PH 108
Basics of Electricity and Magnetism

- Interactive session (Division 3)
  Tuesdays and Fridays 2.00 pm - 3.00 pm

- Instructor : Raghunath Chelakkot
  (raghu@phy.iitb.ac.in)

- Email queries ph108@phy.iitb.ac.in

Lecture plan (Flipped)

- **Two lecture videos per week** - uploaded on Saturdays and Tuesdays

Can be viewed **only** using IITB LDAP id.

- **First interactive session on Tuesday** - discussion on contents uploaded on previous Saturday

- **Second interactive session on Friday** - discussion on contents uploaded on previous Tuesday

Interactive sessions are on MS Teams

Video Quiz

- Every uploaded video contains one video quiz (2 per week)

MUST be attempted via MOODLE

- Deadline to attend first quiz (uploaded on Saturdays): Tuesday 9:00 am.
- Deadline to attend second quiz (uploaded on Tuesdays): Thursday 9.00 am.

Tutorial plan

- Tutorial sheets will be uploaded on Saturdays
- Selected problems will be discussed on the following Wednesday (4pm to 5 pm for D3)
- There will be 8 tutorial batches (for each division)
- Tutorial sessions will be conducted on MS Teams - **you will be** added to a different TEAM by your student TA

Tutorial Quiz

- Last five minutes of the tutorial session will be used for weekly tutorial Quiz
- Will be conducted on SAFE by the student TA

Evaluation Scheme

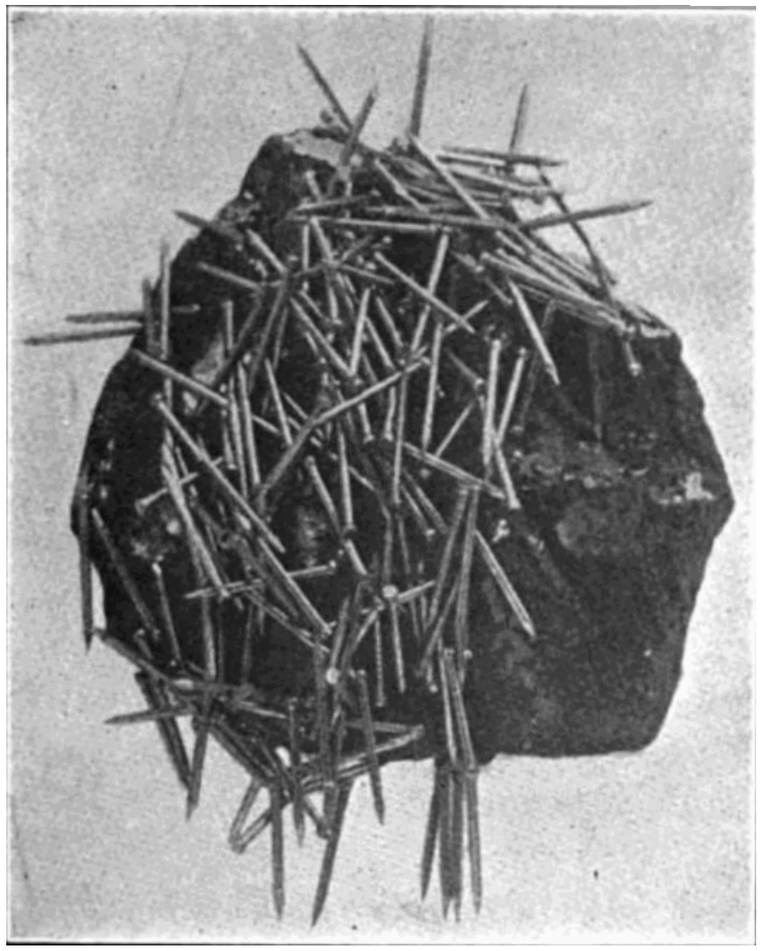
- Lecture Video Quizzes : 10
- Tutorial Quizzes : 10
- Quiz 1 : 15
- Midsem : 20
- Quiz 2 : 15
- Endsem : 30

Reference books

- Introduction to Electrodynamics : David Griffiths.
- Electricity and Magnetism : Edward Purcell
- Murray Spiegel : Vector Analysis (Schaum Series)
- Feynman Lectures on Physics (Vol. 2)
- Classical Electrodynamics: J. D. Jackson

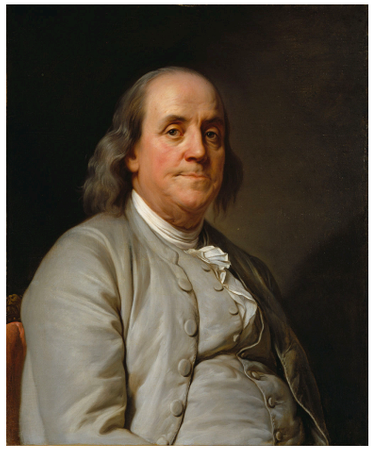
Electric and Magnetic forces

Triboelectric effect



Lodestone (Natural magnets)

Images: Wikipedia



Benjamin Franklin
(1706 -1790)

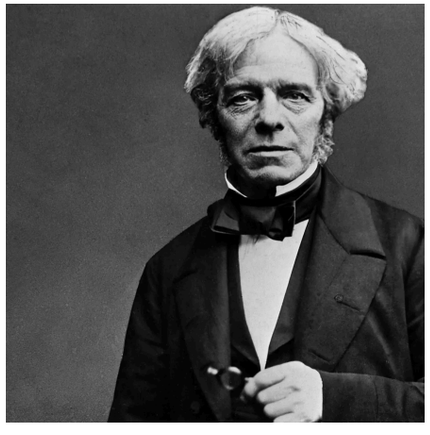
Charles-Augustin de Coulomb
(1736 -1806)

André-Marie Ampère
(1736 -1806)

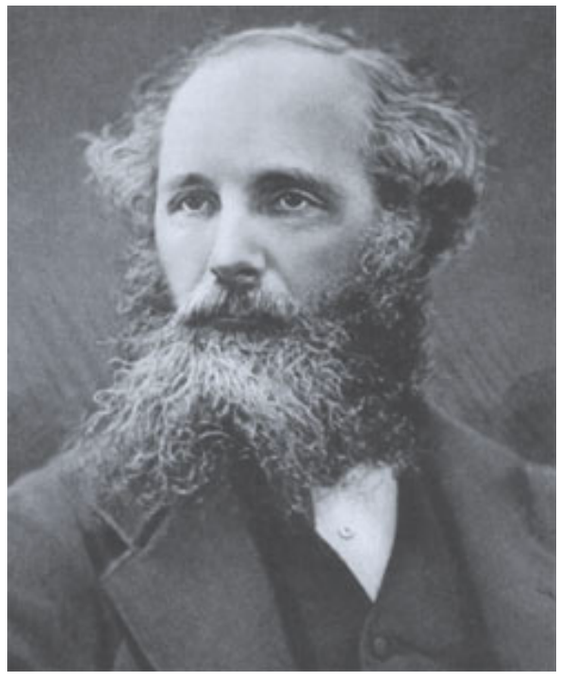
Alessandro Volta
(1745 -1827)

Félix Savart
(1791-1841)

Jean-Baptiste Biot
(1774-1862)



Michael Faraday
(1791 -1867)

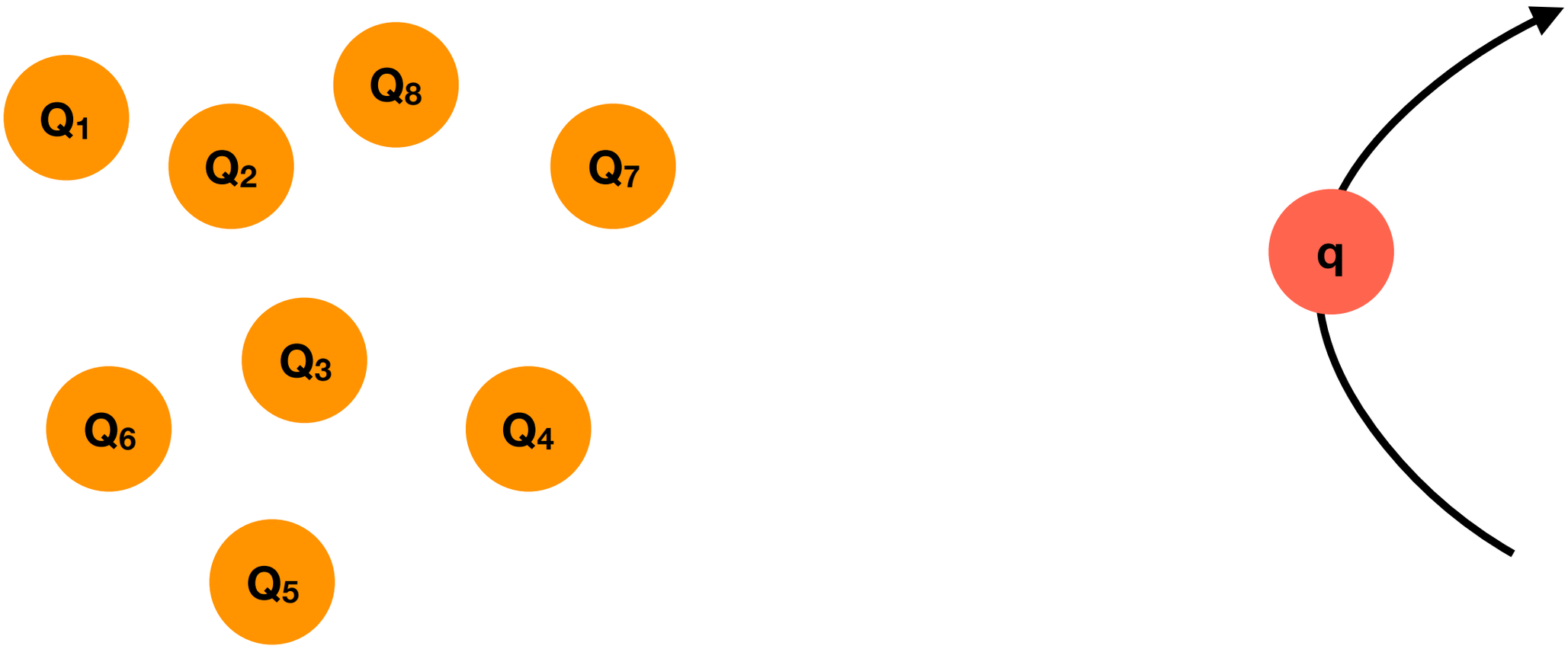


James Clark Maxwell
(1831-1879)

Maxwell's equations

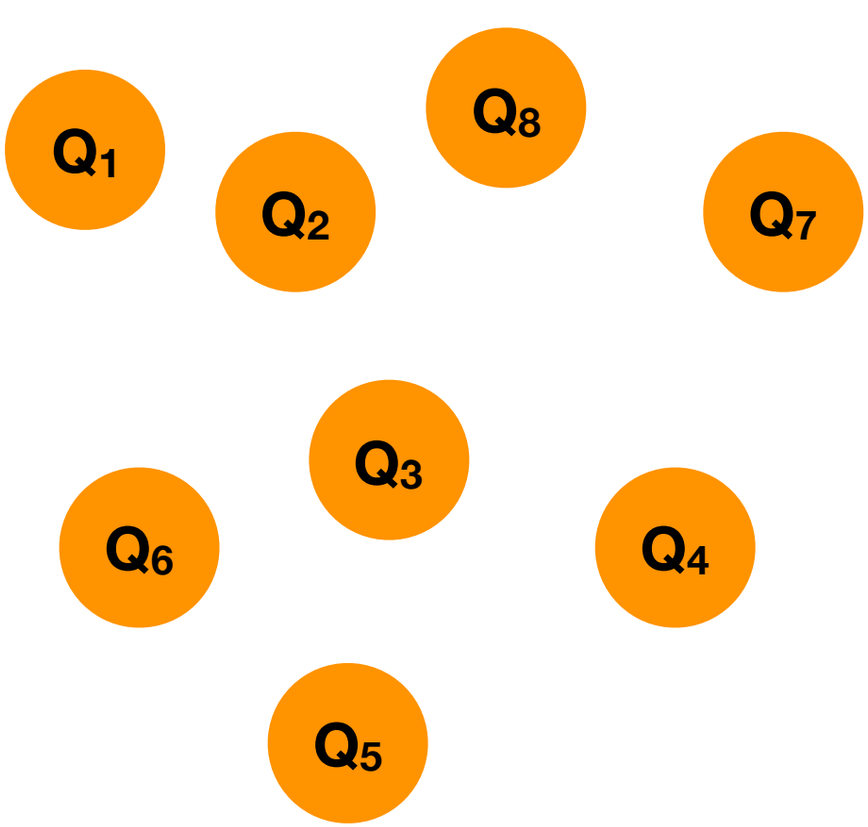
Images: Wikipedia

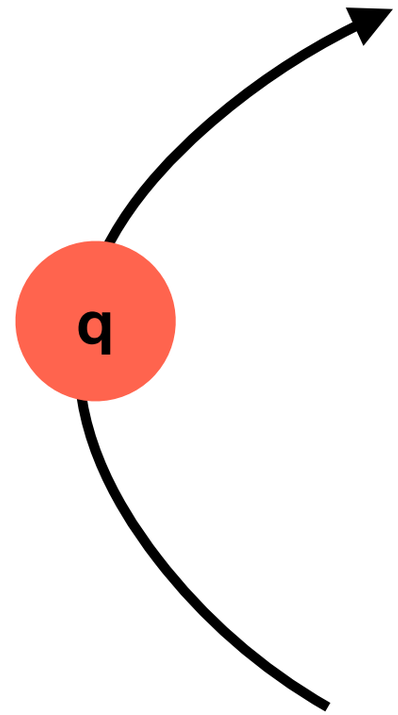
The central question



Given a configuration of charge (in space and time)
What force do they exert on another charge?

Principle of superposition



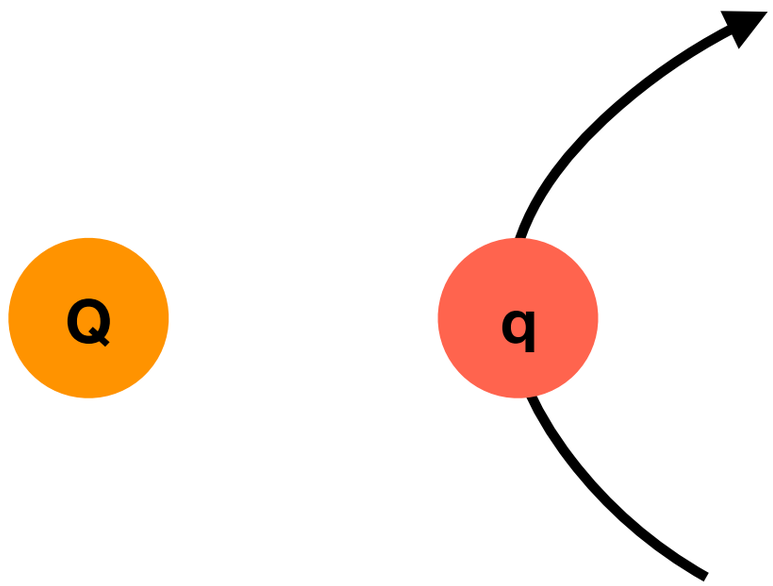


Interaction between two charges are unaffected by the presence of another charge.

$$\vec{F}_q = \vec{F}_{Q_1} + \vec{F}_{Q_2} + \ldots = \sum_i \vec{F}_{Q_1}$$

Interaction between charges
What does it depend on?

- Magnitude of the charges
- Distance between the charges
- Velocities of the charges
- Acceleration of the source charge
- At a past instant of time! (Electromagnetic waves travels at the speed of light -Relativistic effects)



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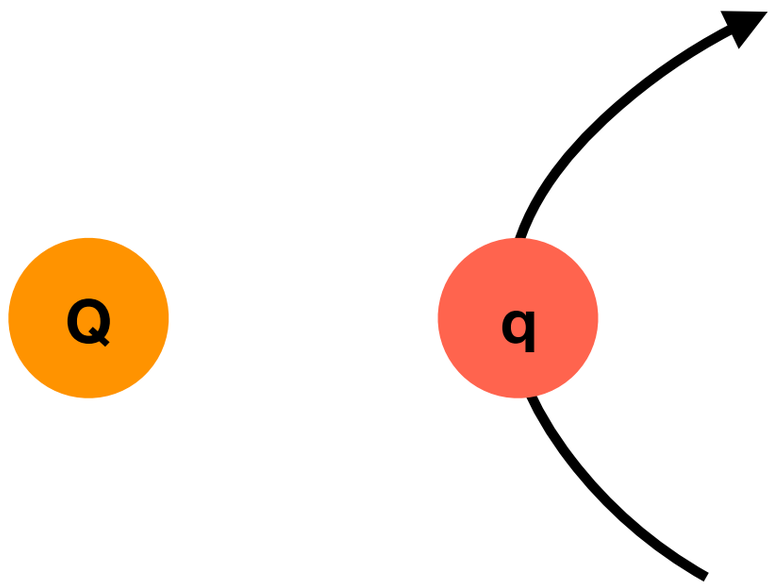
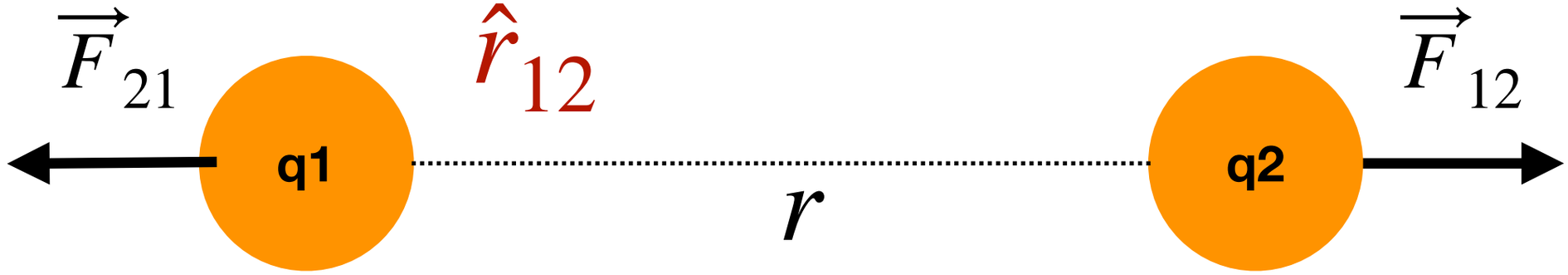


Electrostatics

The Coulomb force law

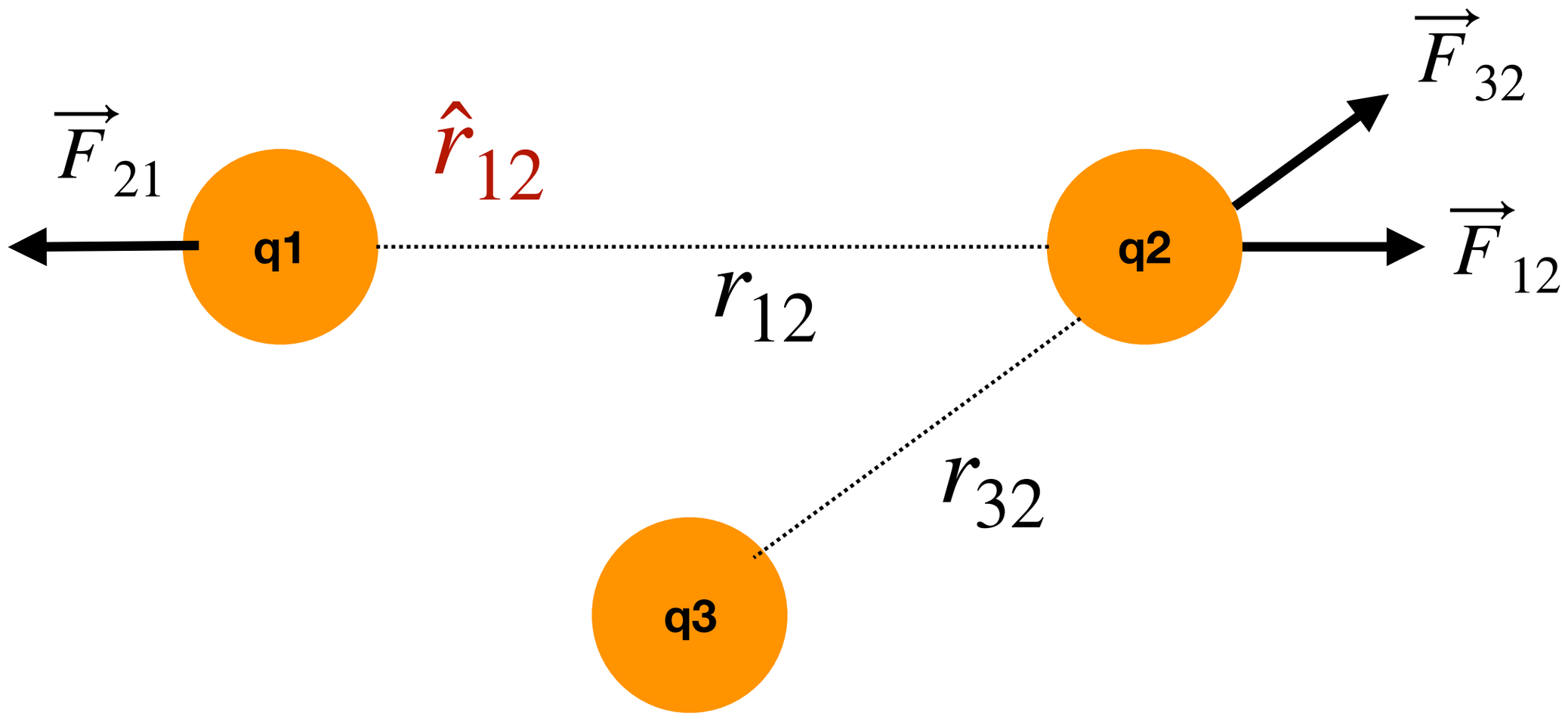


$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

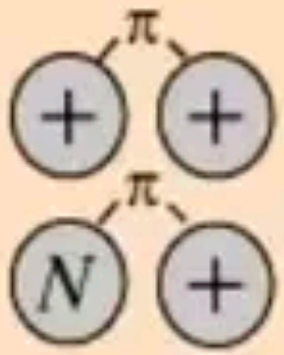
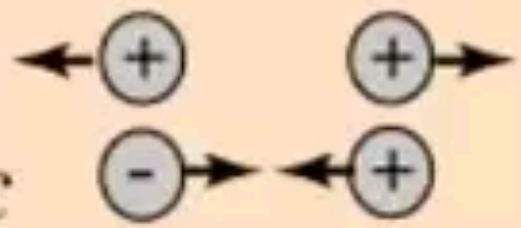
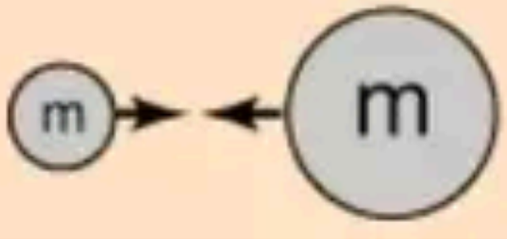
$$q_e = q_p \sim 1.6 \times 10^{-19} C$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$$

The Coulomb force law



Fundamental Forces

		Strength	Range (m)	Particle
Strong	 Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	gluons. π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	 neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

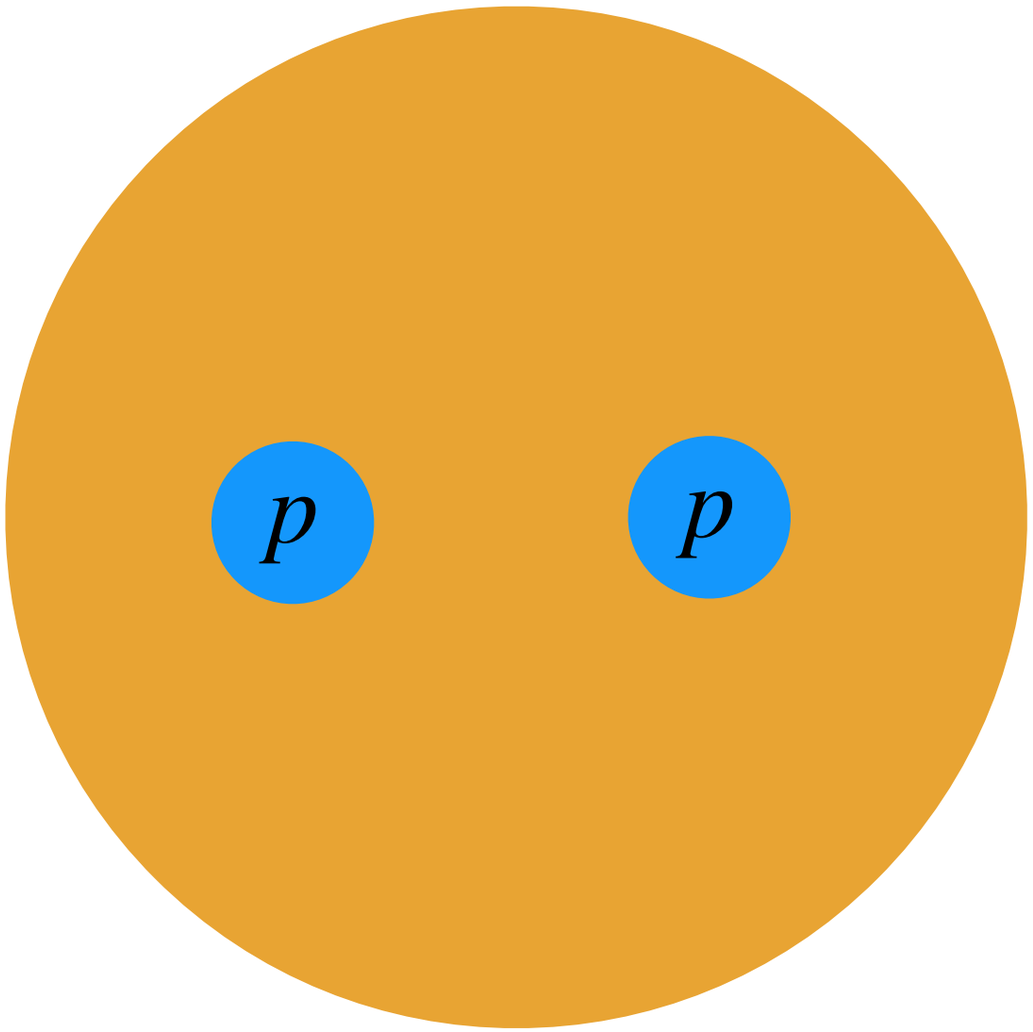
Source: http://theconfusedelectron.blogspot.com/2016/04/fundamental-forces-and-their-range.html

What holds our world together?

What counteracts the electrostatic attraction?

Quantum uncertainty!

What stabilizes the nucleus?



Gravitational vs. Electrical forces

$$F_{el} = 9 \times 10^{9} \frac{(1.6 \times 10^{-19})^2}{r^2}$$

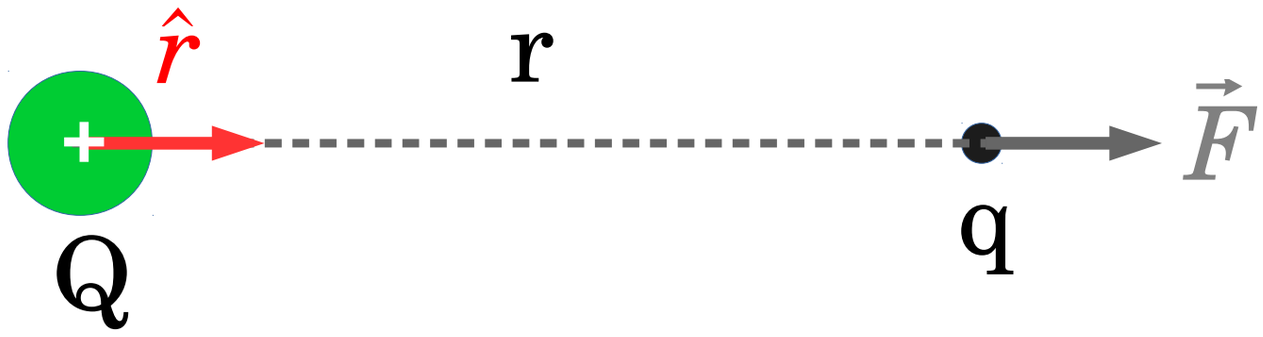
$$F_{gr} = 6.7 \times 10^{-11} \frac{(1.7 \times 10^{-27})^2}{r^2}$$

$$\frac{F_{el}}{F_{gr}} = 10^{36}$$

Nuclear Strong force (Short-ranged)

At astronomical scales? **Gravity wins!**

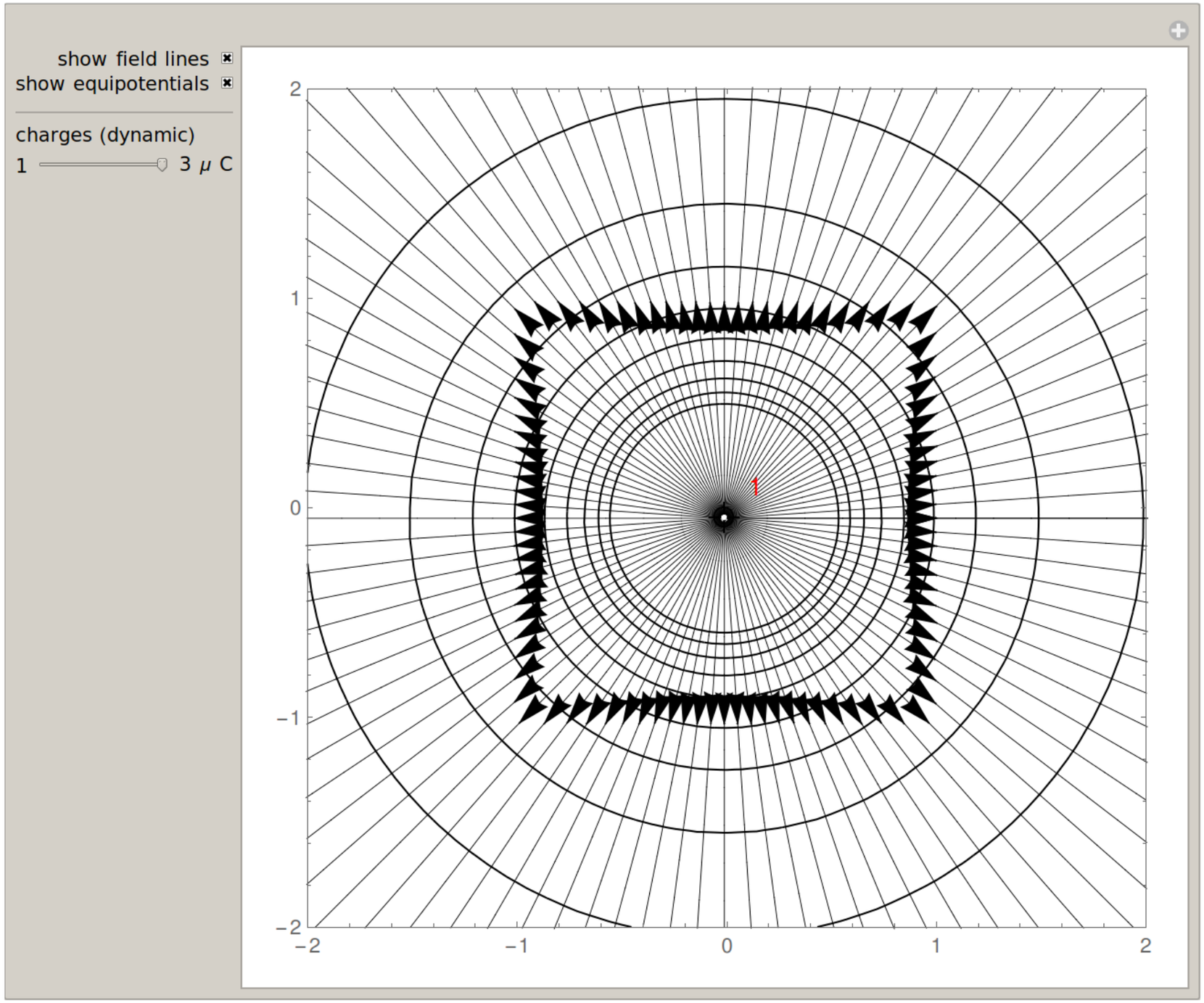
The Electric Field



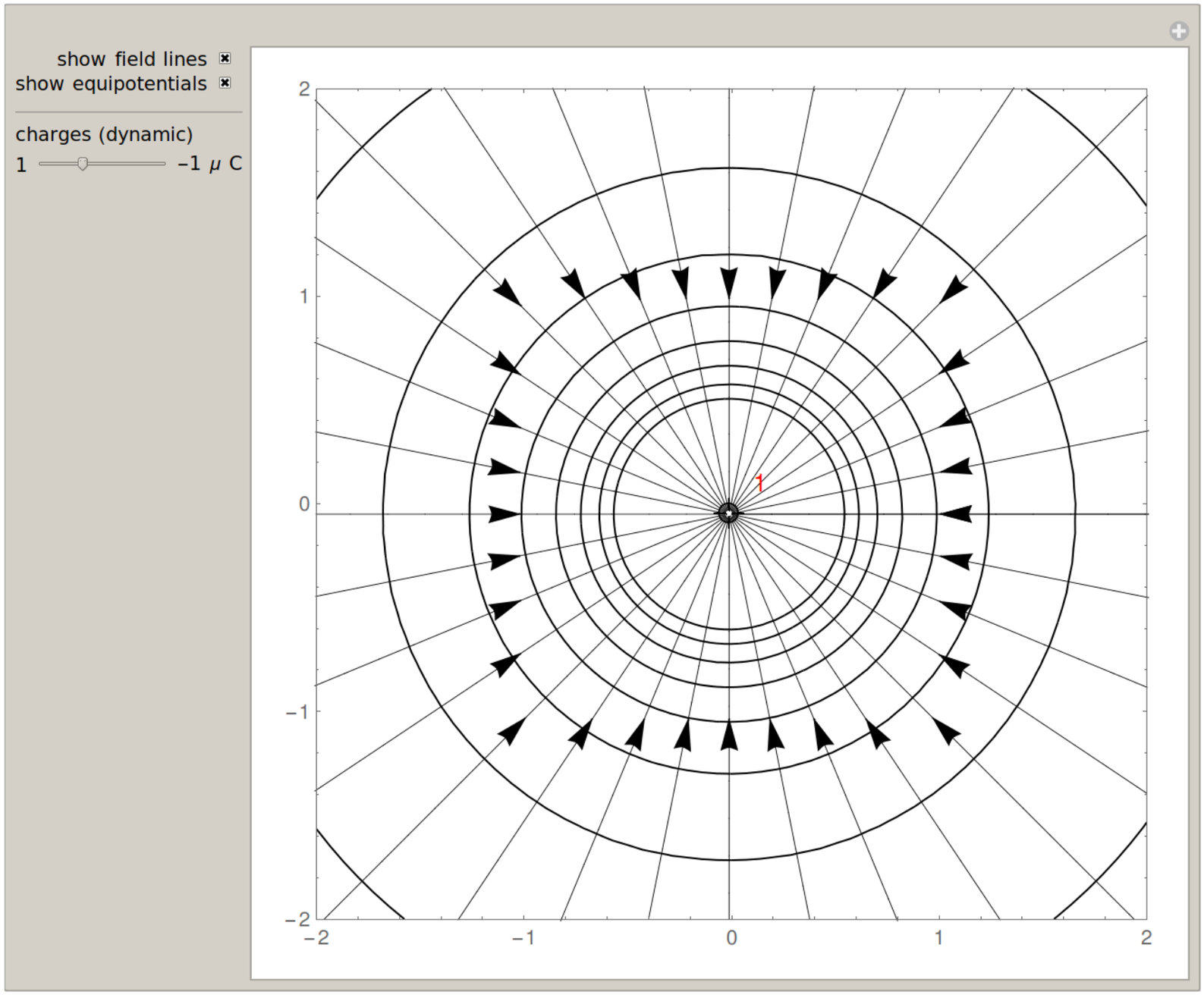
$$\vec{F} = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

The Electric Field



The Electric Field



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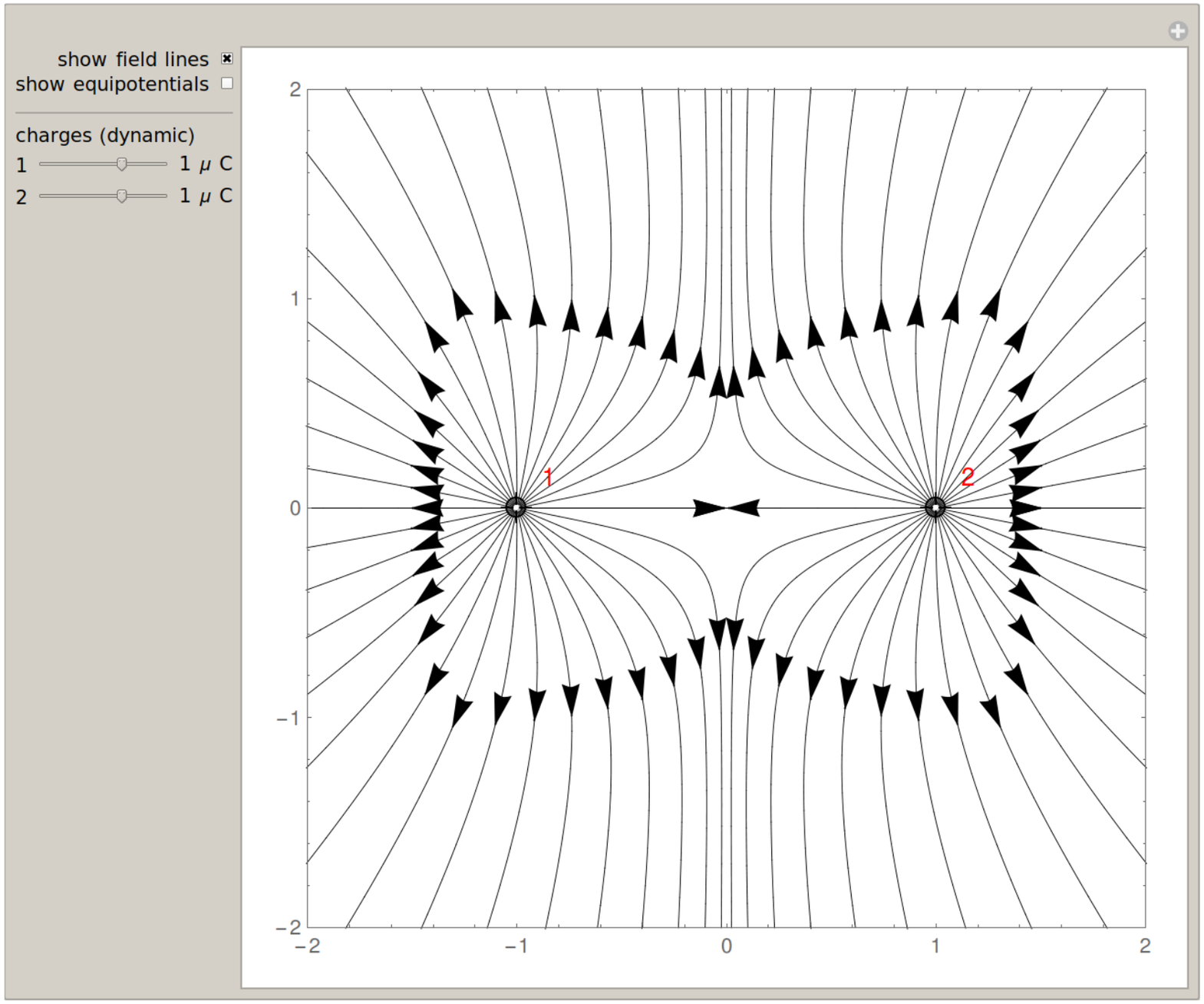

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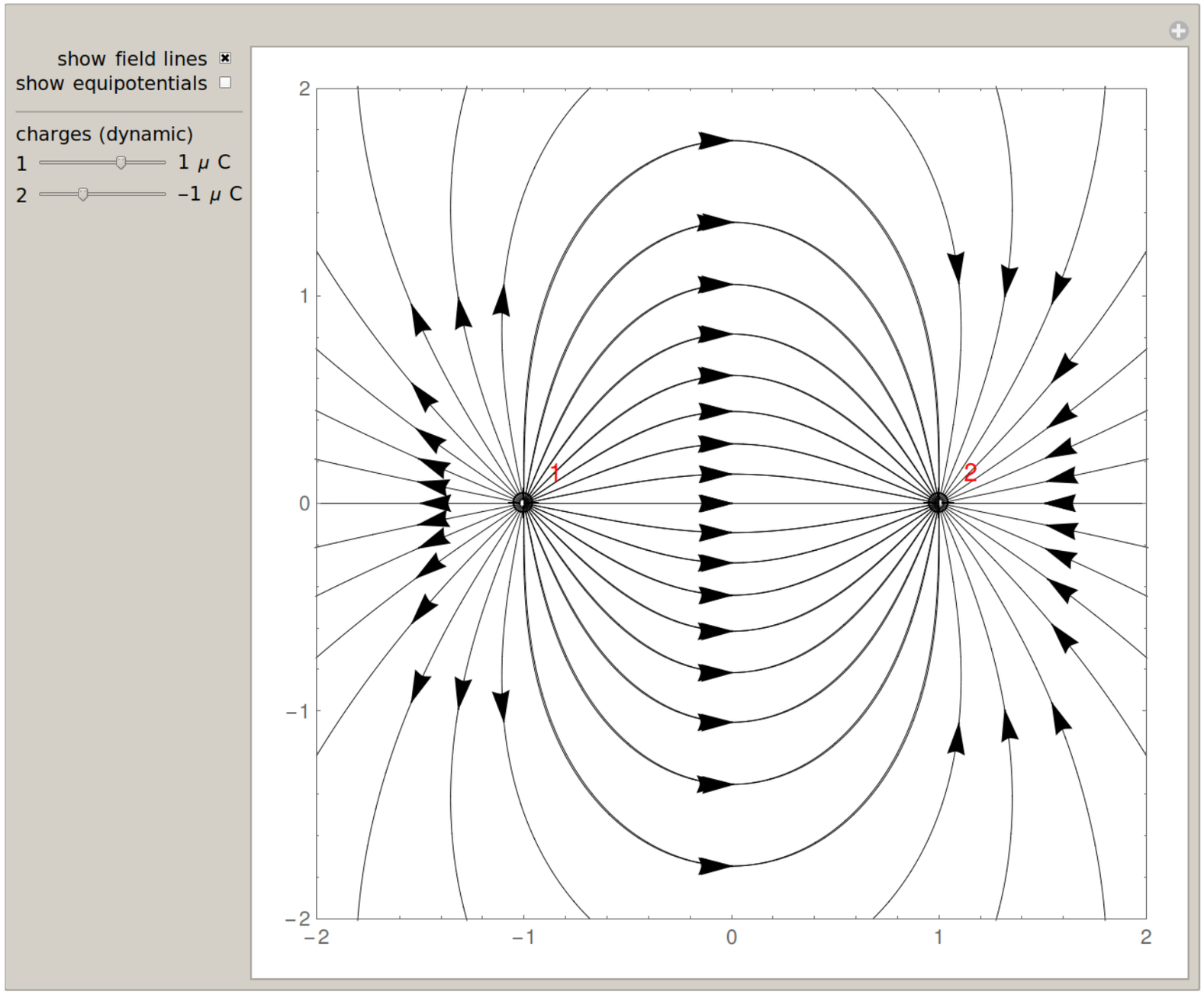


CLASSICAL FIELD THEORIES

A field is a physical quantity that has a value for each point in space and time.

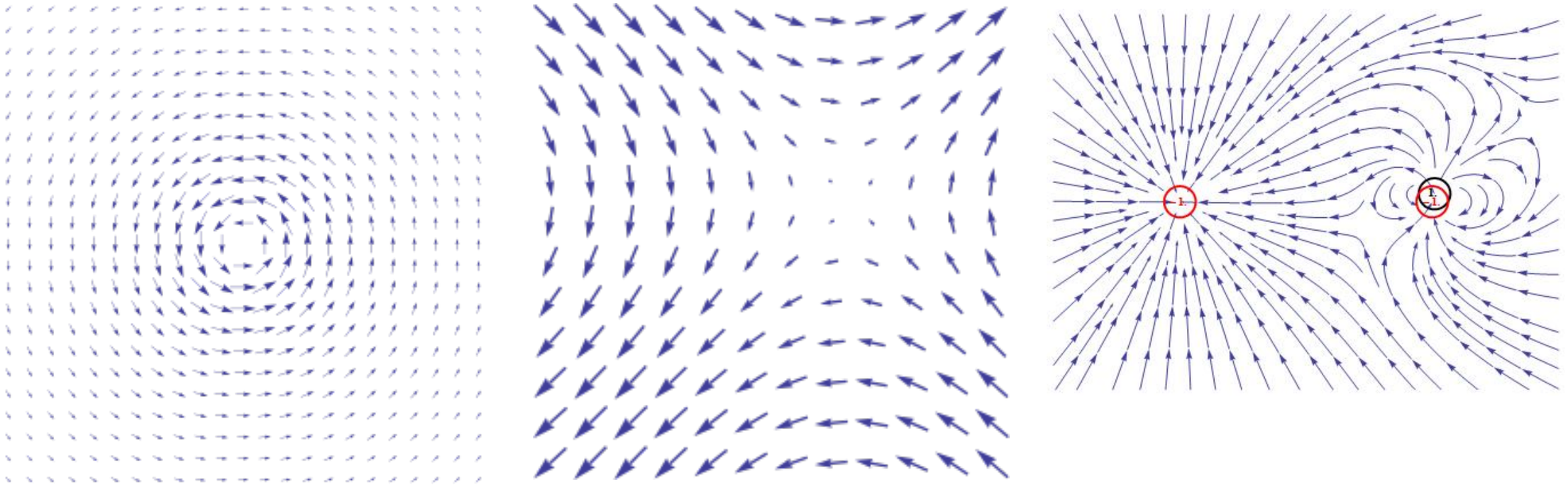
- Scalar field: Temperature T(x,y,z)
- Vector field: Electric field $\vec{E}(x, y, z)$
  Magnetic field $\vec{B}(x, y, z)$
  Velocity field $\vec{v}(x, y, z)$
- Tensor field: Stress/strain tensor field

A classical field theory describes how physical fields interact with matter through field equations.

- Newtonian gravity / Electrodynamics / Hydrodynamics
- General theory of relativity
- Quantum field theory / Quantum electrodynamics

Particles and fields both carry energy and momentum.

MATHEMATICS OF VECTOR FIELDS



Differerential calculus of fields – Gradient, divergence, curl

Integral calculus of fields – Line, surface and volume integrals

Fundamental theorems – Gauss' Theorem, Stokes Theorem

MAXWELL'S EQUATIONS

$$\nabla . \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla . \vec{B} = 0$$

$$\nabla \times \vec{E} = \frac{-\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

LORENTZ FORCE LAW

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$