

Electricity and Magnetism

2/17/04

ISP 209 - 6A

1

We will eventually see that electricity and magnetism go together...

... the culmination is the unified field theory of James Maxwell.

Start today with static electricity.

2/17/04

ISP 209 - 6A

2

Static Electricity

(I) Historical

2/17/04

ISP 209 - 6A

3

Static Electricity

- ▶ Discovered by the Greek philosopher Thales of Miletus – the first philosopher of Western Civilization (624 – 546 BCE).
- ▶ When amber is rubbed with fur, it acquires the ability to attract other materials such as feathers or bits of straw. The force, first observed by Thales, is very weak.
- ▶ William Gilbert (1544 – 1603) showed that many other materials exhibit this small force. He coined the word “electric” (after the Greek word for amber – electron, or $\epsilon\lambda\epsilon\kappa\tau\rho\nu$) for this phenomenon. So etymologically, electricity means “*ambericity*.”

2/17/04

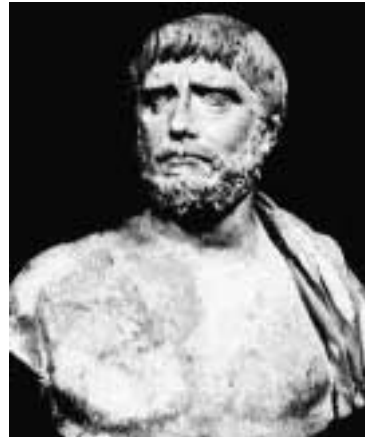
ISP 209 - 6A

4

Thales of Miletus (624 – 546 B C E).

..considered the first philosopher in the history of Western Civilization.

Scientist, mathematician, and engineer. We know about Thales because later philosophers (e.g., Aristotle) wrote about his ideas and discoveries.



Thales' philosophy: Events on Earth are not controlled by the gods(*). Rather, physical events obey natural laws, which mortals can discover and understand.

(* Zeus Poseidon, Apollo, etc)

2/17/04

ISP 209 - 6A

5

Cities of Ancient Greece



2/17/04

ISP 209 - 6A

6

Thales observed that when amber is rubbed with animal fur it acquires the ability to attract other materials (weakly). This mysterious effect was the discovery of static electricity.



2/17/04

ISP 209 - 6A

What is amber?

Amber is a semi-precious material consisting of fossilized plant resin.

7

Static Electricity

- ▶ Discovered by the Greek philosopher Thales of Miletus – the first philosopher of Western Civilization (624 – 546 BCE).
- ▶ When amber is rubbed with fur, it acquires the ability to attract other materials such as feathers or bits of straw. The force, first observed by Thales, is very weak.
- ▶ William Gilbert (1544 – 1603) showed that many other materials exhibit this small force. He coined the word “electric” (after the Greek word for amber – electron, or $\epsilon\lambda\epsilon\kappa\tau\rho\nu$) for this phenomenon. So etymologically, electricity means “*ambericity*.”

2/17/04

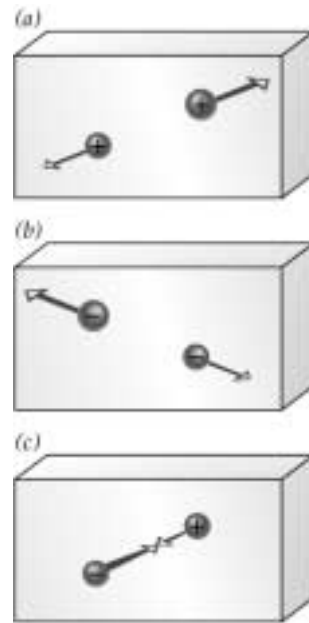
ISP 209 - 6A

8

The electric force

Like charges repel and unlike charges attract.

When objects made of different materials are rubbed together, they become charged with equal but opposite charges. Charged objects either repel one another (for like charges) or attract one another (for unlike charges).



2/17/04

ISP 209 - 6A

9

Benjamin Franklin

Franklin began as an amateur in electricity, but became a famous scientist.

His important theoretical idea: the "*one-fluid model*" – that electricity is carried by a single fluid and an object can be positive (excess of fluid) or negative (deficit of fluid).

→ **Conservation of charge**

His famous kite experiment showed that lightning is an electric discharge.



2/17/04

ISP 209 - 6A

10

Charles Augustin de Coulomb

The force between two small charged objects is...



$$F = \frac{K Q_1 Q_2}{r^2} \quad \text{where} \quad K = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2$$

... an inverse square law, like gravity.

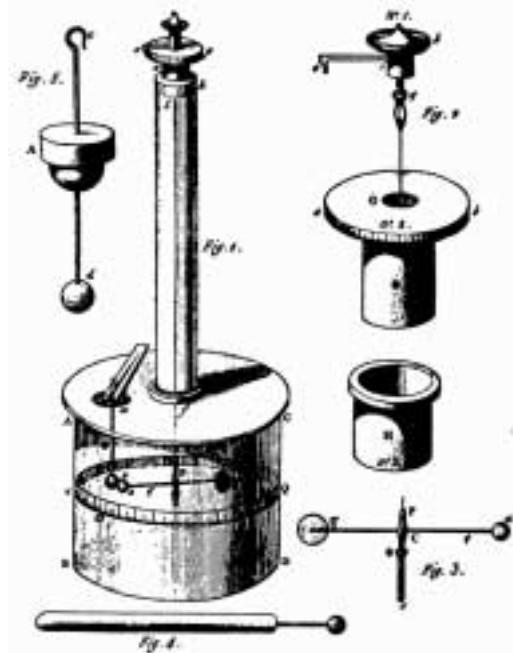
International unit of charge:
1 coulomb (C) = 1 ampere-second

2/17/04

ISP 209 - 6A

11

Coulomb's torsion balance



2/17/04

Example Problem

Calculate the force between a Styfoam peanut and the metal sphere of a van de Graaff generator, if they have equal charges of 10^{-6} C and separation 10 cm.

$$F = 0.9 \text{ N}$$

...larger than the weight of the Styfoam peanut!

2/17/04

ISP 209 - 6A

13

But what is electric charge?

Does an "*electric fluid*" really exist?

Electric charge is a property of the elementary particles of matter – i.e., of subatomic particles.

proton charge = e (positive)
electron charge = $-e$ (negative)
neutron charge = 0

Elementary charge
 $e = 1.6 \times 10^{-19} \text{ C}$

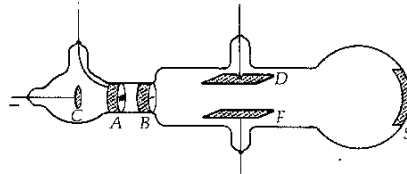
Neutral matter has an equal number of protons and electrons. An object is electrically charged if the numbers of protons and electrons are not equal.

2/17/04

ISP 209 - 6A

14

J J Thomson
The discovery of the electron (1897)



Thomson's tube for measuring q/m for the particles of cathode rays (electrons). Electrons from the cathode C pass through the slits at A and B and strike a phosphorescent screen S. The beam can be deflected by an electric field between plates D and F or by a magnetic field (not shown).

2/17/04

ISP 209 - 6A

15

History of the science of static electricity...

I have mentioned these four names

- Thales – 6th century BCE
- Franklin – 18th century
- Coulomb – 18th century
- Thomson – 20th century

There were many others.

2/17/04

ISP 209 - 6A

16

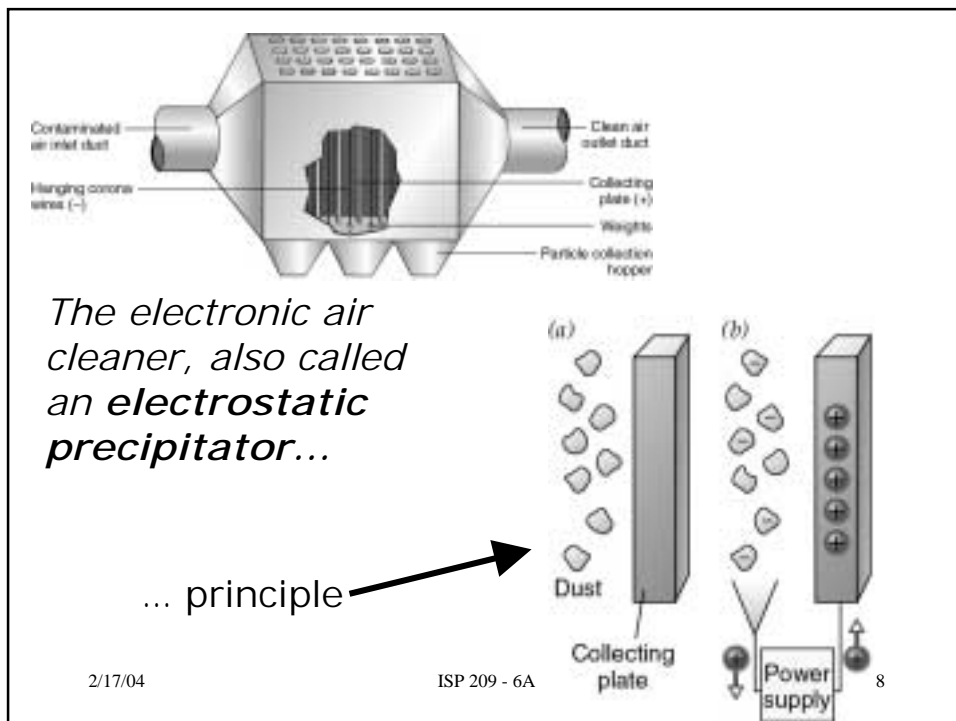
Static Electricity

(II) Applications

2/17/04

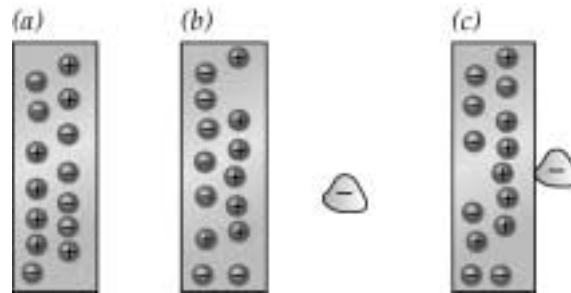
ISP 209 - 6A

17



Polarization

An electrically charged object (positive or negative) is attracted to an electrically neutral object (zero net charge) because the neutral object will become polarized ***and the electric force between charges decreases with distance.***



Bloomfield describes how this phenomenon is used to clean air with an ion generator.

2/17/04

ISP 209 - 6A

19

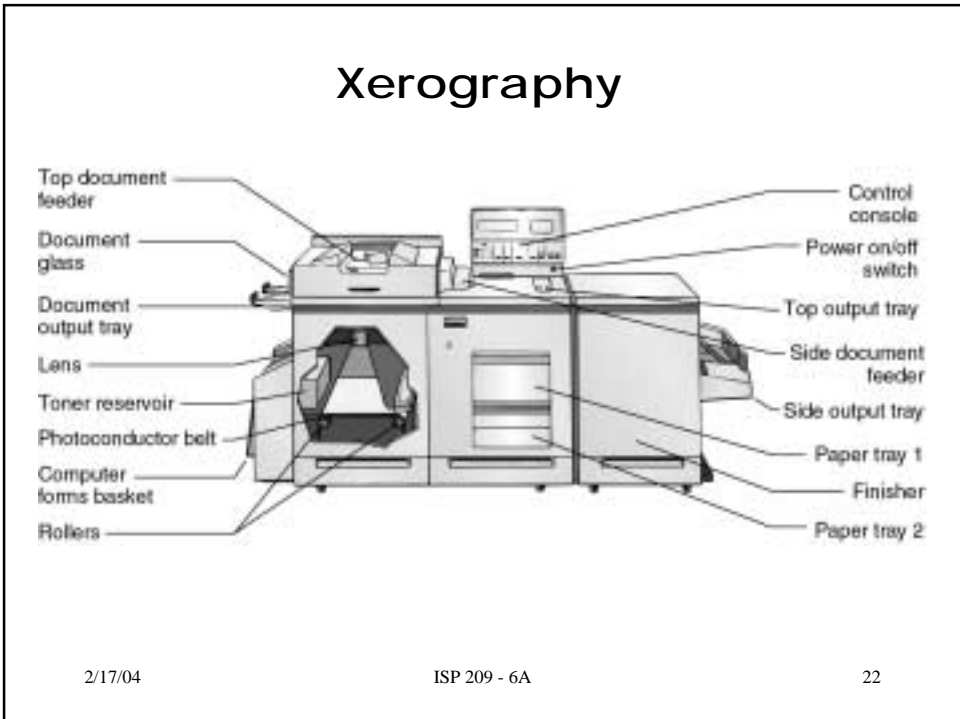
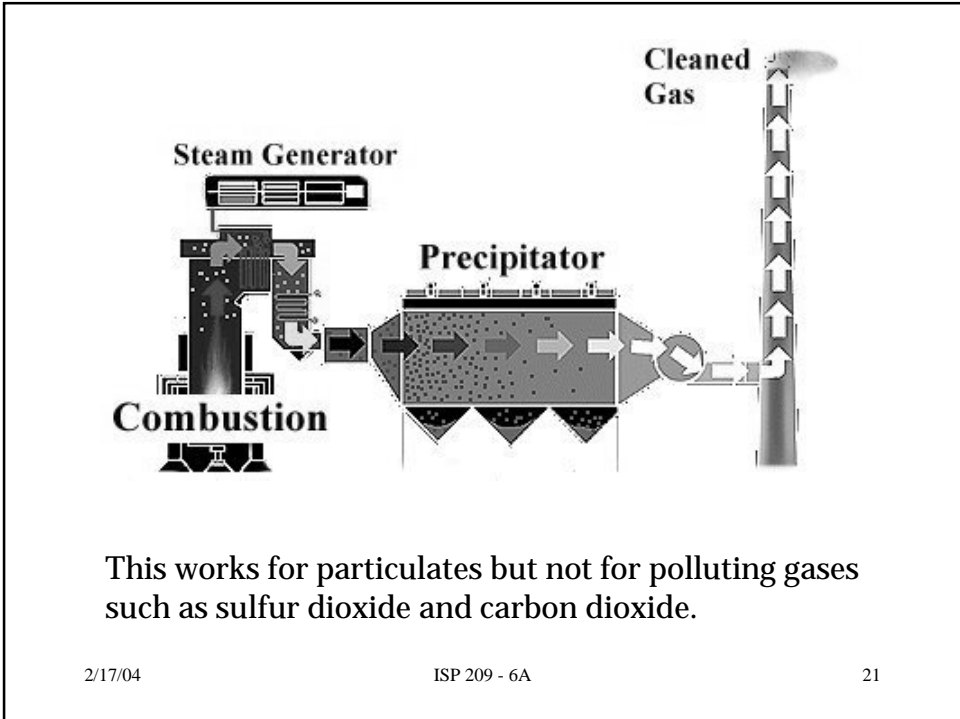
We generate a lot of electricity by burning coal. That produces particulate pollution (smoke). There are environmental laws that require the particles to be removed.

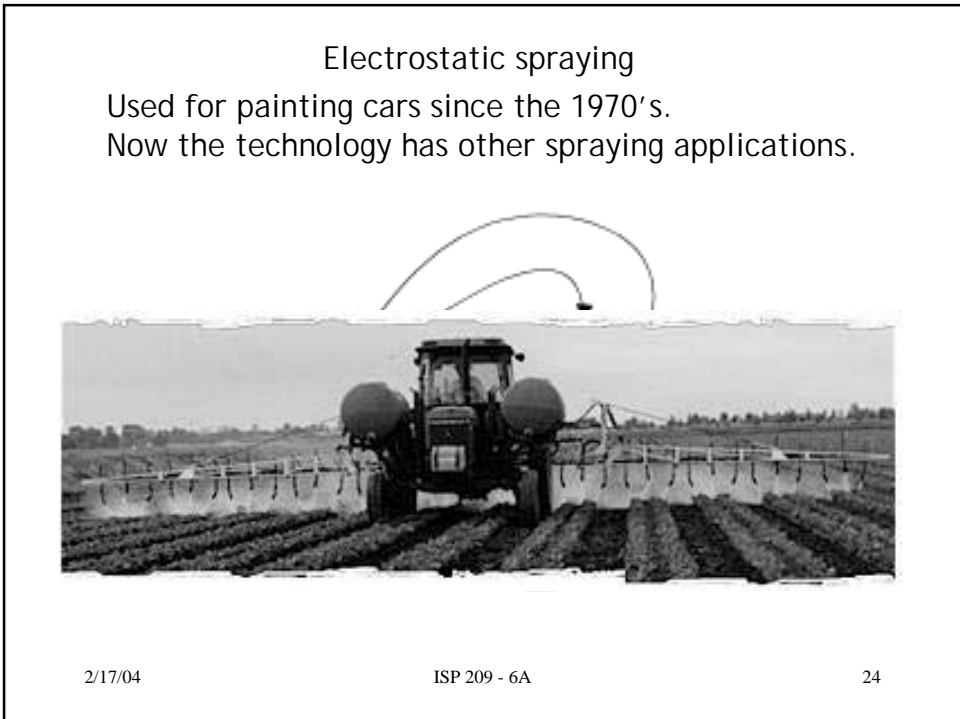
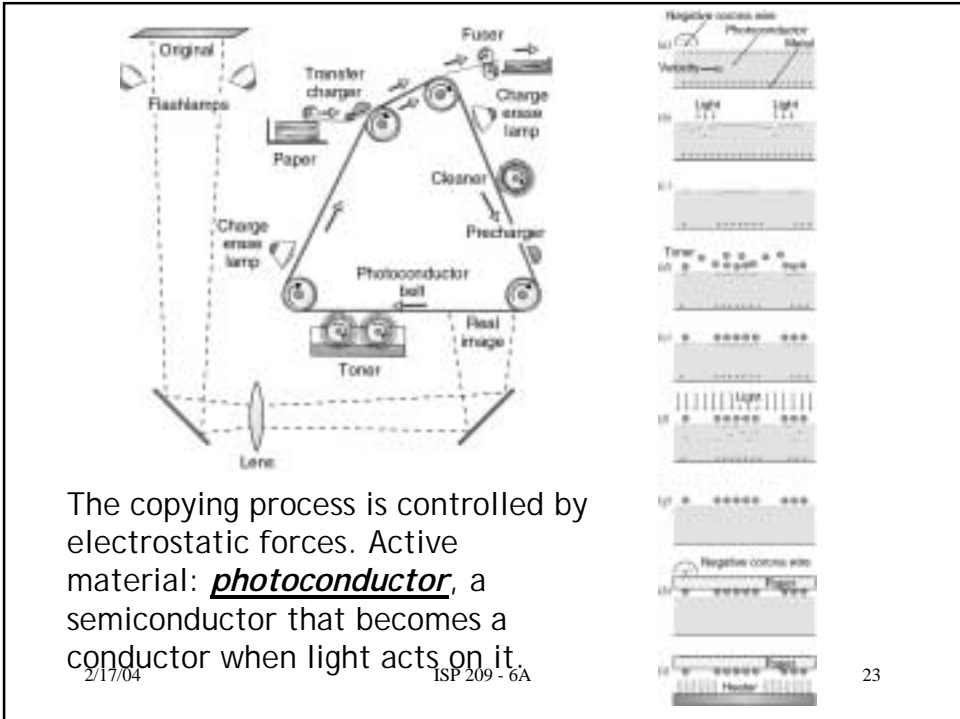
→ electrostatic precipitator in a smoke stack

2/17/04

ISP 209 - 6A

20



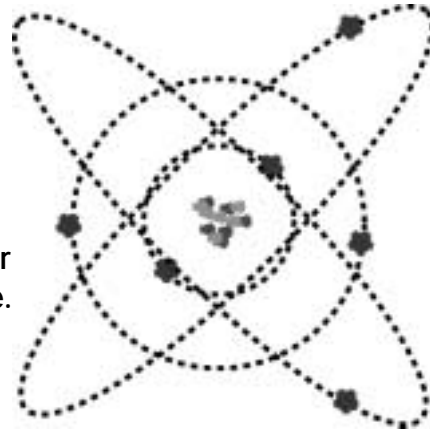


Not really an application...

The electric force binds the electrons to the nucleus in an atom.

Nucleus is positive (made of protons and neutrons held together by the strong nuclear force). Electrons are negative.

**Carbon atom =
6 electrons
6 protons
6 neutrons**



2/17/04

ISP 209 - 6A

25