Electric Motor and Dynamo
the Hall effect

Presentations:

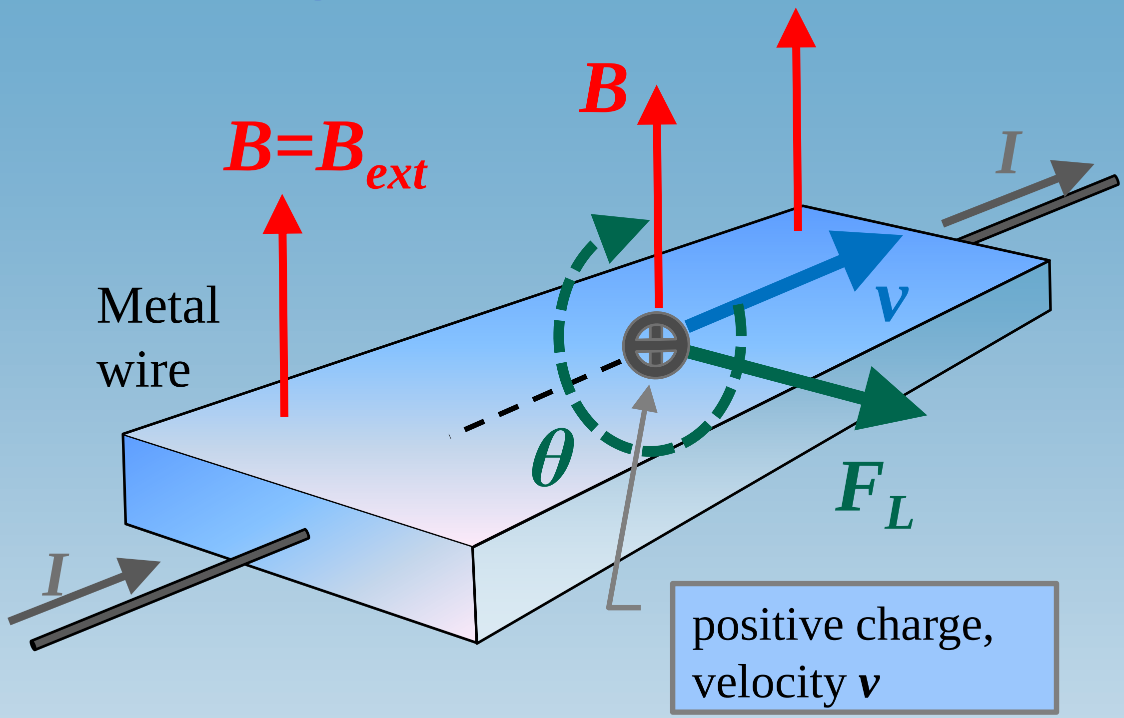
- Electromagnetism: History
- Electromagnetism: Electr. topics
- Electromagnetism: Magn. topics
- Electromagnetism: Waves topics
- Capacitor filling (complete)
- Capacitor filling (partial)
- Divergence Theorem
- E-field of a thin long charged wire
- E-field of a charged disk
- E-field of a dipole
- E-field of a line of dipoles
- E-field of a charged sphere
- E-field of a polarized object
- E-field: field energy
- Electric motor and dynamo; Hall effect
- Electromagnetism: integrations
- Electromagnetism: integration elements
- Gauss' Law for a cylindrical charge
- Gauss' Law for a charged plane
- Laplace's and Poisson's Law
- B-field of a thin long wire carrying a current
- B-field of a conducting charged sphere
- B-field of a homogeneously charged sphere

Downloads: www.demul.net/frits , scroll to "Electricity and Magnetism"

Electric Motor and Dynamo the Hall effect

Contents

1. Magnetic (Lorentz) force



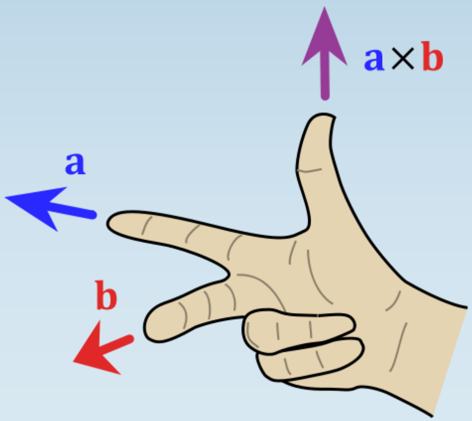
$$F_L = q.\, \boldsymbol{v} \times \boldsymbol{B}$$

q = charge
$\boldsymbol{v}$ = velocity
$\boldsymbol{B}$ = magnetic field ("induction")

To find $\boldsymbol{F}_L$:
Rotate **clockwise** from $\boldsymbol{v}$ to $\boldsymbol{B}$ in the ($\boldsymbol{v}$-$\boldsymbol{B}$) plane….
then $\boldsymbol{F}_L$ follows the direction of the ± "cork screw"
(± depending on the angle θ)

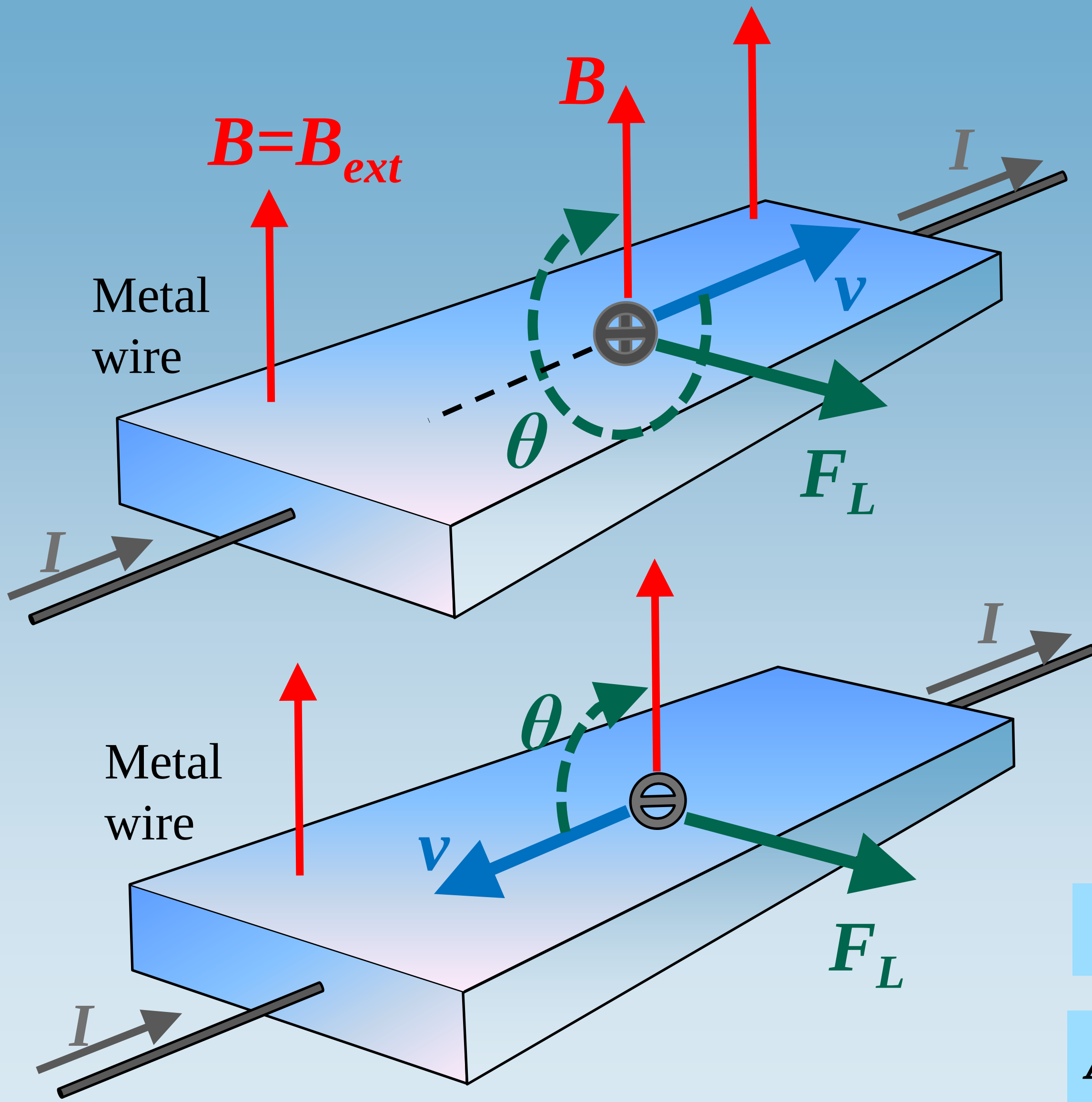
$$F_L = q\, v\, B\, .\sin\theta$$

$0 \le \theta \le 180^0$: $\sin\theta \ge 0$: + cork screw
$180 \le \theta \le 360^0$: $\sin\theta \le 0$: - cork screw



"Right hand rule": rotate from ***a*** to ***b*** over smallest angle: ***a*** x ***b*** follows "cork screw" direction

1. Lorentz force



$F_L = q.\, \boldsymbol{v} \times \boldsymbol{B}$

⊖ = electron has negative charge. q = -1.6x10^{-19} C < 0!

F_L points for + and – charges in same direction.

QUESTION:
F_L "works" on moving charges only ($v \neq 0$)…..

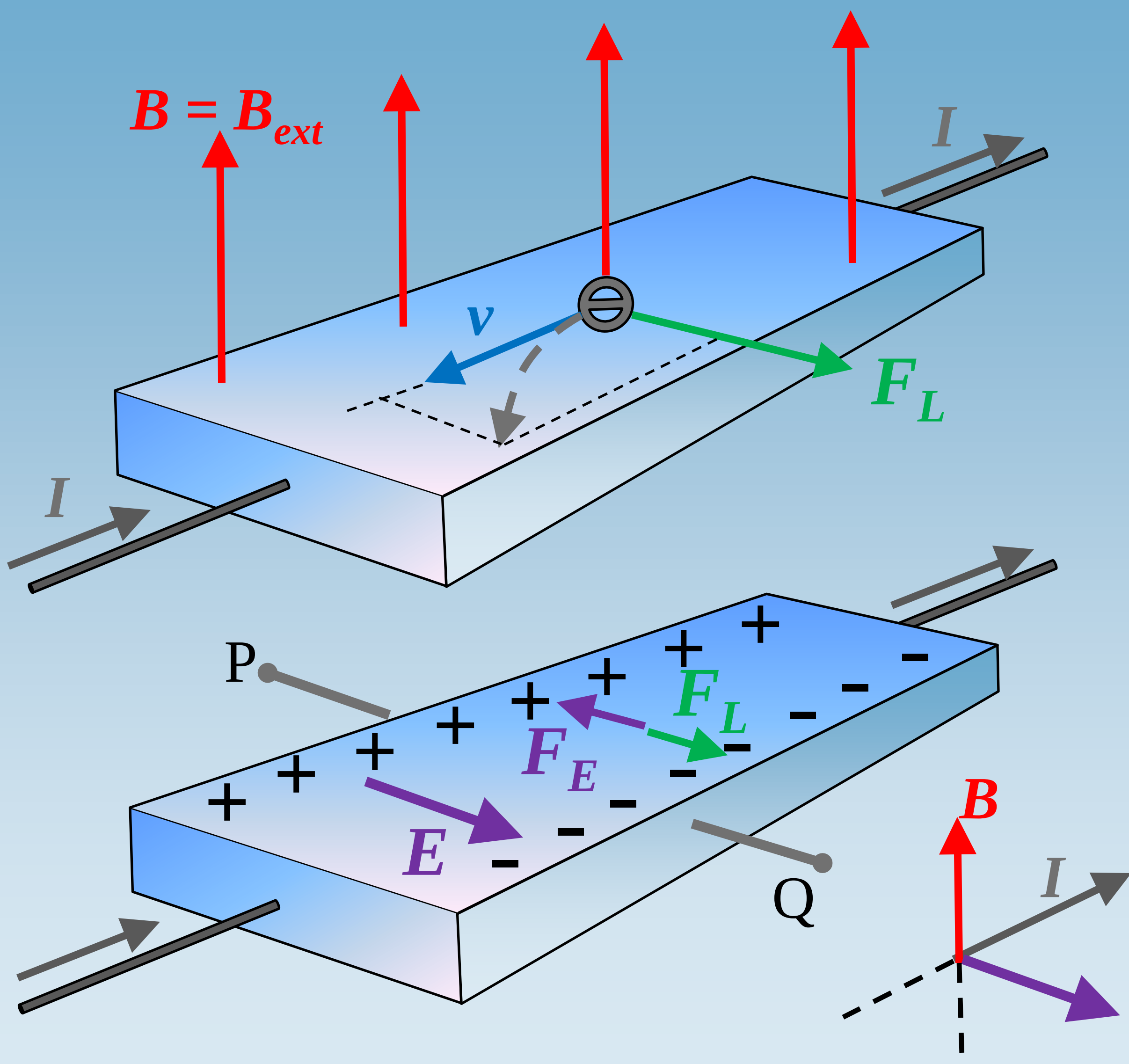
..but metal ions are at rest.

Why does the wire move?

Answer: the Hall effect.

2. Hall effect

Lorentz force: $\boldsymbol{F}_L = q.\boldsymbol{v} \times \boldsymbol{B}$



Electrons will deflect.

Charge build-up.

Field $\boldsymbol{E}$ build-up …

…until electrons feel

$\boldsymbol{F}_E = \boldsymbol{F}_L$

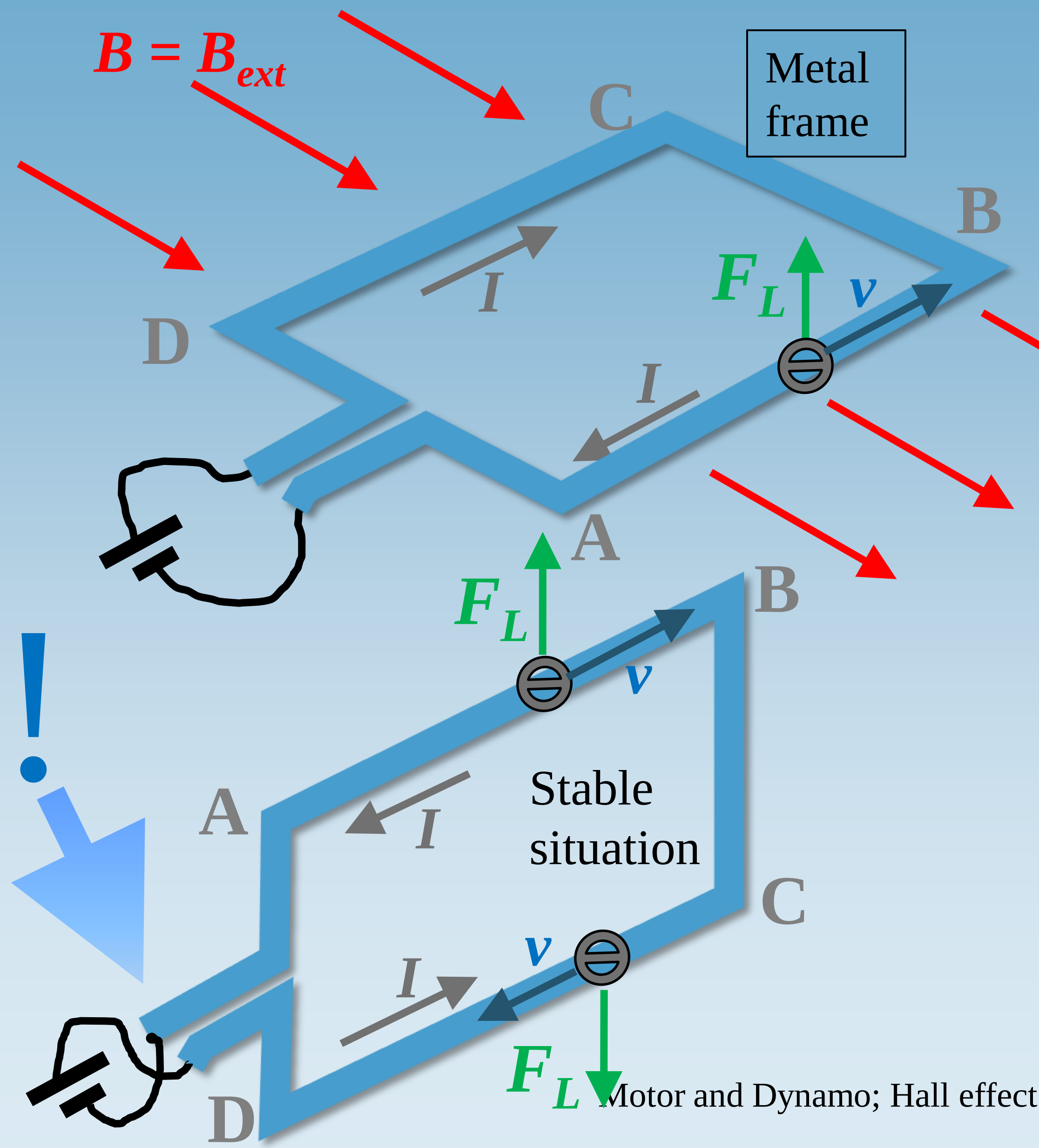
Contacts P and Q.

Metal ions feel $\boldsymbol{E}$ and force $\boldsymbol{F}_E$ (= $\boldsymbol{F}_L$), directed to Q…..

…. and so the wire will move.

$\boldsymbol{F}_L$ seems to act directly on the wire.

3. Electric motor



Lorentz force: $\boldsymbol{F}_L = q.\boldsymbol{v} \times \boldsymbol{B}$

⊖ = electron
q = -1.6x10^{-19} C < 0!

From Hall effect:
Metal ions feel electric force, thus along the $\boldsymbol{F}_L$ working on the electrons.

$\boldsymbol{F}_L$ can be considered as working on the current ***I*** and then acting on the wire.

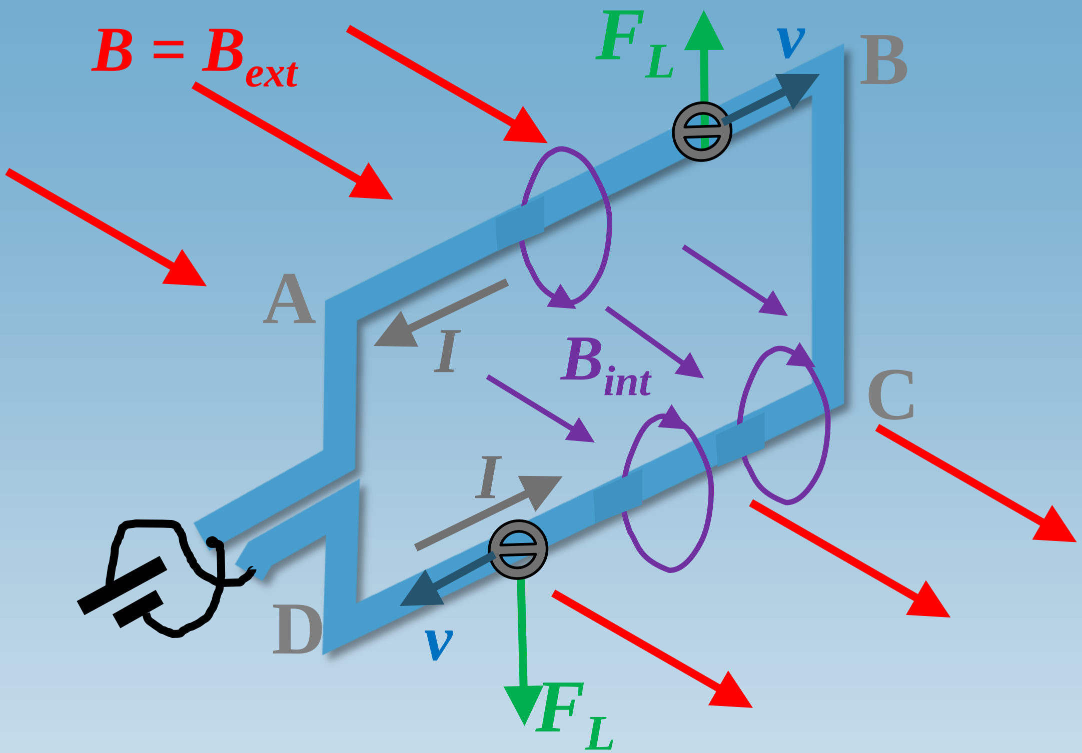
Frame starts rotating…..

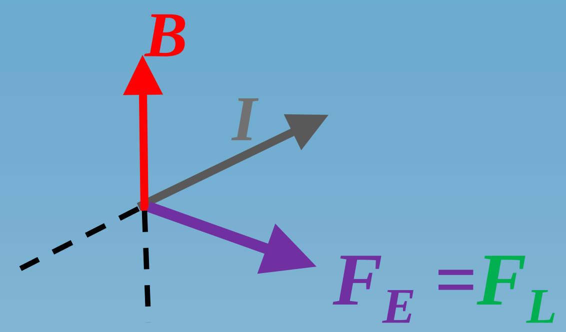
… until AB above CD

Frame tries to enclose as much of the fitting ***B***-field,

by maximizing its area in the fitting position.

3. Electric motor





F_L can be considered as working on the current ***I*** and then acting on the wire.

Frame tries to enclose as much of the fitting ***B***-field,

by maximizing its area in the fitting position,

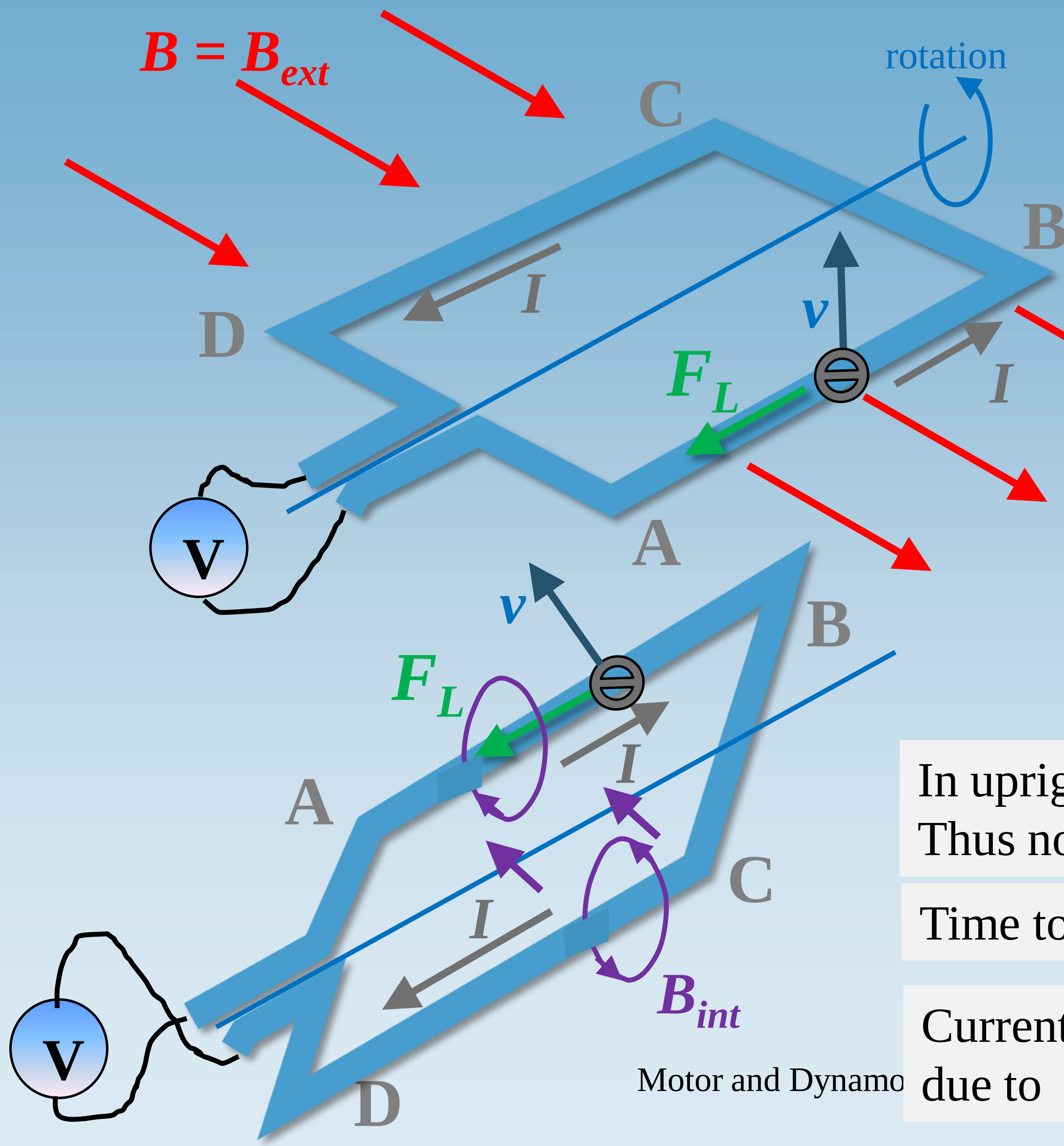
and by producing its own internal field ***B_{int}*** along the external field ***B_{ext}*** ,

since for the current ***I*** the "cork screw rule" holds.

NOW it is time to reverse the contacts!
Then frame will rotate further, over 180^0 ….. etc. etc.

4. Dynamo

Lorentz force: $\boldsymbol{F}_L = q.\boldsymbol{v} \times \boldsymbol{B}$



Now external rotation.

⊖ = electron
q = -1.6x10^{-19} C < 0!

Electrons get velocity $\boldsymbol{v}$ and will feel $\boldsymbol{F}_L$.

This produces current $\boldsymbol{I}$ and $\boldsymbol{B}_{int}$.

Direction of $\boldsymbol{B}_{int}$:
counteracting $\boldsymbol{B}_{ext}$.
(**"Lenz' Law"**)

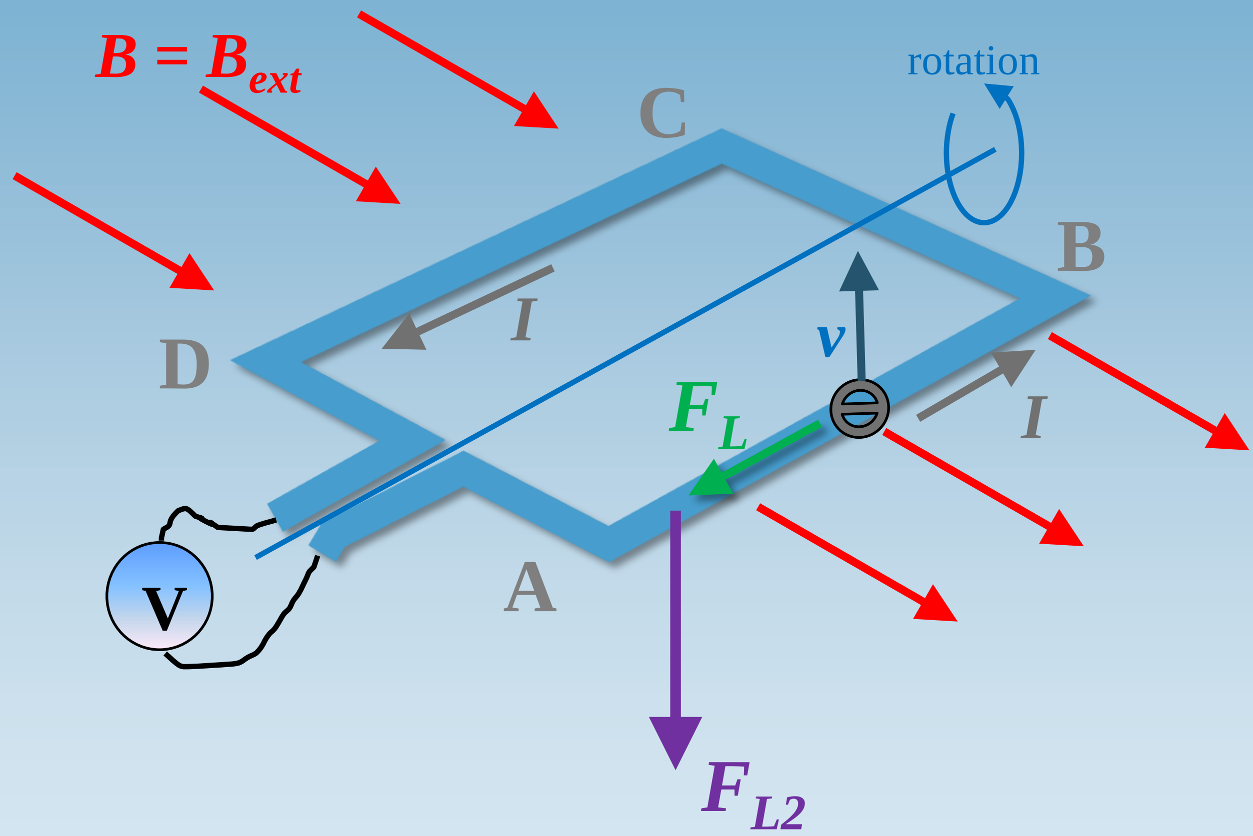
In upright situation: $\boldsymbol{v} \,//\, \boldsymbol{B}_{ext}$,
Thus no $\boldsymbol{F}_L$ and $\boldsymbol{I}$ there.

Time to interchange the contacts!

Current $\boldsymbol{I}$ gets sine shape in time due to $\sin\theta$, and θ varies with time .

4. Dynamo

Lorentz force: $\boldsymbol{F}_L = q.\boldsymbol{v} \times \boldsymbol{B}$



$\boldsymbol{F}_L$ works on electrons and produces current ***I*.**

Secondary effect: current ***I*** with $\boldsymbol{B}_{ext}$ will produce extra $\boldsymbol{F}_{L2}$, working on the wire.

This extra $\boldsymbol{F}_{L2}$ will counteract the rotation!

You have to deliver **mechanical energy** to get the dynamo rotating!

NB. This secondary effect is also present in the electric motor and causes energy losses.

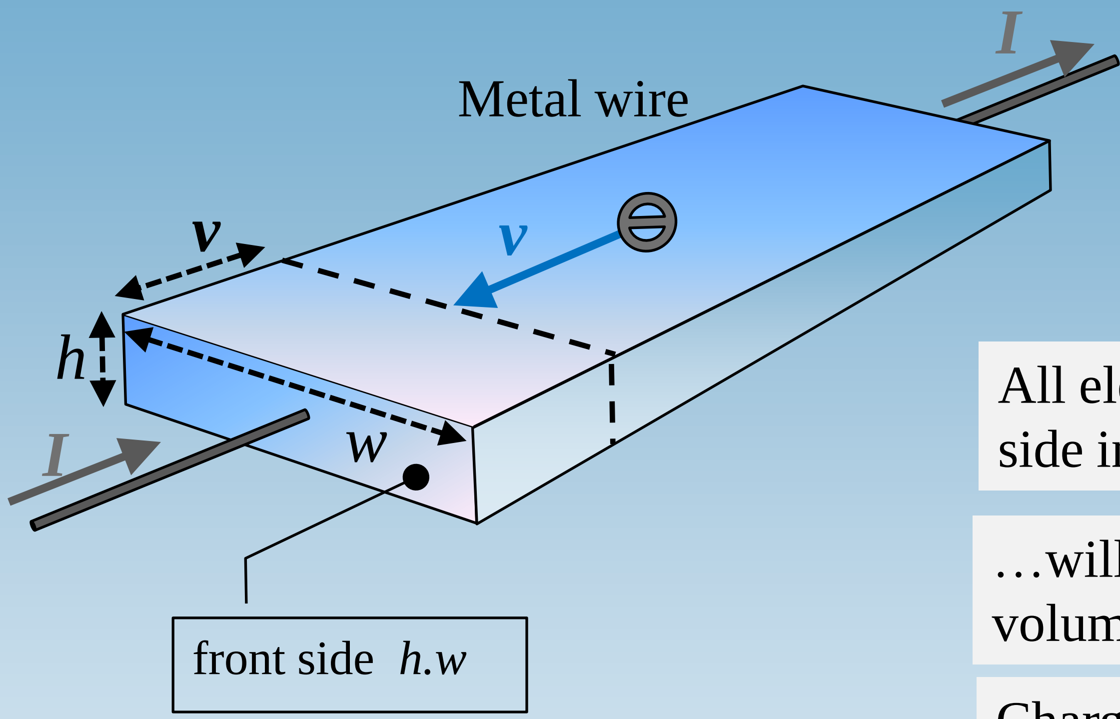
5. Conclusions

1. **Hall effect:**
   - potential difference due to electric balancing force.

2. **Electric motor:**
   - tries to rotate so as to align its internal field with the external field
   - tries to maximize the fitting flux

3. **Dynamo:**
   - produces counteracting current and field

6. Hall effect revisited



Suppose we have
n electrons per m^3 ,
each with velocity *v* (m/s)

All electrons that will pass the front side in the **next** second from **now**….

…will **now** be within block (*hwv)* with volume *hwv* [m^3].

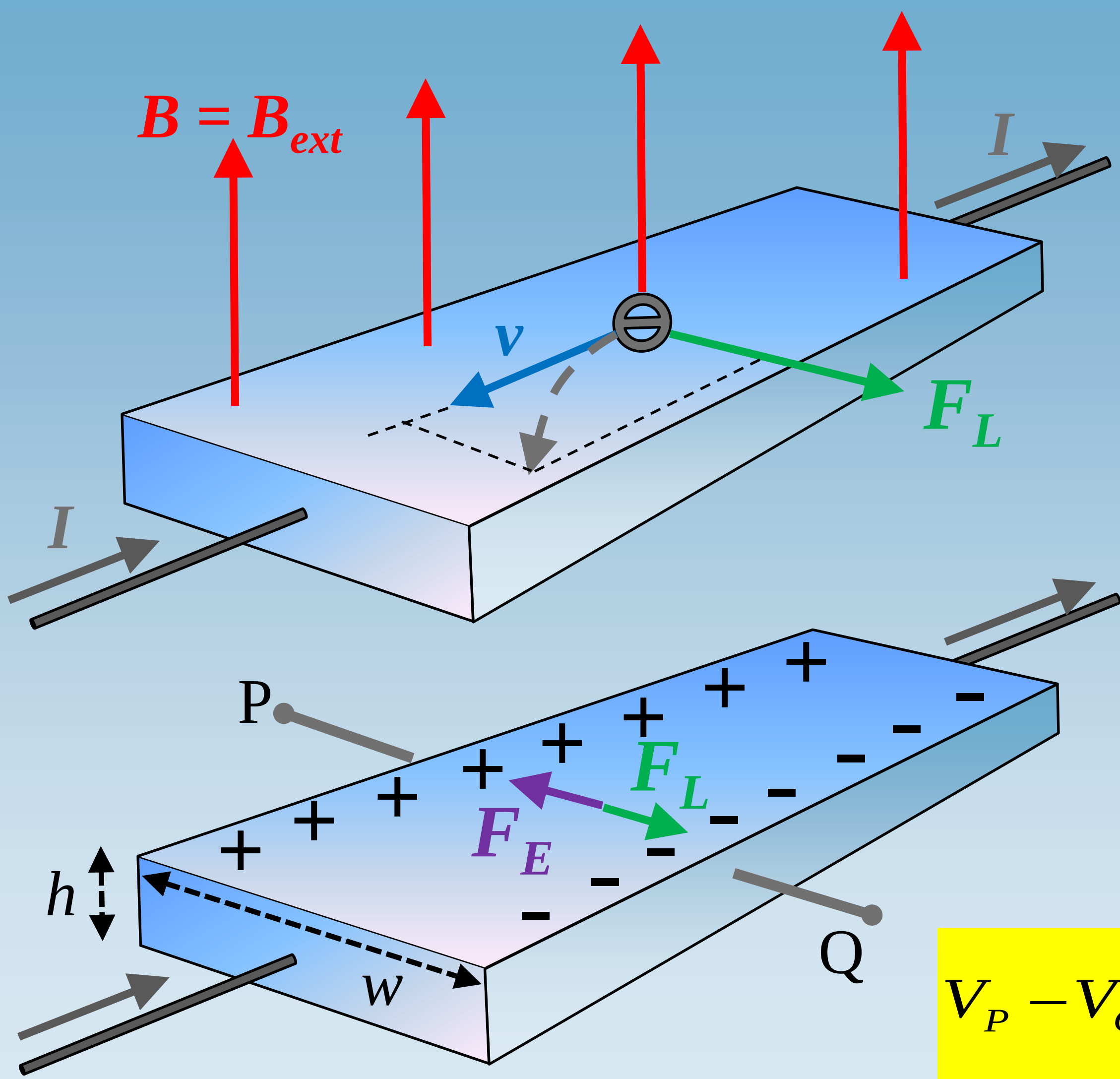
Charge passing front side in this second = *n. q. hwv* [C].

Current $I = -nq.hwv$ [C/s = A].

I is proportional to n and v .

6.Hall effect revisited

Lorentz force : $\boldsymbol{F}_L = q.\boldsymbol{v} \times \boldsymbol{B}$



Electrons will deflect.

Charge build-up.

Eventually: $\boldsymbol{F}_E = \boldsymbol{F}_L$

$$q.\,E = q\,.v\,.B$$

Potential difference:
$V_P - V_Q = E.w = v.B.w$

From previous slide:
$I = -nq.h.\,vw$

$$vw = \frac{-I}{nqh}.$$

$$V_P - V_Q = \frac{-IB}{nqh}$$

$V_P - V_Q \sim B$:
Magnetometer

the end