Coulomb's Law

The number of electrons in an electrically neutral body is equal to the number of positive charges. However when a body is charged, the electrical effects are due only to the unbalanced surplus elementary charges on the surface. We call these the excess elementary charges . Charge is commonly measured in one of two ways: 1) as a number of excess elementary charges, and 2) in coulombs A coulomb is the charge of a standard number of elementary charges.

6.25×10^{18} elementary charges = 1 coulomb
1.6×10^{-19} coulombs = 1 elementary charge

If a metal sphere is charged, all of the excess elementary charges on the surface of the sphere can be considered as acting from the centre of the sphere. Thus, for electrostatics, the distance between two spheres is the distance between the centres of the two spheres.

COULOMB'S LAW

The force of attraction or repulsion between two charges q_1, coulombs and q_2 coulombs situated a distance r metres apart is proportional to the product of the charges and inversely proportional to the square of the distance between the charges.

$$F = \frac{kq_1q_2}{r^2}$$

When two conducting surfaces touch, the charge on them is distributed over both surfaces. For spheres, the ratio of the charges on each after touching is equal to the ratio of their radii. Thus if a charged sphere is touched by a similar uncharged sphere, the charge spreads out uniformly so that exactly half the original charge is on each sphere.

ELECTRIC FORCE

The electric force at any point in a field or fields is the vector sum of the individual forces of attraction or repulsion acting on a small positive charge at that point.

ELECTRIC FIELD

An electric field is the space around an electrically charged body in which it can exert a force on another charged body.

Electric field strength or field intensity at any point in an electric field, due to a charged body, is represented in magnitude and direction by the force per unit charge that would act on a small positive charge placed at that point in the field.

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

where E is the field strength, F is the force, and Q is the charge.

Electric field strength is measured in $\frac{N}{C}$.

The strength and direction of an electric field may be represented by electric lines of force; the strength is represented by the number of lines per unit area, and the direction is represented by that in which a positive charge would move.

ELECTRIC POTENTIAL

As potential energy can be considered as the product of force and distance,

$$E_P = F \quad r$$

$$E_P = \frac{kq_1q_2}{r^2} \quad r$$

$$E_P = \frac{kq_1q_2}{r}$$

The electric potential is defined as the electric potential energy per unit charge:

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

The difference in electric potential between two points is called the potential difference, or "voltage", as it is commonly referred to. The potential difference is defined as the work done per unit charge in moving a small positive charge *q* from one point to another.

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

Potential difference is measured in $\frac{J}{C} = V$ (the volt).

The potential difference is a potential rise if work is done against the field, and a potential drop if work is done with the field.

The Earth is taken as an arbitrary zero of potential; then the potential at a point is the potential difference between it and the Earth.

The electric field can also be defined in terms of

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

and also measured in $\frac{V}{m}$, particularly for the field between parallel charged plates.

CURRENT

If an electric field is applied to the ends of a substance containing free electrons, there will be adrift of these free electrons through it from the negative end to the positive end. Such a substance is *a conductor* and the drift of electrons is the electric *current I,* which is defined as the rate of flow of electric charge Δq.

$$I = \frac{\Delta q}{\Delta t}$$

Thus the units of current are $\frac{C}{s} = A$ (amperes)

Current cannot flow through an insulator because an *insulator contains no free electrons.* The greater the number of free electrons the better the conductor. As the free electrons move along the conductor, their places are taken by those from the applied electric field.

Exercises using **COULOMB'S LAW**

1. How many electrons give a charge equal to 8.0×10^{-18} C?

3. Is it possible to have a charge of 4.8×10^{-18} C?

4. Is it possible to have a charge of 6.0×10^{-19} C?

5. Is it possible to have a charge of 4.0×10^{-4} C?

6. What is the charge in coulombs on 100 electrons?

7. How many excess elementary charges would be required to form a charge of 200 C?

8. Calculate the force acting between two charges of 0.5 C each placed 10 m apart in air.

9. What is the force acting between two charges, one 0.25 C, the other 0.05 C placed, in air, 30 m apart ?

10. Calculate the force acting between two charges of magnitude 0.001 C and 0.0002 C placed 20 m apart in air.

In questions 11 to 14 assume the charges are all negative charges.

11. One metal sphere with 2×10^{-10} C is touched by another sphere, identical in size to the first sphere, but with a charge of 8×10^{-9} C.

    (a) What is the total charge when they are touching? (b) What is the charge on each when they are subsequently separated?

12. If a metal sphere *A* has a charge of 4×10^{10} e *($1\ e = 1.6 \times 10^{-19}$ C)* and a radius of 2 m, and metal sphere *B* has a charge of 12×10^{10} e and a radius of 4 m, what is the charge on sphere *A* after the two have been touched and separated?

13. Two solid spheres are made of the same metal. Sphere *A* has 8 times the volume of sphere *B.* They are both charged with 5×10^{-11} C. What charge is on *A* after the spheres have been touched and separated?

14. Find the field strength at a point 100 m from a point charge of 0.002 C.

15. What is the strength of the electric field at a point 1.0 m from a point charge of 4×10^{-6} C?

16. What is the field strength 3 m from a charge of 0.0001 C?

17. What force would act on a charge of 0. 1 C in a field of 105 N/C?

18. Calculate the force that would act in a field of 200 N/C on a charge of 0.01 C placed in that field.

19. If it takes 4.0 J of energy to move a charge of 0.0005 C from point *A* to *B*, what is the potential difference between *A* and *B*?

20. What is the potential difference between two points if it takes 10 J of work to move 0.02 from one to the other?

21. Calculate the amount of work needed to bring a charge of 1.8×10^{-6} C from A to *B* if the potential difference between A and *B* is 10,000 V.

22. Find the amount of work done in moving a charge of 4.5×10^{-3} C between two points whose potential difference is 2000 V.

23. Calculate the potential difference between two points distant 30 m and 45 m respectively from a point charge of 10^{-4} C.

24. What is the potential difference between two points 50 cm and 75 cm from a point charge of 2×10^{-6} C?

25. Find the potential at a point 1 m from a point charge of 4 µC.

26. A 6 V battery joins two parallel metal plates, which are 1.0 m apart. There are two points, *X* and *Y*, which are between the plates and 0.40 m from each other.

    (a) What is the electric field strength at point *X*?
    (b) If a charge of 2×10^{-11} C is placed at *Y*, what electric force acts on the charge?
    (c) How much work is done, if the charge at *Y* moves to point *X*?