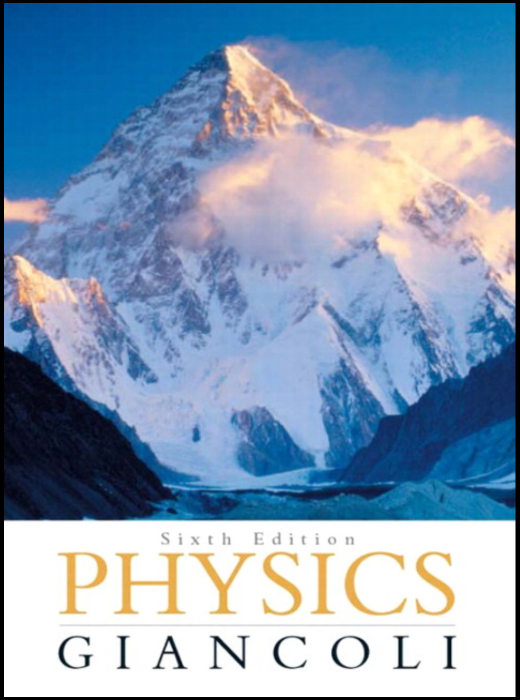


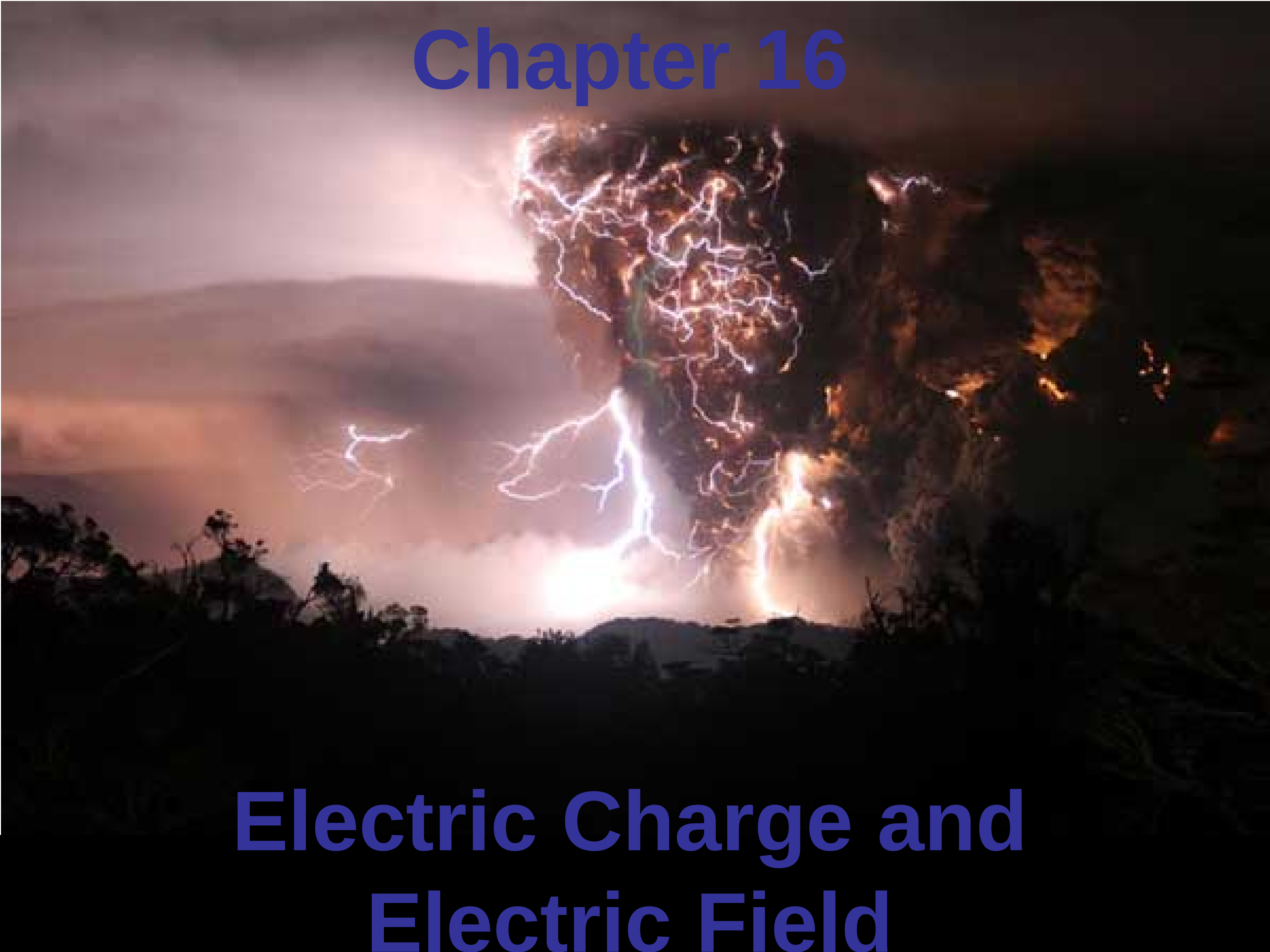
Lecture Power Points

Chapter 16

Physics: Principles with Applications, 6th edition

Giancoli

Chapter 16



Electric Charge and Electric Field

16.7 The Electric Field

Early scientists and philosophers struggled with the idea of "action at a distance".

How was the electric force propagated?

Michael Faraday proposed that a "field" extended outwards from all charged objects, and that these fields interacted with one another.

Fields are a great mathematical convenience.

The Field can be visualized mentally, graphically, and actually <u>seen</u> under certain circumstances……

Math Definition of Electric Field

The electric field E is the vector describing the force exerted by a single charge or distribution of charges, per unit charge.

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

The definition assumes that the field can be calculated anywhere, by computing the force exerted on a tiny “test charge” so small that it doesn’t add its own field to the mix

Calculating the Electric Field

For a point charge Q, we calculate its Electric Field using an imaginary (minute) test charge “q”:

Since the force between 2 charges is given by Coulomb's law, the force felt by our tiny test charge q would be $F = k\ Qq/r^2$

Thus the force per unit charge (Electric field) would be $E = F/Q$

We can work that out: $E = \frac{k\ Qq/r^2}{q}$

the q’s cancel, leaving ->

$$E = k\,\frac{Q}{r^2}$$

If we know the Field, its easy to find the force exerted on charges anywhere in it!

Force on a point charge q in an electric field:

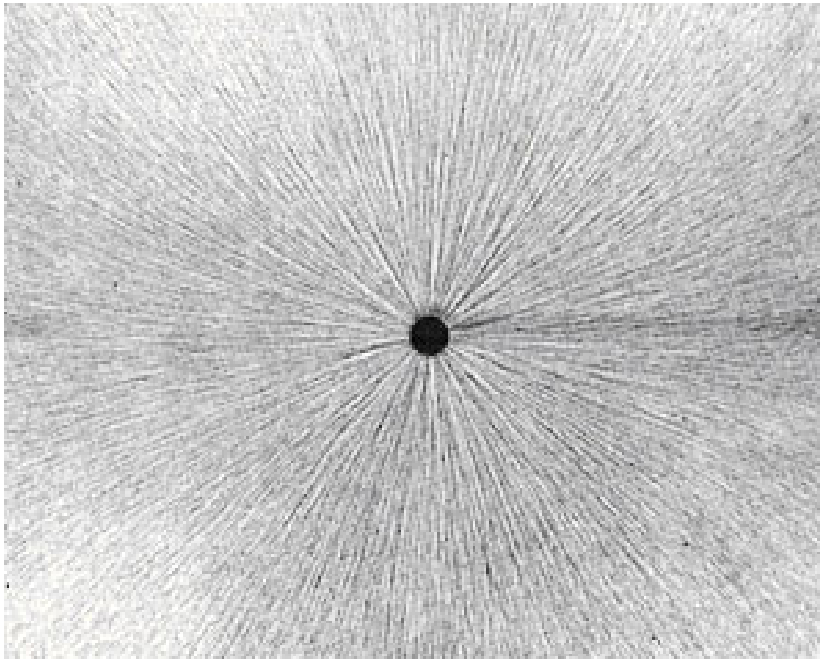
$$\vec{\mathbf{F}} = q\vec{\mathbf{E}}$$

For a complex distribution of Charges, we just add up the contribution of each's field at the point in question:

$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \cdots$$

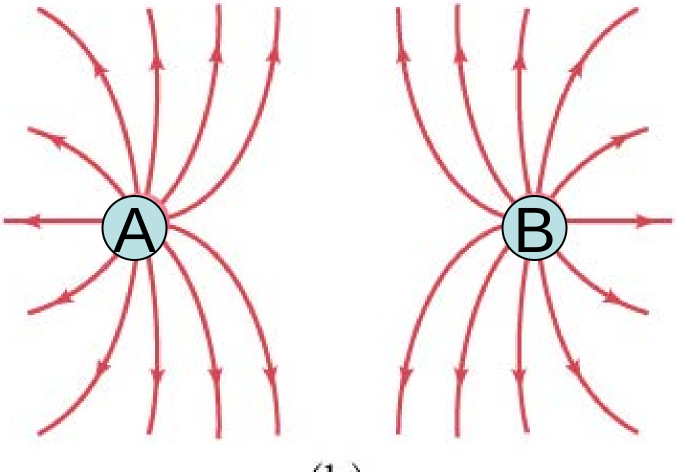
This is called the Superposition principle for electric fields

16.8 Visualizing Electric Fields: A Single Point-Charge



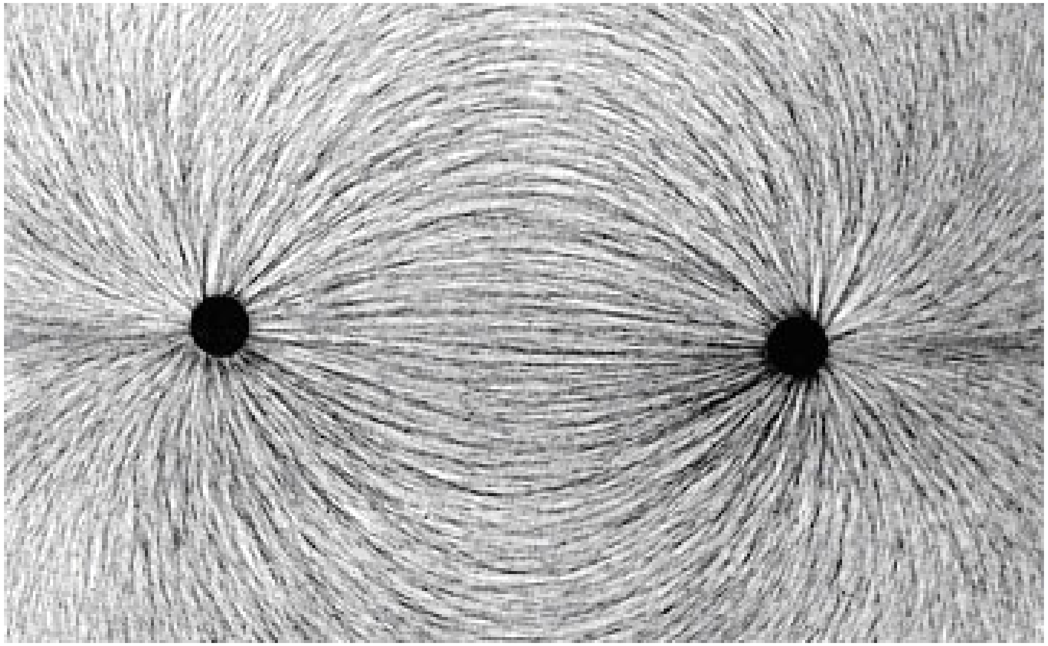
The number of field lines starting (ending) on a positive (negative) charge is proportional to the magnitude of the charge.

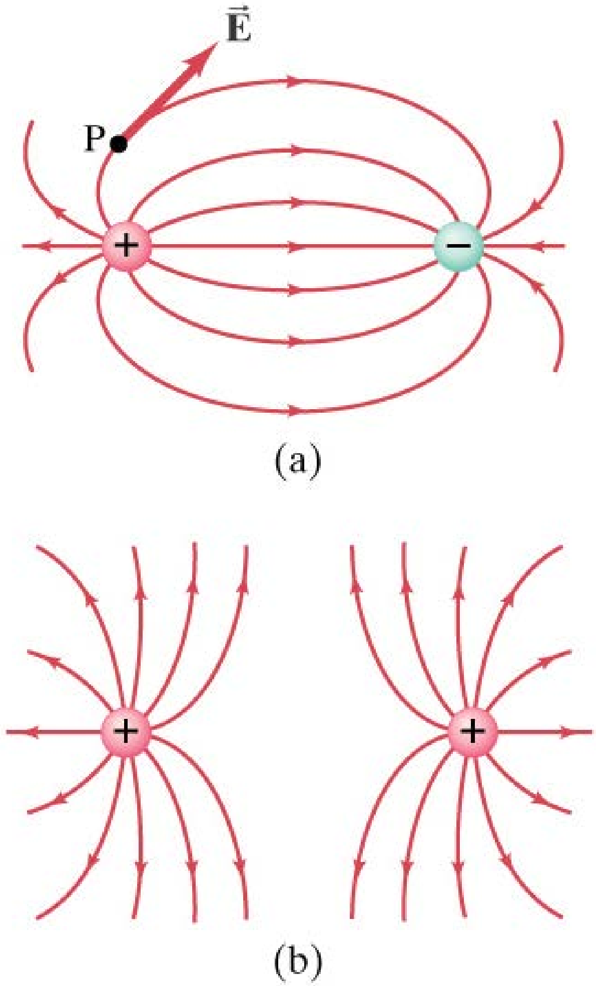
The electric field is stronger where the field lines are closer together.



1. A Negative, B Positive
2. Both Negative
3. Both Positive
4. Cannot tell

Visualizing Electric Fields: Two Charges

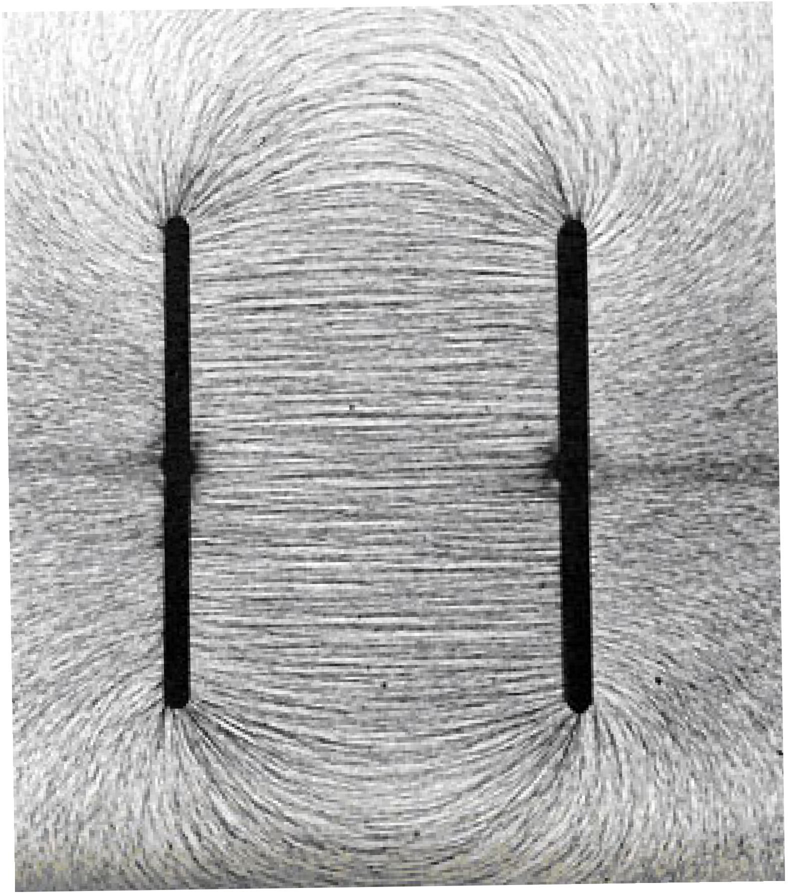


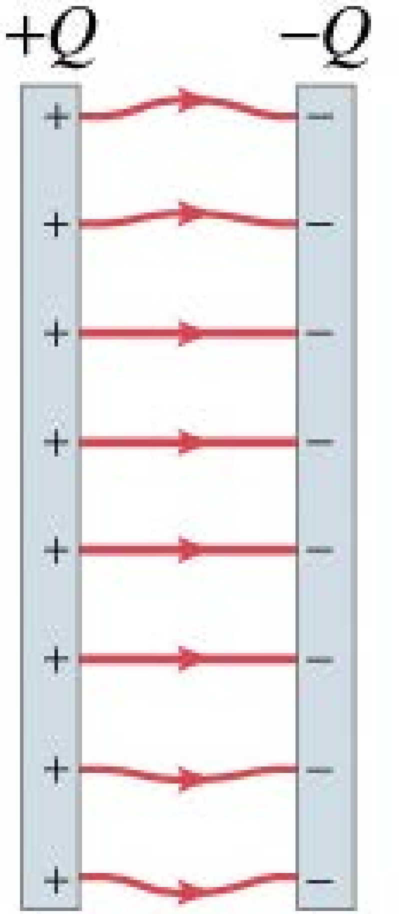


The lines emanating from two equal charges, opposite in sign will connect to form a Dipole (two poles).

While if the charges are the same, the lines will avoid each other, and the charges repel

More Complex Field Lines and Symmetry





The electric field between two closely spaced, oppositely charged parallel plates is constant.

16.9 Distribution of Charge and Static Electric Field in Conductors

Unless an electric current is flowing, all the charges in an object are stationary. So the Charges must be distributed in an equilibrium configuration -Like charges try to get as far apart as possible. Here are the consequences:

1. For a conductor, net charge is always on the surface.
2. Charges are concentrated on corners, and sharp angles. This is why lightning rods have sharp points
3. There is ZERO electric field inside a conductor.

Electric Fields and Conductors

The static electric field inside a conductor is zero. The free charges "instantly" align themselves to totally cancel the external field.

The net charge on a conductor is all on its surface. -Charges want to be as far apart as possible.

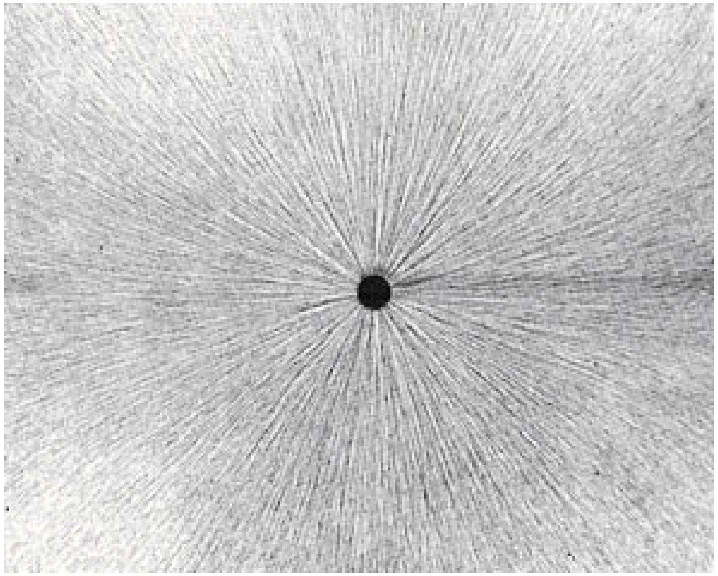
Faraday Cage, Car in Thunderstorm etc…

16.10 Gauss's Law – Electric Flux

The stronger the Electric field (closer to a charge for example) the closer together are the field lines.

Equivalently, more field lines packed tightly together means a stronger field.

Faraday came up with a name for this, the Electric Flux (Φ_E). It is defined (loosely speaking) as the number of field lines threading a region of space, per unit area.



$$\Phi_E = EA\cos\theta$$

Gauss’s Law

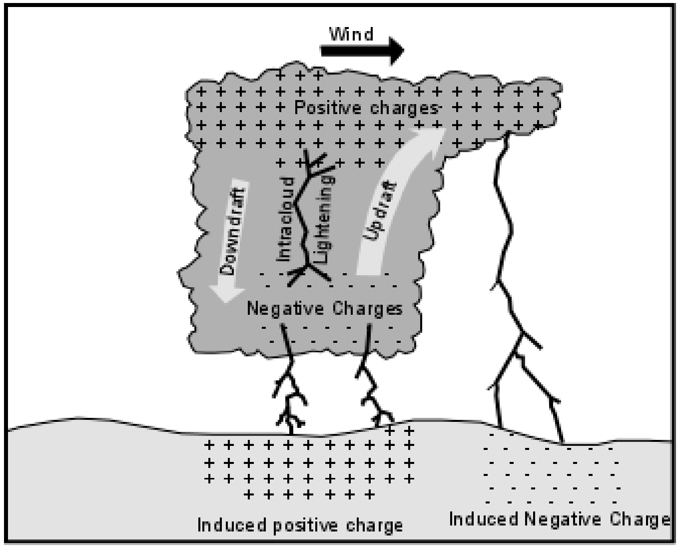
The net number of field lines through the surface is proportional to the charge enclosed, and also to the flux, giving Gauss’s law:

$$\sum_{\substack{\text{closed}\\ \text{surface}}} E_{\perp}\,\Delta A = \frac{Q_{\text{encl}}}{\epsilon_0}$$

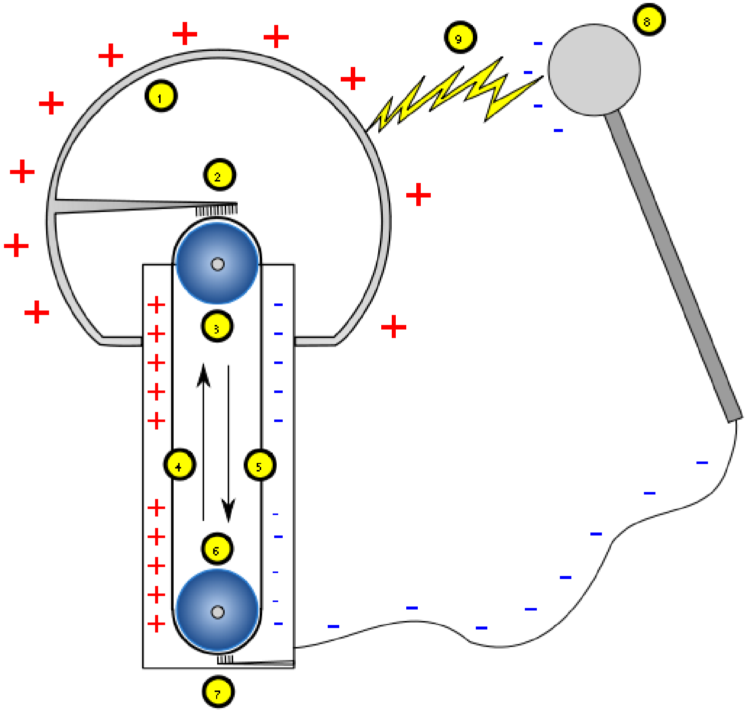
$$\epsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2}$$

This can be used to find the electric field in situations with a high degree of symmetry.

Lightning, Thunderstorms, and a table-top model: the van der Graaf generator



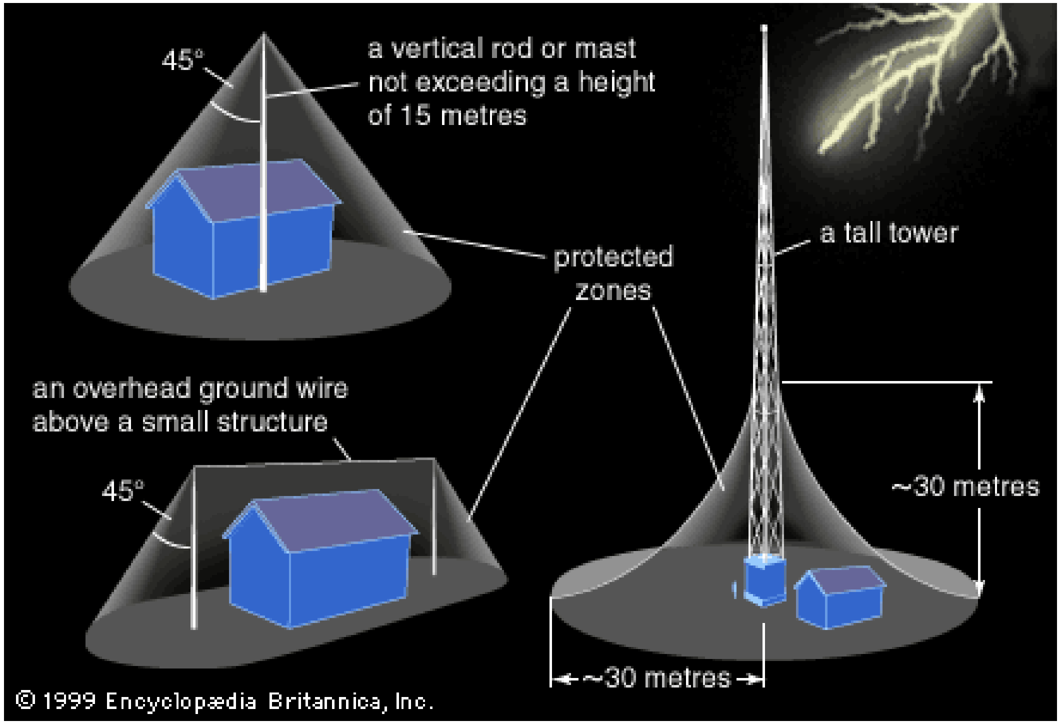
After Abbott (1996)



Raindrops and ice crystals charged by friction as they travel up and down inside the cloud, segregate segregate, causing an electric field.

Moving belt of insulator material carries charge from a wire to the center of a metal globe, where it spreads to the outside.

Another Example - Lighting Rods



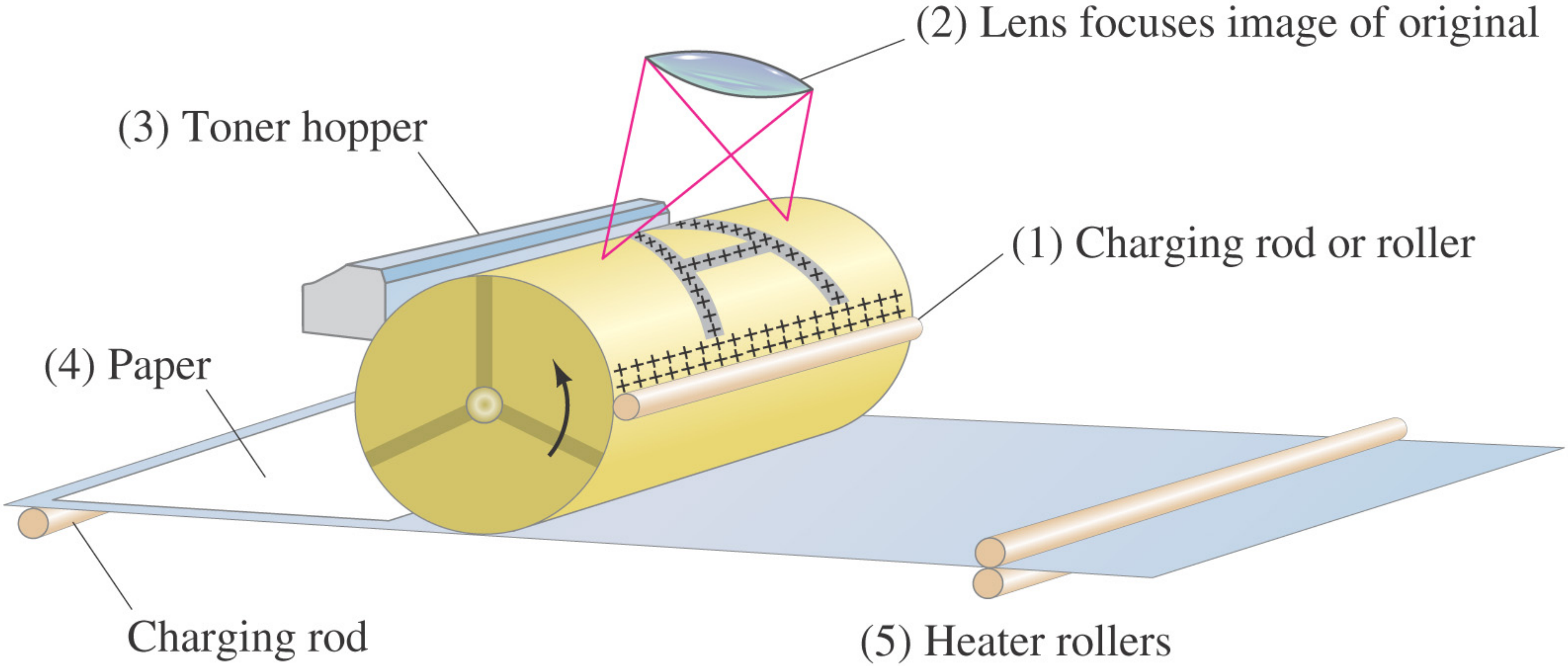
Rods focus the induced electric field that appears in the ground beneath the thunderstorm. With two consequences:

1. Charge can leak away through the air

2. If a breakdown occurs, the stroke will hit the rod and be carried into the ground, protecting nearby areas.

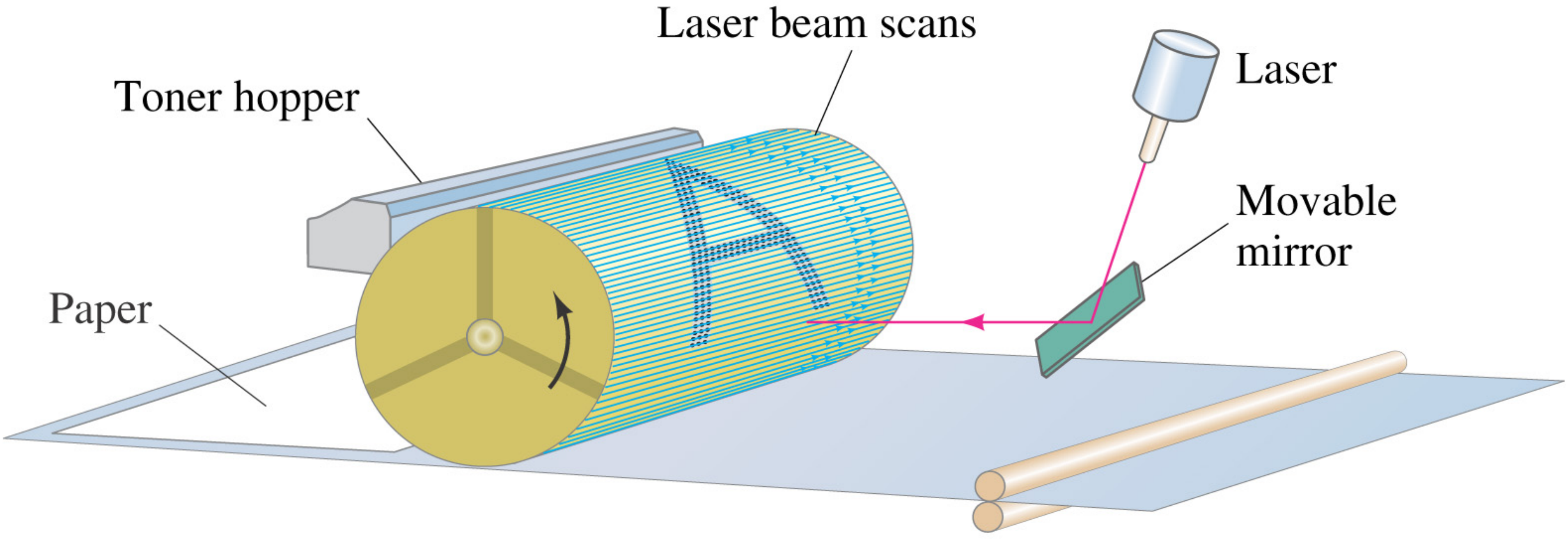
Annually in the USA lightning causes more than 26,000 fires with damage to property in excess of $5-6 billion.

Photocopy Machines and Computer Printers Use Electrostatics



Photocopy Machines and Computer Printers Use Electrostatics

Laser printer is similar, except a computer controls the laser intensity to form the image on the drum



Summary of Chapter 16

- Two kinds of electric charge – positive and negative
- Charge is conserved
- Charge on electron:

$$e = 1.602 \times 10^{-19}\,\mathrm{C}$$

- Conductors: electrons free to move
- Insulators: nonconductors

Summary of Chapter 16

- **Charge is quantized in units of *e***
- **Objects can be charged by conduction or induction**
- **Coulomb's law:**

$$F = k\frac{Q_1 Q_2}{r^2}$$

- **Electric field is force per unit charge:**

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

Summary of Chapter 16

- Electric field of a point charge: $E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$

- Electric field can be represented by electric field lines

- Static electric field inside conductor is zero; surface field is perpendicular to surface

- Electric flux: $\Phi_E = EA\cos\theta$

- Gauss's law:

$$\sum_{\substack{\text{closed}\\ \text{surface}}} E_\perp \,\Delta A = \frac{Q_{\text{encl}}}{\epsilon_0}$$