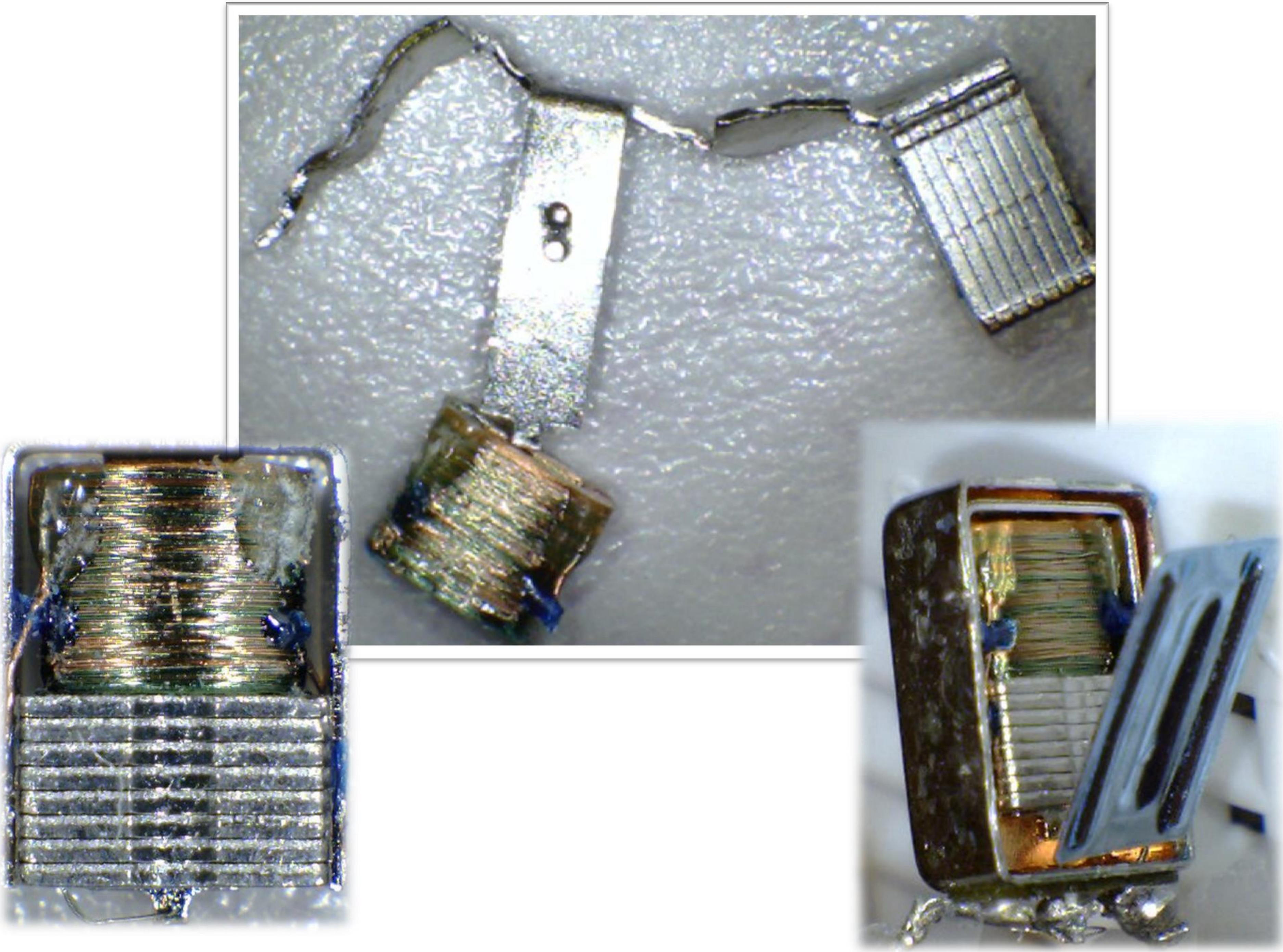
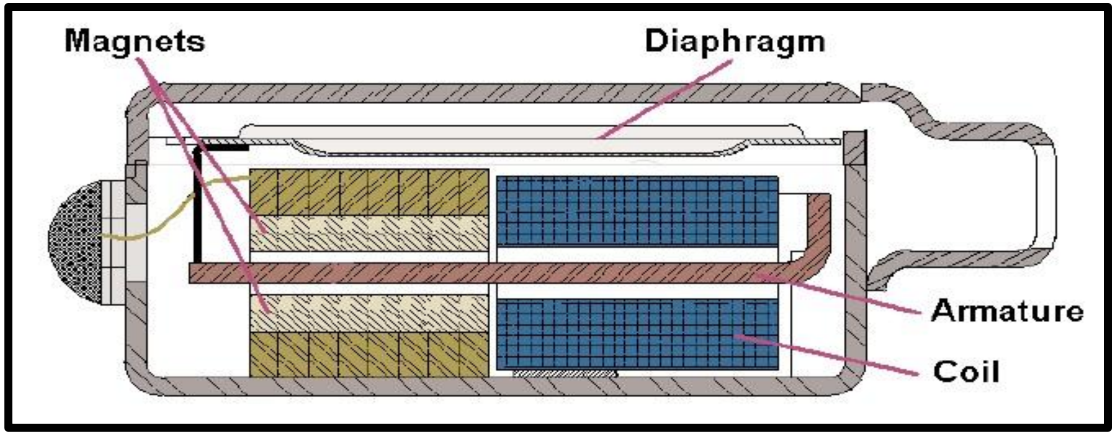
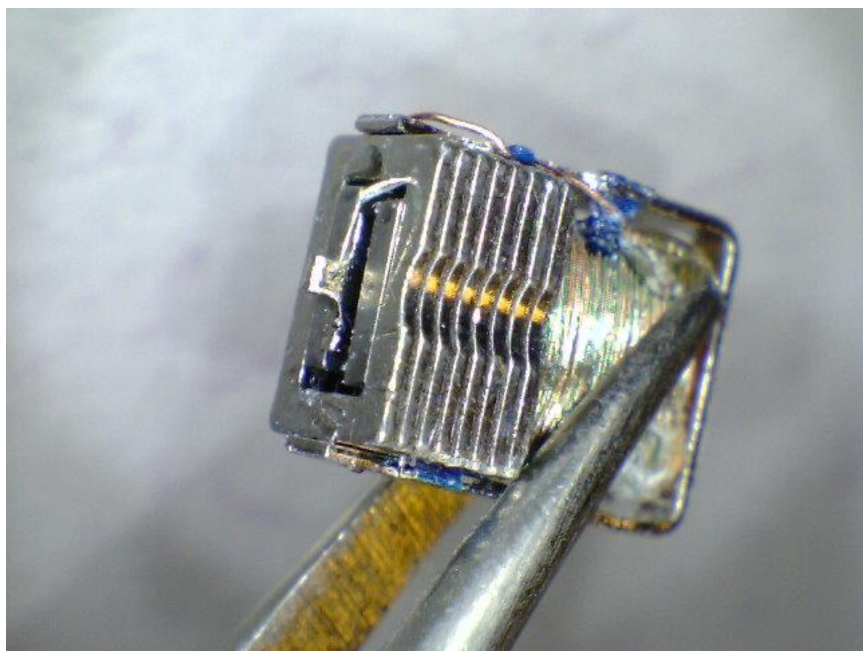
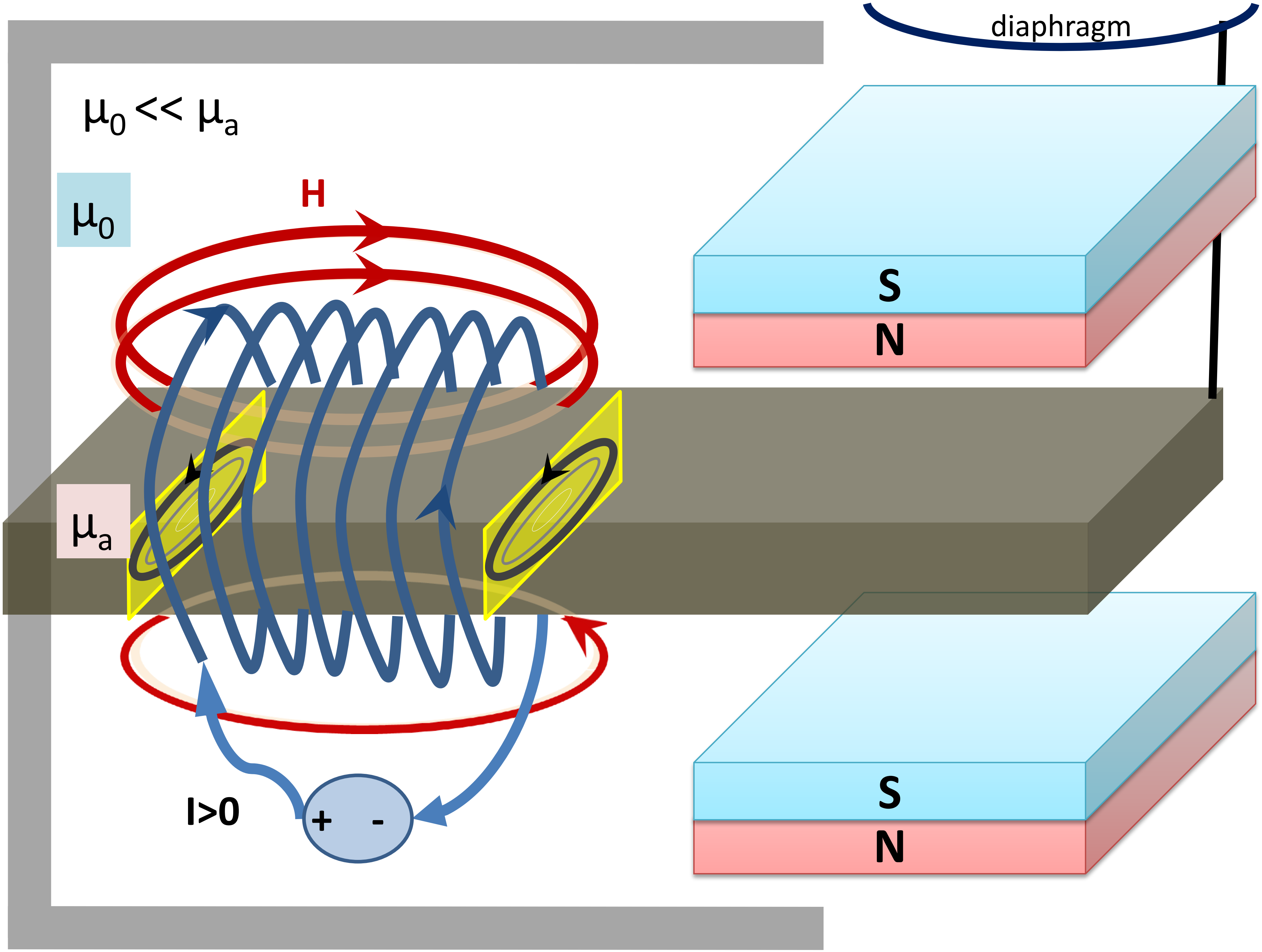


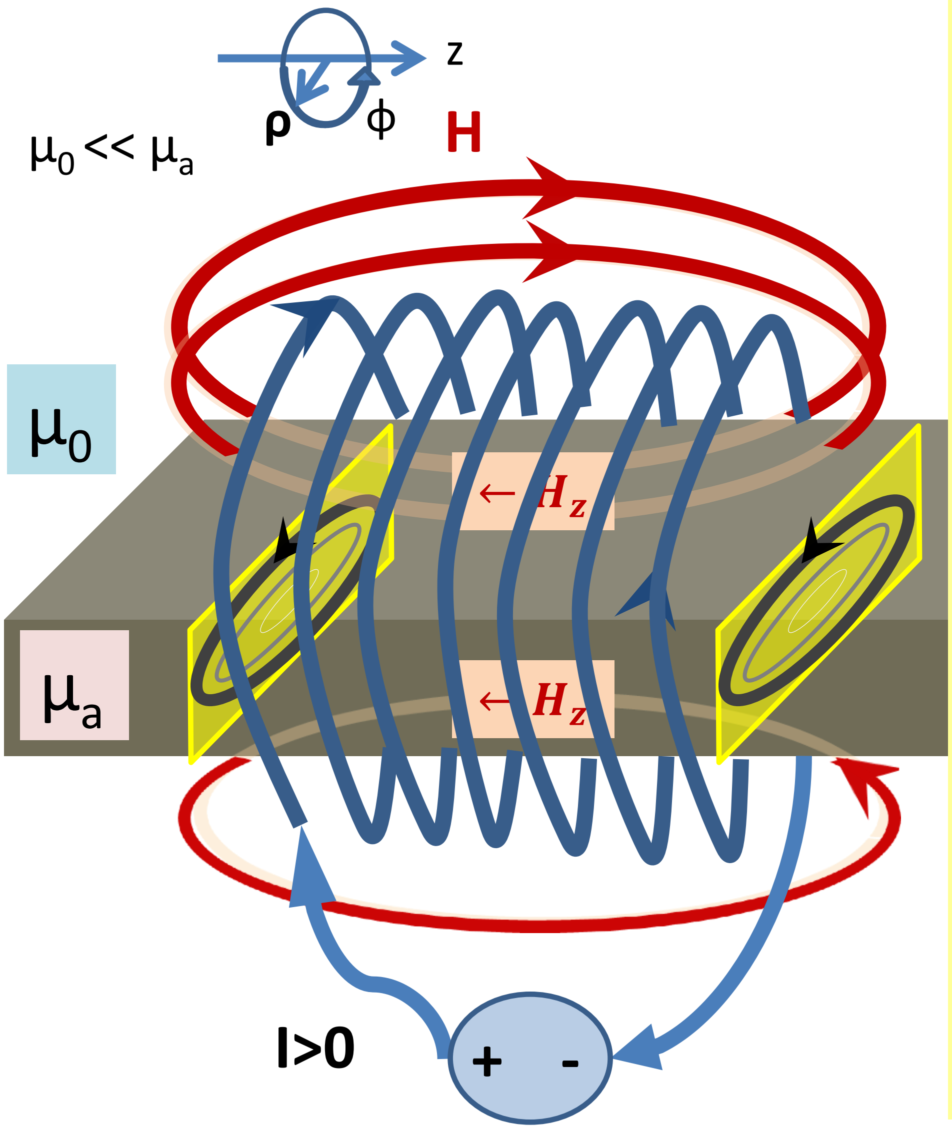


Cross section of Knowles ED receiver




diaphragm
μ0 << μa
μ0
H
μa
S
N
S
N
I>0
+
-

Eddy current



$\nabla \times \boldsymbol{H} = \boldsymbol{J_c} + \dot{\boldsymbol{D}} \approx \boldsymbol{J_c} = \boldsymbol{\sigma E}$ (1. Ampere's law for conducting current)

$\nabla \times \boldsymbol{E} = -\dot{\boldsymbol{B}}$ (2. Faraday's law)

$\int \boldsymbol{H} \cdot \boldsymbol{dl} = \int \nabla \times \boldsymbol{H} \cdot \boldsymbol{dA} = \int \boldsymbol{J_c} \cdot \boldsymbol{dA} = \boldsymbol{nI}$

$\boldsymbol{2H_z} = \boldsymbol{nI}$ (armature side)

$\boldsymbol{B_z} = \frac{\mu_a nI}{2}$ (of the armature)

Use vector identity,

$\nabla \times (\nabla \times \boldsymbol{H}) = \nabla \left(\underbrace{\nabla \cdot \boldsymbol{H}}_{0}\right) - \nabla^2 \boldsymbol{H}$

$\nabla \times (\nabla \times \boldsymbol{H_z}) = -\nabla^2 \boldsymbol{H_z}$

From 1, $\nabla \times (\boldsymbol{\sigma E}) = -\nabla^2 \boldsymbol{H_z}$

Where (2), $\boldsymbol{\sigma} \nabla \times \boldsymbol{E} = -\boldsymbol{\sigma} \dot{\boldsymbol{B}}_z$

$\nabla^2 \boldsymbol{H_z} = \boldsymbol{\sigma} \dot{\boldsymbol{B}}_z$

Therefore,

$\nabla^2 \boldsymbol{H_z} = \boldsymbol{\sigma \mu_a} \frac{\boldsymbol{dH_z}}{\boldsymbol{dt}}$

$(jk)^2 = \boldsymbol{\sigma \mu_a} j\omega$

$k = \pm\sqrt{\boldsymbol{\sigma \mu_a} \omega}\, e^{-\angle 45^\circ}$ (diffusion)

$\boldsymbol{2H_z}(r,t) = \boldsymbol{2H_0 e^{j\omega t - kr}} = \boldsymbol{nI}$

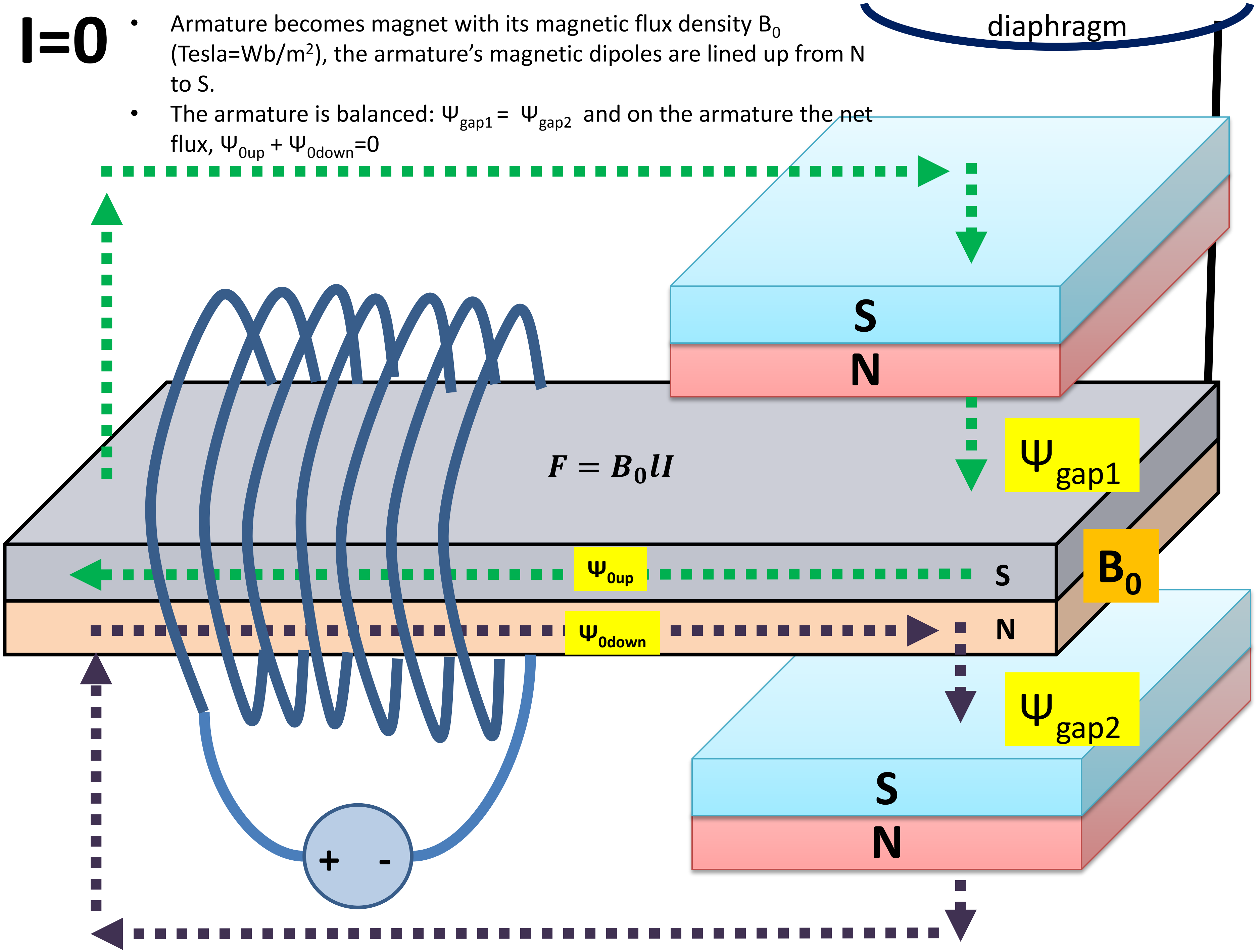
$emf = \int \boldsymbol{E_\phi} \cdot \boldsymbol{dl} = \int \nabla \times \boldsymbol{E_\phi} \cdot \boldsymbol{dA} = -\int \dot{\boldsymbol{B}}_z \cdot \boldsymbol{dA} = -\dot{\Psi}_a$

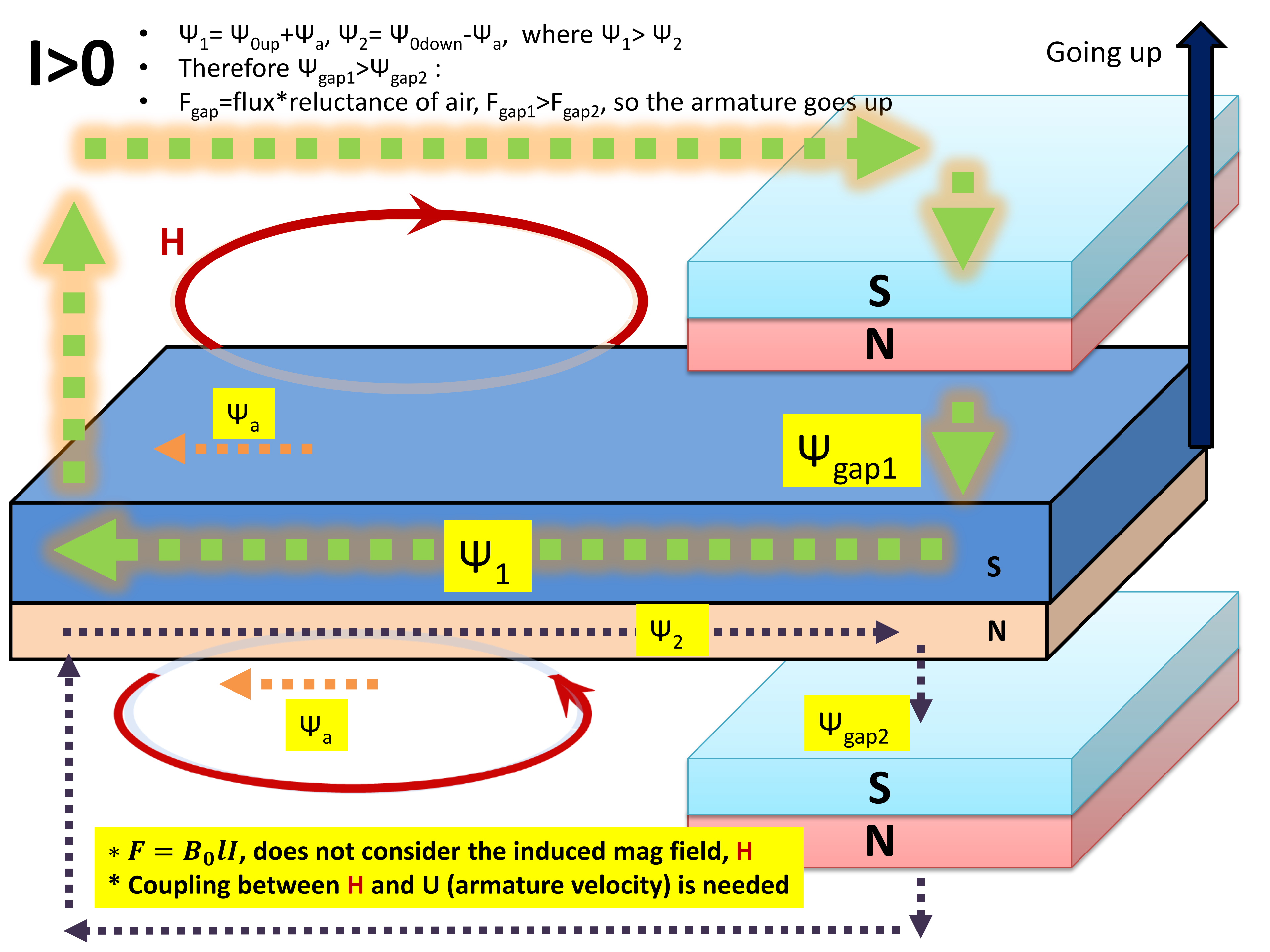
Where, $\boldsymbol{dA}$ is the cross sectional area of the armature core

Emf is Thevenin voltage.

I=0

- Armature becomes magnet with its magnetic flux density B_0 (Tesla=Wb/m^2), the armature's magnetic dipoles are lined up from N to S.
- The armature is balanced: $\Psi_{gap1} = \Psi_{gap2}$ and on the armature the net flux, $\Psi_{0up} + \Psi_{0down} = 0$





I>0
$\Psi_1 = \Psi_{0up} + \Psi_a$, $\Psi_2 = \Psi_{0down} - \Psi_a$, where $\Psi_1 > \Psi_2$
Therefore $\Psi_{gap1} > \Psi_{gap2}$:
F_{gap}=flux*reluctance of air, $F_{gap1} > F_{gap2}$, so the armature goes up
Going up
H
S
N
Ψ_a
Ψ_{gap1}
Ψ_1
S
Ψ_2
N
Ψ_a
Ψ_{gap2}
S
N
* $F = B_0 lI$, does not consider the induced mag field, H
* Coupling between H and U (armature velocity) is needed