Electric Fields

AS Level Physics 9702

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By the end of this topic I can...

- define electric field strength and draw field lines
- use $E = V/d$ for a uniform field
- analyse charges in equilibrium or deflected in a uniform field

Electric field strength

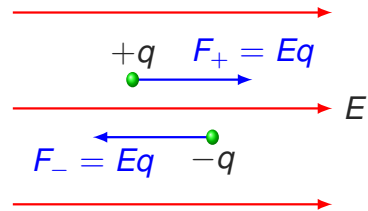
Field strength

Force per unit positive charge.

- vector: direction of force on a positive charge
- unit: N C^{-1} = V m^{-1}

$$E = \frac{F}{q}$$

$$F = Eq$$



Example: force on an electron

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$$F = Eq = 1500 \times 1.60 \times 10^{-19} \quad \Rightarrow \quad F = 2.4 \times 10^{-16}\ \text{N}$$

Field lines

- tangent gives the direction of E
- closer lines: stronger field
- start on positive charge, end on negative charge
- never cross; meet conductors at right angles

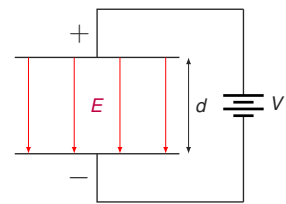
Uniform field

Parallel plates

Parallel, equally spaced lines between plates.

- points from high to low potential

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



Example: field between plates

Example: field between plates

$$E = \frac{V}{d} = \frac{30 - (-50)}{0.10} = 800\ \mathrm{N\,C^{-1}}.$$

Example: proton in a field

Example: proton in a field

electric field strength: $E = \frac{V}{d} = \frac{36}{1.5 \times 10^{-2}} = 2400$ N C^{-1}
electric force: $F_E = Eq = 2400 \times 1.60 \times 10^{-19} \approx 3.84 \times 10^{-16}$ N
weight of the proton: $W = mg = 1.67 \times 10^{-27} \times 9.81 \approx 1.64 \times 10^{-26}$ N
this shows electric force on proton are much stronger than gravitational forces
when dealing with motion of sub-atomic particles (e.g., protons, electrons, etc.) in an electric field, effects of gravity can therefore be ignored

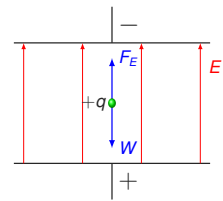
Charge in equilibrium

Equilibrium

Electric force balances weight.

- force upward: negative charge needs a downward field

$$Eq = mg$$



Example: oil droplet

An oil droplet of mass 0.040 g and charge -20 nC is at rest between plates 8.0 cm apart. (a) Find the strength and direction of the field. (b) What p.d. is needed? (c) What happens if the plate separation is reduced?

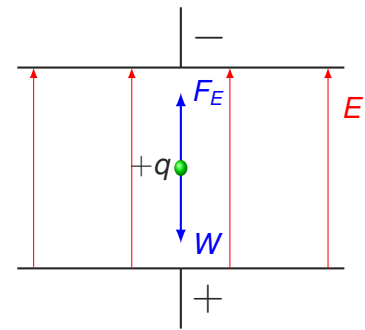
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(a) $F_{\mathrm{E}} = mg = 0.040 \times 10^{-3} \times 9.81 = 3.9 \times 10^{-4}$ N, so $E = \dfrac{F}{q} = \dfrac{3.9 \times 10^{-4}}{20 \times 10^{-9}} = 1.96 \times 10^{4}\ \mathrm{N\,C^{-1}}$. The force must be up and the charge is negative, so the field points downwards.

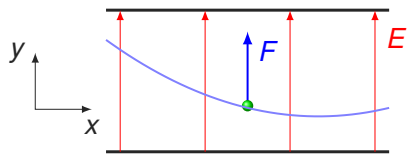
(b) $V = Ed = 1.96 \times 10^{4} \times 0.080 = 1.6 \times 10^{3}$ V.

(c) A smaller d gives a larger E, so $F_{\mathrm{E}} > mg$ and the droplet accelerates upwards.



Deflection in a uniform field

- perpendicular to field: constant velocity
- along field: constant acceleration $a = Eq/m$
- path is a parabola

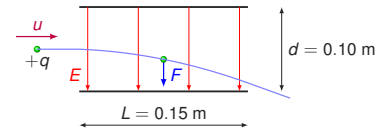


Example: proton and electron

A proton enters a uniform field of strength 1.0×10^4 N C^{-1} at an initial velocity of 5.0×10^5 m s^{-1}. The initial direction of motion is at right angles to the field. The dimensions of the field are shown in the diagram. (a) What is the time taken for the proton to pass through the field? (b) What is the deviation in the direction of the field during this time? (c) If an electron enters the field with the same initial velocity, describe how the deflection of the electron compares with that of the proton.

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constant horizontal velocity, so time taken:

$t = \frac{L}{u} = \frac{0.15}{5.0 \times 10^5} = 3.0 \times 10^{-7}$ s

constant acceleration in direction of field:

$a = \frac{F}{m} = \frac{Eq}{m} = \frac{1.0 \times 10^4 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}} \approx 9.58 \times 10^{11}$ m s^{-2}

Key equations

field strength $E = \frac{F}{q}$

uniform field $E = \frac{V}{d}$

equilibrium $Eq = mg$