جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم الفيزياء الحياتية

Electromagnetism

Introduction and Electric Forces

Mohammed Qasim Taha

Electromagnetism

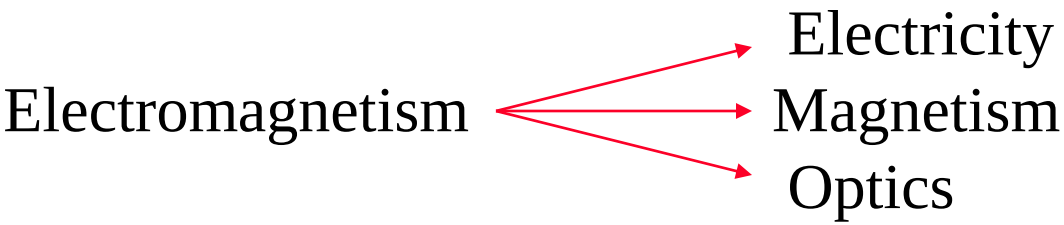
Electromagnetism is one of the fundamental forces in nature, and the the dominant force in a vast range of natural and technological phenomena

 The electromagnetic force is solely responsible for the structure of matter, organic, or inorganic Physics, chemistry, biology, materials science

 The operation of most technological devices is based on electromagnetic forces. From lights, motors, and batteries, to communication and broadcasting systems, as well as microelectronic devices.

 Engineering

Electromagnetism



In this course we are going to discuss the fundamental concepts of electromagnetism:

charge	force	field	potential	current
electric circuit	magnetic field	induction	alternating currents	waves
reflection	refraction	image	interference	diffraction

Once you master these basic concepts, you will be ready to move forward, into more advanced subjects in your specific field of interest

System of Units

We will use the SI system – SI ≡ International System of Units

Fundamental Quantities

Length meter [m]

Mass kilogram [kg]

Time second [s]

Other Units

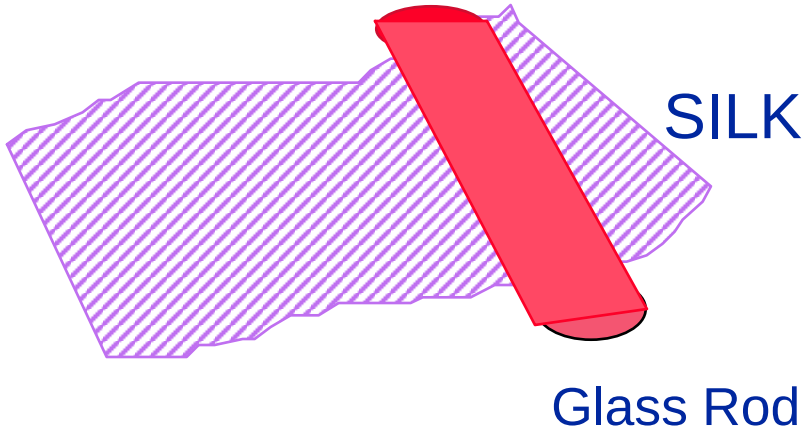
Current ampere [A]

Derived Quantities

Force	newton	$1\ N = 1\ kg\ m / s^2$
Energy	joule	$1\ J = 1\ N\ m$
Charge	coulomb	$1\ C = 1\ A\ s$
Electric Potential	volt	$1\ V = 1\ J / C$
Resistance	ohm	$1\ \Omega = 1\ V / A$

Electric Charge

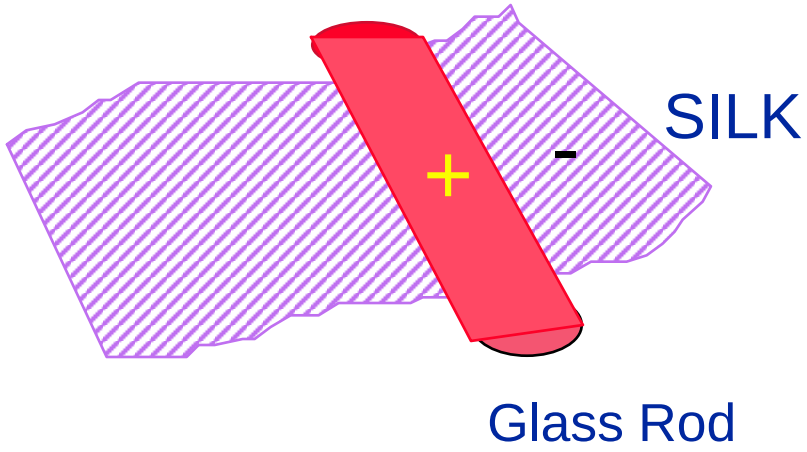
The Transfer of Charge



Some materials attract electrons more than others.

Electric Charge

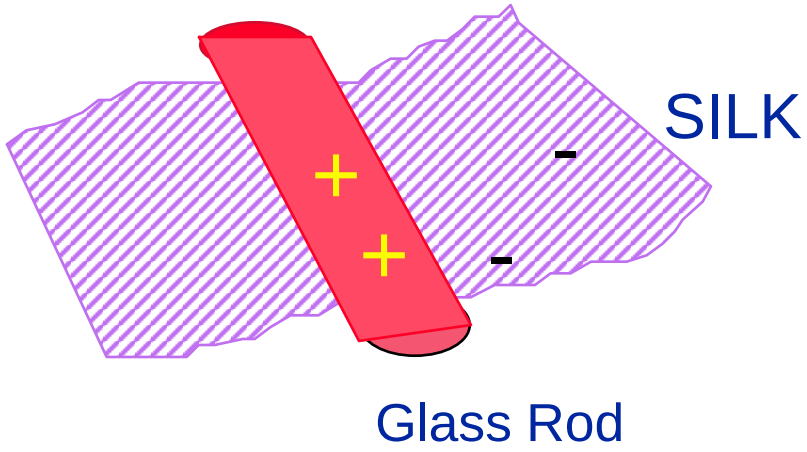
The Transfer of Charge



As the glass rod is rubbed against silk, electrons are pulled off the glass onto the silk.

Electric Charge

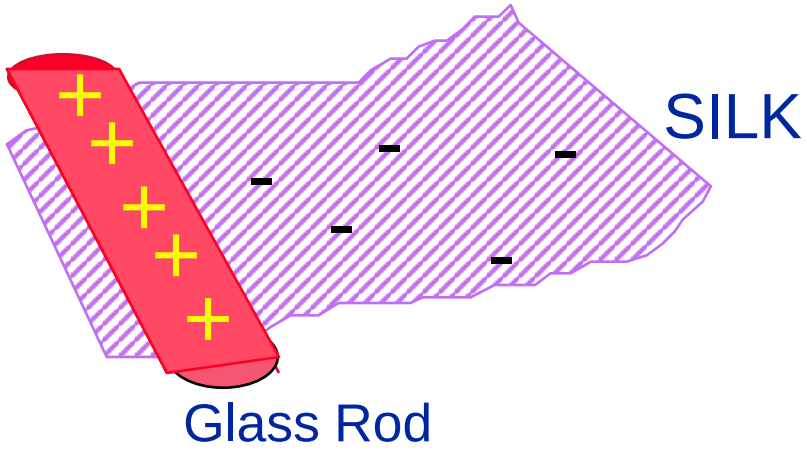
The Transfer of Charge



Usually matter is charge neutral, because the number of electrons and protons are equal. But here the silk has an excess of electrons and the rod a deficit.

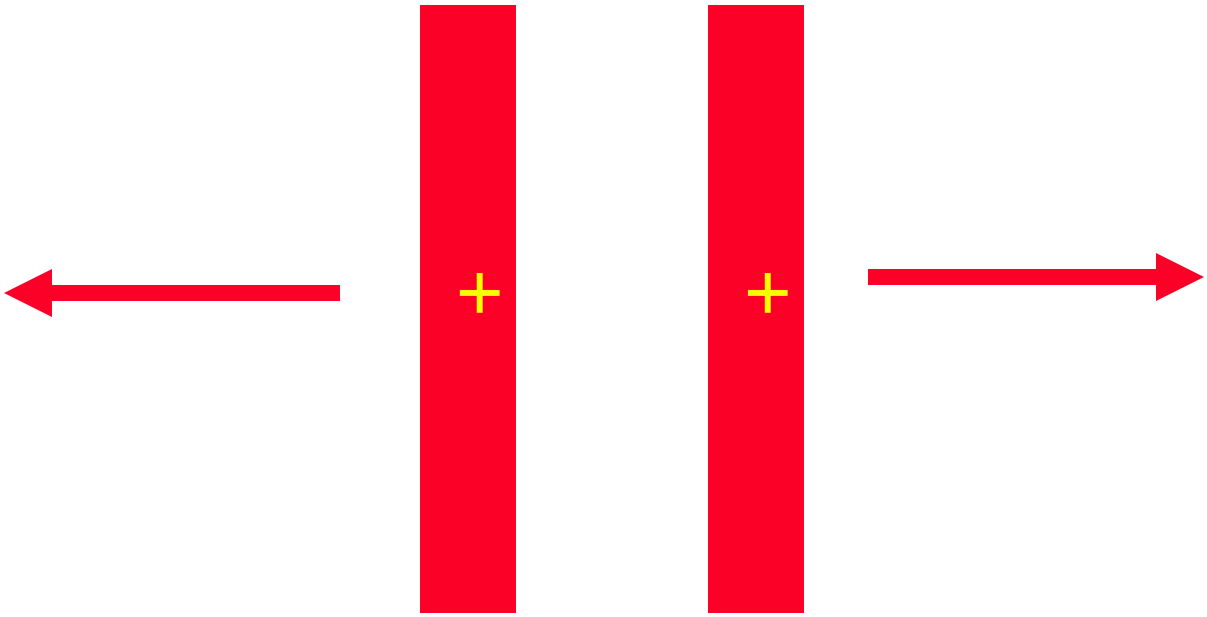
Electric Charge

The Transfer of Charge



Glass and silk are insulators:
charges stuck on them stay put.

Electric Charge



Two positively charged rods repel each other.

Electric Charge

History

600 BC	Greeks first discover attractive properties of amber when rubbed.
1600 AD	Electric bodies repel as well as attract
1735 AD	du Fay: Two distinct types of electricity
1750 AD	Franklin: Positive and Negative Charge
1770 AD	Coulomb: “Inverse Square Law”
1890 AD	J.J. Thompson: Quantization of electric charge - “Electron”

Electric Charge

Summary of things we know:

- There is a property of matter called electric charge. (In the SI system its units are Coulombs.)
- Charges can be negative (like electrons) or positive (like protons).
- In matter, the positive charges are stuck in place in the nuclei. Matter is negatively charged when extra electrons are added, and positively charged when electrons are removed.
- Like charges repel, unlike charges attract.
- Charges travel in conductors, not in insulators
- Force of attraction or repulsion ~ $1 / r^2$

Charge is Quantized

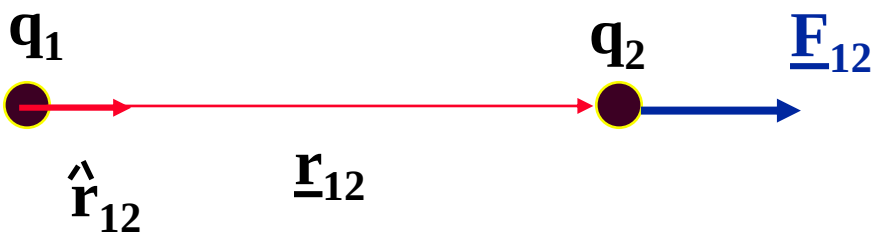
q = multiple of an elementary charge e:

$e = 1.6 \times 10^{-19}$ Coulombs

	Charge	Mass	Diameter
electron	- e	1	0
proton	+e	1836	$\sim 10^{-15}$m
neutron	0	1839	$\sim 10^{-15}$m
positron	+e	1	0

(Protons and neutrons are made up of quarks, whose charge is quantized in multiples of e/3. Quarks can't be isolated.)

Coulomb's Law



$$\underline{\mathbf{F}}_{12} = \frac{kq_1q_2}{r_{12}^2}\,\hat{\mathbf{r}}_{12}$$

Force on 2 due to 1

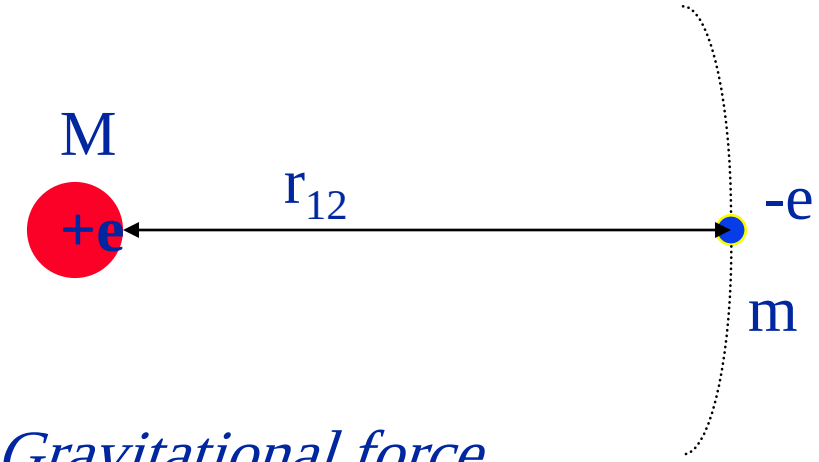
$k = (4\pi\varepsilon_0)^{-1} = 9.0 \times 10^9 \ \mathrm{Nm^2/C^2}$

ε_0 = permitivity of free space

$= 8.86 \times 10^{-12} \ \mathrm{C^2/Nm^2}$

Coulomb's law describes the interaction between bodies due to their charges

Gravitational and Electric Forces in the Hydrogen Atom

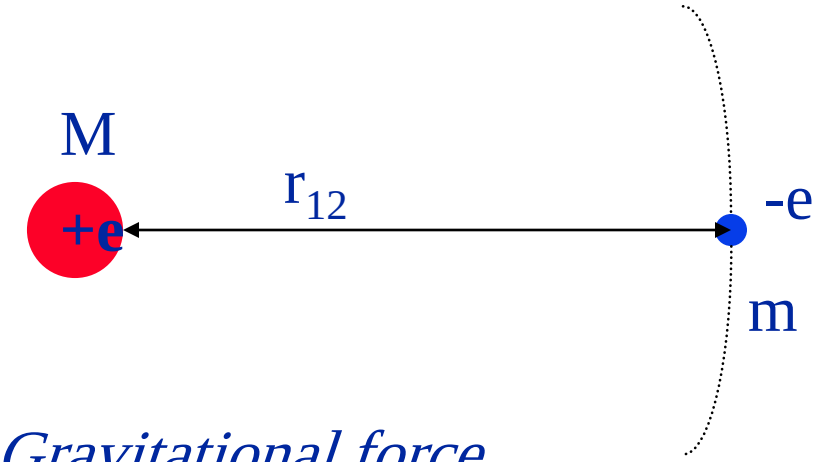


m = 9.1 10^{-31} kg
M = 1.7 10^{-27} kg
r_{12} = 5.3 10^{-11} m

Gravitational force

Electric Force

Gravitational and Electric Forces in the Hydrogen Atom



$m = 9.1\ 10^{-31}$ kg
$M = 1.7\ 10^{-27}$ kg
$r_{12} = 5.3\ 10^{-11}$ m

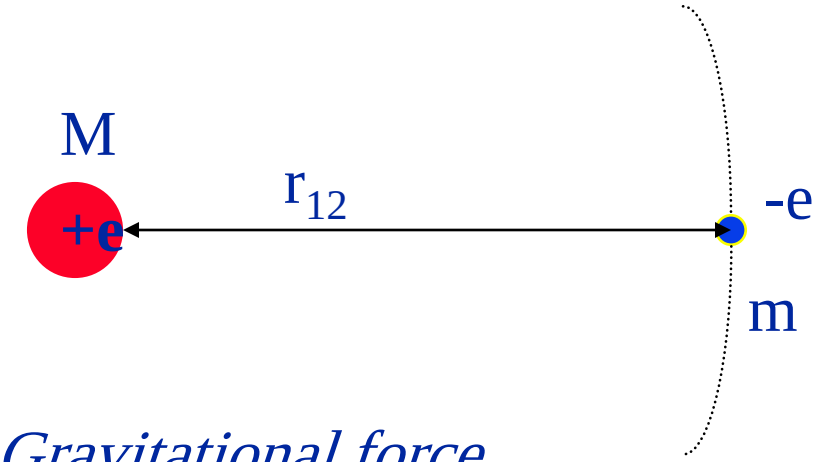
Gravitational force

$$\vec{F}_g = G\frac{Mm}{r_{12}^2}\hat{r}$$

$F_g = 3.6\ 10^{-47}$ N

Electric Force

Gravitational and Electric Forces in the Hydrogen Atom



m = 9.1 10^{-31} kg
M = 1.7 10^{-27} kg
r_{12} = 5.3 10^{-11} m

Gravitational force

$$\vec{F}_g = G\frac{Mm}{r_{12}^2}\hat{r}$$

F_g = 3.6 10^{-47} N

Electric Force

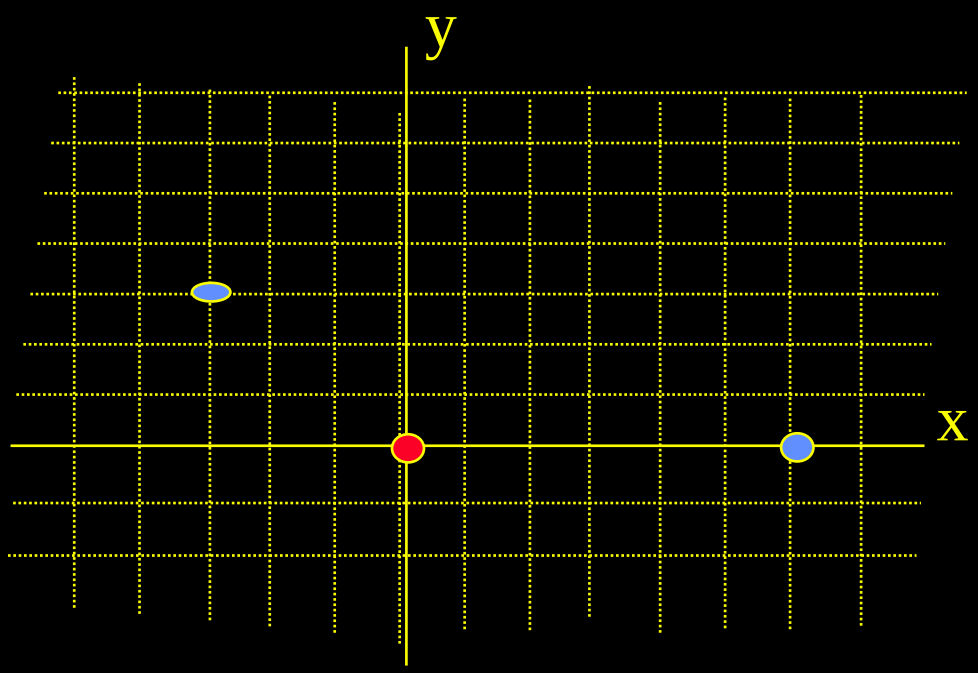
$$\vec{F}_e = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Qq}{r_{12}^2}\hat{r}$$

F_e = 3.6 10^{-8}N

Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

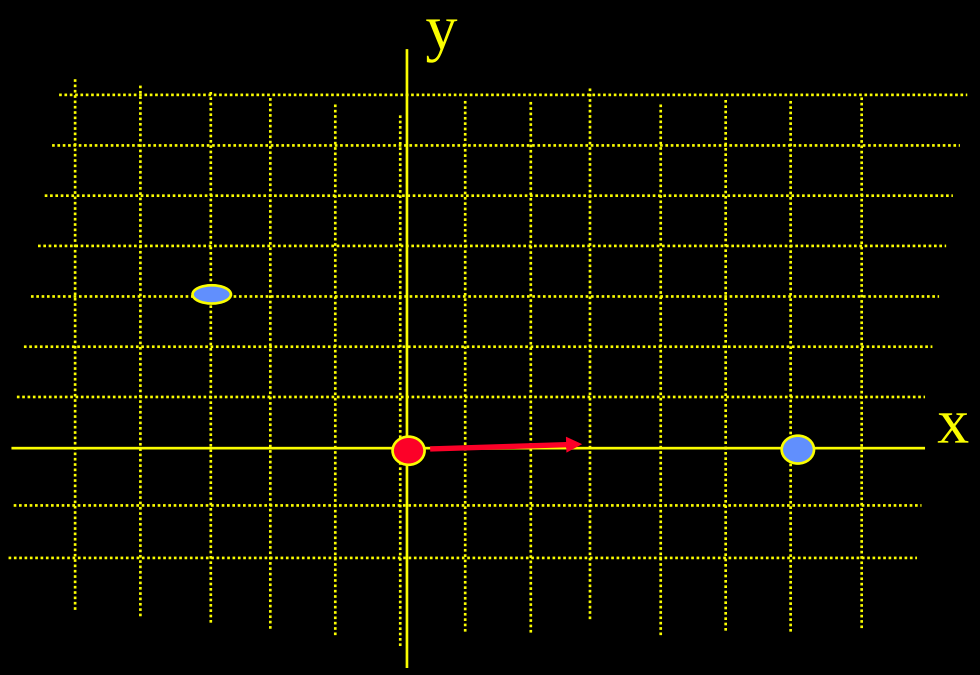


Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Consider effect of each charge separately:

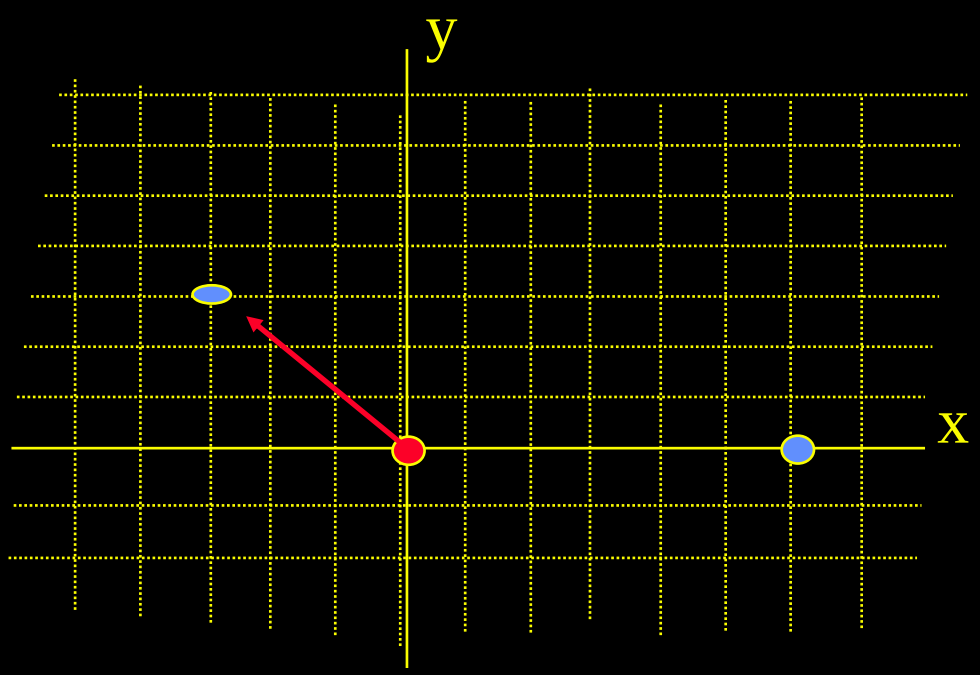


Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Take each charge in turn:

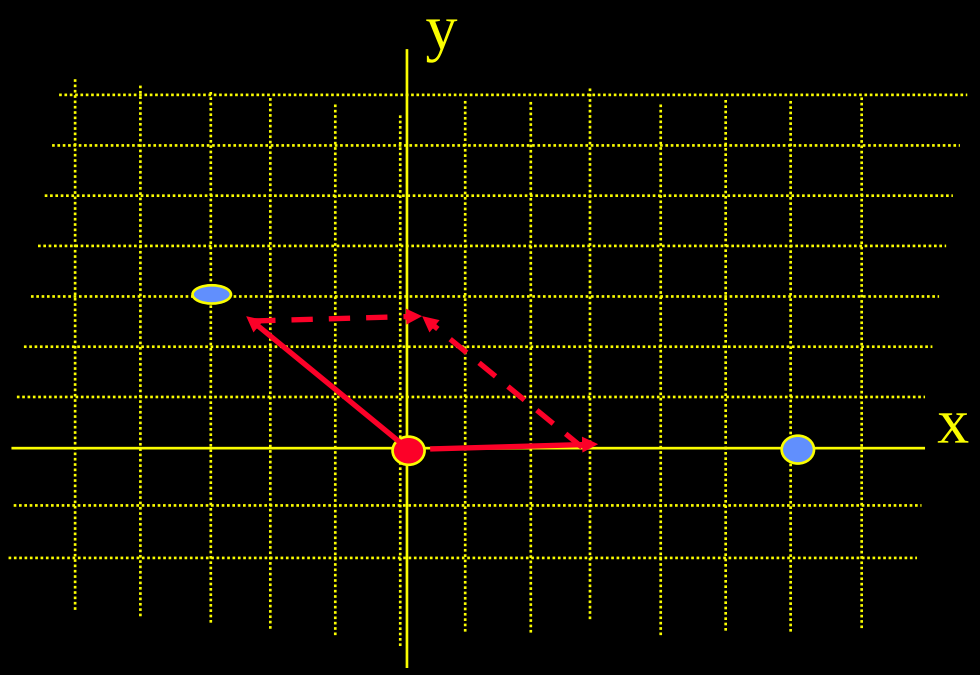


Superposition of forces from two charges

Blue charges fixed , negative, equal charge (-q)

What is force on positive red charge +q ?

Create vector sum:

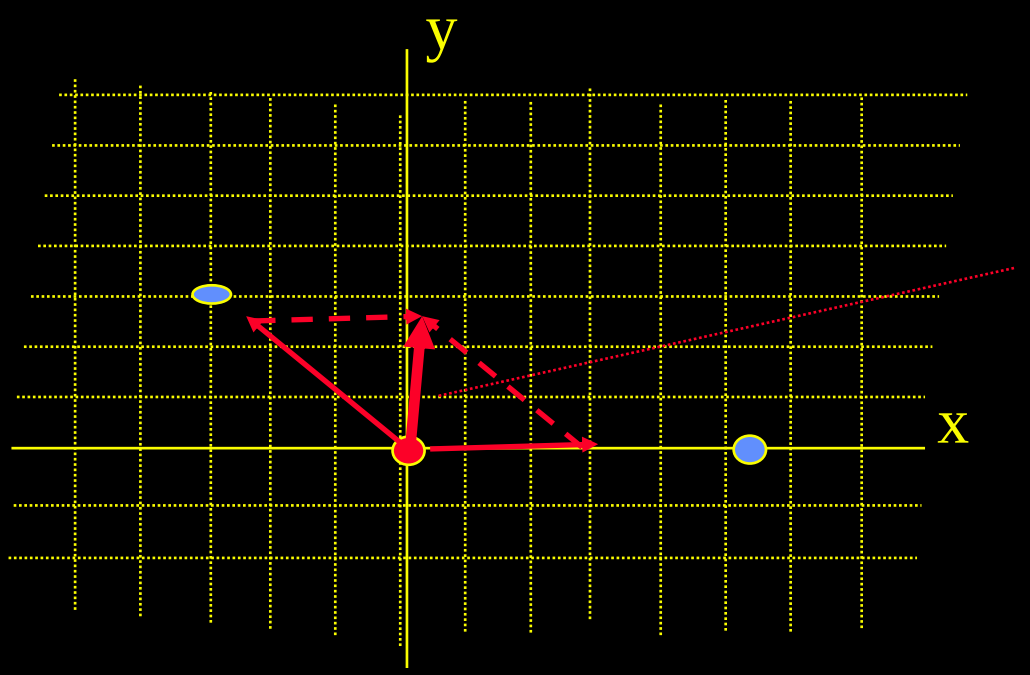


Superposition of forces from two charges

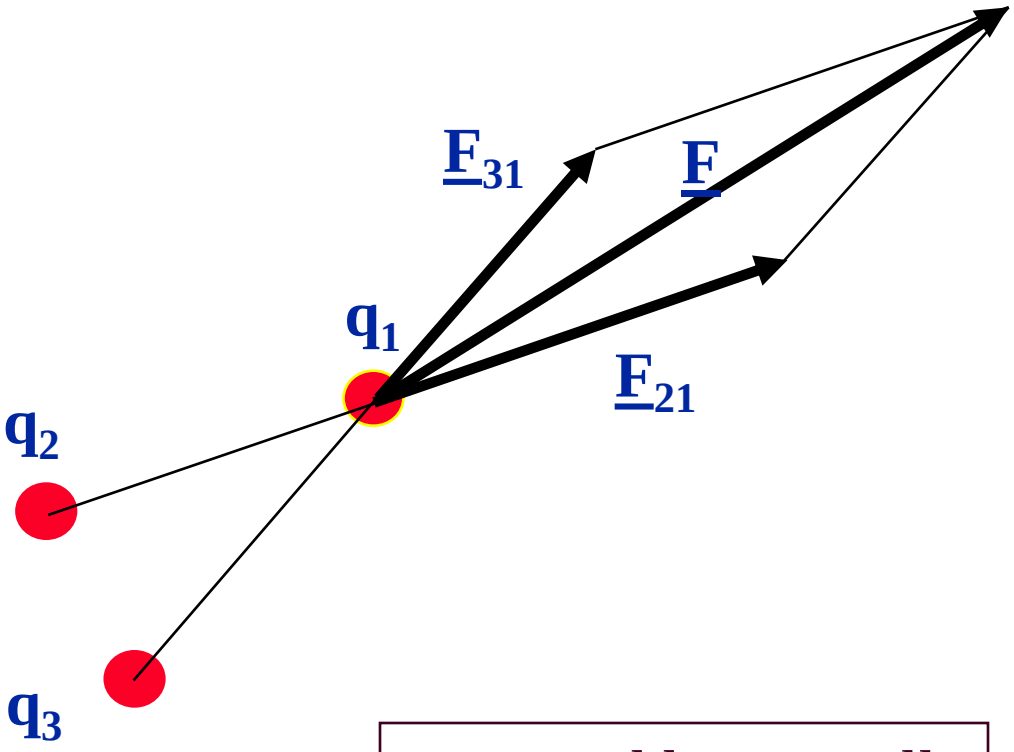
Blue charges fixed , negative, equal charge (-q)

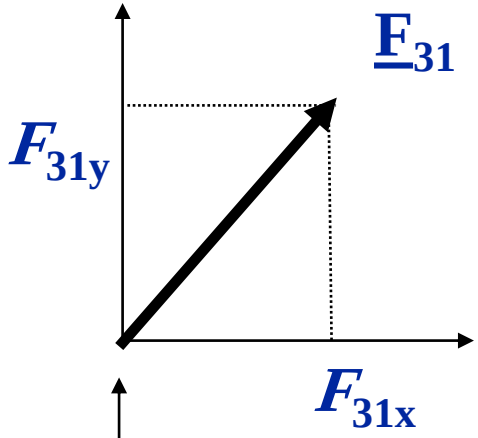
What is force on positive red charge +q ?

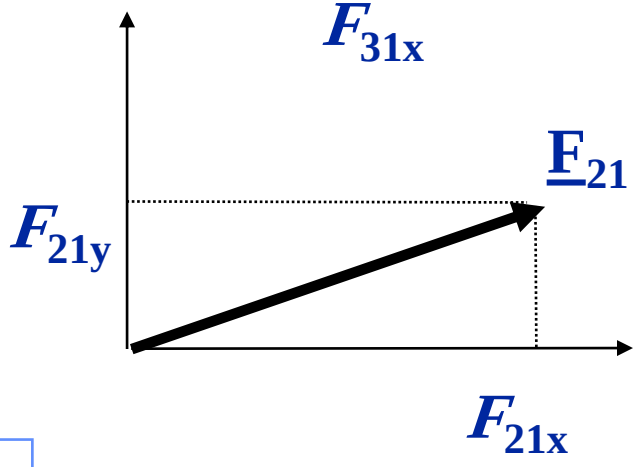
Find resultant:



Superposition Principle







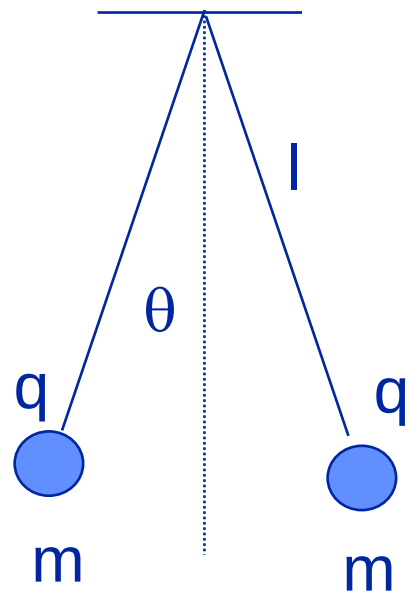
Forces add vectorially

$$\underline{F} = (F_{21x} + F_{31x})\,\underline{x} + (F_{21y} + F_{31y})\,\underline{y}$$

Example: electricity balancing gravity

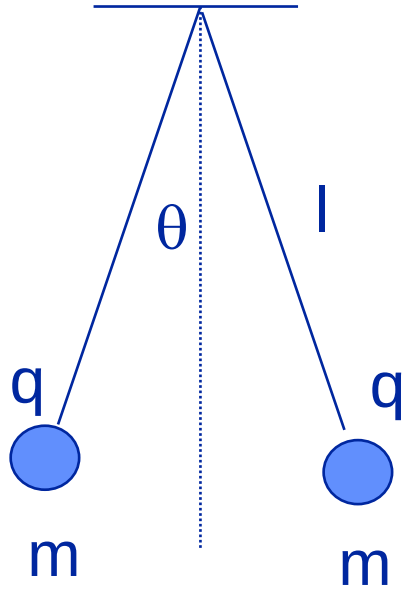
Two identical balls, with mass m and charge q, hang from similar strings of length l.

After equilibrium is reached, find the charge q as a function of θ and l



Example: electricity balancing gravity

What forces are acting on the charged balls ?



Example: electricity balancing gravity

- Draw vector force diagram while identifying the forces.
- Apply Newton's 3rd Law, for a system in equilibrium, to the components of the forces.
- Solve!