A2 Level Physics

Chapter 7 – Electric and Magnetic Fields

7.2.2 Electric Fields

Worked Examples

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Electric Fields

Exam Style Question 1

(a) An electric field always exists around a charged particle.

Explain what is meant by an electric field.

(b) State one difference and one similarity between the electric field of a point charge and the gravitational field of a point mass.

(c) Fig. 1.1 shows the uniform electric field between two vertical parallel plates A and B.

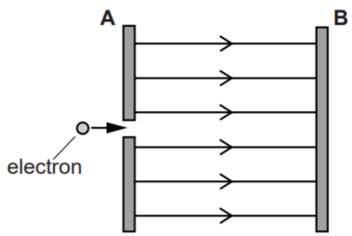

Fig. 1.1

The potential difference between the plates is $6\ V$. An electron of kinetic energy $4\ eV$ is fired in a direction parallel to the electric field through a tiny hole in plate A.

Describe and explain the subsequent motion of the electron in the space between A and B. The weight of the electron has negligible effect on its motion between the plates.

Electric Fields

Exam Style Question 1

(d) Two different minerals acquire opposite charges when they are crushed into tiny particles. These oppositely charged mineral particles fall from a conveyor belt through the uniform electric field between two vertical parallel plates, as shown in Fig. 1.2.

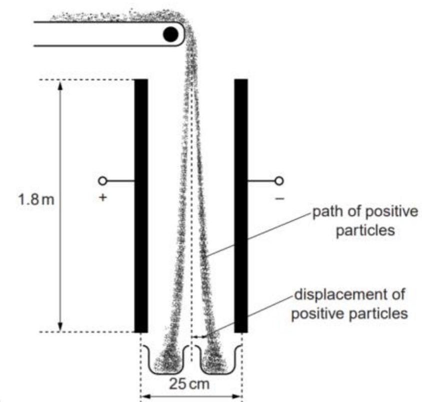

Fig. 1.2

The potential difference across the plates is 60 kV. The separation between the plates is $25\ cm$ and each plate has length $1.8\ m$. The mineral particles fall through the air between the plates with a terminal velocity of $1.2\ m\ s^{-1}$. Each mineral particle has a charge of magnitude $1.5 \times 10^{-13}\ C$ and a mass of $8.0 \times 10^{-7}\ kg$.

(i) Calculate the horizontal electric force experienced by a positively charged mineral particle as it falls between the plates.

(ii) Calculate the horizontal displacement of a positively charged mineral particle after a $1.8\ m$ fall through the electric field of the plates. Ignore any horizontal drag forces due to air.

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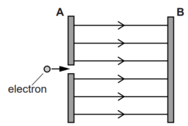

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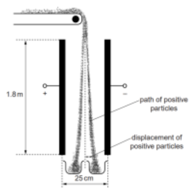

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Electric Fields

Exam Style Question 1

(a) Explain what is meant by an electric field.
A region in which a charged particle experiences a force. Force per unit charge.

(b) State one difference and one similarity between the electric field of a point charge and the gravitational field of a point mass.
Difference: Gravitational field is attractive.
Electric field can be either attractive or repulsive.

Similarity: Force strength inversely proportional to distance squared.
Radial fields.

(c) Describe and explain the subsequent motion of the electron in the space between A and B.

- The electron is repelled by B and attracted by A and therefore experiences a force to the left.
- Initially the electron decelerates and never reaches plate B before reversing direction.
- When it returns to A it has 4 eV of KE.

(d) (i) Calculate the horizontal electric force experienced by a positively charged mineral particle as it falls between the plates.

Use $E = \frac{V}{d}$

$$\therefore E = \frac{60 \times 10^3\ V}{0.25\ m} = 240{,}000\ J$$

Now use $F = QE$ to find the force:

$$F = 1.5 \times 10^{-13}\ C \times 240000\ J$$
$$F = 3.6 \times 10^{-8}\ N$$

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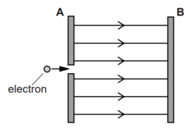

Fig. 1.1

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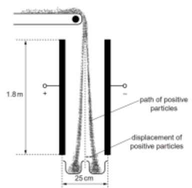

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The potential difference across the plates is 60 kV. The separation between the plates is $25\ cm$ and each plate has length $1.8\ m$. The mineral particles fall through the air between the plates with a terminal velocity of $1.2\ m\ s^{-1}$. Each mineral particle has a charge of magnitude $1.5 \times 10^{-13}\ C$ and a mass of $8.0 \times 10^{-7}\ kg$.

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Electric Fields

Exam Style Question 1

(d) (ii) Calculate the horizontal displacement of a positively charged mineral particle after a $1.8\ m$ fall through the electric field of the plates. Ignore any horizontal drag forces due to air.

As the mineral particles fall through the air with a terminal velocity they have a constant acceleration so we can use SUVAT equations. However we don't know the time and acceleration so calculate those first.

Step 1: Find the time using $t = \frac{d}{s}$

$$t = \frac{1.8\ m}{1.2\ m\ s^{-1}} = 1.5\ s$$

Step 2: Calculate the horizontal acceleration using $F = ma$ and rearrange for a:

$$a = \frac{F}{m} = \frac{3.6 \times 10^{-8}\ N}{8.0 \times 10^{-7}\ kg}$$
$$a = 0.045\ m\ s^{-2}$$

Step 3: Now use SUVAT:

$s = ut + \frac{1}{2}at^2$ and $u = 0$

$$\therefore s = \left(\frac{1}{2}\right)(0.045\ m\ s^{-2})(1.5\ s)^2$$
$$s = 0.050625\ m$$
$$s = 5.1 \times 10^{-2}\ m$$

Electric Fields

Exam Style Question 2

Fig. 2.1 shows two identical negatively charged conducting spheres.

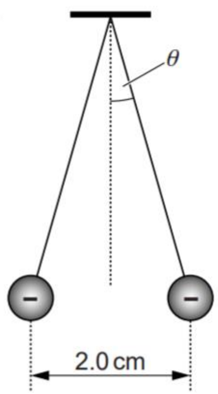


Fig. 2.1

The spheres are tiny and each is suspended from a nylon thread. Each sphere has mass $6.5 \times 10^{-5}\ kg$ and charge $-2.8 \times 10^{-9}\ C$. The separation between the centres of the spheres is $2.0\ cm$.

(a) Calculate the number of excess electrons on the surface of each sphere.

(b) Calculate the repulsive electrical force acting on each sphere.

(c) Each sphere is in equilibrium and experiences three forces. One of the forces acting on each sphere is the electrical force. State the other two forces acting on each sphere.

Electric Fields

Exam Style Question 2

(a)Calculate the number of excess electrons on the surface of each sphere.

$$number = \frac{2.8 \times 10^{-9}\ C}{1.6 \times 10^{-19}\ C}$$

$$number = 1.75 \times 10^{10}$$

There are 1.75×10^{10} excess electrons on the surface of each sphere.

(b) Calculate the repulsive electrical force acting on each sphere.#

Use $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

$$F = \frac{(2.8 \times 10^{-9}\ C)(2.8 \times 10^{-9}\ C)}{(4\pi)(8.85 \times 10^{-12} Fm^{-1})(2.0 \times 10^{-2}\ m)^2}$$

$$F = 1.76 \times 10^{-4}\ N$$

(c) Each sphere is in equilibrium and experiences three forces. One of the forces acting on each sphere is the electrical force. State the other two forces acting on each sphere.

Tension and weight.

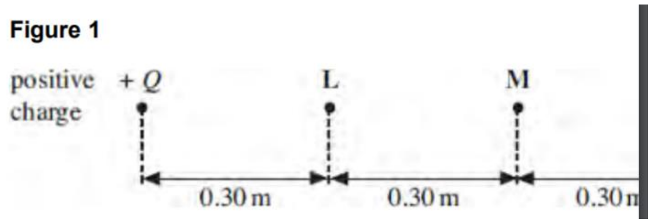
Electric Fields

Exam Style Question 3

(a) Define the electric potential at a point in an electric field.

(b) Figure 1 shows part of the region around a small positive charge.

Figure 1



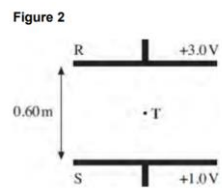
(b) (i) The electric potential at point L due to this charge is $+3.0\ V$. Calculate the magnitude Q of the charge.

(ii) Show that the electric potential at point N, due to the charge, is $+1.0\ V$.

(iii) Show that the electric field strength at point M, which is mid-way between L and N, is $2.5\ Vm^{-1}$.

(c) R and S are two charged parallel plates, $0.60\ m$ apart, as shown in Figure 2. They are at potentials of $+3.0\ V$ and $+1.0\ V$ respectively.

Figure 2



(i) On Figure 2, sketch the electric field between R and S, showing its direction.

(ii) Point T is mid-way between R and S.

Calculate the electric field strength at T.

(iii) Parts (b)(iii) and (c)(ii) both involve the electric field strength at a point mid-way between potentials of $+1.0\ V$ and $+3.0\ V$. Explain why the magnitudes of these electric field strengths are different.

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Electric Fields

Exam Style Question 3

(a)Define the electric potential at a point in an electric field.

Electric potential (V) at a point in a field is the energy needed to move a unit positive charge from infinity to that point.

(b) (i) Calculate the magnitude Q of the charge.

Use $V = \frac{Q}{4\pi\varepsilon_0 r}$ and rearrange for Q

$$Q = 4\pi\varepsilon_0 r\ V$$
$$Q = (4\pi)(8.85 \times 10^{-12}\ Fm^{-1})(0.30\ m)(3.0\ V)$$
$$Q = 1.0 \times 10^{-10}\ C$$

(ii) Show that the electric potential at point N, due to the charge, is $+1.0\ V$.

We know $V \propto \frac{1}{r}$

$$\therefore V = k\frac{1}{r}$$

We have information about point L and we can use that information to calculate the constant:

$$3.0\ V = \frac{k}{0.3\ m}$$
$$k = 0.9$$
$$V_N = \frac{0.9}{0.9\ m} = 1.0\ V$$

(iii) Show that the electric field strength at point M, which is mid-way between L and N, is $2.5\ Vm^{-1}$.

Use $\mathrm{E} = \frac{Q}{4\pi\varepsilon_0 r^2}$

$$E = \frac{1.0 \times 10^{-10}\ C}{(4\pi)(8.85 \times 10^{-12}\ F\ m^{-1})(0.60\ m)^2}$$
$$E = 2.4977 \ldots = 2.50\ V\ m^{-1}$$

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Electric Fields

Exam Style Question 3

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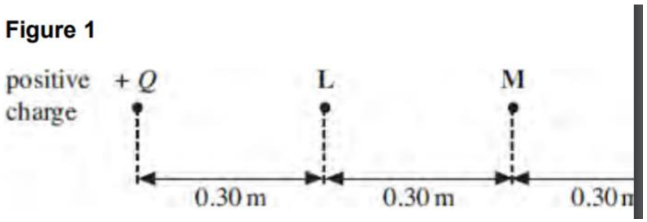

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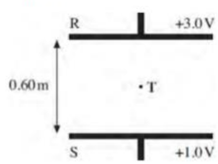

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Electric Fields

Exam Style Question 3

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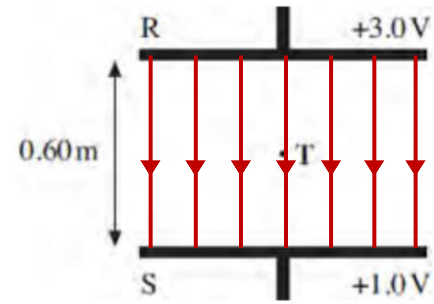

(ii) Calculate the electric field strength at T.

Use $E = \frac{V}{d}$

But we know T is midway between R and S therefore the potential difference at $T = 2.0V$

$$E = \frac{2.0\ V}{0.60\ m} = 3.33\ V\ m^{-1}$$

(iii) Explain why the magnitudes of these electric field strengths are different.

Part (b) is a radial field whilst part (c) is a uniform field.

Please see '7.2.1 Electric Fields notes' pack for revision notes.

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