Electric Fields

Proudly made with LaTeX

Benedict Lee, Zeng Fan Pu

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Expectations

- Please pay attention to this electrifying presentation
- If not you'll miss out on a lot of important content, such as this joke:
  Q: What is the name of the first electricity detective?
  A: Sherlock Ohms

Analogy with Gravity

- Please flip to pg. 26 of your notes
- Notice how similar the laws governing electric fields and gravitational fields are?
- Please keep that in mind as we go through the presentation!

Charges

- Two kinds of charges: Positive charge and negative charge
- Like charges repel, unlike charges attract
- To charge a body negatively, we can add electrons or *(rarely)* remove protons
- To charge a body positively, we can remove protons or *(rarely)* add electrons

	Charge	Mass
Electron	-e = 1.60 x 10-19 C	9.11 x 10-31 kg
Proton	+e = 1.60 x 10-19 C	1.67 x 10-27 kg
Neutron	No charge (0 C)	1.68 x 10-27 kg

Table : Let's see who can memorize this table the fastest

Principle of Conservation of Charges

Principle of Conservation of Charges

The principle of conservation of charges states that charges cannot be created nor destroyed. Hence, for any closed system, the sum of all electric charges must be constant.

Principle of Conservation of Charges

If a system starts out with an equal number of positive and negative charges, theres nothing we can do to create an excess of one kind of charge in that system unless we bring in charge from outside the system (or remove some charge from the system). Likewise, if something starts out with a certain net charge, say $+100$ e, it will always have $+100$ e unless it is allowed to interact with something external to it.

Principle of Quantization of Charges

The charge on a single electron is $q_e = 1.60 \cdot 10^{19} C$ (remember that $1C = 6.242 \cdot 10^{18} e$). All other charges in the universe consist of an integer multiple of this charge. This is known as charge quantisation:

$$Q = nq_e$$

Electrons and protons are not the only things that carry charge. Other particles (positrons, for example) also carry charge in multiples of the electronic charge.

Electric Field

Definition

An electric field is a region of space such that when a charge is placed at a point in the region, it would experience an electrical force acting on it.

Electric Field Strength

Definition

The electric field strength at a given point is the force per unit positive charge that acts on a small test charge placed at that point.

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

Rearranging, we get

$$F = q \cdot E$$

Direction of force on charge is dependent on the sign of the charge!
Let's work out Example 1 together.

Drawing Electric Field Lines

- Electric field lines always extend from a positively charged object to a negatively charged object, from a positively charged object to infinity, or from infinity to a negatively charged object.
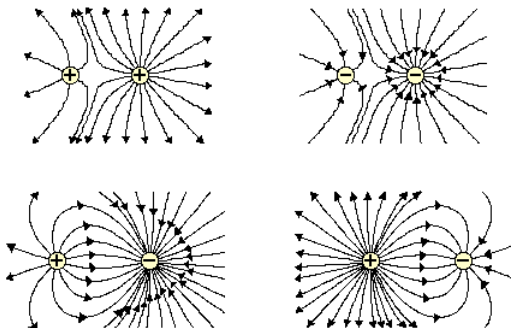

Figure : Representing Electric Field Lines

Drawing Electric Field Lines

- Number of lines drawn is proportional to magnitude of the charge

Electric Field Line Patterns for Objects with Unequal Amounts of Charge
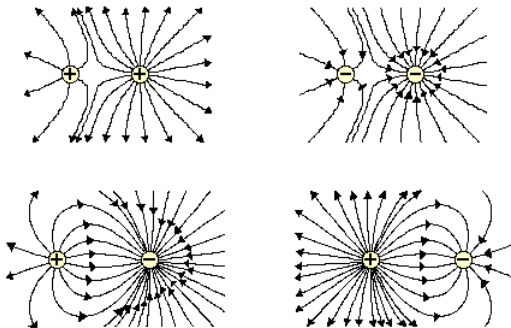
Figure : Representing Electric Field Lines

Drawing Electric Field Lines

- Field lines do not cross because the direction of E at a point is unique.

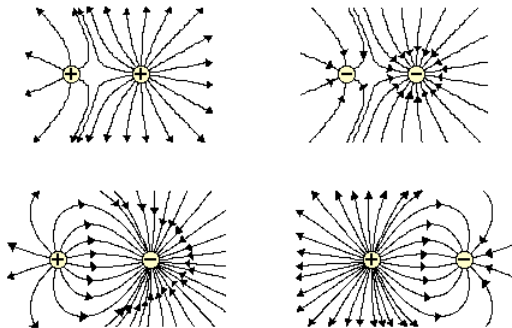Electric Field Line Patterns for Objects with Unequal Amounts of Charge

Figure : Representing Electric Field Lines

Drawing Electric Field Lines

- At locations where electric field lines meet the surface of an object, the lines are perpendicular to the surface

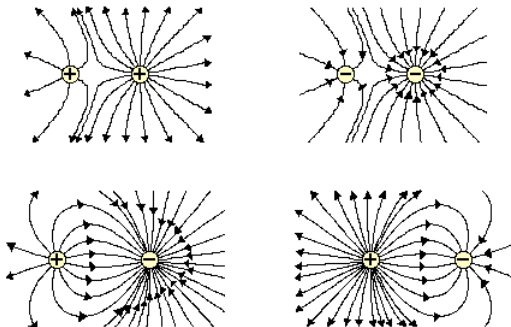Electric Field Line Patterns for Objects with Unequal Amounts of Charge

Figure : Representing Electric Field Lines

Electric Field Lines as an Invisible Reality

- Electric field lines are not real!
- The concept of an electric field arose as scientists attempted to explain the action-at-a-distance that occurs between charged objects
- First introduced by 19th century physicist Michael Faraday
- Rather than thinking in terms of one charge affecting another charge, Faraday used the concept of a field to propose that a charged object (or a massive object in the case of a gravitational field) affects the space that surrounds it
- As another object enters that space, it becomes affected by the field established in that space
- Viewed in this manner, a charge is seen to interact with an electric field as opposed to with another charge

Are you still with us?

Where do electrons play football? On an electric field!

Force between Two Point Charges

Coloumb's Law

The magnitude of the electrical force acting between two point charges is proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them.

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{QQ\prime}{r^2}$$

Permittivity

- Permittivity is the measure of the resistance that is encountered when forming an electric field in a medium. In other words, permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium.
- ϵ_0 is equal to approximately $8.85 \cdot 10^{12}$ farad per meter Fm^{-1} in free space (a vacuum)

Principle of Superposition

Principle of Superposition (for electrical forces)

The resultant force on any one of them equals to the vector sum of the forces exerted by the other individual charges.

Let's work out Example 2 together.

Electric Field around a Point Charge

- Recall Coloumb's Law

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{Qq}{r^2}$$

Electric Field Strength

The magnitude of the electric field strength of a point charge Q at a distance r away from the field is

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

$$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2}$$

Electric Field around a Point Charge

- Analogous to gravitational field strength
- Instead of $g = \frac{F_g}{m}$, we now have $E = \frac{F_E}{q}$!

Electric Field around a Point Charge

- E is a vector quantity, and its direction is at a point is given by the direction of the force experienced by a positive charge if it is placed at that point.
- The field is radial of a point charge. It is directed uniformly in all directions outward from the centre if Q is a positive charge and inward toward the centre if Q is a negative charge. At all points that are equal distance away from Q the magnitude of E is the same.

Principle of Superposition (for Electric Field)

Principle of Superposition (for Electric Field)

The resultant electric field E at a point P in an electric field is the vector sum of the fields at P due to each point charge in the system.

- Very intuitive, right?
- Let's now work on Example 3 together.

Electric Potential

Definition of Electric Potential

The electric potential V, at a point in an electric field, is defined as the work done per unit positive charge, by an external force, in moving a small test charge from infinity to that point in the electric field.

$$V = \frac{W}{q}$$

- SI unit of electric potential is JC^{-1} but it is more common to use the volt, V

- first
- second

Blocks

Block Title

You can also highlight sections of your presentation in a block, with it's own title

Theorem

There are separate environments for theorems, examples, definitions and proofs.

Example

Here is an example of an example block.

Summary

- The first main message of your talk in one or two lines.

- The second main message of your talk in one or two lines.

- Perhaps a third message, but not more than that.

- Outlook
  - Something you haven't solved.
  - Something else you haven't solved.

For Further Reading I

📕 A. Author.
Handbook of Everything.
Some Press, 1990.

📄 S. Someone.
On this and that.
Journal of This and That, 2(1):50–100, 2000.