Physics 30
Electric Forces & Fields

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Unfinished!

Contents

Electric Fields

Micheal Faraday

- Developed the idea of "lines of force" to describe electric fields
- A field is a "sphere of influence" in which a force can affect an object at a distance without contact
- There are electric, gravitational, and magnetic fields
- The symbol for electric field is $|\vec{E}|$

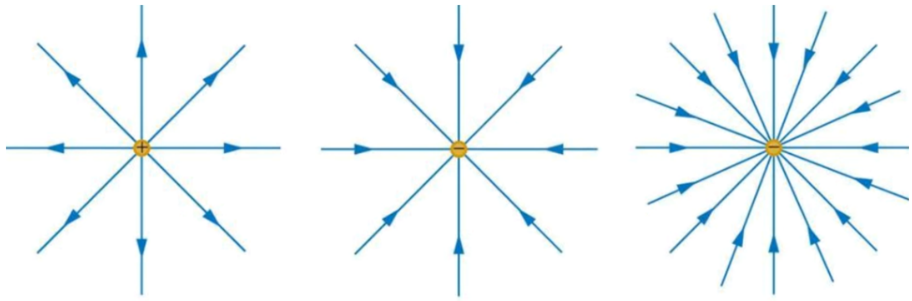
Gravitational Fields

$$\vec{g} = 9.81\,\frac{\mathrm{m}}{\mathrm{s}^2}$$

$$\vec{g} = \frac{Gm}{r^2}$$

- G = gravitational constant ($6.67 \times 10^{-11}\,\mathrm{N} \cdot \mathrm{m}^2/\mathrm{kg}^2$)
- m = mass of planet
- r = radius of the planet

Drawing Electric Field Lines

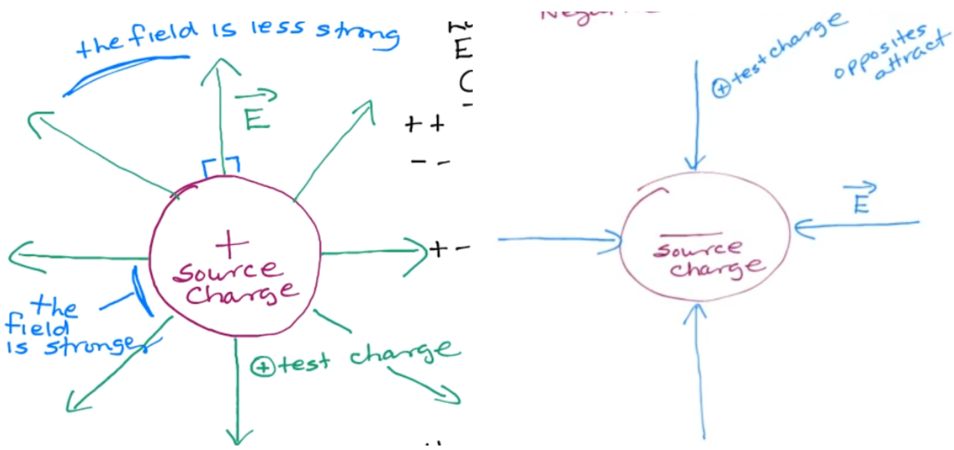


- Like charges repel, opposite charges attract
- The field is stronger the closer to the source charge it is
- We **always** use a small positive test charge to map/draw the electric field

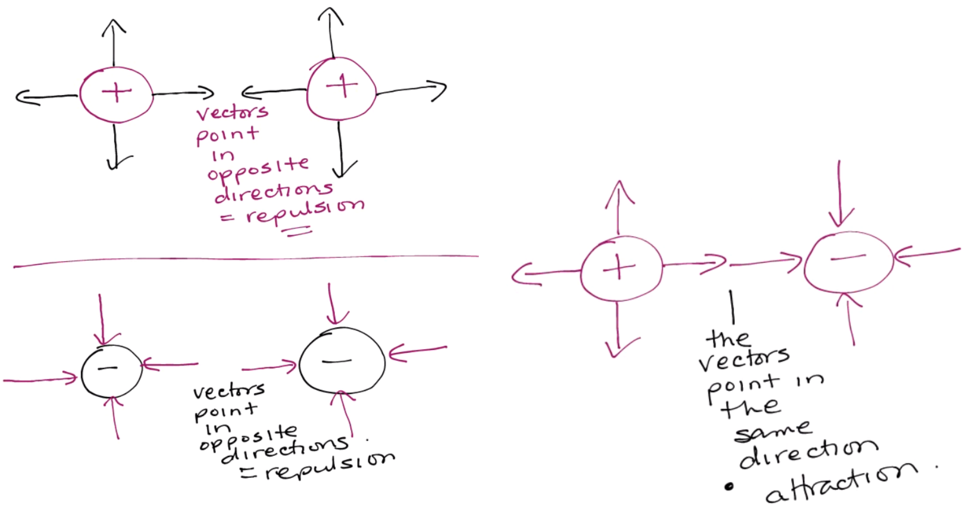
Rules

- The lines must originate on a positive charge and end on a negative charge (positive to negative)
- The electric field line must be perpendicular to the surface of the charge
- The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge
- No two field lines can cross each other

Electric Field Around A Positive v/s Negative Source Charge



Electric Field Interactions



Use this theory with a test particle to determine the direction of an electric field. NOT signs.

Particles

	charge	mass
Alpha particles	$+3.20\times10^{-19}$C	6.65×10^{-27}kg
Electrons	-1.60×10^{-19}C	9.11×10^{-31}kg
Protons	$+1.60\times10^{-19}$C	1.67×10^{-27}kg
Neutrons	0C	1.67×10^{-27}kg

Electric Field Strength

Electric Field Around A Producer (Source Charge)

$$|\vec{E}| = \frac{kq}{r^2}$$

Units: $\frac{\text{N}}{\text{C}}$ or $\frac{\text{V}}{\text{m}}$

- k = Coulomb's Constant (8.99×10^9 N $\cdot$ m^2/C^2)
- q = Value of the source charge (C)
- r = Distance from the source charge (m)

Electric Field Experienced By A Charge

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

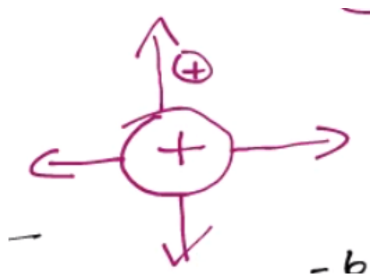
- $\vec{E}$ = Electric Field ($\frac{\text{N}}{\text{C}}$)
- $\vec{F}_e$ = Electrostatic Force (N)
- q = Test Charge (in a field question, its not source charge) (C)

Example

Calculate the electric field 2.00 cm from an alpha particle.

$$|\vec{E}| = \frac{(8.99 \times 10^9\,\text{N}\cdot\text{m}^2/\text{C}^2)(3.20 \times 10^{-19}\,\text{C})}{(2.00 \times 10^{-2}\,\text{m})^2}$$

$$|\vec{E}| = 7.19 \times 10^{-6}\,\frac{\text{N}}{\text{C}}\ \text{radially outward}$$



Example II

Calculate the electric field strength at a point in space where a 3.24×10^{-6} C charge experiences an electrostatic force of 5.29×10^{-3} N.

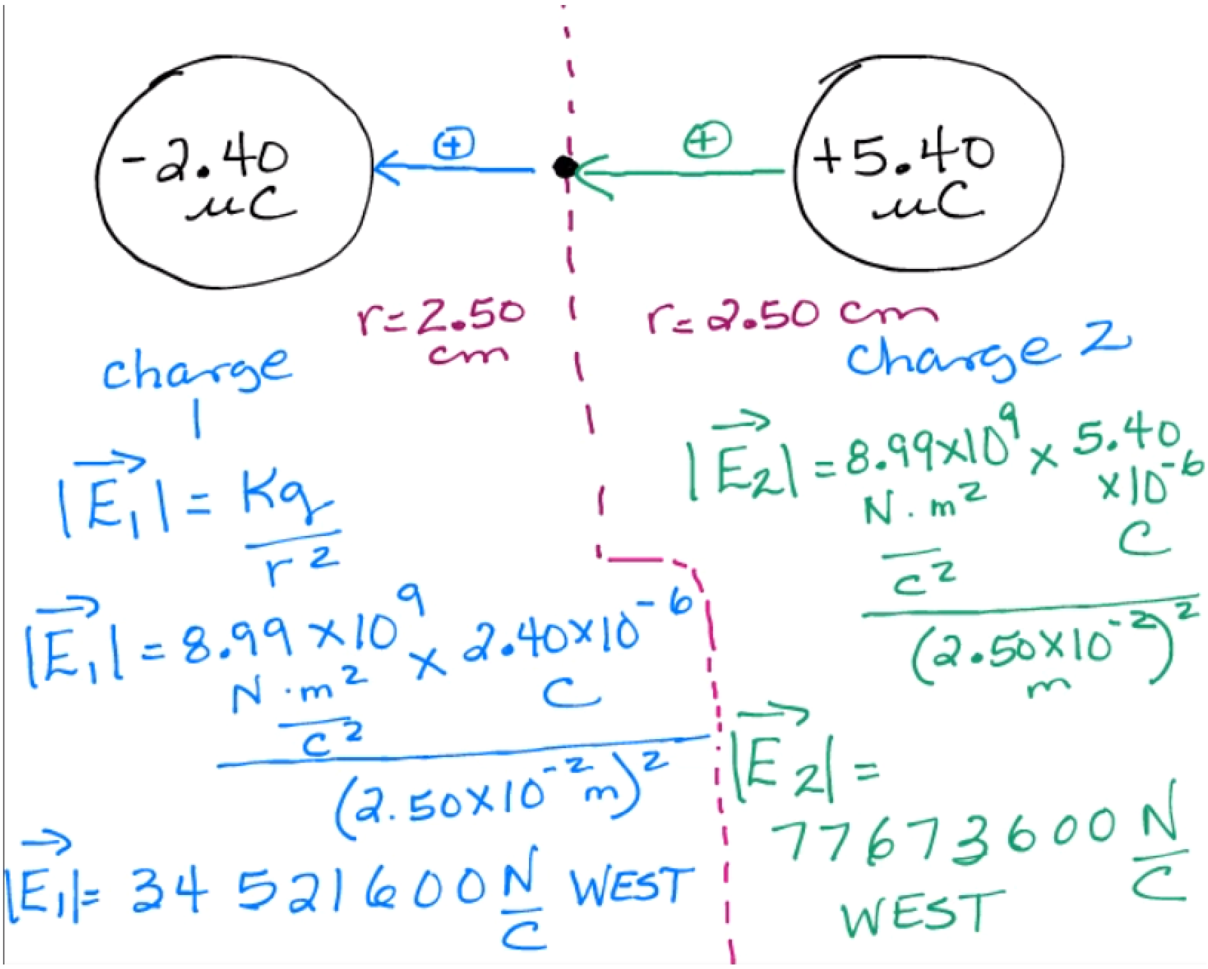
$$\vec{E} = \frac{\vec{F}_e}{q}$$

$$\vec{E} = \frac{5.29 \times 10^{-3}\,\text{N}}{3.24 \times 10^{-6}\,\text{C}}$$

$$\vec{E} = 1.63 \times 10^{3}\,\frac{\text{N}}{\text{C}}$$

Example III

Calculate the electric field midway between the two charges below if they are 5.00 cm apart.



$$|\vec{E}_{net}| = |\vec{E}_1| + |\vec{E}_2|$$

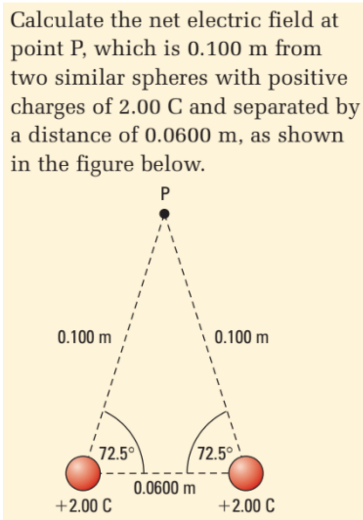
$$|\vec{E}_{net}| = 34\,521\,600\,\frac{\mathsf{N}}{\mathsf{C}},\ \text{west} + 77\,673\,600\,\frac{\mathsf{N}}{\mathsf{C}},\ \text{west}$$

$$|\vec{E}_{net}| = 1.12 \times 10^{8}\,\frac{\mathsf{N}}{\mathsf{C}},\ \text{west}$$

Electric Field Around A Producer in Two Dimensions

- Calculate $\vec{E}$ of the hypotenuse
- Use trig to get the components of the electric field vector on each side
- Direction of the vector is determined by the source charge like before
  - if positive, towards test charge/point (repel)
  - if negative, from test charge/point to source charge (attract)
- Add the x and y components, positive or negative depending on direction
- You are left with the components of the net electric field vector

Example I

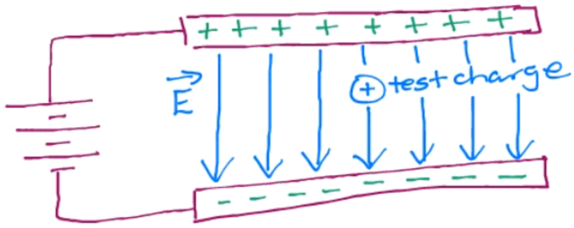

Calculate the net electric field at point P, which is 0.100 m from two similar spheres with positive charges of 2.00 C and separated by a distance of 0.0600 m, as shown in the figure below.

$$= 3.43 \times 10^{12}\,\frac{\text{N}}{\text{C}}$$

Electric Field Between Plates

$$\vec{E} = \frac{V}{d}$$

- V = total voltage across the plate (V)
- d = total distance between the plates (m)



- The electric field between charged parallel plates is uniform — identical at any point
- To determine the direction of the electrical field between charged parallel plates, use a small positive test charge
- Don't forget that work is equal to 0 J if the F_e and d are not along the same line
  - θ (in $W = Fd\cos\theta$) must be either
    0° (force and distance same direction) or
    180° (force and distance opposite directions)

Example

Two parallel plates are connected to a 12.0 V battery. If the plates are 6.00×10^{-2} m apart, calculate the electric field strength between them.

$$\vec{E} = \frac{12.0\,\text{V}}{6.00 \times 10^{-2}\,\text{m}} = 200\,\frac{\text{V}}{\text{m}}$$

Example II

- A proton is placed in an electric field between two parallel plates. If the plates are 5.00 cm apart and have a potential difference between them of 95.0 V, how much work is done against the electric field when the proton is moved 3.00 cm parallel to the electric field?

$d = 5.00\,cm$ $\quad d_{moved} = 3.00\,cm$

$V = 95.0\,V$

$q = 1.60 \times 10^{-19}\,C$

$\vec{E} = \frac{V}{d} = \frac{95.0\,V}{5.00 \times 10^{-2}\,m}$ (total d between the plates)

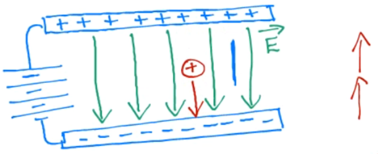
$\vec{E} = 1900\,\frac{V}{m} = \frac{N}{C}$

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

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

$\vec{F_e} = 1900 \frac{N}{C} \times 1.60 \times 10^{-19}\,C$

$\vec{F_e} =$



$W = F_e \times d \times \cos\theta$

$W = 3.04 \times 10^{-16}\,N \times 3.00 \times 10^{-2}\,m \times \cos 0°$

$W = 9.12 \times 10^{-18}\,J$

Electric Field as a Function of r Graph

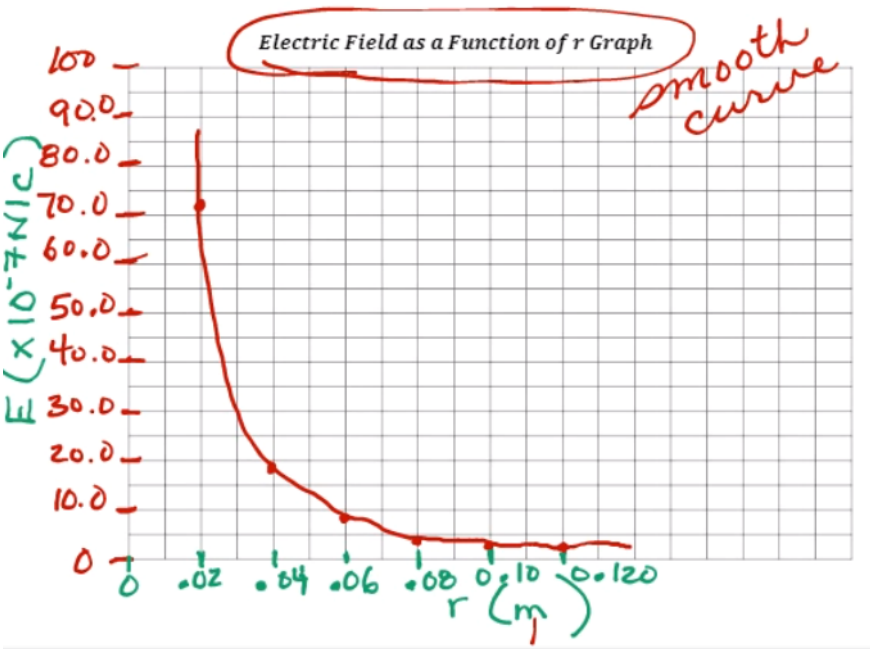
- Make sure all values are times ten to the power of the same exponent before you plot

Create a data table that shows the value of the electric field at the following distances from an alpha particle:

Data Table 1:

x axis (manipulated) | y axis (responding)

r (m)	$\vec{E} = \frac{N}{C}$ $\left(\vec{E} = \frac{kq}{r^2}\right)$	$\times 10^{-7}$
0.0200	* 7.192×10^{-6}	71.9×10^{-7}
0.0400	1.798×10^{-6}	18.0×10^{-7}
0.0600	$7.99111111 \times 10^{-7}$	7.99×10^{-7}
0.0800	4.495×10^{-7}	4.50×10^{-7}
0.100	2.8768×10^{-7}	2.88×10^{-7}
0.120	$1.99777778 \times 10^{-7}$	2.00×10^{-7}



In order to get a graph that is a straight line, set the x to whatever is proportional to y. In this case, $E \propto \frac{1}{r^2}$

	$\frac{1}{r^2}\left(\frac{1}{m^2}\right)$	$\vec{E}\left(\frac{N}{C}\right)$
2.50×10^3	2500	7.19×10^{-6} (71.9×10^{-7})
625	625	1.80×10^{-6} (18.0×10^{-7})
278	277.7777778	7.99×10^{-7}
156	156.25	4.50×10^{-7}
100	100	2.88×10^{-7}
69.4	69.4444444	2.00×10^{-7}