D.2

Static Electricity

IB PHYSICS | FORCE FIELDS

A.2

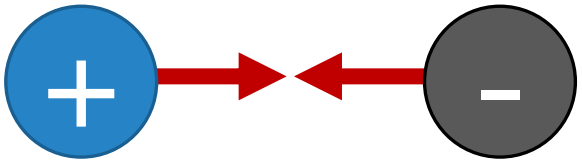
Many Types of Forces

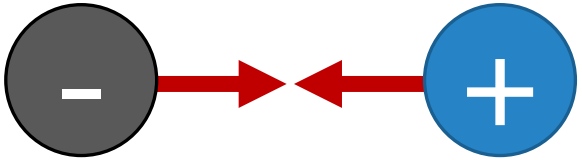
Normal Force	F_N
Surface Frictional Force	F_f
Tension	F_T
Elastic Restoring Force	F_H
Viscous Drag Force	F_d
Buoyant Force	F_b
Gravitational Force	F_g
Electric Force	F_e
Magnetic Force	F_m

Contact

Non-Contact

Charge Interactions





Opposite Charges
Attract

Like Charges
Repel

Which one has more force?

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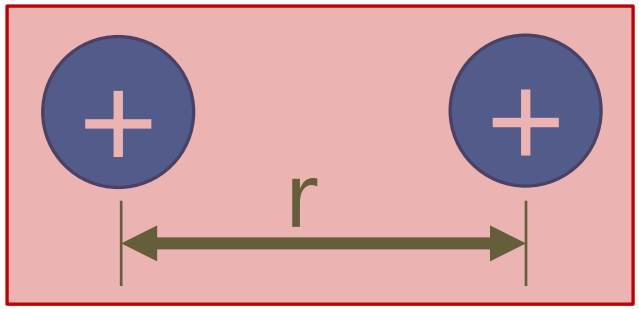
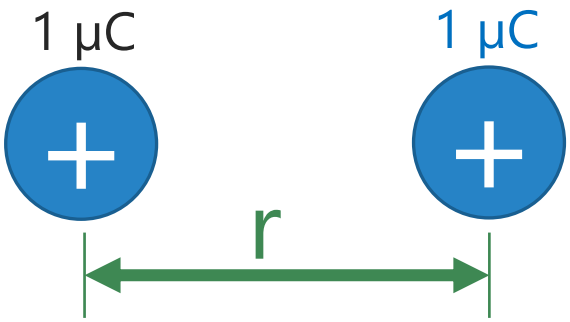
Which charged pair has larger electrostatic forces acting?

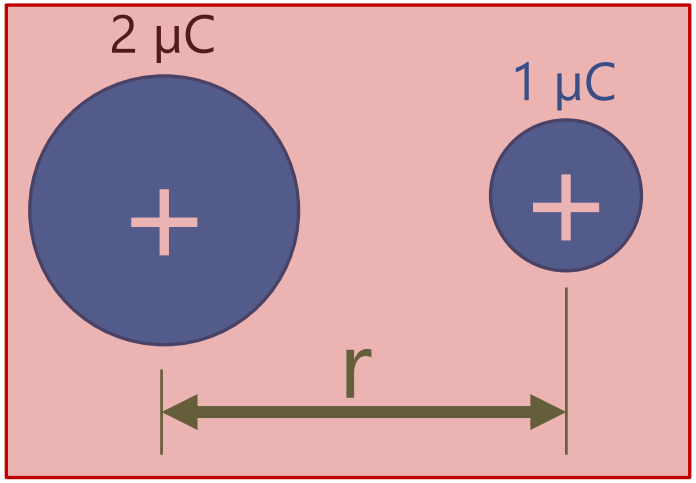


smaller distance = greater force

Which one has more force?

Which charged pair has larger electrostatic forces acting?

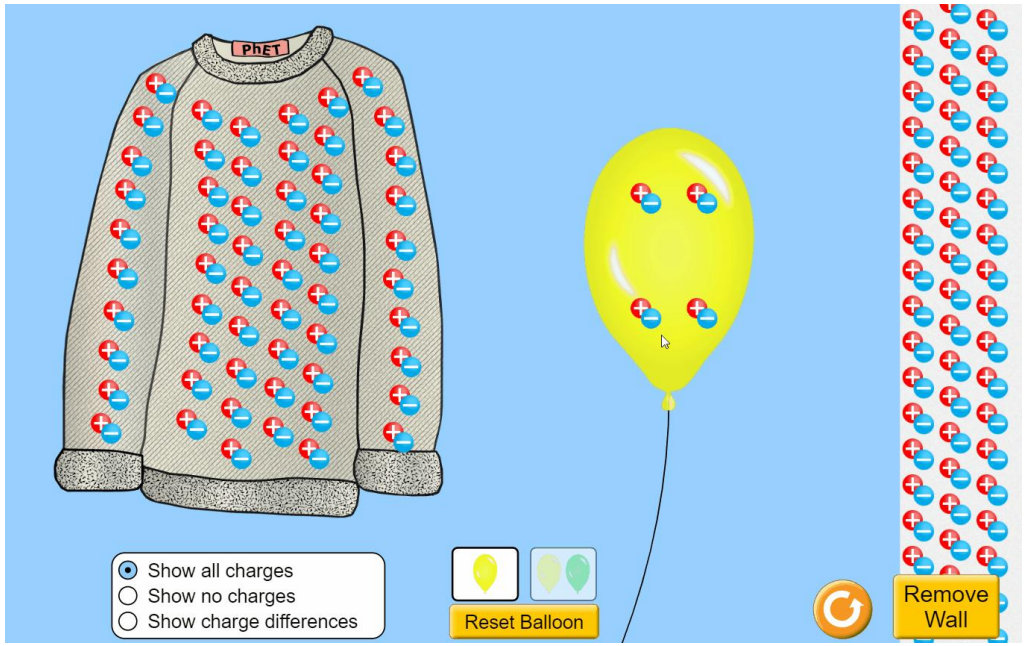




greater charge = greater force

Conservation of Charge

D.2



Click here for Simulation

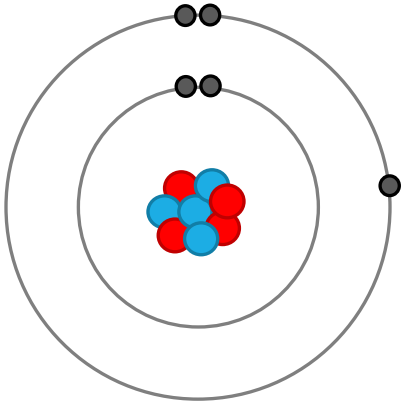
What happens when you rub the balloon on the sweater?

Electrons are transferred
NOT created or destroyed

Conservation of Charge

Charge on an Atom

The **protons** and **neutrons** are buried deep in the nucleus and cannot easily be touched



electrons orbiting the nucleus are easily lost or gained

How do objects become charged?

D.2

Friction	Conduction	Induction

Click here for Simulation

What happens when you rub John Travoltage's foot on the rug?

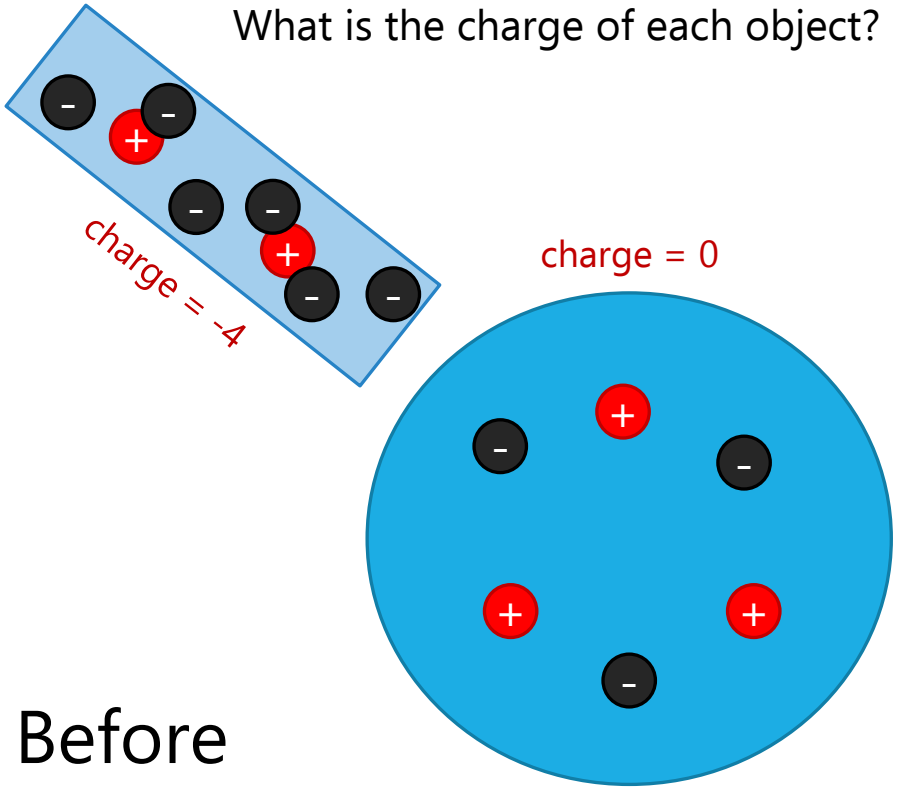
The foot gains electrons from rubbing on the carpet and the electrons spread out

How do objects become charged?

D.2

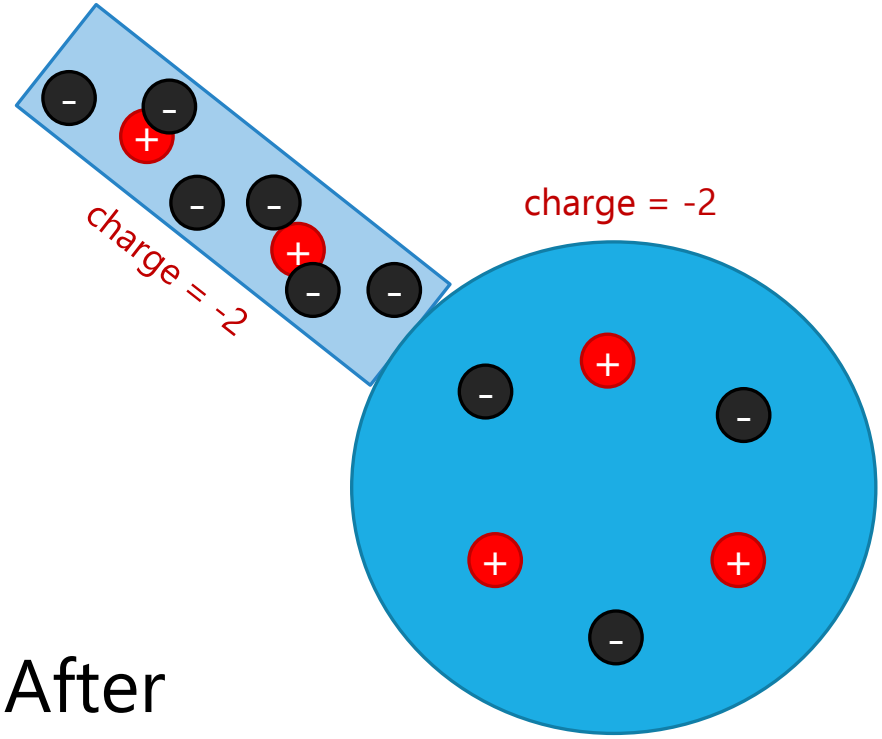
Friction	Conduction	Induction

What is the charge of each object?



Before

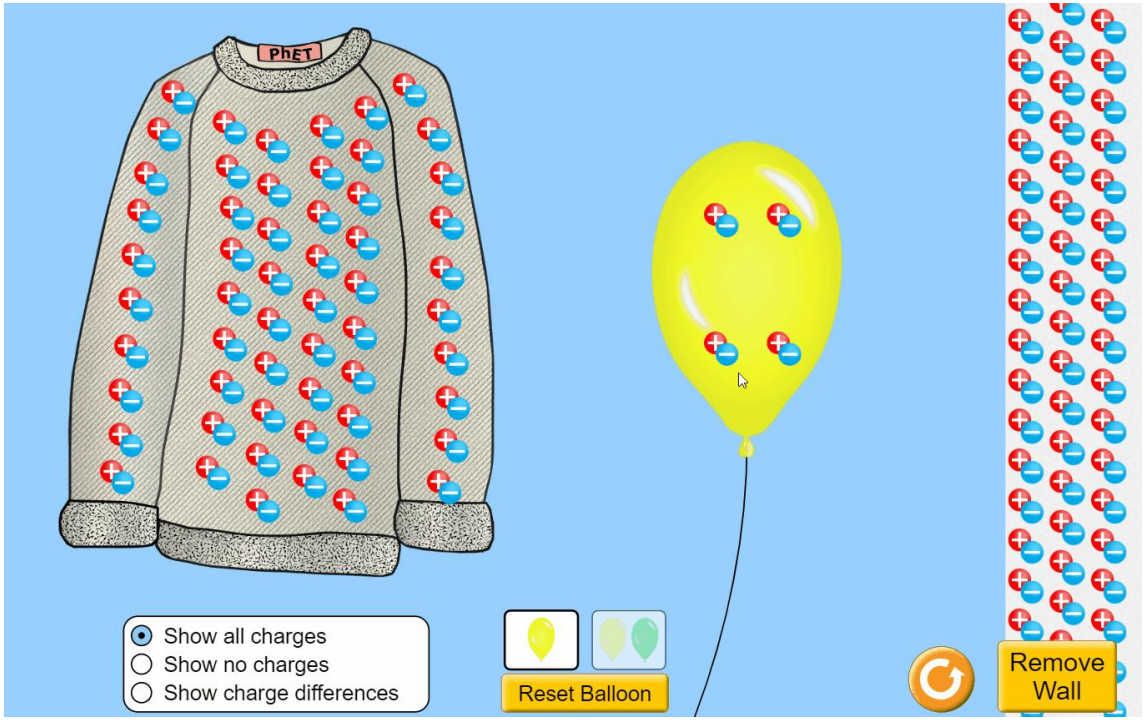
Draw in the Electrons



After

How do objects become charged?

Friction	Conduction	Induction



What happens when you bring the balloon over to the wall?

The electrons in the wall redistribute and move away from the negative source

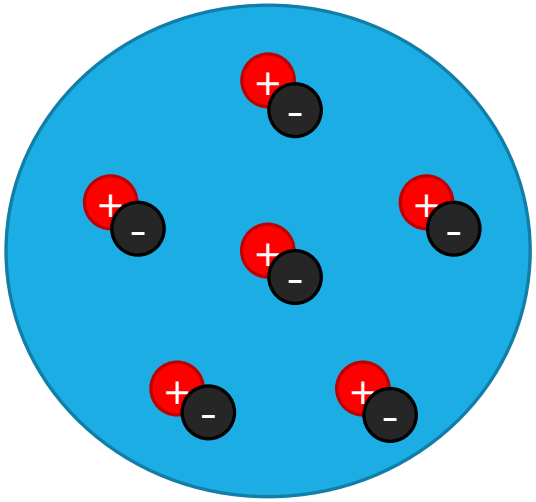
Click here for Simulation

How do objects become charged?

D.2

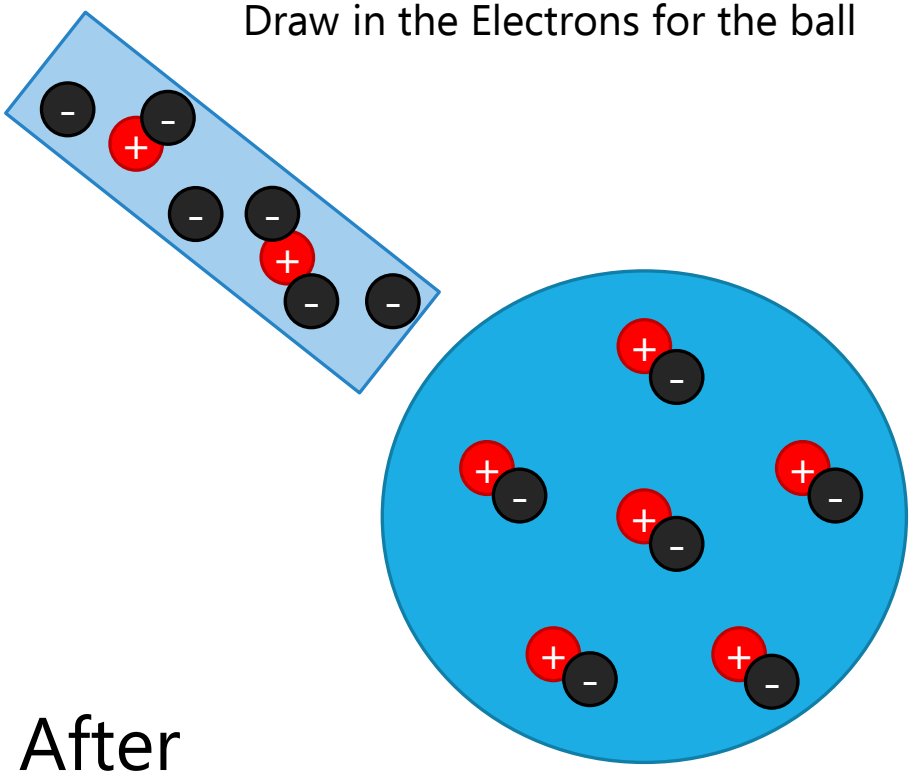
Friction	Conduction	Induction

What is the charge of this object?



Before

Draw in the Electrons for the ball

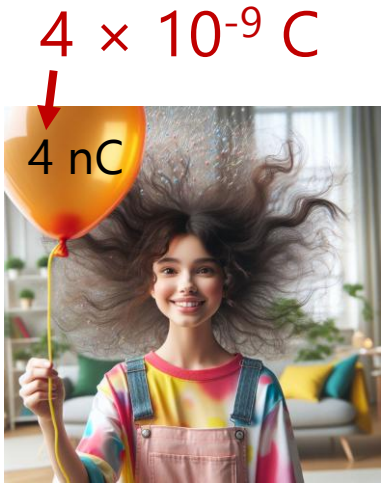


After

Quantifying Charge

Symbol	q

Unit	Coulomb	C

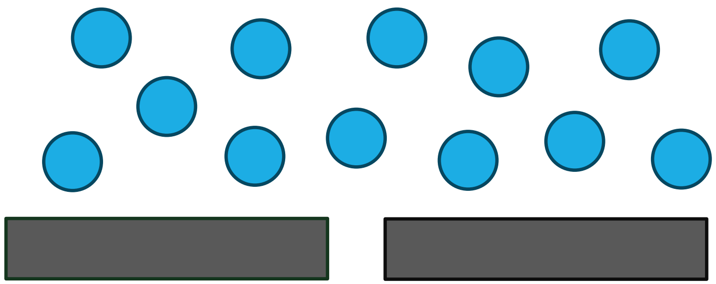


kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

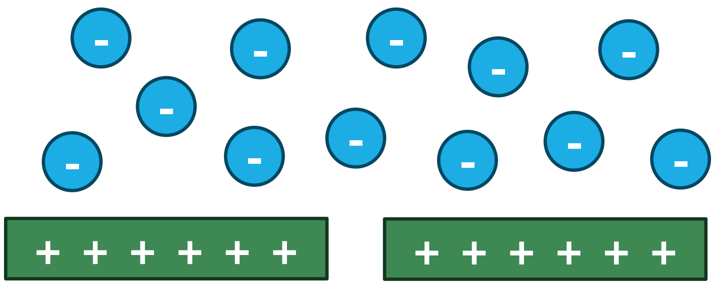
Determining the Electron Charge

D.2

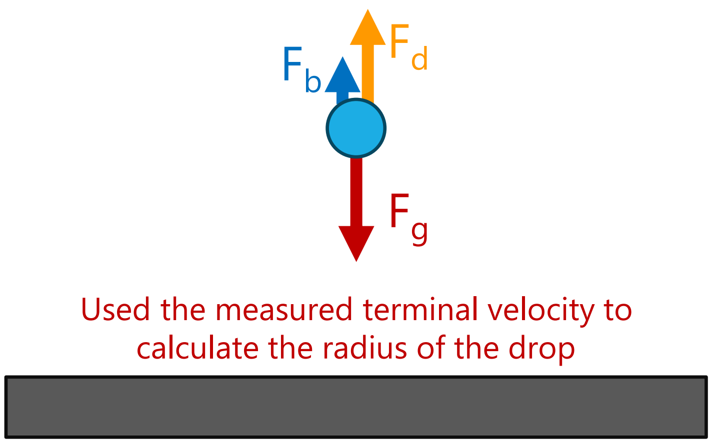
In an effort to quantify the charge of a single electron, Millikan studied falling oil drops



Uncharged

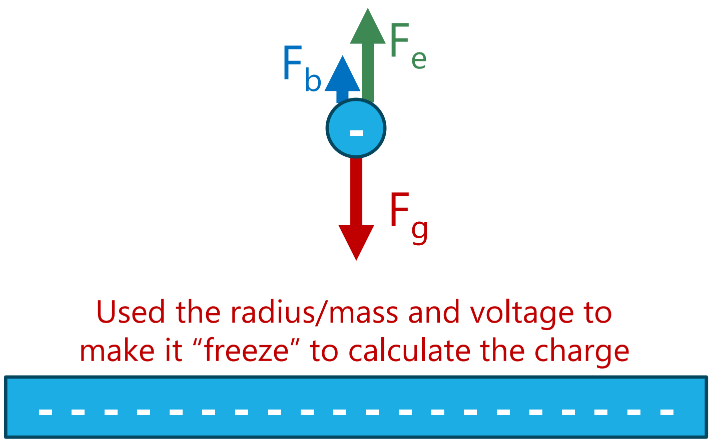


Charged



Used the measured terminal velocity to calculate the radius of the drop

Robert Millikan



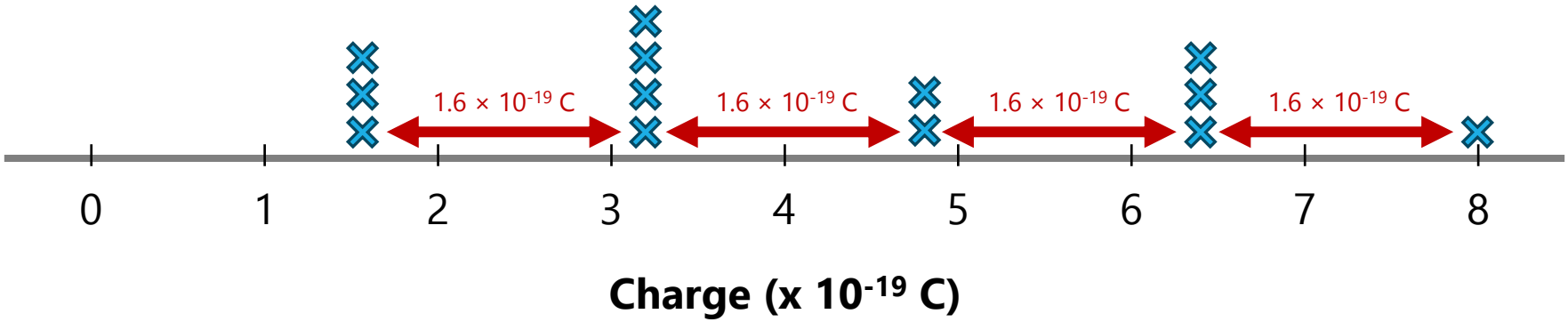
Used the radius/mass and voltage to make it “freeze” to calculate the charge

Link to video explaining the math

Determining the Electron Charge

D.2

By analyzing the motion and forces, the charges of the oil drops were calculated



The resulting charges showed specific intervals

Electron Charge = 1.6×10^{-19} C

Quantifying Charge

The total charge in Coulombs can be related to the number of electrons

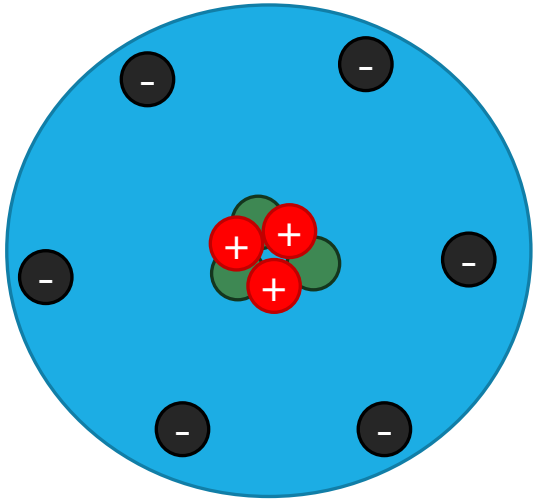
Fundamental constants

Quantity	Symbol	Approximate value
Acceleration of free fall	g	$9.8\,\mathrm{m\,s^{-2}}$ (Earth's surface)
Gravitational constant	G	$6.67\times10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
Avogadro constant	N_A	$6.02\times10^{23}\,\mathrm{mol^{-1}}$
Gas constant	R	$8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann constant	k_B	$1.38\times10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan–Boltzmann constant	σ	$5.67\times10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
Coulomb constant	k	$8.99\times10^{9}\,\mathrm{N\,m^2\,C^{-2}}$
Permittivity of free space	ε_0	$8.85\times10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$
Permeability of free space	μ_0	$4\pi\times10^{-7}\,\mathrm{T\,m\,A^{-1}}$
Speed of light in vacuum	c	$3.00\times10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	h	$6.63\times10^{-34}\,\mathrm{J\,s}$
Elementary charge	e	$1.60\times10^{-19}\,\mathrm{C}$

What is the charge??

An atom has an imbalance of protons and electrons as shown. What is the charge in C?

$$3\ electrons \times \frac{-1.60 \times 10^{-19}\ \mathrm{C}}{1\ electron} = \mathbf{4.8 \times 10^{-19} C}$$



Elementary Charge = 1.60×10^{-19} C

How many electrons??

A small cork carries a charge of −3.2 μC. How many excess electrons does it have?

$-3.2\ \mu C \rightarrow -3.2 \times 10^{-6}\ C$

$$-3.2 \times 10^{-6}\ \text{C} \times \frac{1\ electron}{-1.6 \times 10^{-19}\ \text{C}} = \mathbf{2 \times 10^{13}\ electrons}$$

milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Elementary Charge = 1.60×10^{-19} C

Lesson Takeaways

D.2

- ❑ I can describe the conservation of charge and the types of charging
- ❑ I can describe the process for how Millikan experimentally determined the charge of an electron
- ❑ I can calculate the charge on an object based on the number of electrons and protons