PHY-112 | Principles of Physics-2

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Recap of the previous class!

What we studied in Class 1

Refer to Class 1 slides for details!

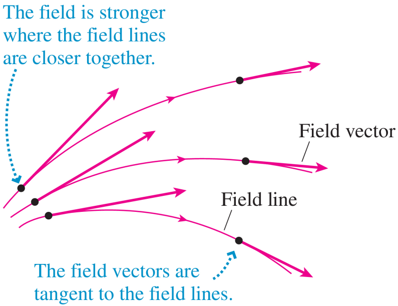
- What Electric Charges are and their properties.
- What is Electric Field, and how is it defined for a point source charge?
- What Coulomb forces are and how they relate to the Electric Field.
- Using the superposition principle, how to find the net Coulomb force and the net Electric field on an observer point charge in 1D and 2D.

How to *See* the Electric Field?

Electric Field Lines

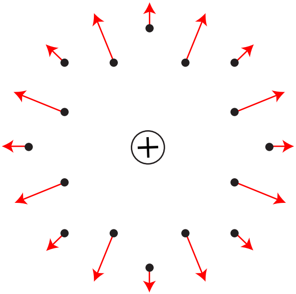
They are imaginary, but the intuition is very real

- They are *continuous* curves tangent to the electric field vectors
- Closely spaced field lines indicate a greater field strength; widely spaced field lines indicate a smaller field strength
- They start on positive charges and end on negative charges, and no two electric field lines will intersect

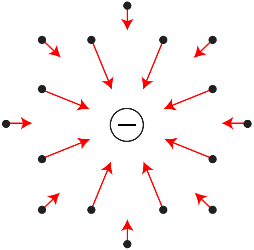


Electric field lines of Charged Particles

Think 3D. Radially means across the radius of an imaginary sphere



Radially Outward

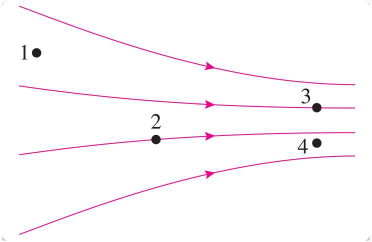


Radially Inward

Incepting Ideas (1)

Hint: Follow the lines and their density

Q: Rank in order, from largest to smallest, the electric field strengths E_1 to E_4 at points 1 to 4, shown in the diagram below.



Food for thought!

Are single point charges (positive or negative) sources of uniform electric fields? If so, why? If not, why not? Explain your reasoning.

Motion of Charged Particles in $\vec{E}$ field

What you need in this section

Laws of Motion from PHY-111

$$\vec{v} = \vec{v}_0 + \vec{a}t \tag{1}$$

$$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2 \tag{2}$$

$$\vec{r} = \vec{r}_0 + \frac{1}{2}(\vec{v} + \vec{v}_0)t = \vec{r}_0 + \bar{\vec{v}}t \tag{3}$$

$$\vec{v}^{\,2} = \vec{v}_0^{\,2} + 2\vec{a}(\vec{r} - \vec{r}_0), \tag{4}$$

where

$$\begin{aligned} \vec{r} - \vec{r}_0 = \vec{d} \quad &\rightarrow \quad \text{displacement} \\ t \quad &\rightarrow \quad \text{time interval} \\ \vec{a} \quad &\rightarrow \quad \text{constant acceleration} \\ \vec{v} \quad &\rightarrow \quad \text{final velocity} \\ \vec{v}_0 \quad &\rightarrow \quad \text{initial velocity} \end{aligned}$$

Electric Field and Forces

How forces come due to the field!

The direction of the electric field at a given point is **the direction in which a positive test charge would experience a force if placed at that same point** around the source charge that made the field.

$$\vec{F}_E = q_0 \vec{E}$$

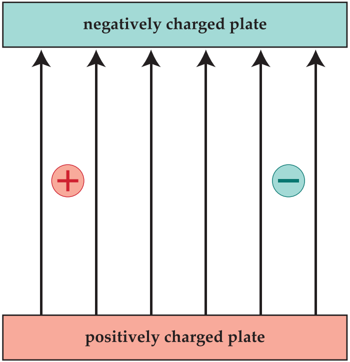
$$\vec{a} = \frac{q_0}{m_0} \vec{E}$$

where $\vec{F}_E \rightarrow$ Coulomb force felt by the observer charge q_0 in presence of $\vec{E}$. The field is produced by charge q.

Remember, q_0 did not make this $\vec{E}$. q_0 only measures its effect.

1D Motion of charged particle in $\vec{E}$

Motion in Uniform $\vec{E}$ Field: Straight
When shot parallel/antiparallel to $\vec{E}$ field



We will explore these plates/electrodes and what they mean and how they determine the electric field direction very soon, once we get to introduce *Electric Potential*. For now, take them at face value as a means of producing uniform electric fields.

Incepting Ideas (2)

Hint: Use 1D linear mechanics motion

Q: An electron with a speed of 5.00×10^8 cm s^{-1} enters an electric field of magnitude 1.00×10^3 N C^{-1}, traveling along a field line in the direction that halts its motion. (a) How far will the electron travel in the field before stopping momentarily, and (b) how much time will have elapsed? (c) If the region containing the electric field is 8.00 mm long (too short for the electron to stop within it), what fraction of the electron's initial kinetic energy will be lost in that region?

Incepting Ideas (3)

Hint: Use 1D linear mechanics motion

Homework Practice Problem: Try it Yourself

Q1: A uniform electric field exists in a region between two oppositely charged plates. An electron is released from rest at the surface of the negatively charged plate and strikes the surface of the opposite plate, 2.0 cm away, in a time 1.5×10^{-8} s. (a) What is the speed of the electron as it strikes the second plate? (b) What is the magnitude of the electric field $\vec{E}$?

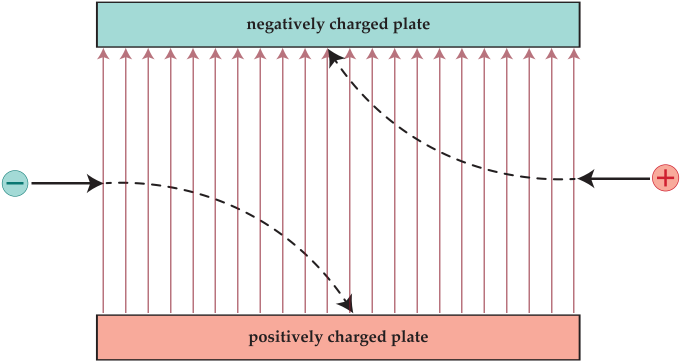
Q2: An electron is accelerated Eastward at $1.80 \times 10^{9}\ \mathrm{m\,s^{-2}}$ by an electric field. Determine the field (a) magnitude and (b) direction.

Alternative parameters to try

Try Q2 with a proton and/or positron, moving westward and southward, respectively. **Note**: Positron is the anti-particle of an electron with $+1e$ charge, with mass equal to that of electrons.

2D Motion of charged particle in $\vec{E}$

Motion in Uniform $\vec{E}$ Field: Parabolic
When shot perpendicular to $\vec{E}$ field



The charged particle now perpendicularly enters the field, with uniform velocity.

Incepting Ideas (4)

Hint: Use 2D planar mechanics motion

Q: An ink drop with a mass m of 1.3×10^{-10} kg and a negative charge of magnitude $Q = 1.5 \times 10^{-13}$ C enters the region between two charged plates, initially moving along the $-x$ axis with speed $v_x = 18\ \mathrm{m\,s^{-1}}$. The length L of each plate is 1.6 cm. The plates produce a uniform electric field, acting downward, and have a magnitude of $1.4 \times 10^{6}\ \mathrm{N\,C^{-1}}$. (a) What is the vertical deflection of the droplet at the far edge of the plates? (b) Find the velocity (in unit vector notation) of the ink mass at that location.

Alternative parameters to try (SP 22.04, p-647 | RH)

Try the same problem with the same parameters but with a charge $-Q$ and the same mass.

Incepting Ideas (5)

Hint: Practice! Practice! Practice!

Some Problems to Practice at Home on today's topic

Example Problem Example 21.7, p-721 | Young-Freedman
Exercise Problem 21.27, p-738, 21.78, p-742 | YF
Exercise Problem 41, 42, 47, 49, p-656, 53, 54, 55, p-657 | RH

YouTube:

- https://youtu.be/Gx44jjFBjdM

That is it for today!