Electric Field-I

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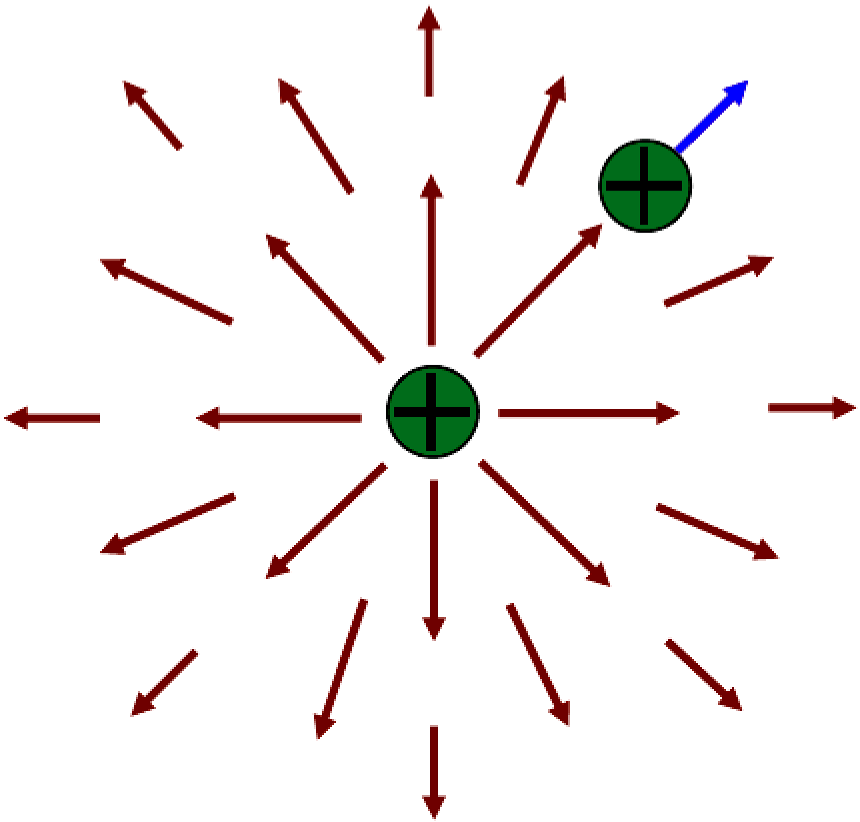
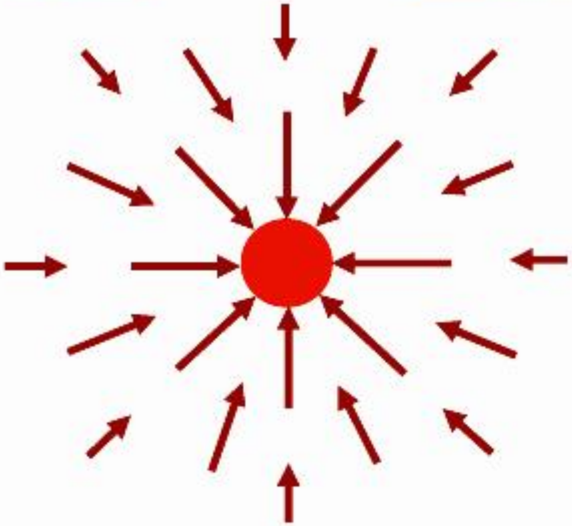
Electric Force and Field Force

- What? -- Action on a distance
- How? – Electric Field
- Why? – Field Force
- Where? – in the space surrounding charges



Fields

- Scalar Fields:
  - Temperature – T(r)
  - Pressure – P(r)
  - Potential energy – U(r)
- Vector Fields:
  - Velocity field – $\vec{v}(\vec{r})$
  - Gravitational field – $\vec{g}(\vec{r})$
  - Electric field – $\vec{E}(\vec{r})$
  - Magnetic field – $\vec{B}(\vec{r})$

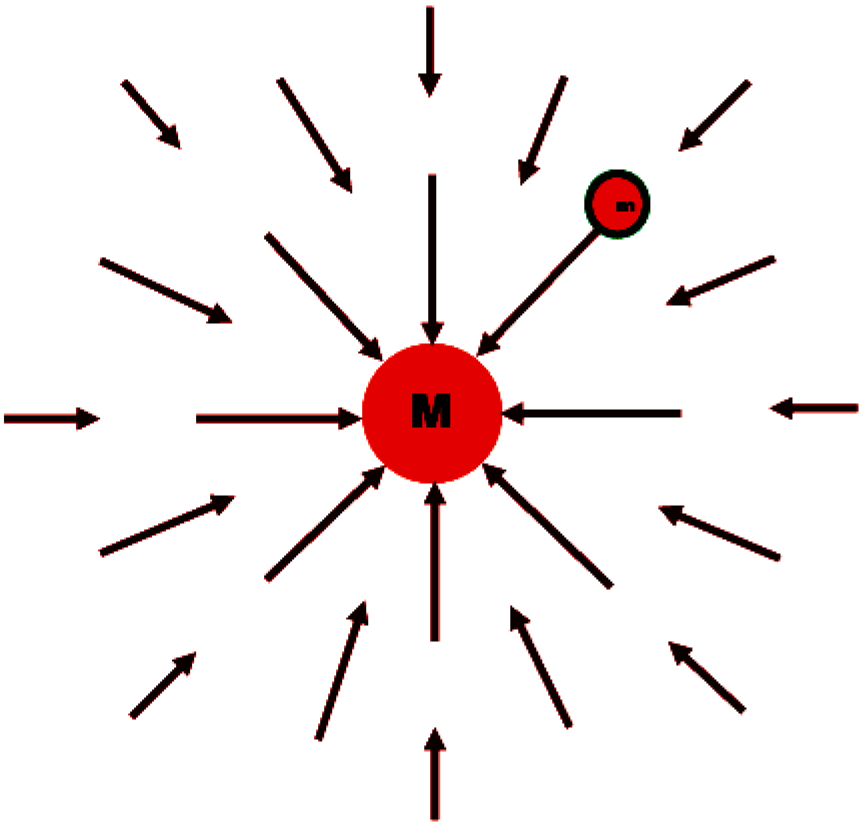


Vector Field Due to Gravity

- When you consider the force of Earth's gravity in space, it points everywhere in the direction of the center of the Earth. But remember that the strength is:

$$\vec{F} = -G\frac{Mm}{r^2}\hat{r}$$

- This is an example of an inverse-square force (proportional to the inverse square of the distance).



Idea of Test Masses

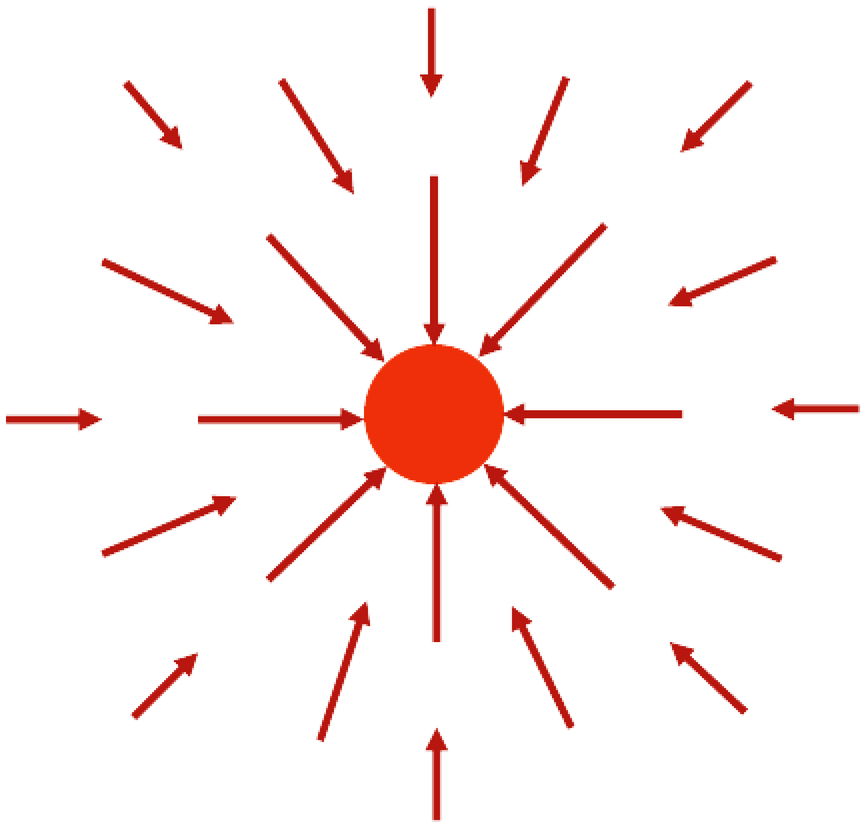
- Notice that the actual amount of force depends on the mass, m:

$$\vec{F} = -\frac{GMm}{r^2}\hat{r}$$

- It is convenient to ask what is the force per unit mass. The idea is to imagine putting a unit test mass near the Earth, and observe the effect on it:

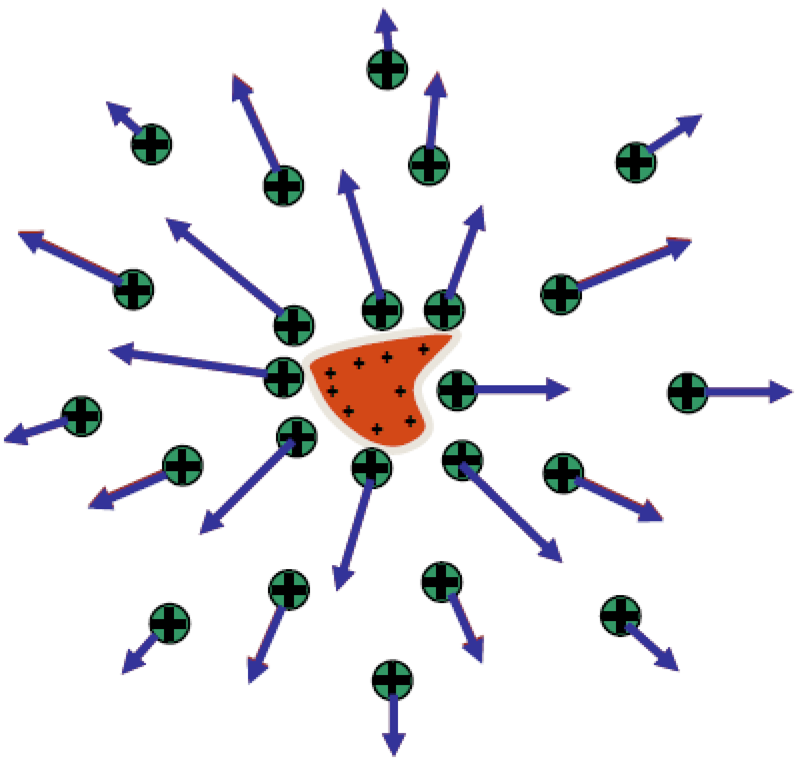
$$\frac{\vec{F}}{m} = -\frac{GM}{r^2}\hat{r} = -g(r)\hat{r}$$

- $g(r)$ is the "gravitational field."



Electric Field

- Electric field is said to exist in the region of space around a charged object: the source charge.
- Concept of test charge:
  - Small and positive
  - Does not affect charge distribution
- Electric field: $\vec{E} = \dfrac{\vec{F}}{q_0}$
  - Existence of an electric field is a property of its source;
  - Presence of test charge is not necessary for the field to exist;



Fields and Forces

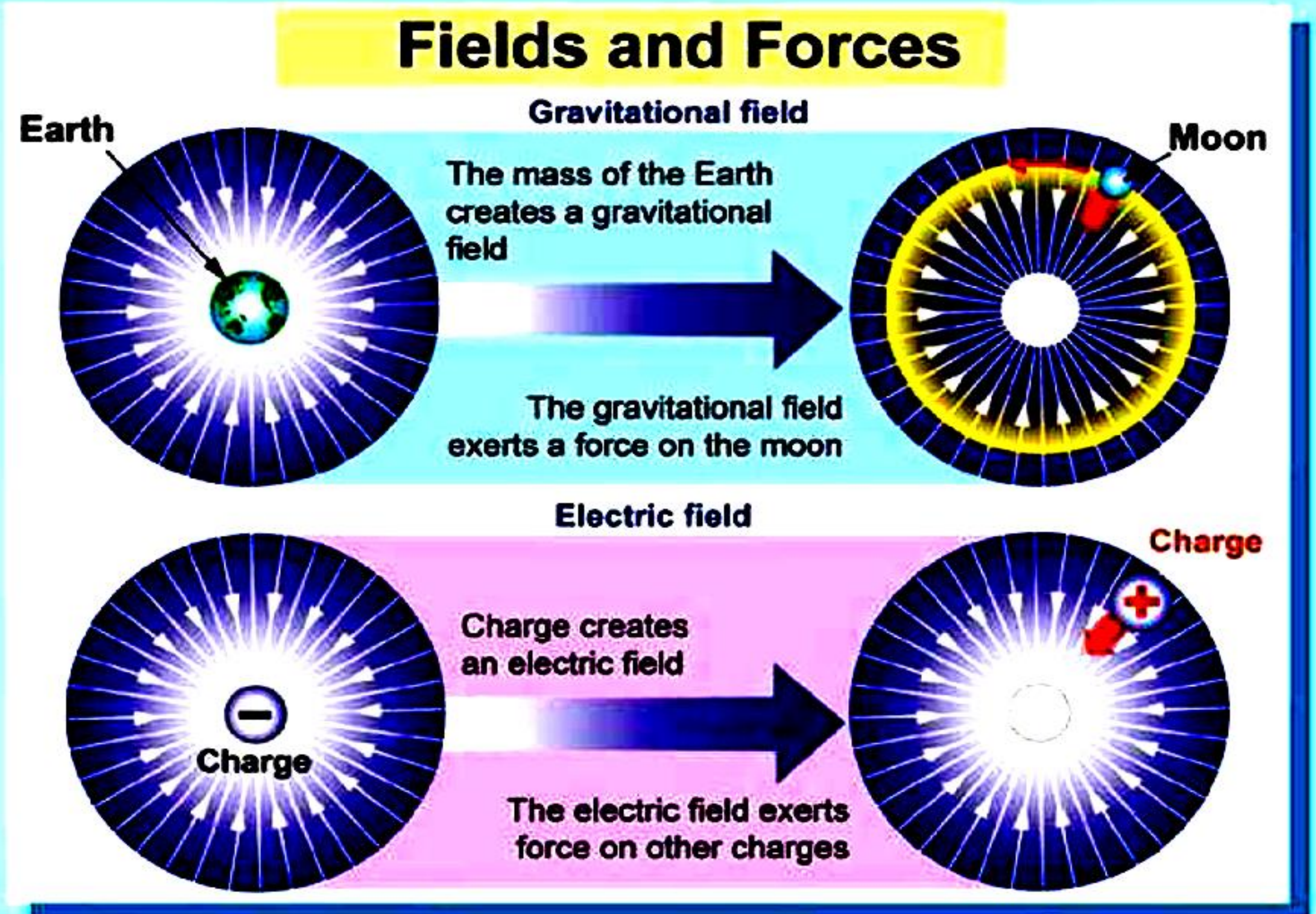
- The concept of a field is used to describe any quantity that has a value for all points in space.
- You can think of the field as the *way* forces are transmitted between objects.
- Mass creates a gravitational field g that exerts forces on other masses.

$$\vec{F} = m\vec{g}$$

- On the Earth's surface, the gravitational field creates 9.8 N of force on each kilogram of mass.
- With gravity, the strength of the field is in Newton's per kilogram (N/kg) because the field describes the amount of force per kilogram of mass.

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

- Charge creates an electric field E that creates forces on other charges.
- The electric field describes the amount of force per coulomb of charge.
- With the electric field, the strength is in Newton's per coulomb (N/C).


Fields and Forces
Gravitational field
Earth
Moon
The mass of the Earth creates a gravitational field
The gravitational field exerts a force on the moon
Electric field
Charge
Charge creates an electric field
The electric field exerts force on other charges
Charge

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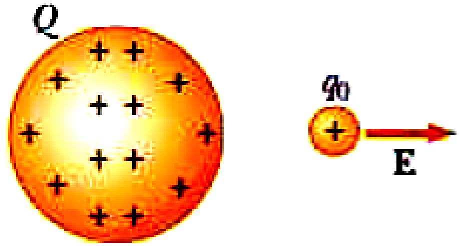
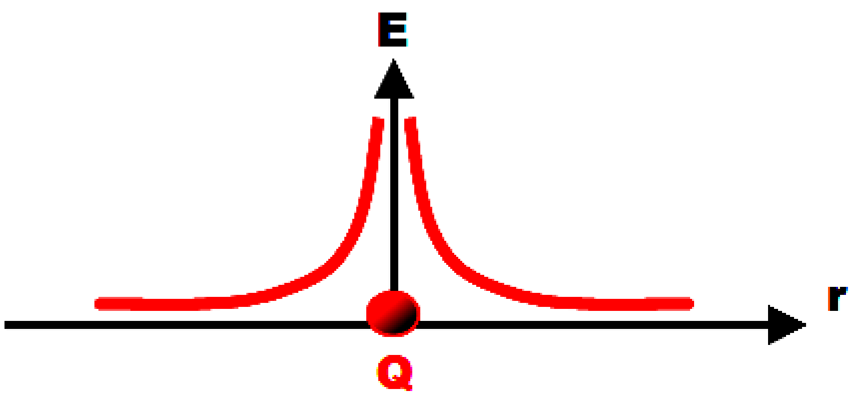
Electric Field due to Point Charges

- An electric field is said to exist in the region of space around a charged object.
- The electric field E at a point in space is defined as the electric force F acting on a positive test charge q_0 placed at that point divided by the magnitude of the test charge:

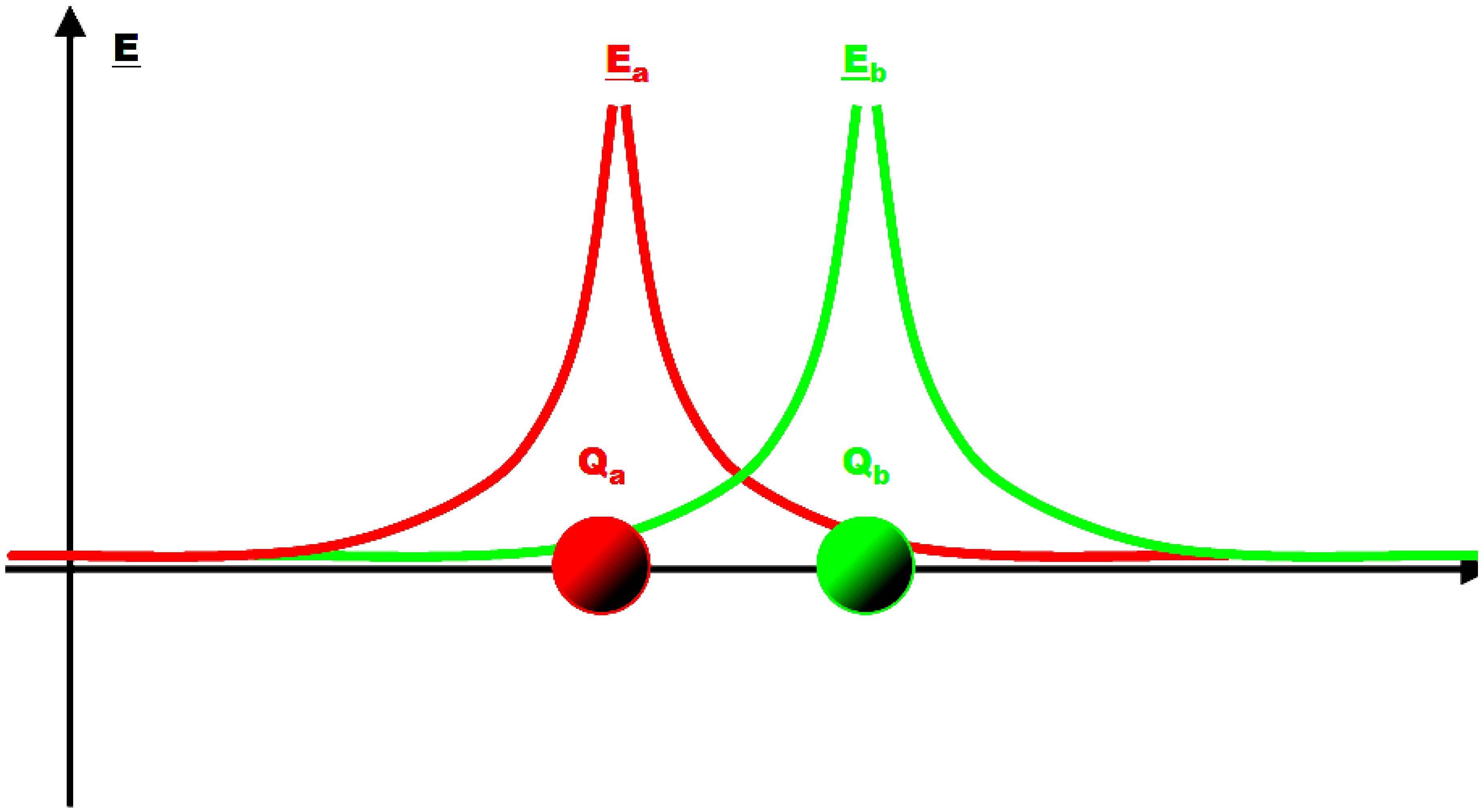
$$\vec{E} = \frac{\vec{F}}{q_\circ}$$

$$\boxed{\vec{E} = \frac{kQ}{r^2}\hat{r}}$$





Two Positive and Equal Charges



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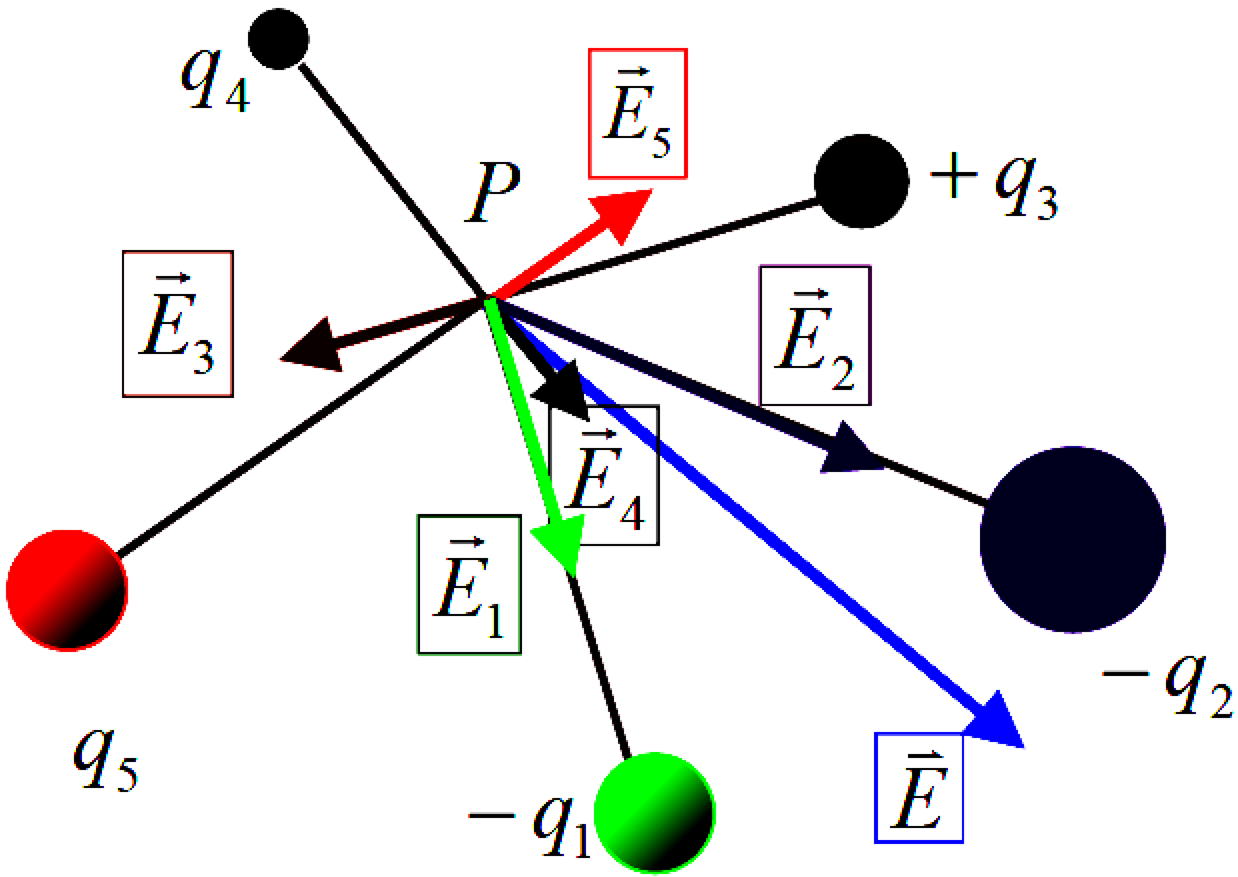
Superposition

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 + \vec{E}_5$$



Electric field at a point P is vector sum of electric field from all charges.

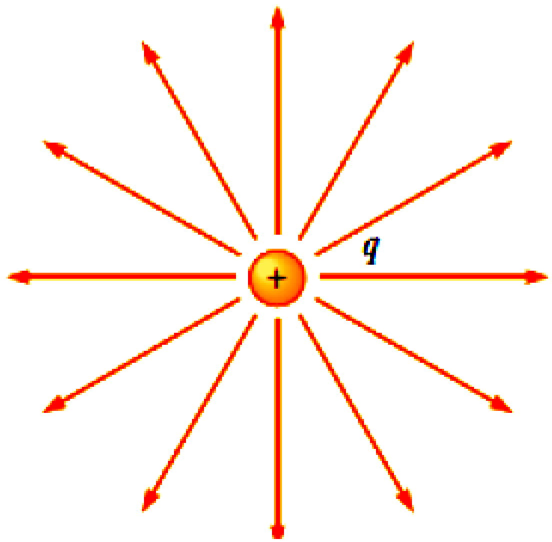
Typical Electric Field Values

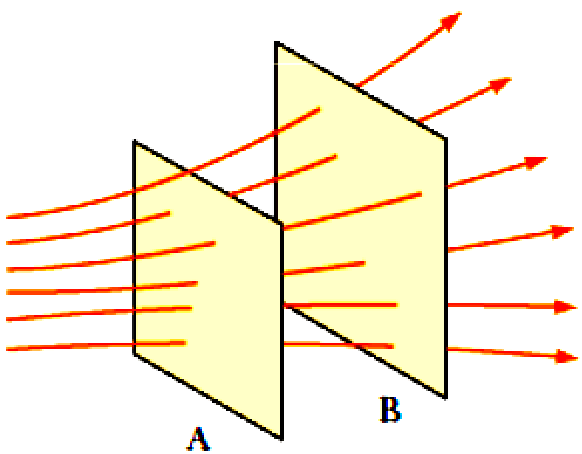
Source	E (N/C)
Fluorescent lighting tube	10
Atmosphere (fair weather)	10,0
Balloon rubbed on hair	10,00
Atmosphere (under thundercloud)	10,000
Photocopier	10,0000
Spark in air	>3000000
Near electron in hydrogen atom	5×10^{11}

Electric Field Lines

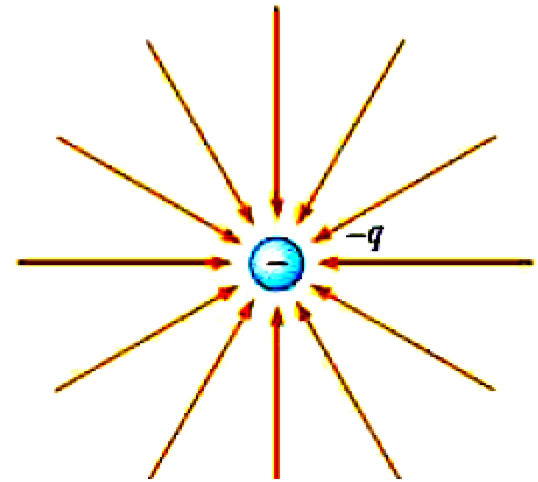
A convenient way of visualizing electric field patterns is to draw lines. These lines, called electric field lines, are related to the electric field in any region of space in the following manner:

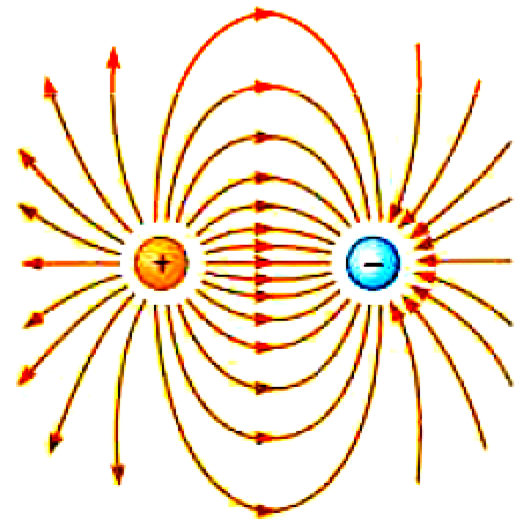
- For a positive point charge, the lines are directed radially outward.
- For a negative point charge, the lines are directed radially inward.
- The electric field vector E is tangent to the electric field line at each point.
- The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region. Thus, E is greater when the field lines are close together and smaller when they are far apart.
- No two field lines can cross.





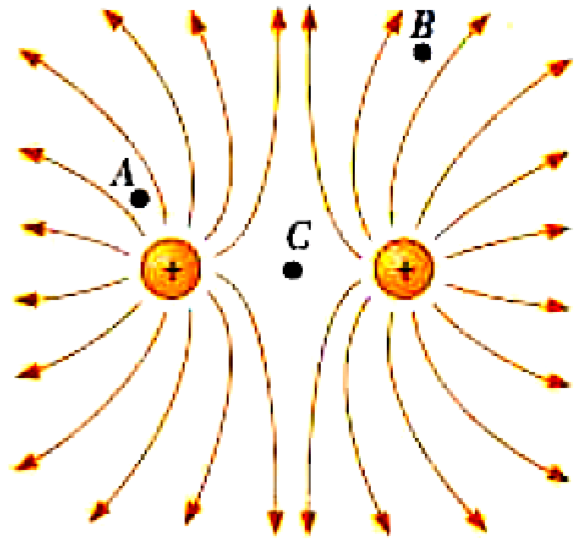
The magnitude of the field is greater on surface A than on surface B. $E_A > E_B$





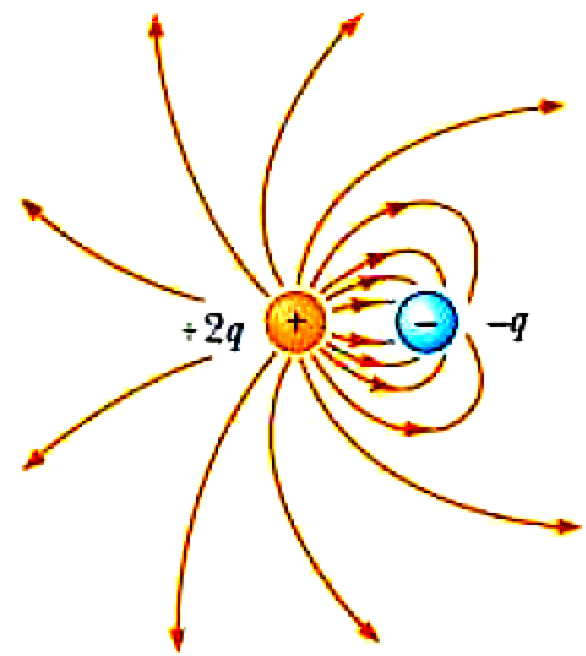
The lines must begin on a positive charge and terminate on a negative charge.

The electric field lines for two positive point charges. The field is greatest at point A because this is where the field lines are closest together. The absence of lines at point C indicates that the electric field there is zero.

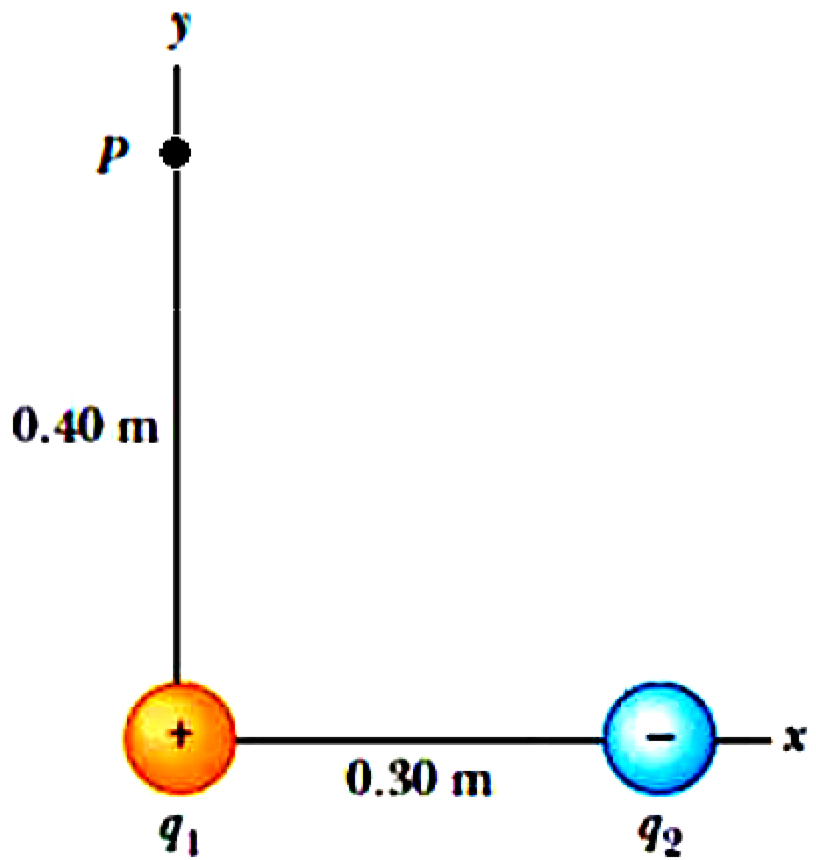


$$E_A > E_B > E_C$$

The electric field lines for a point charge 2q and a second point charge -q. Note that two lines leave 2q for every one that terminates on -q.



A charge $q_1=7.0\ \mu C$ is located at the origin, and a second charge $q_2=-5.0\mu\ C$ is located on the x axis, 0.30 m from the origin as shown in figure. Find the electric field at the point P, which has coordinates (0,0.40).



A charge q1=7.0 μC is located at the origin, and a second charge q2=-5.0μ C is located on the x axis, 0.30 m from the origin as shown in figure. Find the electric field at the point P, which has coordinates (0,0.40).

Magnitude of electric field at P due to q1 is

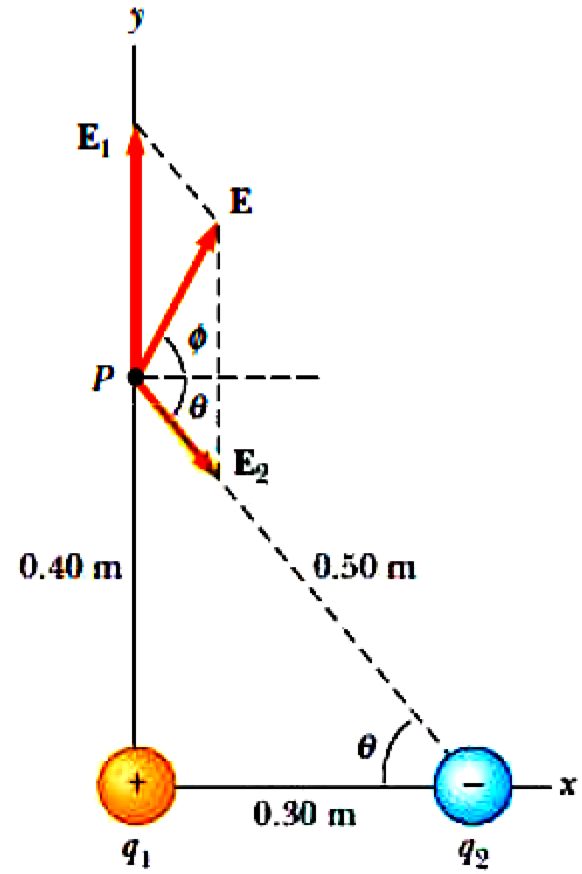
$$E_1 = \frac{kq_1}{(0.4)^2} = 3.0\times10^5 \, N/C$$

$$E_{1x} = 0 \qquad E_{1y} = 3.9\times10^5$$

$$\vec{E}_1 = 3.9\times10^5 \, \hat{j}$$

Magnitude of electric field at P due to q2 is

$$E_2 = \frac{kq_2}{(0.5)^2} = 1.8\times10^5 \, N/C$$



$$E_{2x} = E_2 \cos\theta = 1.1\times10^5 \qquad \therefore \cos\theta = 3/5$$

$$E_{2y} = E_2 \sin\theta = 1.4\times 10^5 \qquad \therefore \sin\theta = 4/5$$

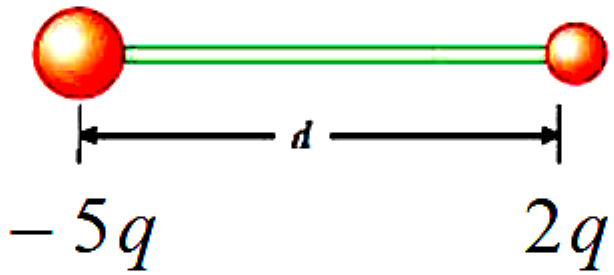
$$\vec{E}_2 = 1.1\times 10^5\,\hat{i} - 1.4\times 10^5\,\hat{j}$$

Net electric field at P is

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

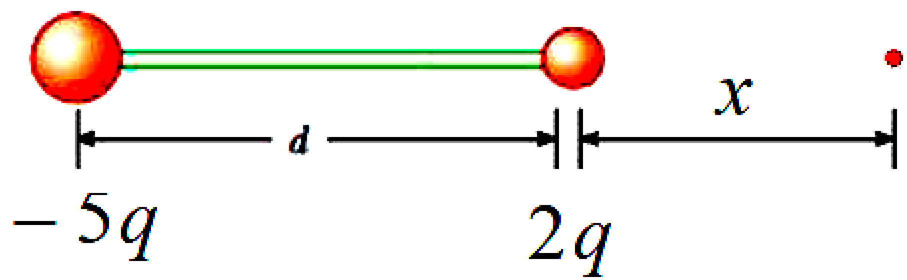
$$= 1.1\times 10^5\,\hat{i} + 2.5\times 10^5\,\hat{j}$$

In the configuration given below, Locate the point at which electric field is zero.



In the configuration given below, Locate the point at which electric field is zero.

The electric field is zero nearer to the smaller charge; since the charges have opposite signs it must be to the right of the +2q charge. Equating the magnitudes of the two fields,



$$\frac{k2q}{(x)^2} = \frac{k5q}{(d+x)^2}$$

$$2(d+x)^2 = 5x^2$$

$$3x^2 - 4dx - 2d^2 = 0$$

$$\boxed{x = 1.7d} \qquad \cancel{x = -0.36d}$$