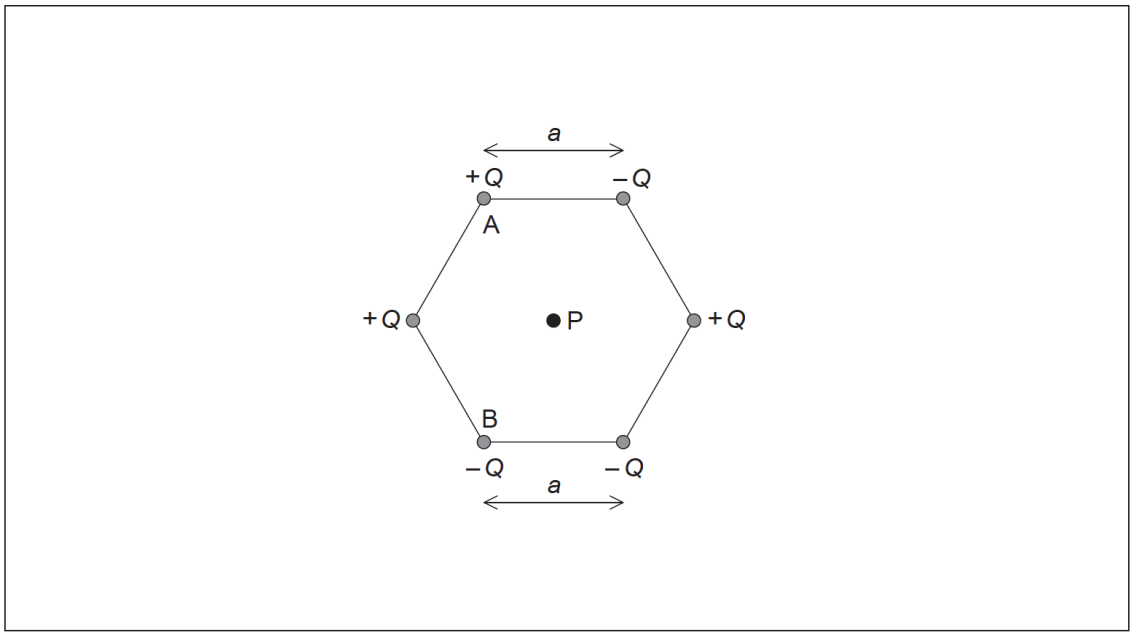
Part 2 Electric point charges

1a. Define *electric field strength* at a point in an electric field. *[2 marks]*

Markscheme

electric force per unit charge;
acting on a small/point positive (test) charge;

1b. Six point charges of equal magnitude *Q* are held at the corners of a hexagon with the signs of the charges as shown. Each side of the hexagon has a length *a*. *[8 marks]*



P is at the centre of the hexagon.

(i) Show, using Coulomb's law, that the magnitude of the electric field strength at point P due to **one** of the point charges is

$$\frac{kQ}{a^2}$$

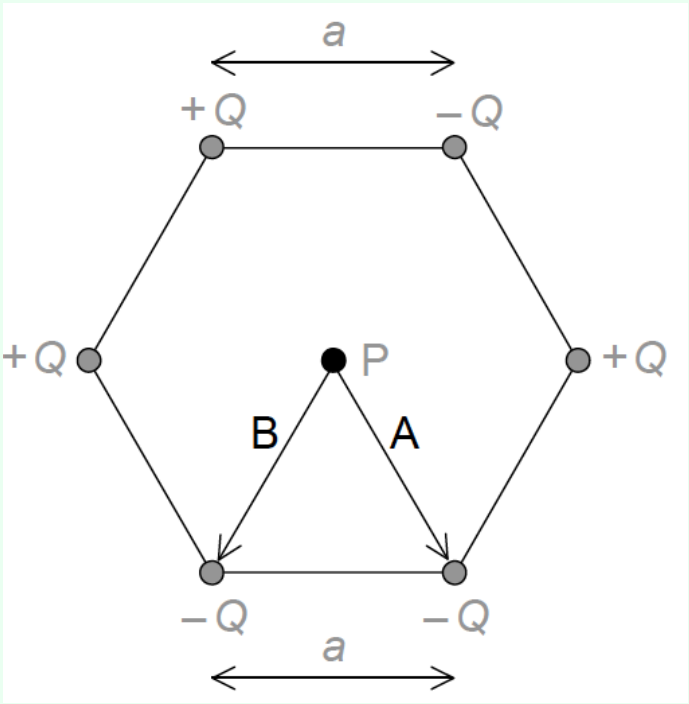
(ii) On the diagram, draw arrows to represent the direction of the field at P due to point charge A (label this direction A) and point charge B (label this direction B).

(iii) The magnitude of *Q* is 3.2 μC and length *a* is 0.15 m. Determine the magnitude and the direction of the electric field strength at point P due to all six charges.

Markscheme

(i) states Coulomb's law as $\frac{kQq}{r^2}$ ***or*** $\frac{F}{q} = \frac{kQ}{r^2}$
states explicitly q=1;
states r=a;

(ii)



arrow labelled A pointing to lower right charge;
arrow labelled B point to lower left charge;
Arrows can be anywhere on diagram.

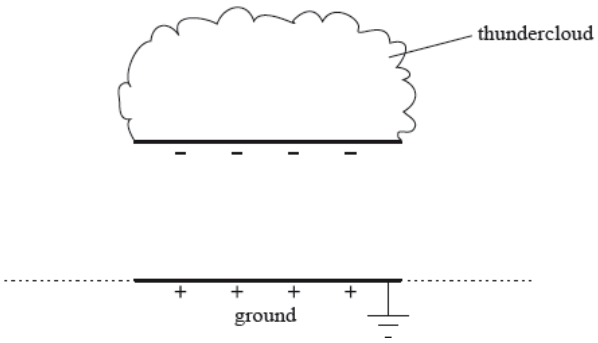
(iii) overall force is due to +Q top left and -Q bottom right / top right and bottom left and centre charges all cancel; } *(can be seen on diagram)*
force is therefore $\frac{2kQ}{a^2}$;

2.6×106 (N C^{-1}) ;
towards bottom right charge; *(allow clear arrow on diagram showing direction)*

This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about fuel for heating.

Part 1 Lightning discharge

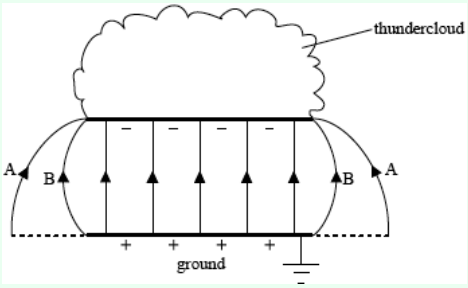
2a. A thundercloud can be modelled as a negatively charged plate that is parallel to the ground. *[3 marks]*



The magnitude of the charge on the plate increases due to processes in the atmosphere. Eventually a current discharges from the thundercloud to the ground.

On the diagram, draw the electric field pattern between the thundercloud base and the ground.

Markscheme



lines connecting plate and ground equally spaced in the central region of thundercloud and touching both plates; *(judge by eye)*

edge effects shown; *(accept either edge effect A or B shown on diagram)*

field direction correct;

The magnitude of the electric field strength E between two infinite charged parallel plates is given by the expression

$$E = \frac{\sigma}{\varepsilon_0}$$

where σ is the charge per unit area on one of the plates.

A thundercloud carries a charge of magnitude 35 C spread over its base. The area of the base is $1.2 \times 10^7\ \text{m}^2$.

2b. (i) Determine the magnitude of the electric field between the base of the thundercloud and the ground. *[12 marks]*

(ii) State **two** assumptions made in (c)(i).

1.

2.

(iii) When the thundercloud discharges, the average discharge current is 1.8 kA. Estimate the discharge time.

(iv) The potential difference between the thundercloud and the ground before discharge is $2.5 \times 10^8\ \text{V}$. Determine the energy released in the discharge.

Markscheme

(i) $\sigma = \left(\frac{35}{1.2\times10^7} =\right)\ 2.917 \times 10^{-6}\ (\text{C m}^{-2})$;

$E = \frac{2.917\times10^{-6}}{8.85\times10^{-12}}$;

$= 3.3 \times 10^5\ \text{N C}^{-1}$ ***or*** V m^{-1};

*Award **[3]** for bald correct answer.*

(ii) edge of thundercloud parallel to ground;

thundercloud and ground effectively of infinite length;

permittivity of air same as vacuum;

(iii) $t = \frac{Q}{I}$;

$t = \frac{35}{1800}$;

$= 20\ \text{ms}$;

(iv) use of energy $= \text{p.d.} \times \text{charge}$;

$\text{average p.d.} = 1.25 \times 10^8\ (\text{V})$;

$\text{energy released} = 1.25 \times 10^8 \times 35$;

$= 4.4 \times 10^9\ \text{J}$;

*Award **[3 max]** for 8.8 GJ if average p.d. point omitted.*

Accept solution which uses average current $\left(from \frac{charge}{time}\right)$.

Allow ecf from (c)(ii).

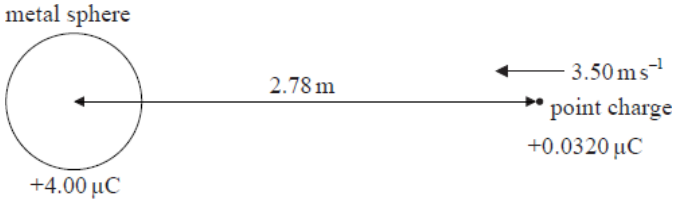
This question is about electric potential.

3a. Define *electric potential* at a point in an electric field. *[3 marks]*

Markscheme

the work done per unit charge;
when a small/test/point positive charge; *(charge sign is essential)*
is moved from infinity to the point;

3b. A positive point charge is moving towards a small, charged metal sphere along a radial path. *[6 marks]*



At the position shown in the diagram, the point charge has a speed of 3.50 m s $^{-1}$ and is at a distance of 2.78 m from the centre of the metal sphere. The charge on the sphere is +4.00 μC.

(i) State the direction of the velocity of the point charge with respect to an equipotential surface due to the metal sphere.

(ii) Show that the electric potential *V* due to the charged sphere at a distance of 2.78 m from its centre is 1.29 ×10^4 V.

(iii) The electric potential at the surface of the sphere is 7.20 ×10 ^{4} V. The point charge has a charge of +0.0320 μC and its mass is 1.20 ×10^{-4} kg. Determine if the point charge will collide with the metal sphere.

Markscheme

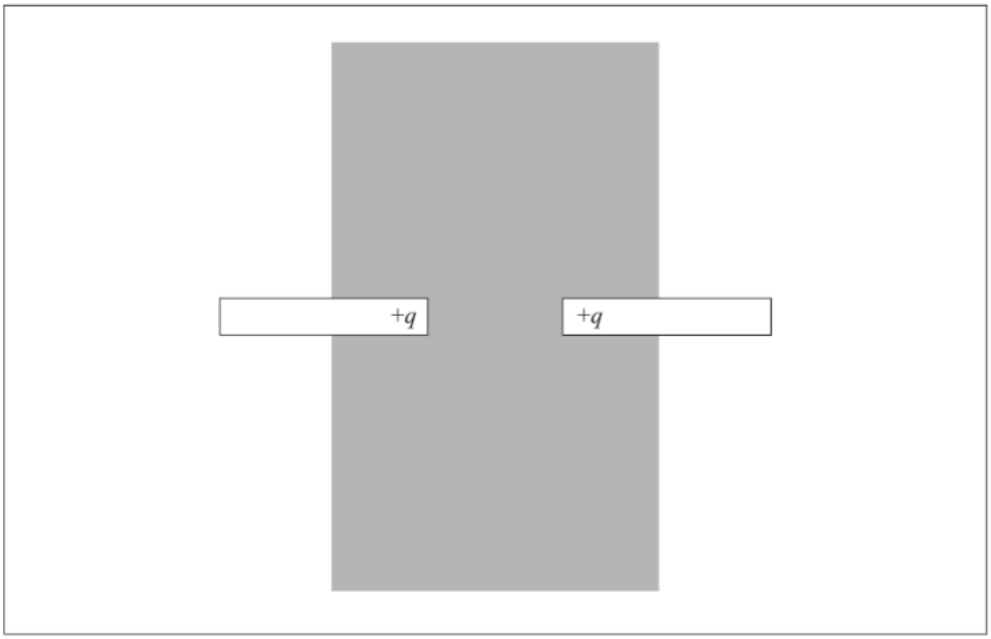
(i) perpendicular / at right angles / at 90° / normal;

(ii) $V = \frac{8.99\times10^{9}\times4.00\times10^{-6}}{2.78}$ ***or*** $1.2935 \times 10^{4}\text{V}$; (*use of* $\frac{1}{4\pi\varepsilon_0}$ *gives 1.29378×10^4*)
(≈1.29×10^{4}V)

This question is in **two** parts. **Part 1** is about electric charge and resistance. **Part 2** is about orbital motion.

Part 1 Electric charge and resistance

4. Two plastic rods each have a positive charge + *q* situated at one end. The rods are arranged as shown. *[3 marks]*



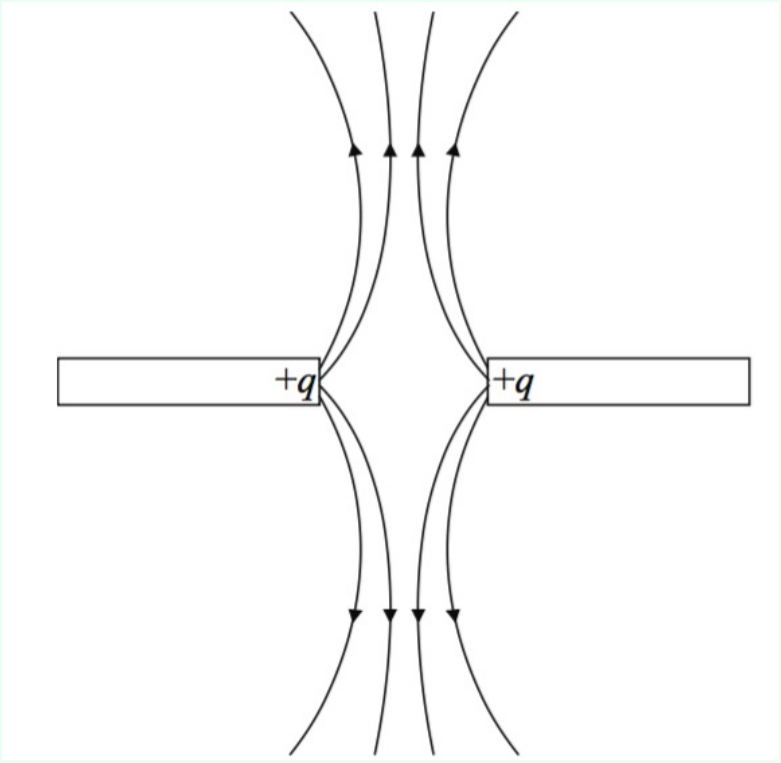
Assume that the charge at the end of each rod behaves as a point charge. Draw, in the shaded area on the diagram

(i) the electric field pattern due to the two charges.

(ii) a line to represent an equipotential surface. Label the line with the letter V.

Markscheme

(i)



at least four field lines (minimum two per rod) to show overall shape of pattern; direction of lines all away from poles;
Ignore all working outside region.
Any field lines crossing loses first mark even if accidental.

(ii) any line labelled V perpendicular to the field lines it traverses; *(judge by eye)*
Ignore unlabelled lines as they could be field lines.