Electric Fields

a ~~figment~~ reality of our imagination…

Electrostatics

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

II. Field and Potential
- **electric field strength & lines**
- electric energy and work

III. Capacitance

	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 – 8
2	State and apply Coulomb's Law to solve problems relating force, charge, and distance.	9 – 15
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.	16 – 20
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A **field** is a region where a particular force has influence. There are many types of fields in physics: gravitational fields, magnetic fields, electric fields, etc.

Field strength is defined as the amount of force per unit of affected property.

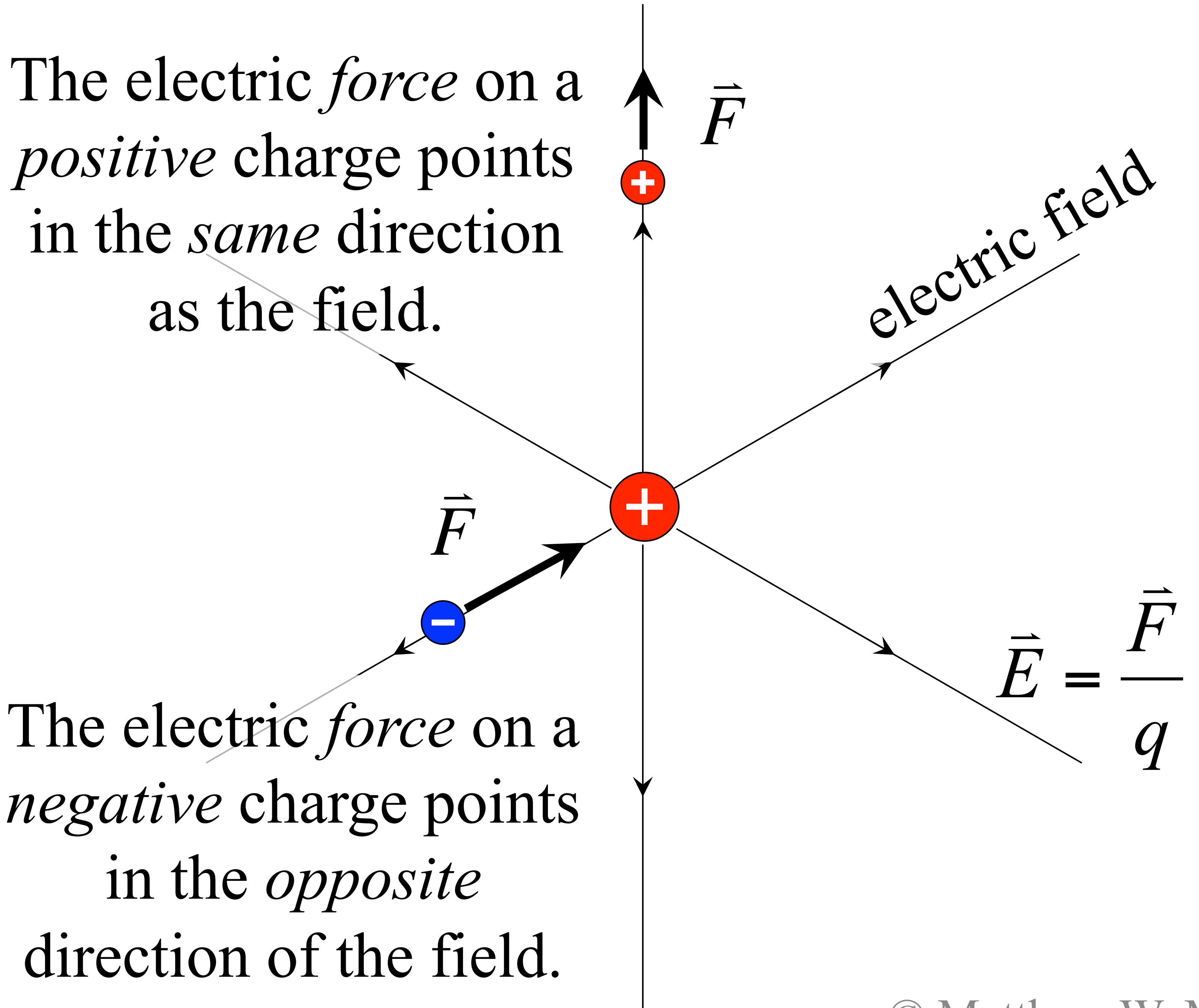
A field has direction the same as the force. A field can be visualized as a series of vectors or lines that point in the direction of the force.

Electric Field

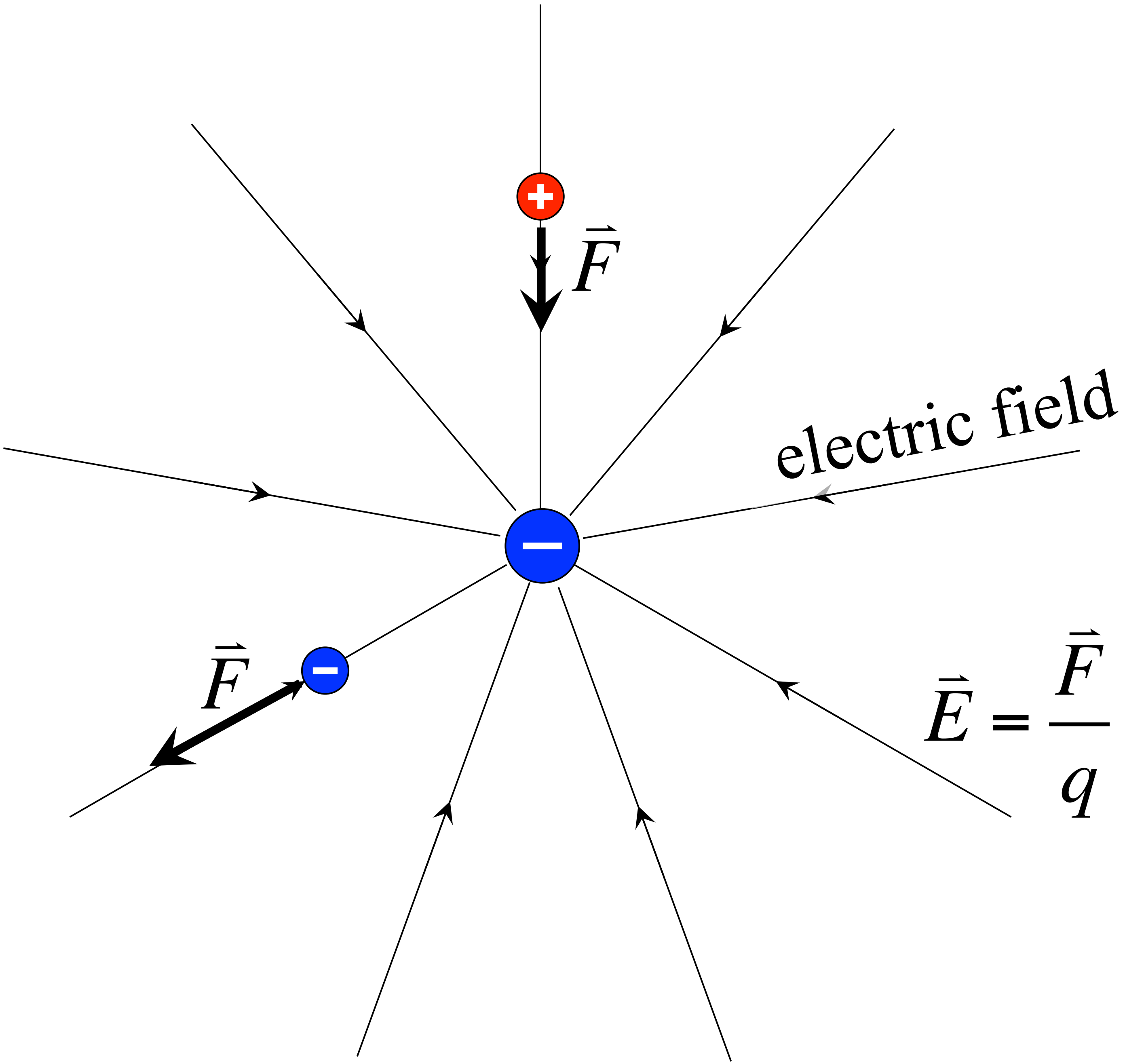
An electric field is defined as the amount of electrostatic force per charge:

$$\vec{E} = \frac{\vec{F}}{q}$$

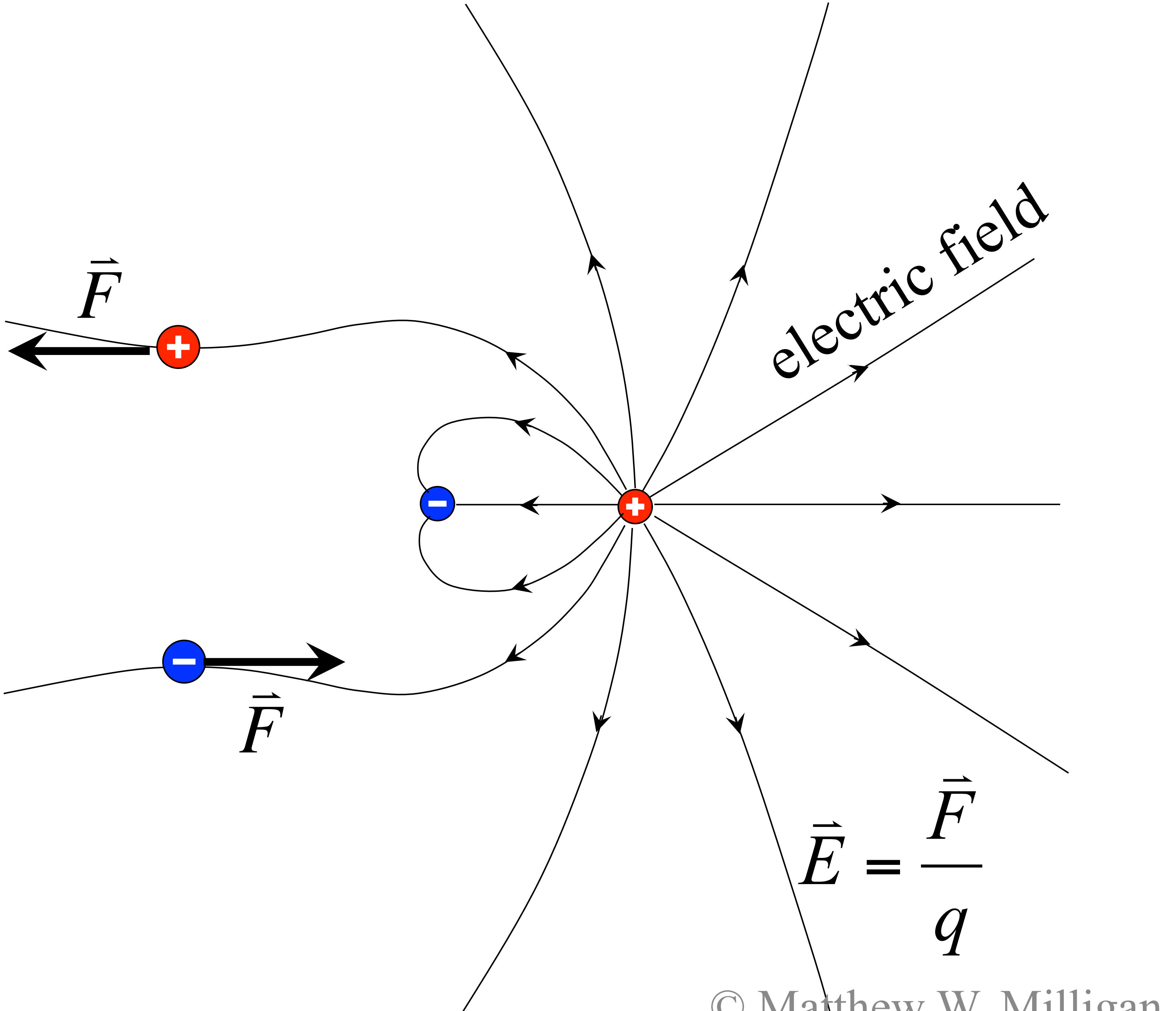
where: E = electric field
F = force on "test charge"
q = test charge in field



The electric *force* on a *positive* charge points in the *same* direction as the field.
$\vec{F}$
electric field
$\vec{F}$
$\vec{E} = \frac{\vec{F}}{q}$
The electric *force* on a *negative* charge points in the *opposite* direction of the field.

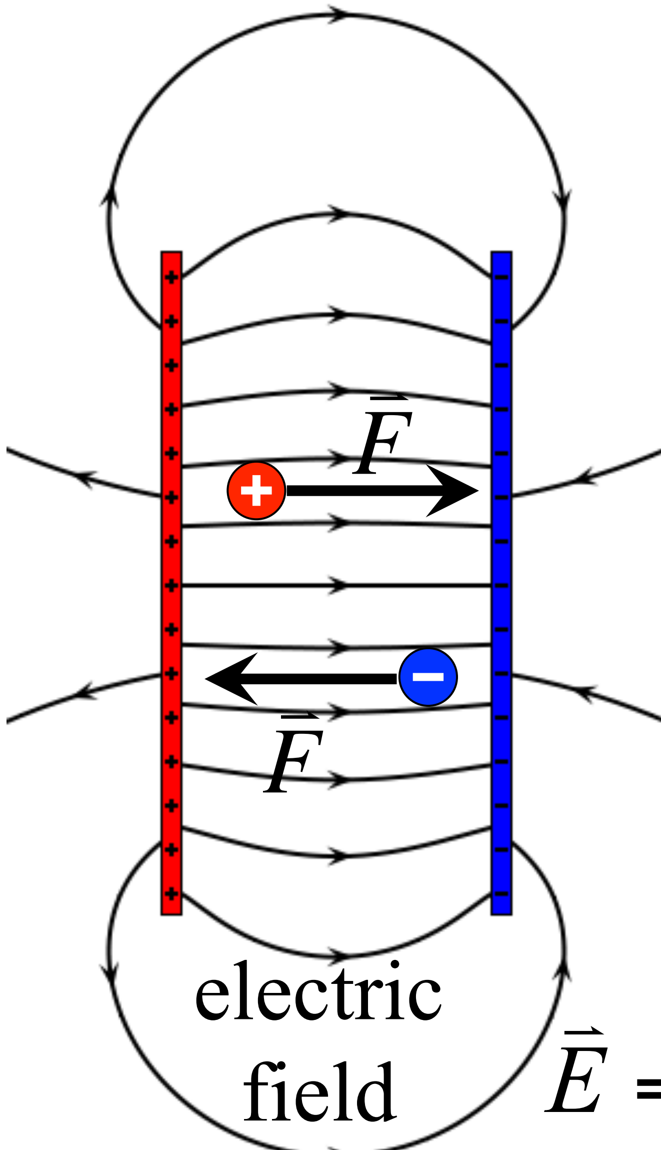


$\vec{F}$
electric field
$\vec{F}$
$\vec{E} = \dfrac{\vec{F}}{q}$



$\vec{F}$
electric field
$\vec{F}$
$\vec{E} = \dfrac{\vec{F}}{q}$

Electric Field – Parallel Plates



$$\vec{E} = \frac{\vec{F}}{q}$$

Credit: Geek3, Wikipedia

Sources of Electric Fields

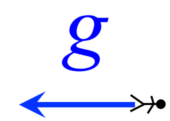
- Any charged object "creates" a surrounding electric field.
- Said charge could be referred to as the "source" of the field.
- It is often required to determine the electric field as a function of the source charge(s).

Electric Field

$$\boxed{E = k\frac{Q}{r^2}}$$

where: Q = charge of the field's *source*
(spherically symmetric charge)
r = distance between centers
k = Coulomb's Law constant

Gravitational Field



$$g = G\frac{M}{r^2}$$

where: M = mass of the field's *source*

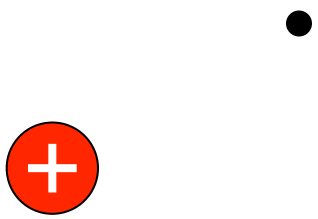
r = distance between centers

G = universal gravitational constant:

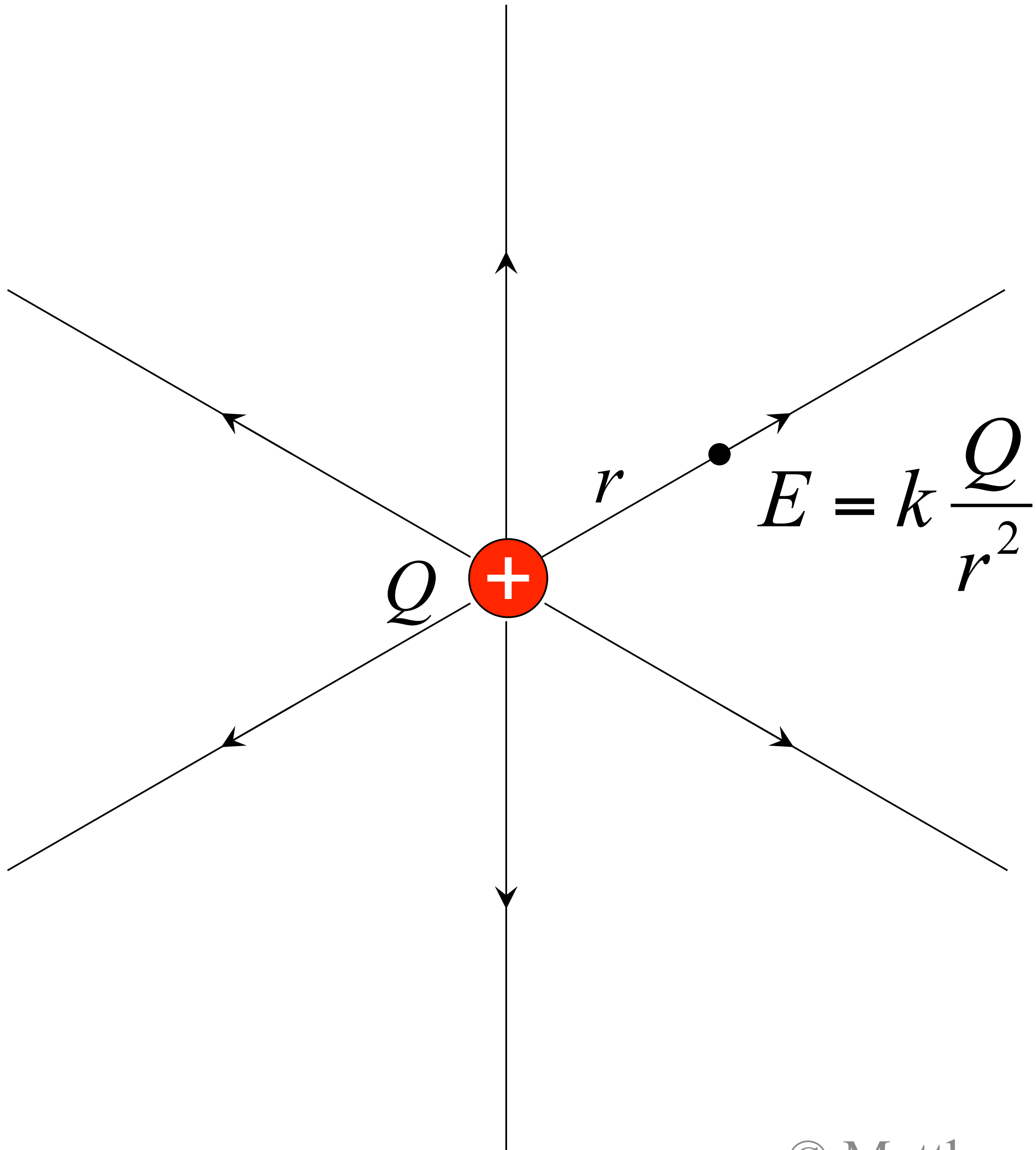
$6.674 \times 10^{-11}\ \text{m}^3/\text{kg s}^2$

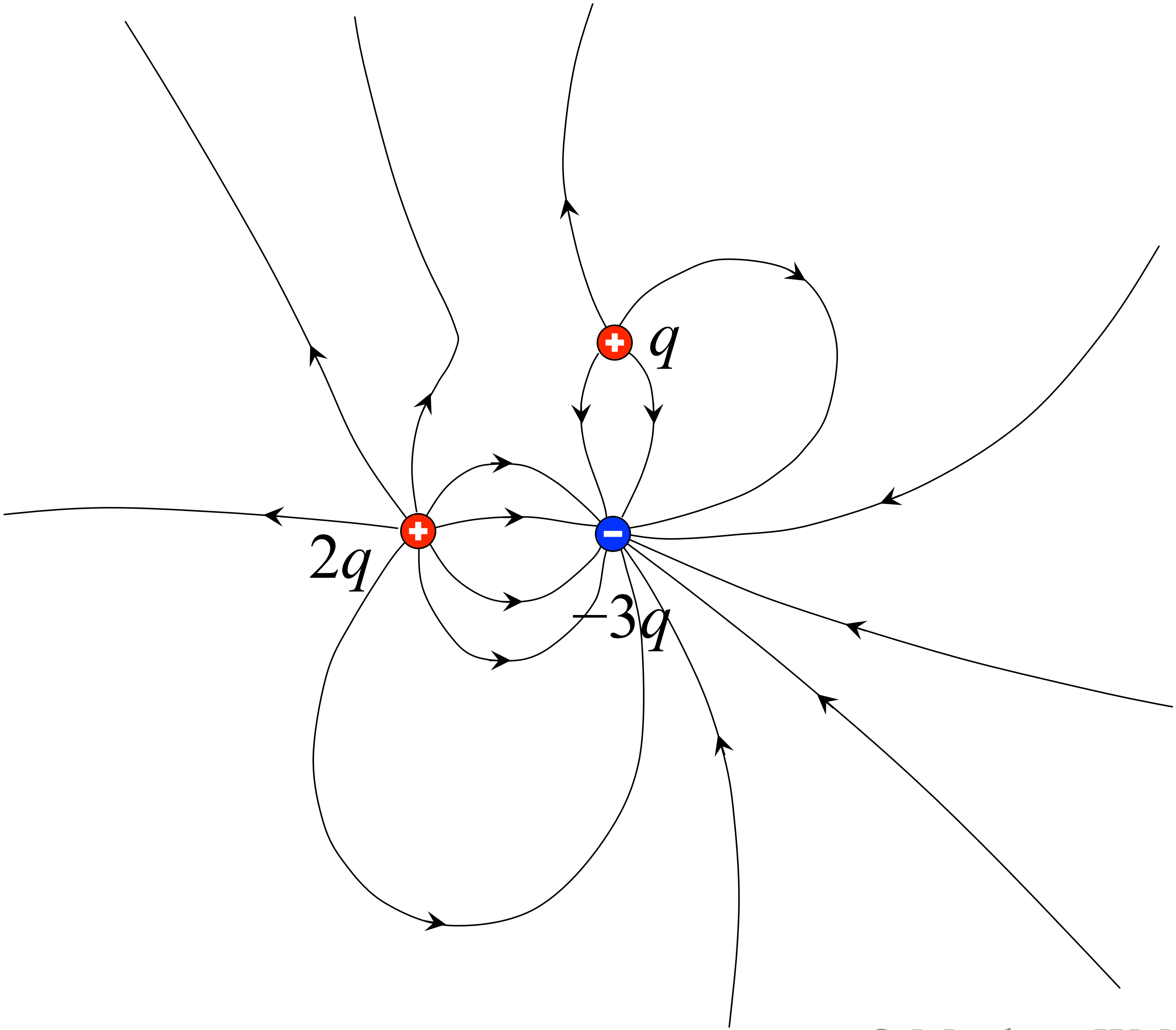
Gravitational Force:	Electrostatic Force:
$$F_G = G\frac{m_1 m_2}{r^2}$$	$$F_E = k\frac{q_1 q_2}{r^2}$$
$$F_G = mg$$	$$F_E = qE$$
$$g = G\frac{M}{r^2}$$	$$E = k\frac{Q}{r^2}$$

Note the many similarities between gravitational force and field and electrical force and field.



$$E = ?$$

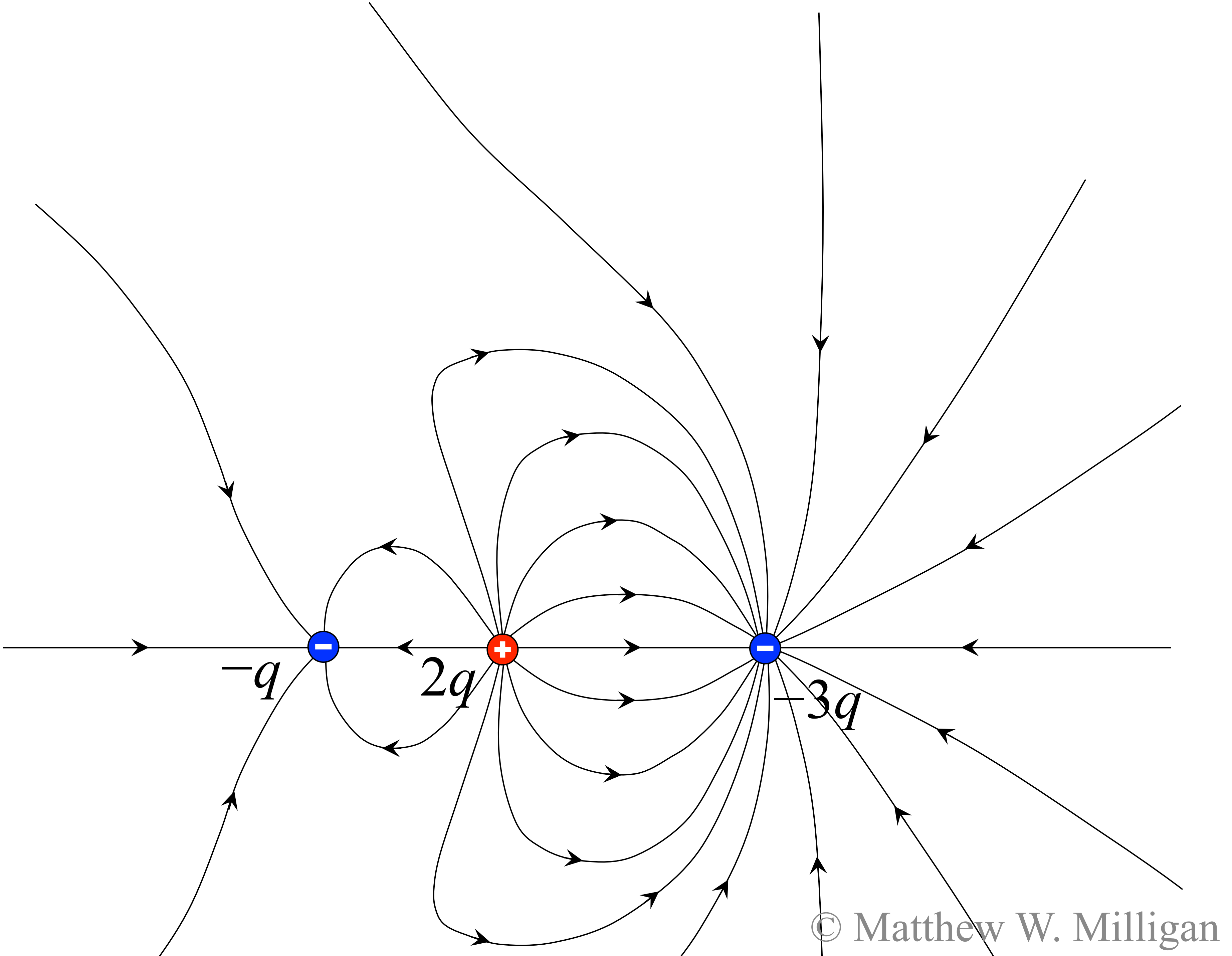

r
Q
$E = k\dfrac{Q}{r^2}$



q
2q
−3q

Superposition Principle

- An electric field produced by multiple charges can have complex properties.
- This net electric field can be thought of as a superposition of individual fields.
- The net electric field is the vector sum of the individual fields produced by each charge.



−q
2q
−3q
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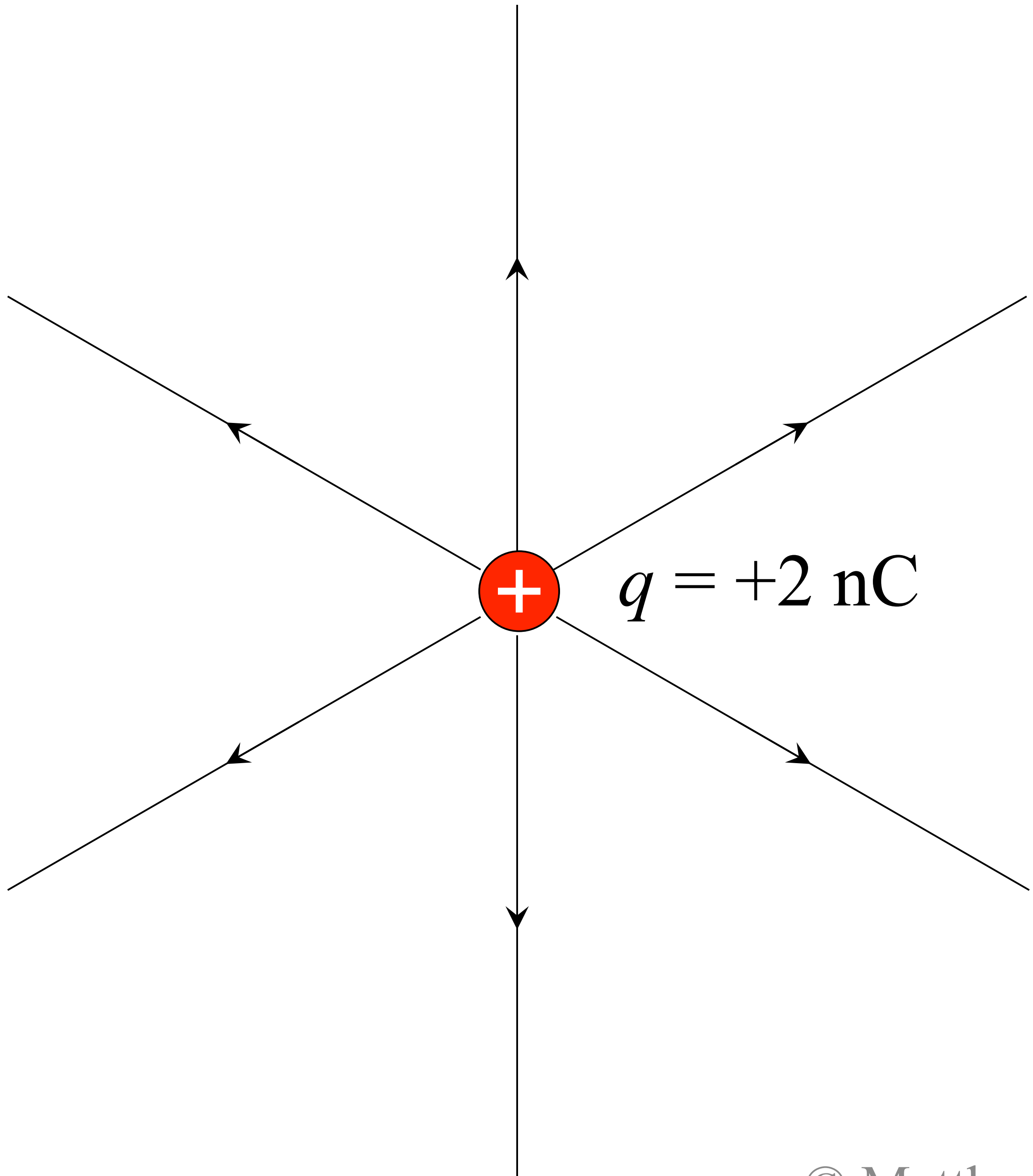
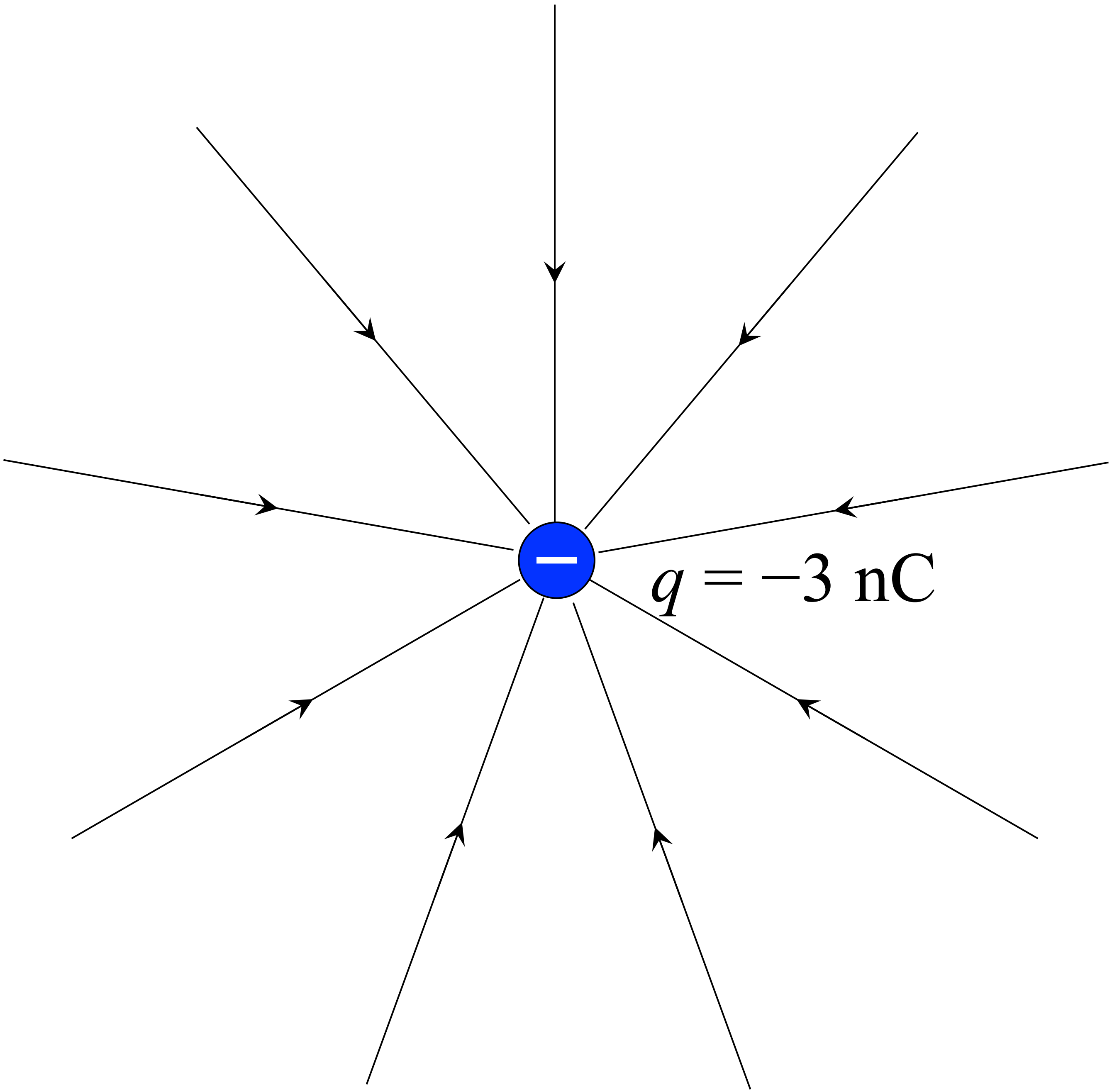
Electric Field Lines

- Electric force is tangent or collinear with a field line at any point.
- Lines originate on positive charge and terminate on negative charge.
- Lines point away from positive charges and toward negative charges.
- The number of lines originating or terminating on a charge is proportional to the amount of charge.

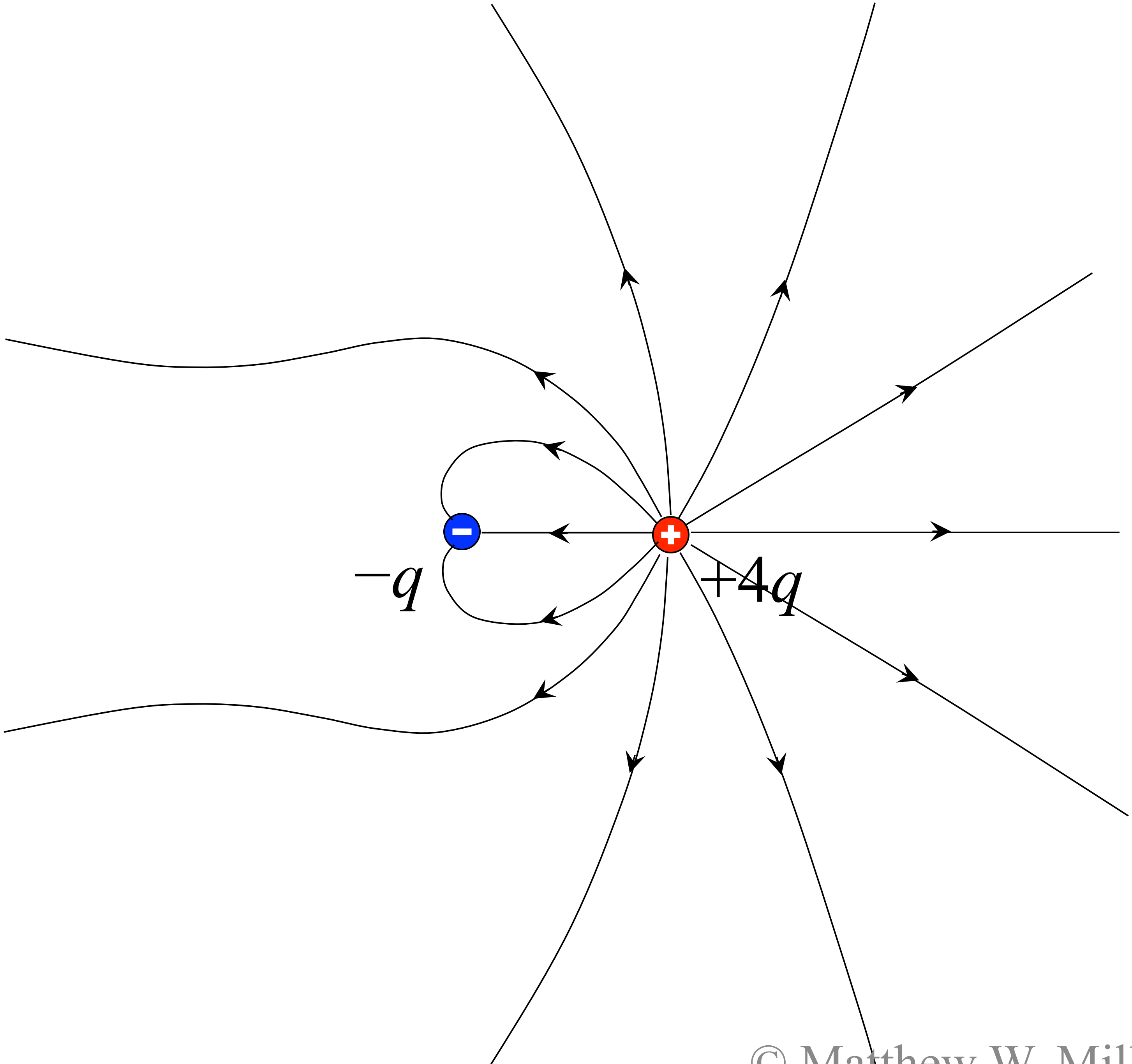
Electric Field Lines

- If drawn properly the strength or magnitude of the electric field is proportional to the number of lines per unit cross-sectional area.
- *i.e.* The closer together the lines the greater the magnitude of the electric field.

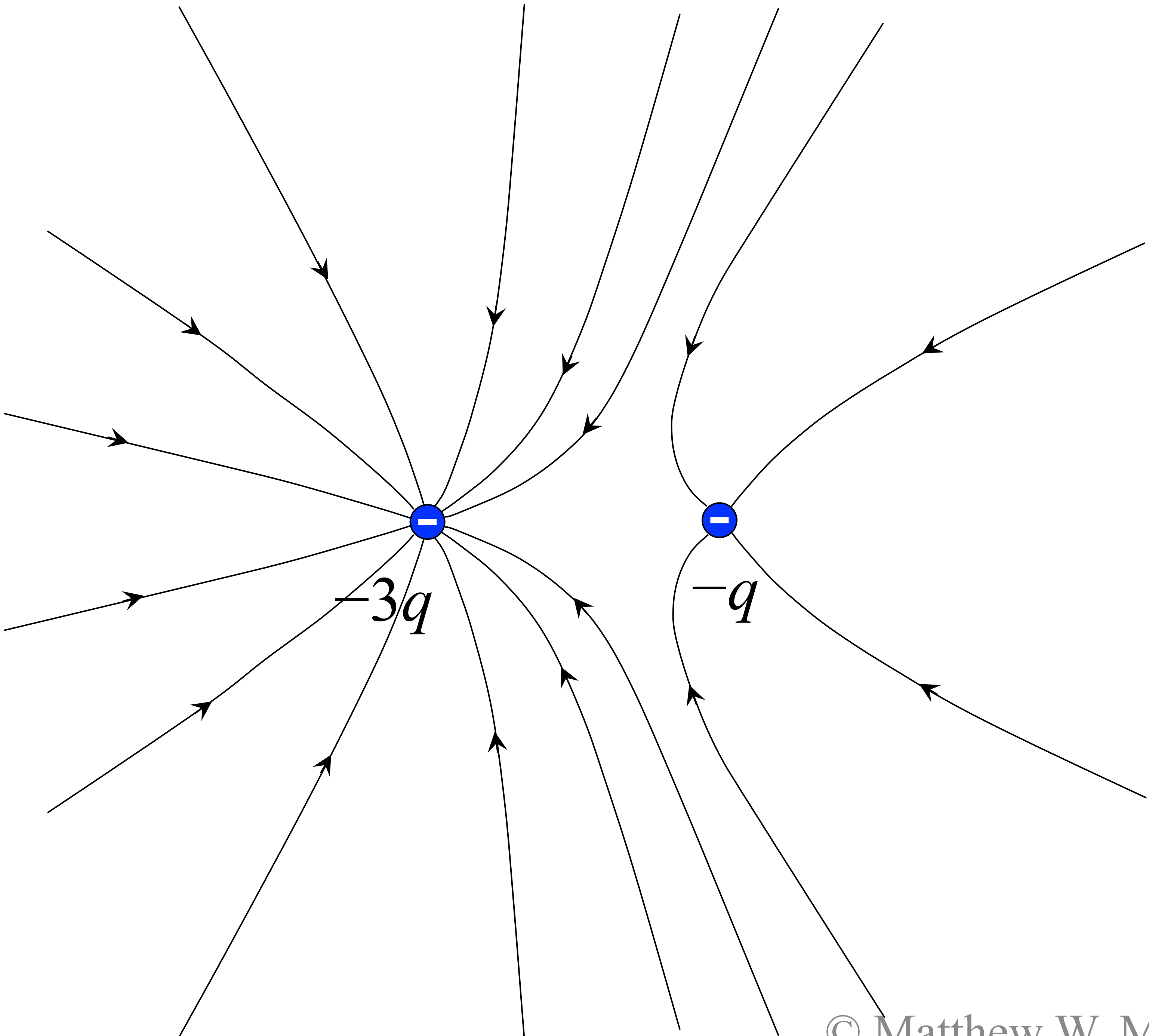

+
$q = +2$ nC



−
$q = -3$ nC



$-q$
$+4q$



−3q
−q

Electric Potential

Work and Energy for Charges

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Work and Energy for Charges

Work must be done by an external force in order to separate opposite charges.

Opposite charges that have been separated represent **potential energy** because of the attractive force between such charges. (There is the potential for work to be done by the electric force as the separation decreases.)

Work and Energy for Charges

Likewise work must be done in order to *decrease* the separation of *like* charges.

Like charges that have been pushed together represent potential energy because of the *repulsive* force. (There is the potential for work to be done by the electric force as the separation *increases*.)

Electric Potential

$$\boxed{V = \frac{W}{q}}$$

OR

$$\boxed{V = \frac{E}{q}}$$

where: V = electric potential

W = work done to move charge q between two points

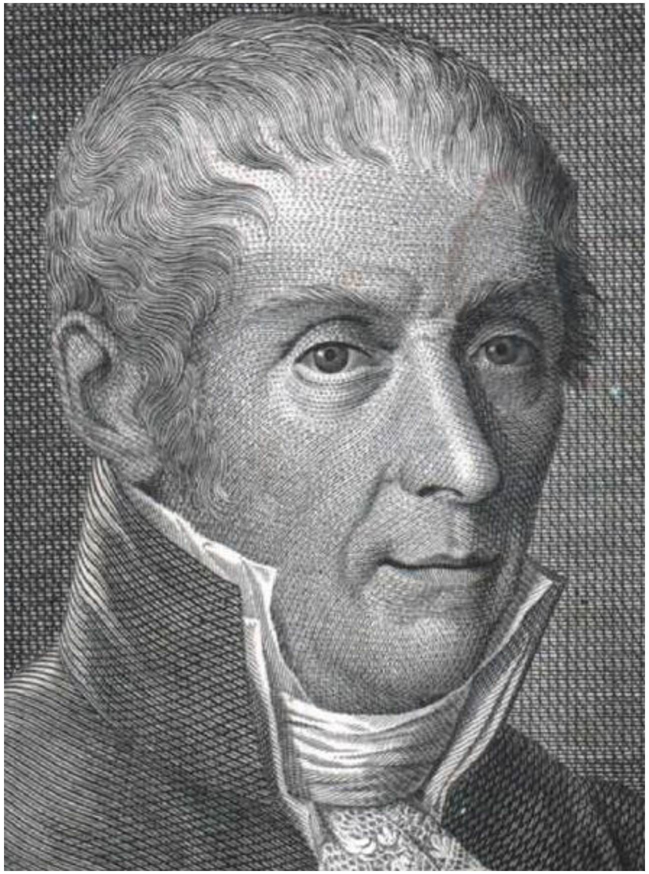
E = potential energy due to position of charge q

Units of Electric Potential

- The SI unit for electric potential is the **volt**.
- One volt is equal to one joule of work or energy per every one coulomb of charge:

$$1\ \text{V} = 1\ \text{J/C}$$

- Other names for electric potential: voltage, potential difference, potential, electromotive force (or emf).

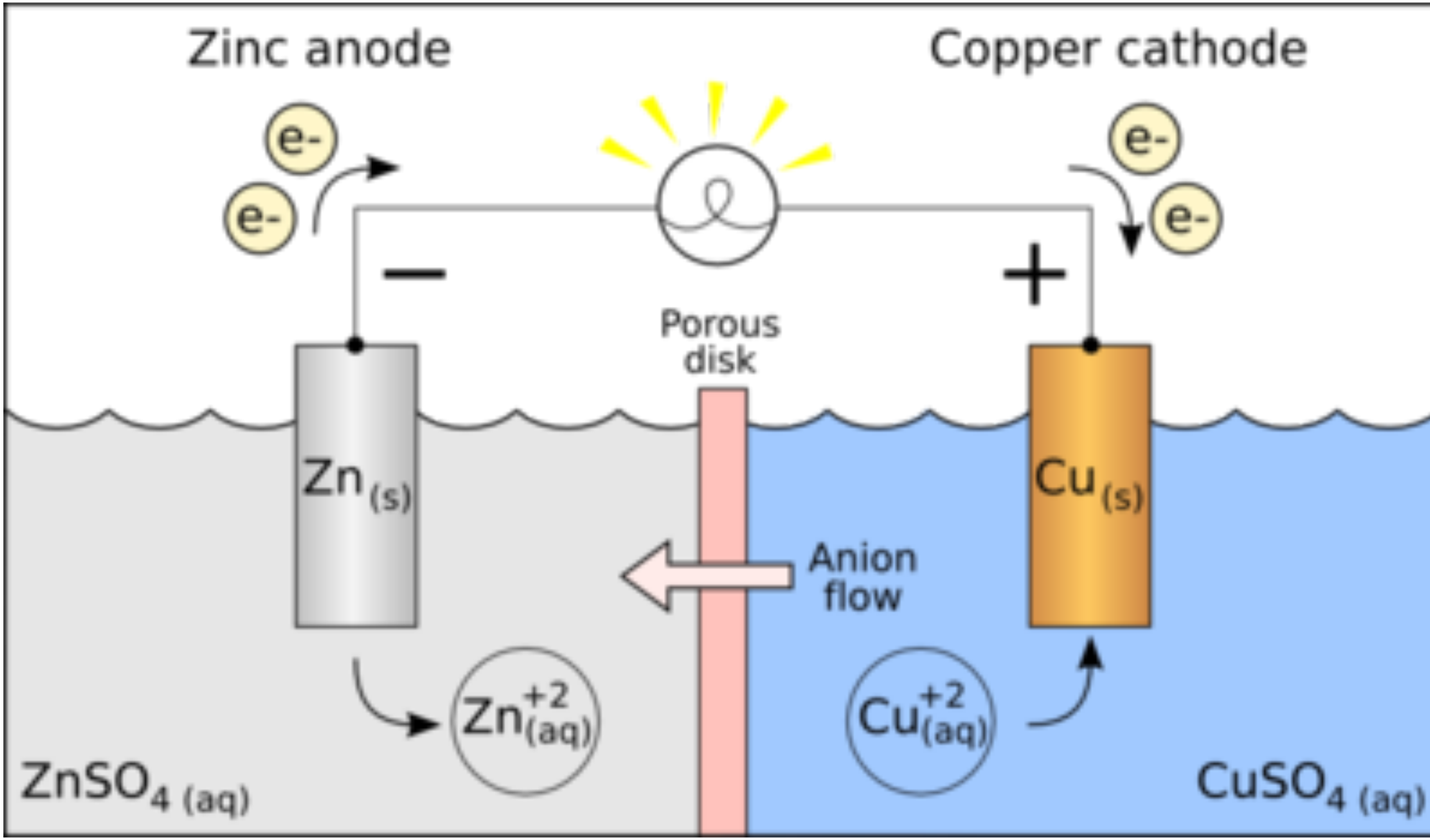


Alessandro Volta invented the first battery around 1800.

a "voltaic pile"

Sources of Electric Potential

- Voltaic cells – *i.e.* "batteries" – chemical energy is converted to electric energy
- Electric Generator – mechanical work results in electric energy
- Solar cells – *i.e.* photovoltaic cells – light energy is converted to electric energy
- Van de Graaff – mechanical work results in electric energy

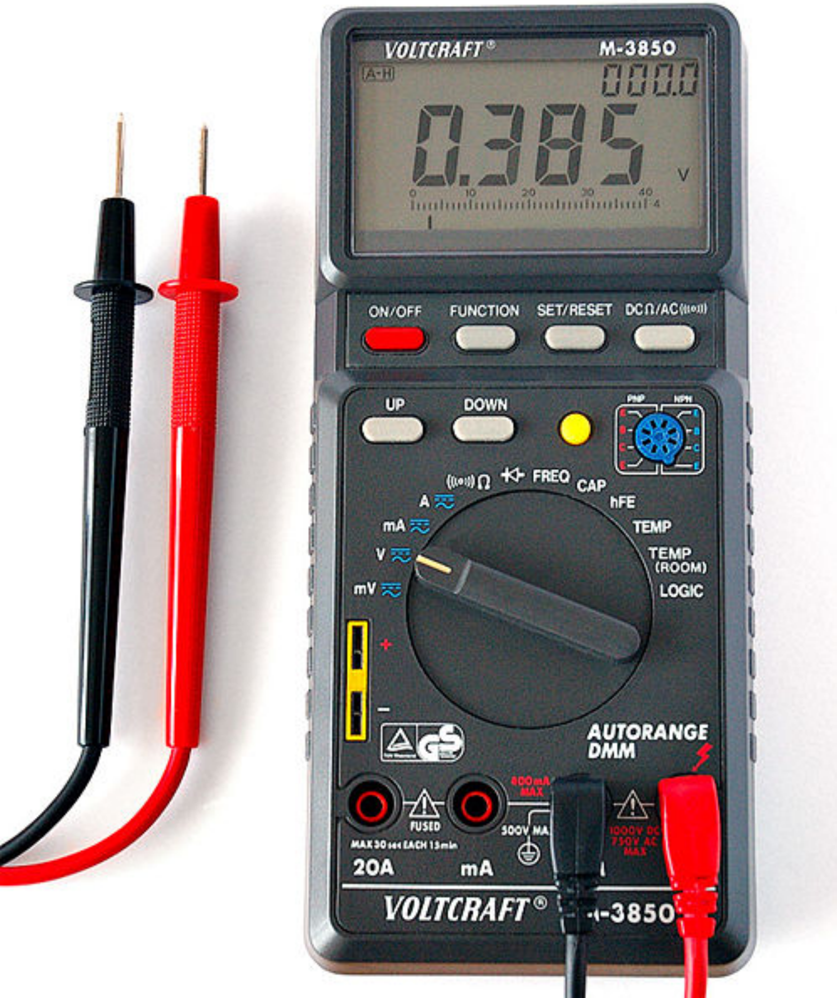


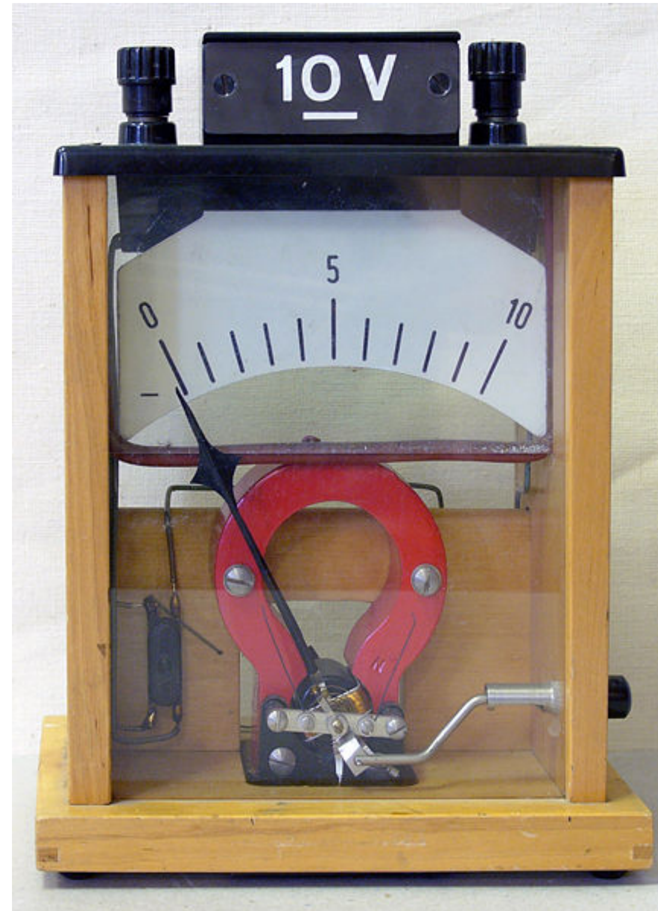
source: Wikipedia, Ohiostandard

Voltage of a cell is a measure of the work done per charge by the chemical reaction, which also indicates the energy per charge available to power a device.

Measuring Electric Potential

Digital Multimeter





Analog Voltmeter

Either device can indicate the potential difference between the two probes or leads.