Electric Force between Two Point Charges

- When calculating force between 2 point charges, air is treated as a vacuum.
  - Hence relative permittivity of free space is used.

    $\varepsilon_0 = 8.85 \times 10^{-12}$ ______ units ↑

- For a point outside a spherical conductor, the charge of the sphere may be considered to be a point charge at its center.
- A uniform spherical conductor is one where its charge is distributed evenly.
- The electric field lines around a spherical conductor are therefore identical to those around a point charge.

- An example of a spherical conductor is a charged sphere.
- The field lines are radial and their direction depends on the polarity.

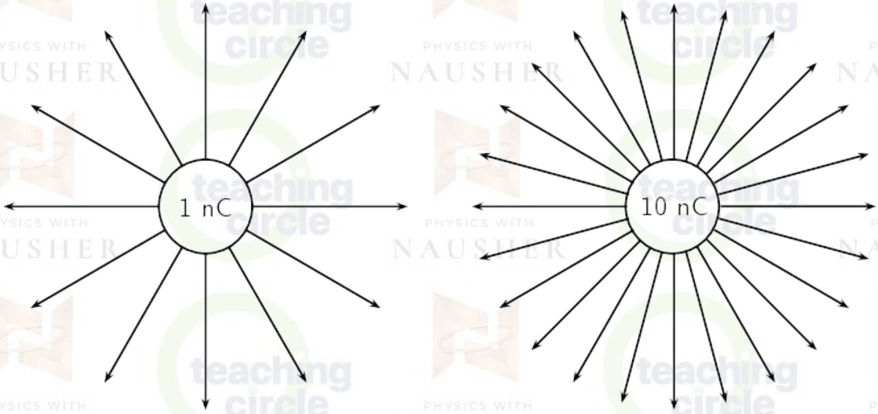
e.g if a sphere is positively charged, field lines are directed away from the center of the sphere.

if a sphere is negatively charged, field lines are directed towards the center of the sphere.

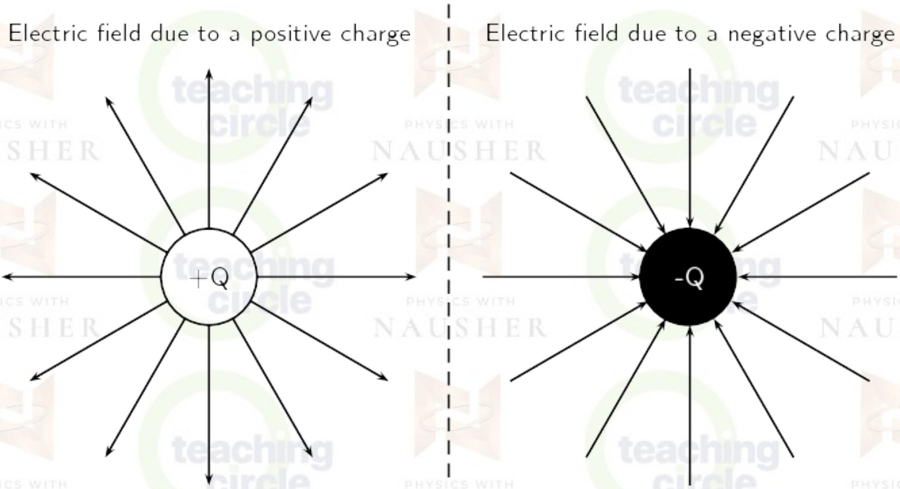
Note: <u>Comparison with gravitational field lines</u>

Similarities:

- Both types of field lines show the direction of force.
- Density of the field lines indicates the strength of the field: closer lines represent stronger fields.
- Both types of field lines are radial. They are perpendicular to the surface.



Density of field lines indicates strength.



Field lines are radial

Differences:

- Gravitational field lines are always inward pointing. Electric field lines point away from positive charges and point towards negative charges.

Comparison with gravitational fields

Similarities:

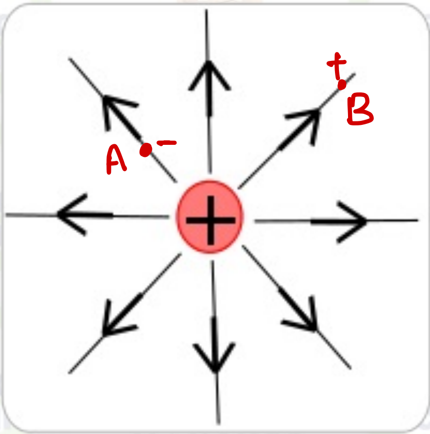
- Both types of fields decrease in strength as distance from the source increases, following inverse square law.

Differences:

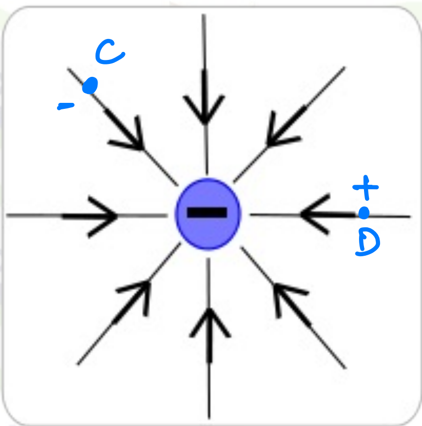
- The source of gravitational fields is mass, the source of electric field is charge.
- Gravitational fields are always attractive, electric fields ________________ ________ depending on polarity of charge.

Coulomb's Law

- All charged particles generate an electric field. This field exerts a force on charged particles nearby.



Label the direction of force on each charged particle A, B, C, D.



Coulomb's Law

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

$$F = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{r^2}$$

P.S: vector

F: force (N)

Q_1, Q_2: point charges (C)

r: separation between the charges (m)

ε_0: permittivity of free space.

8.85×10^{-12} ____________

↑ unit.

Note: ε_0 represents the capability of a field to spread in vacuum. Air is assumed as vacuum as well.

- All other materials have a higher permittivity.
- This is because they have atoms which can polarize, increasing the materials ability to store electrical energy.
- Hence vacuum has lowest possible permittivity.

- Which material would have a higher ε

  A. Wood

  B. Water

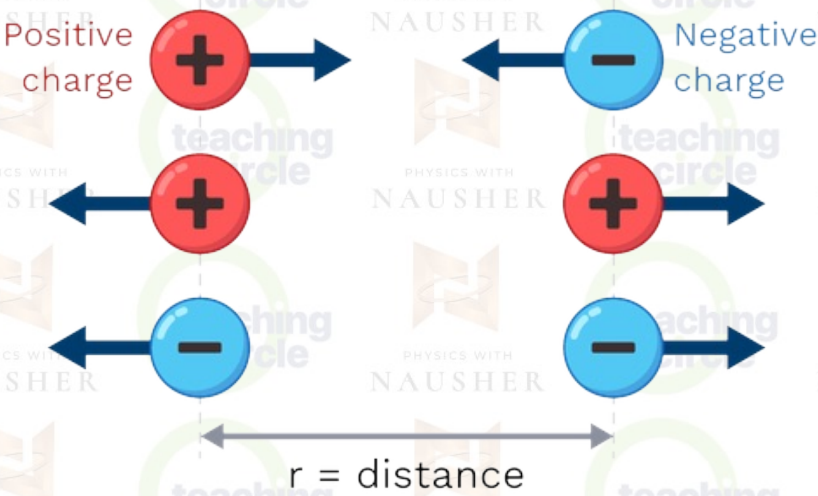
- For calculations:

$$k = \frac{1}{4\pi\varepsilon_0} = \frac{1}{4\pi(8.85\times10^{-12})}$$

$$k = 8.99\times10^{9}$$ ________

units ↗

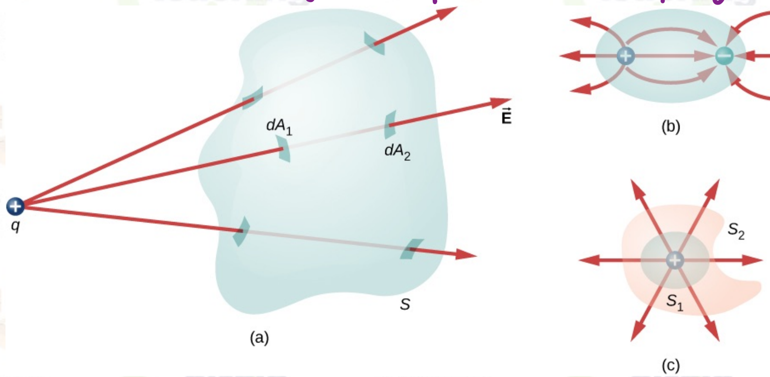
Working:



- Electric force can be attractive or repulsive
- Like charges / Similar charges:
  - product Q_1Q_2 is +ve
  - A positive force means repulsion.
- Unlike charges / opposite charges:
  - product Q_1Q_2 is −ve
  - A negative force means attraction.

Note:

- ε_0, k are given in Data booklet so don't worry if you can't memorize them.
- Coulomb's law applies to charged spheres whose size is much smaller than their separation. Only then, point charge approximation is valid.
- r is the distance from center of charge 1 to center of charge 2
- Coulomb's law cannot be applied to charges distributed on irregularly shaped objects. Hence not in syllabus. You will do this if you pursue physics/engineering in college.



Question:

A proton is placed **3.0 mm** from a copper nucleus in a vacuum.

Taking them as point charges, calculate the magnitude of the electric force acting between the proton and the copper nucleus.

Data:

- Proton number of copper = **29**
- Charge of a proton = 1.6×10^{-19} C

Solution:

We use **Coulomb's Law** to calculate the electric force:

$$F = k\frac{q_1 q_2}{r^2}$$

Step 1: Calculate the total charge of the copper nucleus

The copper nucleus has 29 protons, so:

$$q_2 = 29 \times 1.6 \times 10^{-19} = 4.64 \times 10^{-18}\,\mathrm{C}$$

Step 2: Substitute values into the formula

$$F = \left(8.99 \times 10^{9}\right) \frac{\left(1.6 \times 10^{-19}\right)\left(4.64 \times 10^{-18}\right)}{\left(3.0 \times 10^{-3}\right)^2}$$

Step 3: Perform the calculations

1. Multiply the charges:

$$q_1 \cdot q_2 = \left(1.6 \times 10^{-19}\right)\left(4.64 \times 10^{-18}\right) = 7.424 \times 10^{-37}\,\mathrm{C}^2$$

2. Square the distance:

$$r^2 = \left(3.0 \times 10^{-3}\right)^2 = 9.0 \times 10^{-6}\,\mathrm{m}^2$$

3. Divide by r^2:

$$\frac{q_1 q_2}{r^2} = \frac{7.424 \times 10^{-37}}{9.0 \times 10^{-6}} = 8.249 \times 10^{-32}\,\mathrm{C}^2/\mathrm{m}^2$$

4. Multiply by k:

$$F = \left(8.99 \times 10^{9}\right)\left(8.249 \times 10^{-32}\right) = 7.42 \times 10^{-22}\,\mathrm{N}$$