# Lecture tutorial 2D

## Using E- and B-fields to deflect electrons: Velocity filter

`el31`

$$F_e = F_b$$

$$qE = qvB$$

$$v = \frac{E}{B}$$

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## Determine $\frac{e}{m}$

`em39`

Assuming a charged particle moving perpendicular to an uniform magnetic field, there will be a forces exerted on the particles. The force will deflect the particle and, as the force is always perpendicular to the direction of movement, causes the particle to move on a circular path (if the charged particles stays within the magnetic field the entire time) with a centripetal acceleration magnitude of $a = \frac{v^2}{r}$ (see mechanics lectures). For a circular trajectory, the centripetal force and the force due to the magnetic field must be equal

$$\sum F = ma$$

$$F_b = F_r$$

$$evB = \frac{mv^2}{r}$$

$$eB = \frac{mv}{r}$$

$$\frac{e}{m} = \frac{v}{Br}$$

The velocity of the charged particles, i.e. electrons, is unknown but we can derive it from the energy conservation at the anode-cathode, with the potential energy being equal to $U = qV$:

$$U = K$$

$$eV = \frac{m}{2}v^2$$

$$v = \sqrt{\frac{2eV}{m}}$$

Putting everything together, we obtain

$$\frac{e}{m} = \frac{\sqrt{\frac{2eV}{m}}}{Br}$$

Squaring the equation and we get our final relationship:

$$\frac{e^2}{m^2} = \frac{\frac{2eV}{m}}{B^2r^2}$$

$$\frac{e}{m} = \frac{2V}{B^2r^2}$$

Now this servers for a single measurement, but if we repeat if while varying the magnetic field and measuring the resulting radius, we obtain can solve it via a linear regression:

$$\frac{1}{r} = \sqrt{\frac{e}{2mV}}B$$

The slope $s$ will be $\sqrt{\frac{e}{2mV}}$. Thus, the $e/m$ is obtained from the slope as:

$$\frac{e}{m} = 2Vs^2$$

**Are the results the same for electrons traveling clock- or anti-clockwise?**

FYI: The numerical value of $\frac{e}{m_e}$ is 1.759 $\times 10^{11}$ C/kg.

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# Long distance power lines

`ew08`

## Without transformers

- find the current in the power line

$$P_{out} = V_{out}I_{line} \leftrightarrow I_{line} = \frac{P_{out}}{V_{out}}$$

- assuming 2,200 W and 220 V we get a current of 10A
- the power loss is for 1 $\Omega$ resistance in the power line

$$P_{loss} = V_{out}I_{line} = R_{line}I_{line}^2 = 100W$$

## With transformer

- assuming the step-up transformer increases the voltage by a factor 10, the current in the power line is

$$I_{line} = \frac{P_{out}}{10, V_{out}} = 1A$$

- the power loss in the cable is therefore:

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

$$P = VI$$

$$P_{\text{loss}} = I^2 R_{\text{cable}}$$

$$P_{loss} = V_{out} I_{line} = R_{line} I_{line}^2 = 1W$$

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# High voltage & high current transformer

`ew03`

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

- "Hörner Blitzableiter"
- break down voltage of air about $\mathbf{3 \times 10^6}$ kV/m
- corona discharge a.k.a. "weak spark" around conductor but not "jump across gap" (corona discharge is a localized electrical discharge that occurs when the electric field near a conductor is strong enough to ionize the surrounding air, but not strong enough to cause a full electrical breakdown or arc)
- **lighter causes ionized air to generate plasma** (*ionization* = breaking apart a neutral air molecule into a positive ion + free electron; *plasma* = ionized gas made of free electrons and positive ions that conducts electricity and responds to electric and magnetic fields)
- thermodynamics cause plasma beam to rise