Electrostatics

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

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

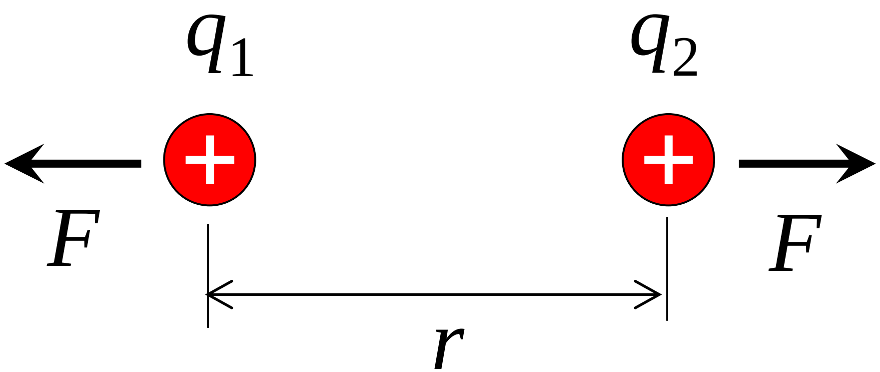
III. Potential
- relation to work, energy, field
- association with charge

	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

Coulomb's Law

Coulomb's Law describes the force that acts between two charged particles:

$$\left|\vec{F}_E\right| = k\left|\frac{q_1 q_2}{r^2}\right|$$



where: q = amount of charge
r = separation
k = the "electrostatic constant"

Coulomb's Law Details

Charge is measured in SI units of coulombs.

In 2019 the coulomb was redefined such that the elementary charge (on a proton or electron) has magnitude: $e = 1.602176634 \times 10^{-19}$ C

The amount of charge on 6.2415×10^{18} electrons (or protons) is approximately one coulomb.

The electrostatic constant k is:

$k = 8.99 \times 10^9$ N m^2/C^2 (in a vacuum)

<u>Very often</u> this value is rounded to:

$k = 9.0 \times 10^9$ N m^2/C^2 (use unless directed otherwise)

Coulomb's Law Alternate Version!

$$\left|\vec{F}_E\right| = \frac{1}{4\pi\varepsilon_0}\left|\frac{q_1 q_2}{r^2}\right|$$

The constant ε_0 is called the "permittivity of free space" or vacuum permittivity:

$$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N\ m^2}$$

$$k = \frac{1}{4pe_0} \qquad e_0 = \frac{1}{4pk}$$

Electric Fields

a ~~figment~~ reality of our imagination…

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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.

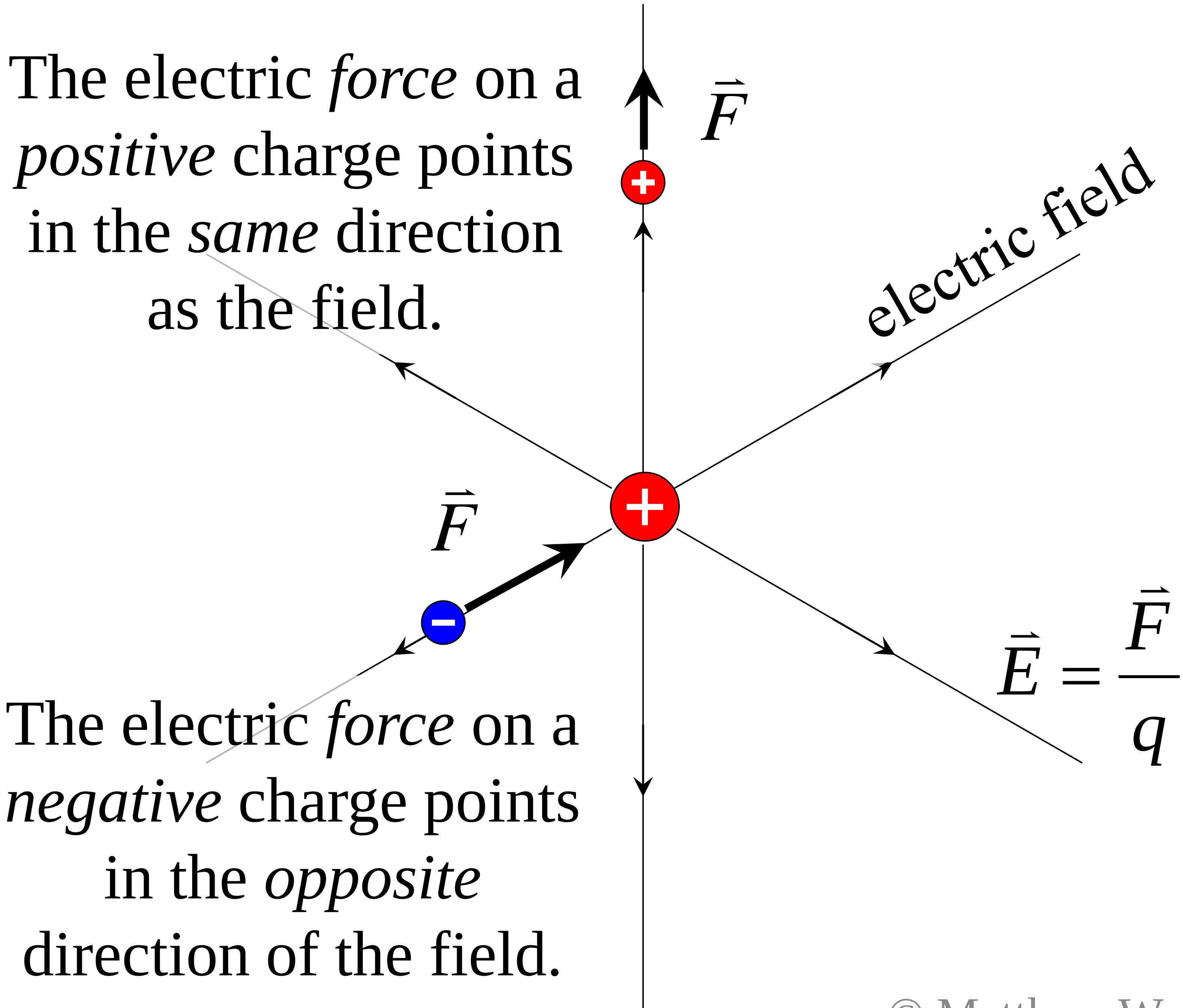
A field is visualized as a series of vectors or lines. The direction of the force that results from the field determines the direction of the field.

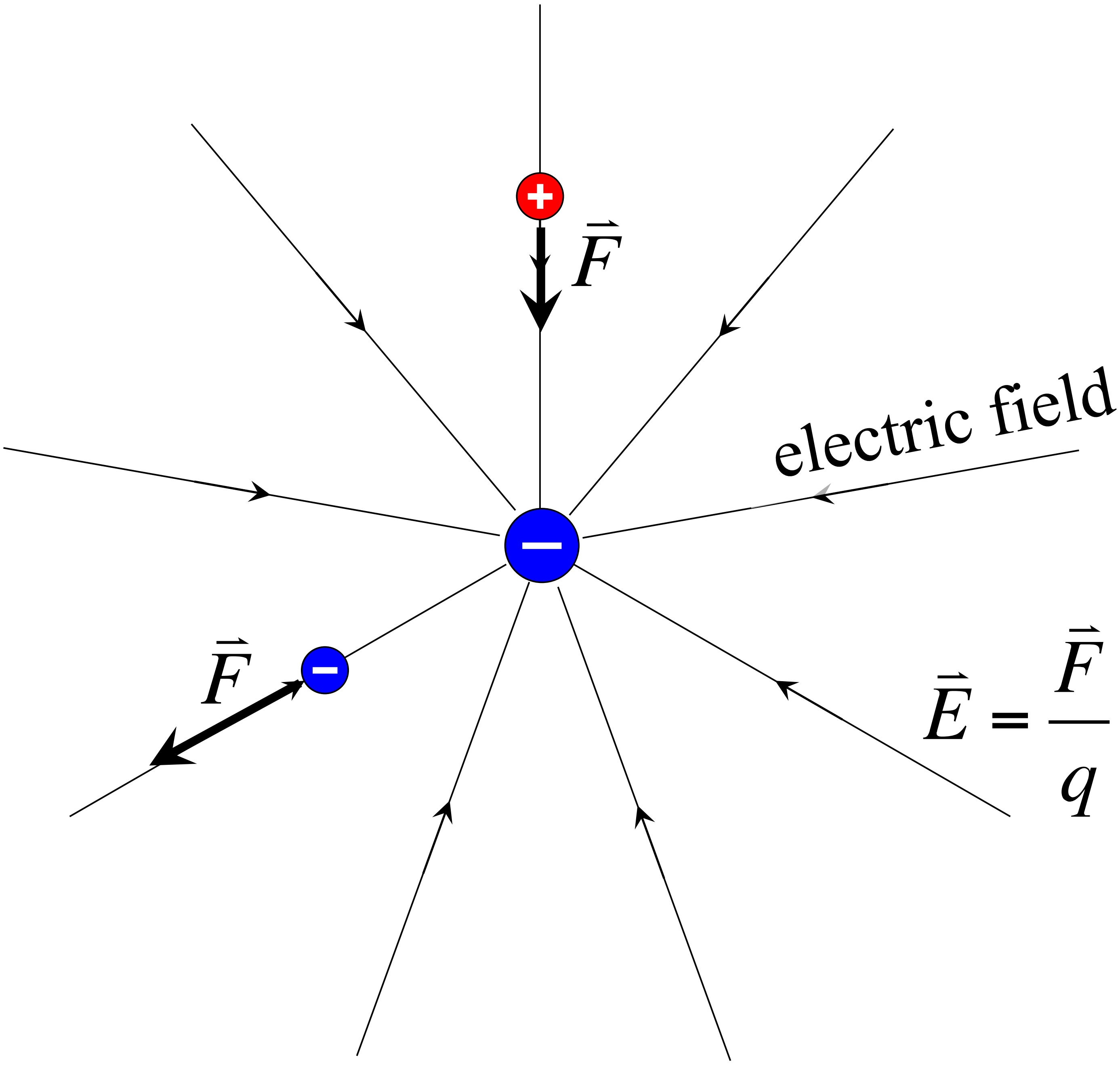
Electric Field

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

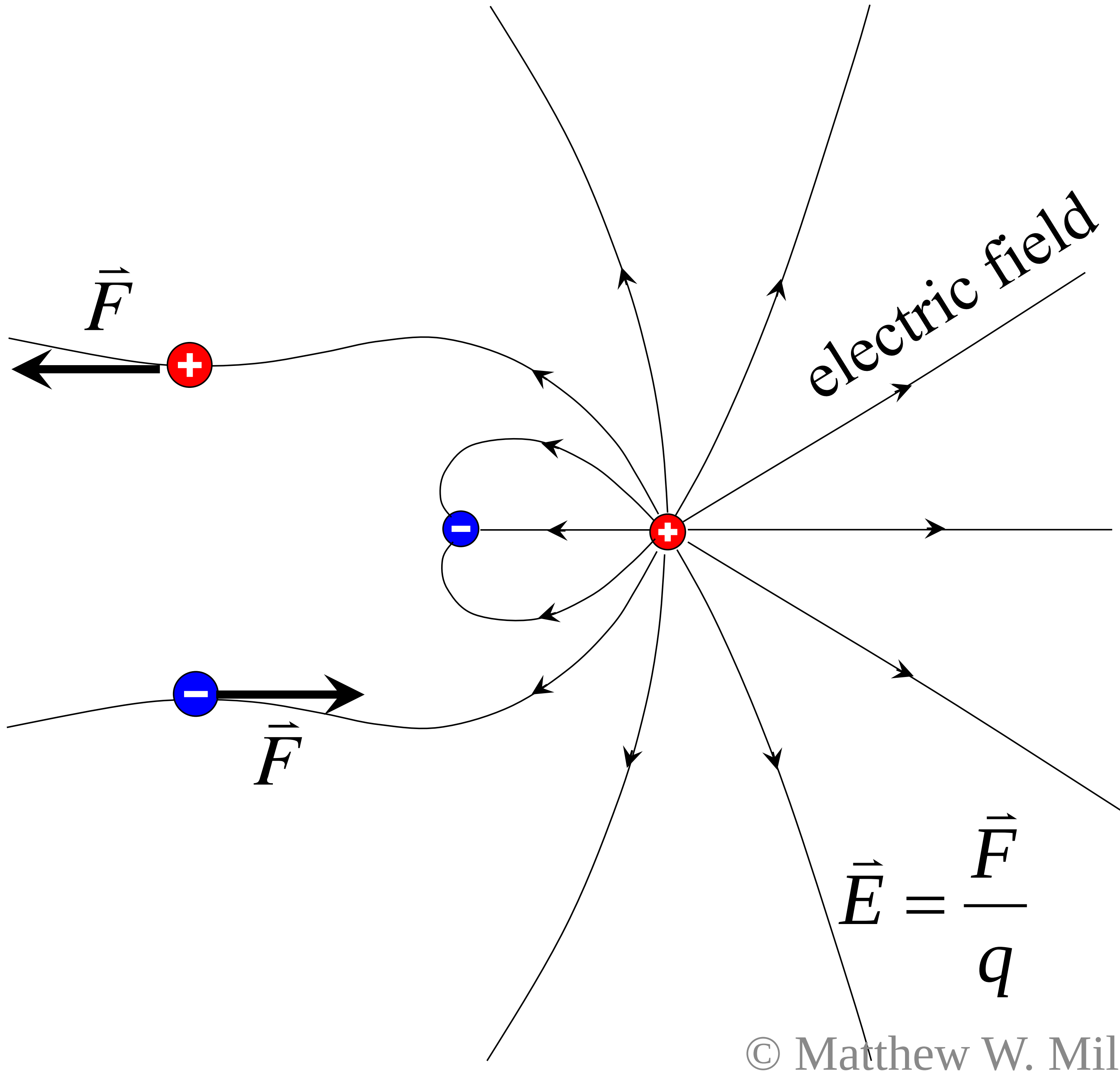
$$\vec{E} = \frac{\vec{F}}{q}$$

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.

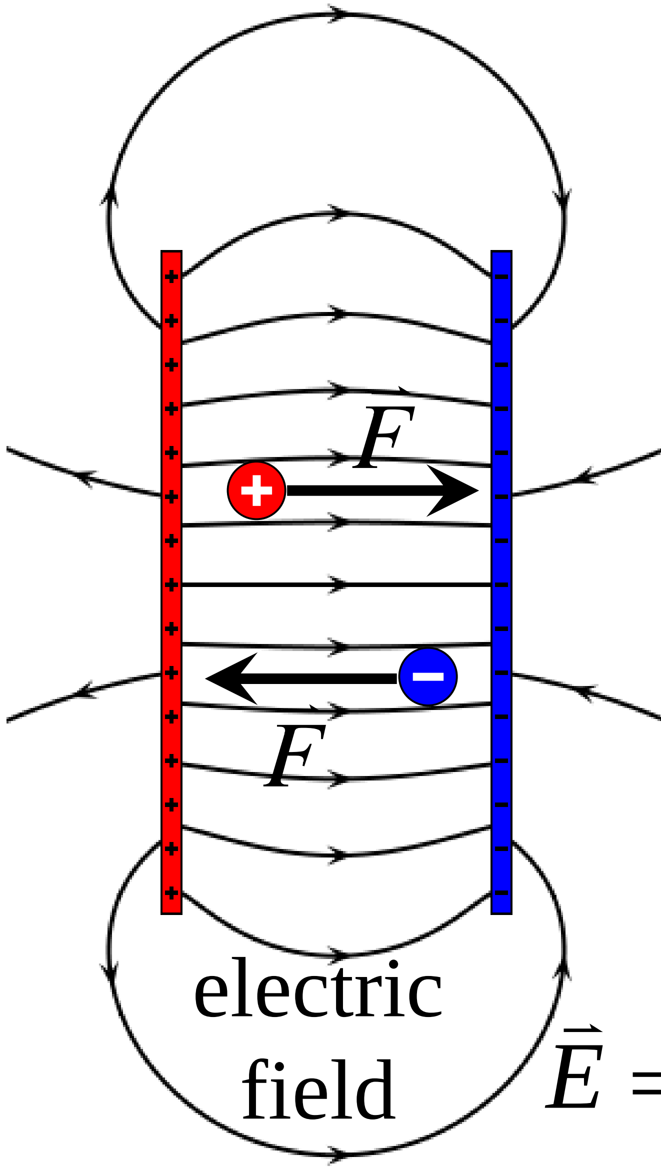


$\vec{F}$
electric field
$\vec{F}$
$\vec{E} = \frac{\vec{F}}{q}$



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

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

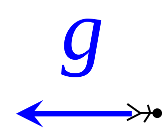
$$E = k\frac{Q}{r^2}$$

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

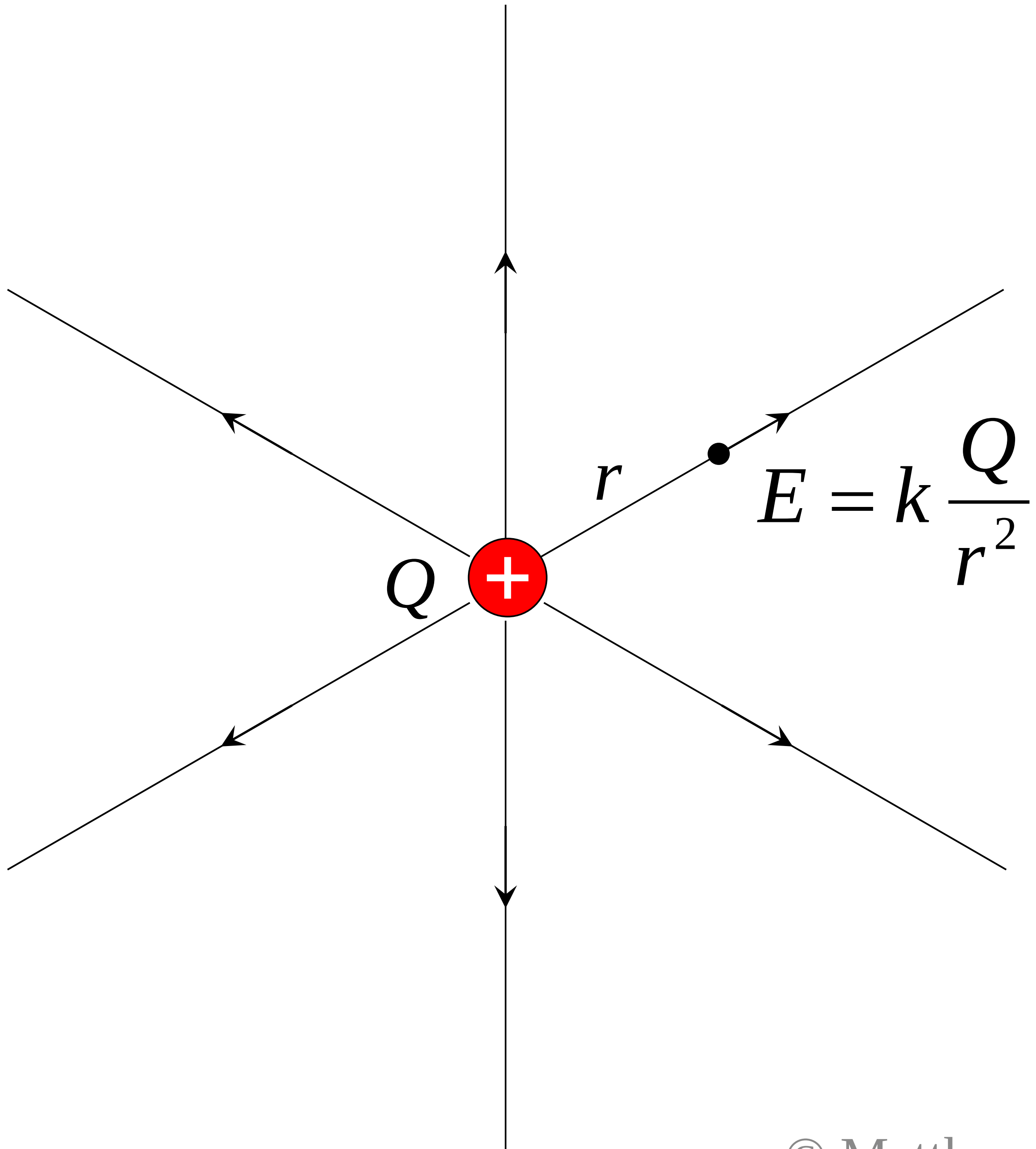
G = universal gravitational constant:

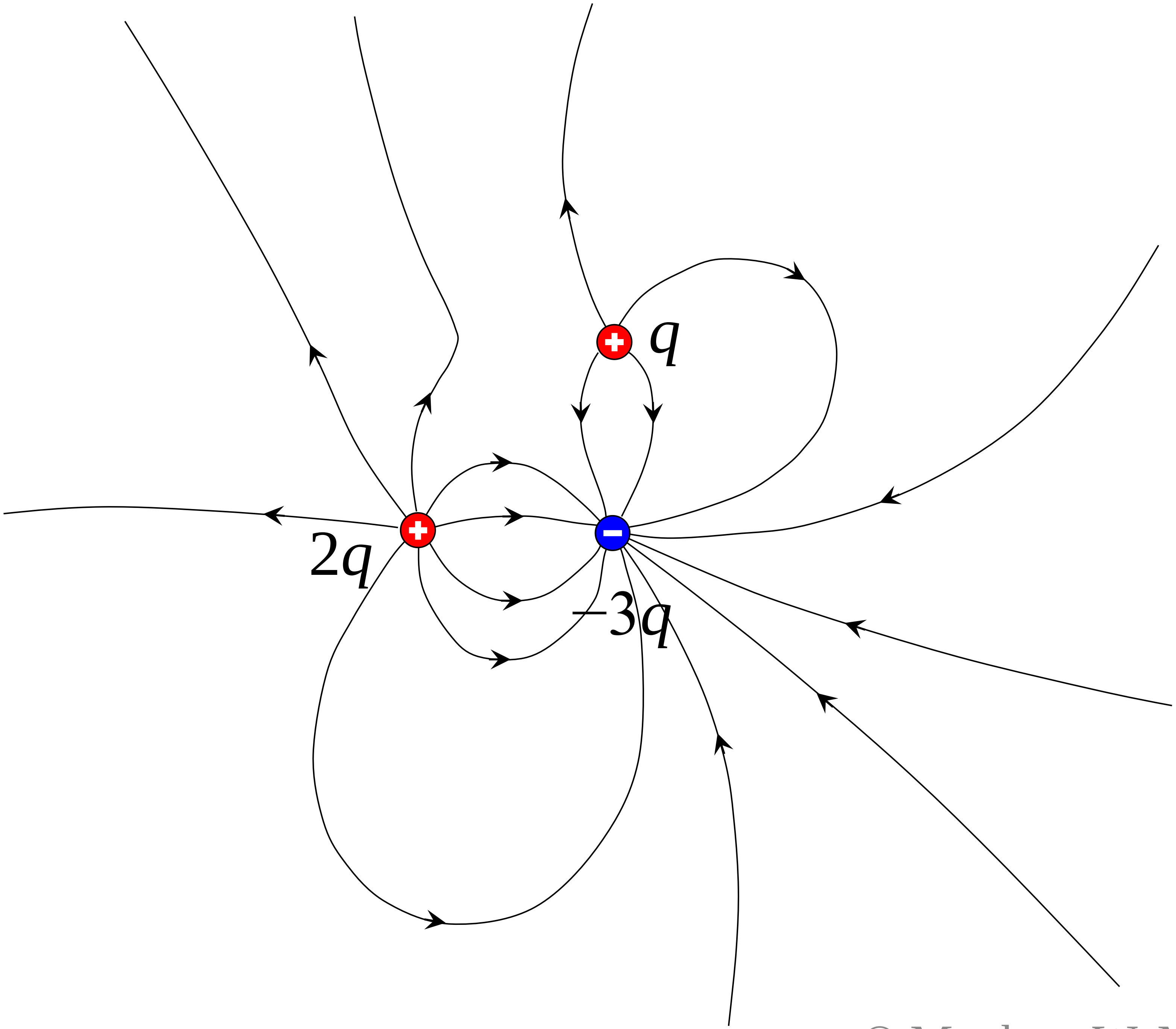
$6.674 \times 10^{-11}\ \mathrm{m^3/kg\ s^2}$

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.

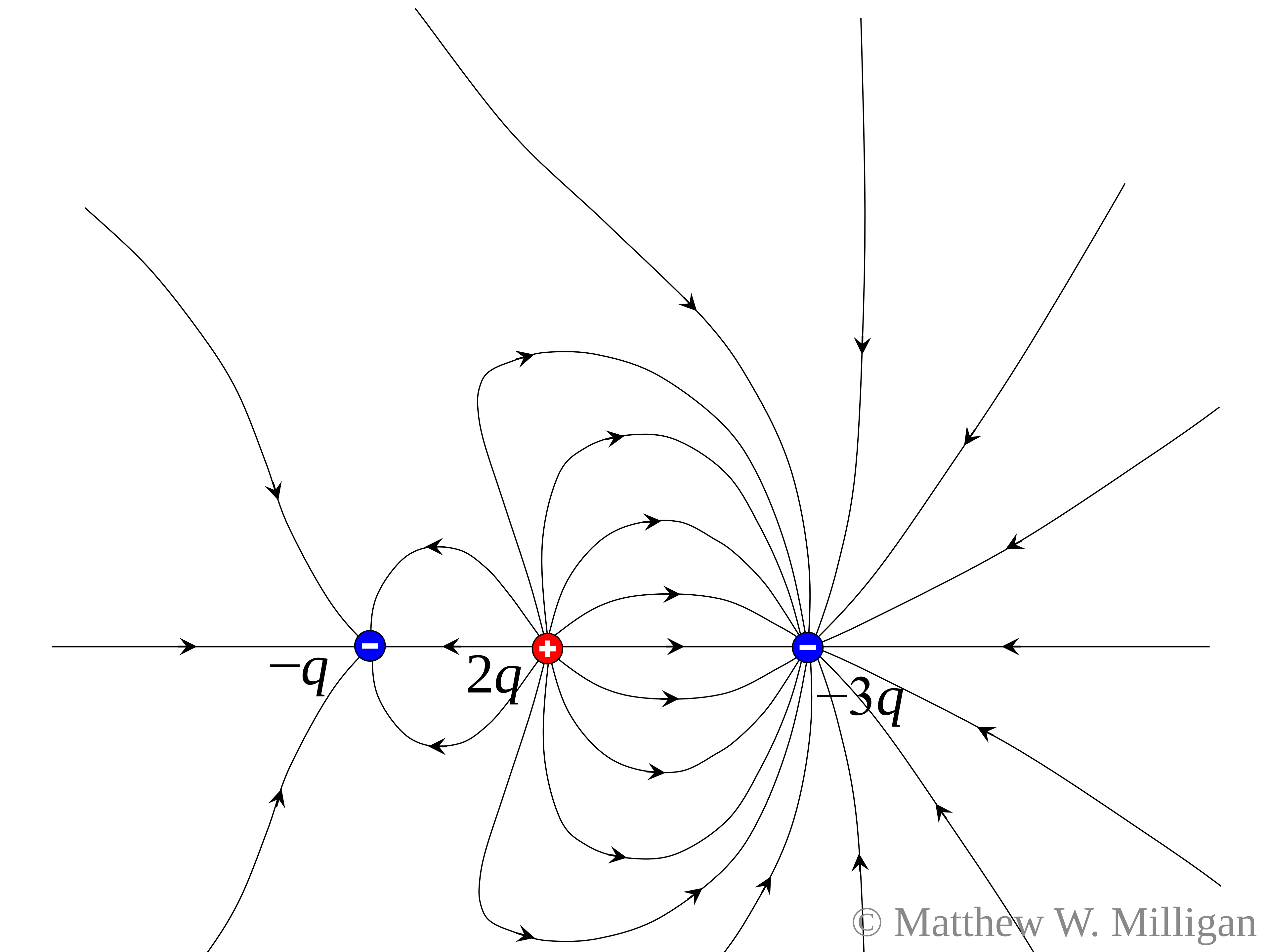

E = ?


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


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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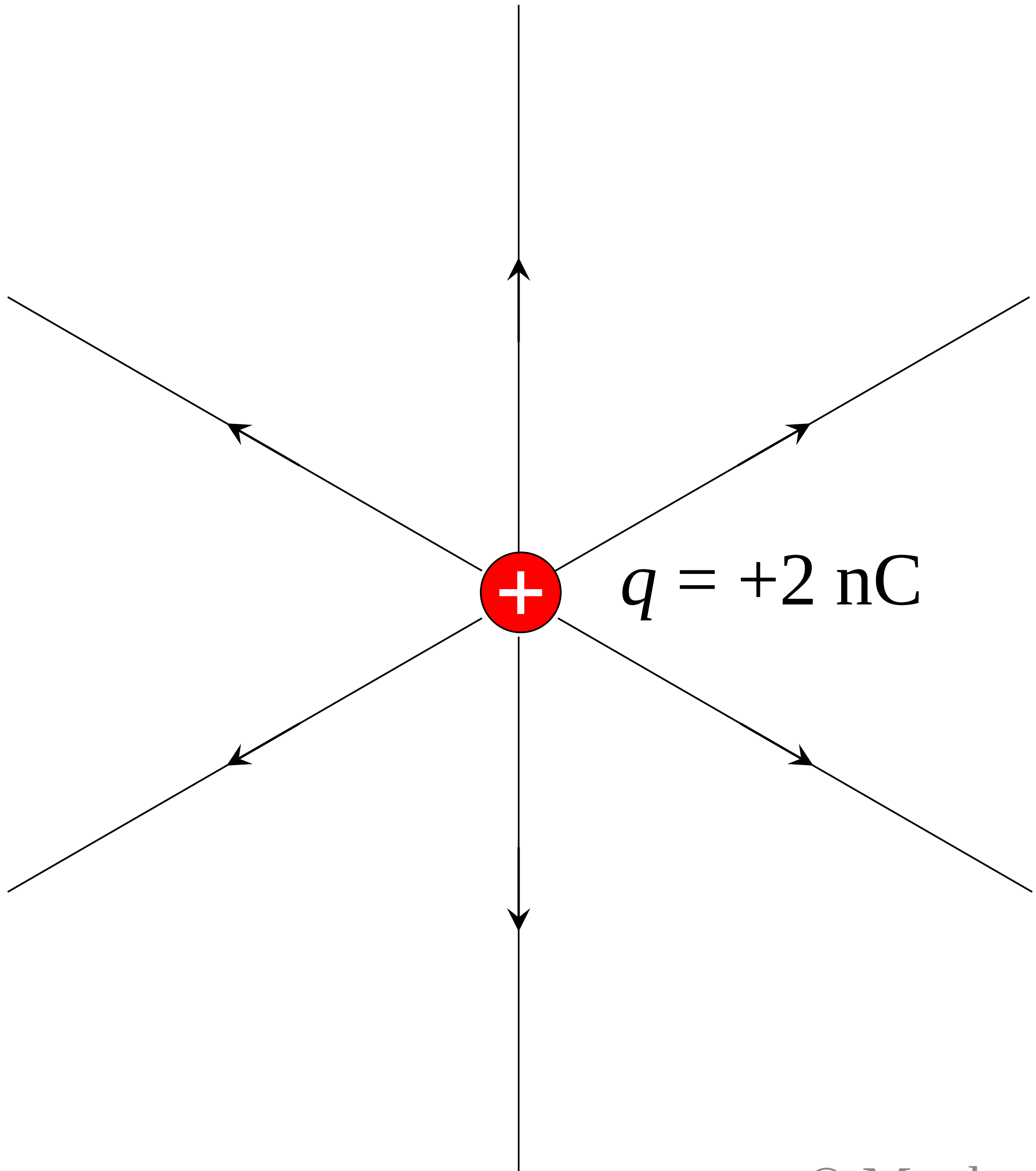
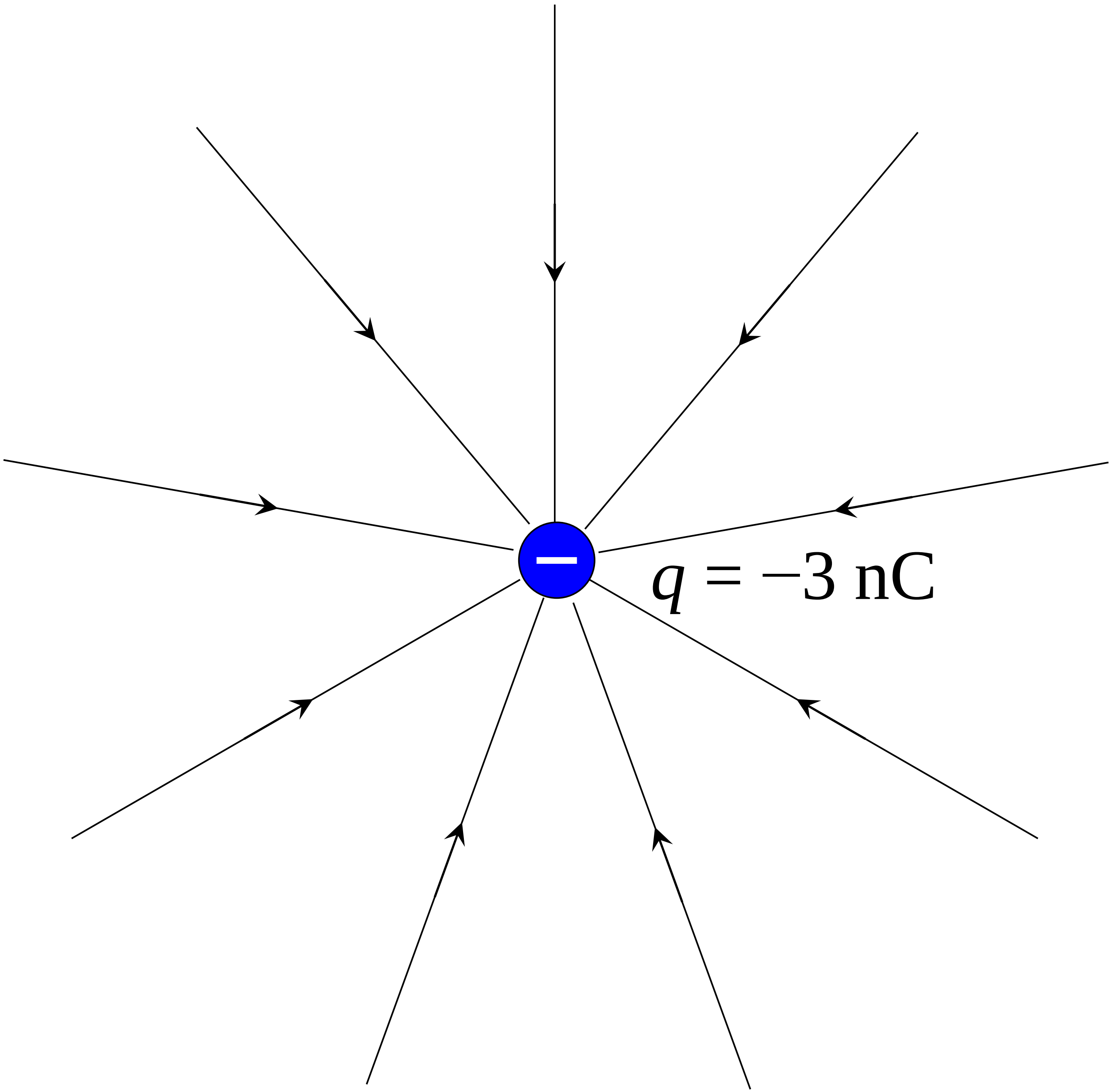
Electric Field Lines

- 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.

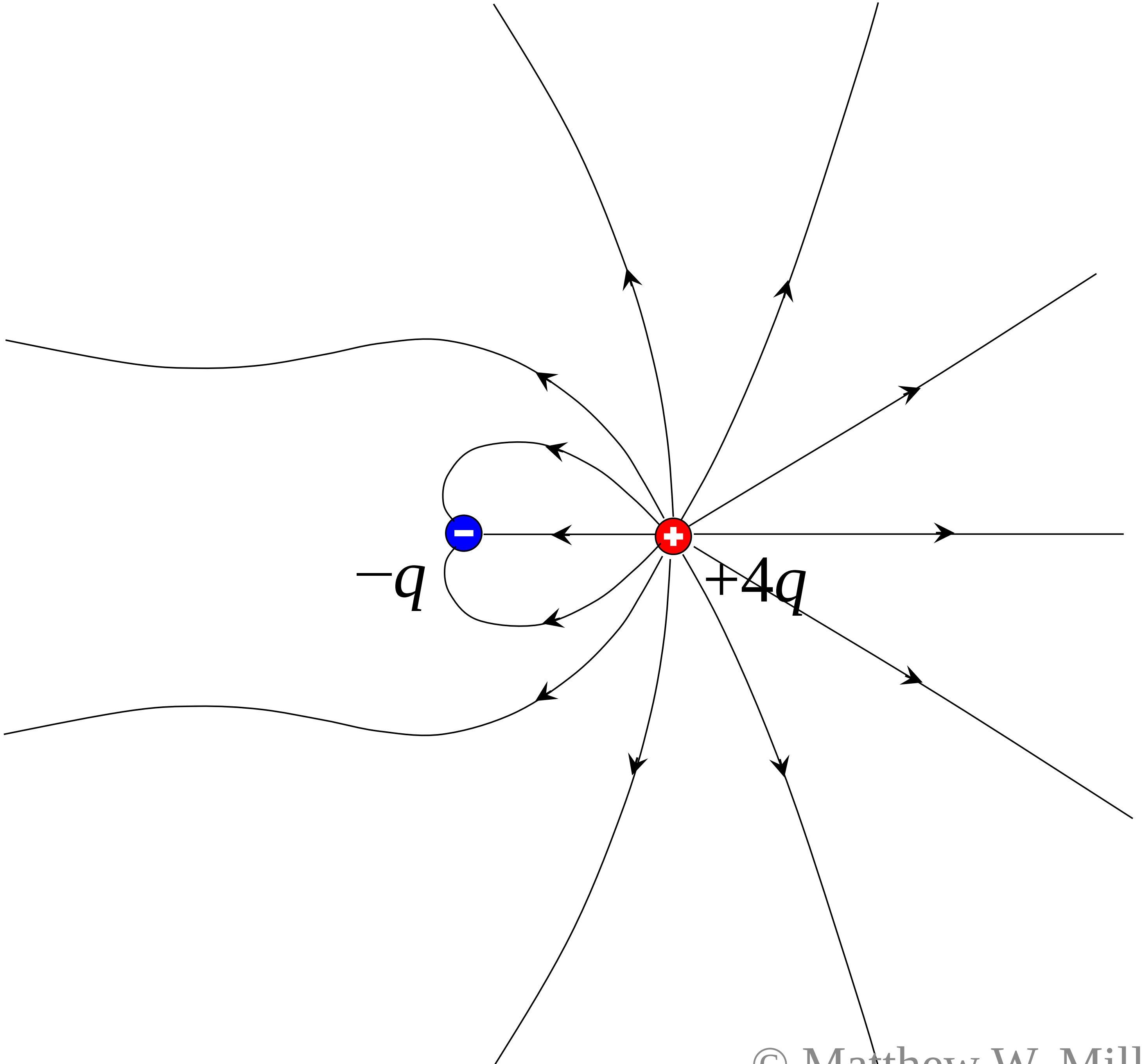
Electric Field Lines

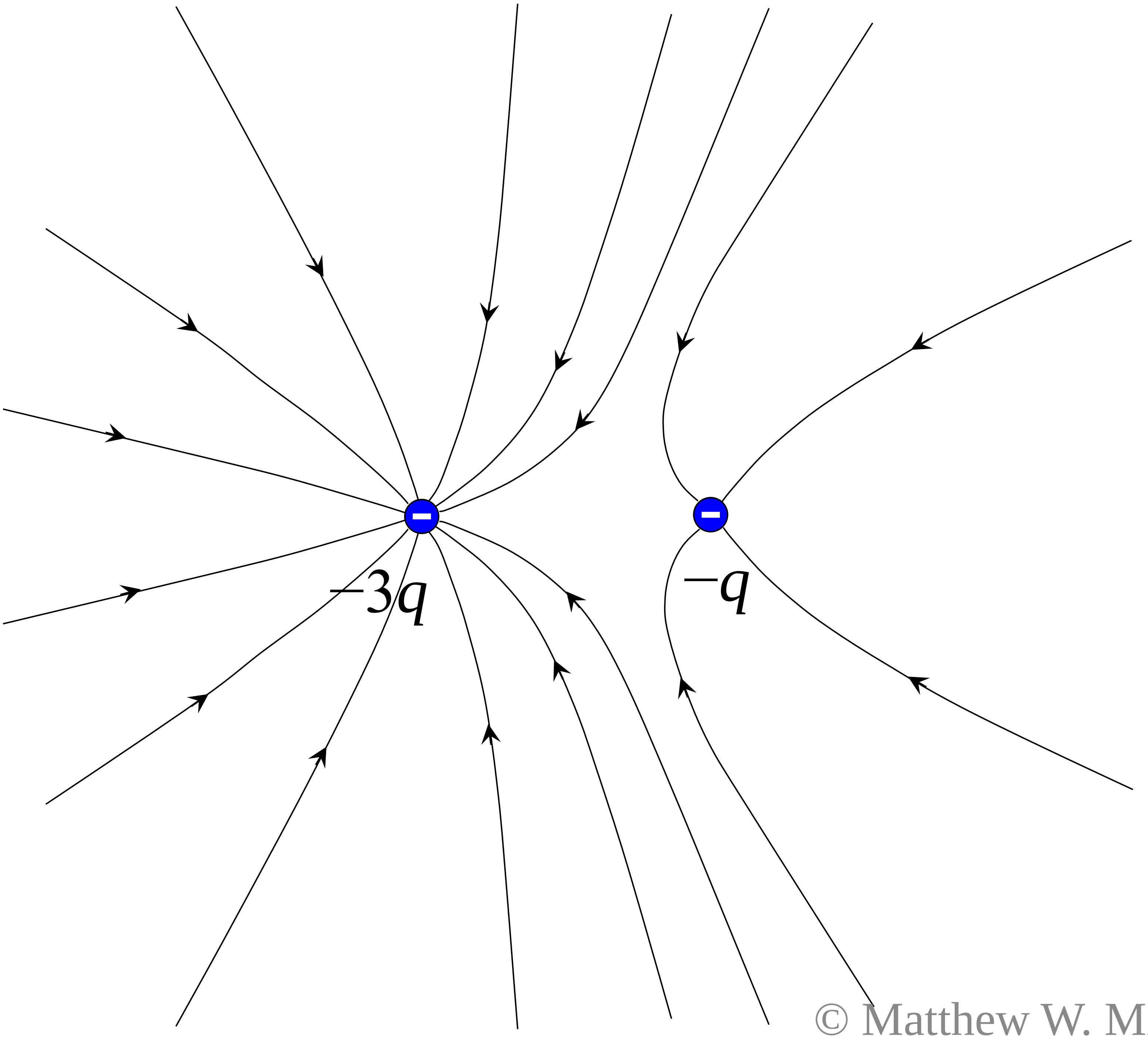
- If drawn properly the strength or magnitude of the electric field is proportional to the number of lines per unit cross-sectional area.
- *i.e.* The closer together the lines the greater the magnitude of the electric field.


+
q = +2 nC



$q = -3$ nC


−q
+4q


−3q
−q