Jacobs University Bremen

Electric motors

Introduction

Automation
CO23-320203

Organisational issues

- Next session (Friday 29 March): some hands-on work
  - CLAMV lab (West Hall basement)
  - Make sure you have your account created – if not, write to a.gelessus@jacobs-university.de
  - You can also work on your own laptop, if you have a working simulink/matlab installation
  - Installation files for Jacobs students available from

    `\\clabfs2.clamv.jacobs-university.de\windows`

    or:

    ```
    mount 10.72.1.12:/disk/software/LinuxInst /mnt
    cd /mnt/Matlab/Matlab_R2018b/
    (sudo) ./install
    ```
- Homework will be connected to these exercises

Organisational issues

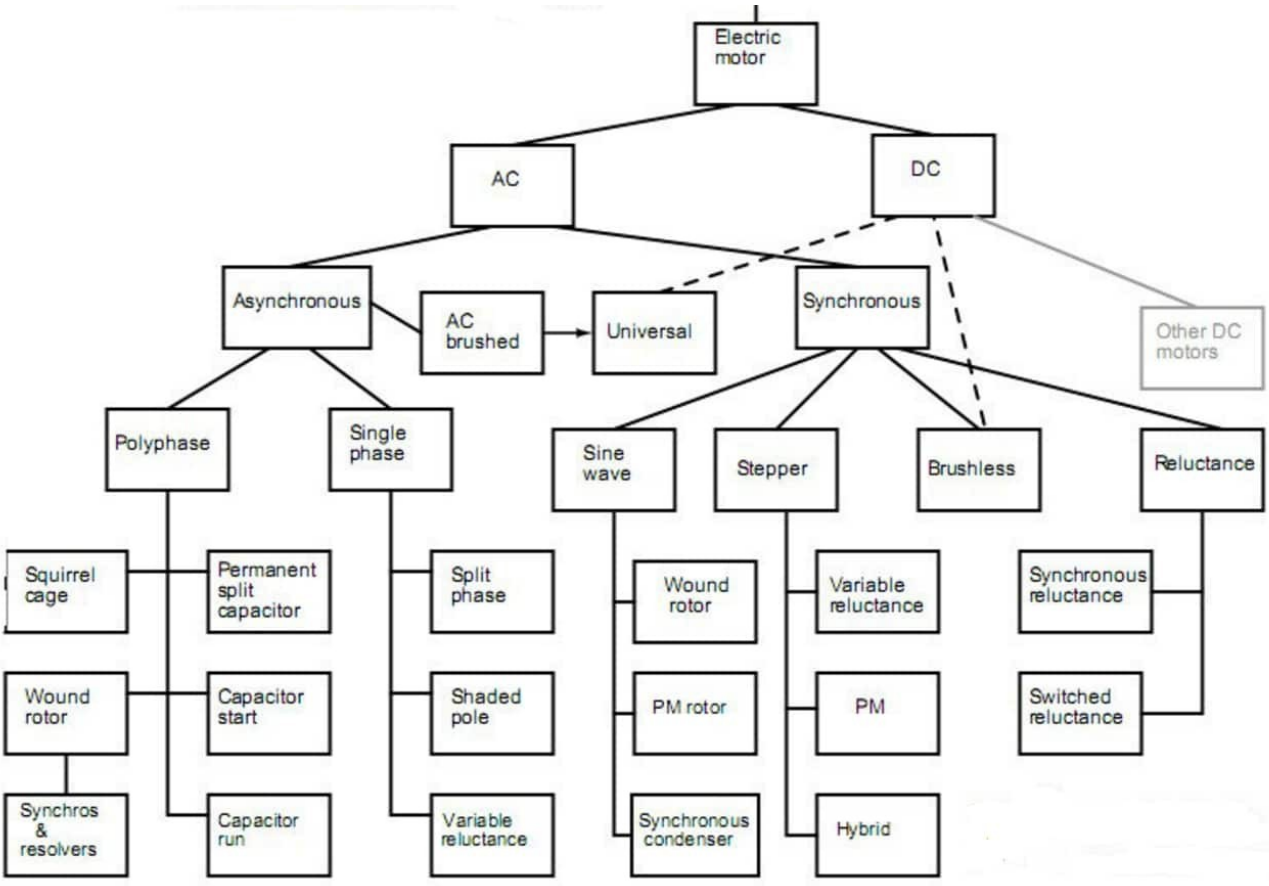
- The whole next week in Hannover: **Hannover Messe**
- One of the world's largest trade fairs, taking place since 1947
- Spinned CeBit off in 1980s
- Themes this year:
  - Industry 4.0
  - Sector coupling
  - Artificial intelligence
  - Cobots
  - Lightweight construction
  - Platform economics
  - 5G
- Free ticket courtesy of Siemens:

  https://new.siemens.com/global/en/company/fairs-events/hannover-messe.html#Tickets
- Free train ride to Hannover with your semester ticket then a simple local ride to Hannover Messe/Laatzen!
- Jobs, demos, freebies, contacts!

Automation

Part 2: Actuators

Electric motor family



Electric motor family

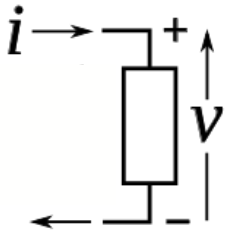
- It’s difficult to become a motor specialist overnight!
- But we can learn about how major motor types work and what parameters are important design inputs

Ultimate Beginners Guide to Using Electric Motors for Makers and DIY Projects
https://www.youtube.com/watch?v=SrPHQh-M3pM

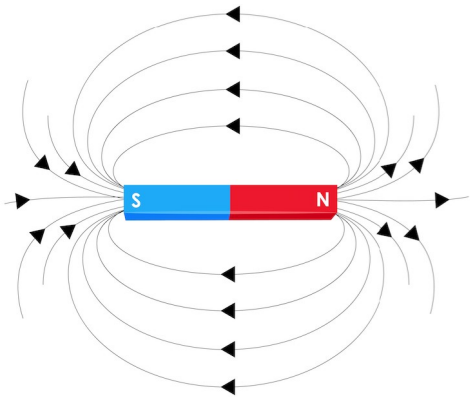
Electric motors

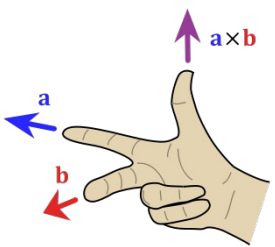
- Electric motors are ubiquitous in virtually all mechanisms surrounding us
- Without electric motors…
  - No space conquest
  - No Challenger Deep descent
- Make it you today's exercise: try to see motors everywhere you look!

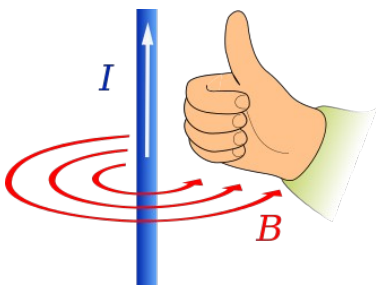
Before we begin...



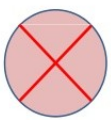
- Conventions!
  - Electric current is considered to flow from + to – despite the fact that the electrons are flowing in the opposite direction
  - Magnetic field field lines are joining north (N) pole to south (S) pole
  - Right hand rule(s)
  - Cross – dot convention for vectors out and into the plane of the drawing



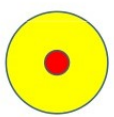




Current INTO the plane of paper

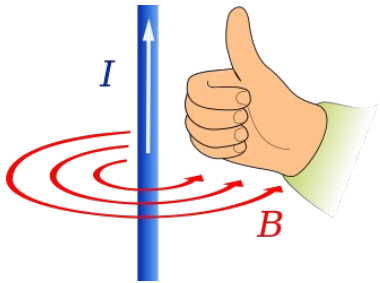


Current Coming Out of the plane of paper



Magnetic and electric worlds meet

- Hans Christian Ørsted discovers that electric conductors create magnetic field during a lecture in 1820



Lorentz Force

- The force f [N] acting on an electric charge of magnitude q [C] in an electric field E [V/m or N/C] and magnetic field B [T]:

$$\mathbf{f} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$ *Lorentz law*

- Even in absence of the electric field, this electric charge in a magnetic field might experience a force
  - if it's moving at a certain speed v
  - in the right direction

$$\mathbf{f} = q\mathbf{v} \times \mathbf{B}$$

- We can also express this situation in terms of current and its density J [A/m^2]:

$$\mathbf{f}_v = \rho(\mathbf{v} \times \mathbf{B})$$
$$= \mathbf{J} \times \mathbf{B}$$

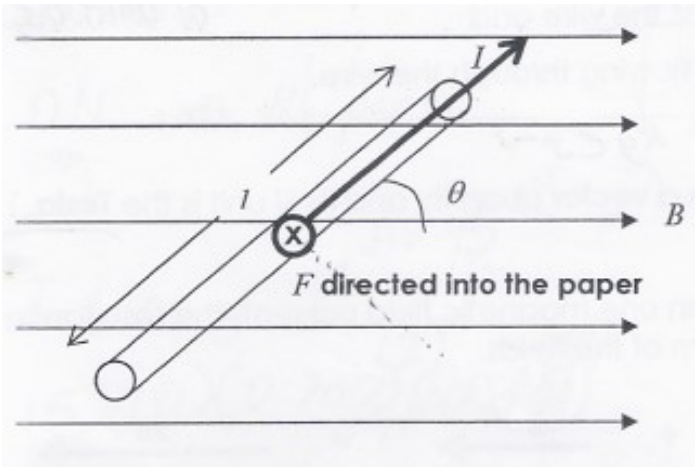
Ampere's law

- While the previous formulation encompasses the phenomenon, we will by typically dealing with a current being carried by a conductor

$$\begin{aligned}\mathbf{f} &= (\mathbf{J}A) \times \mathbf{B} \\ &= \mathbf{I} \times \mathbf{B}\end{aligned}$$

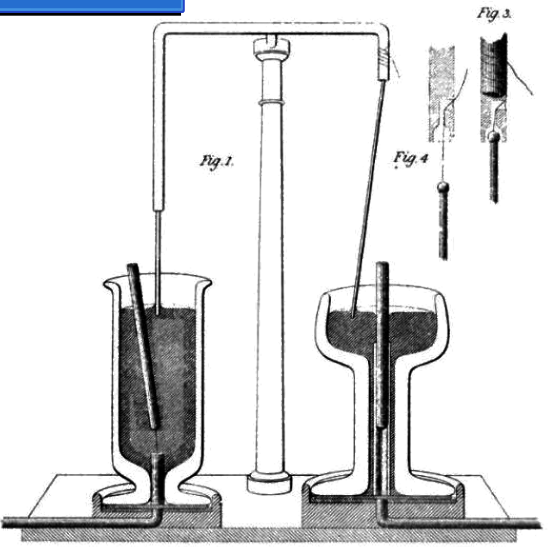
(this force is per unit length of the conductor!)

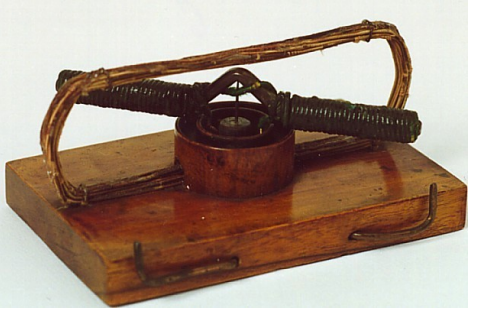
- With the cross product in the equation, we will have to watch out for the angle that the conductor is forming with the magnetic field!

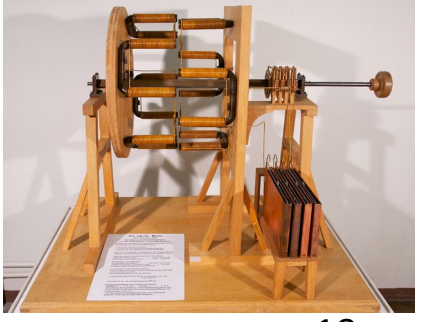


First electric motors

- Follows closely the invention of a battery by Alessandro Volta in 1799
- Homopolar motor by Michael Faraday in 1821
- Ányos Jedlik's electromagnetic self-rotors in 1827
- Jacobi's first electric boat propulsion in 1838 delivers practical mechanical power

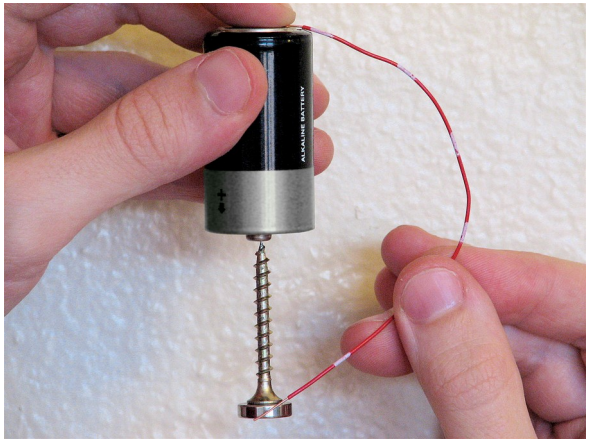


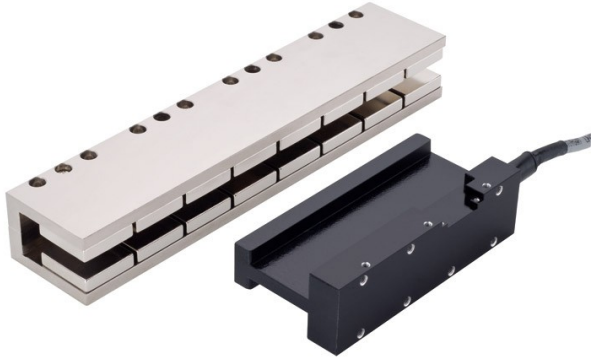




First electric motors

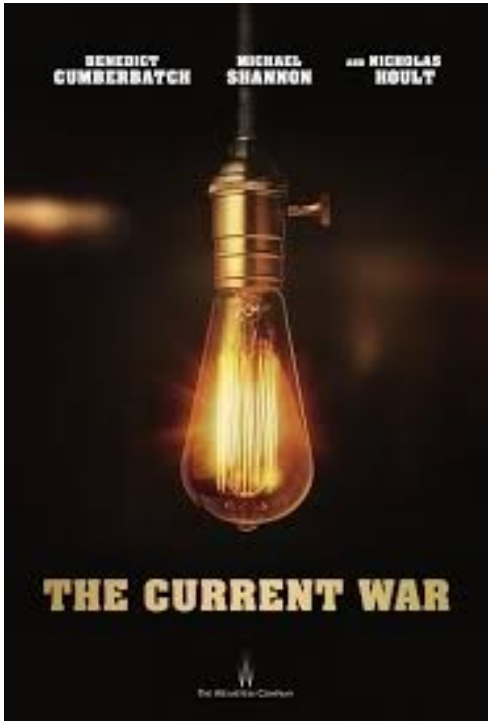
- The same principles can still be tested easily today!
- The common principle: to convert electric energy to movement
  - Not necessarily rotary, but in most cases yes
  - What sort of energy?
    - Battery? Direct current (DC)
    - Grid? Alternating current (AC)





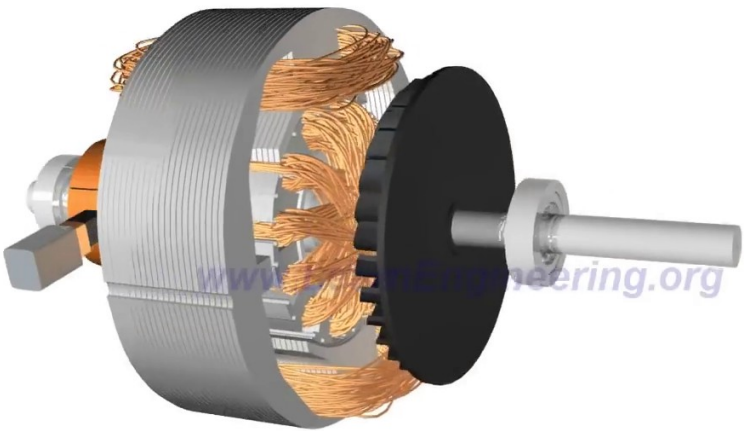
AC – DC question

- The debate is very much related to motors or, to be precise, their cousins: the generators
- Subject of a long battle of which concept would eventually electrify America between Thomas Edison and George Westinghouse in 1870s



DC Motor

- The basic principle, variations and issues
  - Torque and back E.M.F. generated
  - Universal, shunt and series motors
  - Commutation, starting



"How do Universal Motors work ?"
https://www.youtube.com/watch?v=0PDRJKz-mqE