Announcements:

When you register your Iclicker, use your RUID, not your NETID. If you have already registered with your NETID, please re-register!
Reasons to introduce electric (gravitational, magnetic, etc.) field:


Cure for the “action-at-a-distance” problem ⇒ charges generate “fields”, and these fields act upon other charges. The field perturbation travels in vacuum with the speed of light.

- The electromagnetic field is an objective reality, it possesses energy and momentum (Sun’s energy reaches us by means of electric and magnetic fields).
Electric Field $\vec{E}(\vec{r})$: the force per unit probe charge

$F_{q\rightarrow Q} = \frac{1}{4\pi\varepsilon_0} \frac{qQ}{(r_{qQ})^2} = q \frac{1}{4\pi\varepsilon_0} \frac{Q}{(r_{qQ})^2} = qE_q(\vec{r}_Q)$

Units of the electric field: $\frac{N}{C}$

(Intensity of) the gravitational field at Earth’s surface? Units?

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the $E$ field due to $q$ at the location of $Q$

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Consider two charges: +Q (at the origin) and +q (at $\vec{r}$).

The force exerted by Q on q:

$$\vec{F}_{Q\to q}(\vec{r}) = \frac{1}{4\pi \varepsilon_0} \frac{Qq}{r^2} \hat{r}$$

The electric field due to Q at the location $\vec{r}$:

$$\vec{E}_Q(\vec{r}) \equiv \frac{\vec{F}_{Q\to q}(\vec{r})}{q} = \frac{1}{4\pi \varepsilon_0} \frac{Q}{r^2} \hat{r}$$

$\vec{E}$ is directed along $\hat{r}$ for $+Q$, along $-\hat{r}$ for $-Q$. 

\[11\]
The electric fields created by different charges do not interact with each other, the net field is the **vector** sum of the fields due to individual point charges:

\[ \vec{E}(\vec{r}) = \sum_i \vec{E}_i(\vec{r}) \]

- the field at the location \( \vec{r} \) due to all other charges

\[ \vec{F}_{\text{net}} = \sum_i \vec{F}_i \]

- the force on a charge at the location \( \vec{r} \) due to all other charges
Electric field lines:
- direction of the field vector is tangential to the field line (curve);
- intensity of the field at a given point is proportional to the local density of field lines.

Density of lines: (relative) number of lines per unit area perpendicular to the lines.
Shown are the electric field lines, the charges that produced the electric field are not shown. Rank the magnitude of the electric field for the points labeled A through F.

\[ E_C \cong E_D > E_E > E_A > E_B > E_F \]
For a point charge, \( E(r) \propto \frac{1}{r^2} \) \( \Rightarrow \)

the density of lines \( \propto \frac{1}{r^2} \).

The area of a sphere centered at the charge \( \propto r^2 \).

Thus, **the total number** of lines is fixed: they don’t “vanish into thin air”, must be terminated either at another (negative) charge or continue to infinity.

This picture resembles a laminar flow of some fluid from positive charges (“source”) to negative charges (“sink”), **though there is no real displacement of matter in space.**
1. Charge separation by friction.

2. The girl acquires a charge distributed across her surface.

3. Like charges on individual hairs repel each other and force the hairs to stand away from each other and the girl’s head.

4. Girl’s hairs (roughly) follow the field lines.
Demonstration: Van de Graaff Generator

Robert J. Van de Graaff
1901-1967

1) hollow metal sphere
2) upper collecting electrode
3) upper roller (for example an acrylic glass)
4) side of the belt with positive charges
5) opposite side of the belt with negative charges
6) lower roller (metal)
7) lower electrode (ground)
8) spherical device with negative charges, used to discharge the main sphere
9) spark between the electrodes
How to Draw the Electric Field Lines

Convention:
- the electric field lines originate on positive charges;
- terminate on negative charges.

Field lines don’t form sharp bends (there is only one tangent line to a field “curve” at each point).
Electric Field of a Dipole

Dipoles: the second most important (after a point charge) configuration of charges.

2D plot of the field lines in the x-y plane
3D plot of the field intensity in the x-y plane
Conclusion

Electric Field: math. tool and phys. reality

Electric Field Lines