Electric Fields Notes

1 Static Electricity

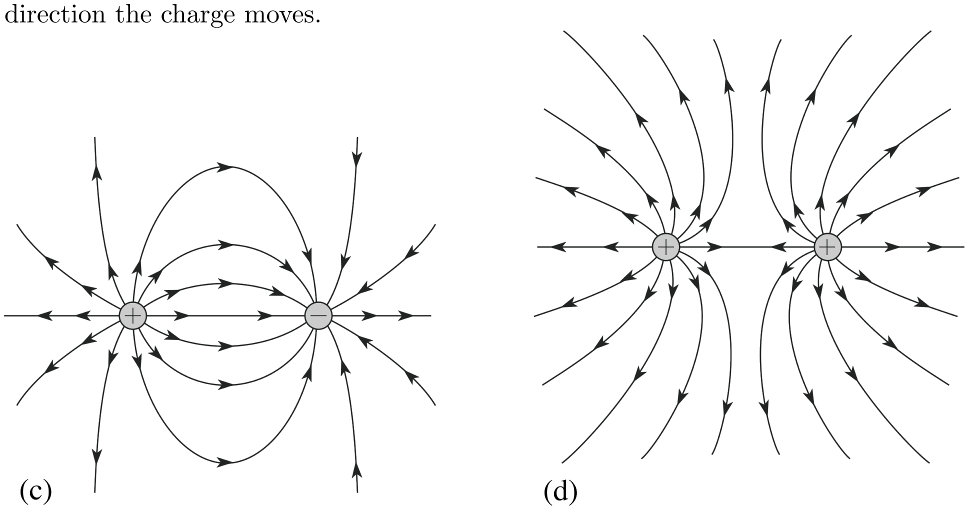
Like charges repel; unlike charges attract
Electrical conductors have many free electrons, these can move in the material and are not attached to any atom. To charge a metal, it must be isolated from the earth to stop the charge being neutralised by electrons from the earth. It can then be charged by direct contact with a charged object. If an isolated conductor is charged then earthed, the electrons will transfer to neutralise it.
Electrically insulating materials do not contain free electrons, all electrons are attached to atoms. Some insulators can be charged easily because their surface atoms easily gain or lose electrons.
A **gold leaf electroscope** is used to detect charge. If it is in contact with charge the gold leaf and the metal stem have the same charge and so repel.

2 Shuttling ball experiment

A ball swinging between one positively charged plate and one negatively charged plate will lose electrons at the positive plate and so be repelled towards the negative plate where it will pick up electrons and gets repelled away, and so the process repeats.

3 Field lines and patterns

Electric fields surround each charged object, if a small charged object is placed near a larger same charged object the path the small charge will follow is called a **line of force** or **field line**. The direction of an electric field is the direction the charge moves.



4 Electric field strength

The field strength of a uniform field is constant at all points.
The electric field strength, E, at a point in the field is defined as the force per unit charge on a positive test charge placed at that point.
The unit of electric field strength is Newton per coulomb NC^{-1}
If a positive charge of **Q** us acted on by a force **F** the electric field strength at that point is
$E = \frac{F}{Q}$

5 The electric field between two parallel plates

Field lines between two parallel plates are:

- Parallel to each other
- At right angles to the plates
- From the positive plate to the negative plate

- Uniform

  $E = \frac{V}{d}$
  V=Potential difference between plates
  d= Separation between plates
  Proof:
  $F = QE$
  $Workdone = Force \times Distance$
  $d = QEd$

  $V = \frac{W}{Q} = \frac{QEd}{Q} = Ed$
  $E = \frac{V}{d}$

6 Field Factors

The greater the charge on a body, the stronger the electric field is. The more concentrated the charge is on the surface, the greater the strength of the electric field is above the surface.

For a charge,**Q**, on a plate of surface area,**A**, the electric field is proportional to $\frac{Q}{A}$

Including a constant of proportionality the equation gives $\frac{Q}{A} = \epsilon_0 E$

The unit of ϵ_0 is Fm^{-1} and is called the **Permittivity of free space** as it represents the charge per unit area on a surface in a vacuum that produces an electric field strength of one volt per one metre between the plates.

7 The Van de Graff generator

A Van de Graff generator works by rubbing a rubber belt against a pad up to a metal dome. This increased the PD between the dome and the earth until sparks start.
The electric potential at a certain position in any electric field is defined as the work done per unit charge on a positive test charge when it is moved from infinity to that position.
$E_P = QV$ or $V = \frac{E_P}{Q}$

8 Potential gradients

Equipotentials are surfaces of constant potential. A test charge moving along an equipotential has constant potential energy. The **potential gradient** at any position in an electric field is the change in potential per unit change of distance in a given direction.
If the field is **non-uniform** the potential gradient varies according to position and direction. The closer the equipotentials are, the greater the potential gradient at right angles to the equipotentials.
If the field is **uniform** the equipotentials between the plates are equally spaced lines parallel to the plates.
In a uniform field the potential gradient is

- Constant
- Potential increases in the opposite direction to the electric field
- Equal to $\frac{V}{d}$

  The electric field strength is equal to the negative of the potential gradient

  The potential gradient at any position in an electric field is $\frac{\Delta V}{\Delta x}$ where ΔV is the potential difference between two points and ΔX is the distance between the points.
  $E = -\frac{\Delta V}{\Delta X}$

9 Coulomb's law

$F = \frac{KQ_1Q_2}{r^2}$
F=Force between two point charges
K=$\frac{1}{4\pi\epsilon_0}$
Q_1=Point charge 1
Q_2=Point charge 2
r=Distance between the two point charges
$F = \frac{1}{4\pi\epsilon_0}\frac{Q_1Q_2}{r^2}$

10 Charged particles in electric fields

10.1 Force

Force is the same throughout the journey.
Calculated by

- $f = EQ$
- $E = \frac{V}{d}$

10.2 Velocity

Horizontal velocity is constant
Vertical velocity increases as the particle passes through the field

11 Point charges

A point charge is a charge where the distances considered are much larger than the object, meaning the charge can be thought of as being in one place.
The electric field strength at a distance r from Q is:
$E = \frac{Q}{4\pi\epsilon_0 r^2}$
Note that Q is negative

12 Electric field strength as a vector

In general, the electric field strength is the vector sum of the individual electric field strengths

12.1 Forces in the same direction

$F = F_1 + F_2 = qE_1 + qE_2$
Therefore $E = \frac{F}{q} = \frac{qE_1 + qE_2}{q} = E_1 + E_2$

12.2 Forces in opposite directions

$F = F_1 - F_2 = qE_1 - qE_2$
Therefore $E = \frac{F}{q} = \frac{qE_1 - qE_2}{q} = E_1 - E_2$

12.3 Forces at right angles to each other

$F^2 = {F_1}^2 + {F_2}^2$
$E = \frac{F}{q}$
$E^2 = {E_1}^2 + {E_2}^2$

13 More about radial fields

The electric field lines surrounding a point charge are radial.
Coulomb's law and Newton's law are similar as they have inverse square relationships.
The equation for electric potential near a point charge and gravitational potential near a point mass are also very similar.

14 The relationship between electric field strength and electric potential

Electric field strength = -gradient of a potential vs distance graph.
Change in potential = Area under an electric field vs distance graph.

15 Comparing electric fields and gravitational fields

	Gravitational Fields	Electrostatic fields
	Similarities	
Line of force	Path of a free test mass in the field	Path of a free test charge in the field
Inverse square law of gravitation	Newton's law of gravitation	Coulomb's law of force
Field strength	$g = \frac{F}{m}$	$E = \frac{F}{q}$
Unit of field strength	Nkg^{-1} or ms^{-2}	NC^{-1} or Vm^{-1}
Uniform fields	G is the same everywhere and field lines are parallel and equally spaced	E is the same everywhere and field lines are parallel and equally spaced
Unit of potential	Jkg^{-1}	JC^{-1}
Potential energy of two point mass or charges	$E_P = \frac{-Gm_1m_2}{r}$	$E_P = \frac{Q_1Q_2}{4\pi\epsilon_0 r}$
	Differences	
Action at a difference	Between any two masses	Between two charged objects
Force	Attracts only	Unlike charges attract; like charges repel
Constant of proportionality in force law	G	$\frac{1}{4\pi\epsilon_0}$