Documentation for Java^{TM} Applet
Electrostatics

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Abstract

This documentation is a manual for a Java Applet[1], which visualizes many problems in electrostatics. For study purposes the interface implements three different charge configurations. The applet is based on the emstatic[2] version created by *Paul Falstad*. It has been published within the OWL Project *e-Module for Visualisations of Theoretical Physics*[3].

[1]Java and all Java-based trademarks of Sum Microsystems, Inc. in the United States, other countries, or both.
[2]`http://www.falstad.com/emstatic/`
[3]Translated to English by Philipp Loske 19.03.2014

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About us

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(*Knowledge through Learning*)
e-Module for Visualisations of Theoretical Physics
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1 Introduction

This Java-Applet visualizes the characteristic numbers of a (two-dimensional) electrostatic field. In the simulated square it is possible to configure the distribution of monopoles, statistical currents, dielectrics, space charges and electrical conductors. Within this scenario different field quantities can be visualized with the button **show** in the interface.

What this Applet is able to visualize:

- Potentials field vectors and lines for almost any charge, conductor or dielectric distributions
- Fields around statistical currents in conductors
- Polarisation in conductors
- Multipoles (the characteristic field is visible up to octupoles)

What this Applet is not able to visualize:

- three-dimensional fields (have a look at the 3D-Applet[4])
- dynamical fields
- absolute charge values
- non linear dielectrics

The menu allows to add charges all the time. The plot panels actualizes constantly. It is advisable to stop the calculation while configuring very complex charge distributions (**Stop Calculation**).
To modify (or plot) the conductibility is is necessary to select an option under **Show Material Type** (or all conductors keep grey).

2 Manual

After starting the applet (initializes in the browser with opening the applet's website), a new window opens on the screen with the initial configuration of the electrical central field. On the ride side of the plot panel is a control panel to configure the applet.

[4] `http://www.falstad.com/emstatic/`

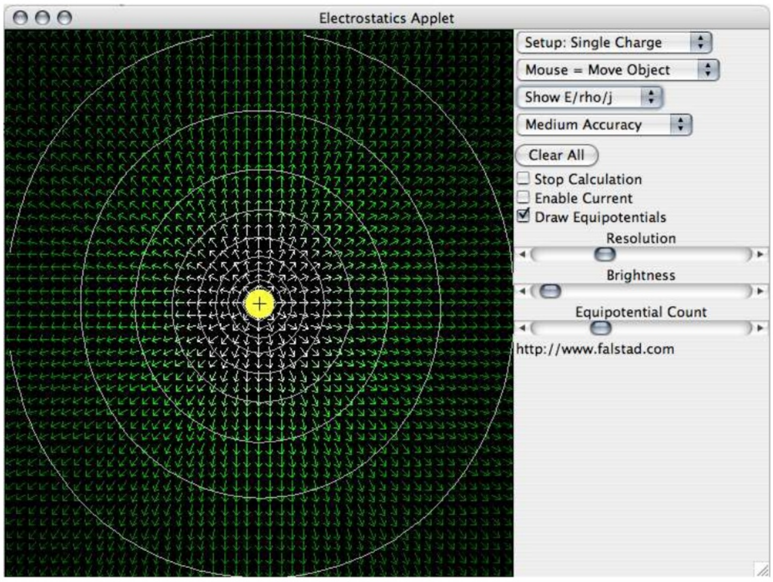
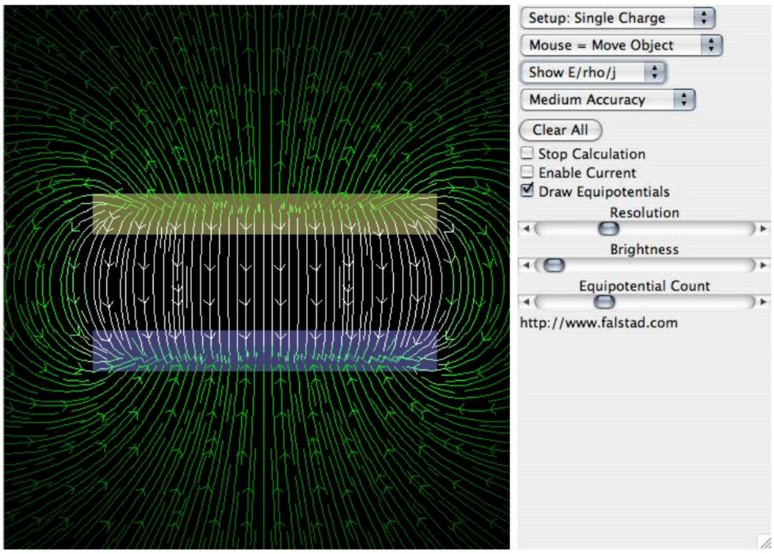


Figure 1: Applet at the first start



(a) **Feldquadrat** (b) **Aktionswahl**

2.1 Plot panel [Figure (a)]

Click and move the mouse to create and delete different objects. The panel actualizes constantly.

2.2 Explanation of the control elements

***Setup* menu**
Choose between many different pre-configured scenarios:

- **Single Charge**: Single, central positive charge
- **Double Charge**: Two positive charges
- **Dipole Charge**: A positive and a negative charge (dipole field)
- **Charge + Plane**: Single charged and grounded plane (analogue to dipole field)
- **Dipole + Uniform**: Dipole in the standard field
- **Quadrupole Charge**: Two positive and two negative charges with a diagonal position
- **Conducting Planes**: Two planes with opposite potentials
- **Charged Planes**: Two planes with same charges

***Mouse* menu**
This menu controls what happens when clicking into the plot panel with the mouse.

- **Mouse = Move Object**: Moves conductor, point and space charges and dielectrics
- **Mouse = Delete Object**: Deletes the same objects
- **Mouse = Add + Draggable Charge**: Creates a moveable positive charge at a mouse click
- **Mouse = Add − Draggable Chaage**: Creates a moveable negative charge at a mouse click
- **Mouse = Clear Square**: Deletes conductor, point and space charges and dielectrics only in the selected area
- **Mouse = Add Conductor (Gnd)**: Creates a grounded conductor on empty quadrant (deletes it at a click on an already existing conductor)

- **Mouse = Add + Conductor**: Creates conductor with a constant positive potential
- **Mouse = Add − Conductor**: Creates conductor with a constant negative potential
- **Mouse = Add + Charge Square**: Creates a positive space charge
- **Mouse = Add − Charge Square**: Creates a negative space charge
- **Mouse = Add Dielectric**: Creates a dielectric square
- **Mouse = Make Floater**: Changes a conductor's potential from constant to variable. The conductor does now have a constant charge and changes the distribution according to the charge distribution outside the conductor. Only one conductor can be defined as a *Floater*
- **Mouse = Adjust Conductivity**: With this tool it is possible to change the conductibility inside a selected area with the conductivity slider. Select a area by selecting an rectangle while keeping the mouse button pressed down. (The *Show Material Type* menu shows numbers and proportion)
- **Mouse = Adjust Dielectric**: Works in the same way as *Adjust Conductivity* but for the dielectricity
- **Mouse = Adjust Potential**:Works in the same way as *Adjust Conductivity* but for the potentials of conductors
- **Mouse = Adjust Charge**: Works in the same way as *Adjust Conductivity* but for the charge within the space charge areas with a Charge-slider

***Show* menu**
This menu determines which fields and parameters are shown.

- **Show Electric Field (E)**: Shows the electrical field vectors. Attention: The vectors are standardised and their length measure for the field intensity. The field intensity is visualized through a table of colours reaching from dark green (weak field) to bright green (stronger) to white (maximum field intensity)
- **Show E Lines**: Shows the force lines. Attention: The thickness of the lines is constant and does no indicator for the field intensity. The field intensity is visualized through a colour table as well
- **Show Potential (Phi)**: Shows the potential: green means positive, red means negative and black stands for grounded parts

- **Show Vector Potential**: Shows the vector potential (A) with vectors
- **Show Magnetic Field (B)**: Shows the magnetic field in green (positive, in the direction of the user) or red (negative, against the direction of the user)
- **Show Current (j)**: Shows the flux density with yellow arrows
- **Show Charge (Rho)**: Shows the charge density (ρ) in yellow (positive) or blue (negative)
- **Show Displacement (D)**: Shows electrical displacement vector
- **Show Polarisation (P)**: Shows electrical polarisation
- **Show Polarisation Charge**: Shows the polarisation-charge density
- **Show Material Type**: This menu differentiate between material types (otherwise all material types are coloured in grey)
  - Conductor: cyan
  - Conductor with variable potential: violet
  - Dielectrics: orange (brighter colour stands for a stronger dielectricity)
  - Space charges: blue or yellow
- **Show rho/j**: Shows charge and flux density
- **Show E/rho**: Shows electric field and charge density
- **Show E lines/rho**: Shows electric force lines and charge density
- **Show E/j**: Shows flux density inside conductors and outside the electric field
- **Show E lines/j**: Shows flux density inside conductors and electric force lines outside
- **Show E/rho/j**: Shows flux density inside conductors, the resulting electric field and ρ
- **Show E lines/rho/j**: Shows flux density inside conductors, the electric field outside the conductors and ρ
- **Show E/phi**: Shows the electric field and the resulting potential
- **Show E lines/phi**: Shows force lines and potential
- **Show E/phi in conductors**: Shows electric field and the conductors' potential

- **Show E lines/phi in conductors**: Shows force lines and the conductors' potential
- **Show E/phi/j**: Shows flux density, conductors' potential and the force lines outside
- **Show E lines/phi/j**: Shows flux density and conductors' potential and the force lines outside
- **Show B/j**: Shows the magnetic field and flux density
- **Show E/B/rho/j**: Shows the electromagnetic field outside the conductors, the conductors' flux density and ρ
- **Show E lines/B/rho**: Shows the magnetic field and the electric force lines outside the conductors and their charge and flux density
- **Show Ex**: Shows the X component of the electric field
- **Show Ey**: Shows the Y component of the electric field
- **Show Dx**: Shows the X component of the dielectric displacement
- **Show Dy**: Shows the Y component of the dielectric displacement

***Accuracy* menu**
This menu gives lets you choose between four levels of accuracy for the visualisation.

- **"Clear All" - Button**: Deletes all objects from the plot panel (Case of vacuum only)
- **Checkbox *Stop Calculation***: Stops the calculation of visualising intermediate steps. If f.e. it is necessary to construct a lot of charges or conductors it is advisable to avoid visualising intermediate steps which would take a lot of time to compute. All variables calculate again when activating this checkbox.
- **Checkbox *Enable Current***: Allows charges to flow. Therefore the potential on top of the window is set to positive and the potential at the bottom is set to negative. A cconnection between both sides with a conductor creates a current flow. All isolated conductors get grounded
- **Checkbox *Draw Equipotentials***: Draws equipotential lines
- **Slider *Resolution***: Changes the resolution (a higher resolution might take more time to calculate)

- **Slider *Brightness***: Changes the field force (equipotential lines get a higher density)
- **Slider *Equipotential Count***: Changes the number of equipotential lines independent from brightness (field force does not change)

2.3 Legend

- **yellow circle**: positive current
- **blue circle**: negative current
- **white lines**: equipotential lines
- **arrows**: field force *Field force is visualized by colour instead of vector length: dark green means weak force field, bright green to white means strong field*

2.4 Tips for presentation

The *Pull Down Menu* already implements a number of classical situations for a presentation

- The octupol: Eight charges can be placed in different positions. For example in shape of a cube or a flat octagon

2.5 Stand alone Version

The applets starts in different ways. It is possible to start the applet directly in the browser. Another possibility is to start the applet with the Java applet-Viewer. Therefore the following line needs to be written in the terminal:

```
appletviewer <Adress of the HTML-file of the applet>
```

The second option allows the user to start the applet without an internet connection. This requires only two files: One is the *.jar* file "emstatic.jar" and two is the HTLM file to start the applet which is stored in the .jar file. Both files need to be saved to a local folder and started with the applet viewer as mentioned before.

3 Theory

3.1 Basics

Every charged object creates an electric field. This interacts with other charges in two different ways: It attracts opposite charges and repels objects equally charged. The coulomb force between charges in the distance d is conservative and inverse proportional to the square of the distance.

$$F_{q12} \propto \frac{q_1 q_2}{d^2} \tag{1}$$

The force in coulomb units results from transforming the electric field intensity in vacuum:

$$\vec{F}(\vec{r}) = \frac{q_1 q_2}{4\pi\epsilon_0} \cdot \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|^3}$$

If the objects are not moved around, the space around them is filled with a static electric field. The variable $\vec{E}$ results from a test charge placed at every point in the space.

$$\vec{E}(\vec{r}) = \lim_{q \to 0} \frac{\vec{F}(\vec{r})}{q(\vec{r})}$$

So an additional charge Q at $\vec{r}$ is affected by the force $\vec{F}$:

$$\vec{F}(\vec{r}) = Q \cdot \vec{E}(\vec{r})$$

All fields overlay with each other linear within the principle of superposition:

$$\vec{F}(\vec{r})_{ges} = \sum_{i=1...n} \vec{F}_i(\vec{r})$$

The field can be described with force lines (virtual lines, which describe the movement of positive charged test charges) or field vectors $\vec{E}(\vec{r})$ Every field that is conservative has a potential ϕ:

$$\vec{E}(\vec{r}) = -\nabla\phi$$

The electric field $\vec{E}$ is always vertical towards the equipotential lines $\phi(\vec{r}) = const.$ The Maxwell equation $\nabla E = \frac{\rho}{\epsilon_0}$ leads directly to the potential with solving the Poisson's equation:

$$\Delta\phi = -\frac{\rho(\vec{r})}{\epsilon_0}$$

with the charge density $\rho(\vec{r})$.
For continuous charge distributions $\rho(\vec{r})$ the electric field can be calculated with the principle of superposition from Coulomb's law:

$$\vec{E}(\vec{r}) = \int_V \rho(\vec{r}) \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|^3} d^3 r'$$

The total charge is:

$$Q = \int_V \rho(\vec{r}) d^3 r$$

3.2 Dielectrics

If a substance contains as many bonded positive as negative charges (f.e. water), it becomes neutral from the outside. If the microscopical electric dipoles are able to orient freely, they can be polarised from an external field and create an opposing field. This extends Poisson's equation and the Maxwell equation with the polarisation $\vec{P}$ and the polarisation density $\rho_P = -\nabla \vec{P}$. The total field results to:

$$\epsilon_0 \nabla \vec{E} = \rho + \rho_P \qquad \Rightarrow \nabla(\epsilon_0 \vec{E} + \nabla \vec{P}) = \rho$$

$\vec{P}$ is linear connected with $\vec{E}$ through the electric susceptibility χ

$$\vec{P} = \epsilon_0 \chi \vec{E}$$

with

$$\epsilon = 1 + \chi.$$

So the polarisation is linked to the displacement density $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$ as well. $\Rightarrow$

$$\vec{D} = \epsilon_0 \epsilon \vec{E}$$

If two different polarised areas 1 and 2 are divided by an interface, $\vec{D}$ and $\vec{E}$ underlie the following boundary conditions. σ is the area charge density of the interface.

$$(\vec{D}_1 - \vec{D}_2) \cdot \vec{n} = \sigma \qquad (\vec{E}_1 - \vec{E}_2) \times \vec{n} = 0$$

The continuity conditions of the tangential components of the electric field leads to an discontinuous transition of the normal component of the $\vec{D}$ field. Accordingly the force lines of the $\vec{D}$ or $\vec{E}$ fields move towards the perpendicular, if $\epsilon_2 > \epsilon_1$, otherwise (at the transition to the optically thicker medium) it moves away from the perpendicular.