Electrostatics

Force, Field, and Potential

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Electrostatics

I. Charge and Force
- concepts and definition
- Coulomb's Law

II. Electric Fields
- effect on charge
- production by charge

III. Potential
- relation to work, energy, field
- association with charge

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	The student will be able to:	HW:
1	Relate electrical phenomena to the motion and position of the fundamental charge found on electrons and protons and recognize the coulomb as the SI unit of charge and *e* as the elementary quantum of charge.	1 – 5
2	State and apply Coulomb's Law to solve problems relating force, charge, and distance.	6 – 13
3	Define and apply the concept of an electric field and sketch field lines for a given distribution of charge and solve for the electric field strength at any point relative to a collection of point charges.	14 – 22
4	Define electric potential and potential difference and the volt and solve problems relating electric potential to charge, work or energy, electric field strength and distance.	23 – 32
5	Define and calculate potential and isolines for common charge distributions and solve related problems.	33 – 38

What is “electricity”?

What is "electricity"?

All electrical phenomena relate to the fundamental quantity of **electric charge**.

"Charge" is a property of matter that governs electromagnetic forces.

Based on observations of the electric force it is clear that there are two *types* of charge, denoted as **positive** and **negative**.

Like charges repel and opposite charges attract.

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Type of Charge and Force

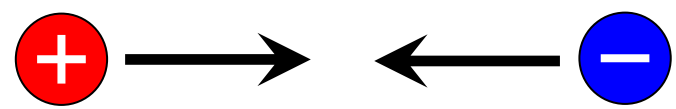
Like charges repel one another:

positive repels positive

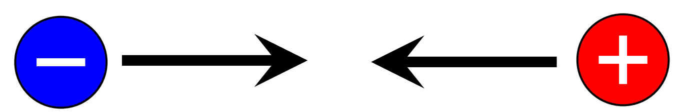
negative repels negative

Opposite charges attract one another:

positive attracts negative



negative attracts positive



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"Modern" Explanation of Charge

In ordinary matter, positive charge is found on protons and negative charge is found on electrons. The two particles have equal amounts of charge (but opposite signs).

Often the number of protons equals the number of electrons. This is said to be zero net charge. An object becomes charged (*i.e.* has a *net* charge) if the number of protons is unequal to the number of electrons.

This occurs almost always as a result of electrons being transferred to or from an object.

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Conservation of Charge

Charge is conserved! The net amount of charge produced in any process is zero.

This may seem to mean that protons and electrons cannot be created or destroyed, but in fact they can! Nonetheless, the *charge* of these particles is a conserved property.

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Insulators and Conductors

Both conductors and insulators can possess charge.

Key difference:

Charge can travel freely through a conductor.

Charge cannot travel freely through an insulator, but rather tends to be "locked" in place.

In conductors, (metals) the outermost electrons are not bound tightly to nuclei and are hence "free to roam" through the material. In insulators, electrons are more tightly bound to nuclei and cannot freely move through the material.

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Two Means of Charging:

Conduction occurs when charge is literally transferred from one object to another as a result of contact or sparking.

Induction occurs when charge within an object is rearranged due to the proximity of a charged object (or presence of an external electric field).

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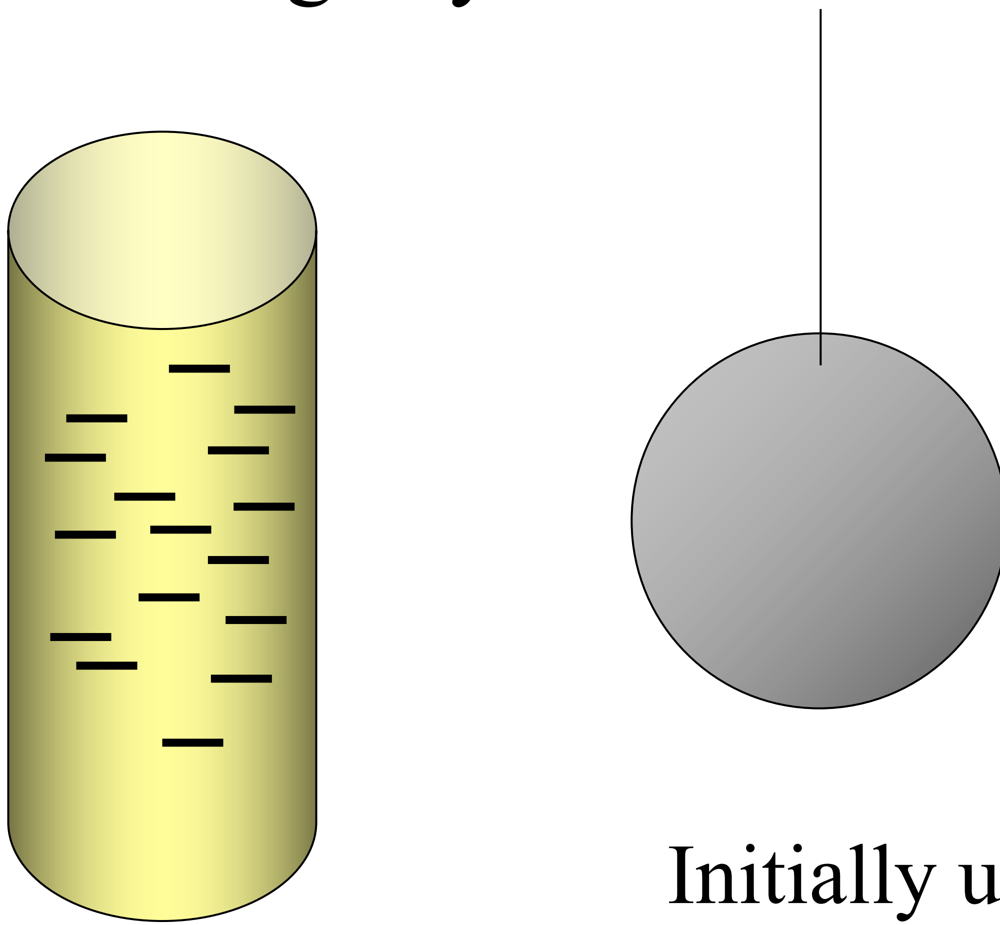
Charge by Conduction



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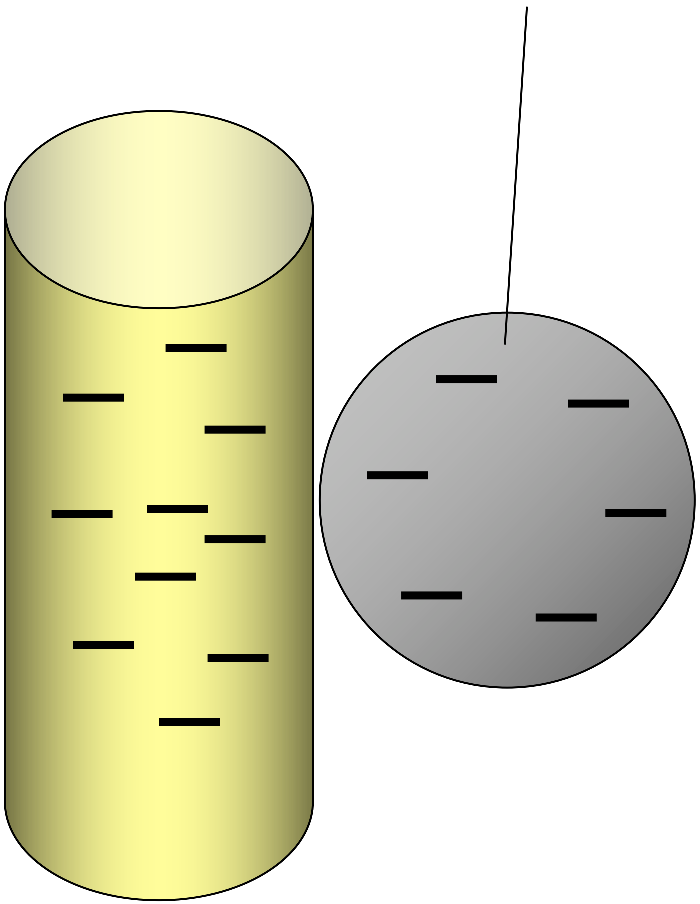
Charge by Conduction



Negative charge is transferred from the pipe to the ball through the point of contact or a spark.

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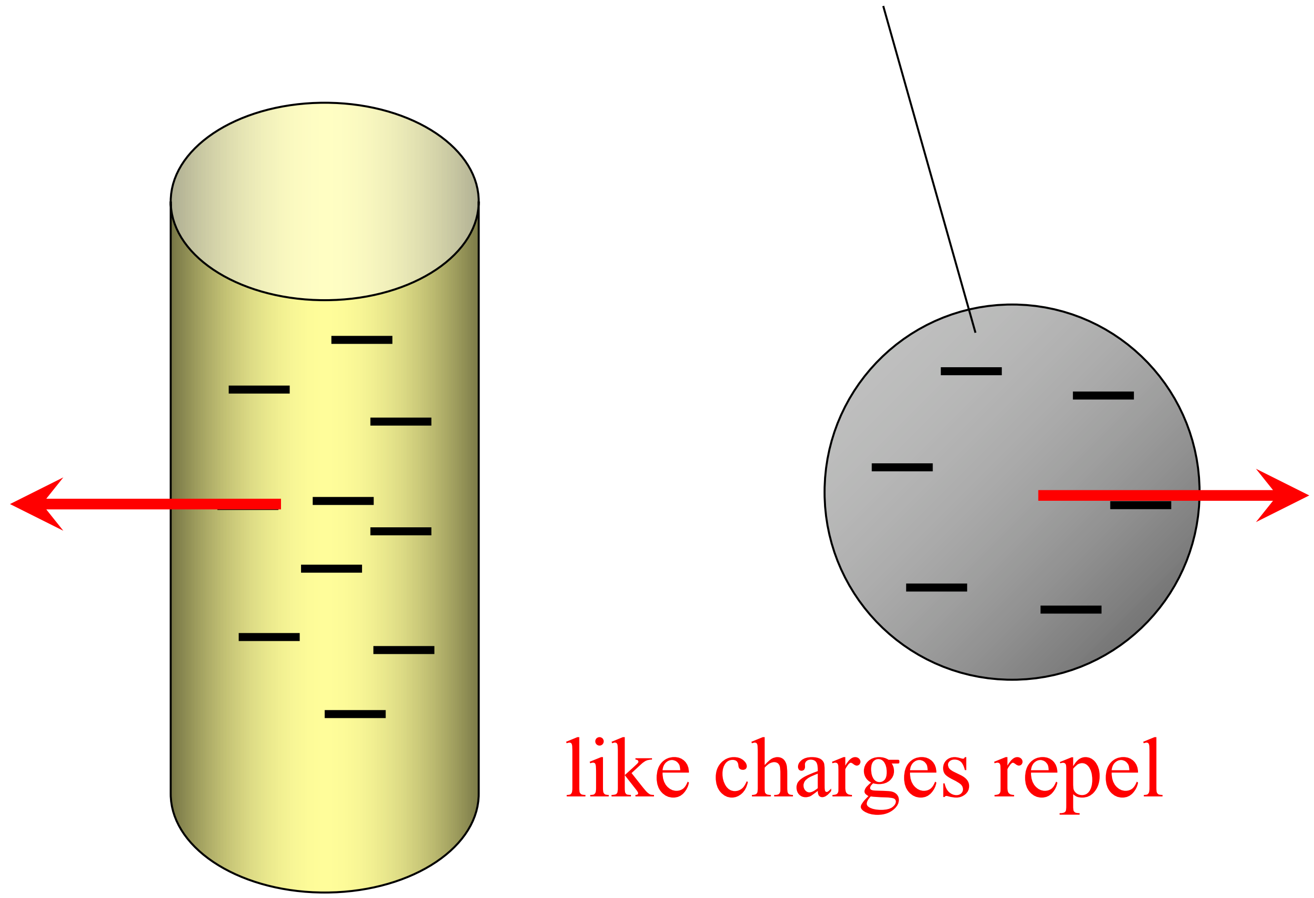
Charge by Conduction



Although the pipe loses some charge it remains negative (and does not become neutral).

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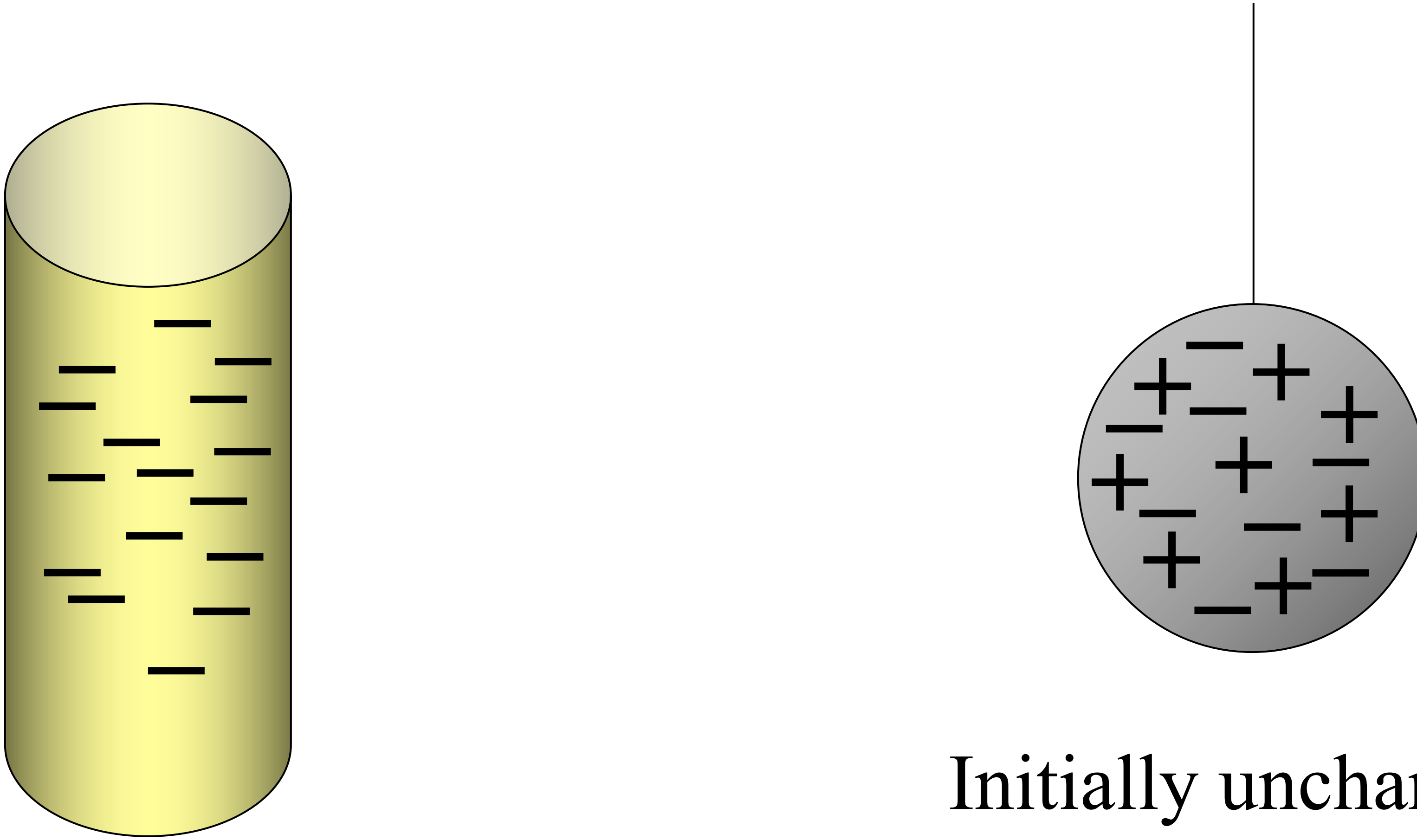
Charge by Induction



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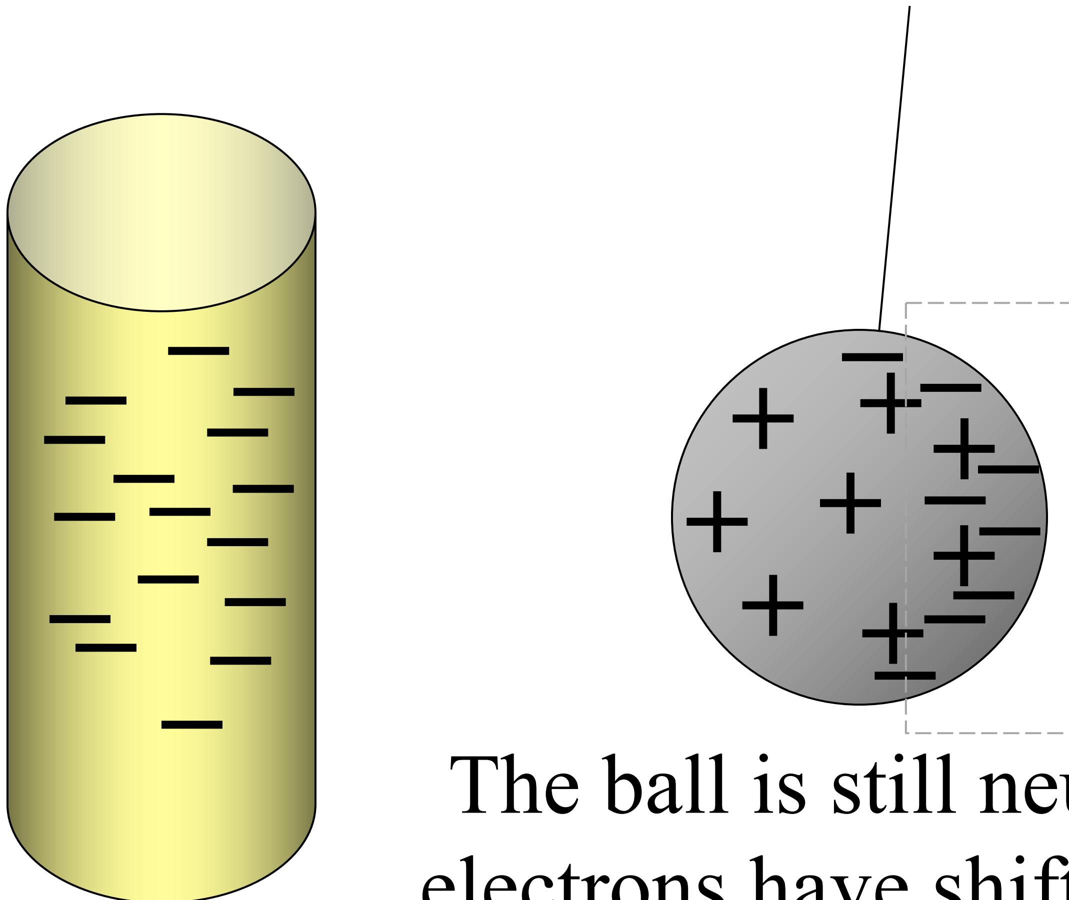
Charge by Induction



No charge is transferred from pipe to ball.

The ball is still neutral, but electrons have shifted to one side of the ball because of repulsion from the pipe.

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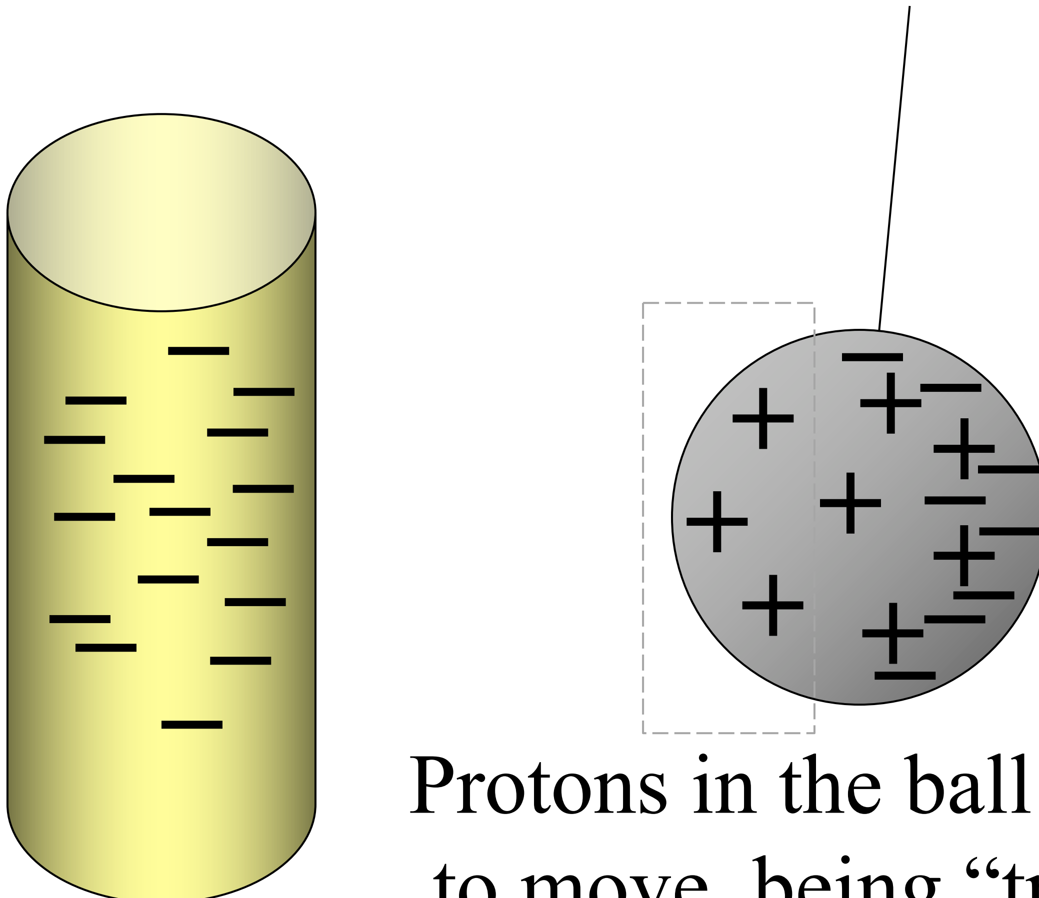
Charge by Induction



No charge is transferred from pipe to ball.

Protons in the ball are unable to move, being "trapped" in the nucleus. This leaves the other side of the ball positive.

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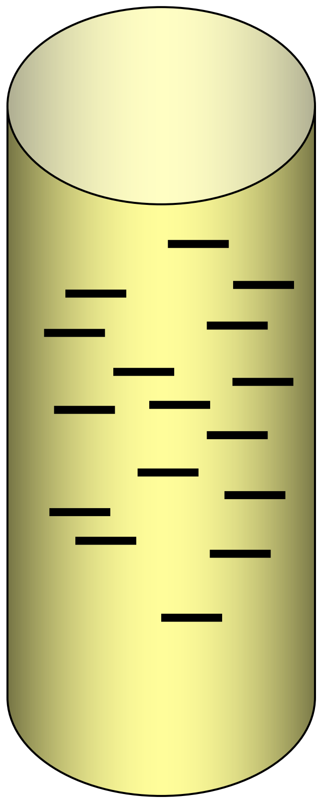
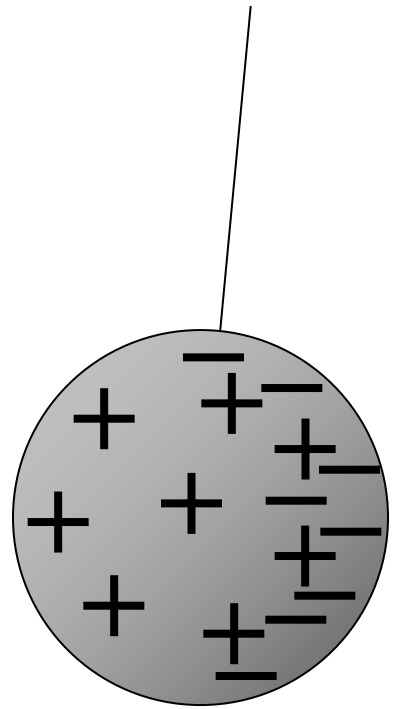
Charge by Induction



No charge is transferred from pipe to ball.



Hence, a positive charge is induced on the near side and a negative charge is induced on the far side of the ball.

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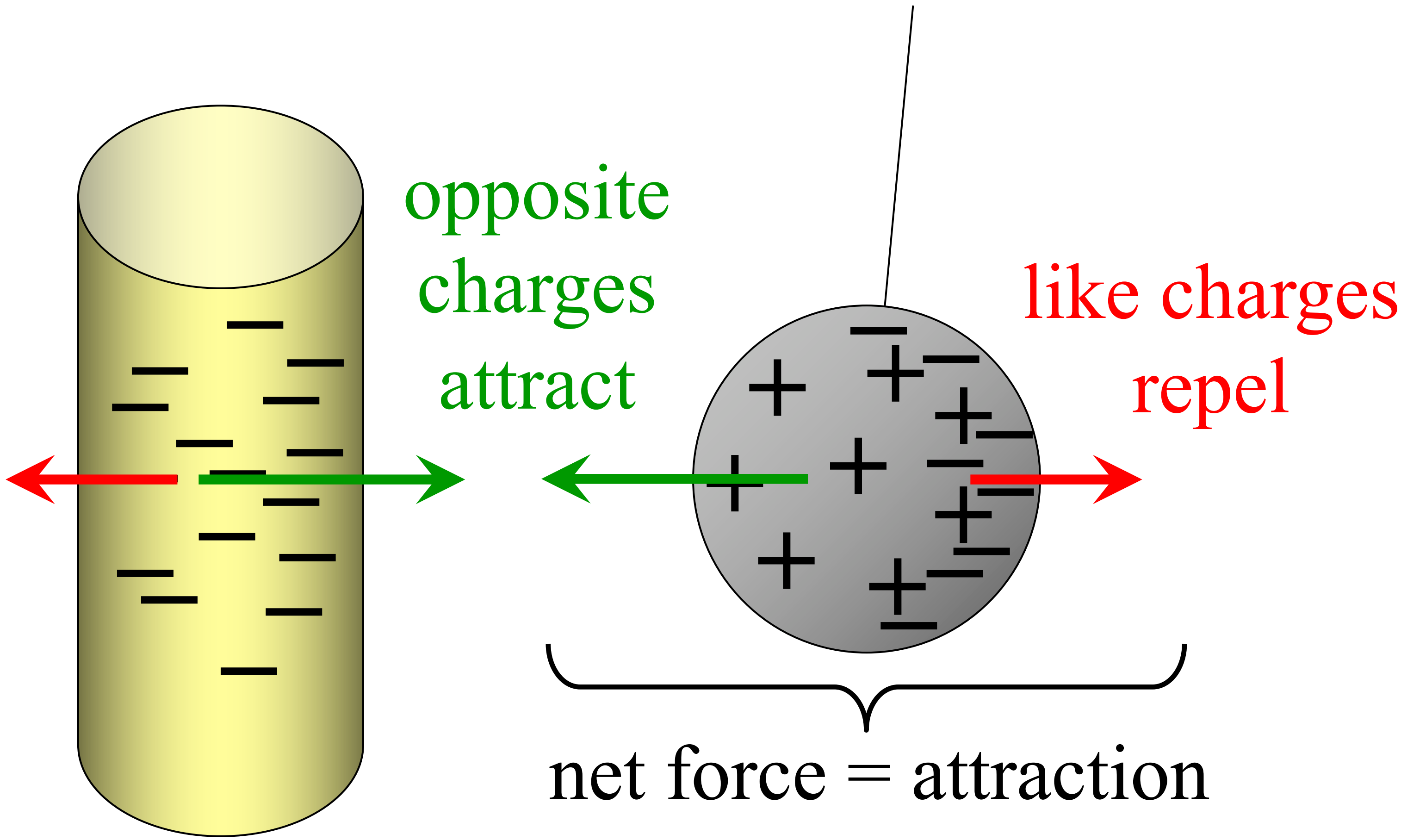
Charge by Induction



Because the negative side of the ball is farther from the pipe than the positive side, the attraction is greater.

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Quantization of Charge

A Curious Property…

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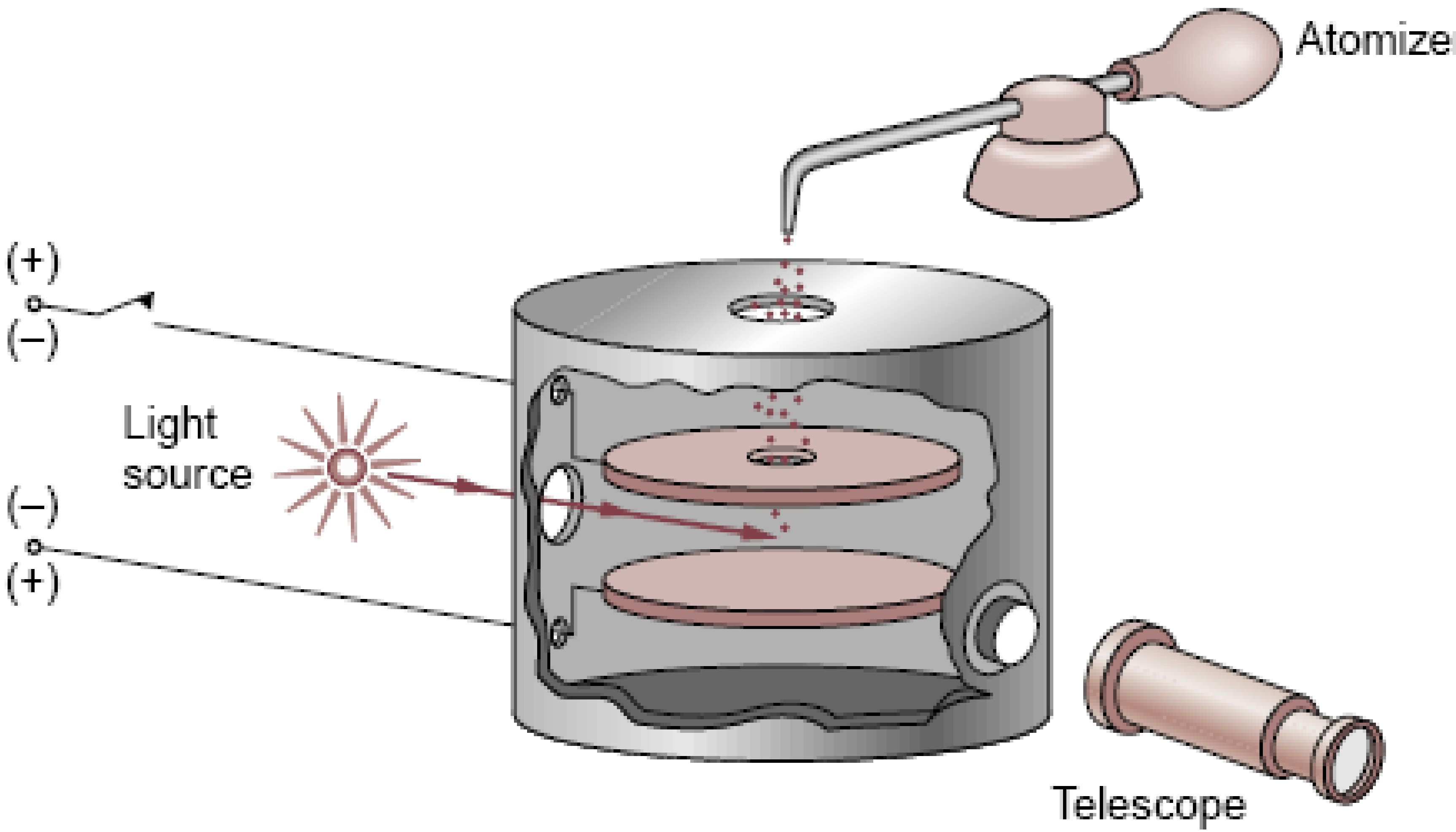
Millikan's Oil Drop Experiment



Millikan's Oil Drop Experiment

In 1909 Robert Millikan carefully determined the charge on tiny drops of oil and discovered values such as these:

$$q = \pm\ 3.2 \times 10^{-19}\ \text{C}$$
$$q = \pm\ 4.8 \times 10^{-19}\ \text{C}$$
$$q = \pm\ 6.4 \times 10^{-19}\ \text{C}$$
$$q = \pm\ 8.0 \times 10^{-19}\ \text{C}$$

etc.

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Millikan's Oil Drop Experiment

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etc.

The implication of these results is that charge occurs in *integer multiples* of 1.6×10^{-19} C.

It also implies that 1.6×10^{-19} C is the *smallest possible charge*!

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The Elementary Charge

The smallest possible amount of charge is equal to that on an electron or proton. This amount is called the fundamental or elementary charge, *e*.

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

an electron's charge: $q = -e = -1.602 \times 10^{-19}$ C

a proton's charge: $q = +e = +1.602 \times 10^{-19}$ C

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Quantization of Charge

Any amount of charge greater than e is an integer multiple of e:

$$q = n \cdot e$$

where: $n = \pm 1, \pm 2, \pm 3$, etc.

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