Sensors of position, speed and vibration

AE3B38SME - Sensors and Measurement

Sensors of position

Classification

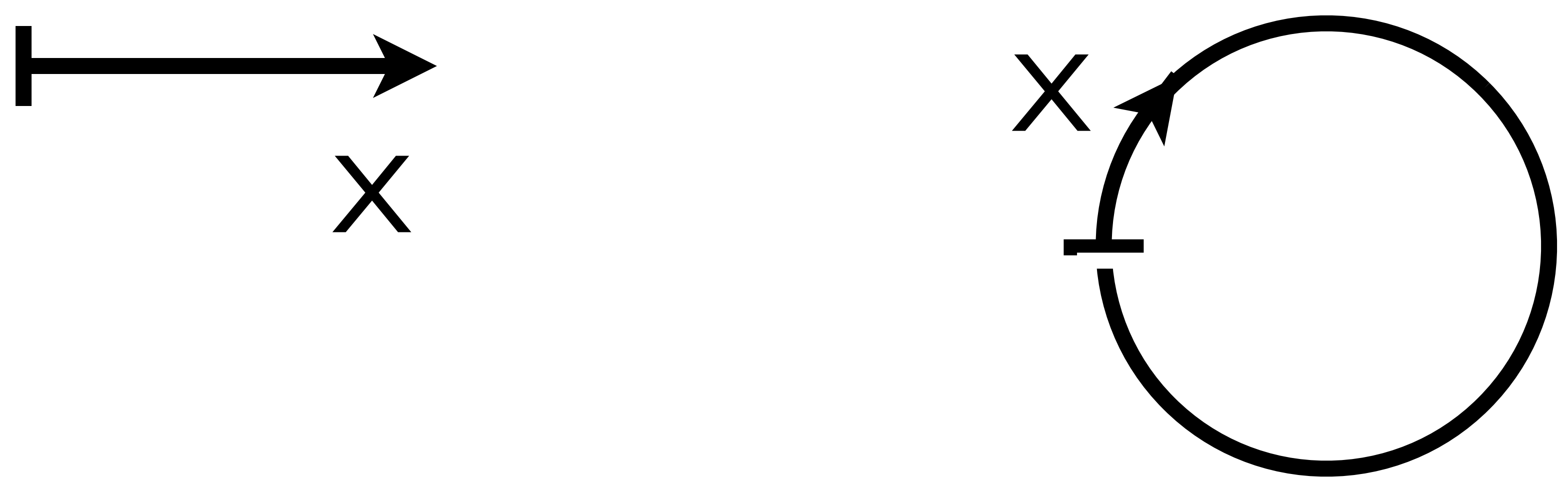
continuos	bistable
They measure the actual distance of the object	They detect if an object is closer than threashold

Sensors of position

Classification

linear

rotational

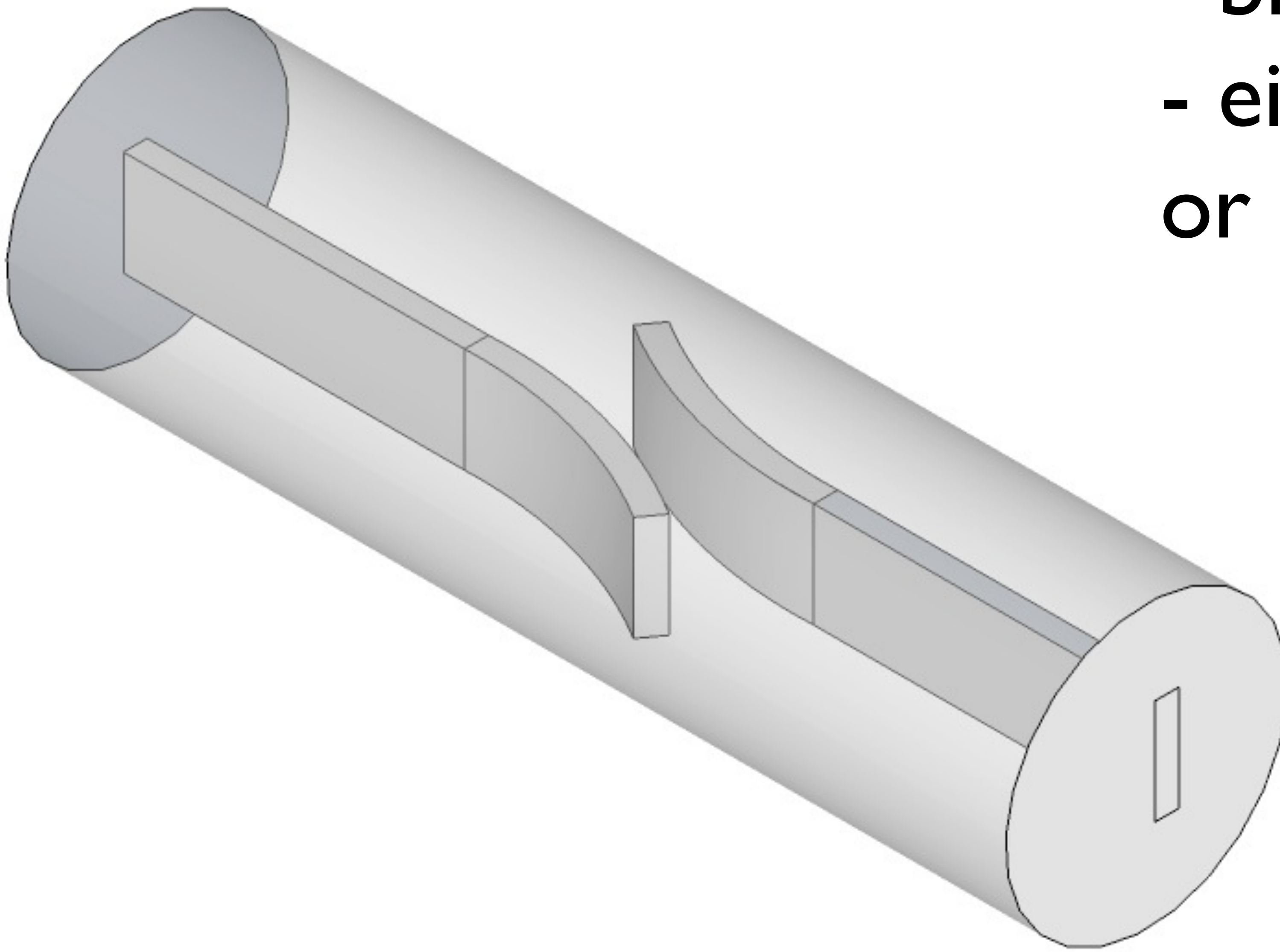


Sensors of position

Classification

Physical principle
- resistance
- capacity
- optic
- ultrasound

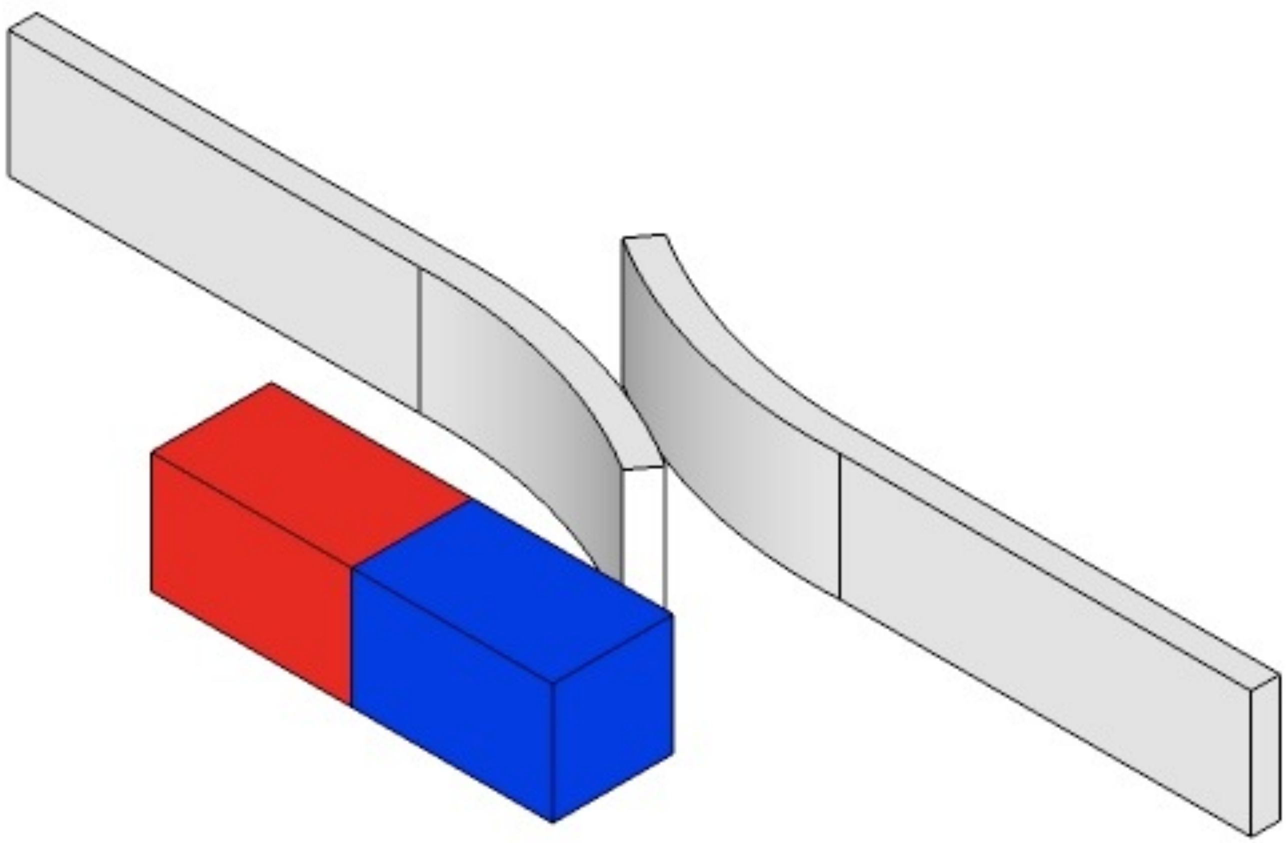
Reed contacts



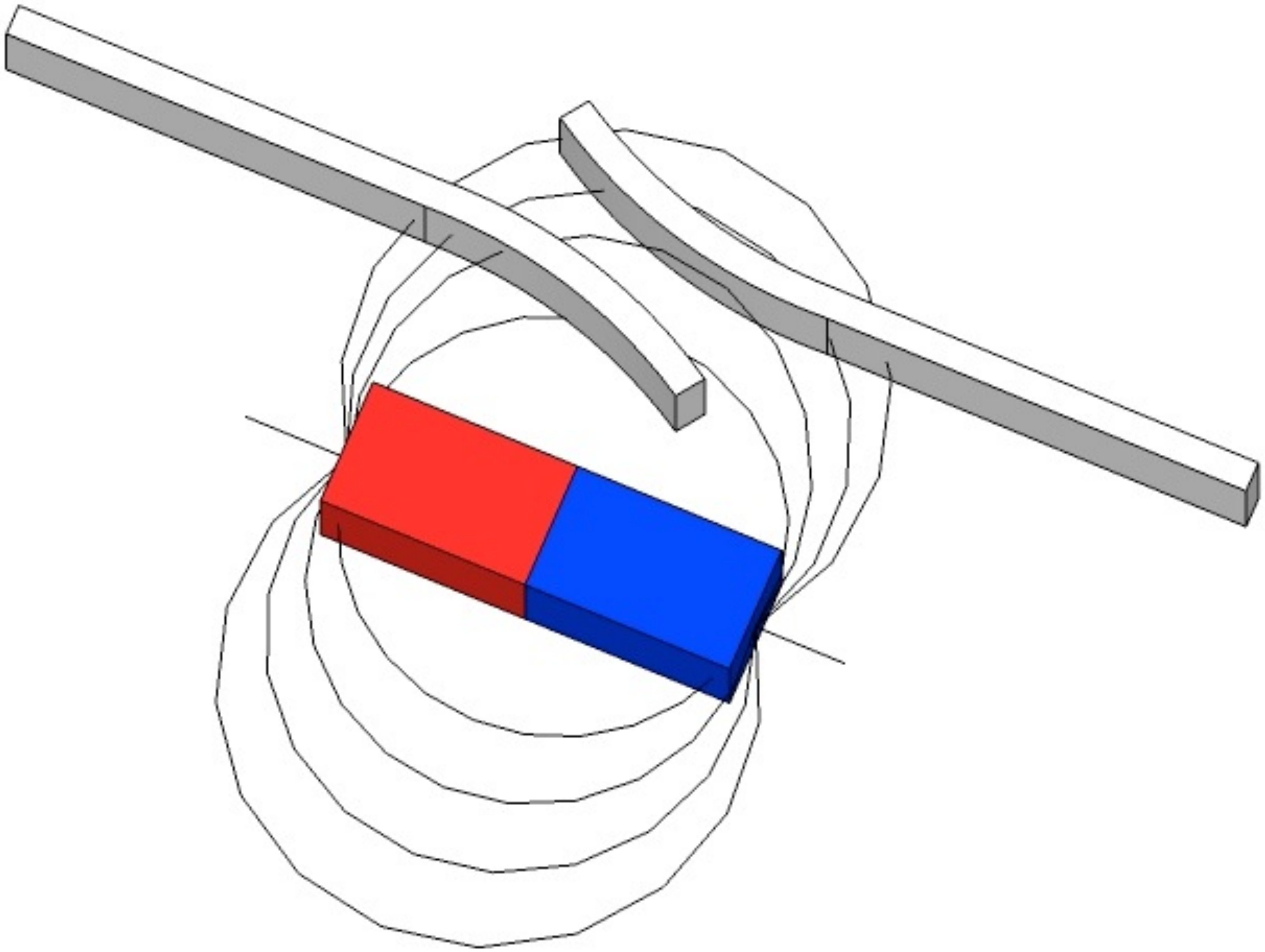
- bistable
- either normally close or normally open

symbol

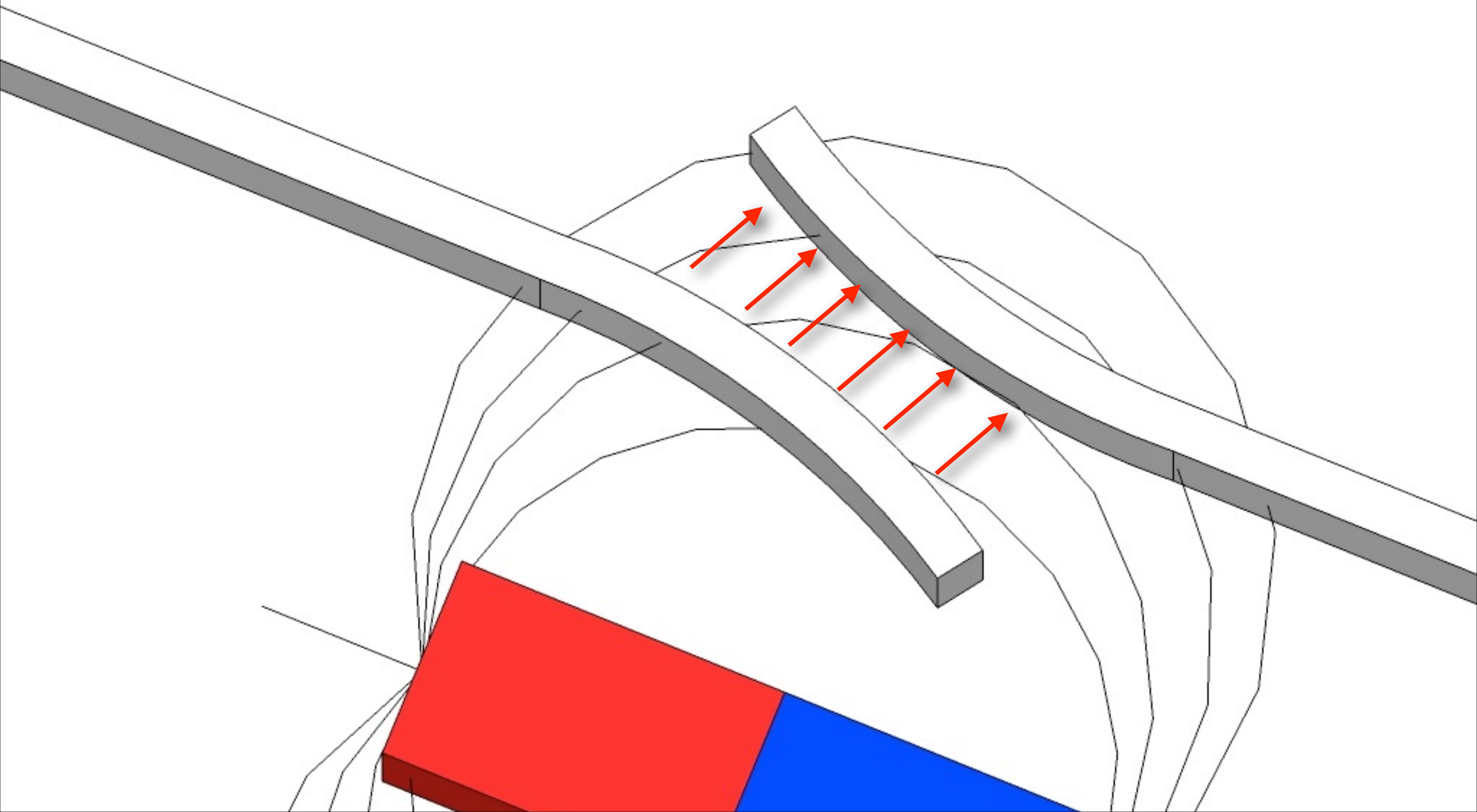
Reed contacts



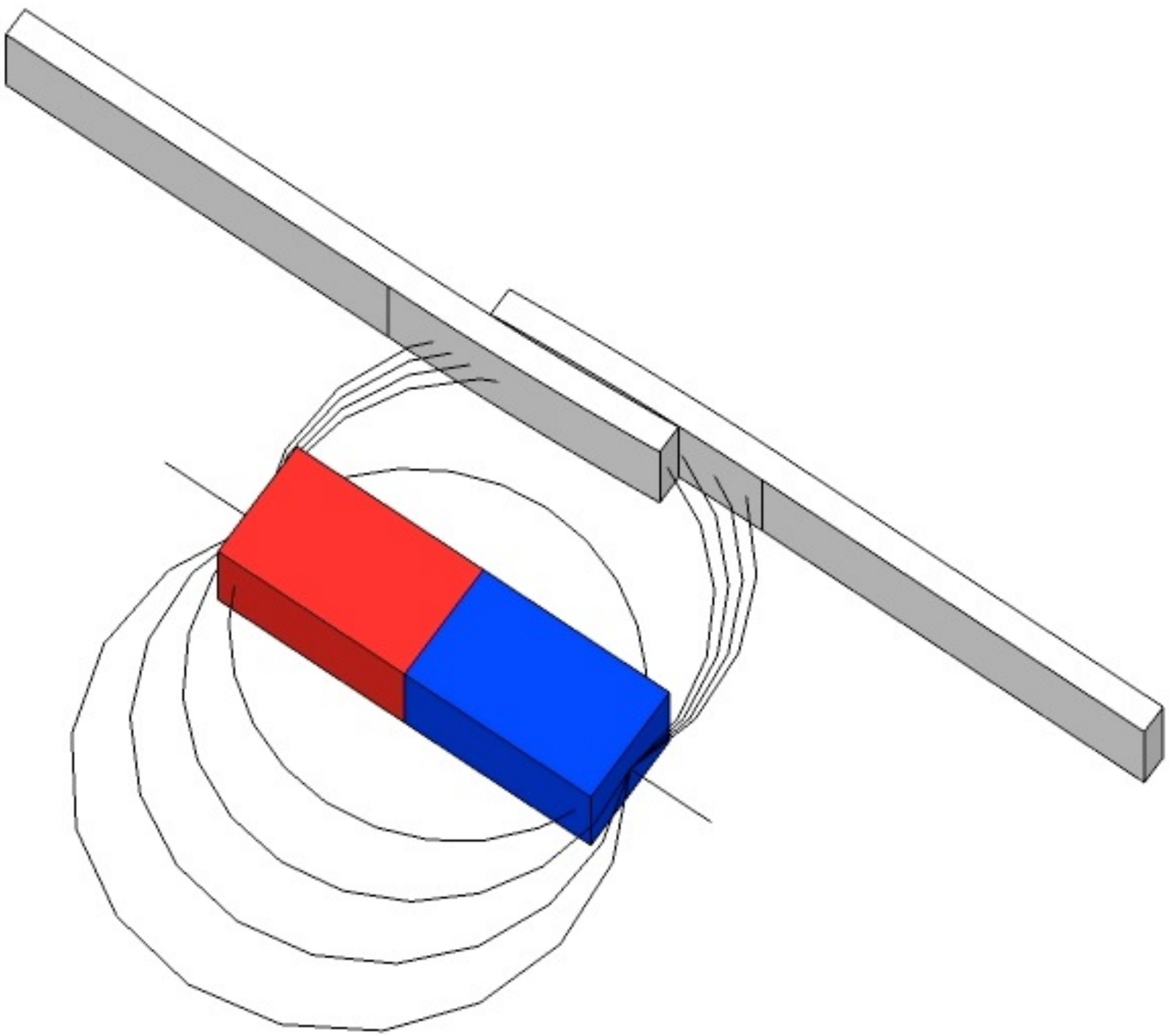
Reed contacts



Reed contacts



Reed contacts



Reed contacts
- parameters-

RI-01B Series Dry Reed Switch

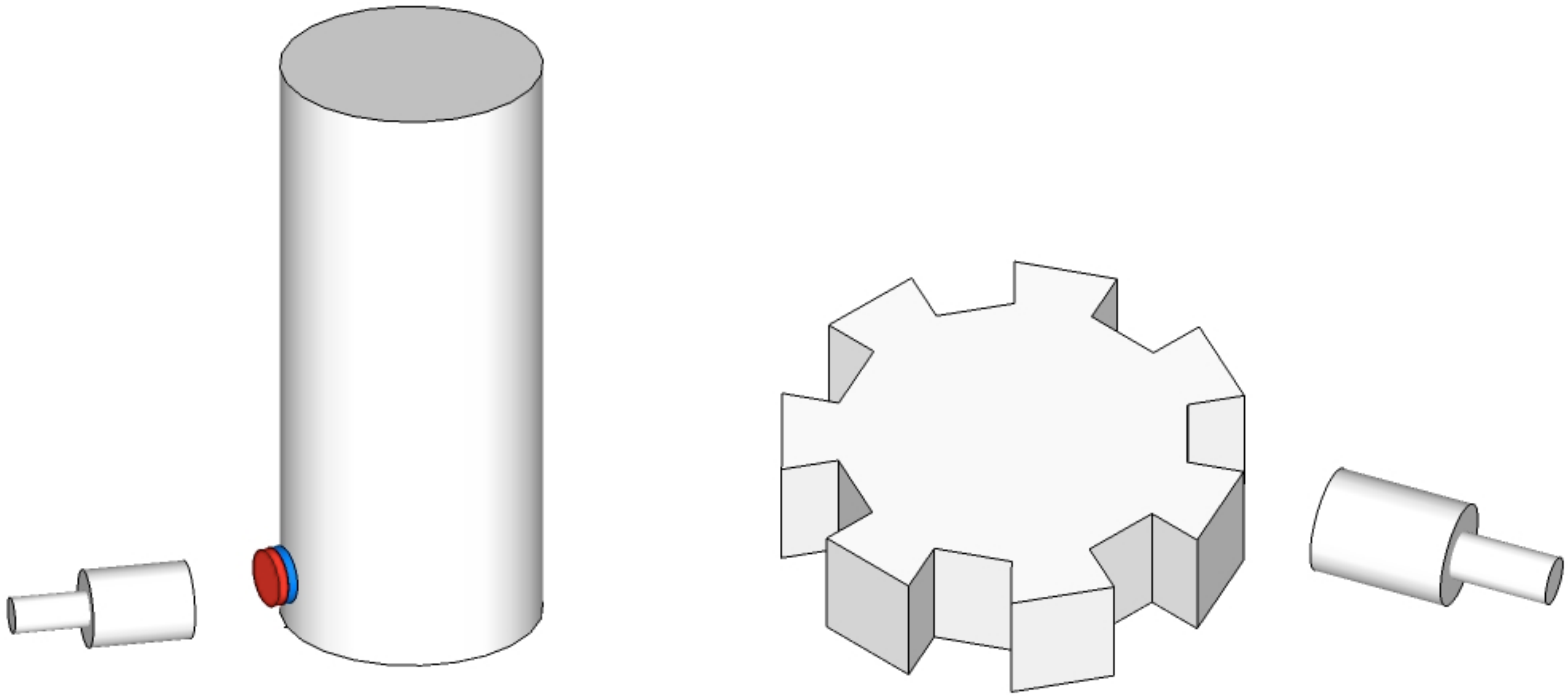
Technical Specifications

Parameters	Test Conditions	Units	RI-01BAAA	RI-01BAA	RI-01B
Operating Characteristics					
Operate Range		AT	6-16	14-23	18-32
Release Range		AT	3-15.5	4-21	5-27
Operate Time - including Bounce (typ.)		ms	0.1	0.25	0.25
Bounce Time (typ.)		ms	0.05	0.15	0.15
Release Time (max)		µs	70	30	30
Resonant Frequency (typ.)		Hz	5500	5500	5500
Electrical Characteristics					
Switched Power (max)		W	5	10	10
Switched Voltage DC (max)		V	160	200	200
Switched Voltage AC, RMS value (max)		V	110	140	140
Switched Current DC (max)		mA	250	500	500
[illegible]		mA	250	500	500

From COMUS Group - http://www.comus-group.com

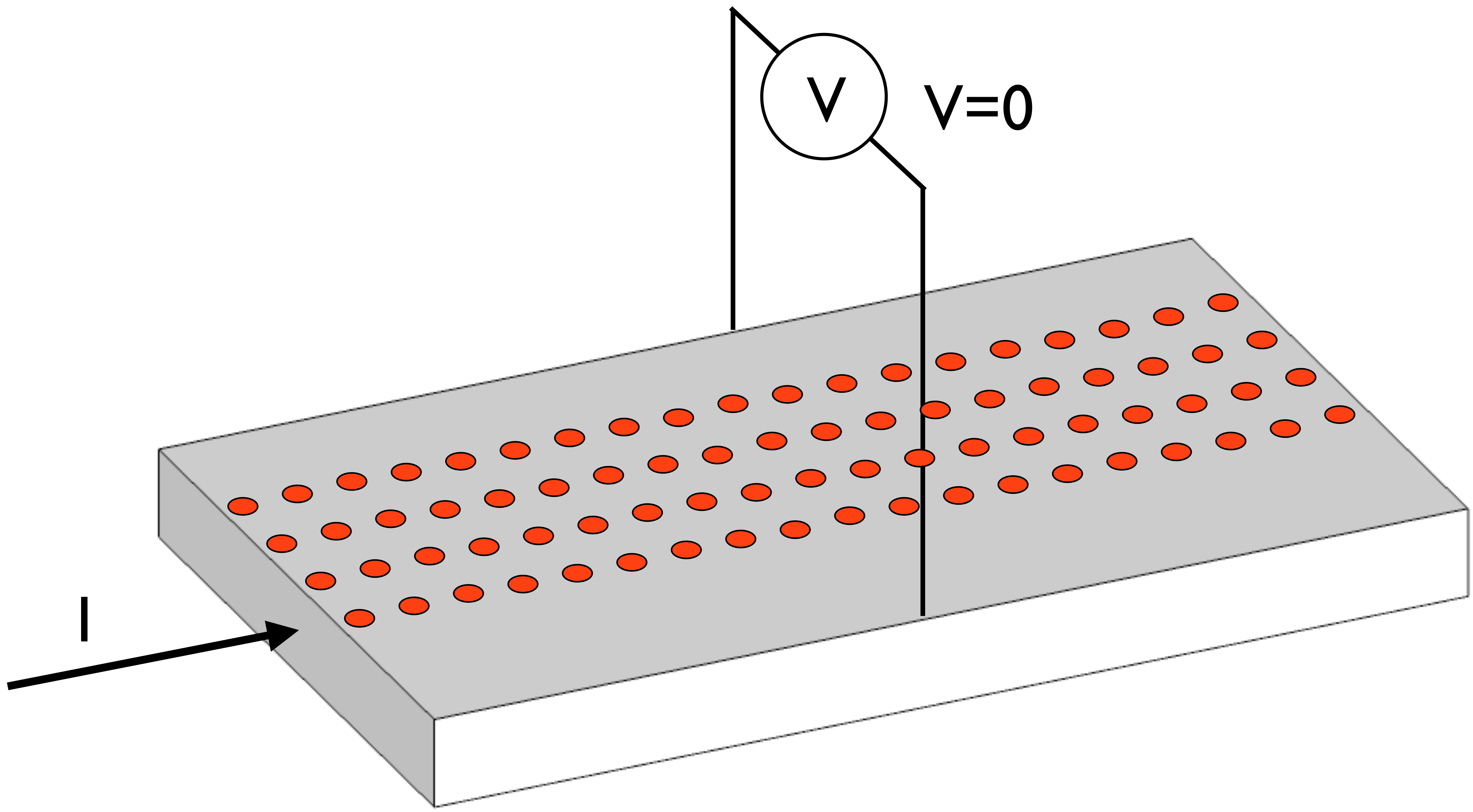
Magnetic sensors

They are used to measure the magnetic field generated by a magnet or a ferromagnetic component

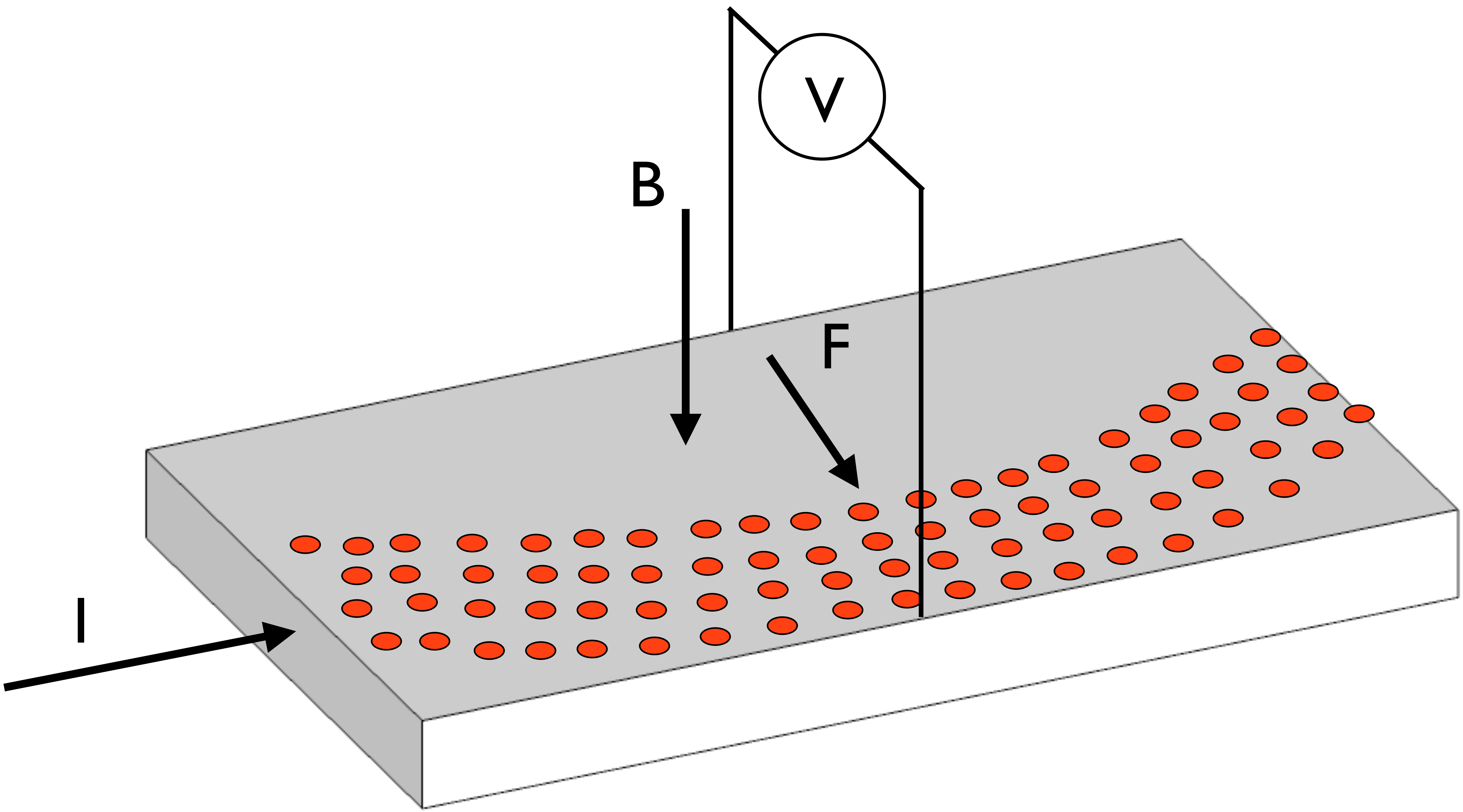


Hall effect
AMR
GMR

Hall effect sensor

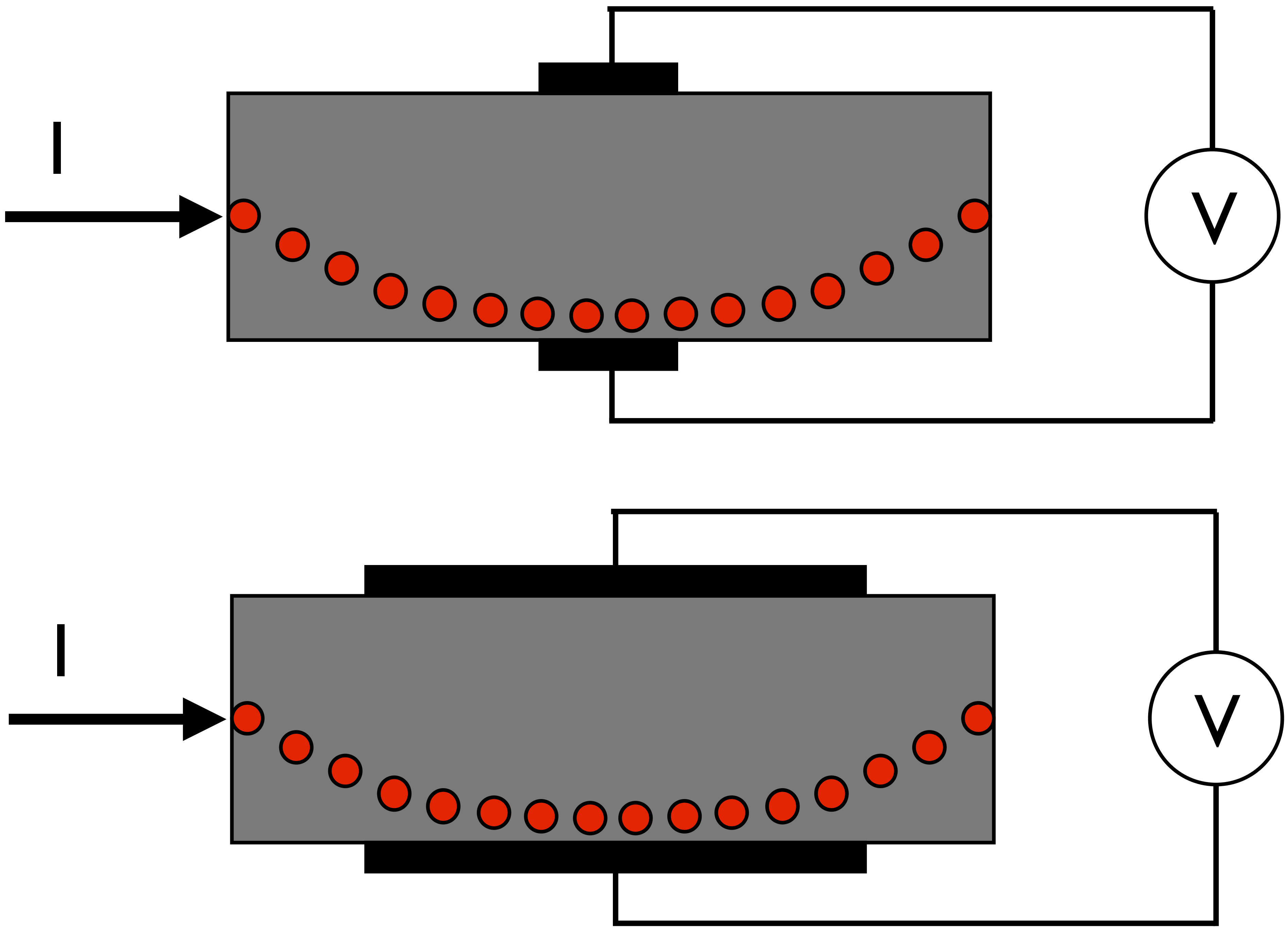


Hall effect sensor

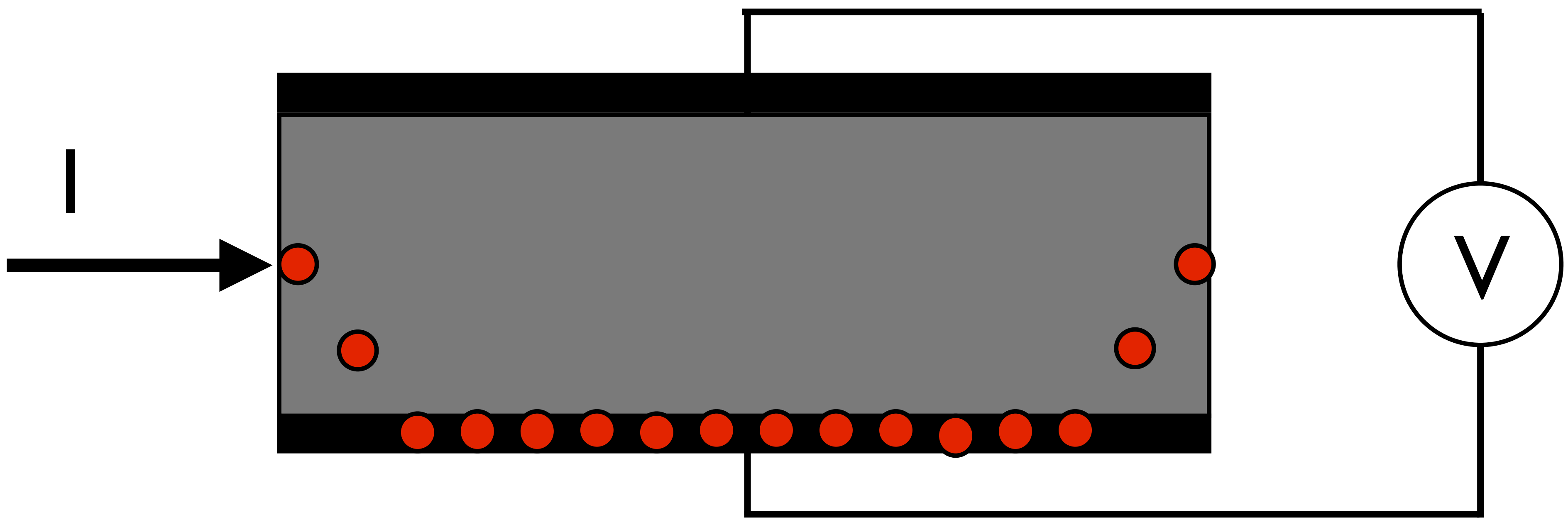


$$V = k \cdot F = k \cdot I \cdot B$$

Problem 1. How can I pick up the voltage?

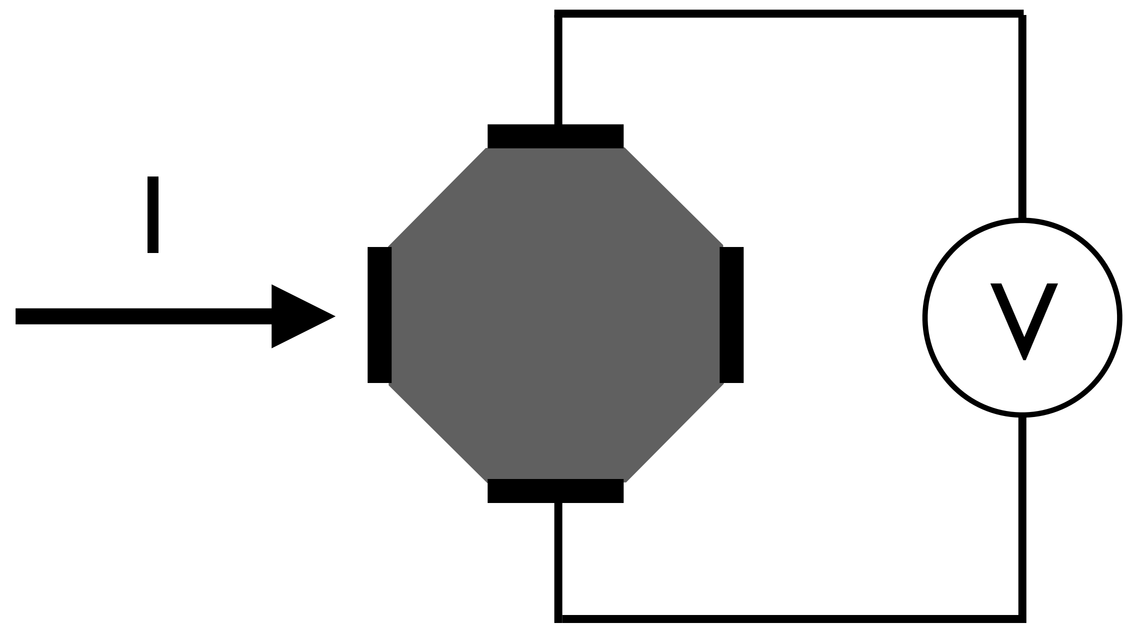


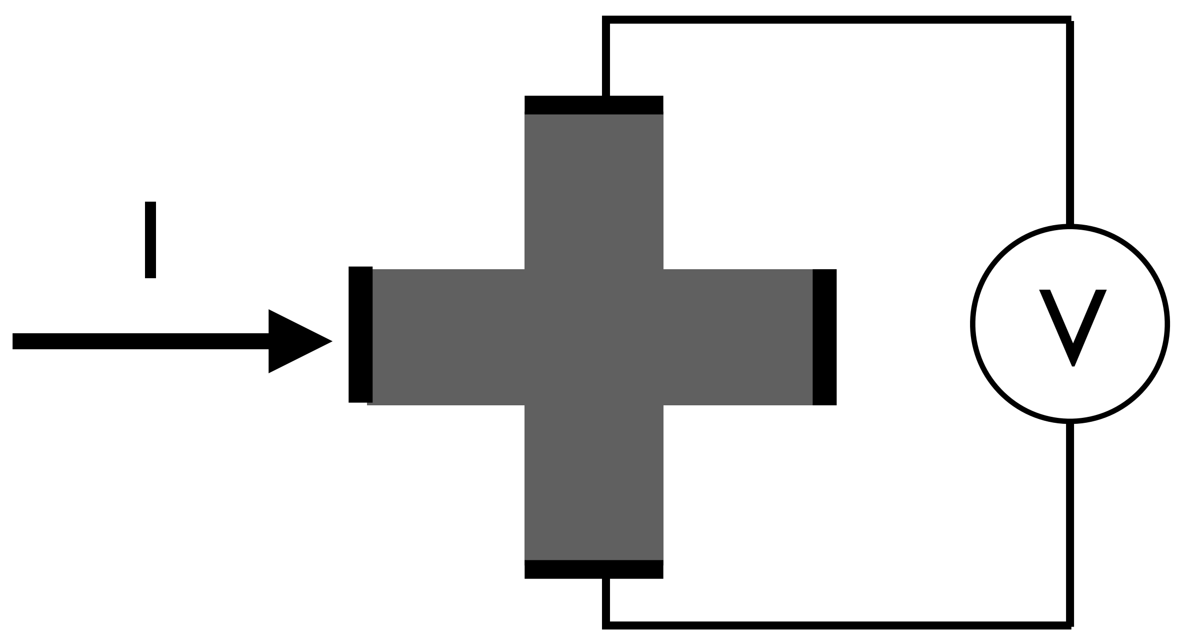
I would like to have the contacts as large as possible



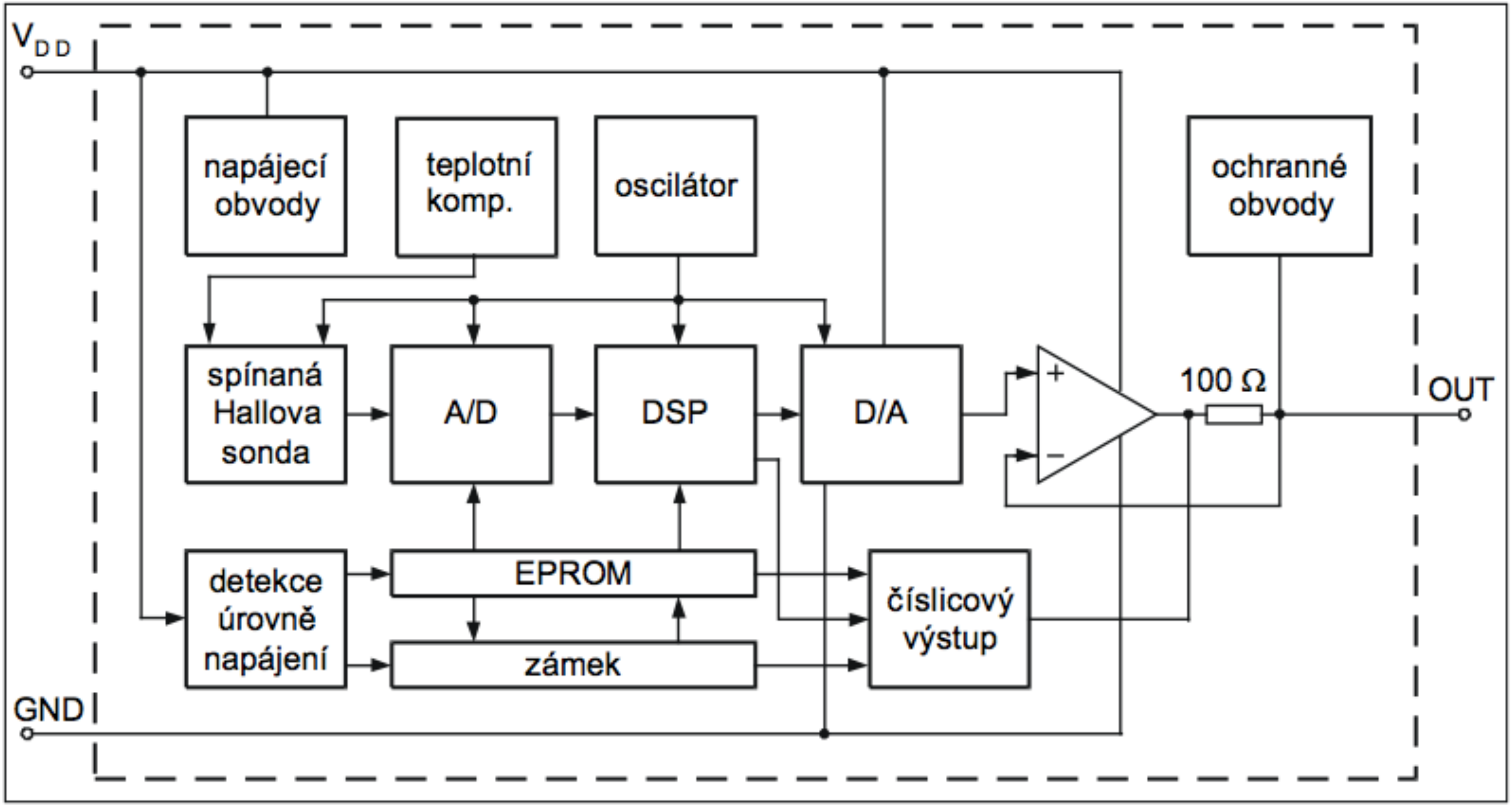
but if the contacts are too large
they short circuit the current

Several shapes provide a compromise

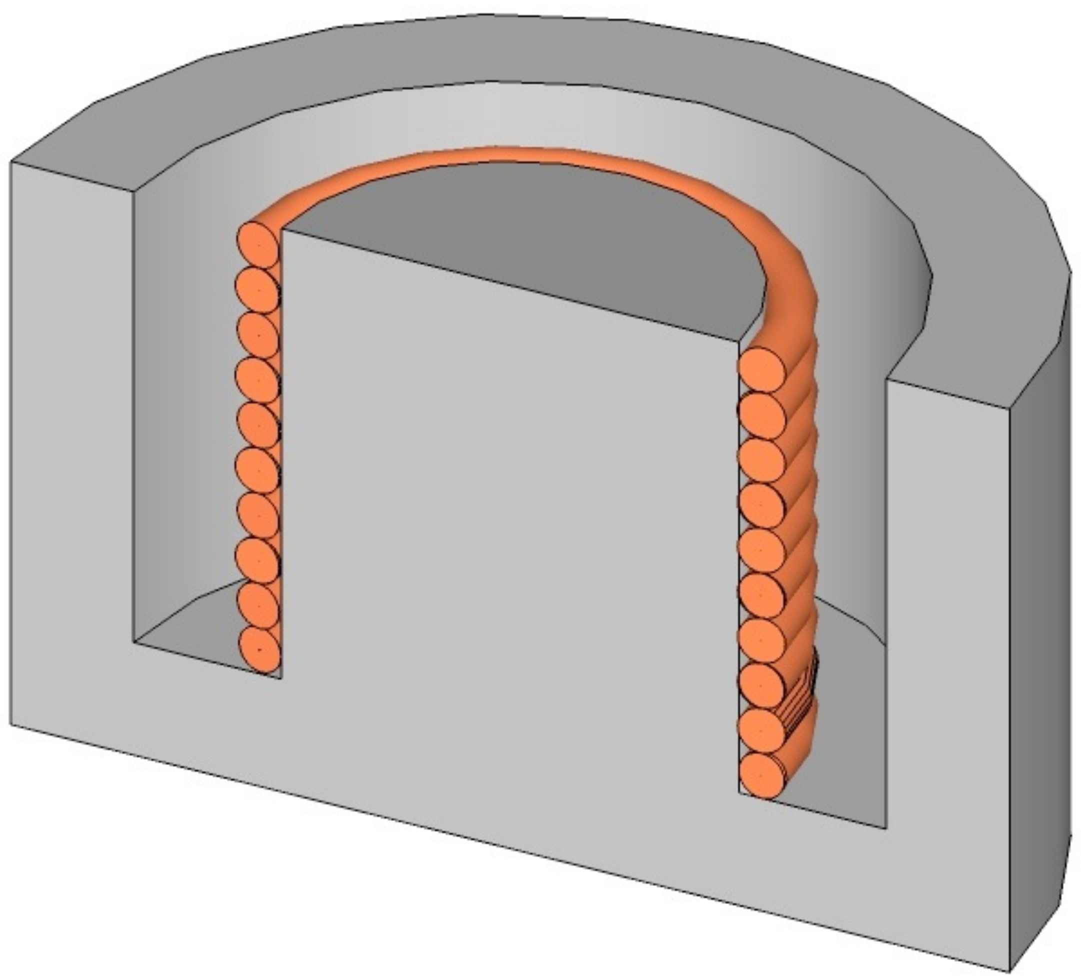




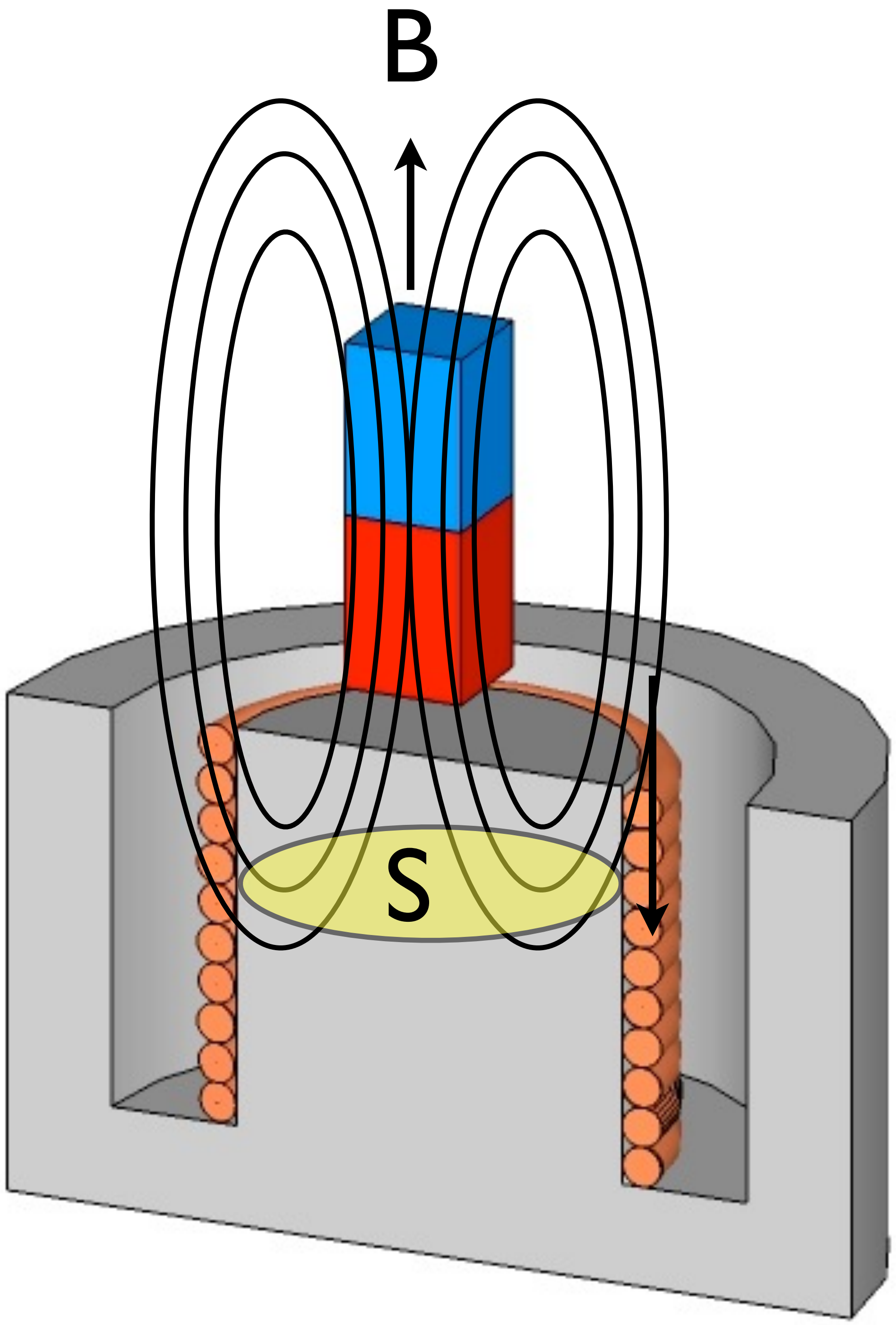
Intelligent Hall effect sensor



Induction coil



Induction coil



$$v = -\frac{d\phi}{dt}$$

Based on Faraday's induction law

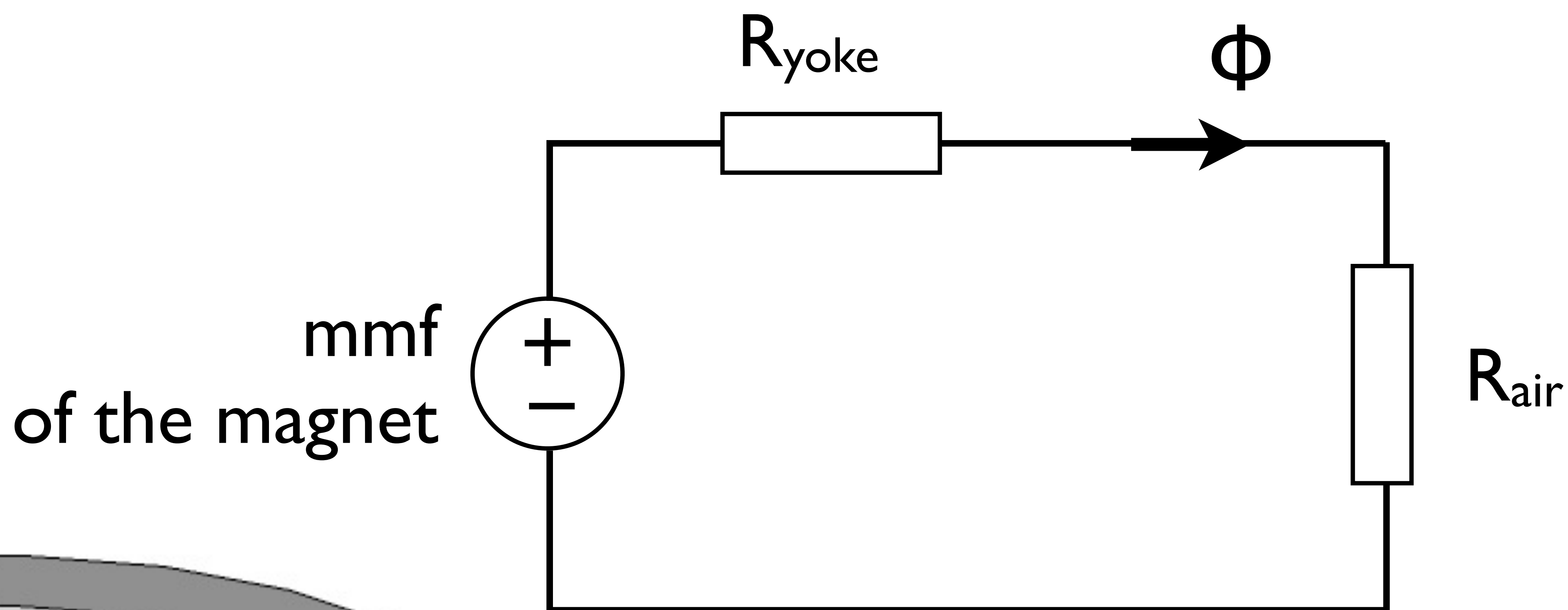
The amplitude of the pulse depends on the speed of the magnet

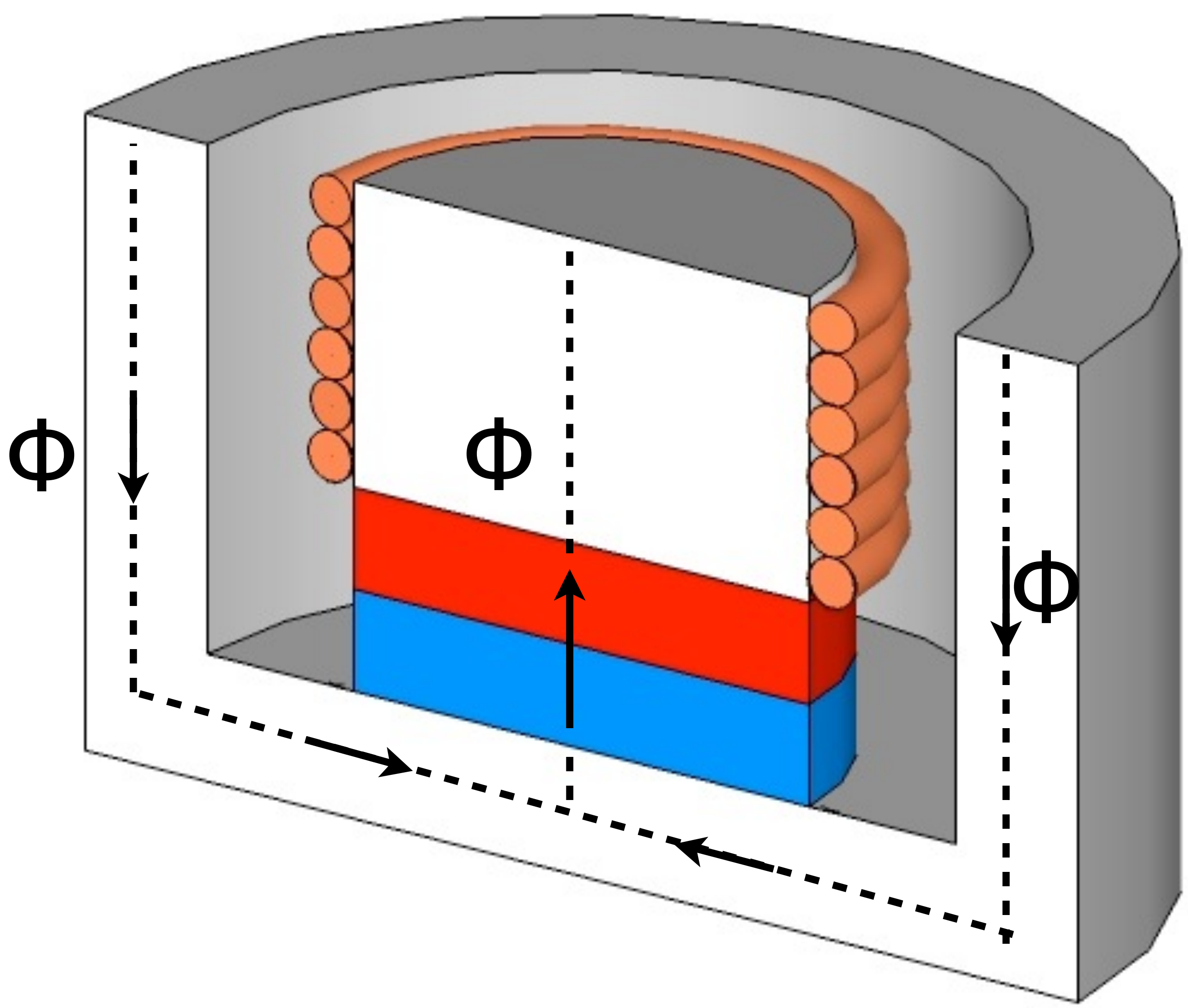
At low speed the signal is too low

Φ = magnetic flux

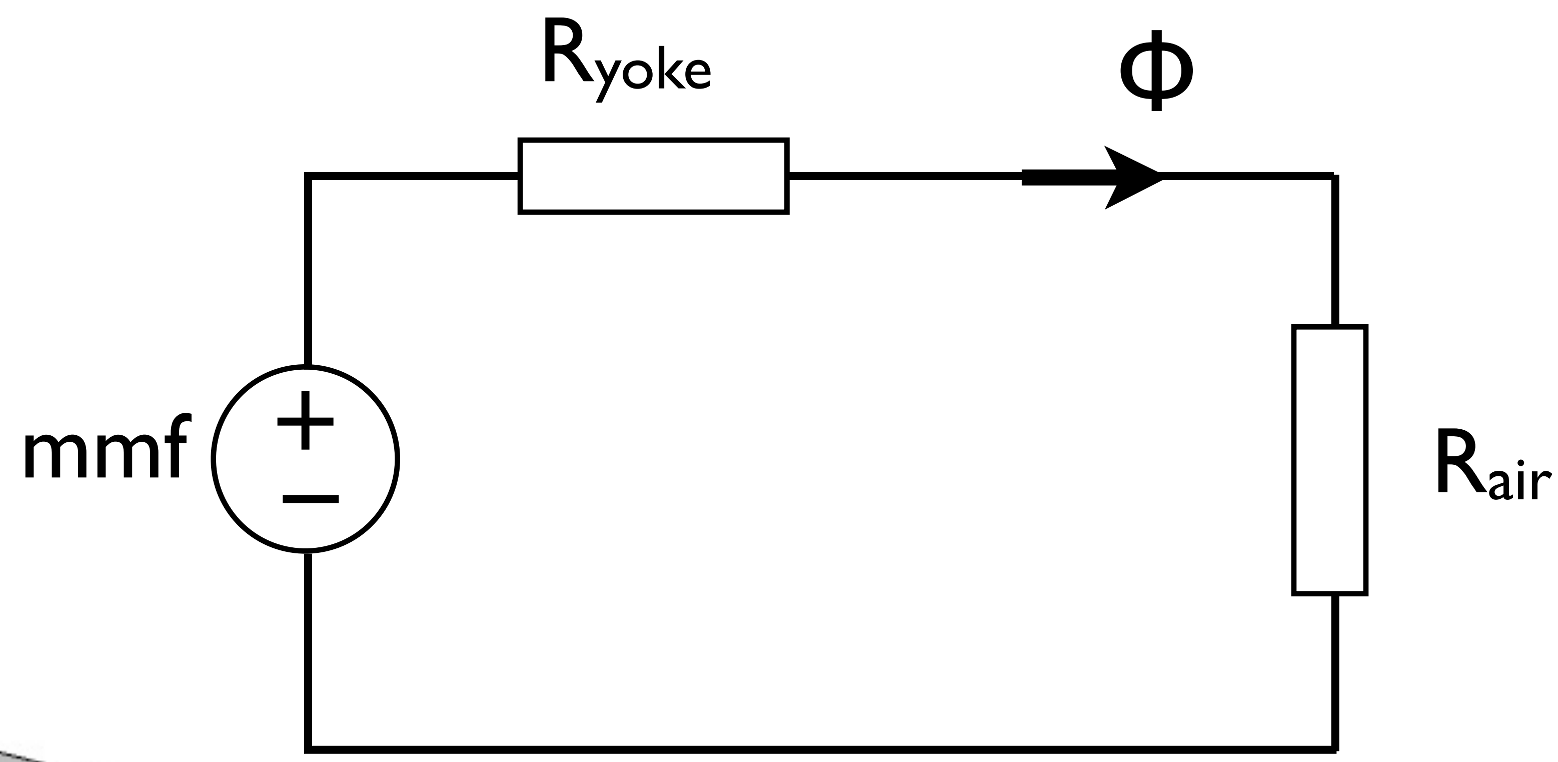
$$\phi = \int_S \bar{B} \cdot \bar{n} \, ds$$

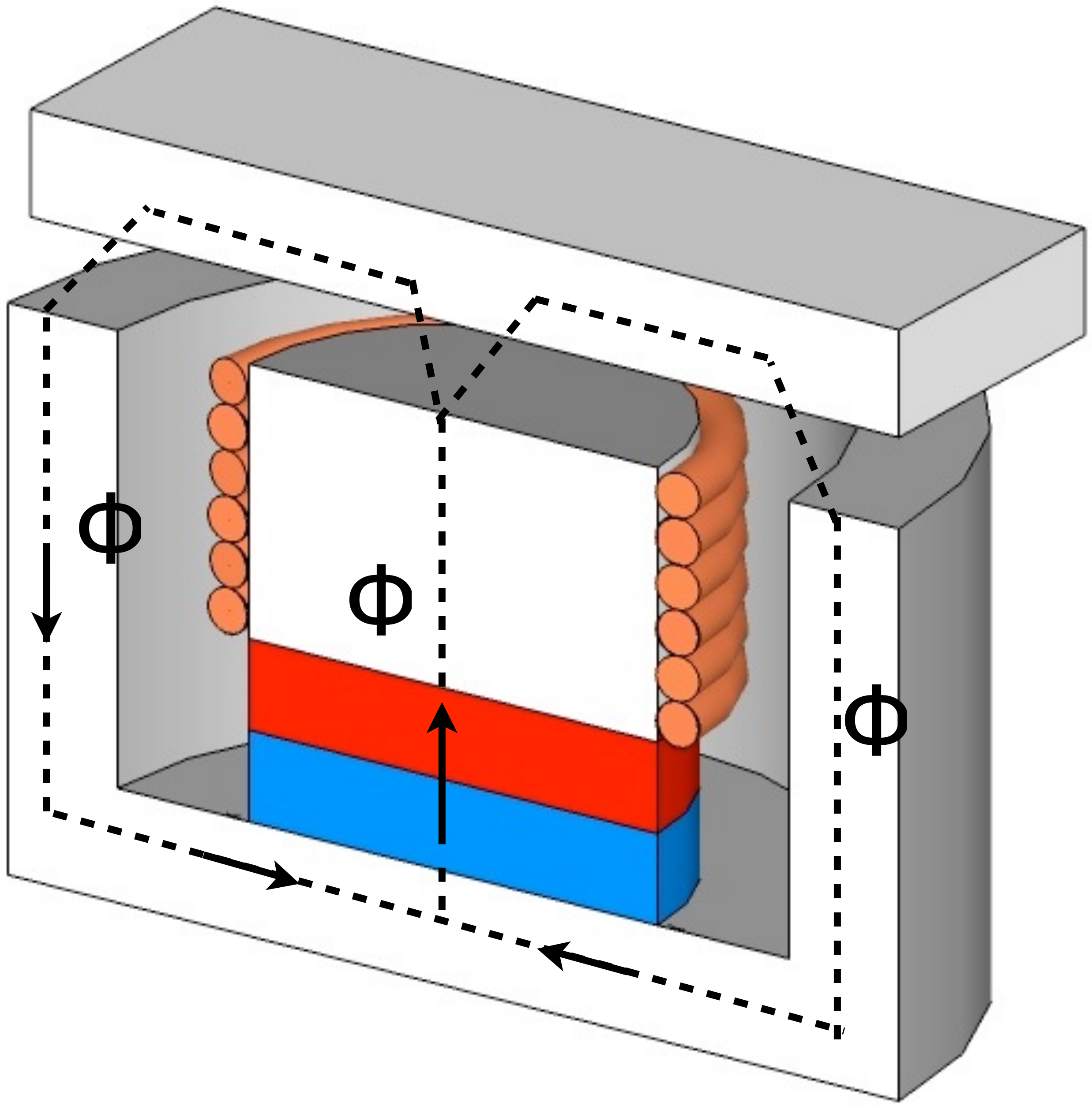
An alternative: the magnet is placed inside.





$$\phi = \frac{\mathrm{mmf}}{R_{yoke} + R_{air}}$$



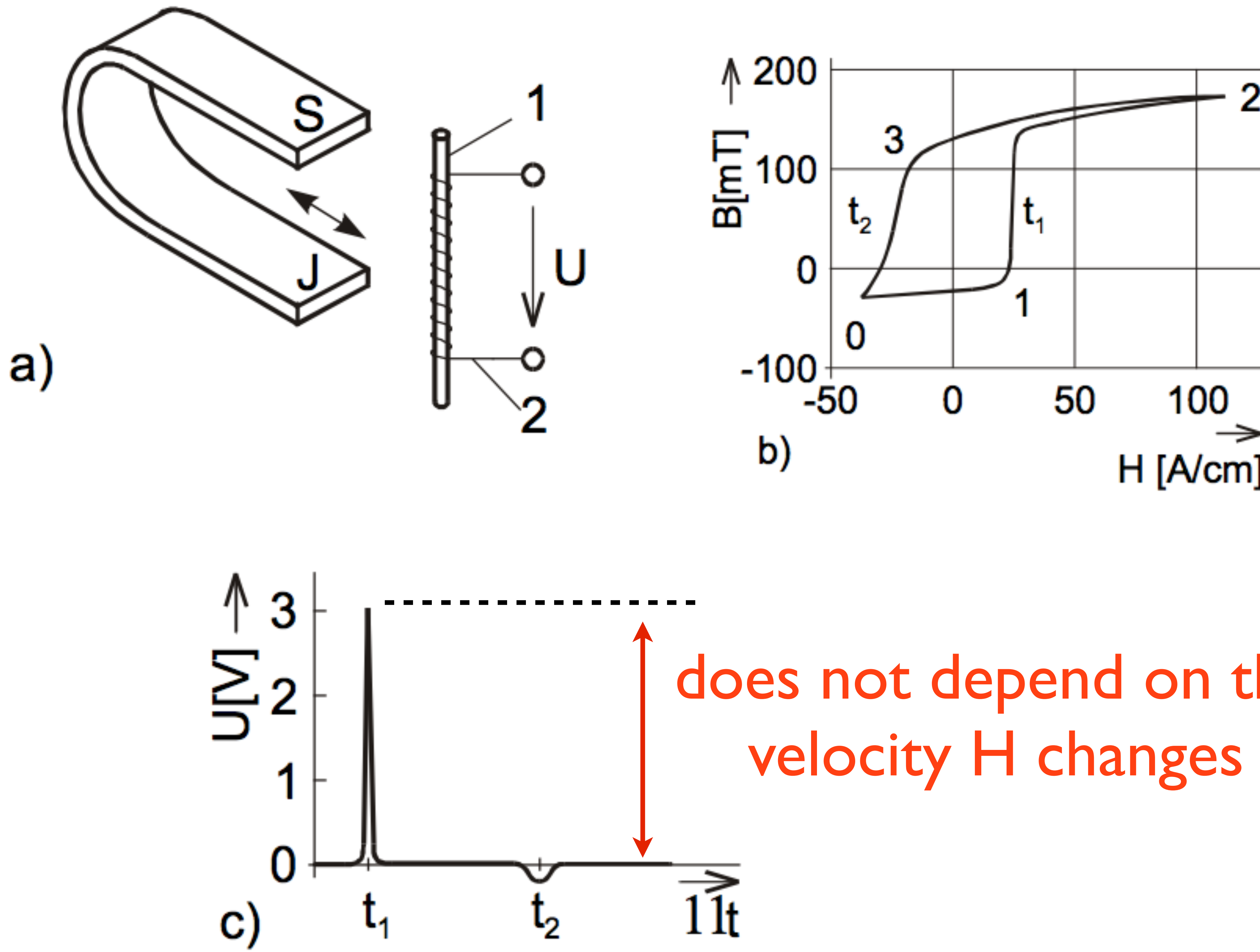


$$\phi = \frac{\text{mmf}}{R_{yoke} + R_{air}}$$

if R_{air} decreases, Φ increases

$$v = -\frac{d\phi}{dt}$$

Wiegan's wire

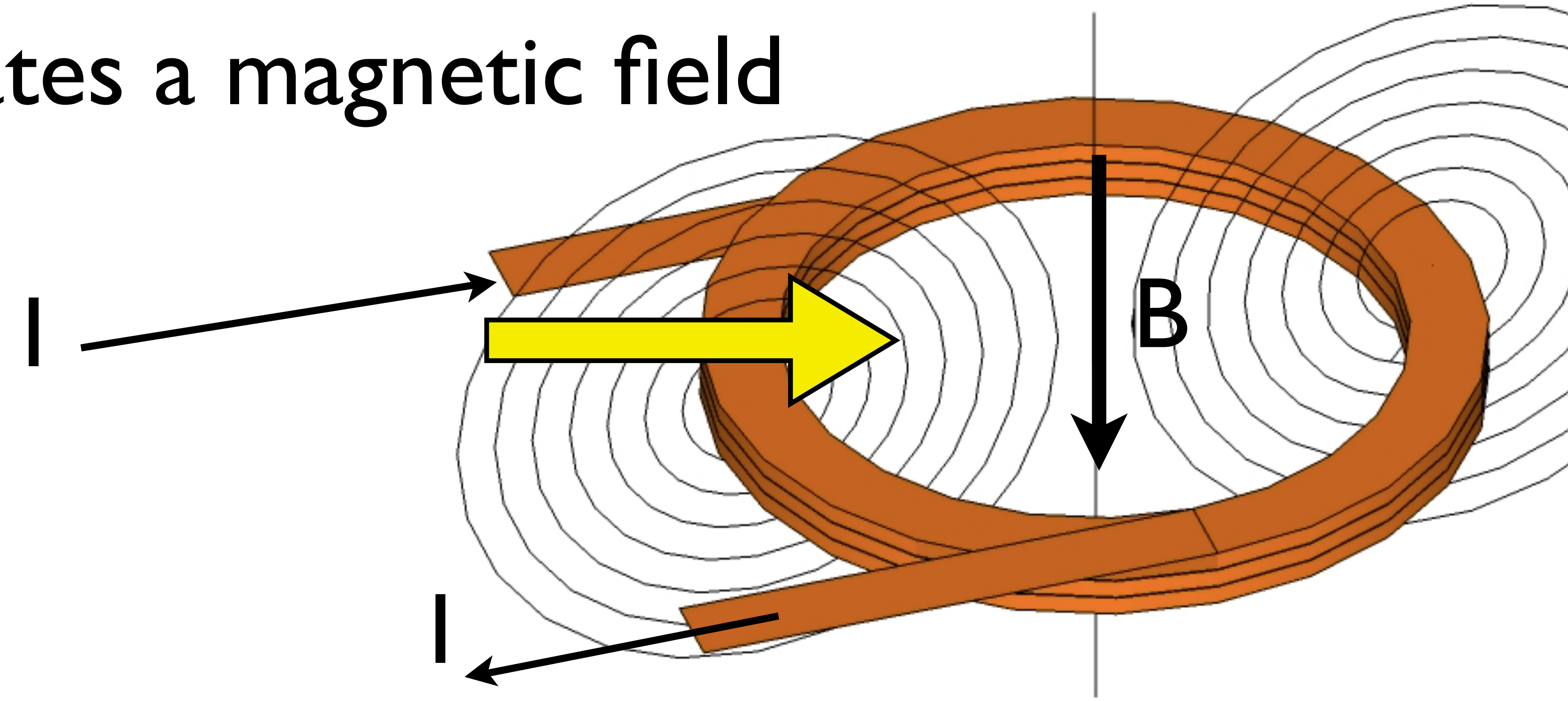


does not depend on the velocity H changes

Eddy current sensors

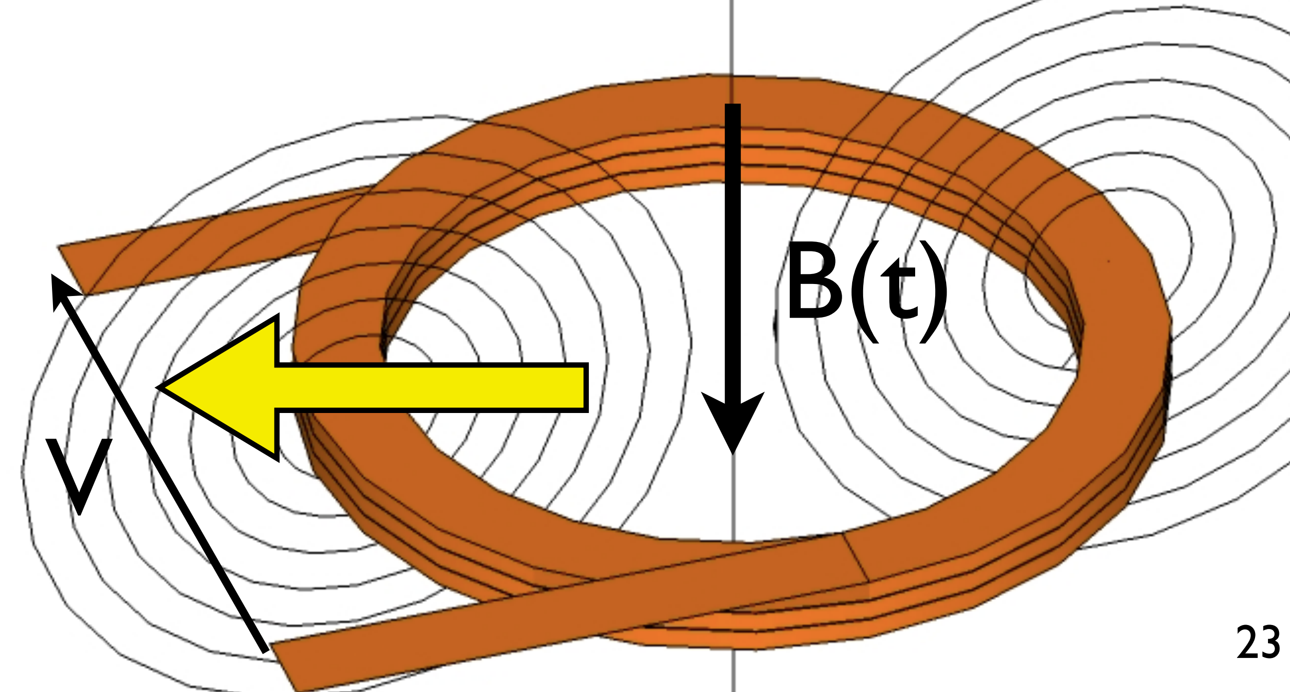
Two principles:

1) A current generates a magnetic field

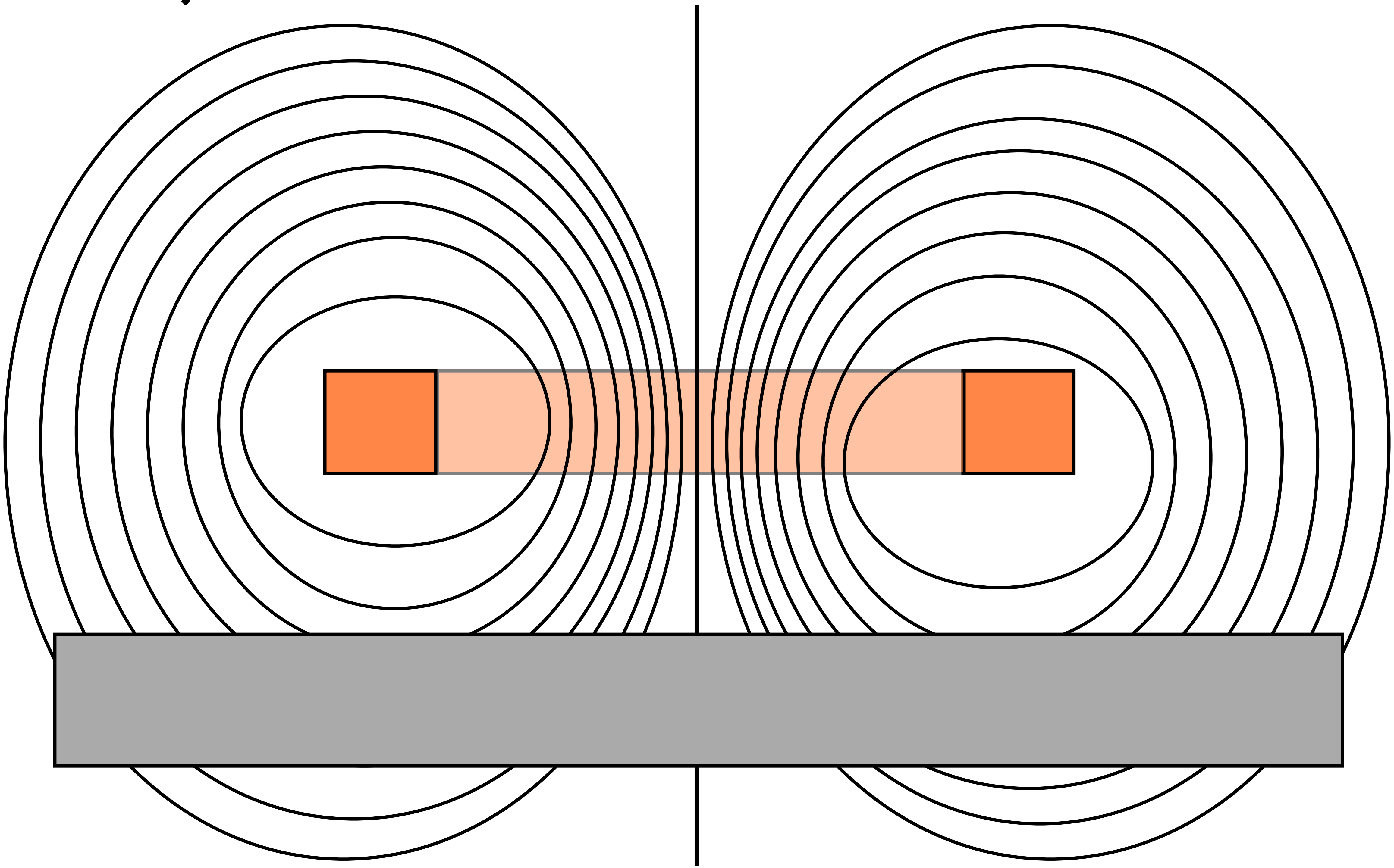


2) A time-varying magnetic field induces a voltage.

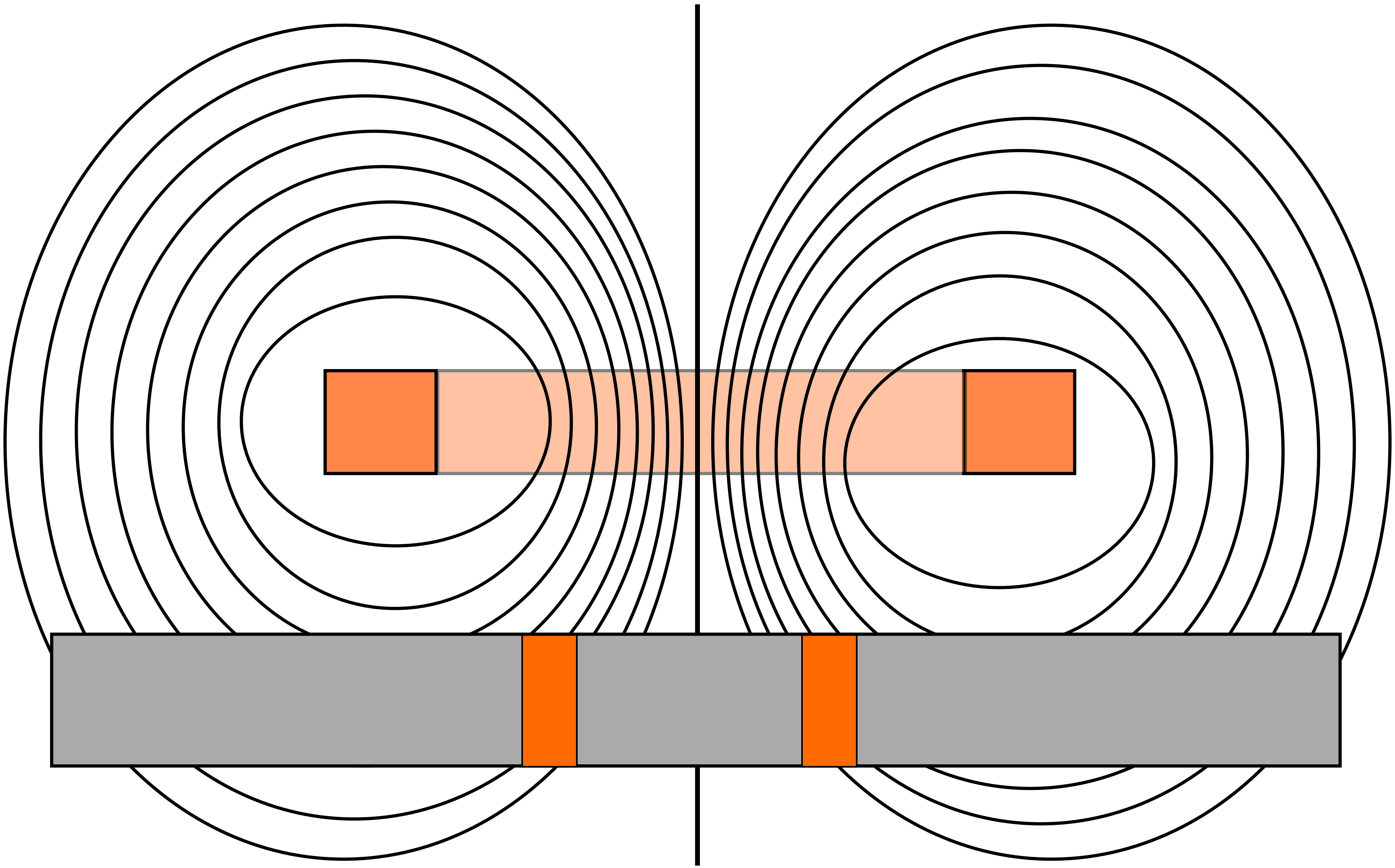
[and, of course, if the voltage is applied to conductive material a current is generated]



First of all I use a coil to generate a magnetic field above a metal object



The metal can be seen as a union of several coils



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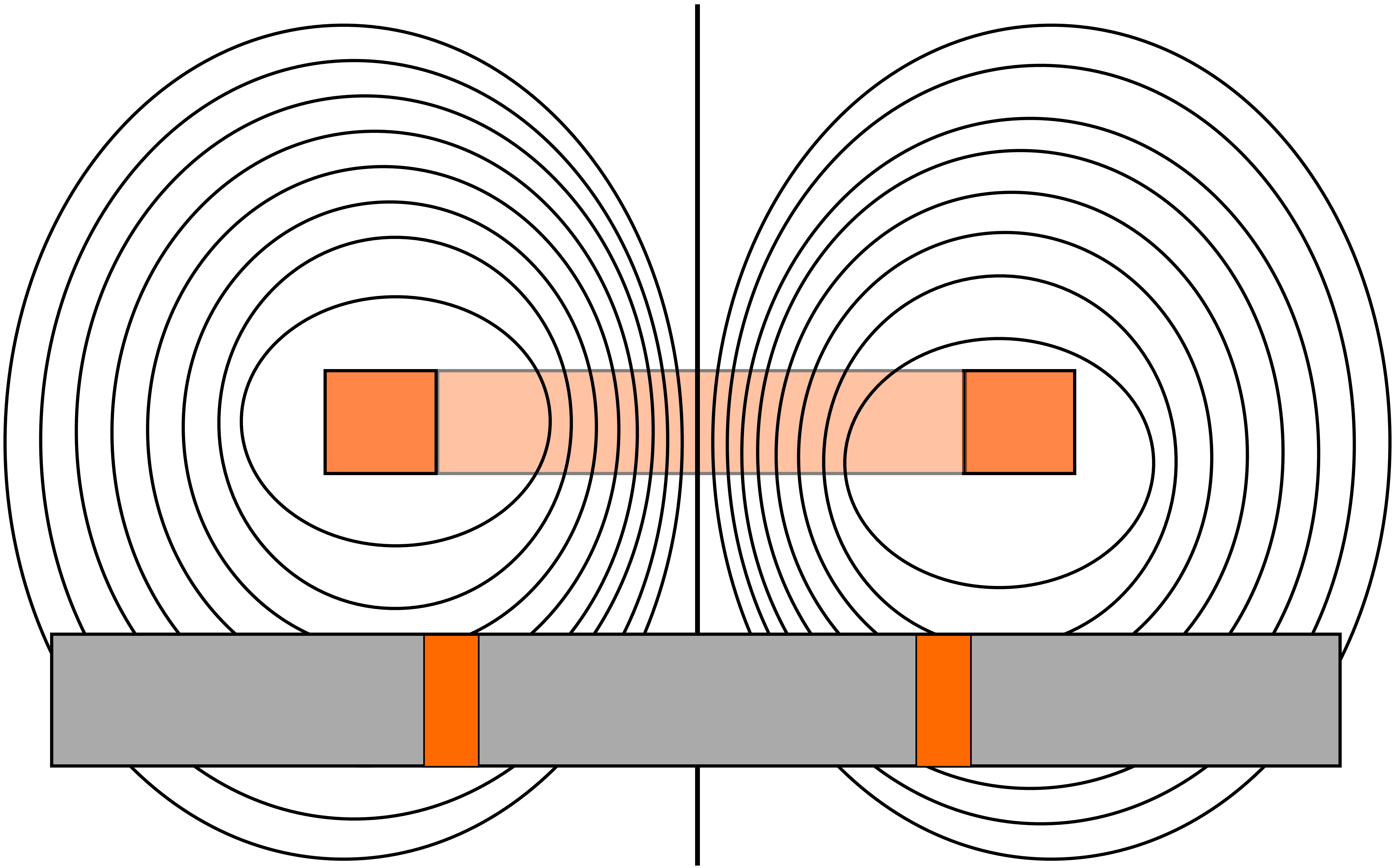
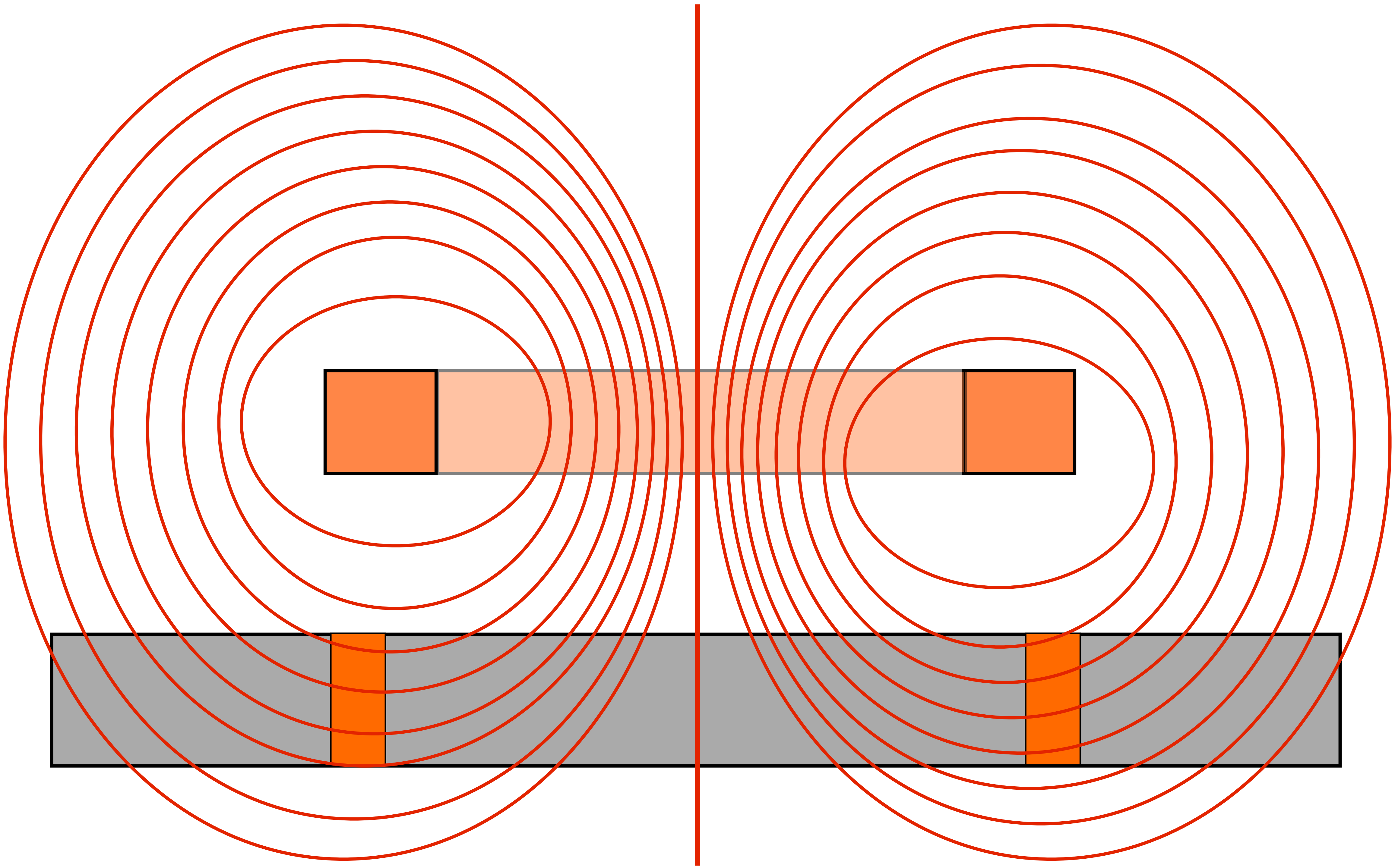


In any these coils there is a time-varying magnetic field



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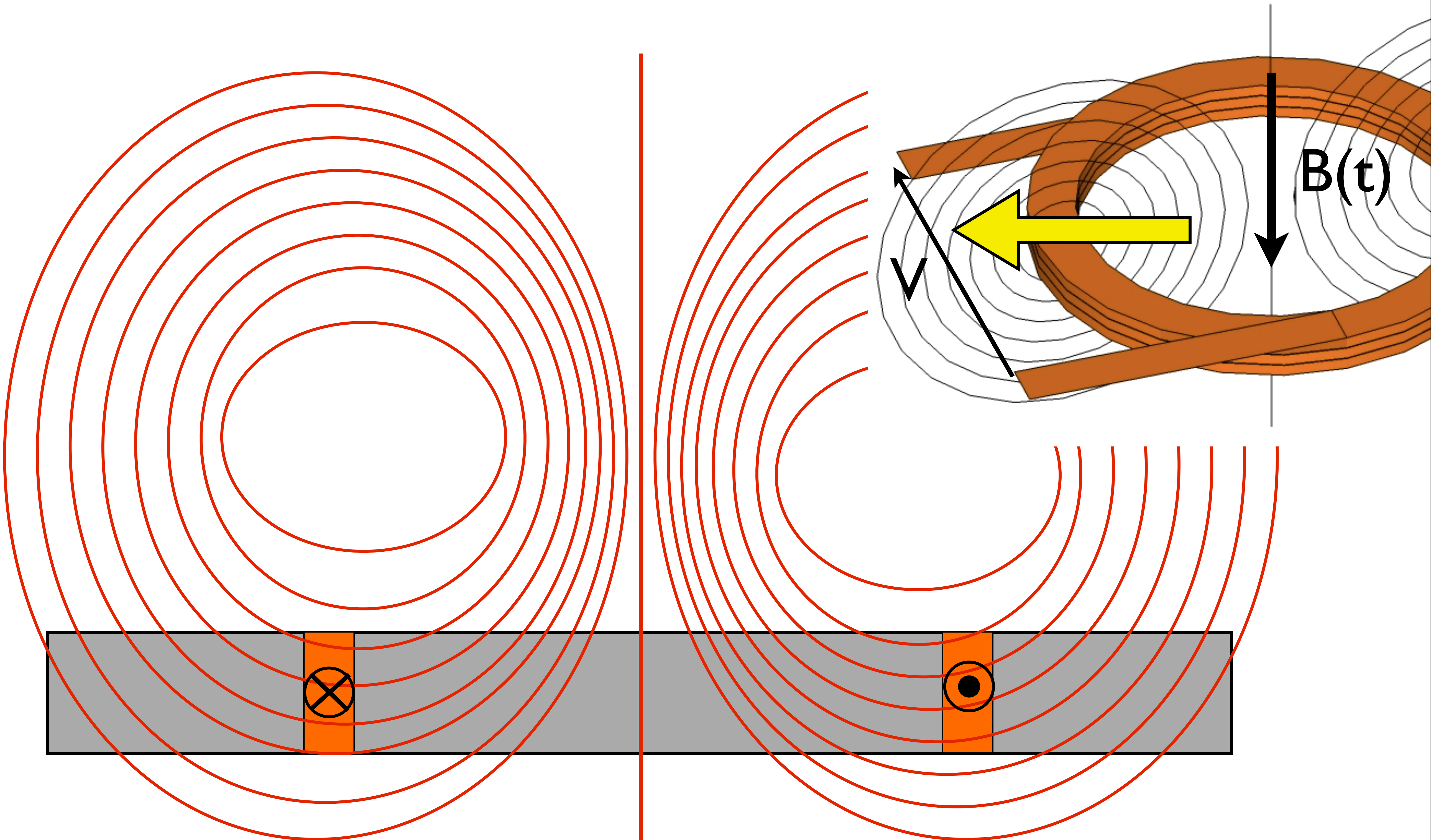
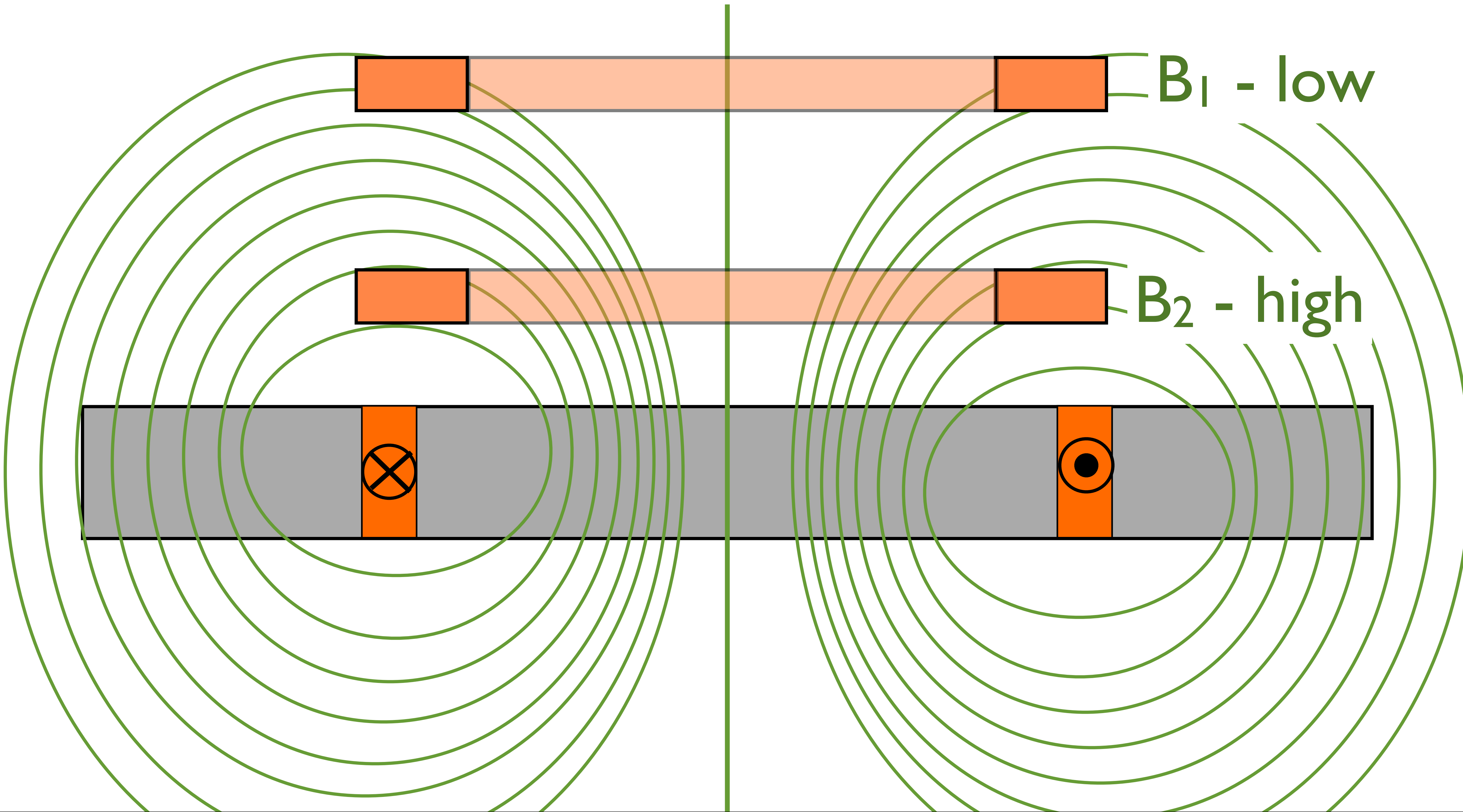


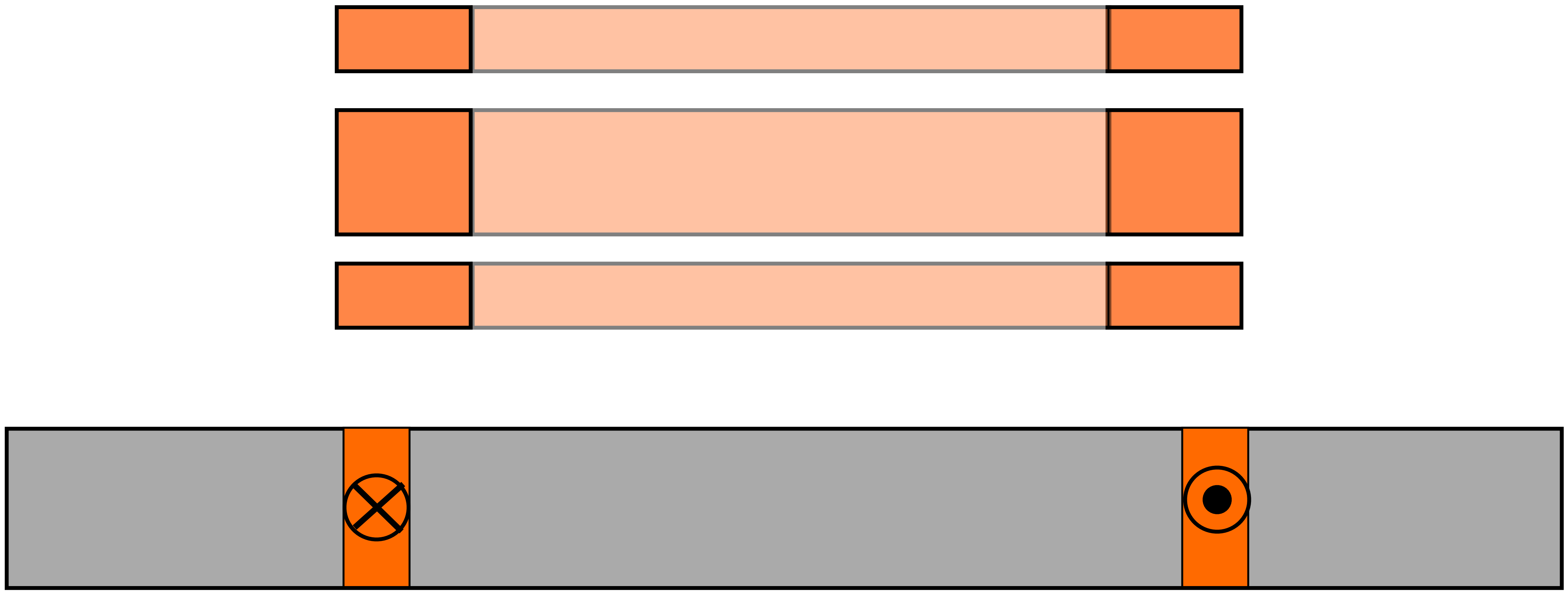
Therefore a voltage is generated, and since che material is conductive a current flows (eddy current)

The eddy currents generate also a magnetic field which is as low as the distance from the metallic object decreases.

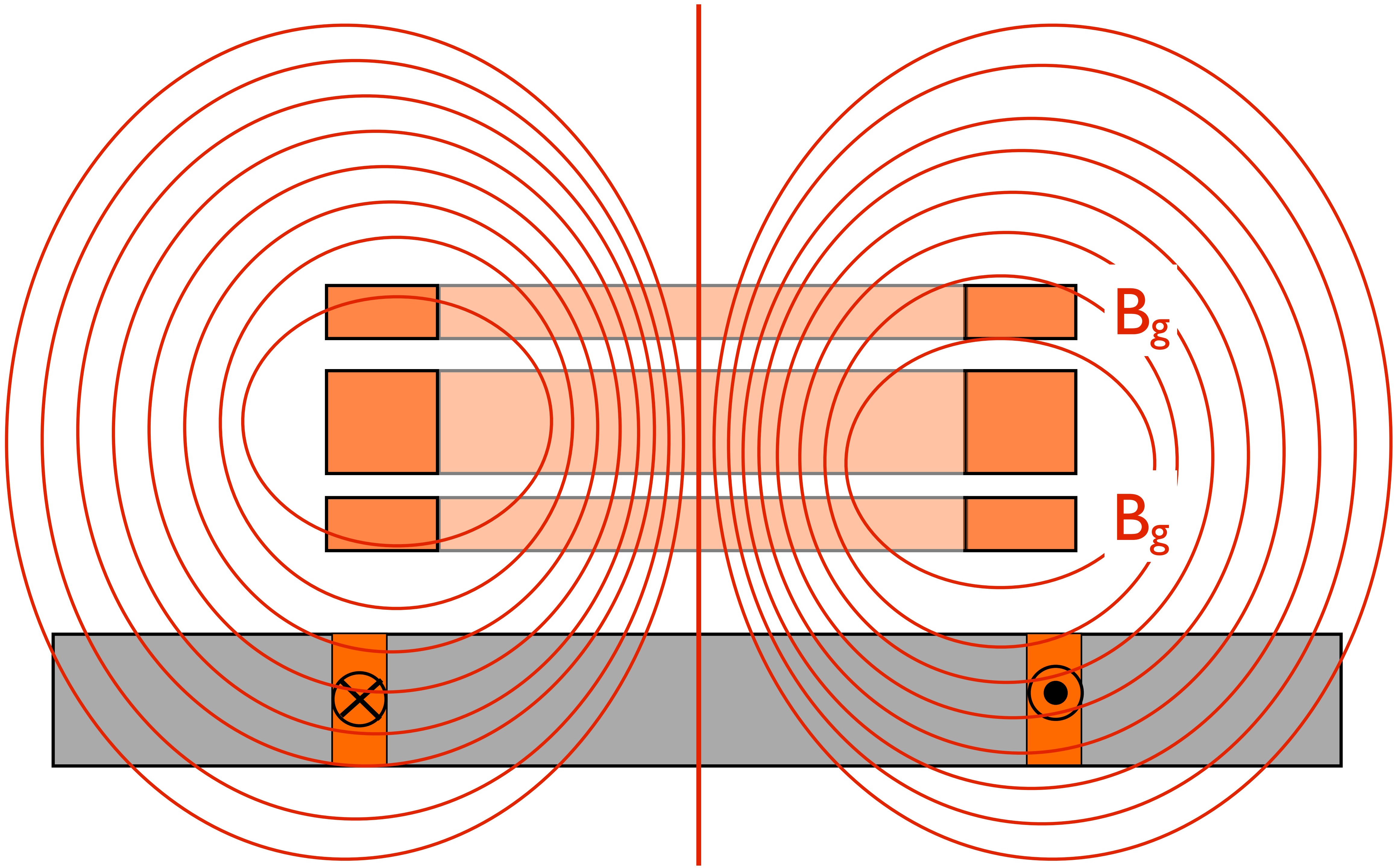
I use two coils to detect it, place at different distance



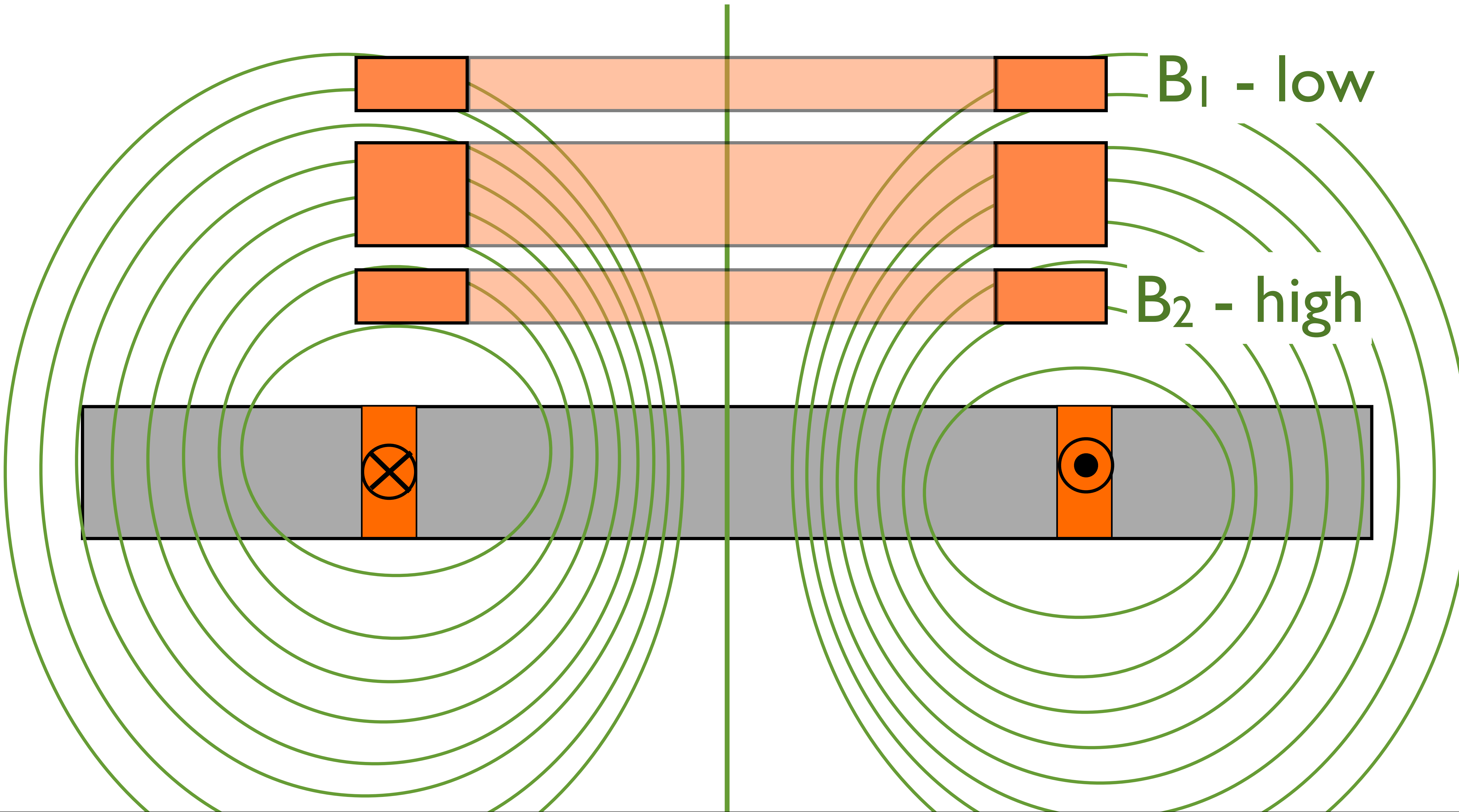
The two detection coils are place symmetrically to the generating coil. They receive both the field by the generating coil and the field generated by the eddy current



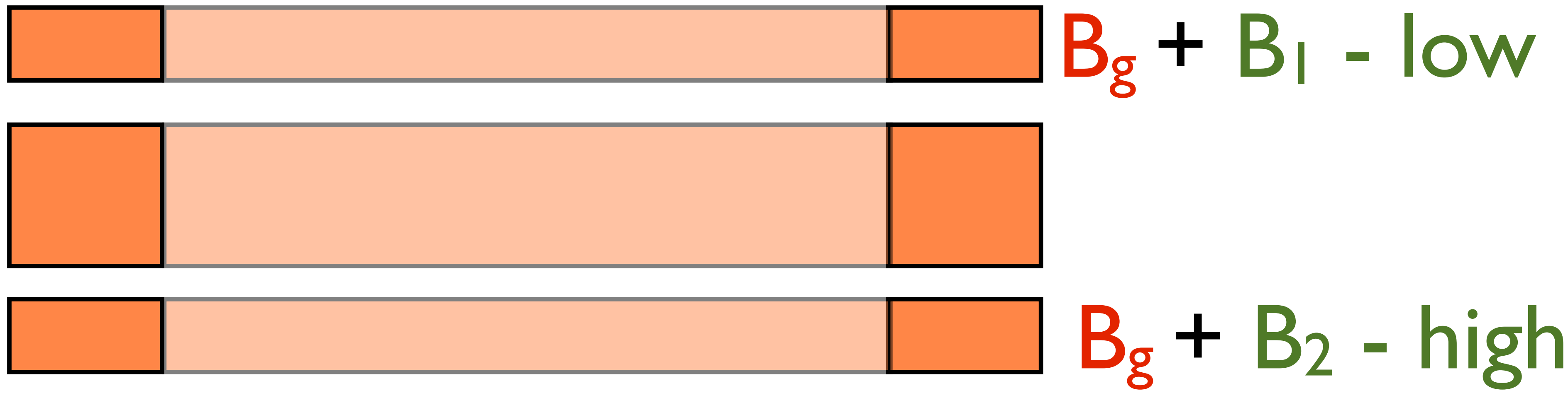
The field created by the generating coil is equal for both coil1 and coil 2 (they are at the same distance)

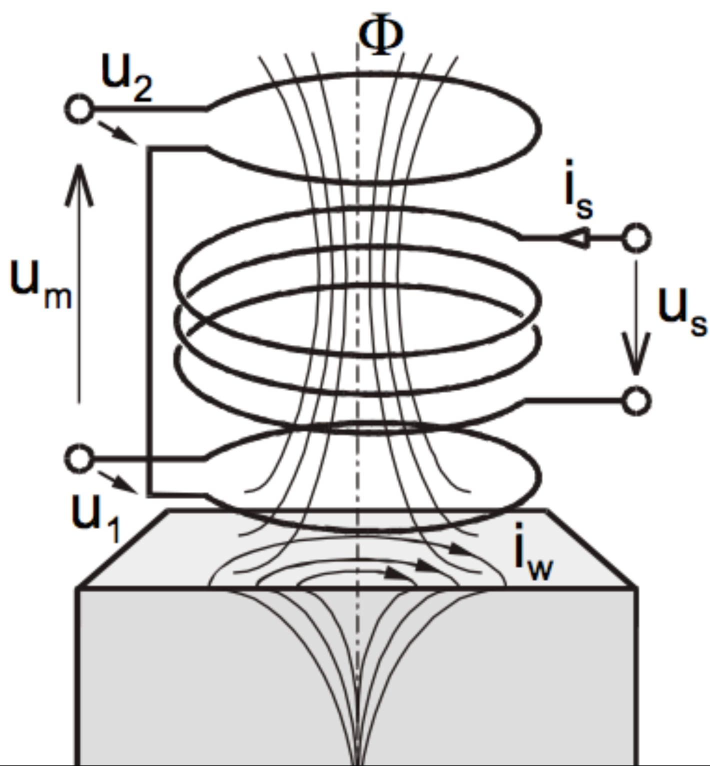


While the field generated by eddy current is larger in coil 2 than in coil 1

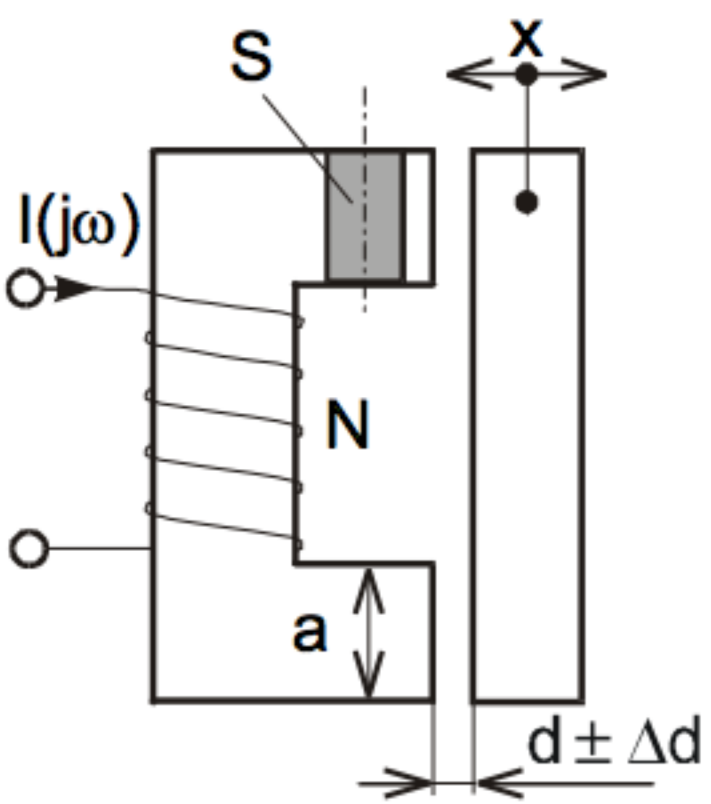


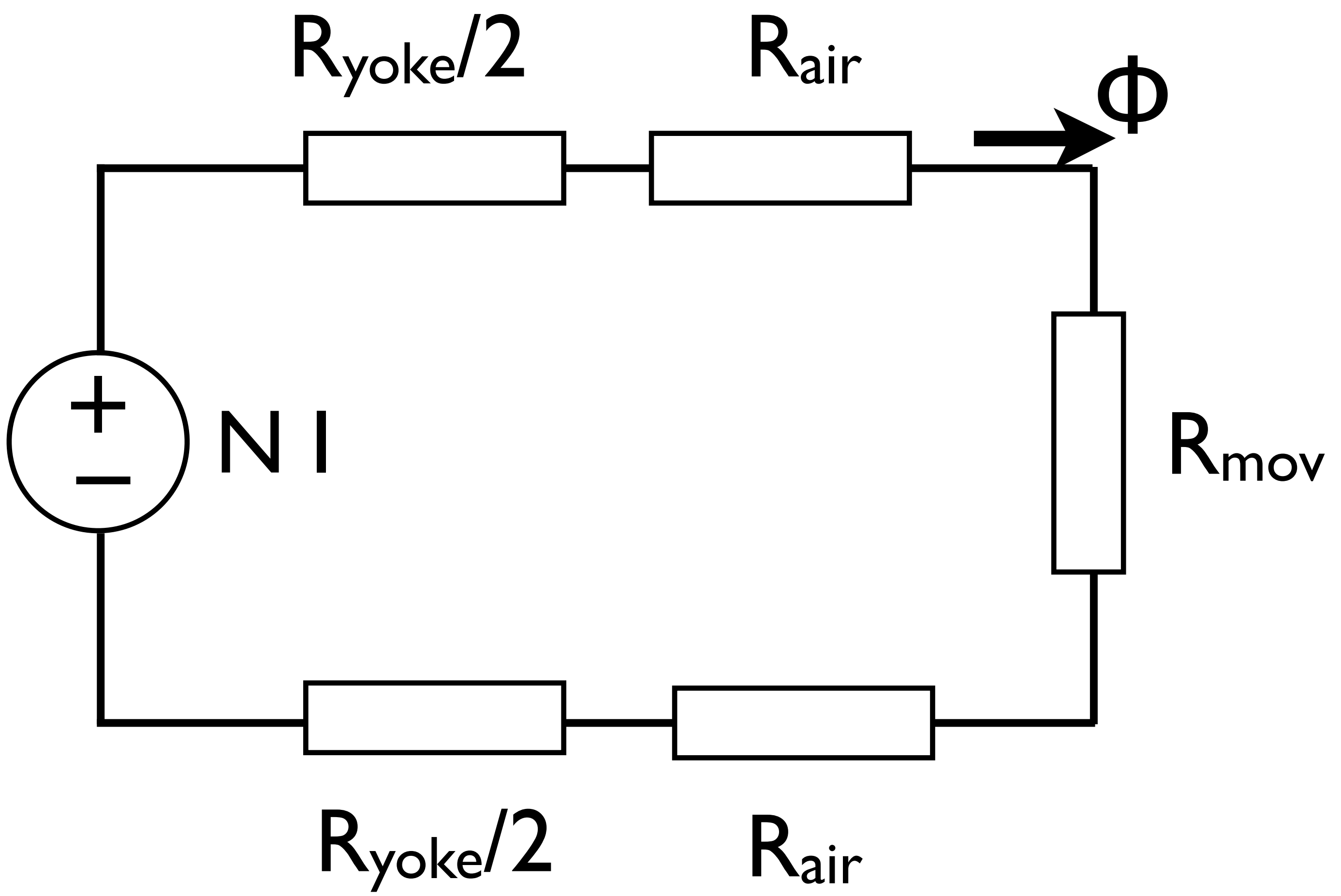
We take the difference between the voltage induced the two coils





Inductive sensors with variable air gap





N I = magnetomotive force

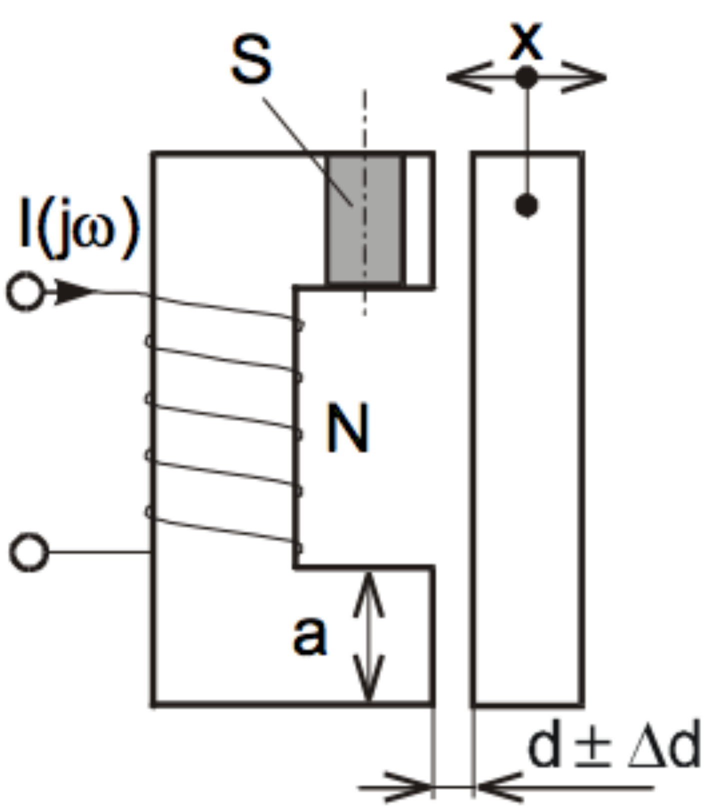
Φ = magnetic flux

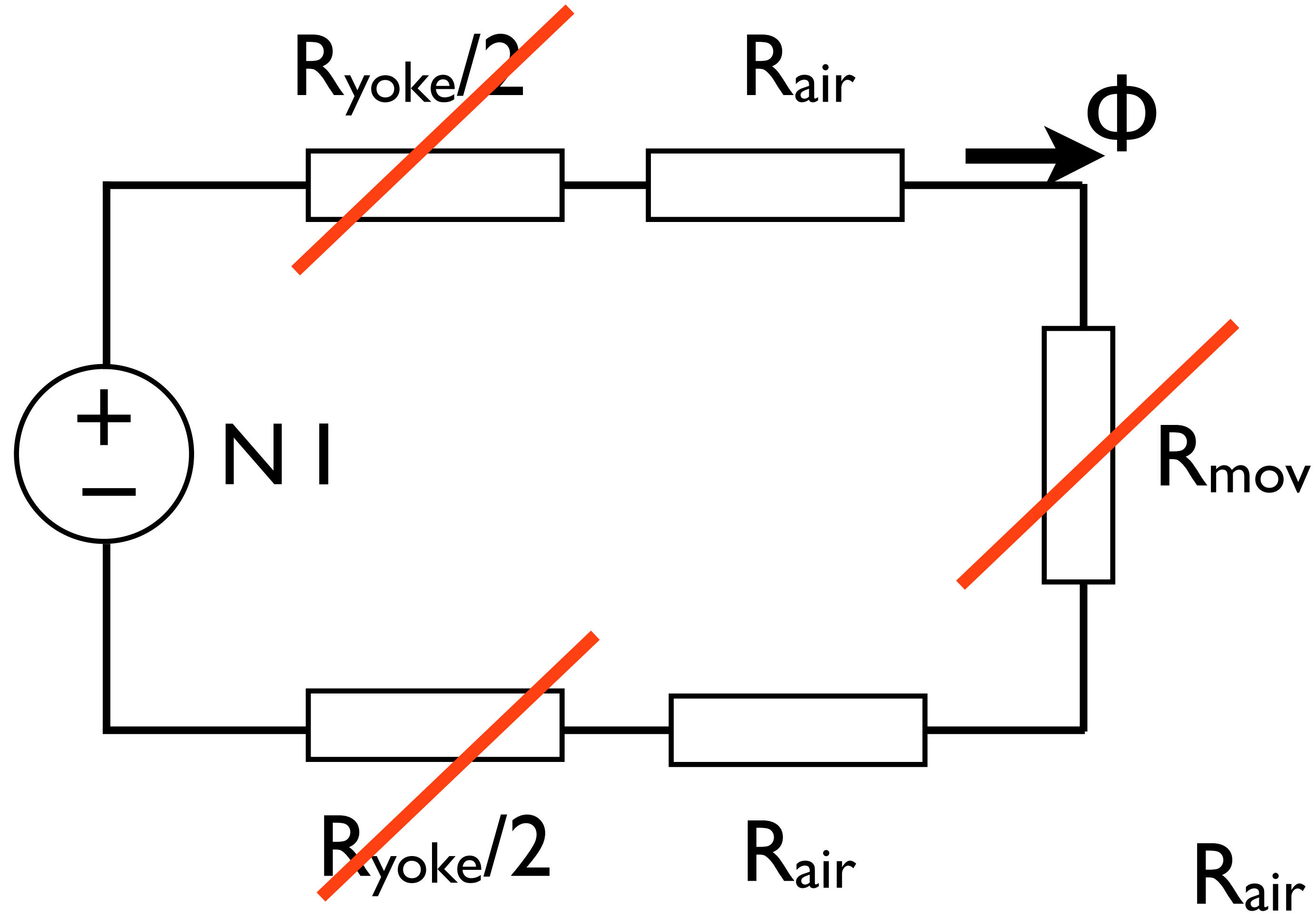
R_{yoke} = reluctance of the yoke

R_{air} = reluctance of air gap

R_{mov} = reluctance of movable part

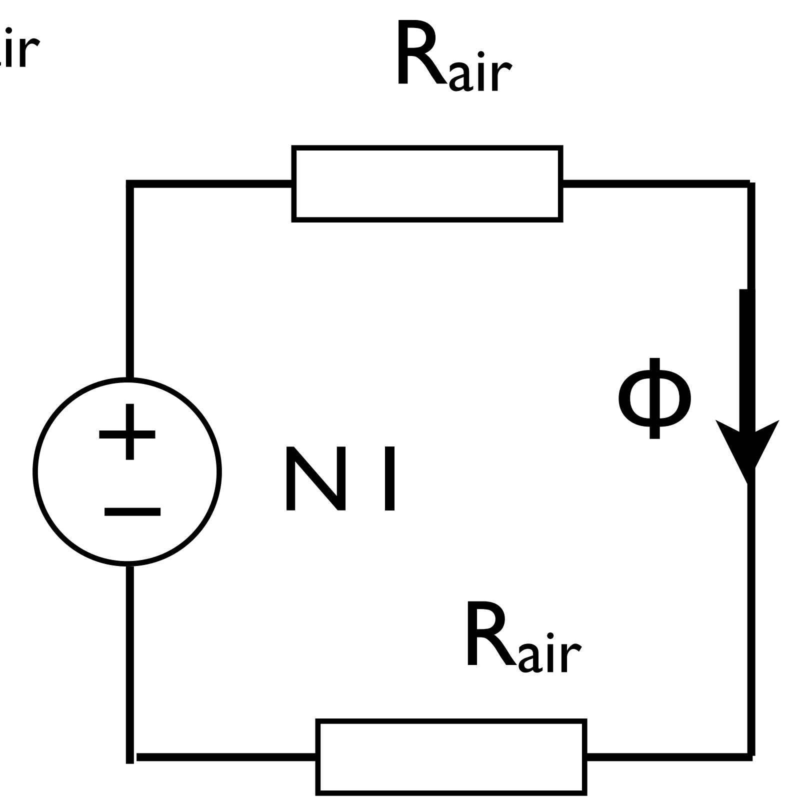
Inductive sensors with variable air gap



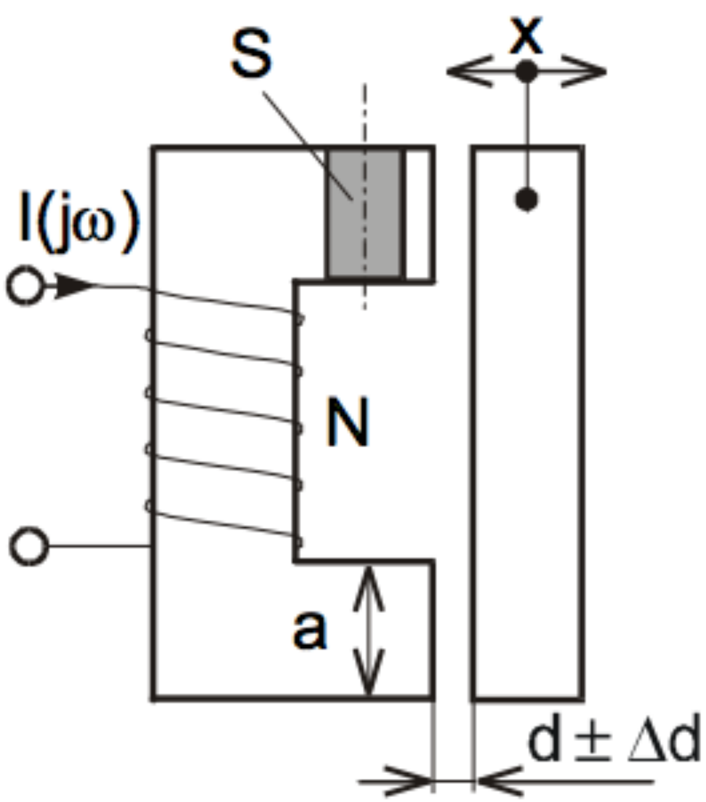


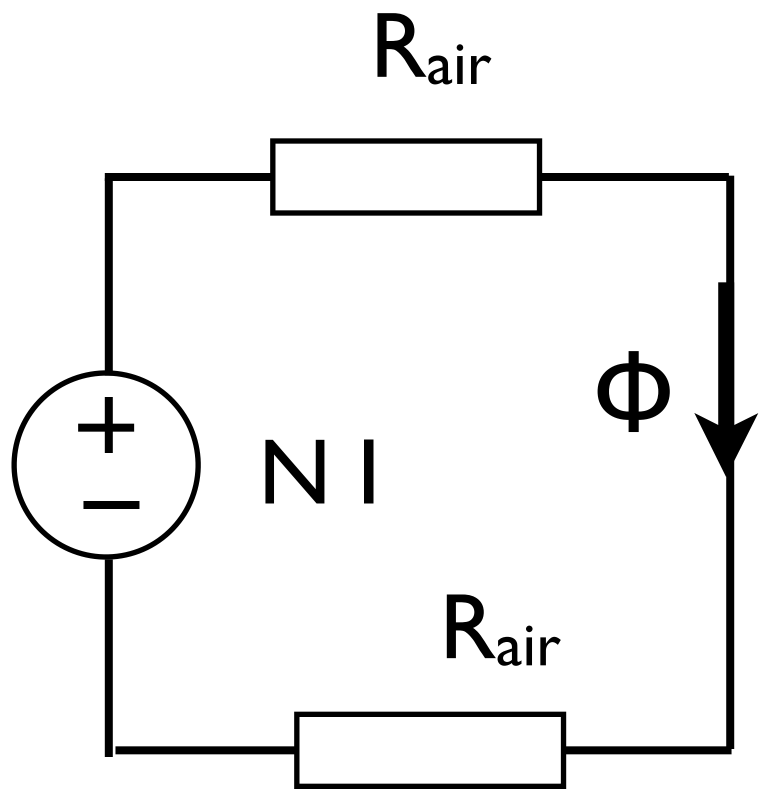
R= length / (μ · Surface)

We neglect R_{yoke} and R_{mov} because $\mu_{Fe} >> \mu_0$



Inductive sensors with variable air gap

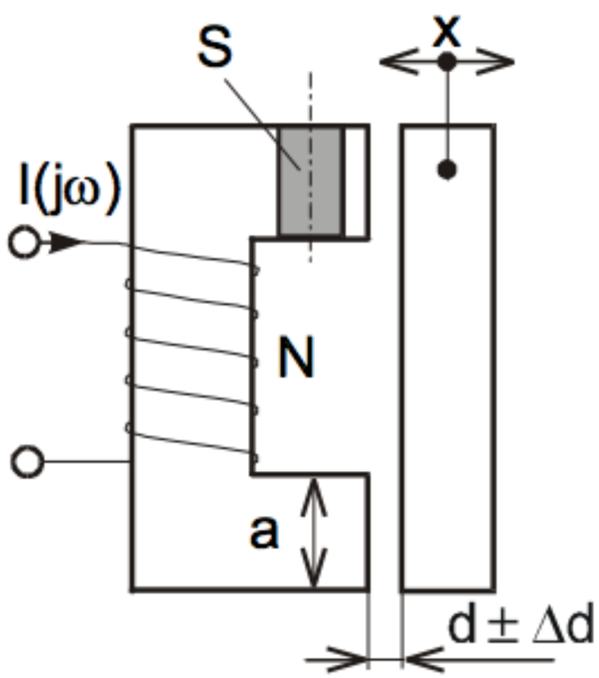


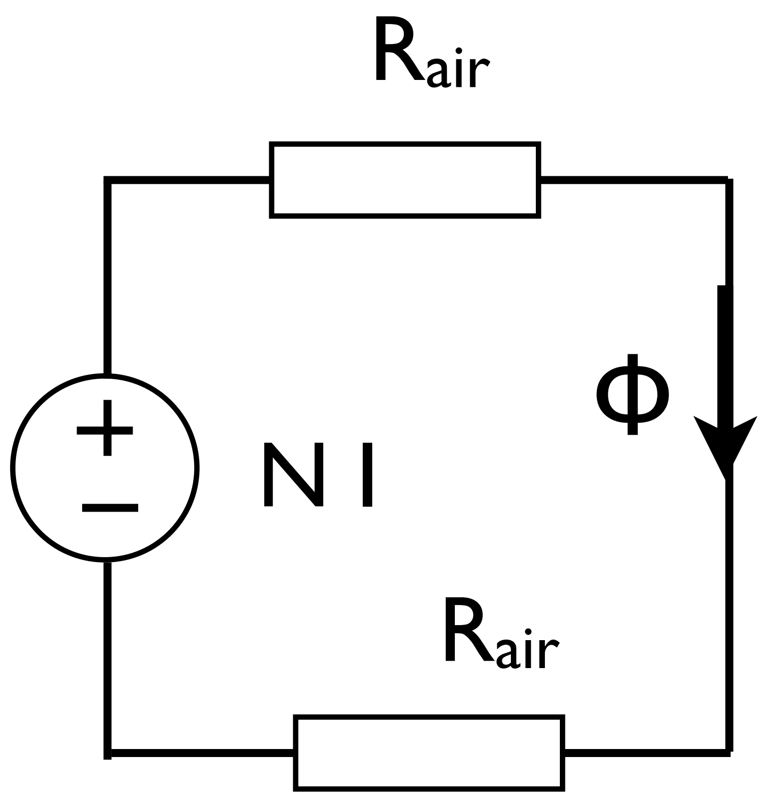


$R_{air} = d / (\mu_0 \cdot S)$

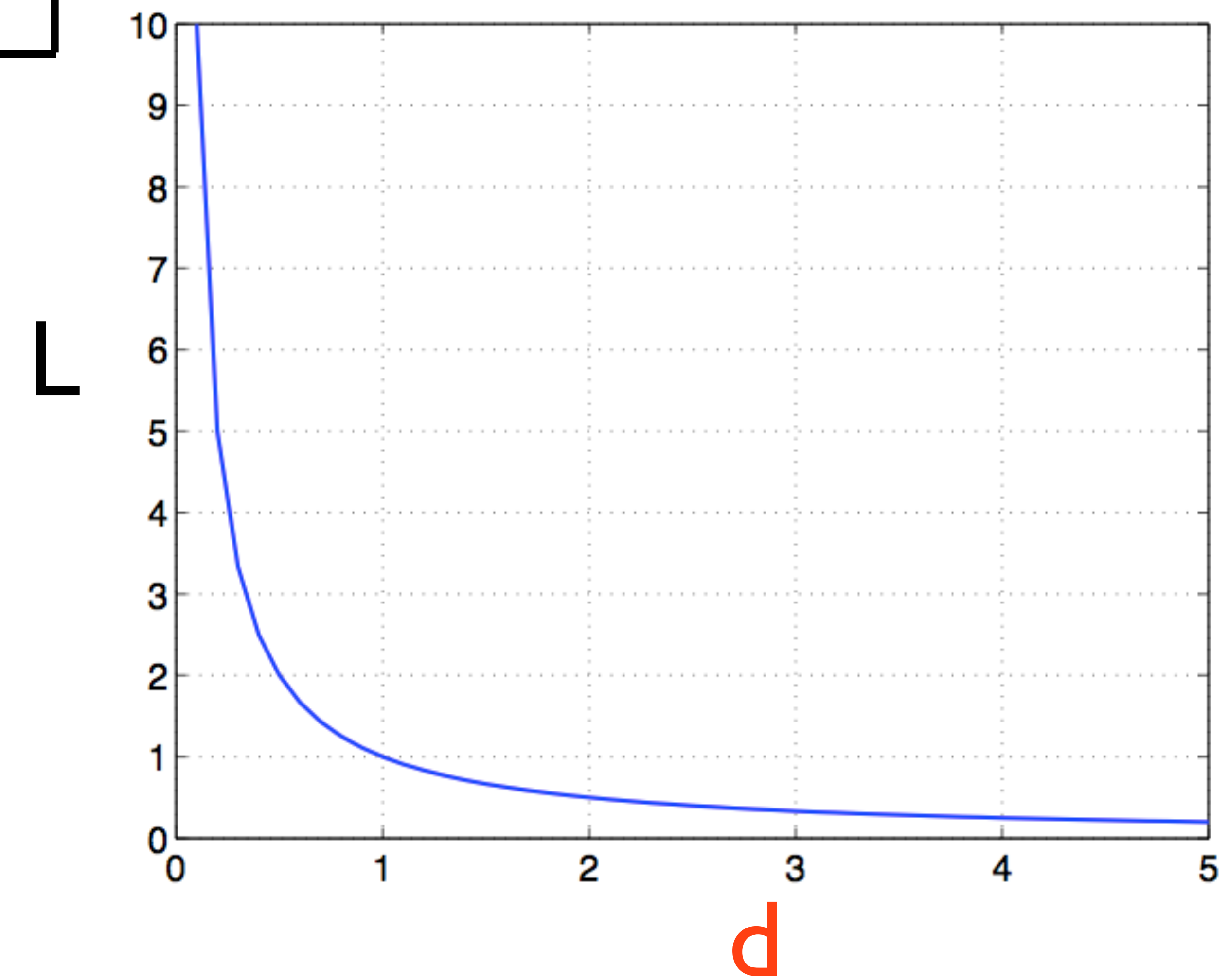
$$\phi = \frac{NI}{2R_{air}} = \frac{NI}{2d}\mu_0 S \qquad L = N\frac{\phi}{I} = \frac{N^2}{2d}\mu_0 S$$

Inductive sensors with variable air gap

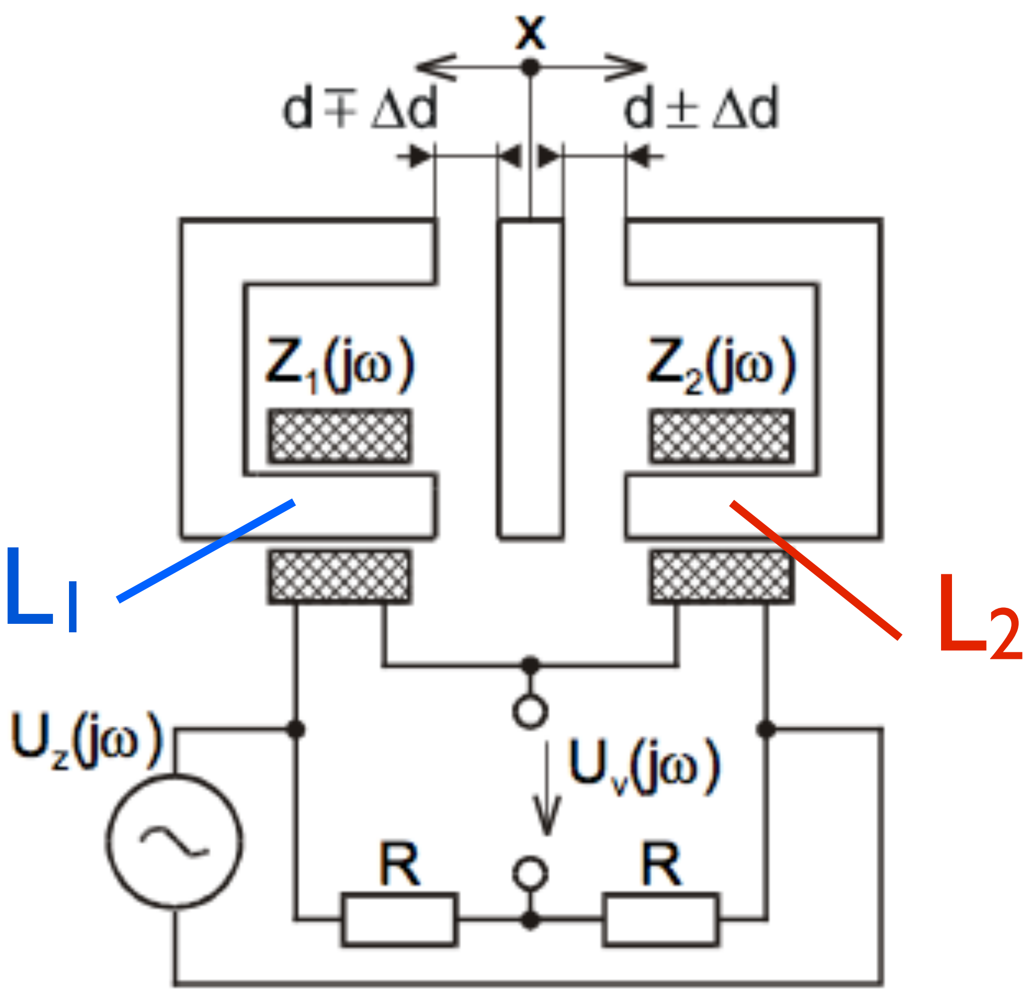


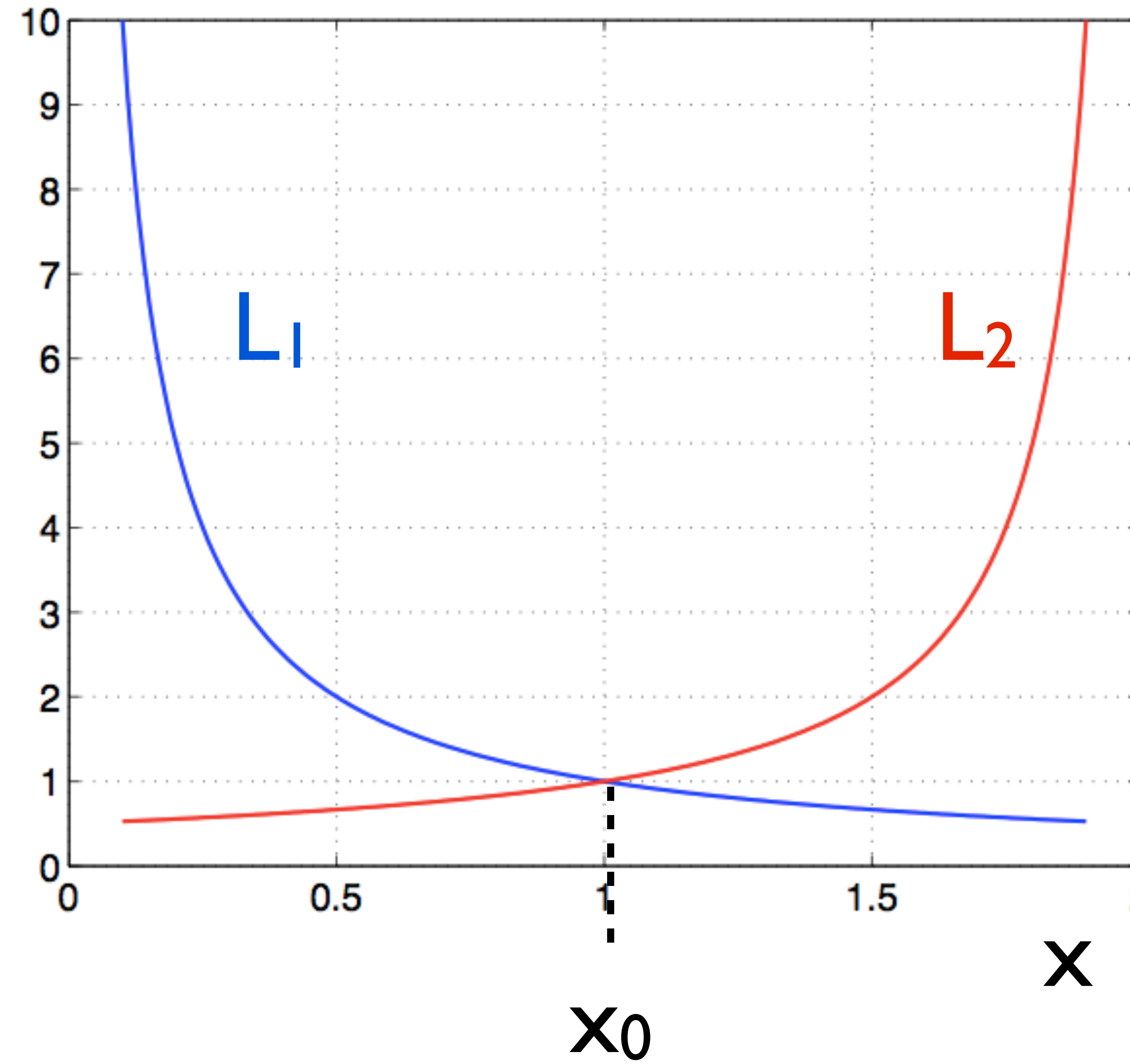


$$L = \frac{N^2}{2d} \mu_0 S$$

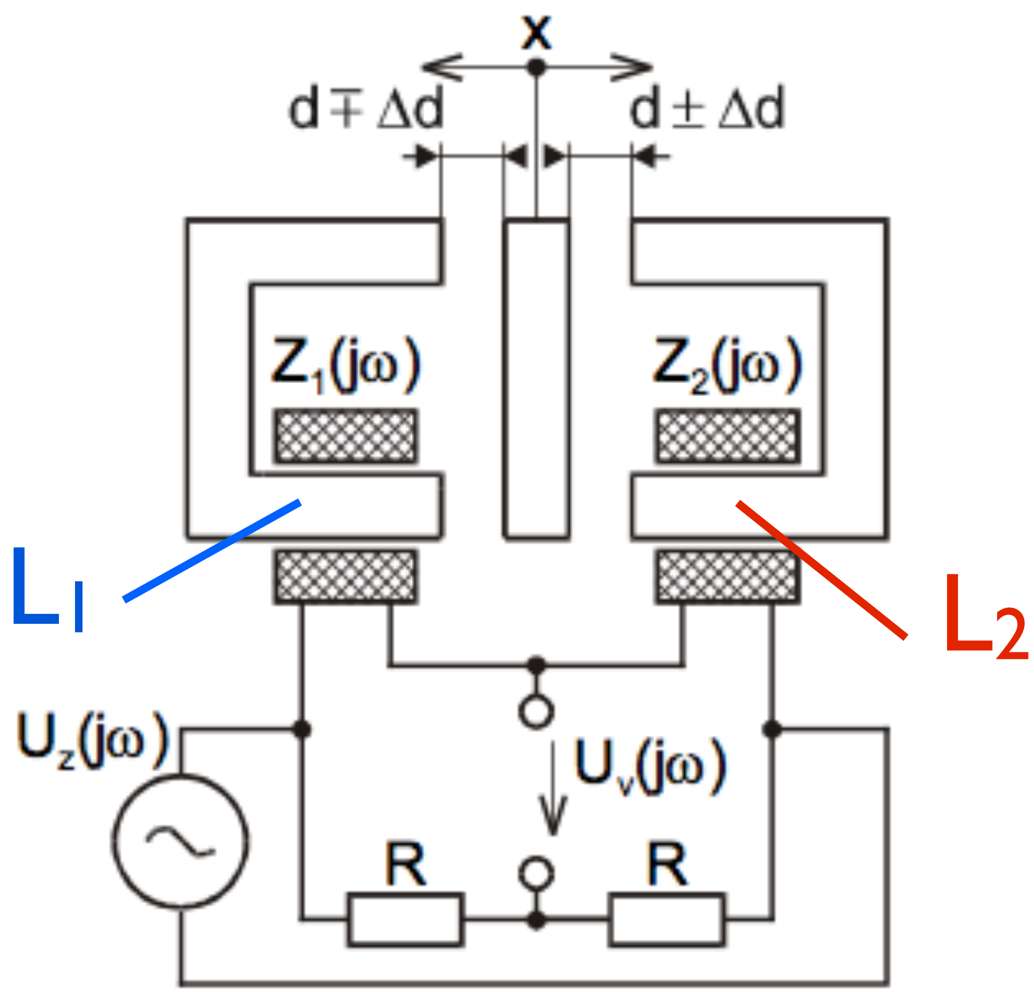


Differential inductive sensor

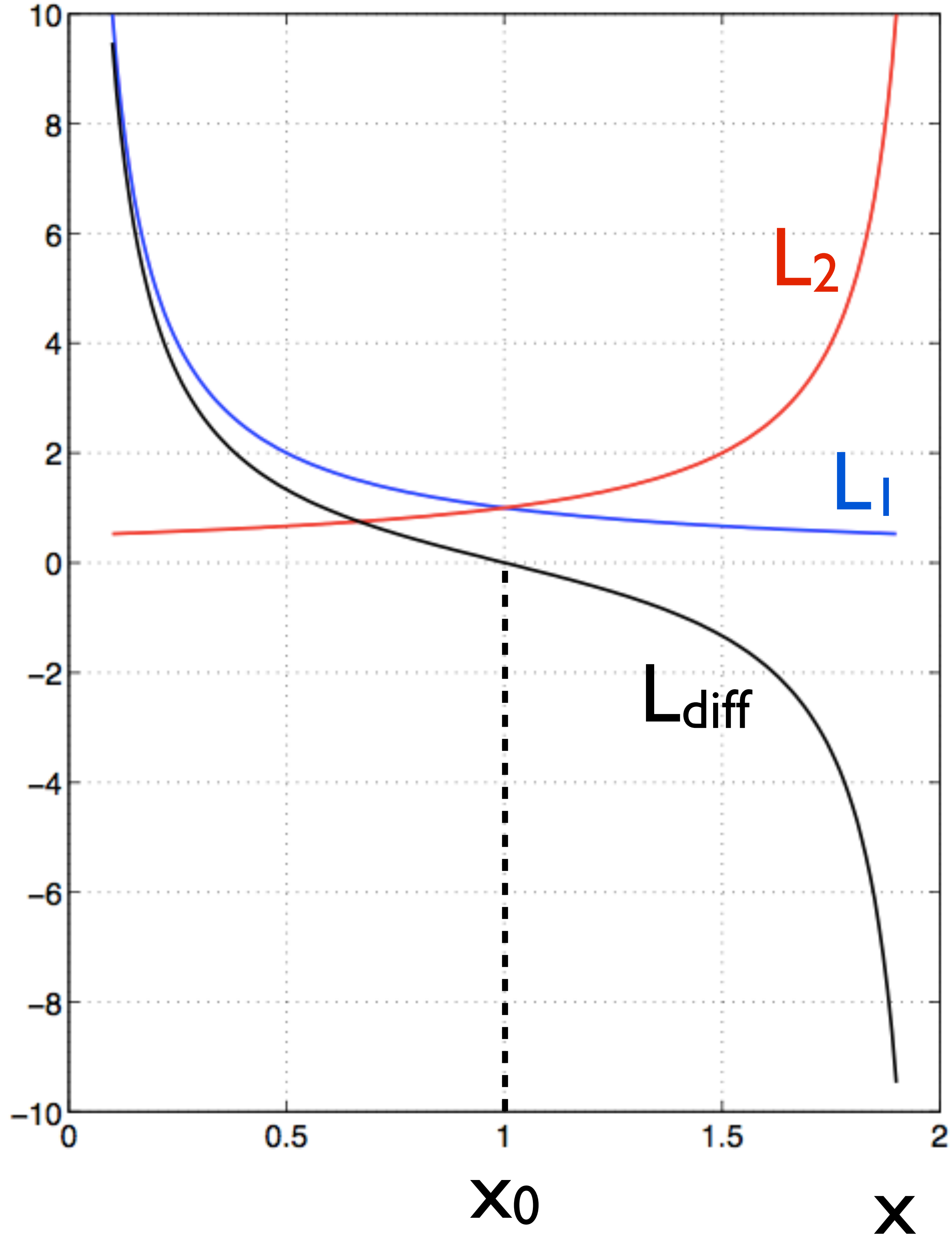




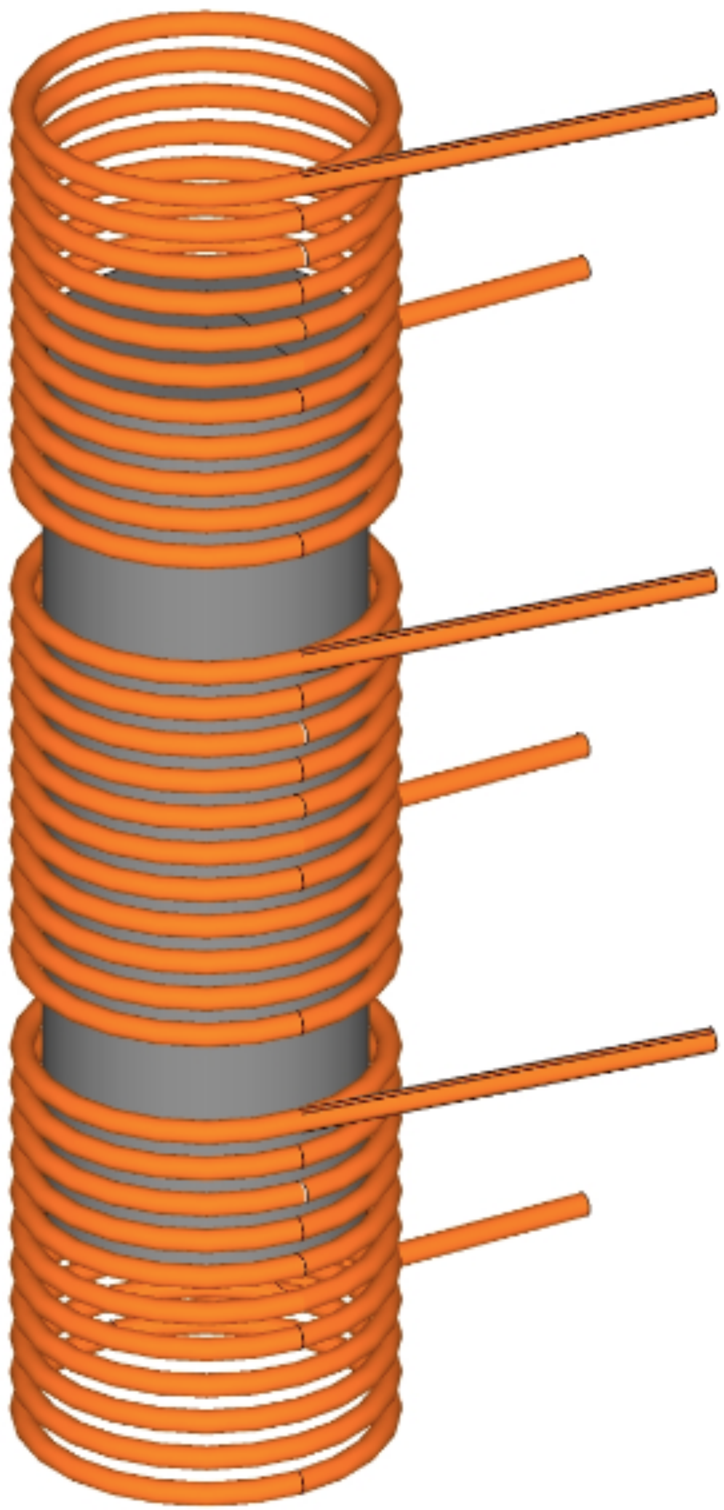
Differential inductive sensor



$$L_{diff} = L_1 - L_2$$



LVDT - Linear Variable Differential Transformer

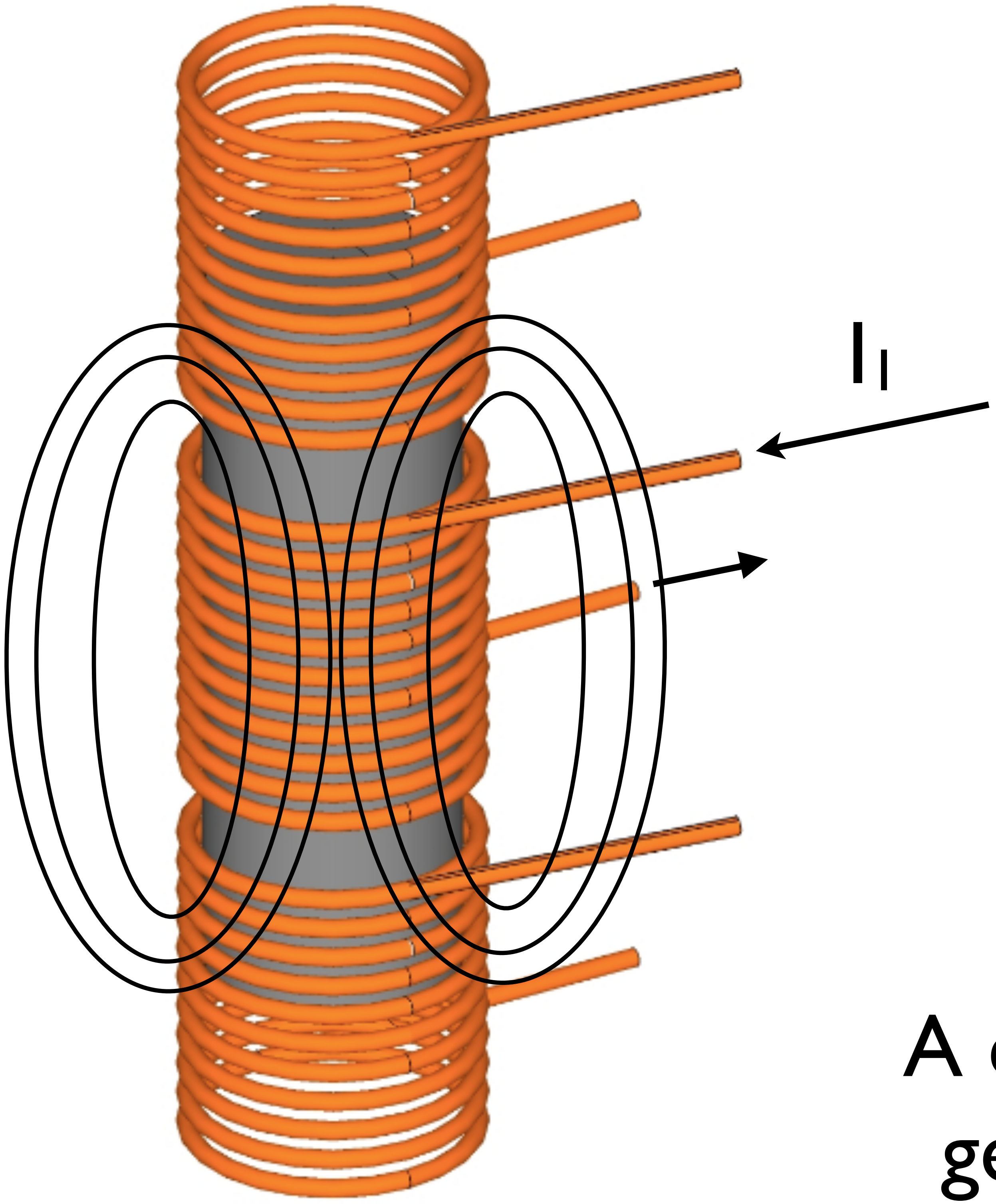


- It's a Transformer
(it works only in AC);

- it has one primary coil and
two secondary coils;

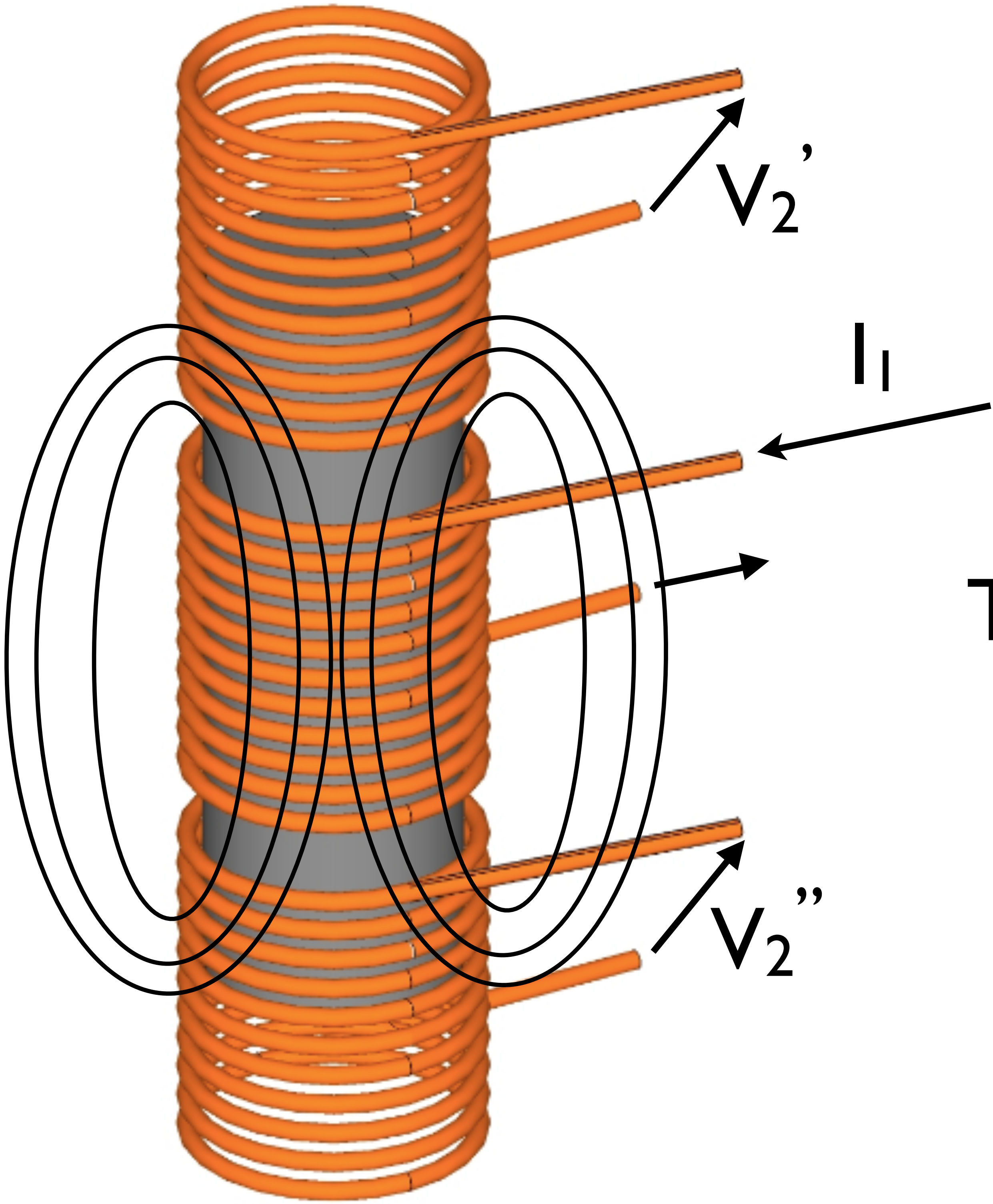
- it has a movable core.

LVDT - Linear Variable Differential Transformer



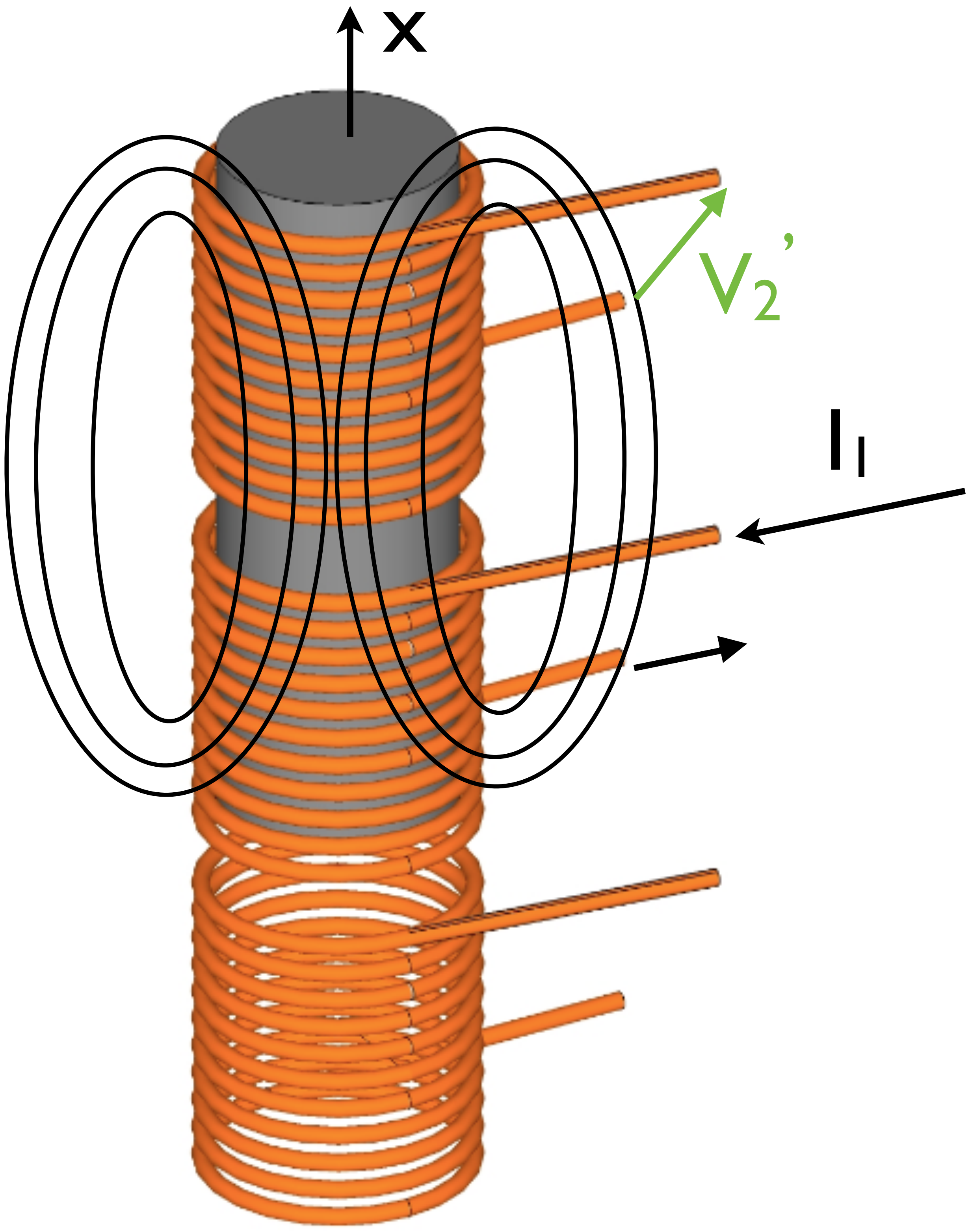
A current in the central coil generates a magnetic field

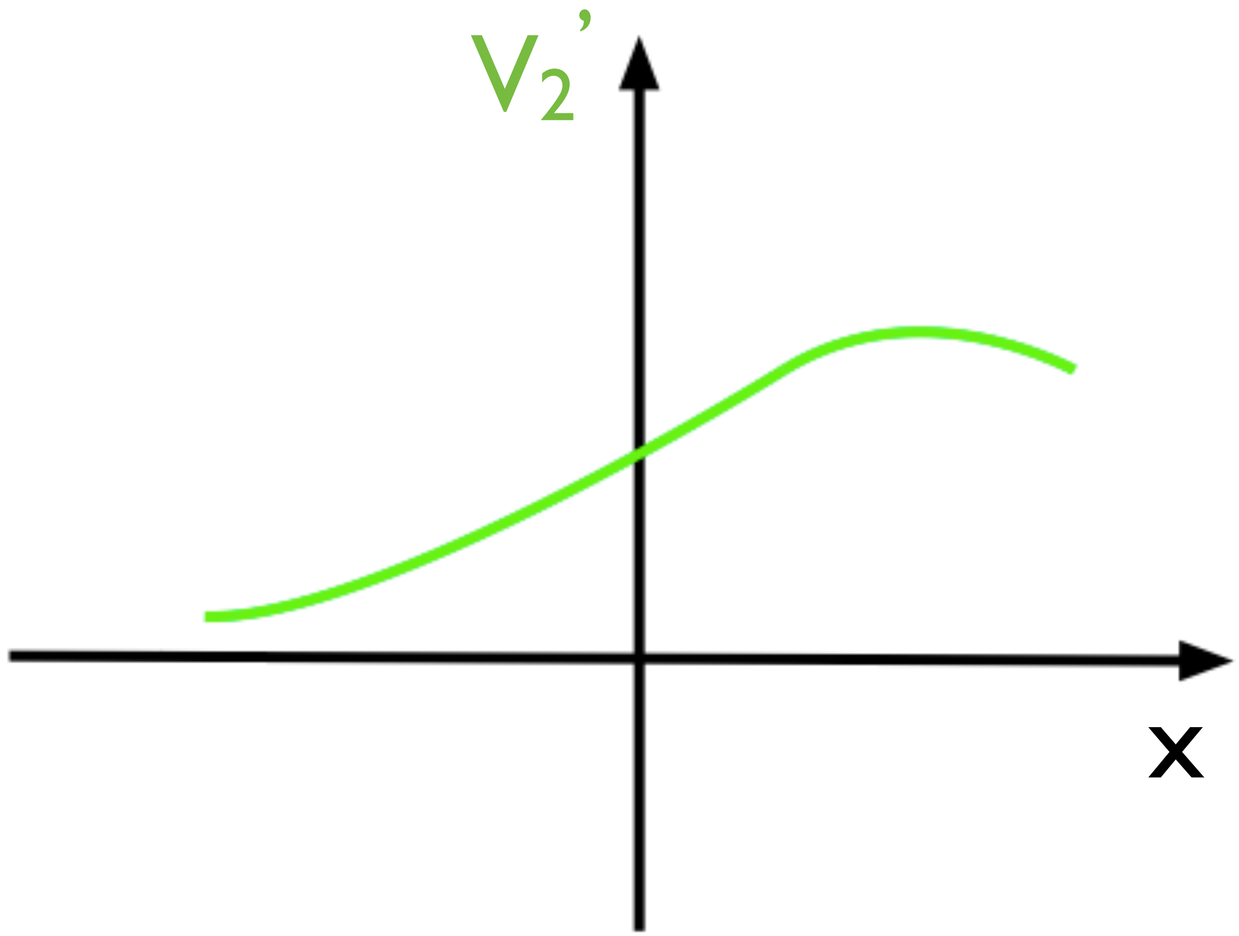
LVDT - Linear Variable Differential Transformer



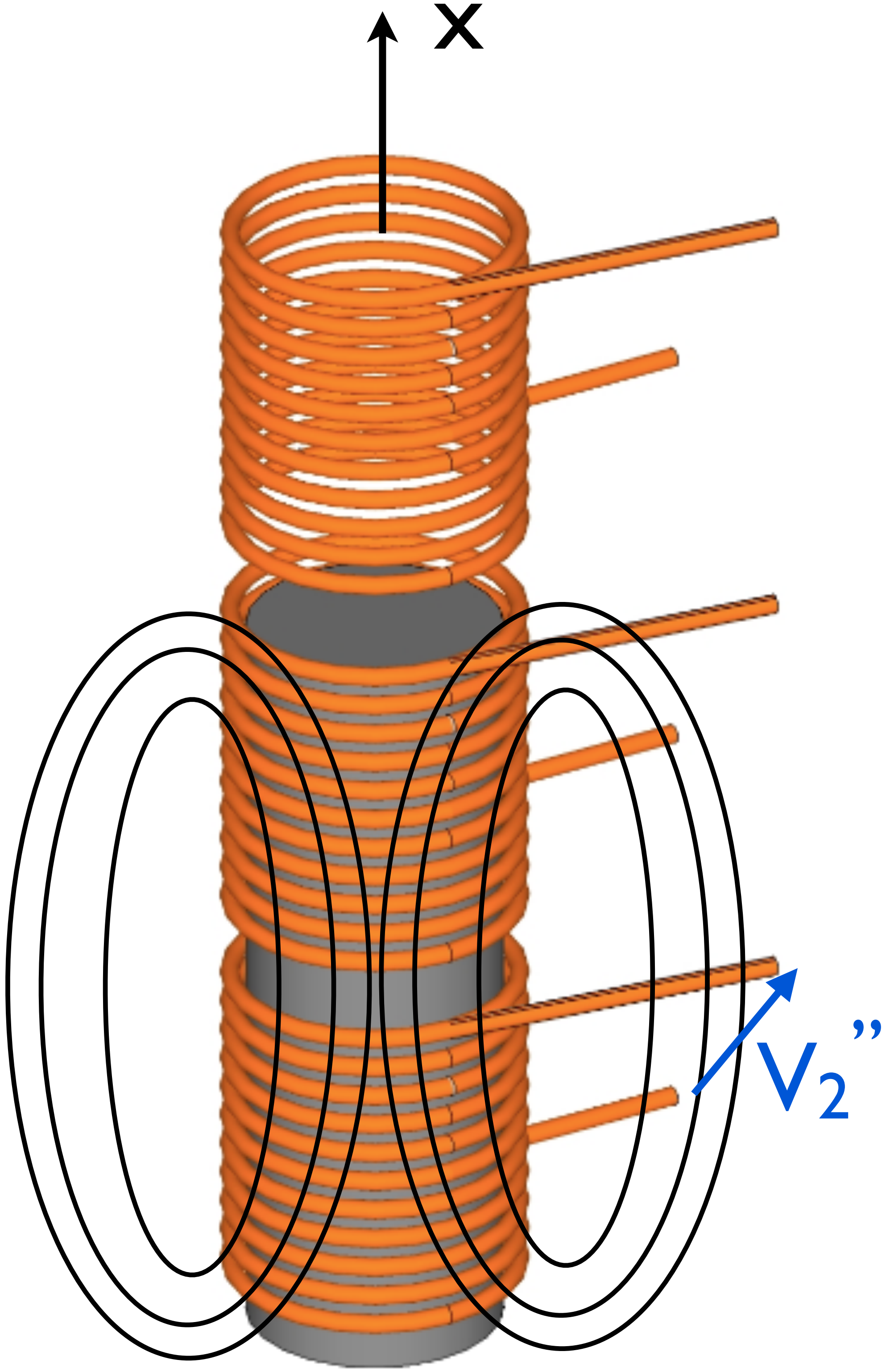
The time-varying magnetic field induces a voltage in the external coils

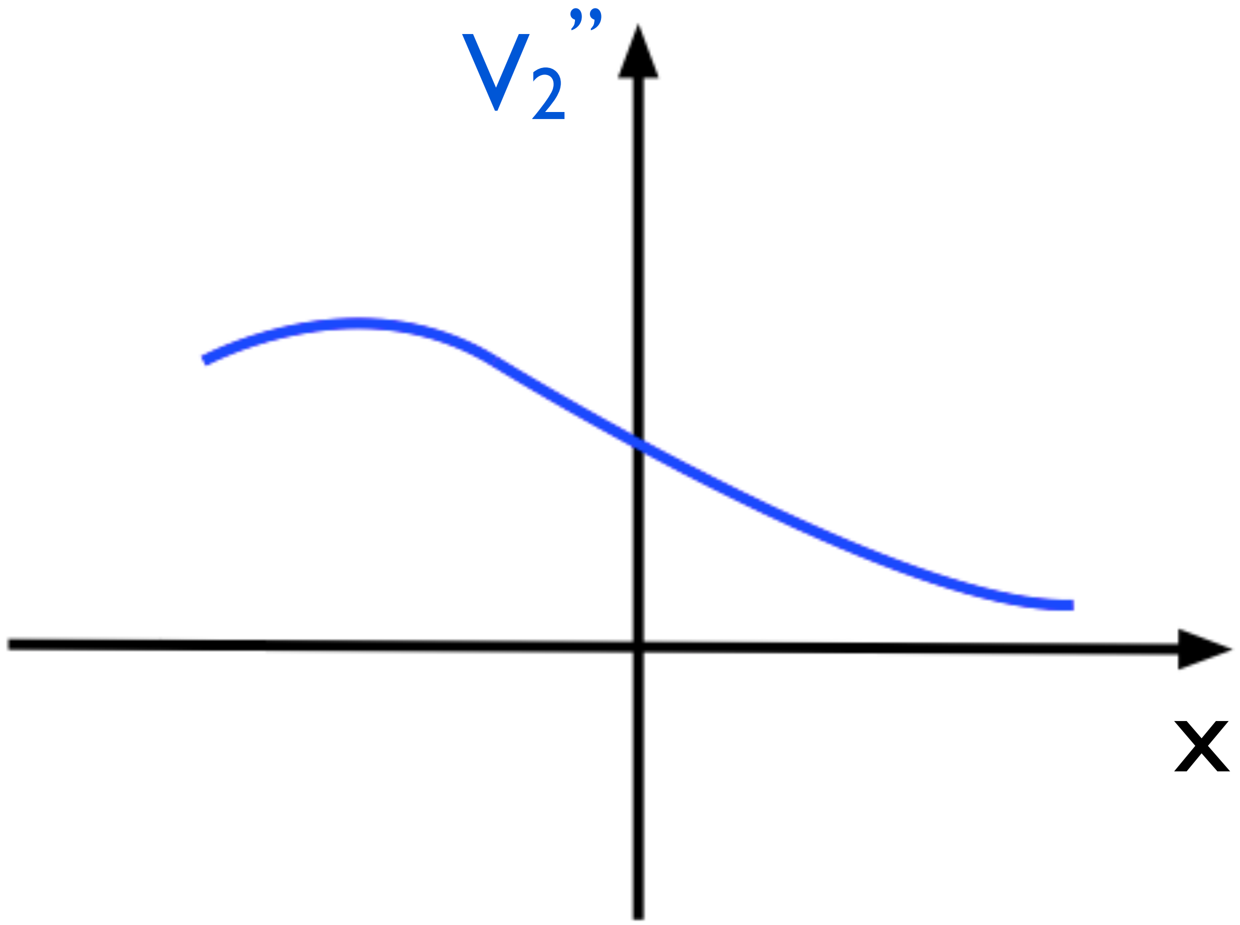
LVDT - Linear Variable Differential Transformer



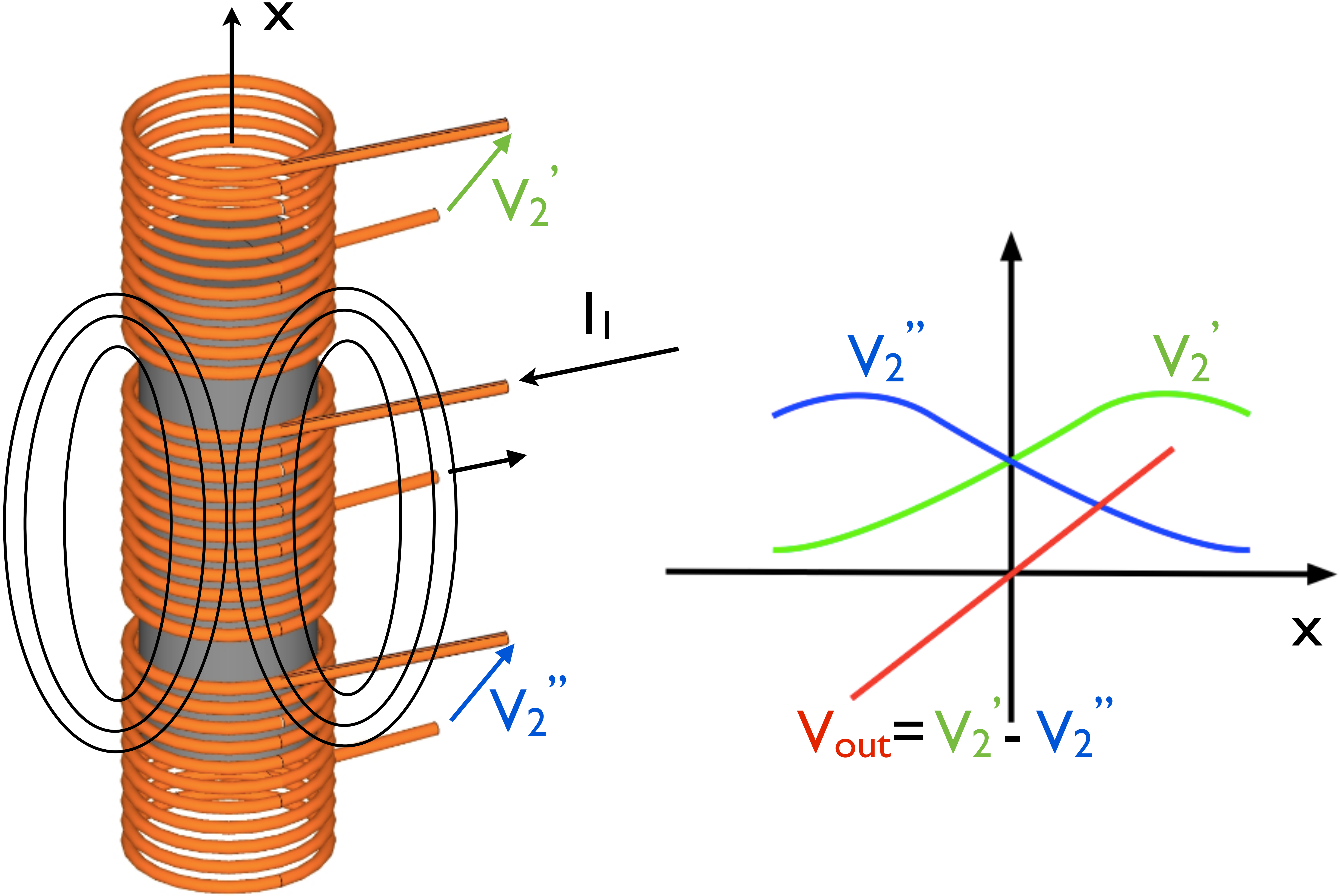


LVDT - Linear Variable Differential Transformer



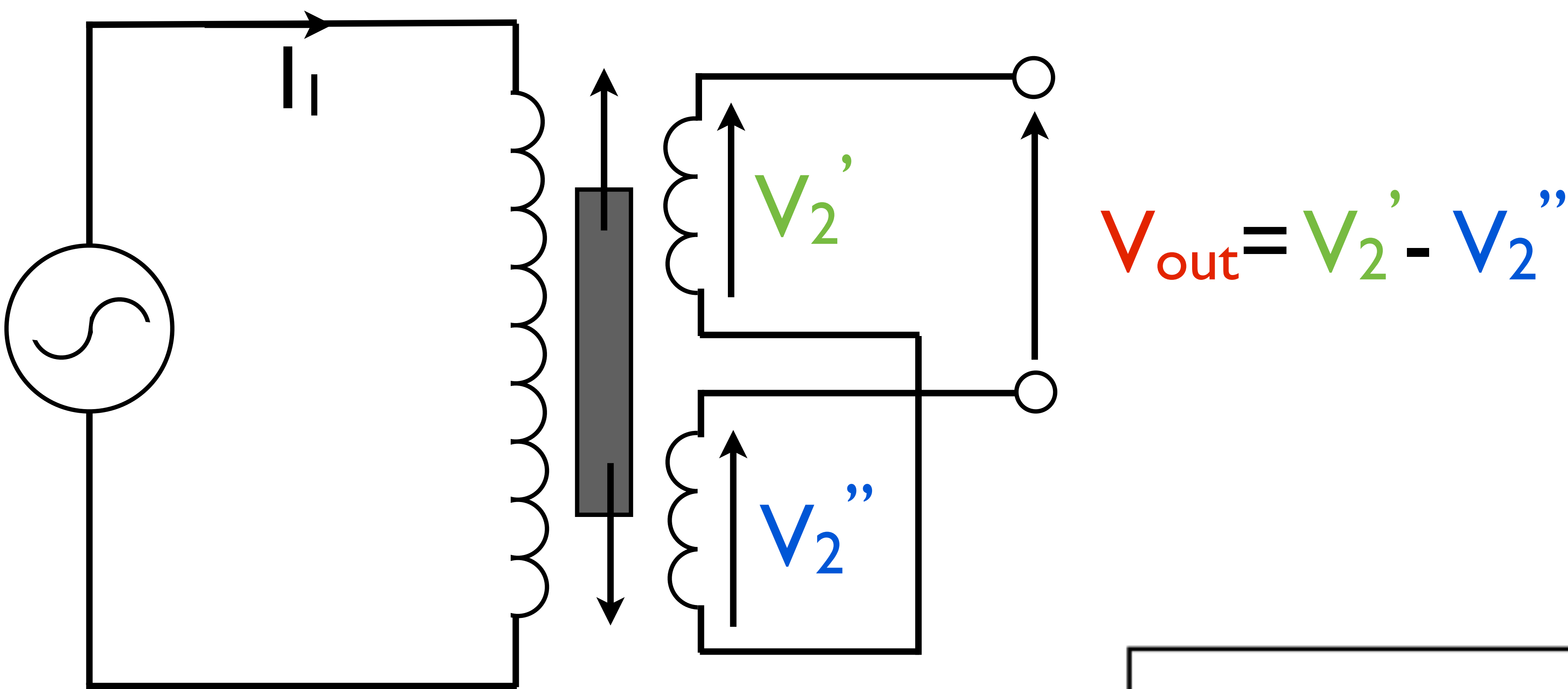


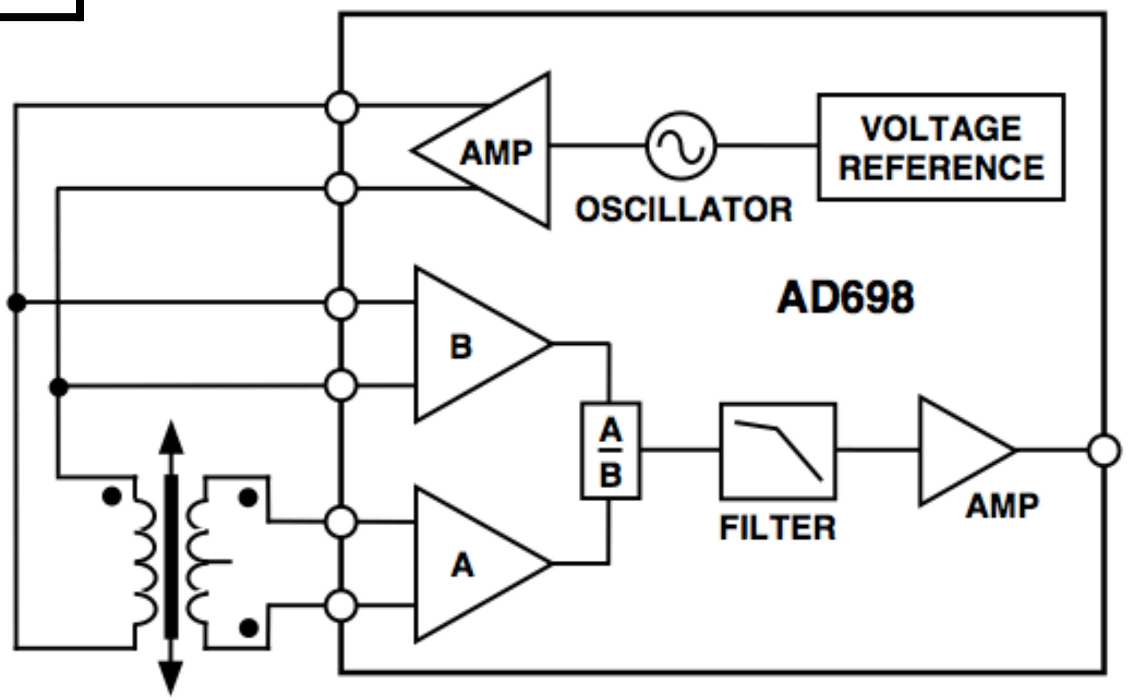
LVDT - Linear Variable Differential Transformer



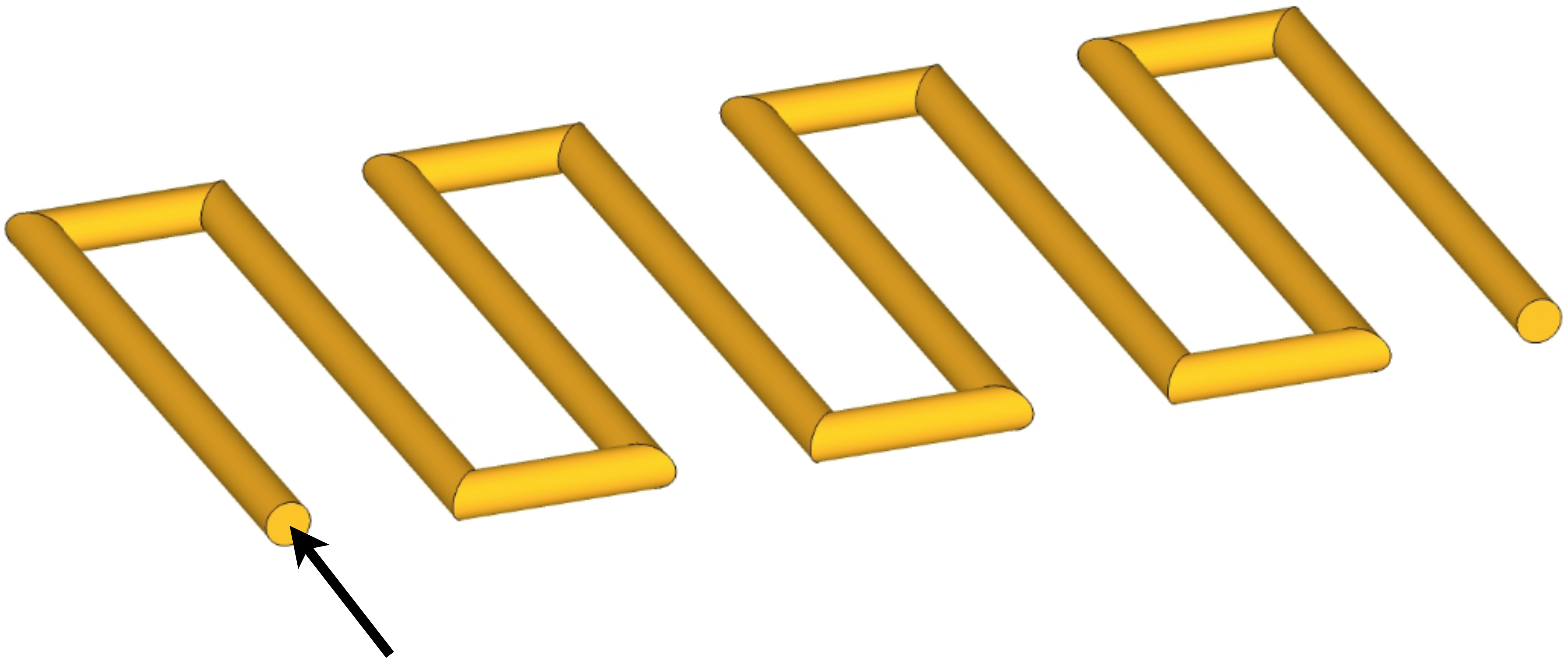
LVDT - Linear Variable Differential Transformer

Scheme

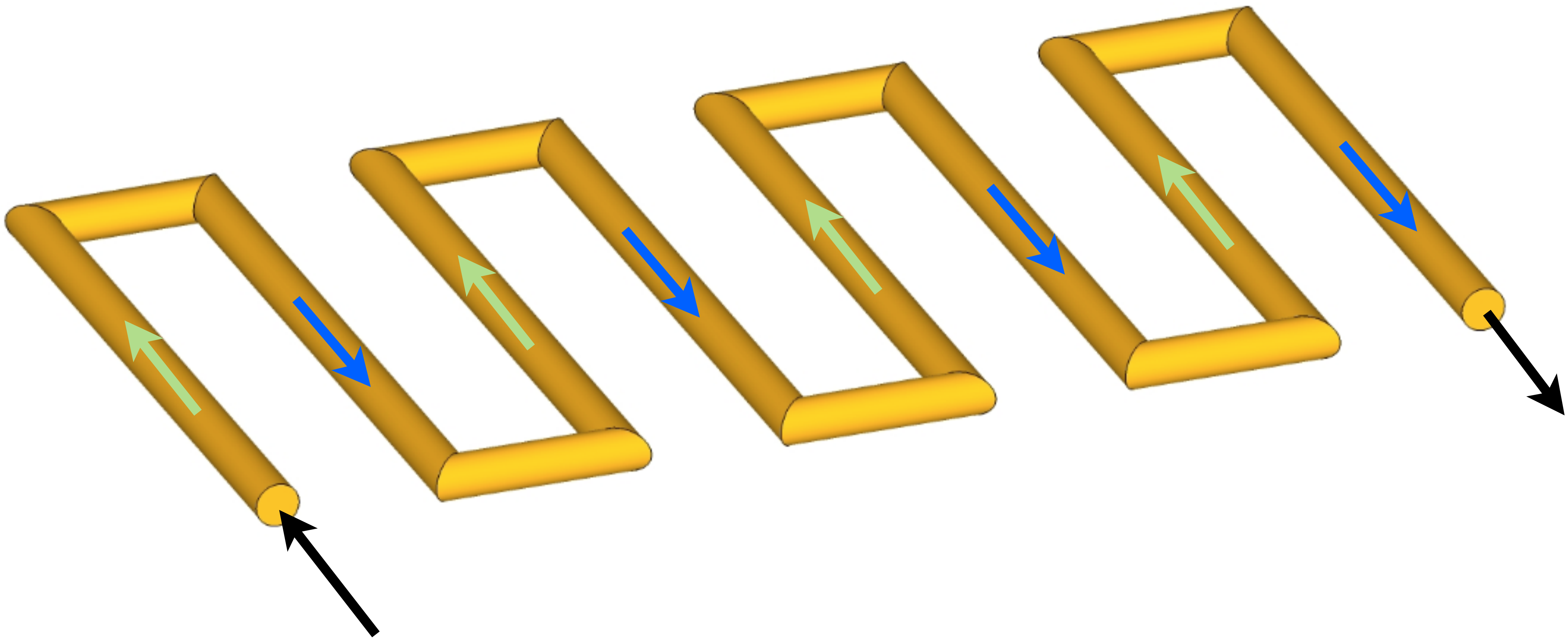




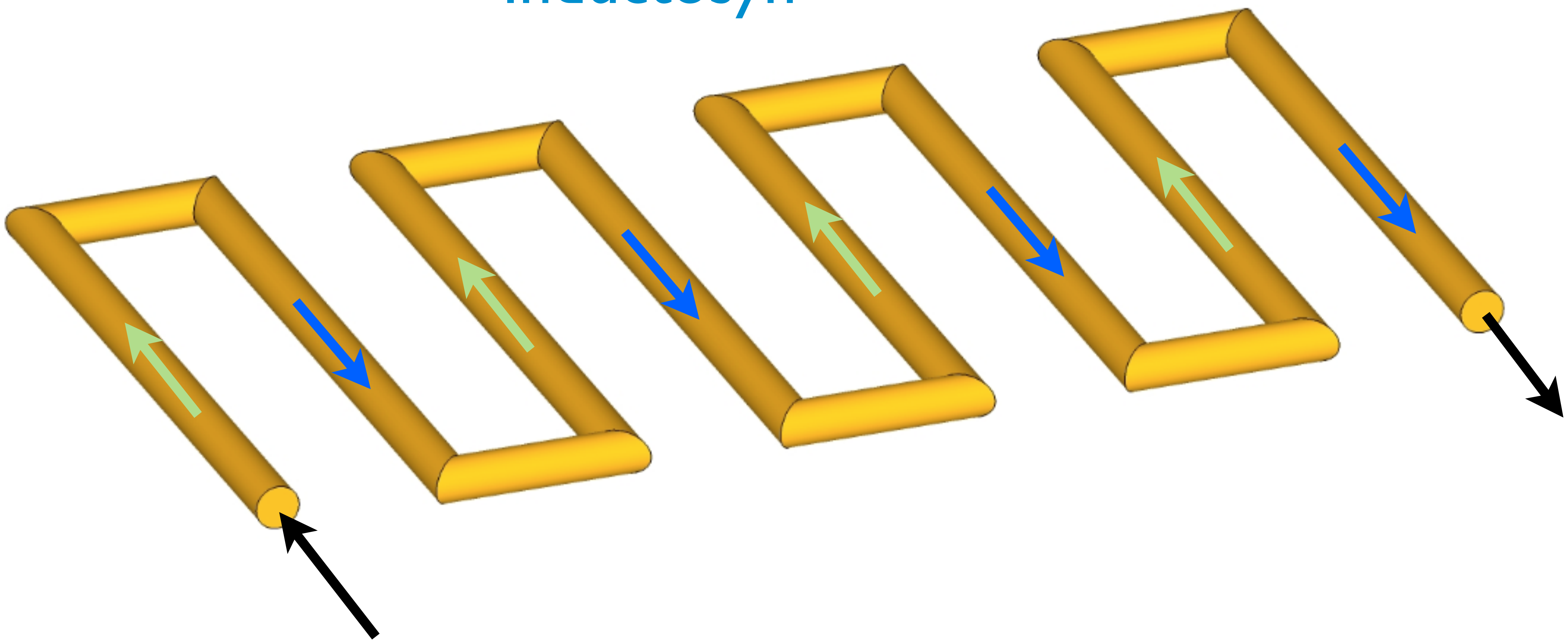
Inductosyn

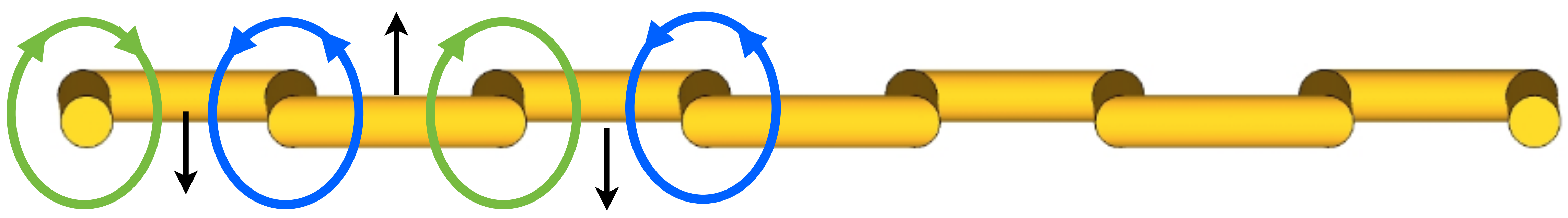


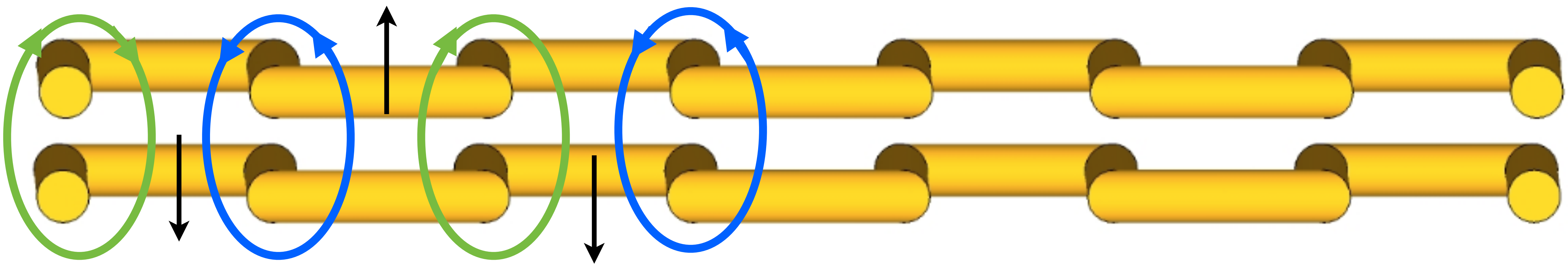
Inductosyn



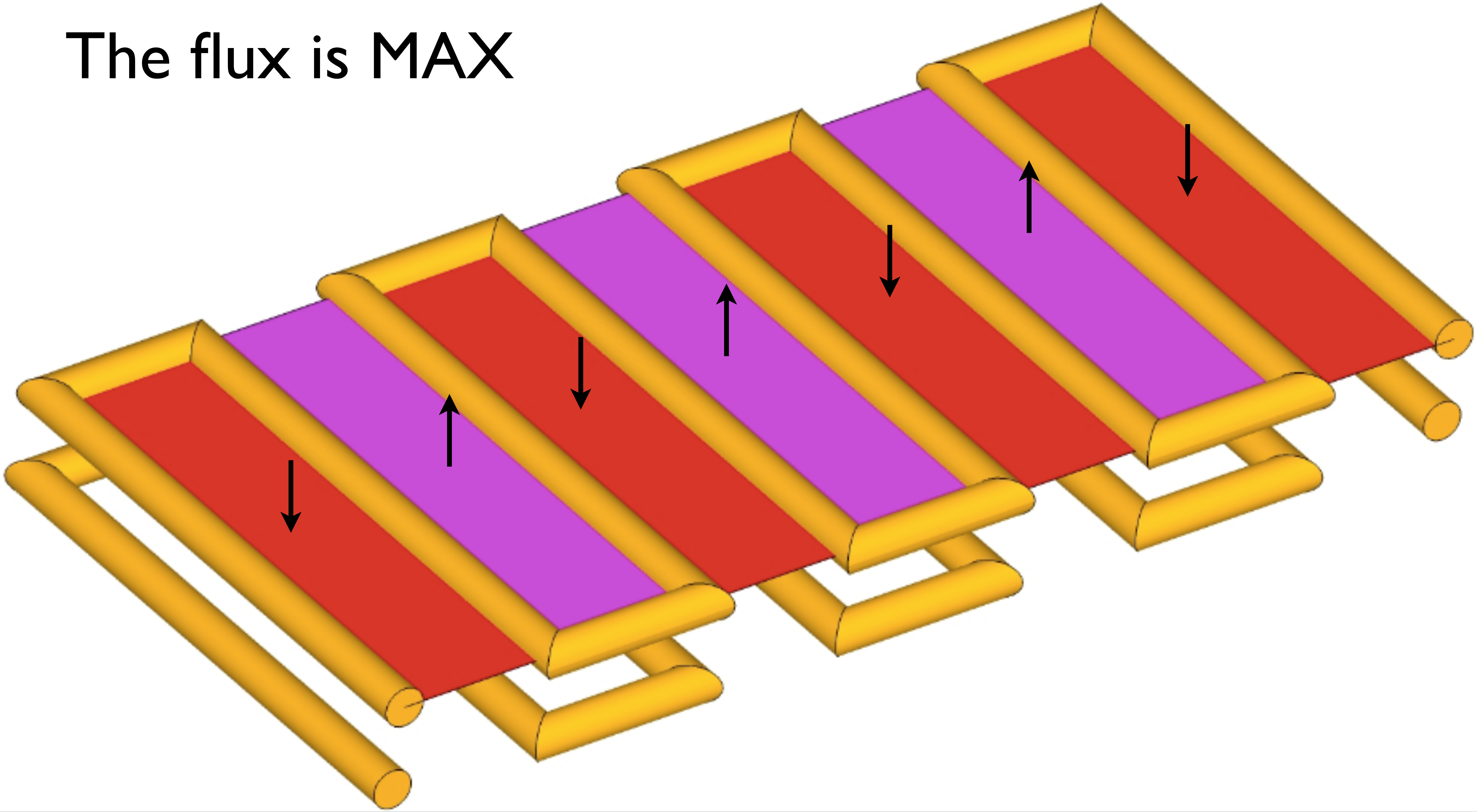
Inductosyn

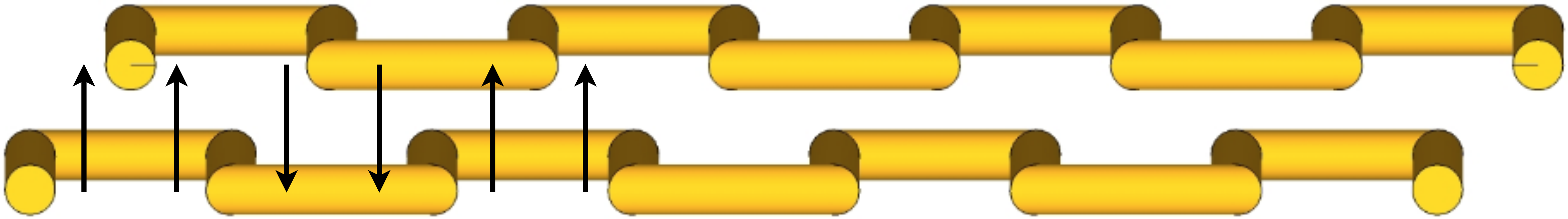




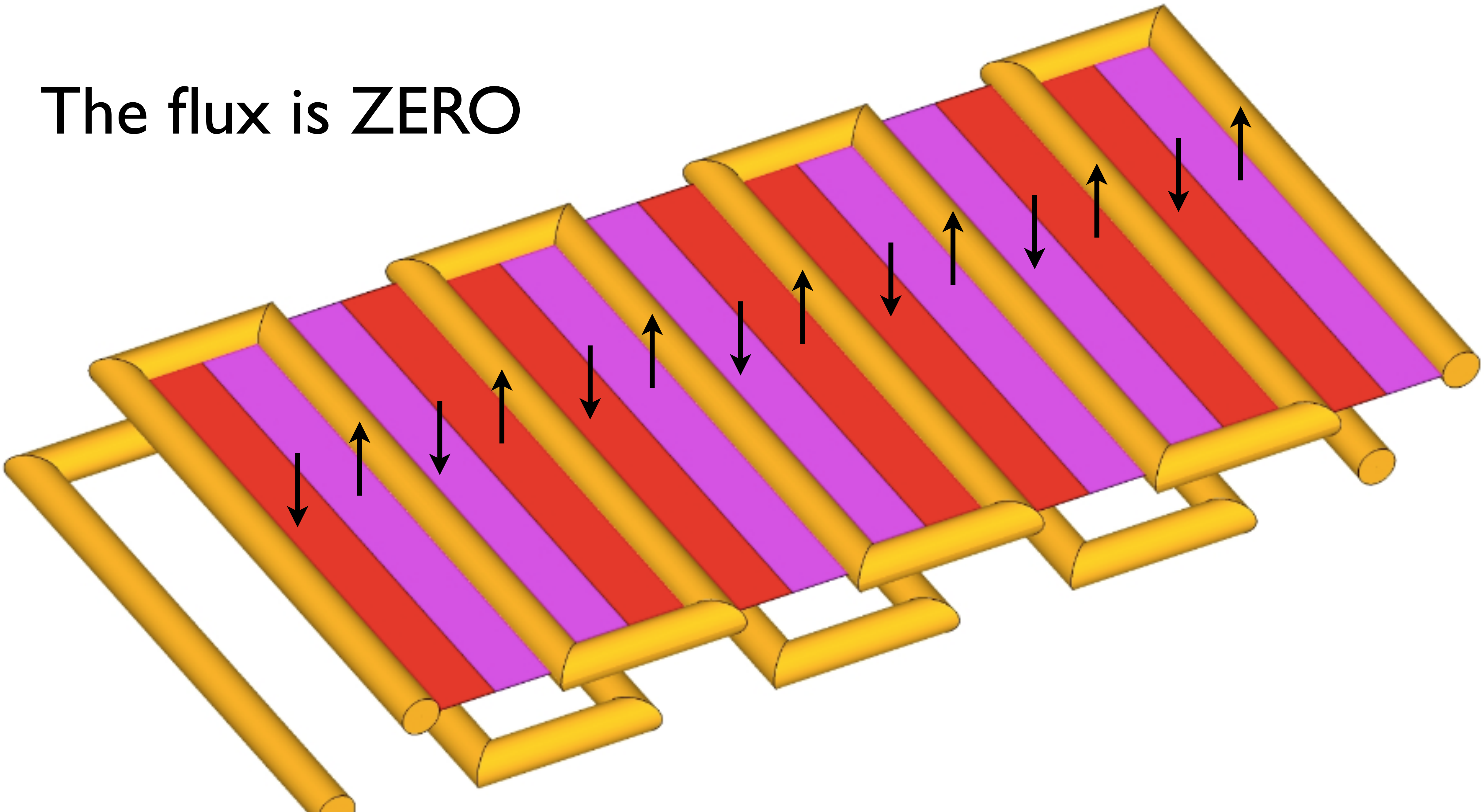


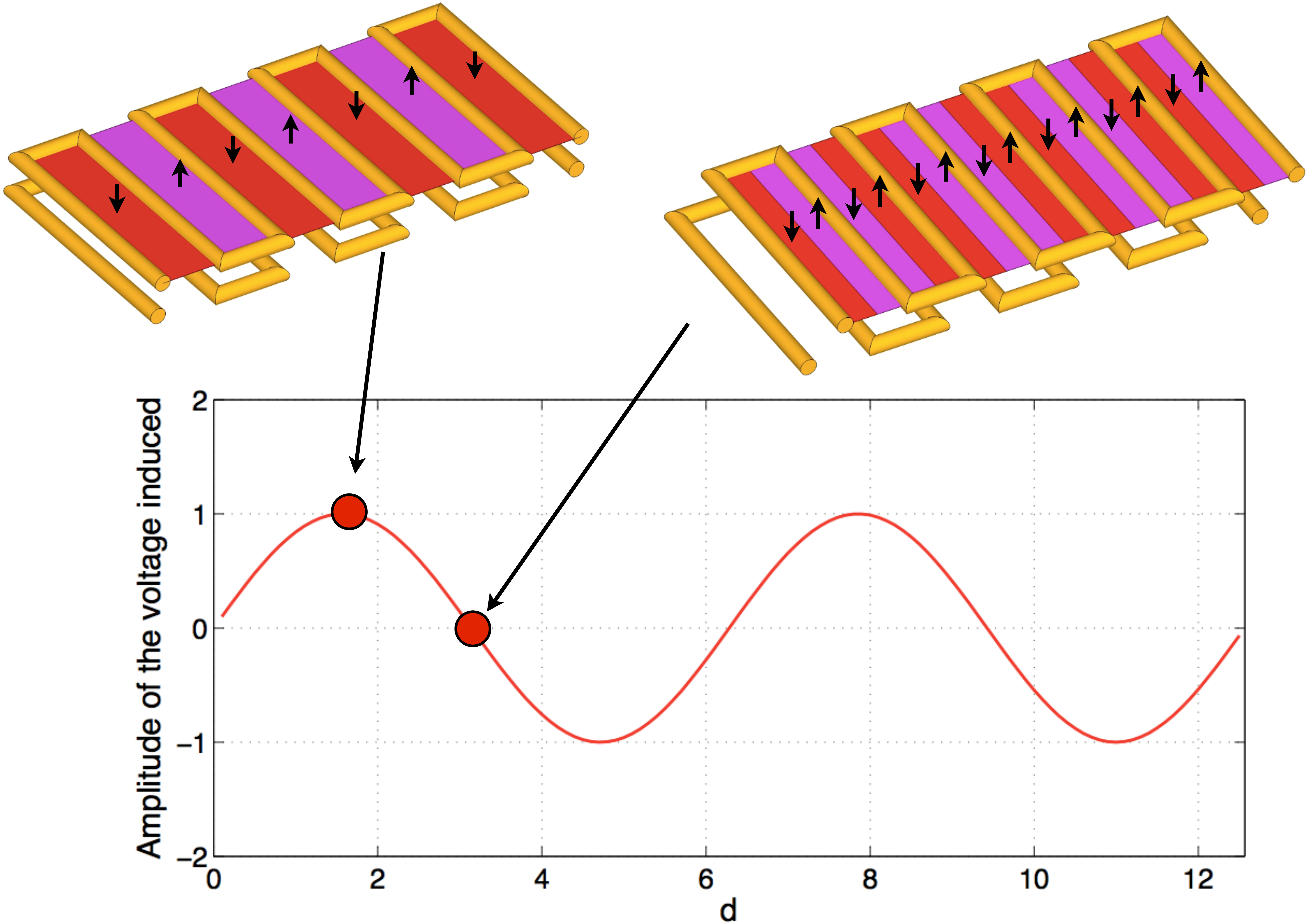
The flux is MAX



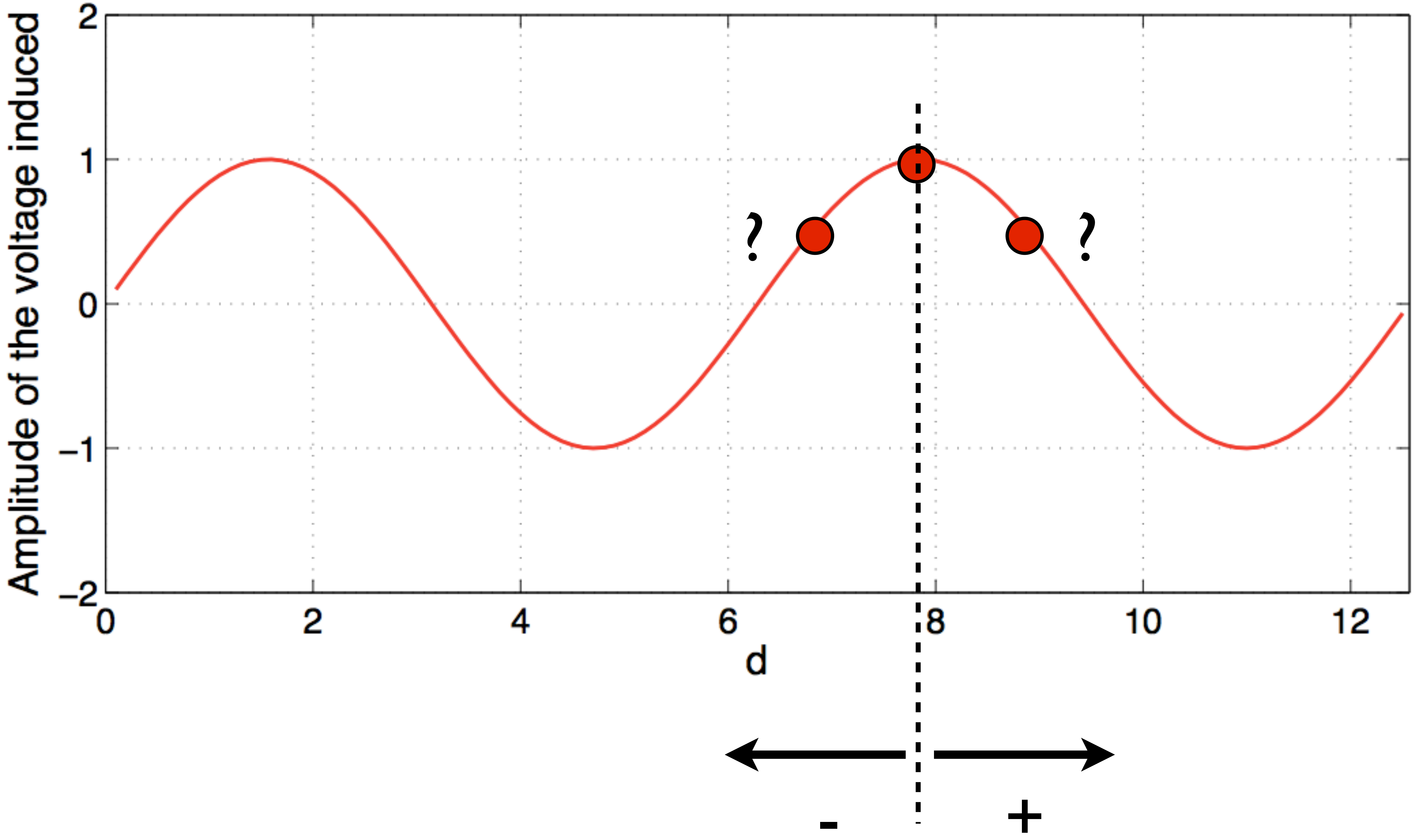


The flux is ZERO



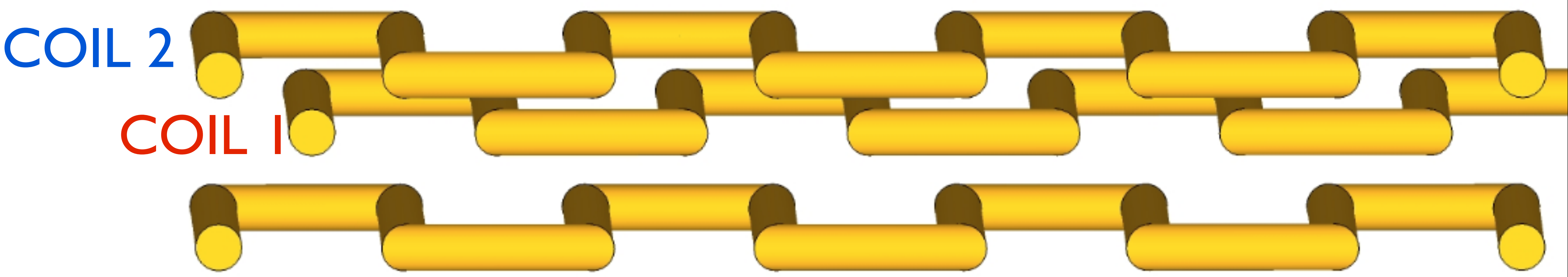

Amplitude of the voltage induced
d
2
1
0
−1
−2
0
2
4
6
8
10
12

Inductosyn
- problem -



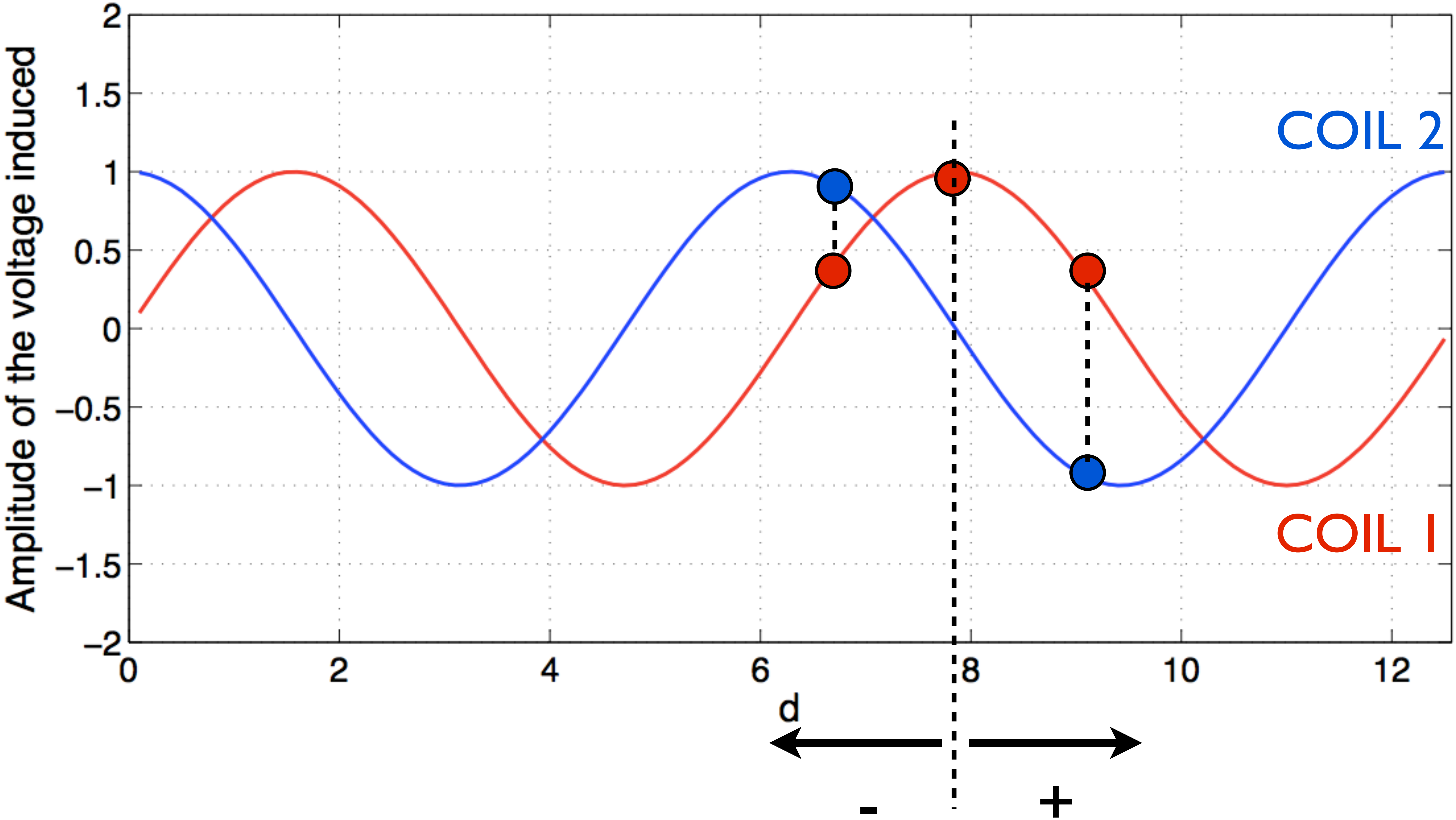
Inductosyn

- solution -

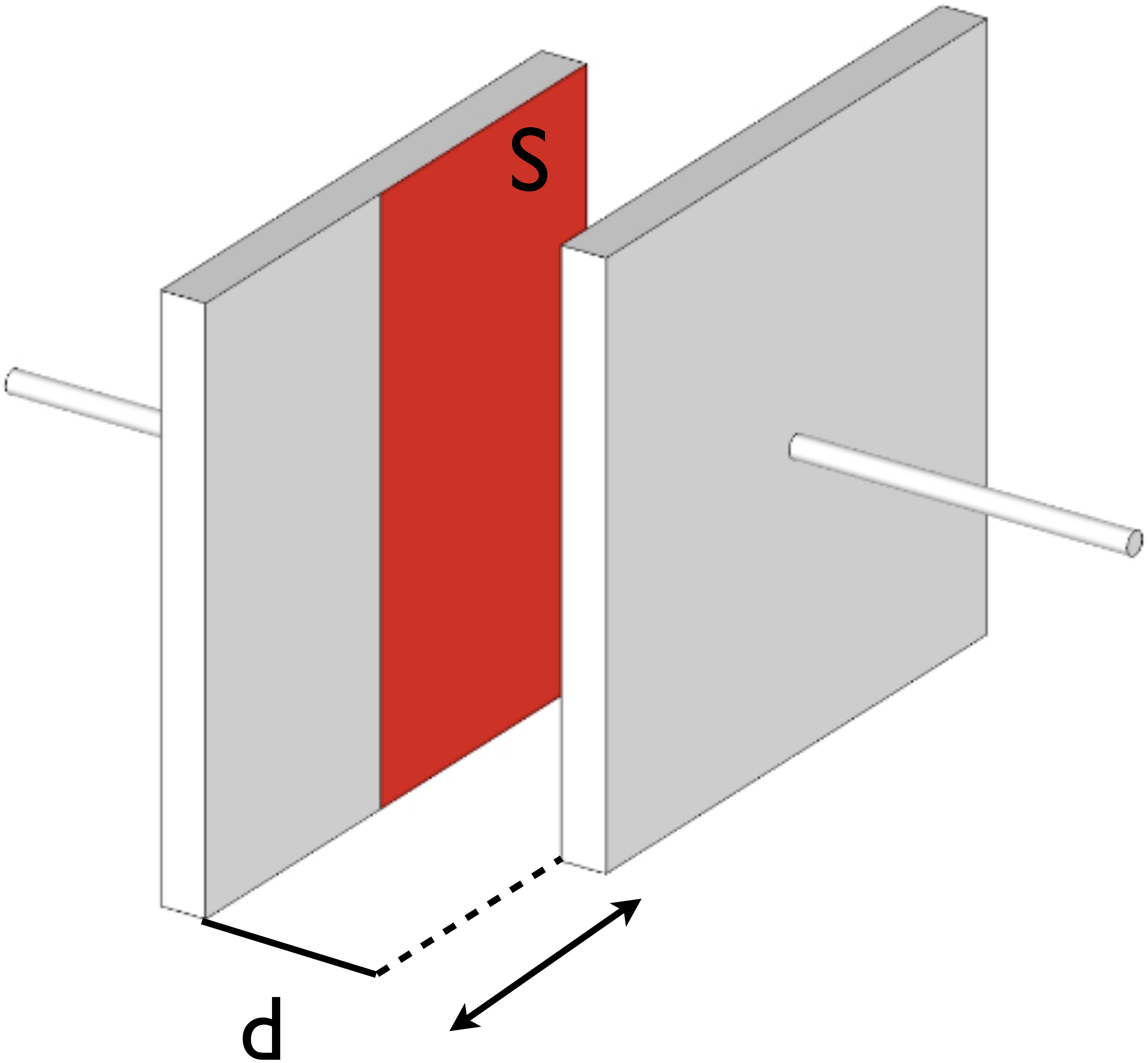


Inductosyn

- solution -

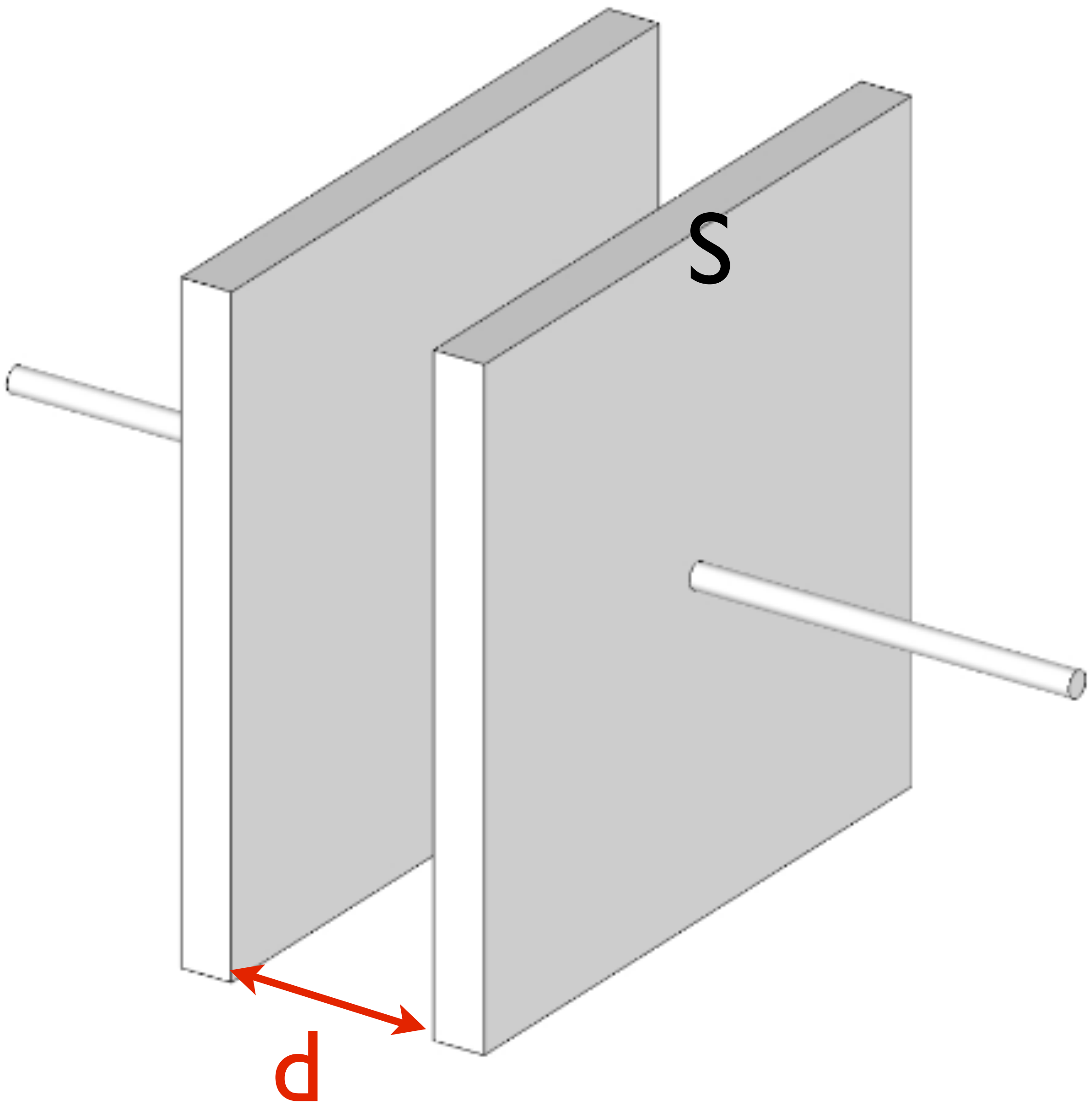


Capacitive sensor

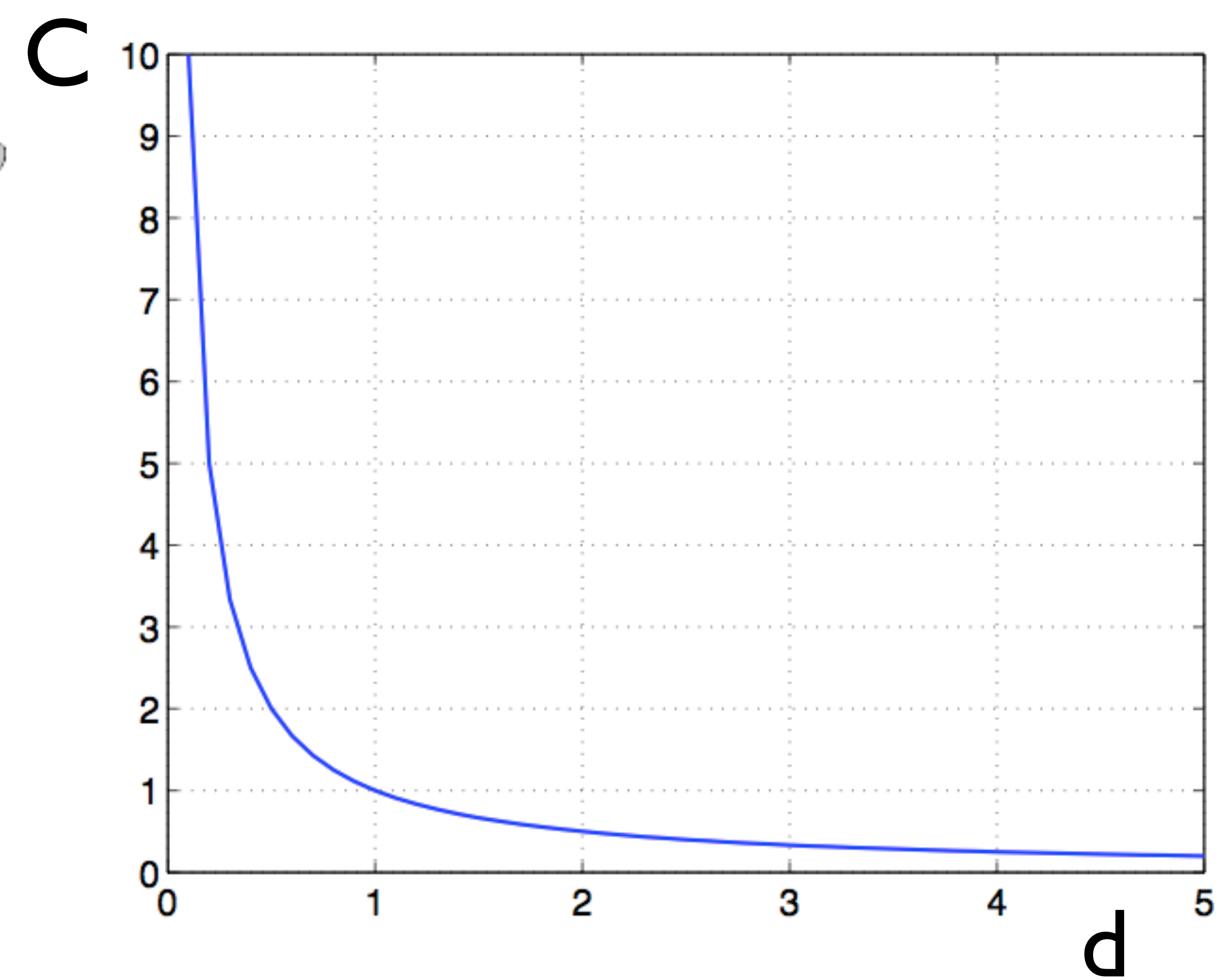


$$C = \varepsilon \frac{S}{d}$$

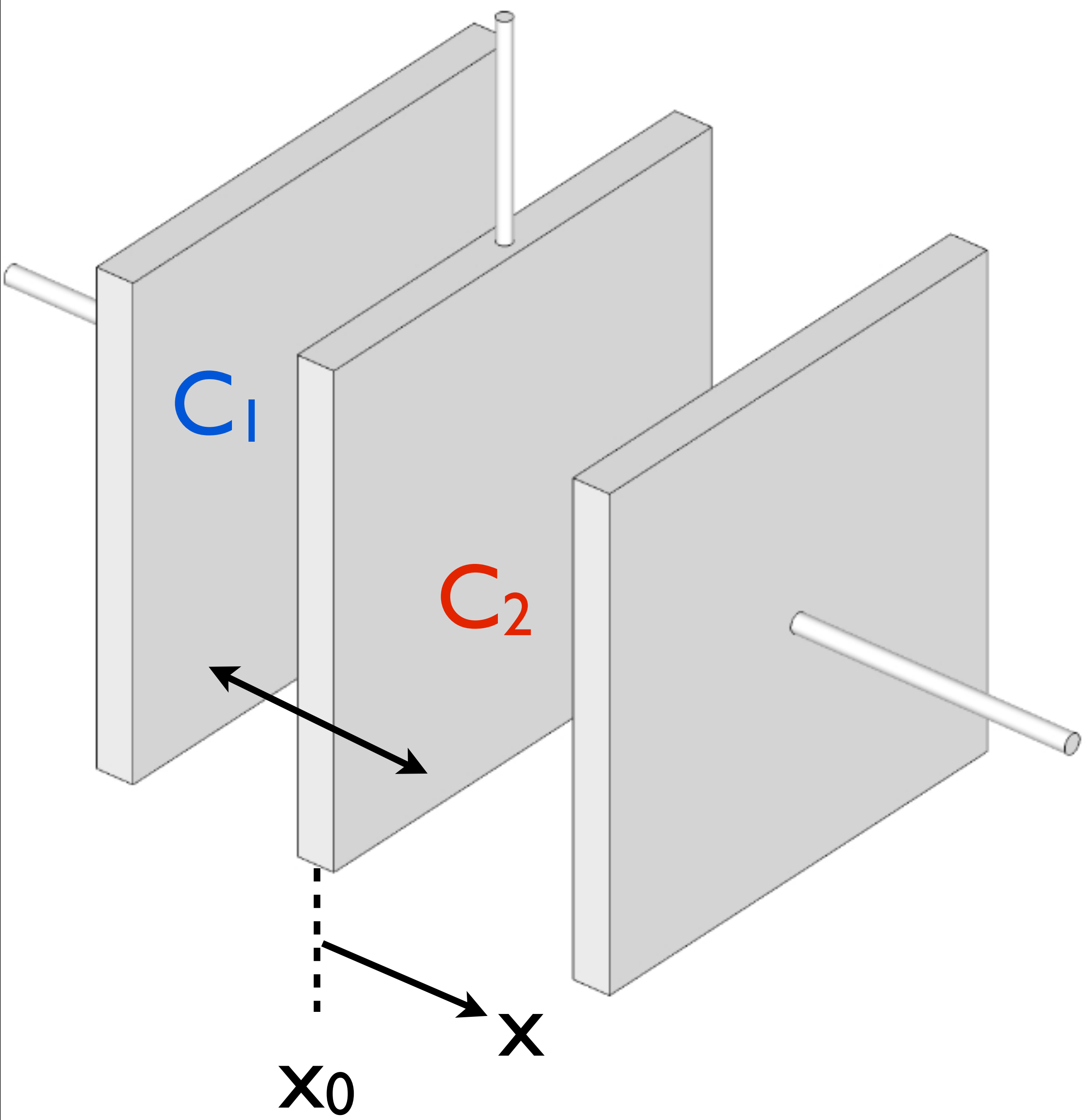
Capacitive sensor

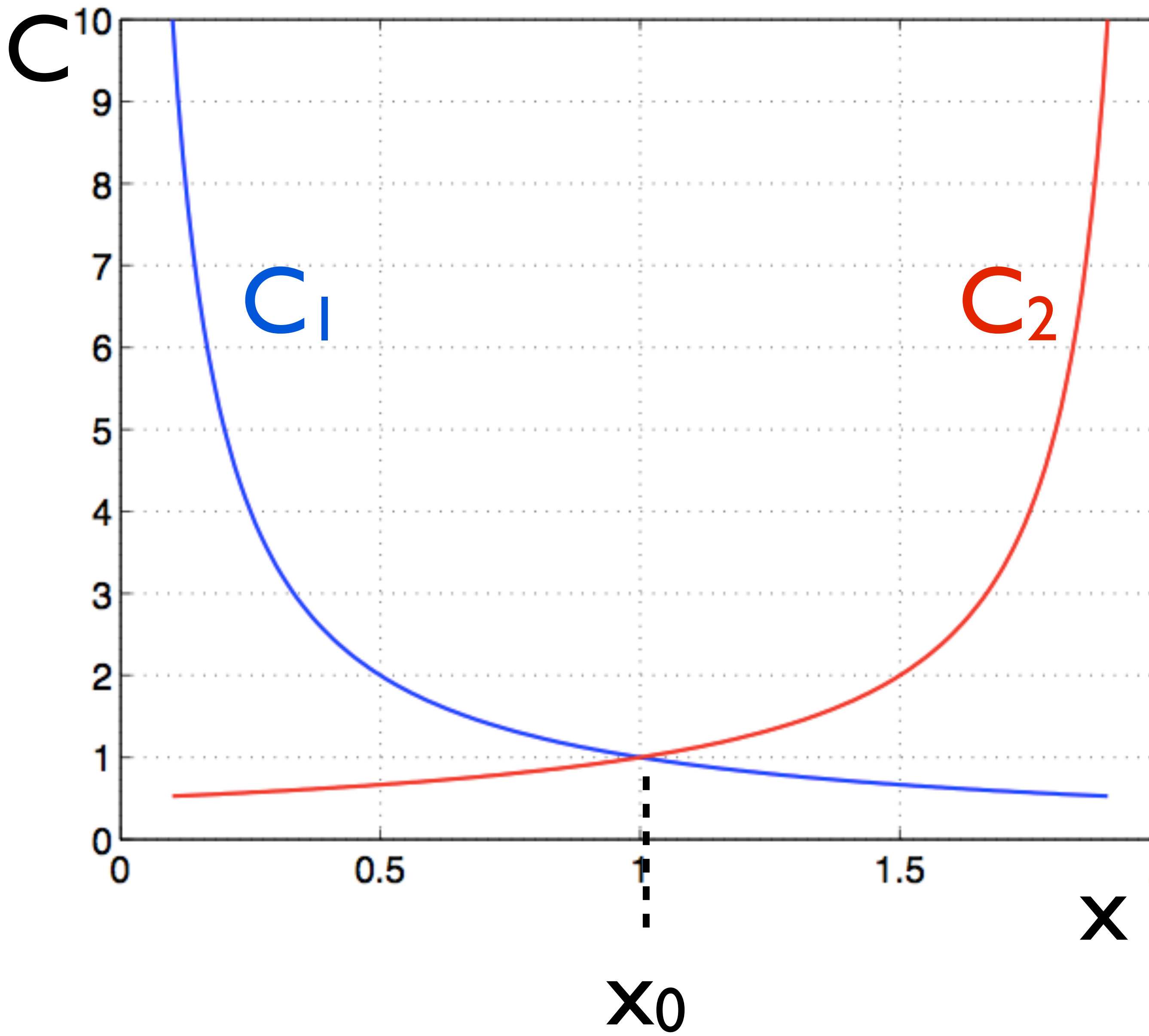


$$C = \varepsilon \frac{S}{d}$$

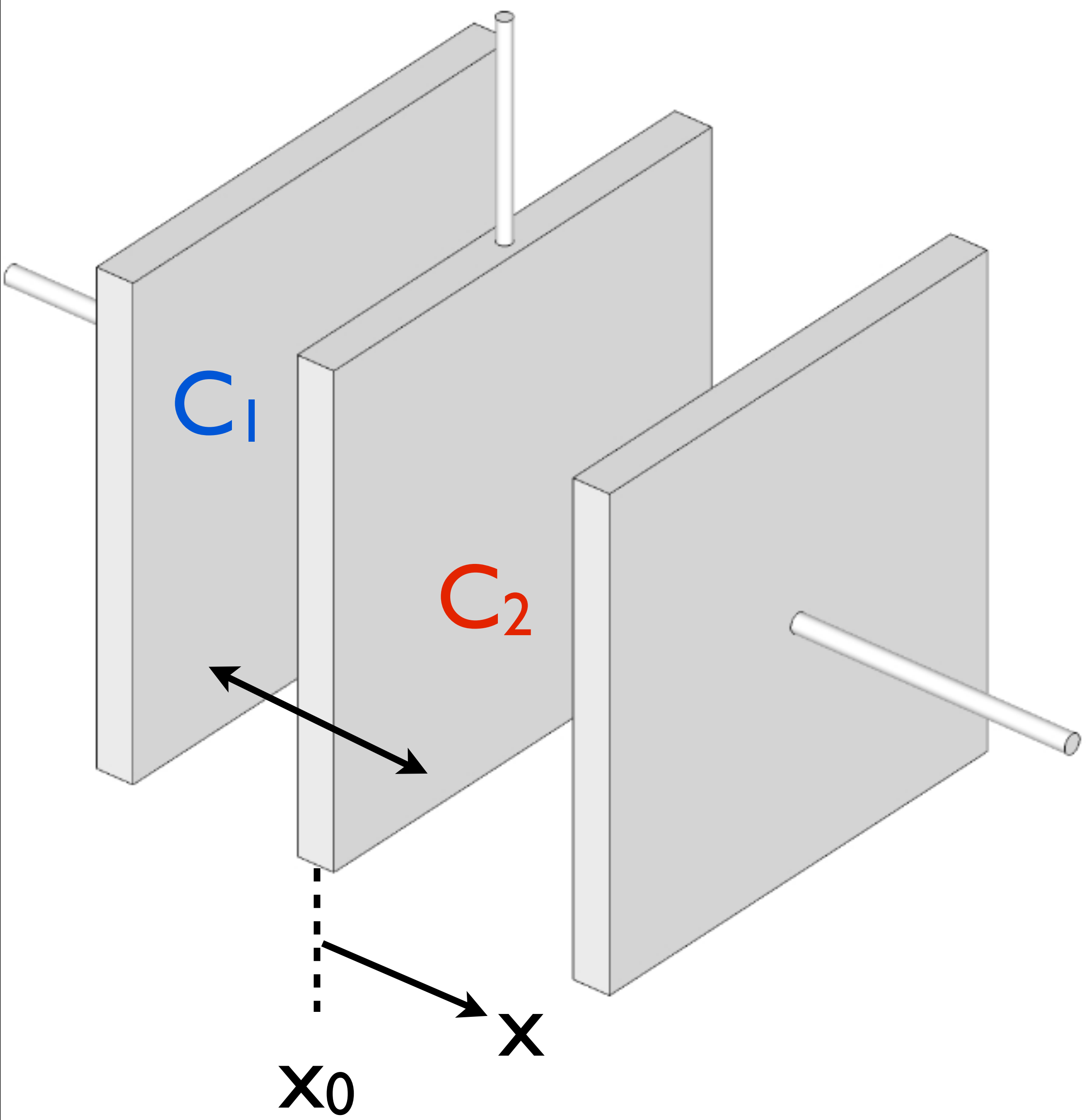


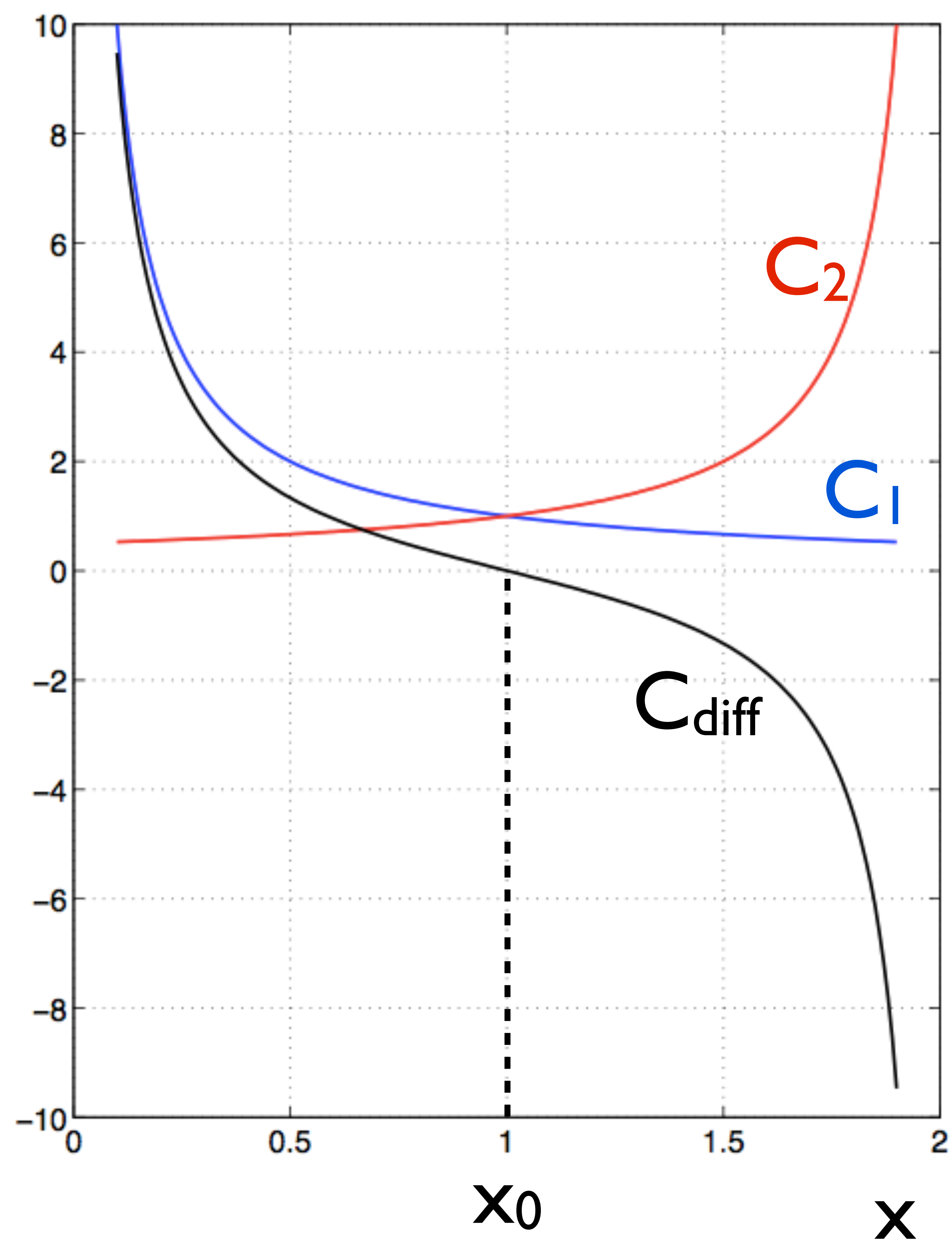
Capacitive sensor





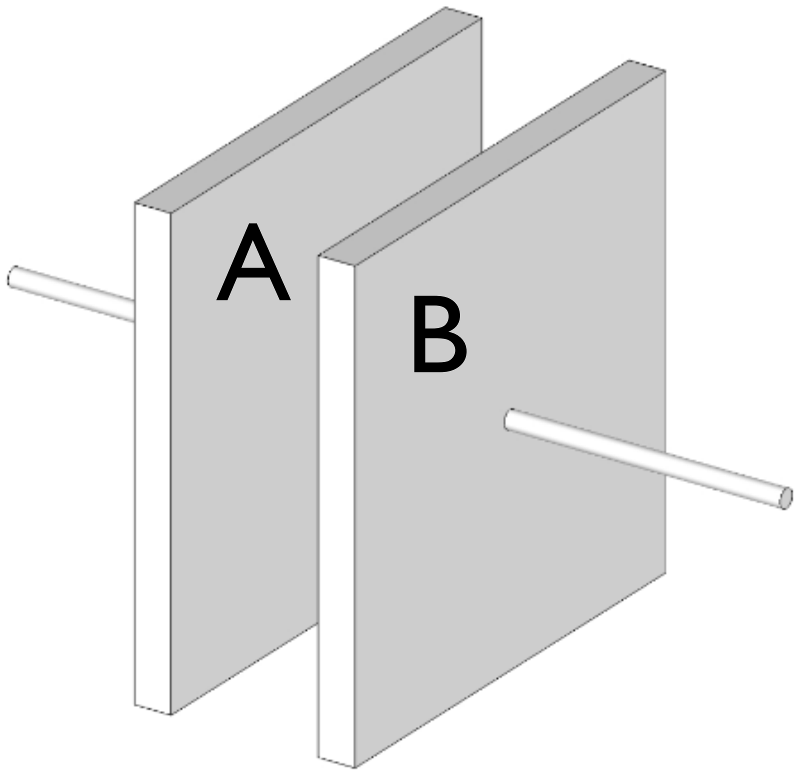
Capacitive sensor

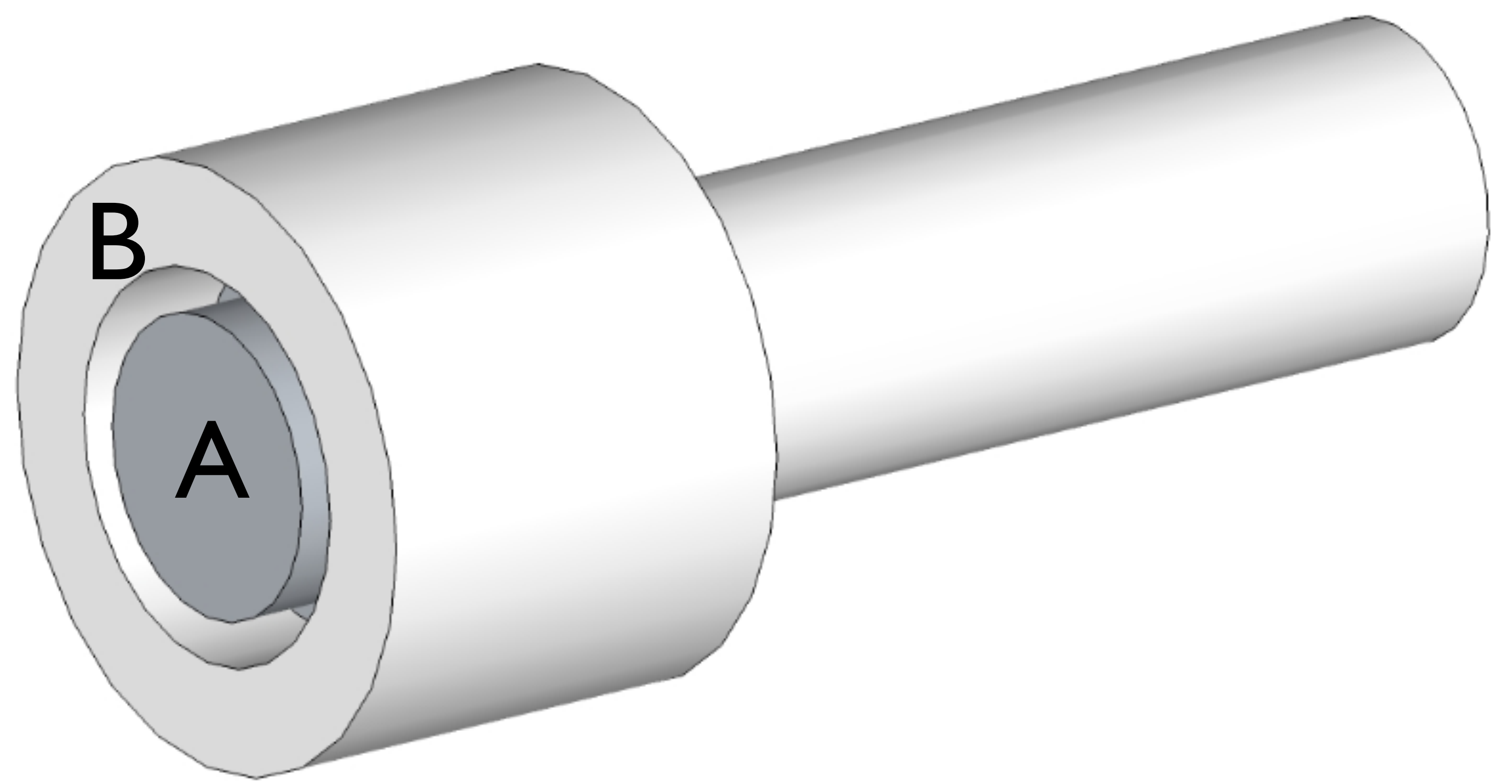




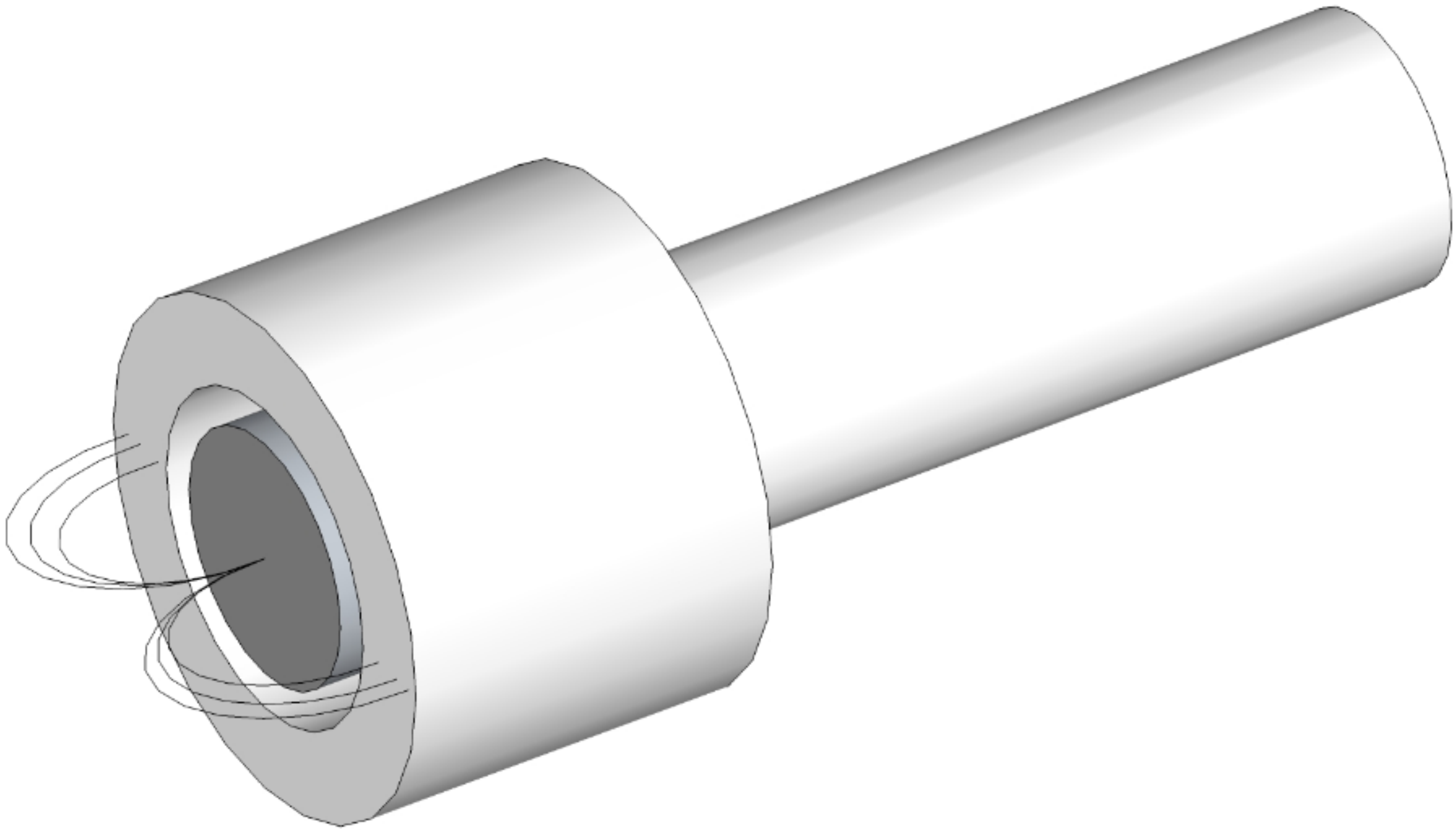
$C_{diff} = C_1 - C_2$

Capacitive Proximity sensor

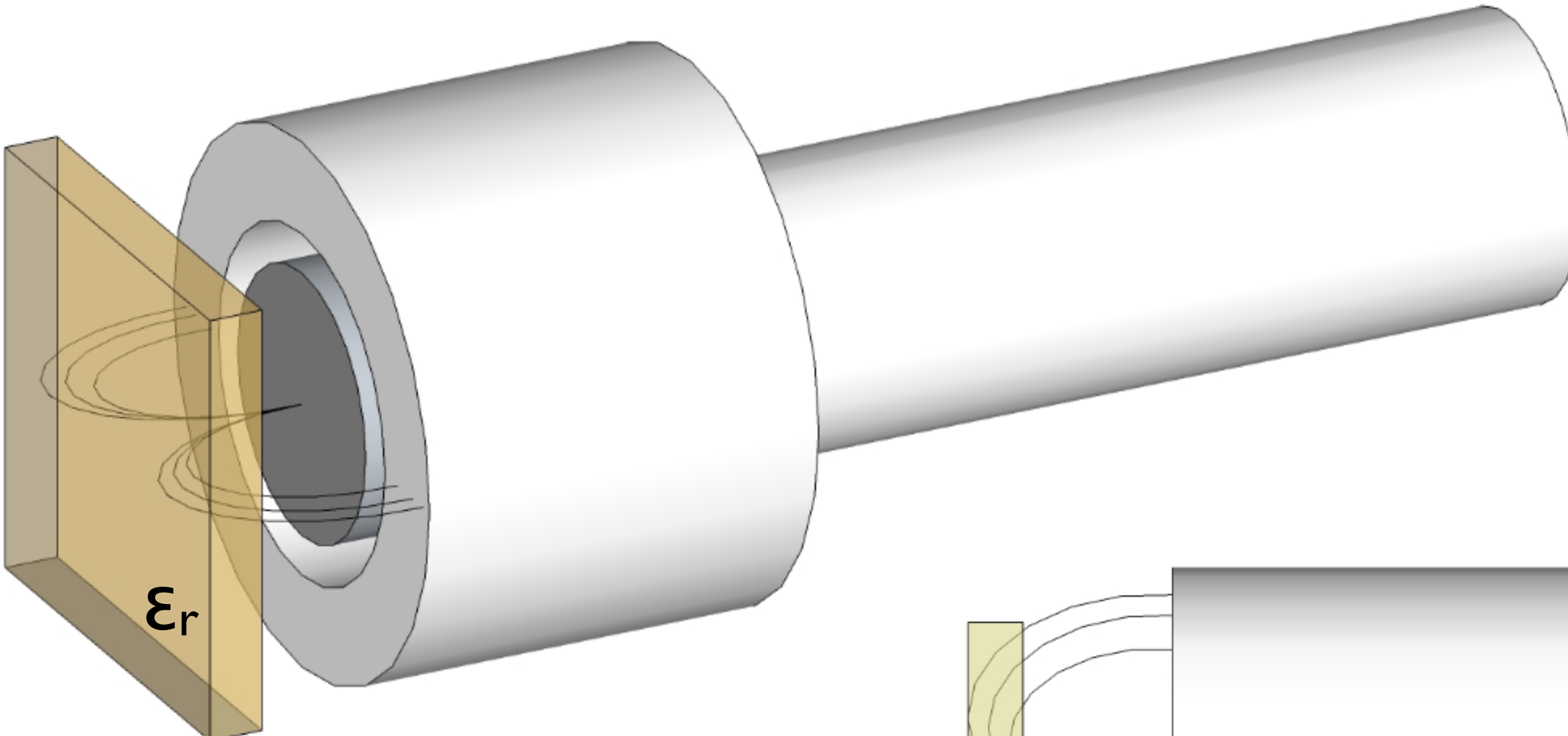


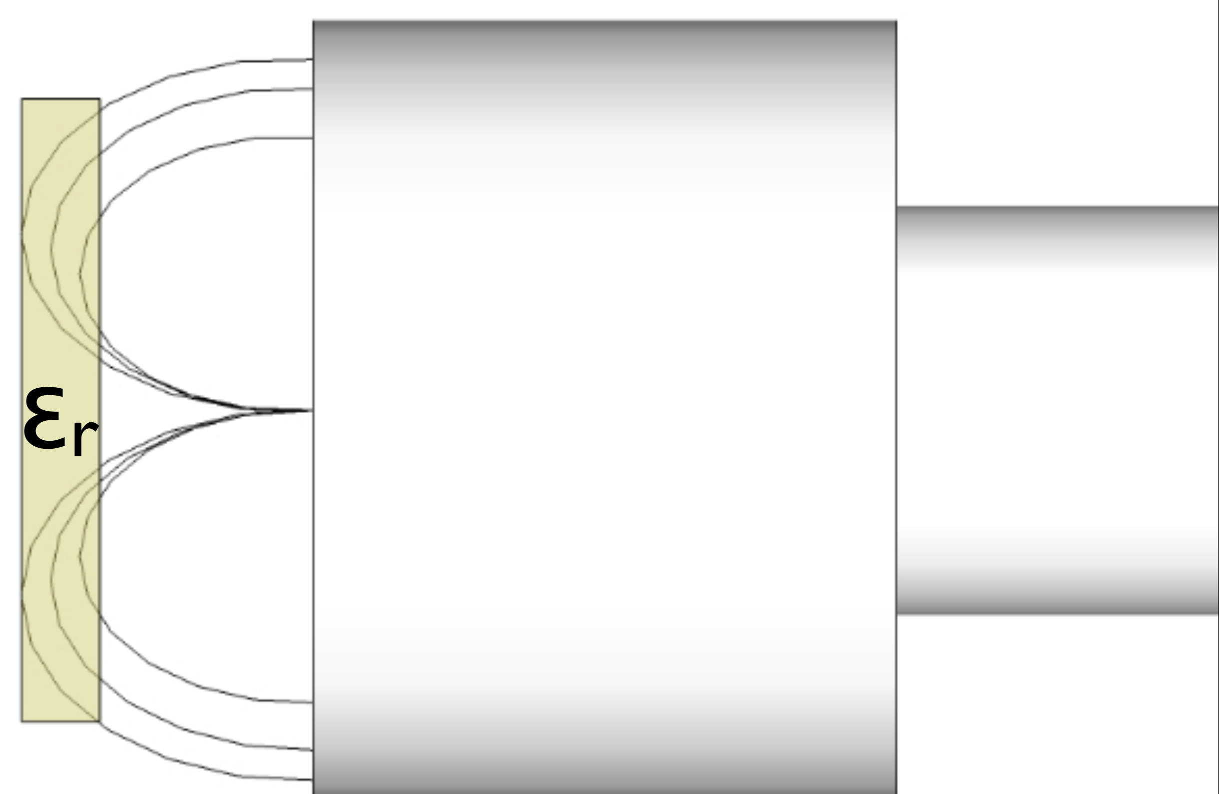


Capacitive Proximity sensor



Capacitive Proximity sensor

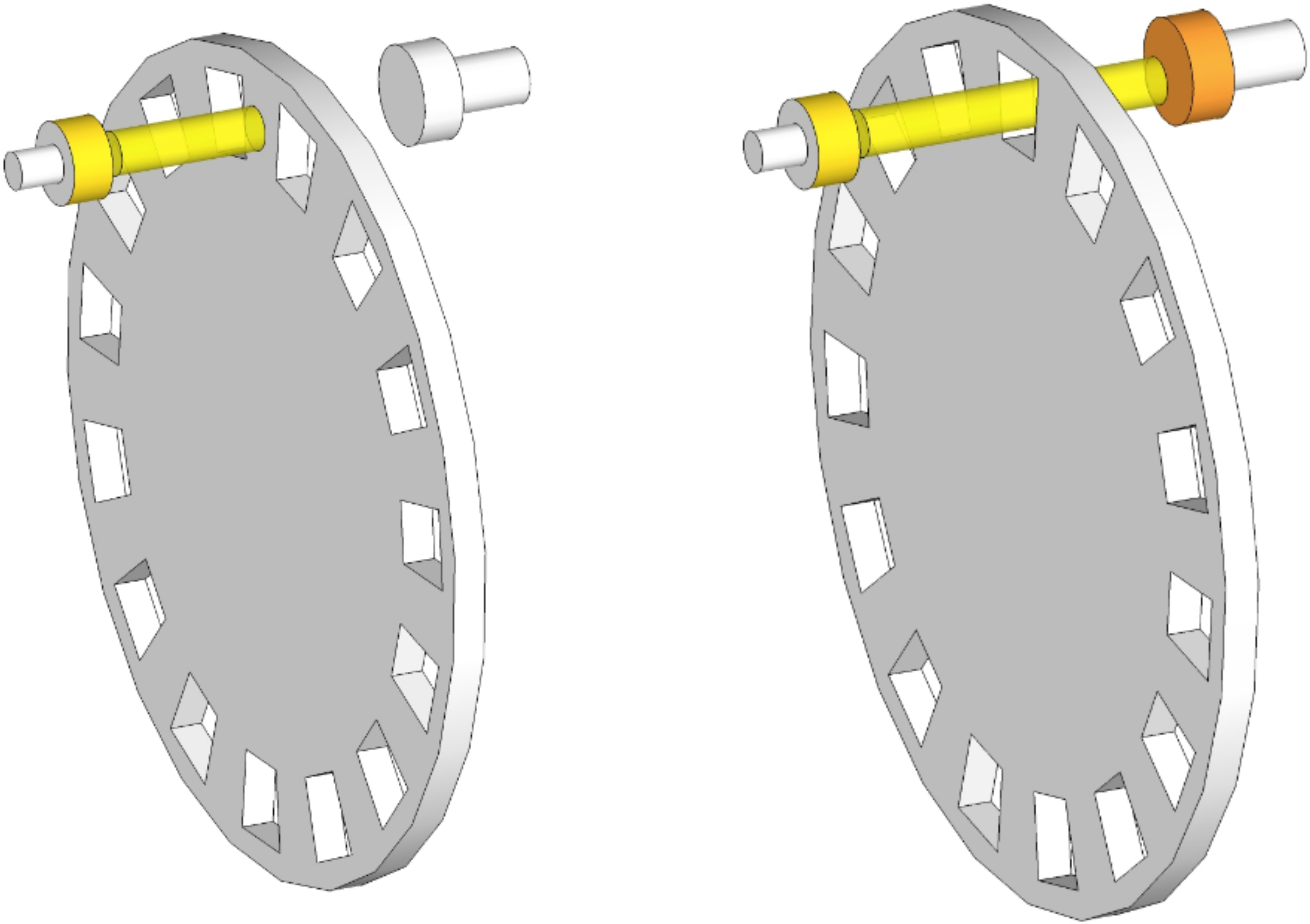




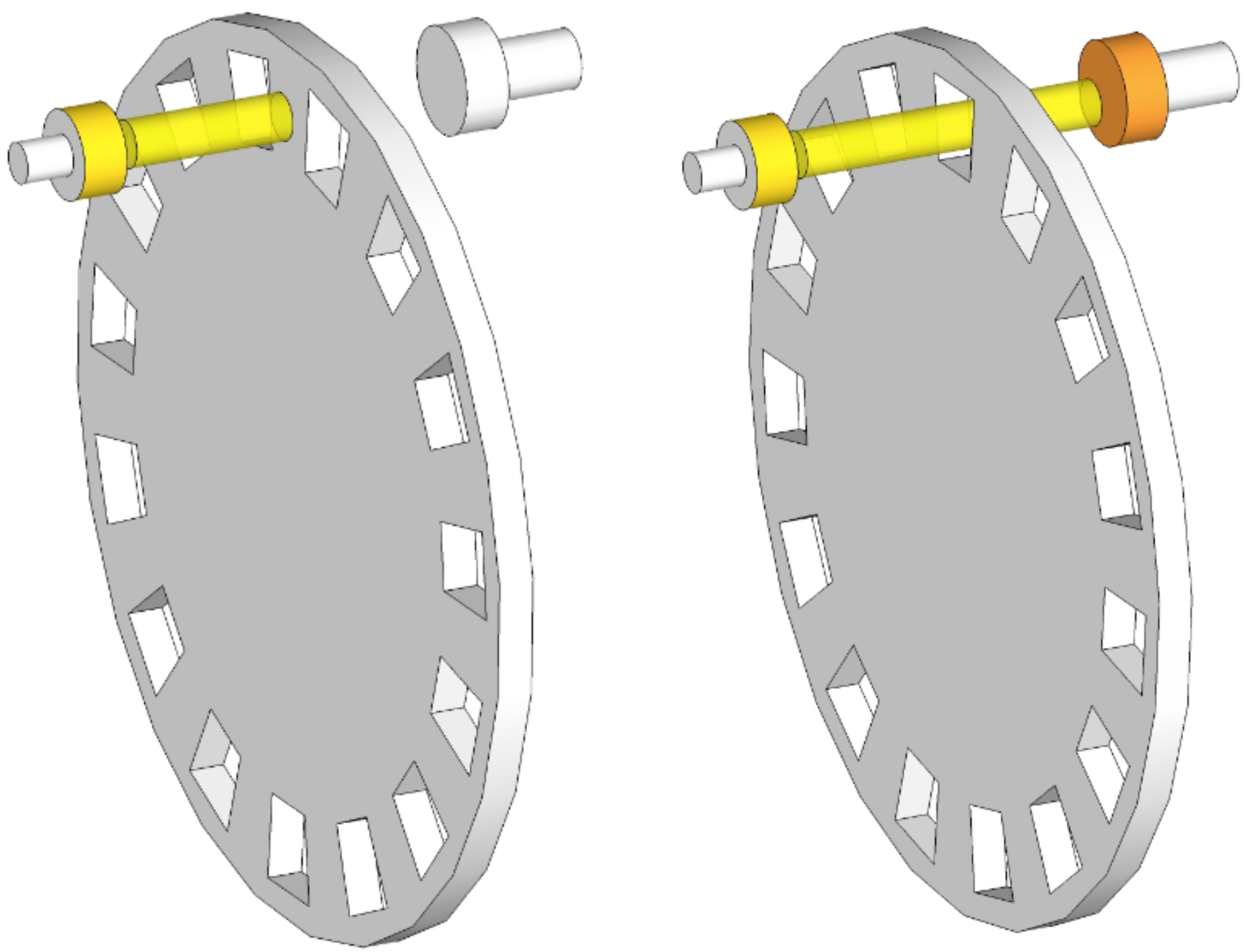
The capacity depends on both ε_r and distance

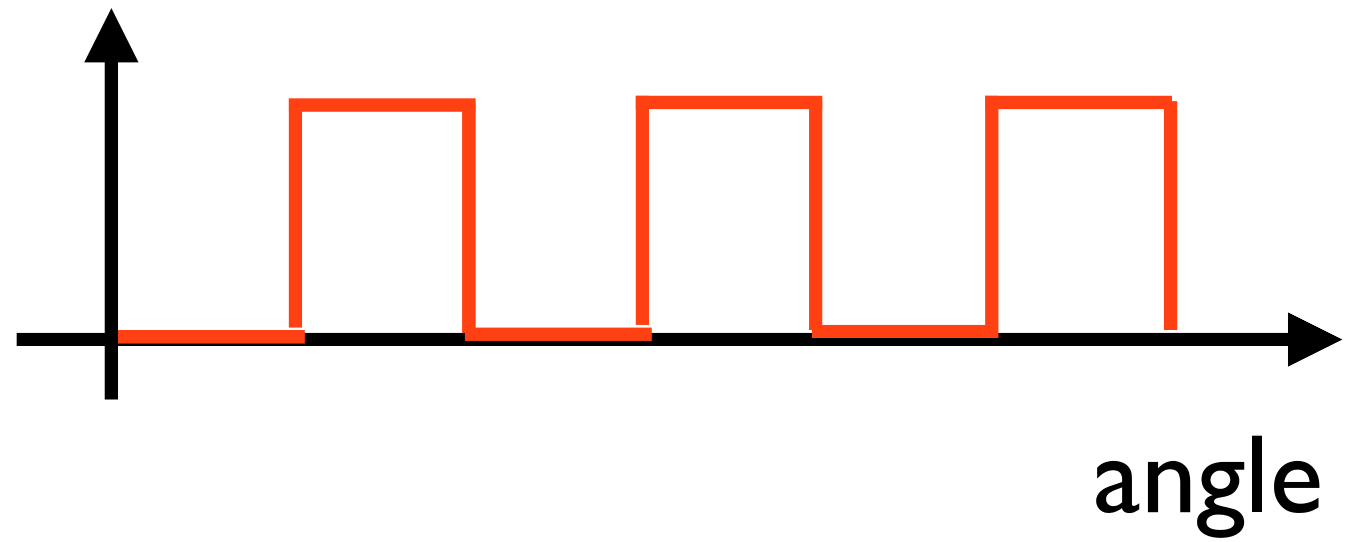
Incremental optical sensor

- rotative -

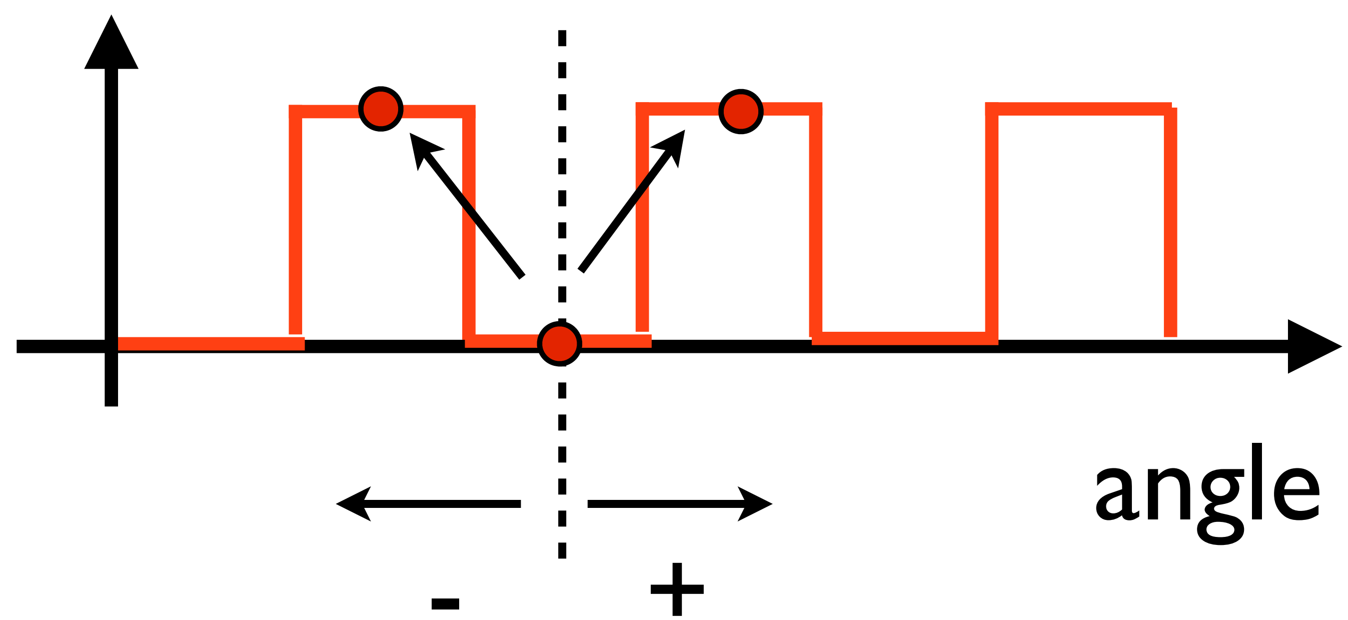


Incremental optical sensor



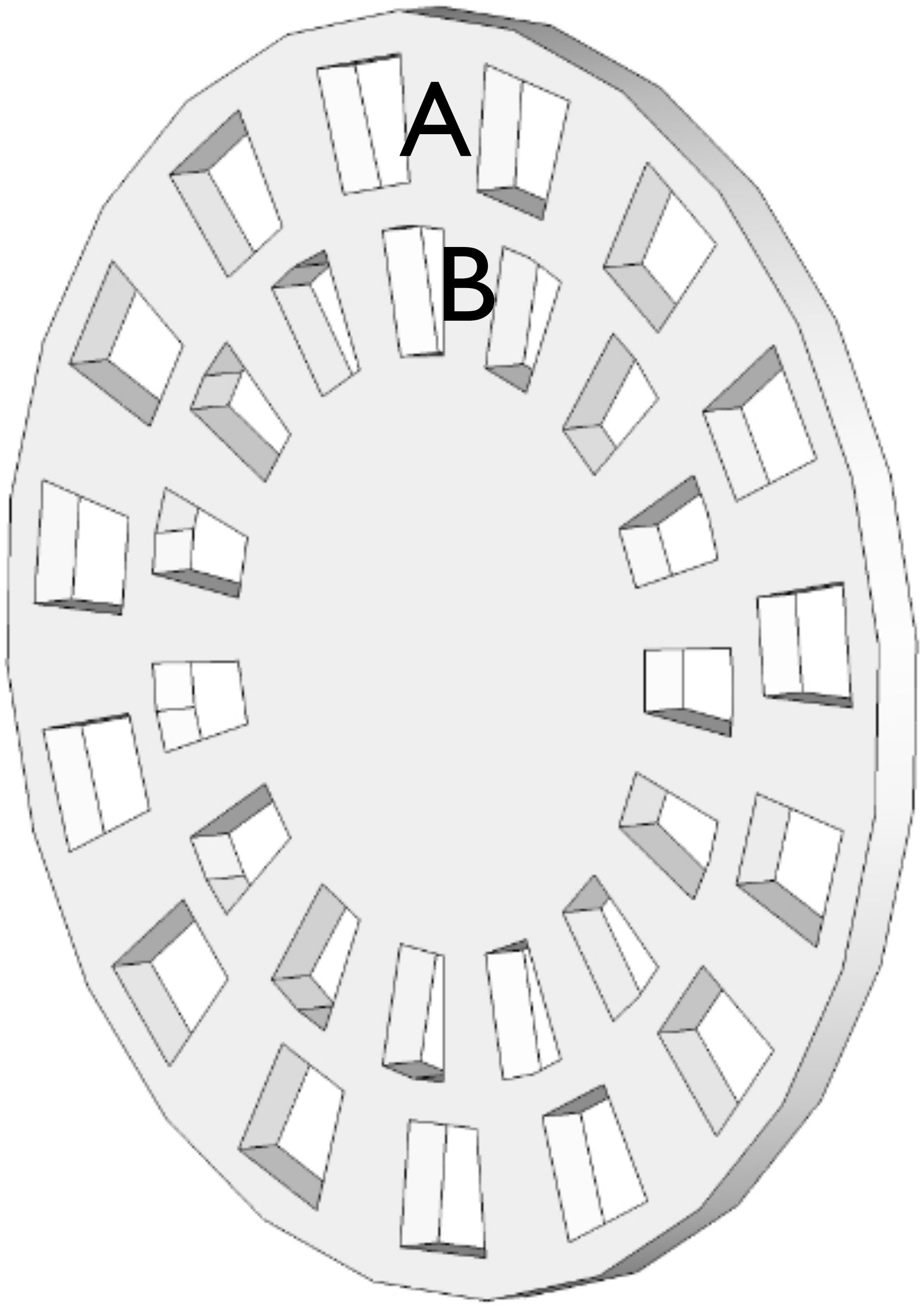


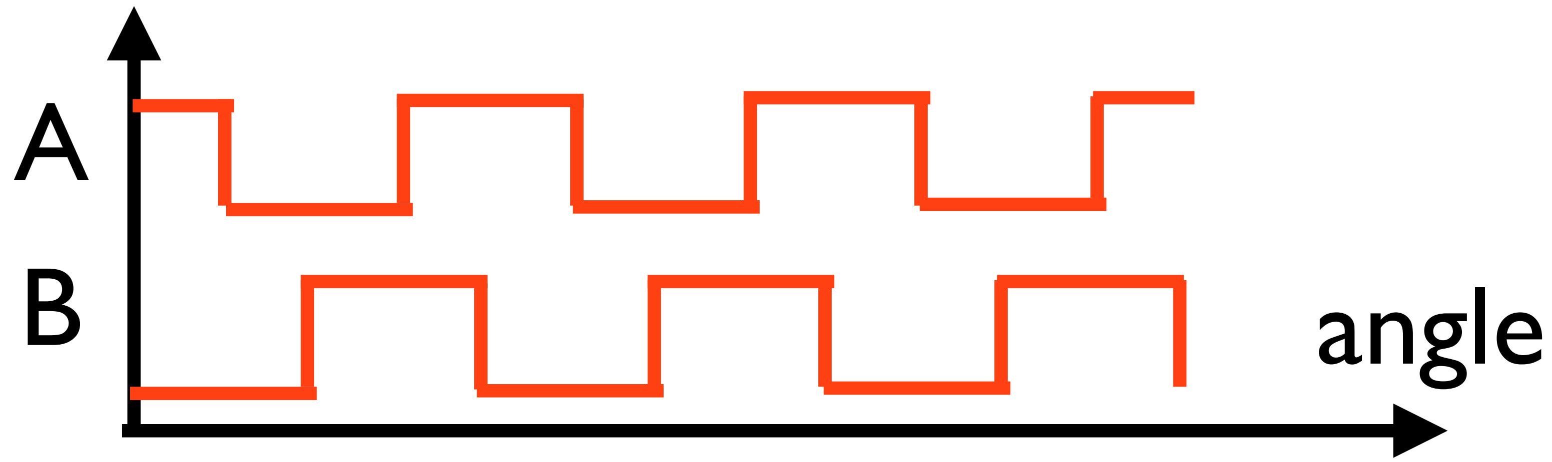
Problem

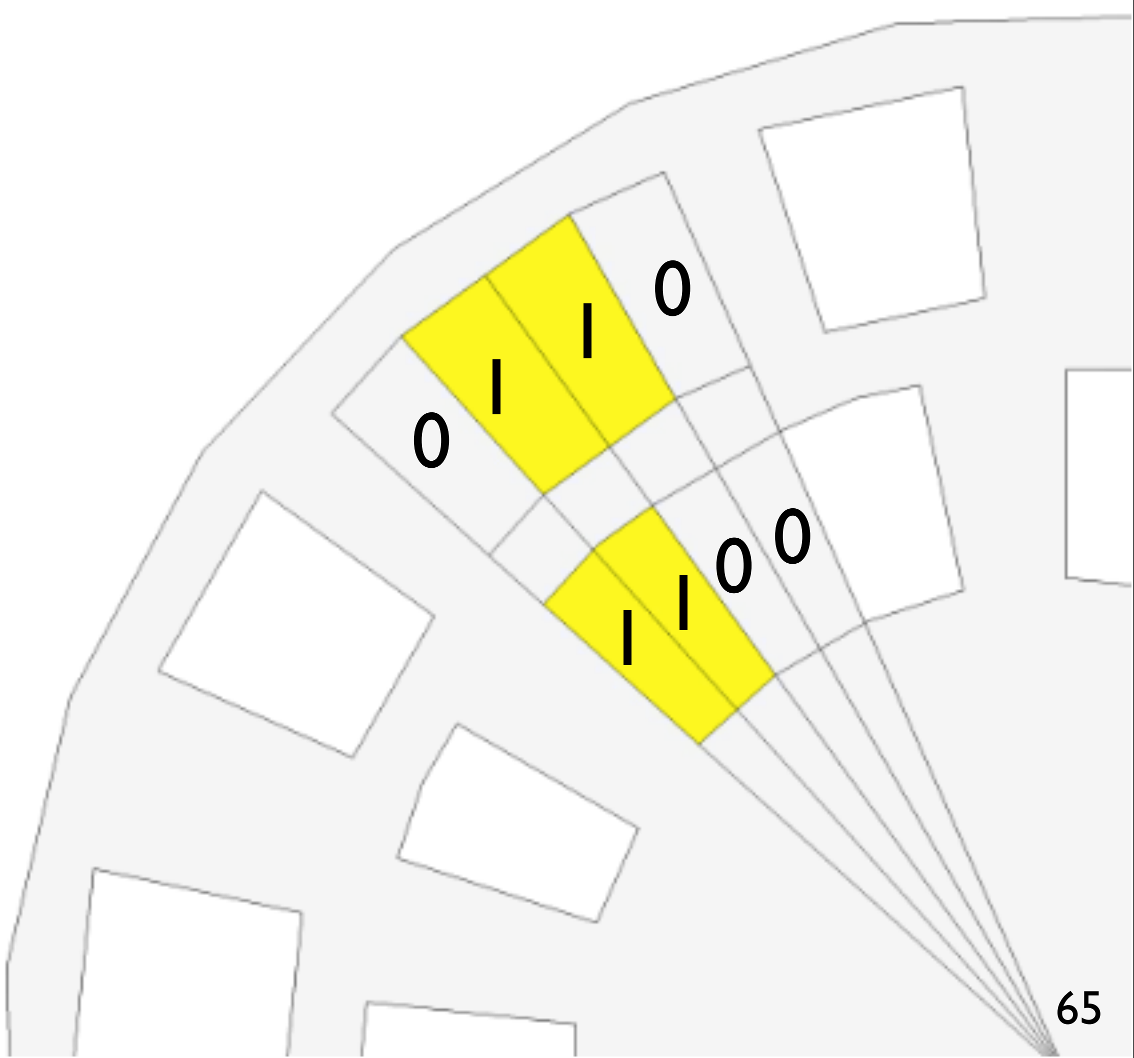


Incremental optical sensor

- solution -

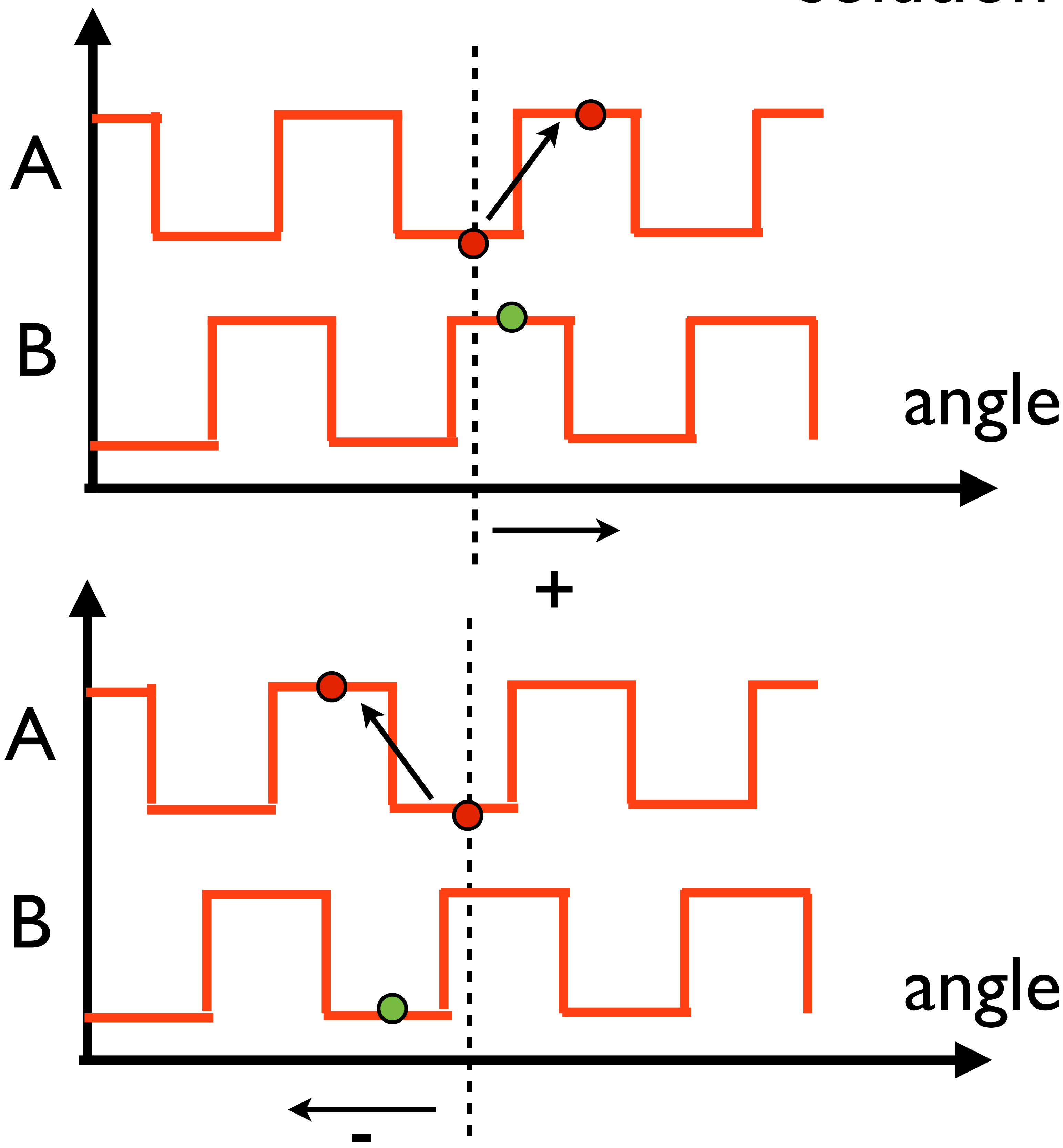


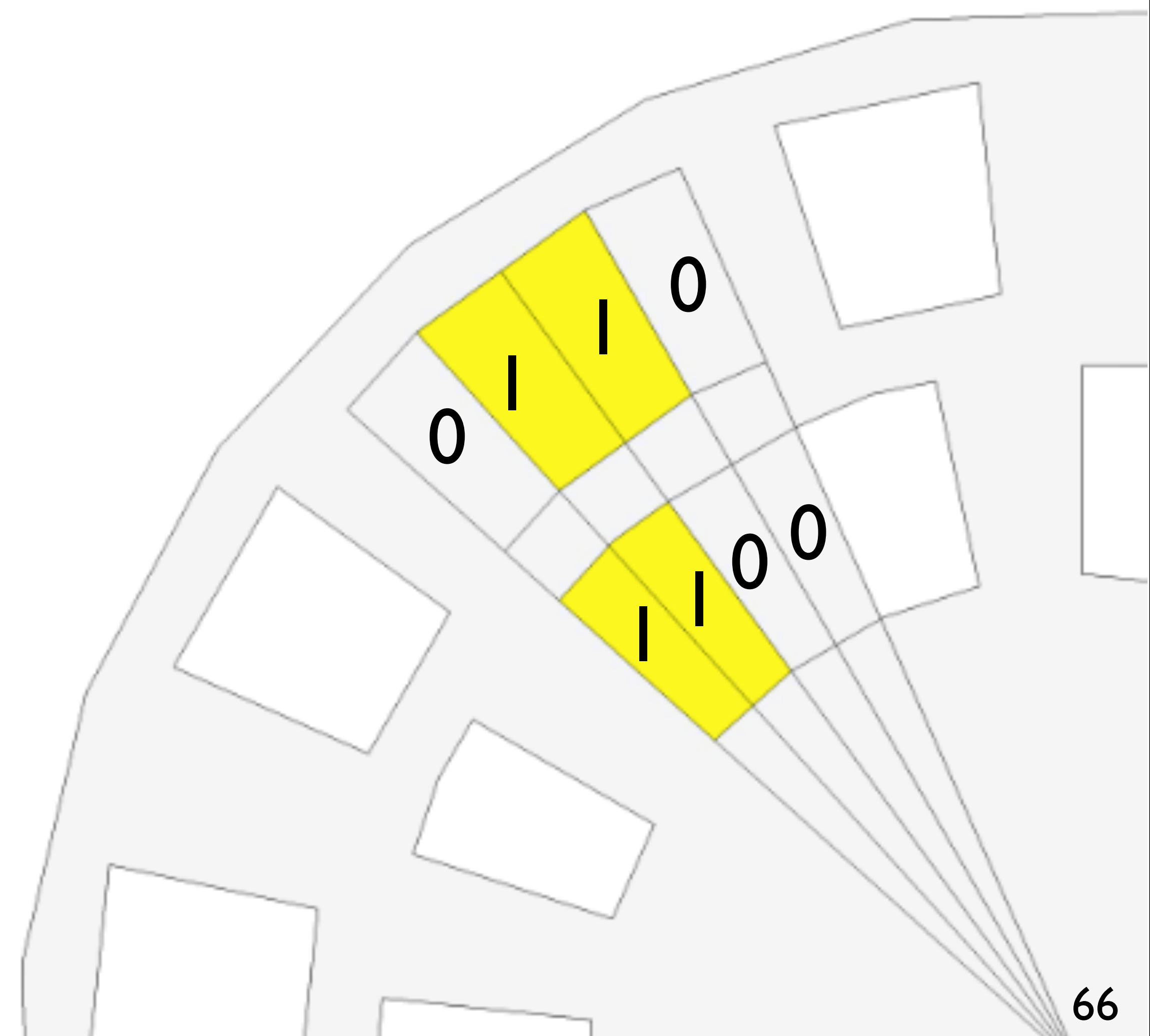




Incremental optical sensor

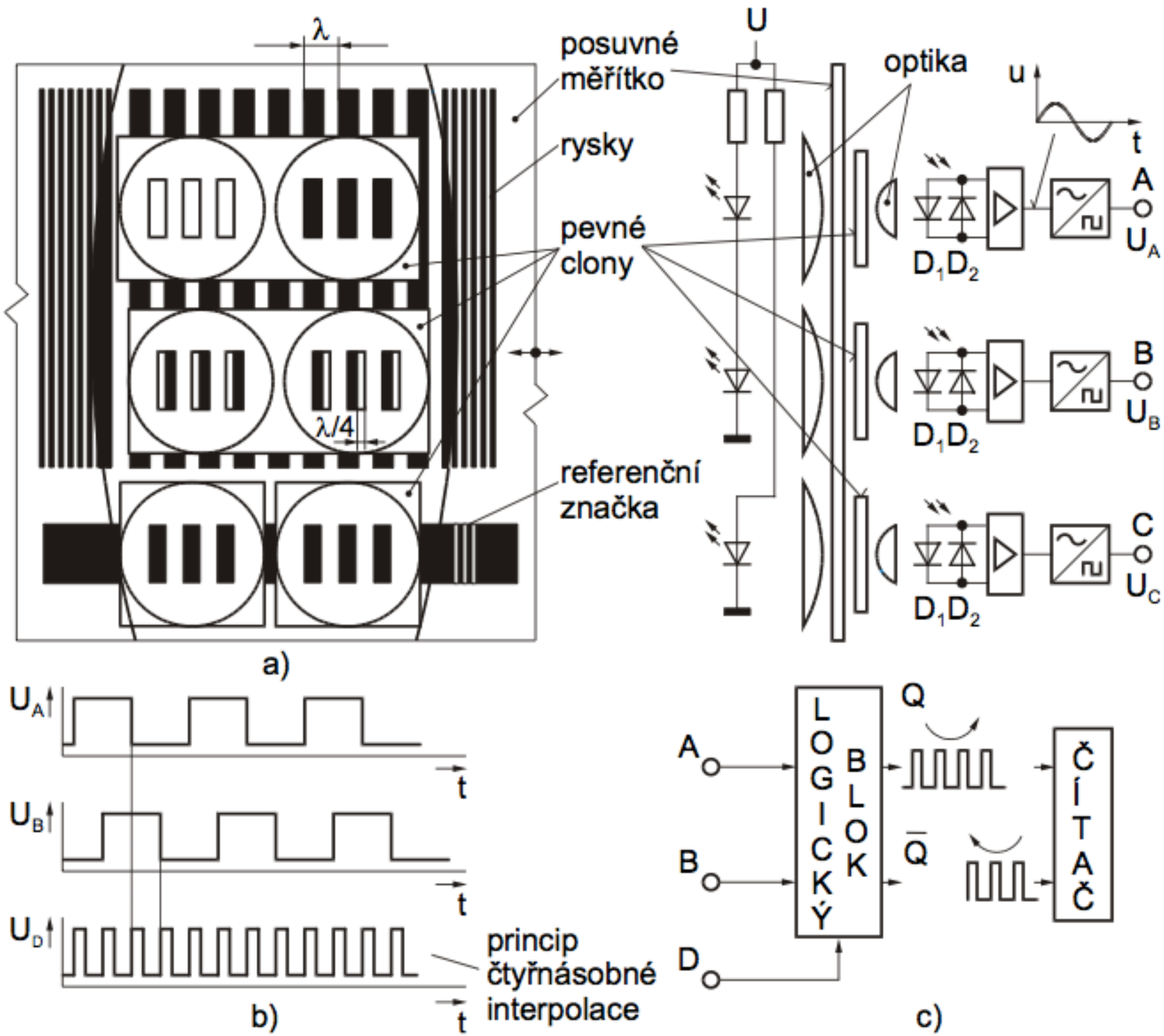
- solution -



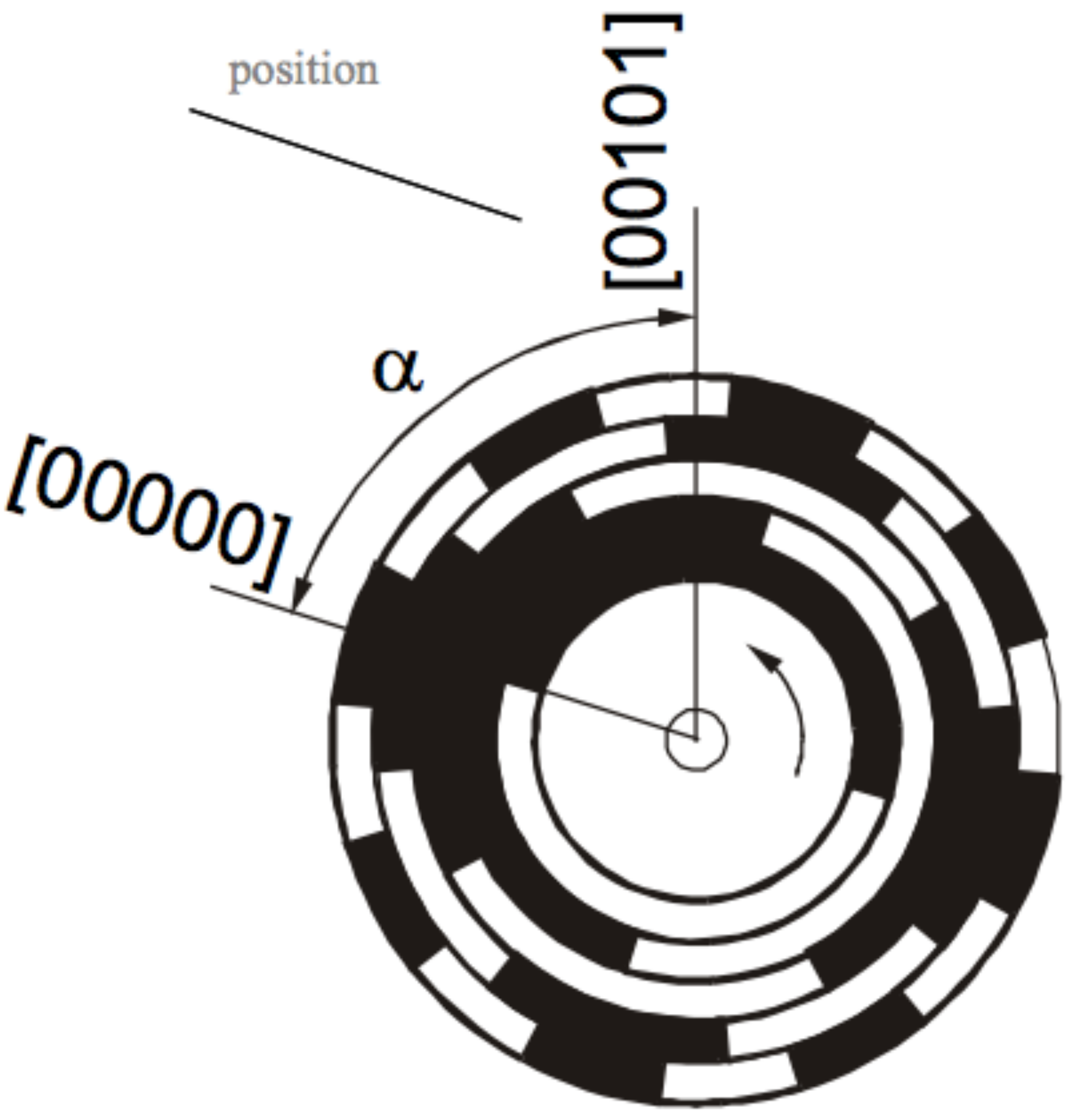


Incremental optical sensor

- linear -

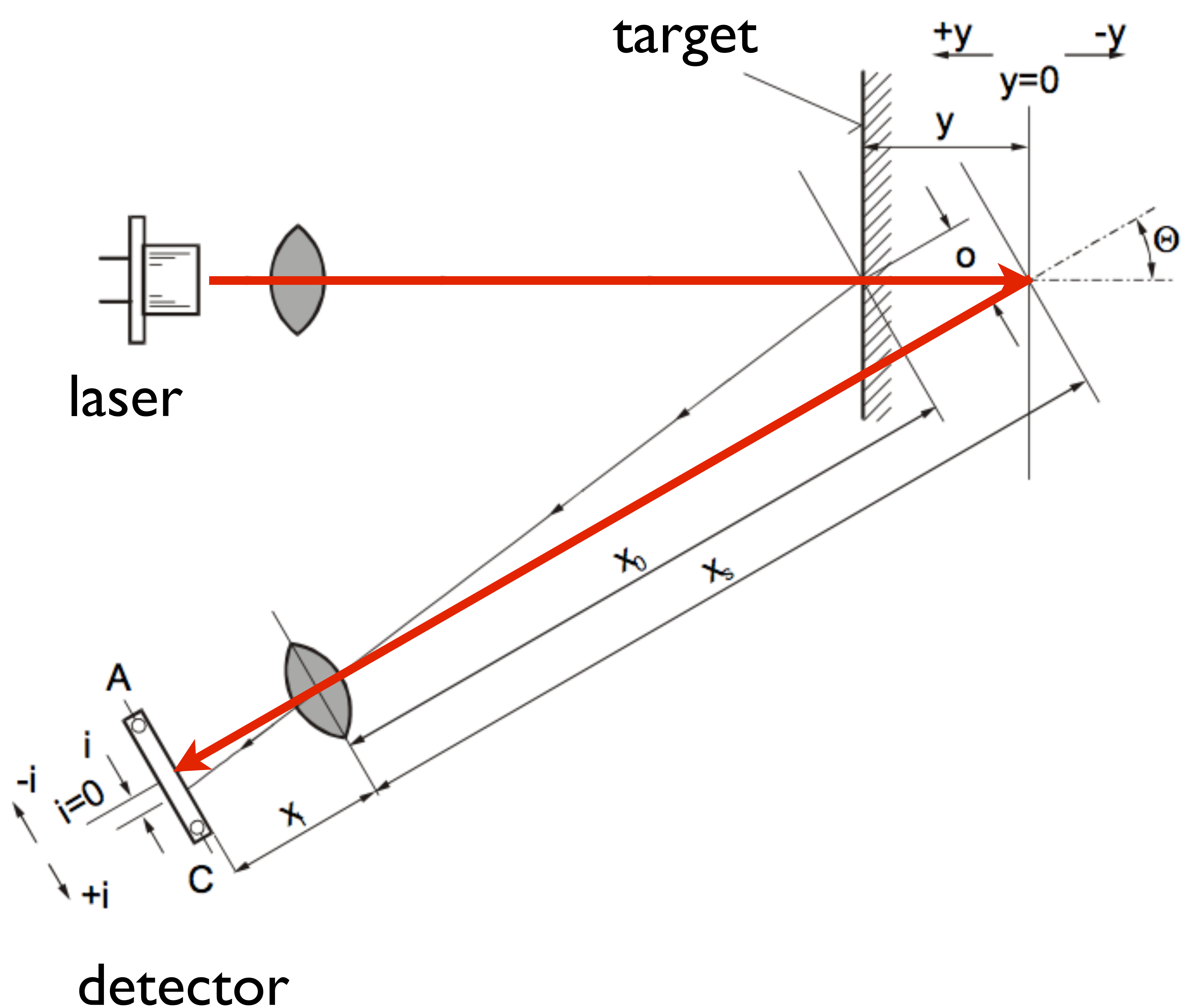


Absolute optical sensor

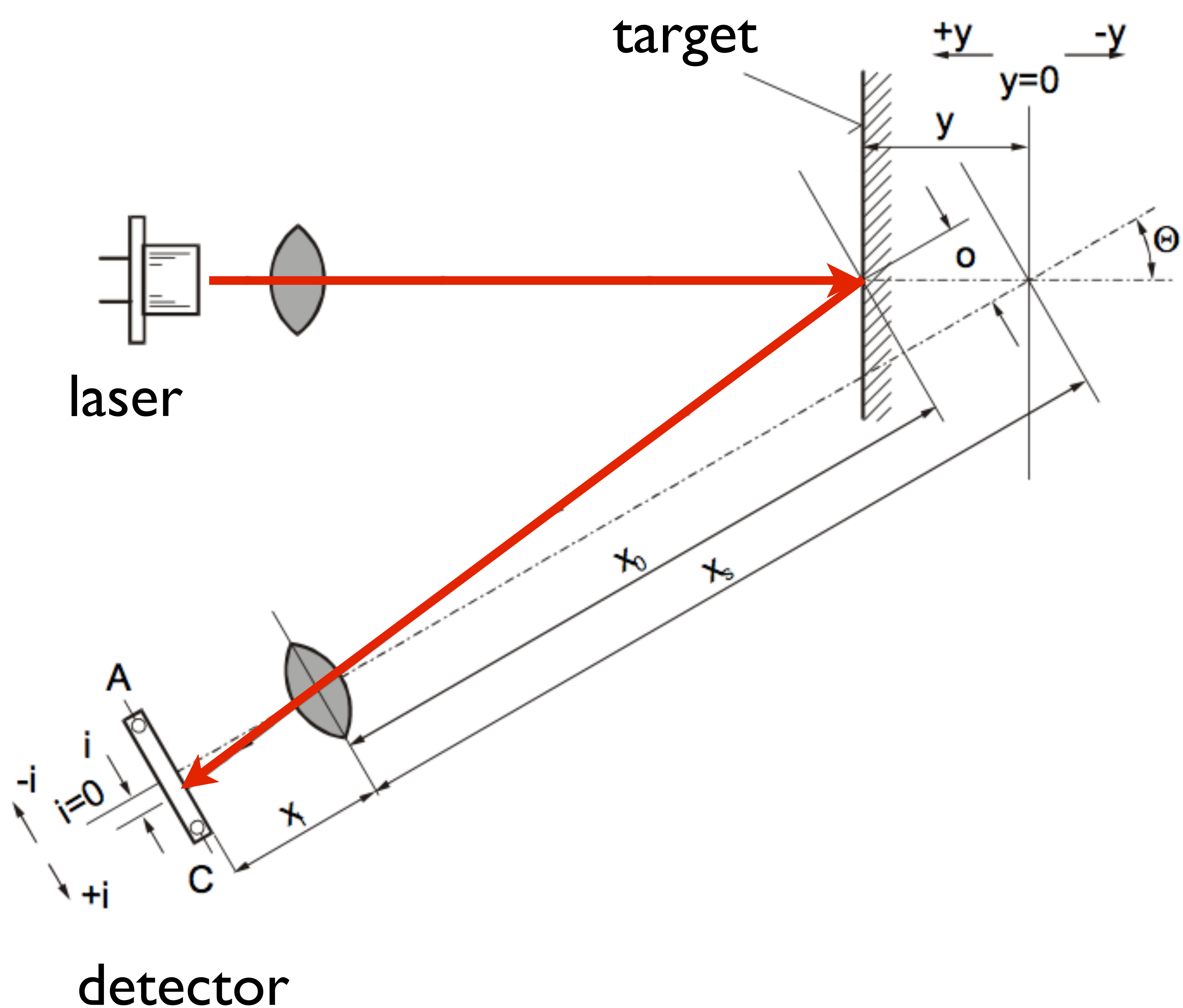


Omron

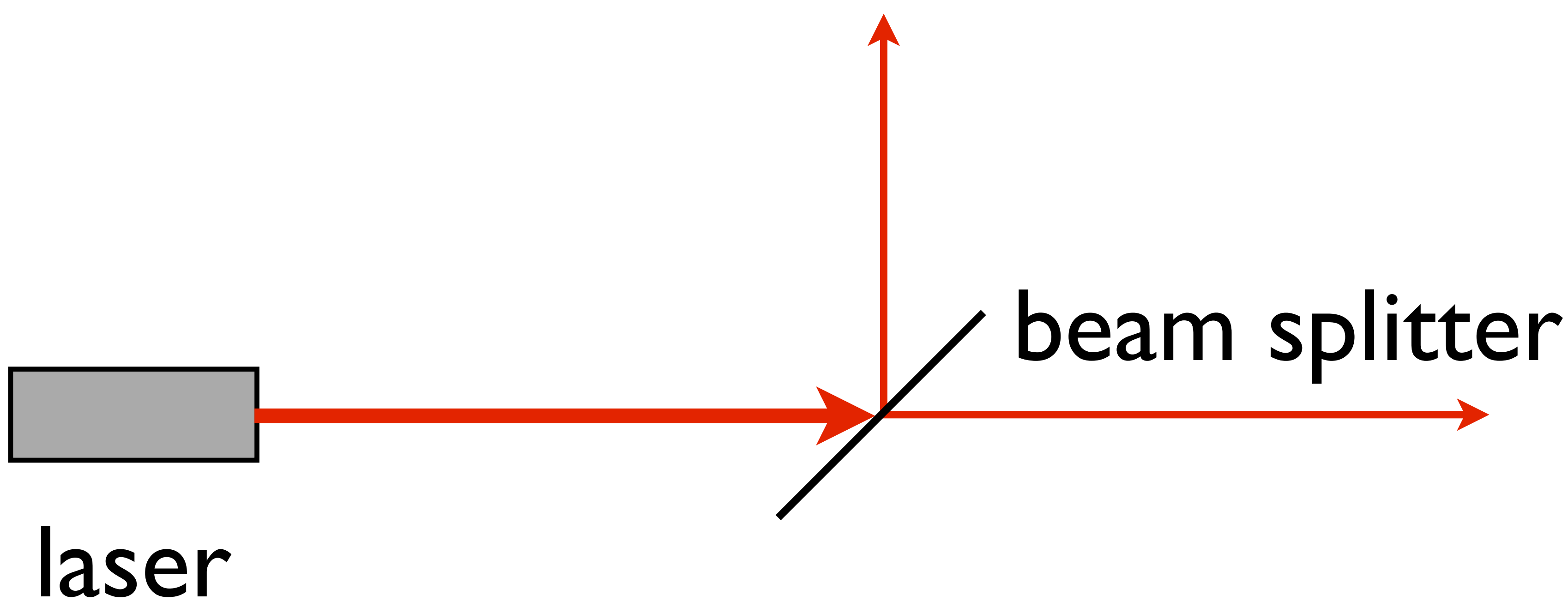
Triangulation optical sensor



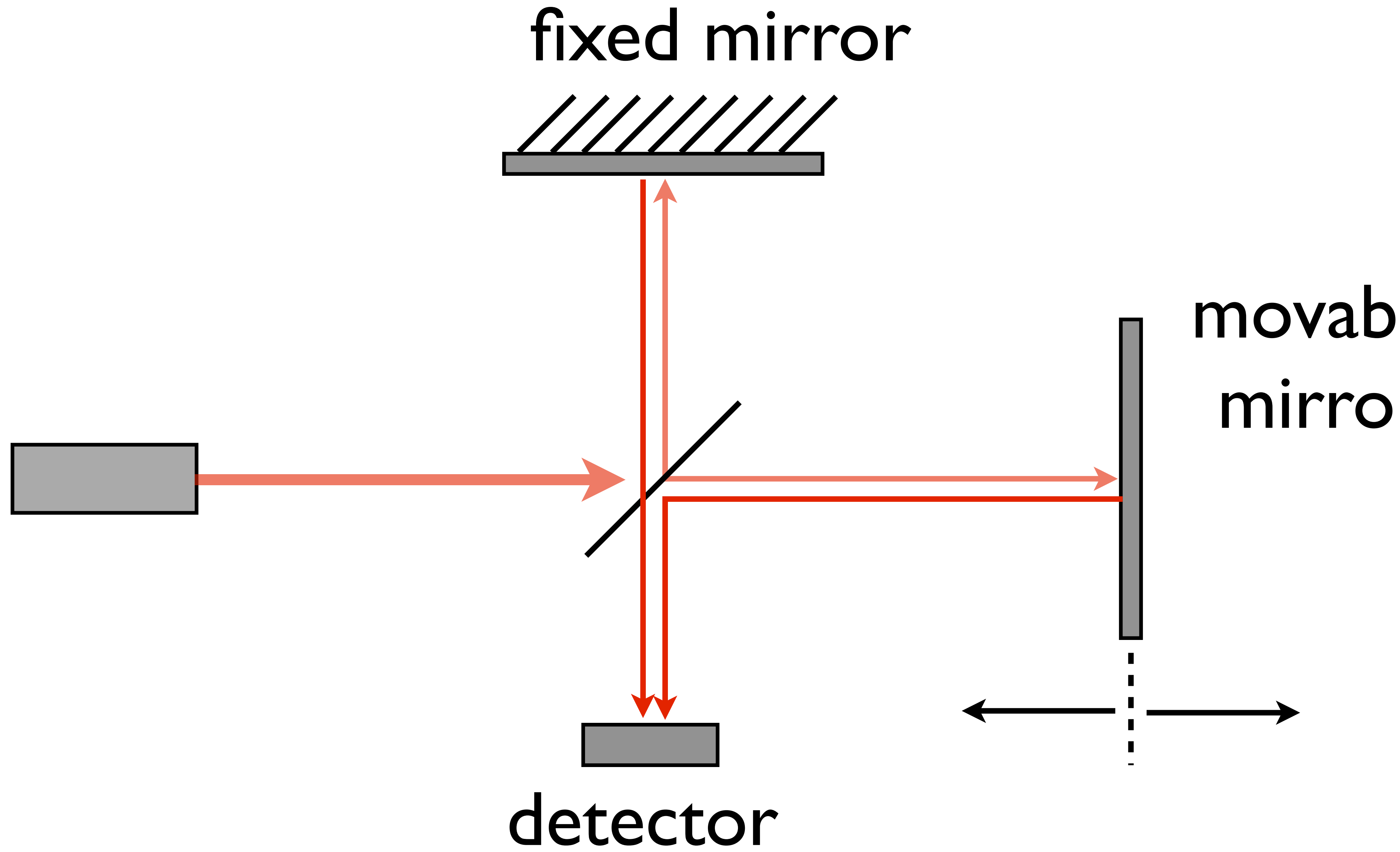
Triangulation optical sensor



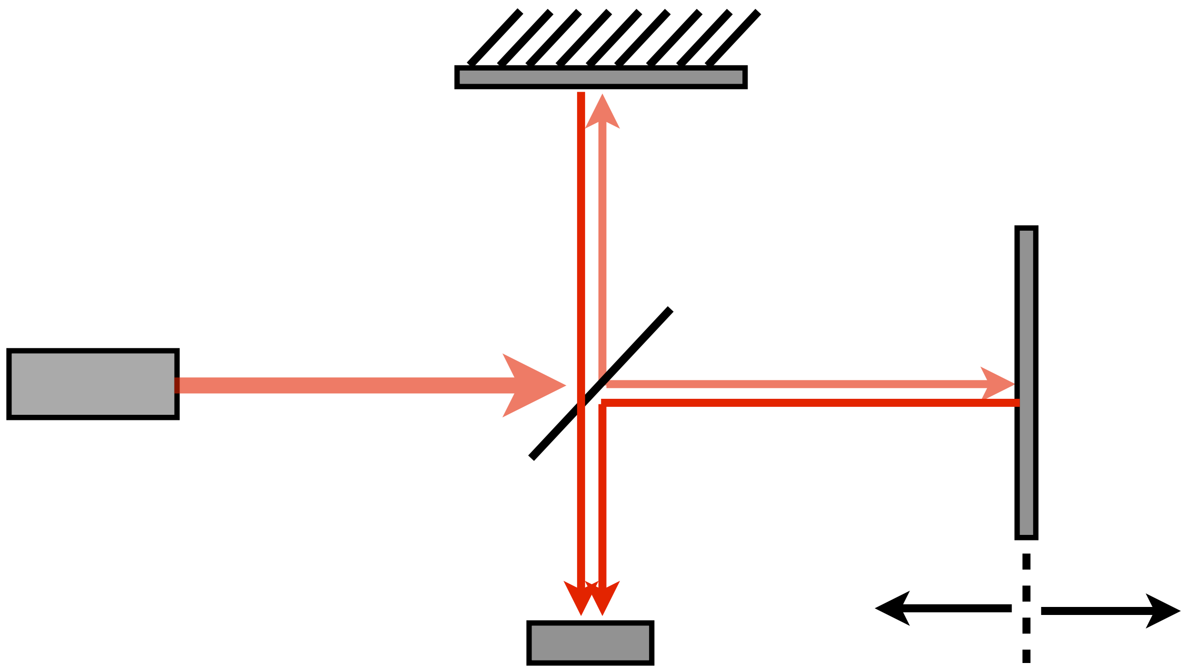
Michelson Interferometer

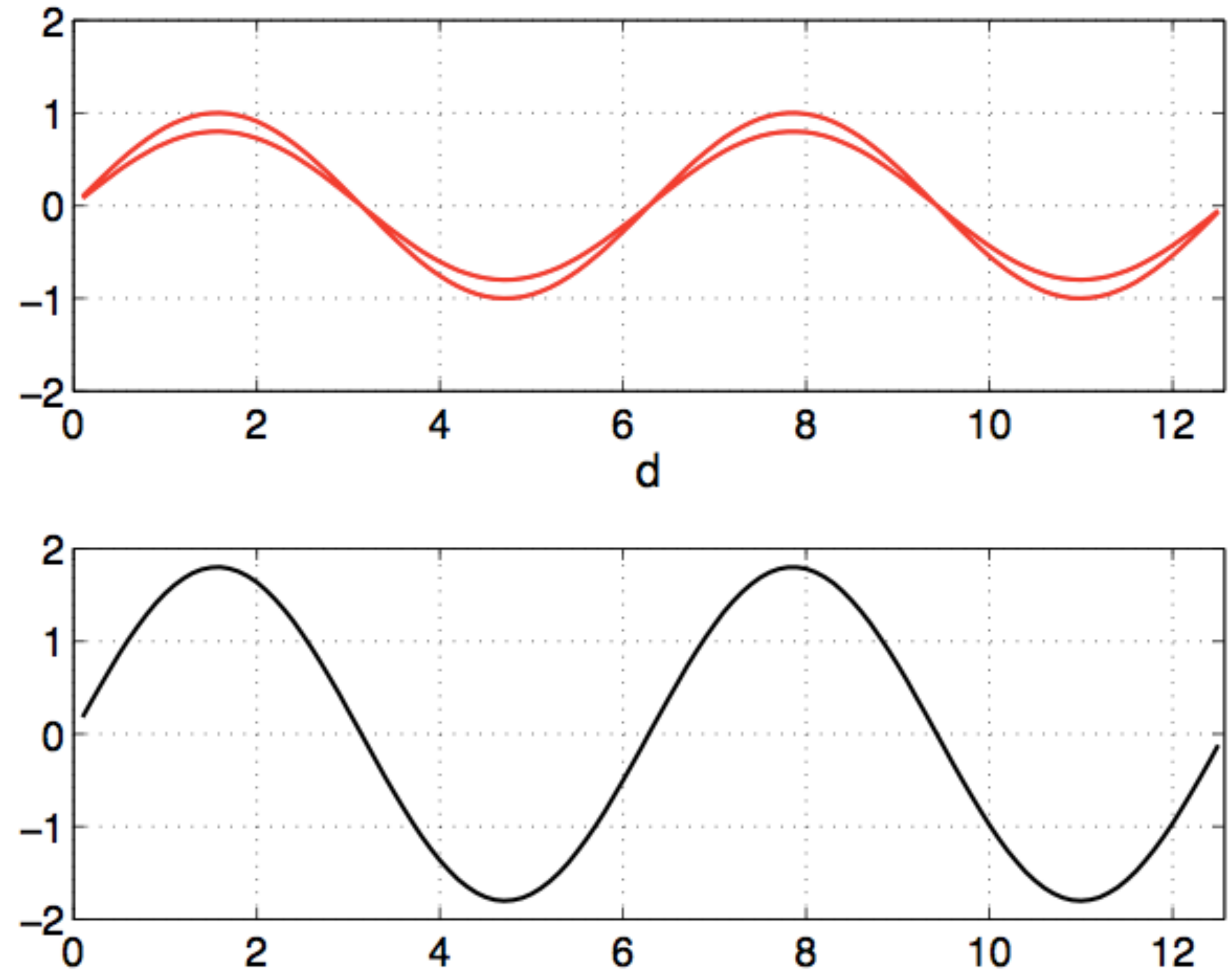


Michelson Interferometer

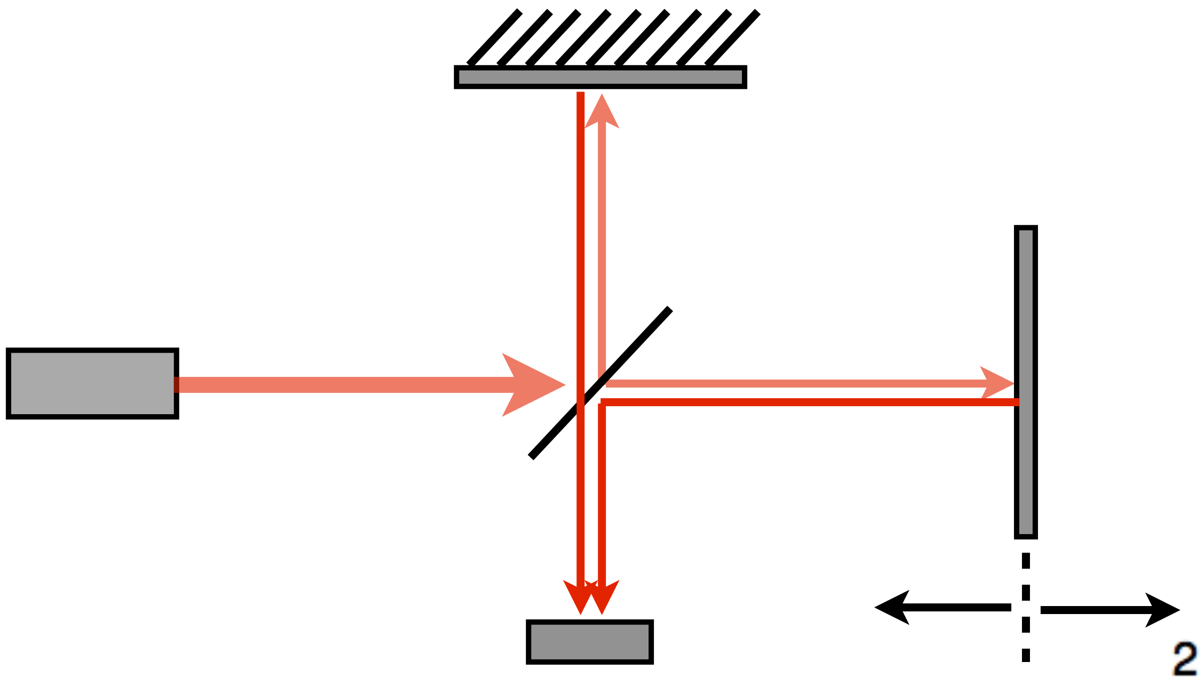


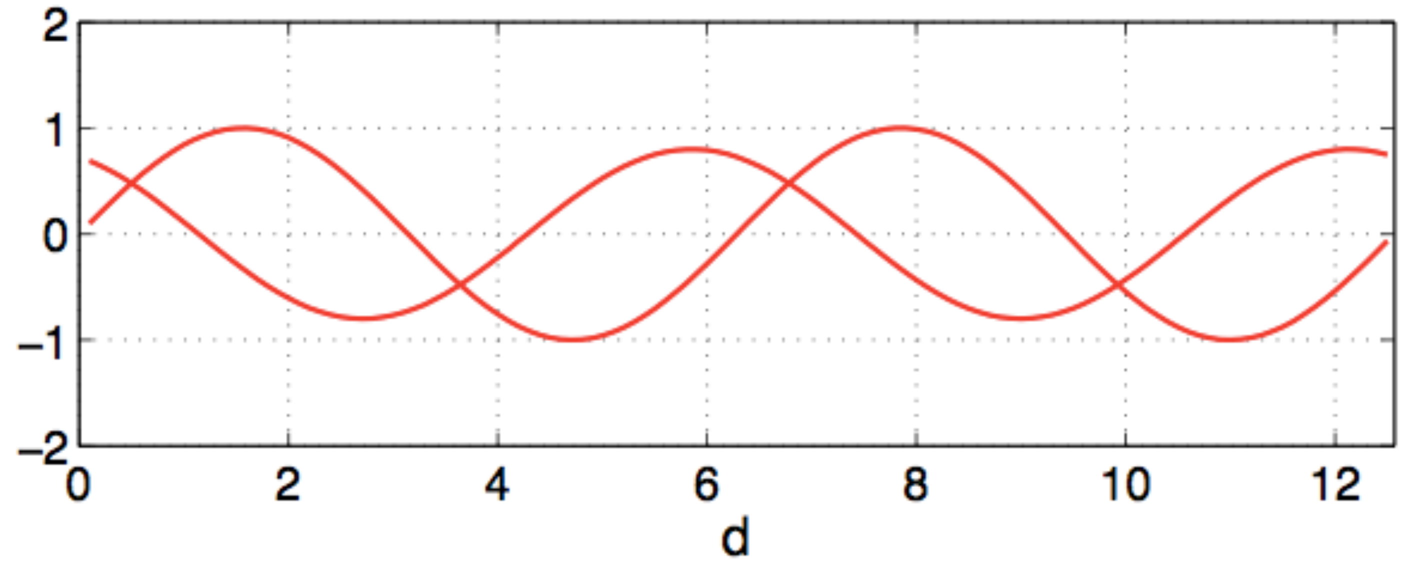
Michelson Interferometer

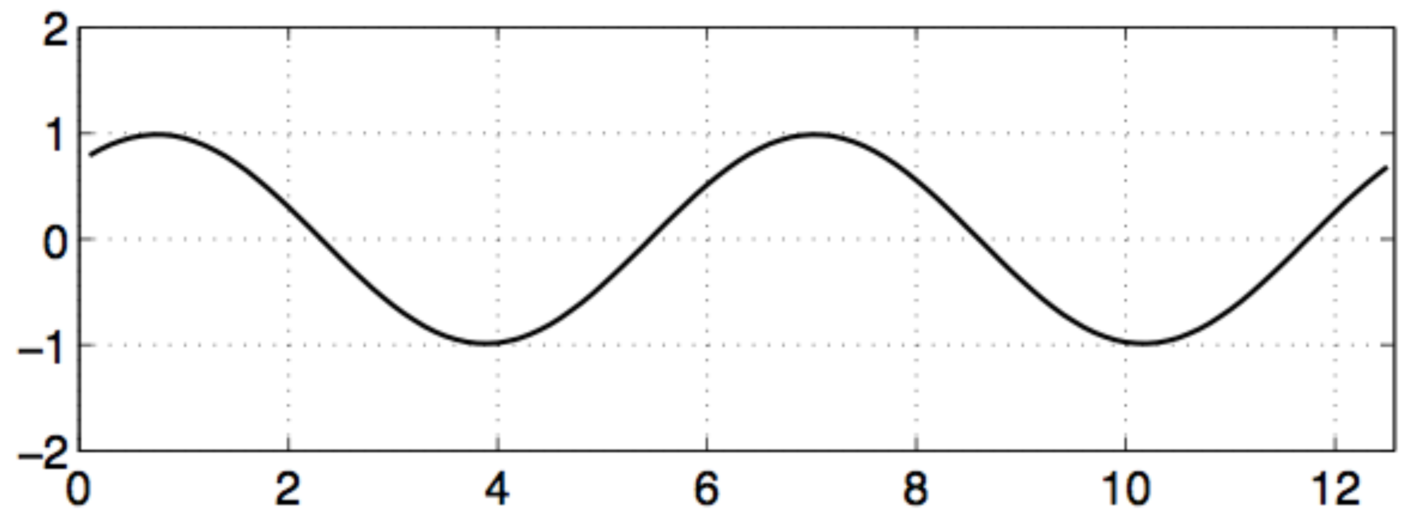




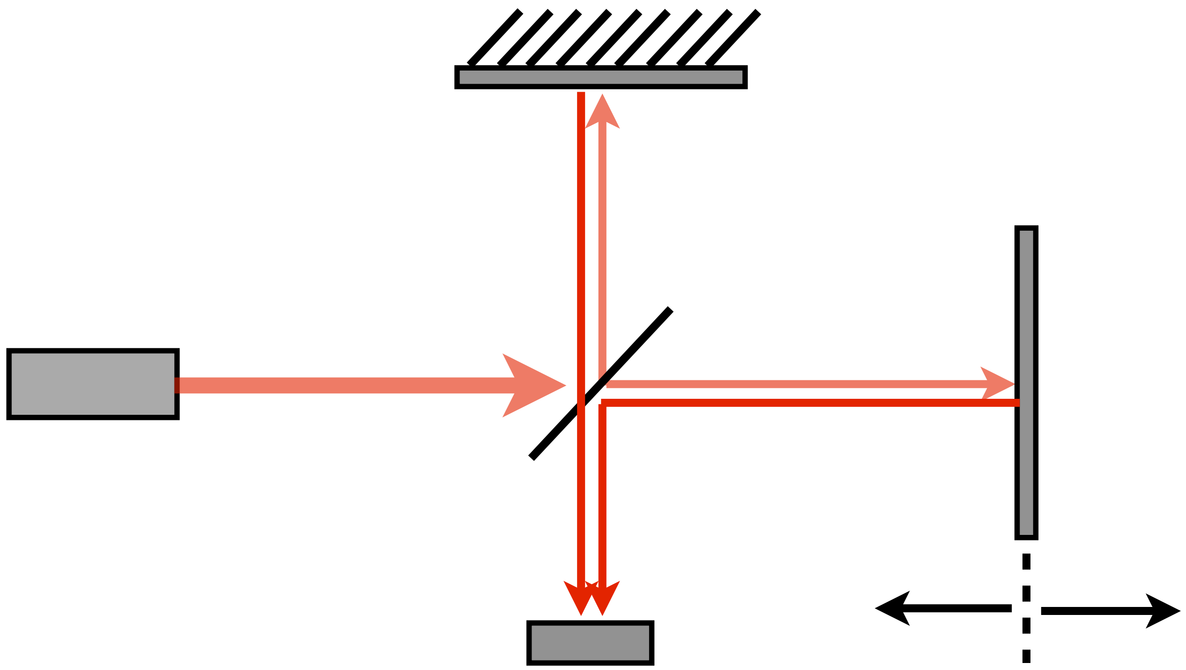
Michelson Interferometer

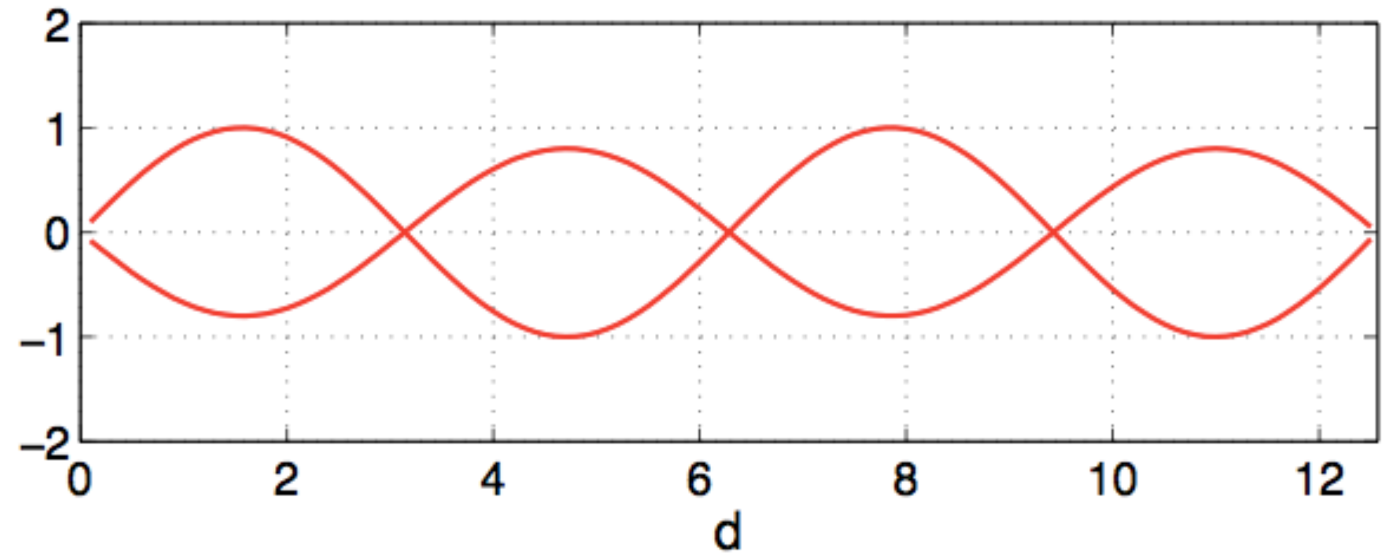


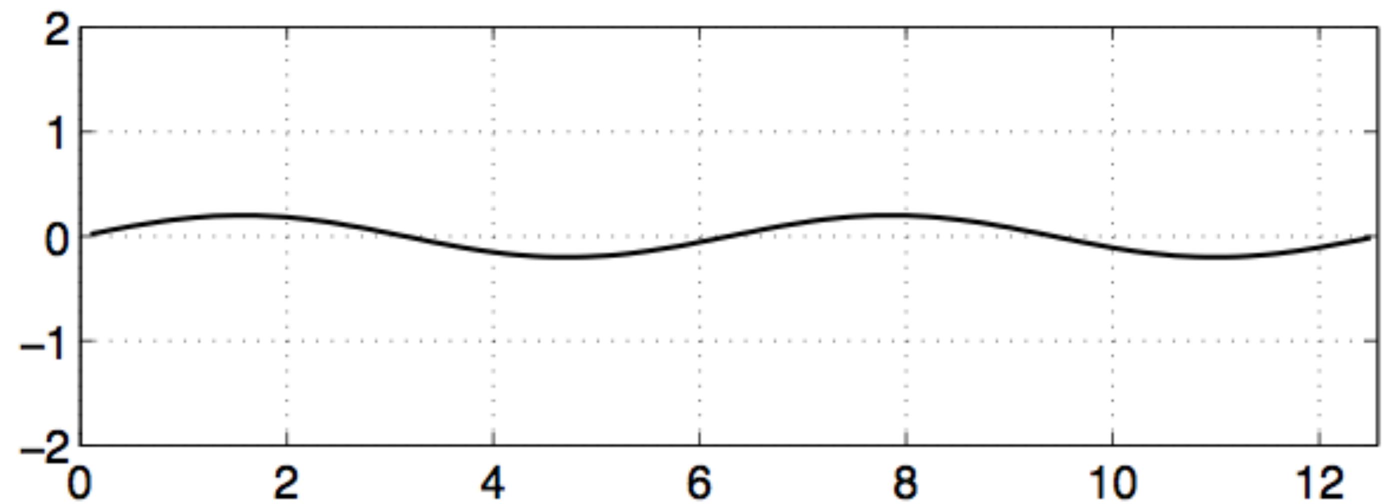




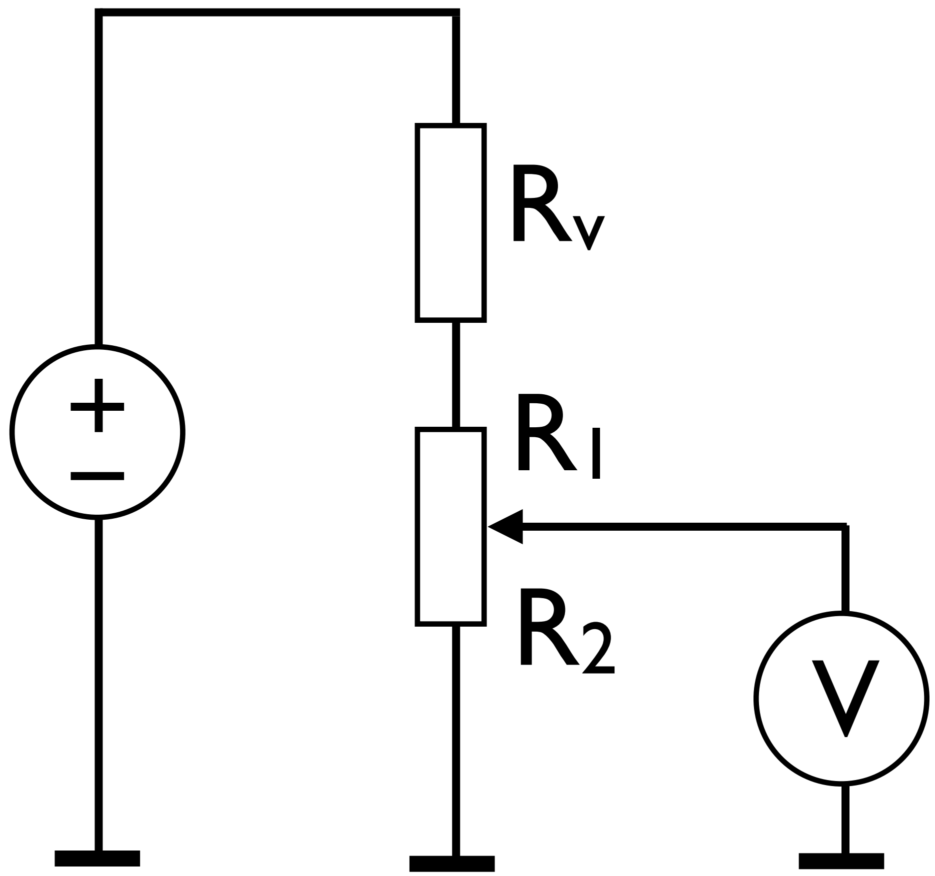
Michelson Interferometer

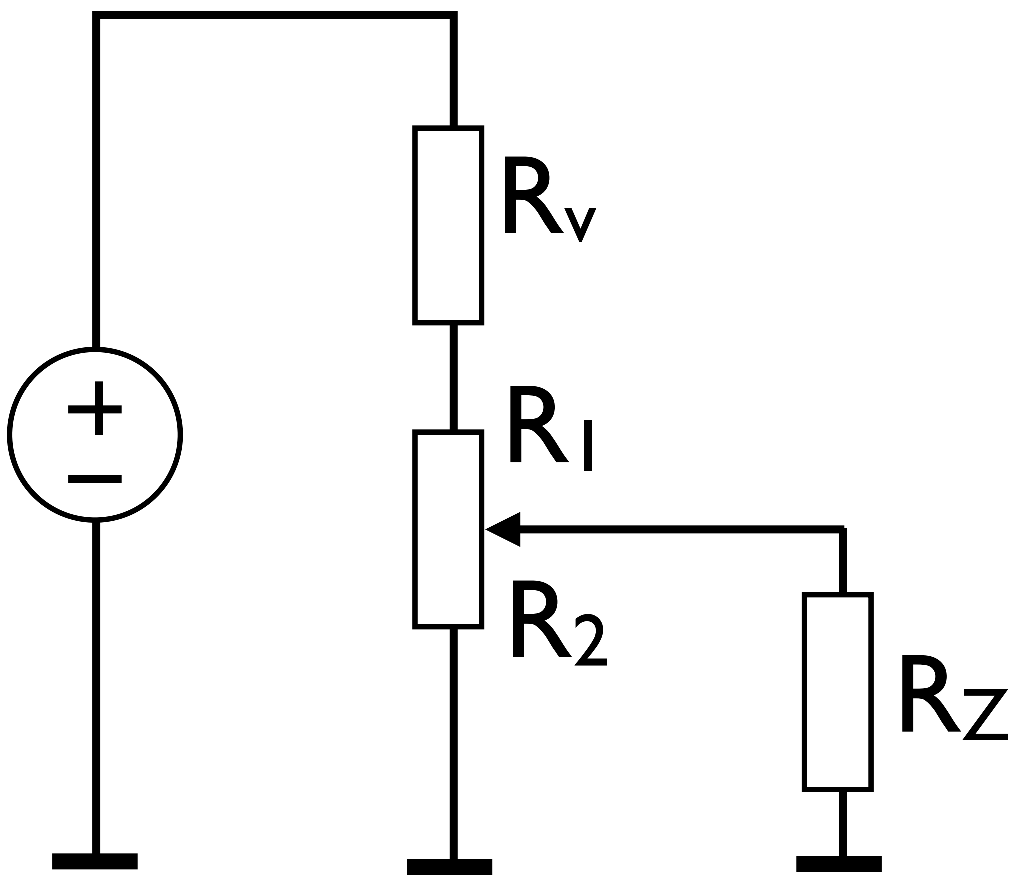


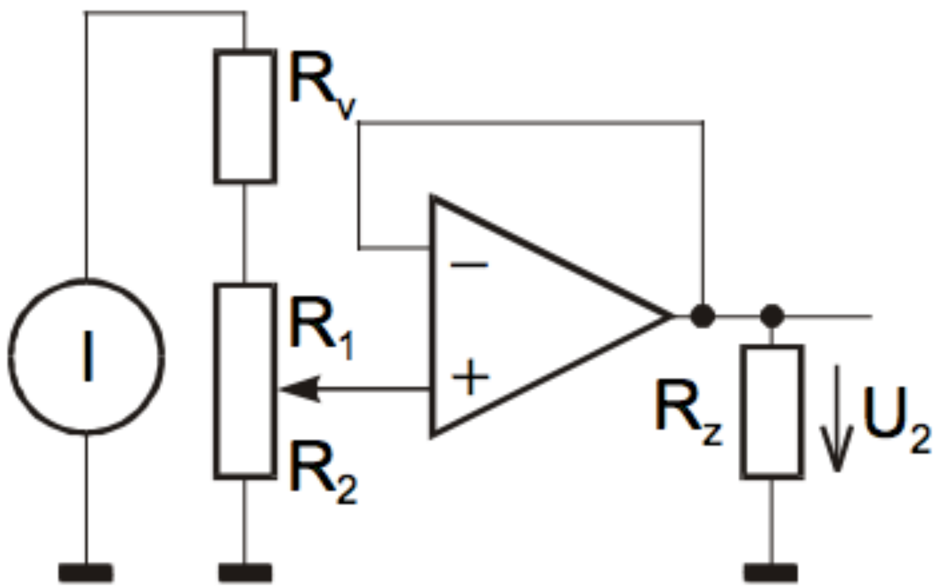


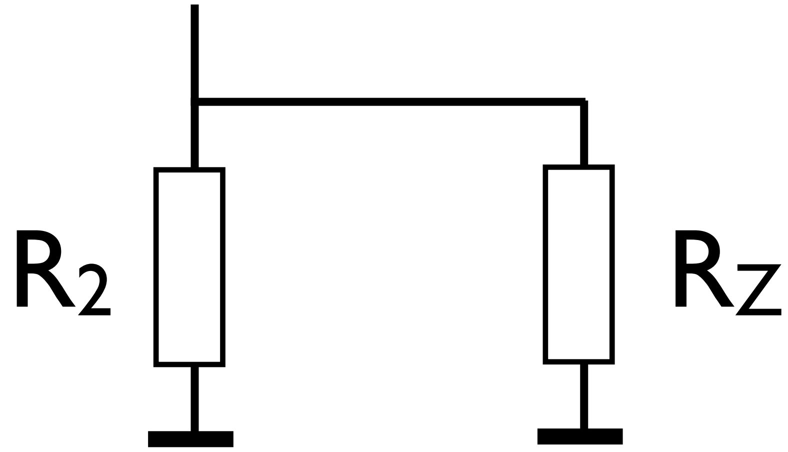


Resistive sensors

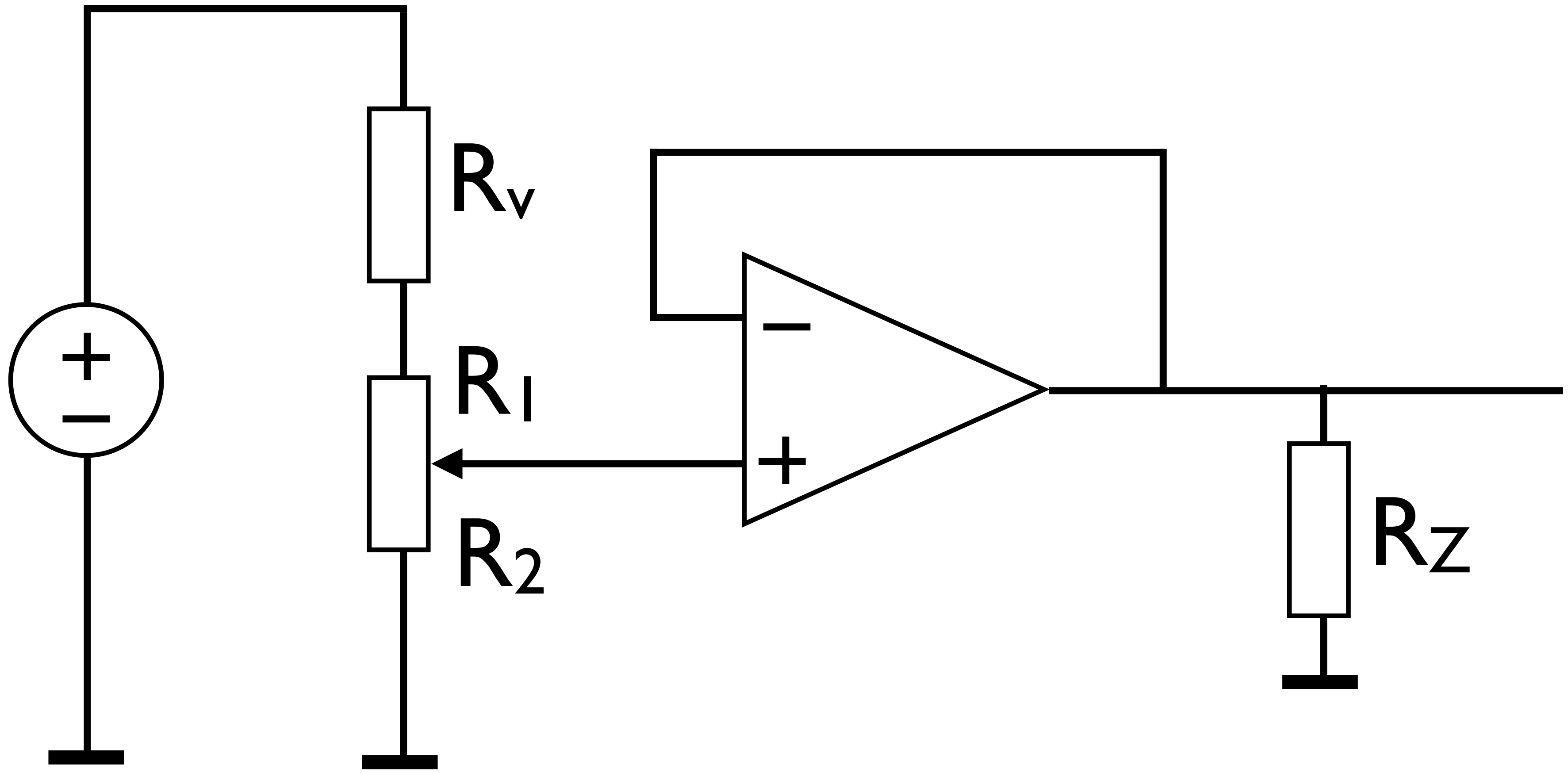




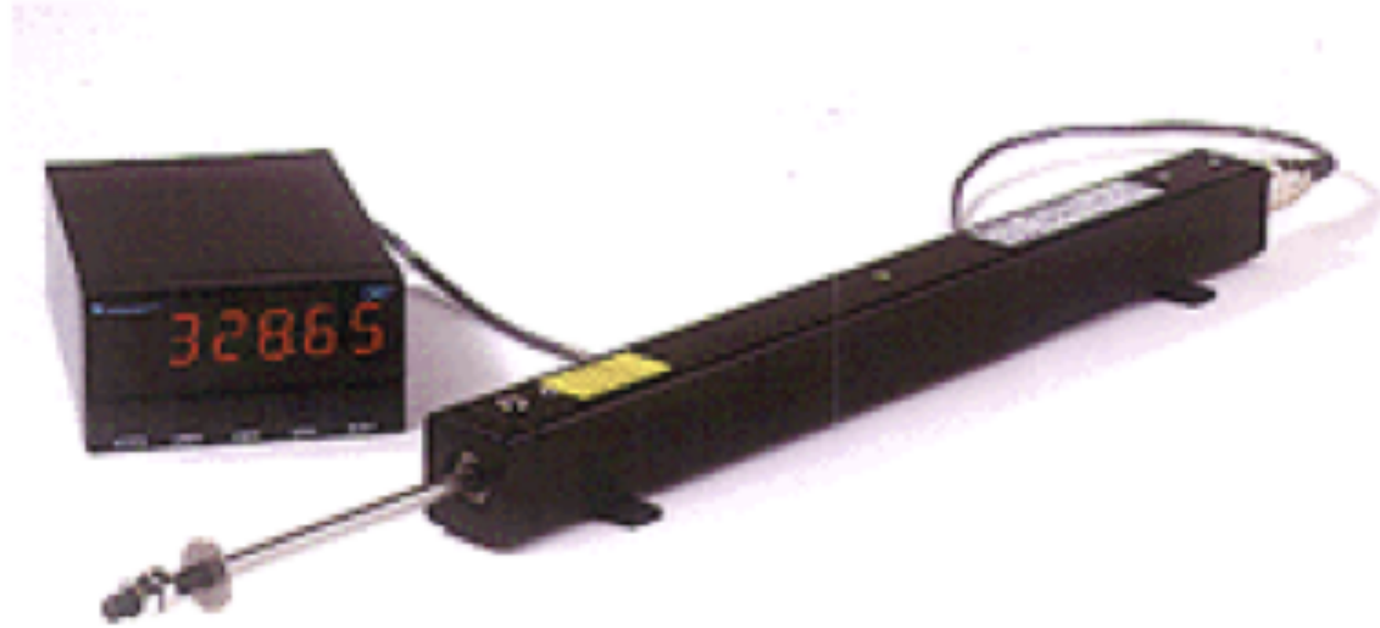




Resistive sensors



LONG STROKE LINEAR POTENTIOMETERS

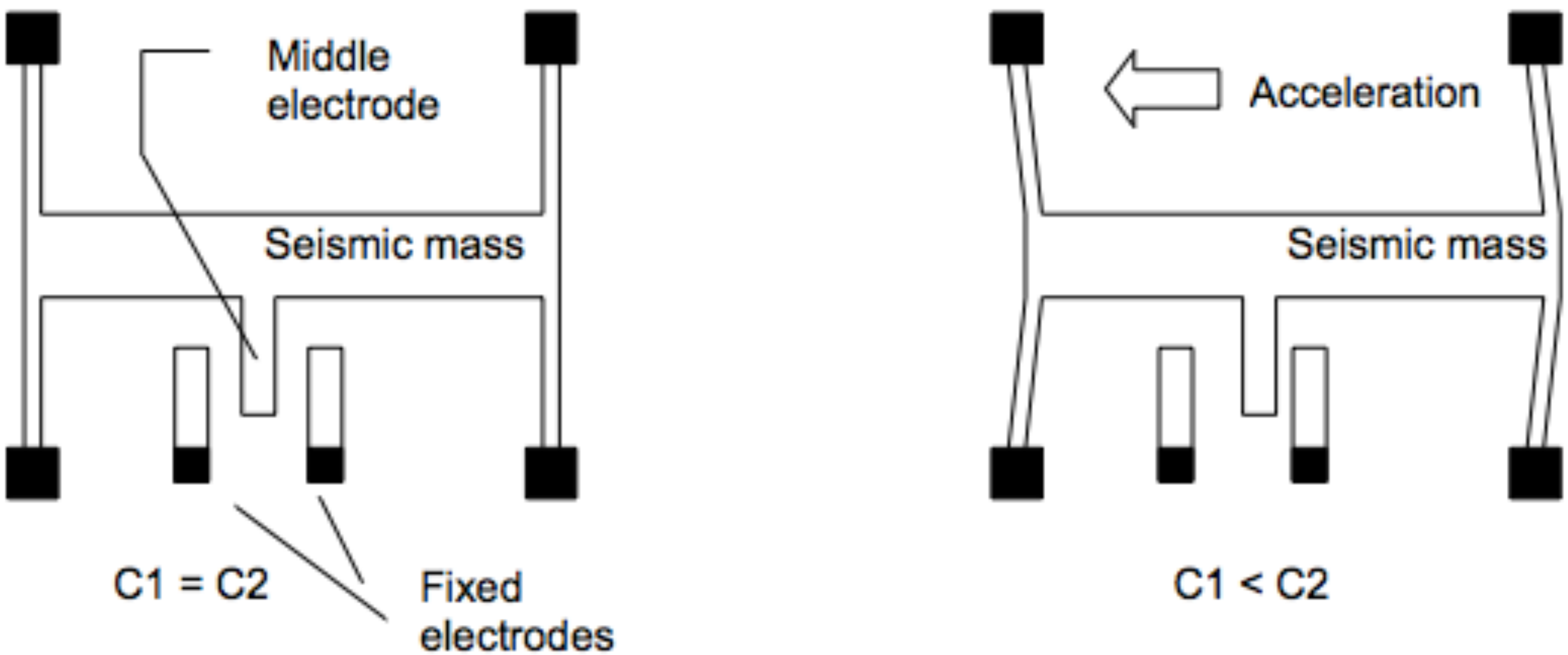


SPECIFICATIONS

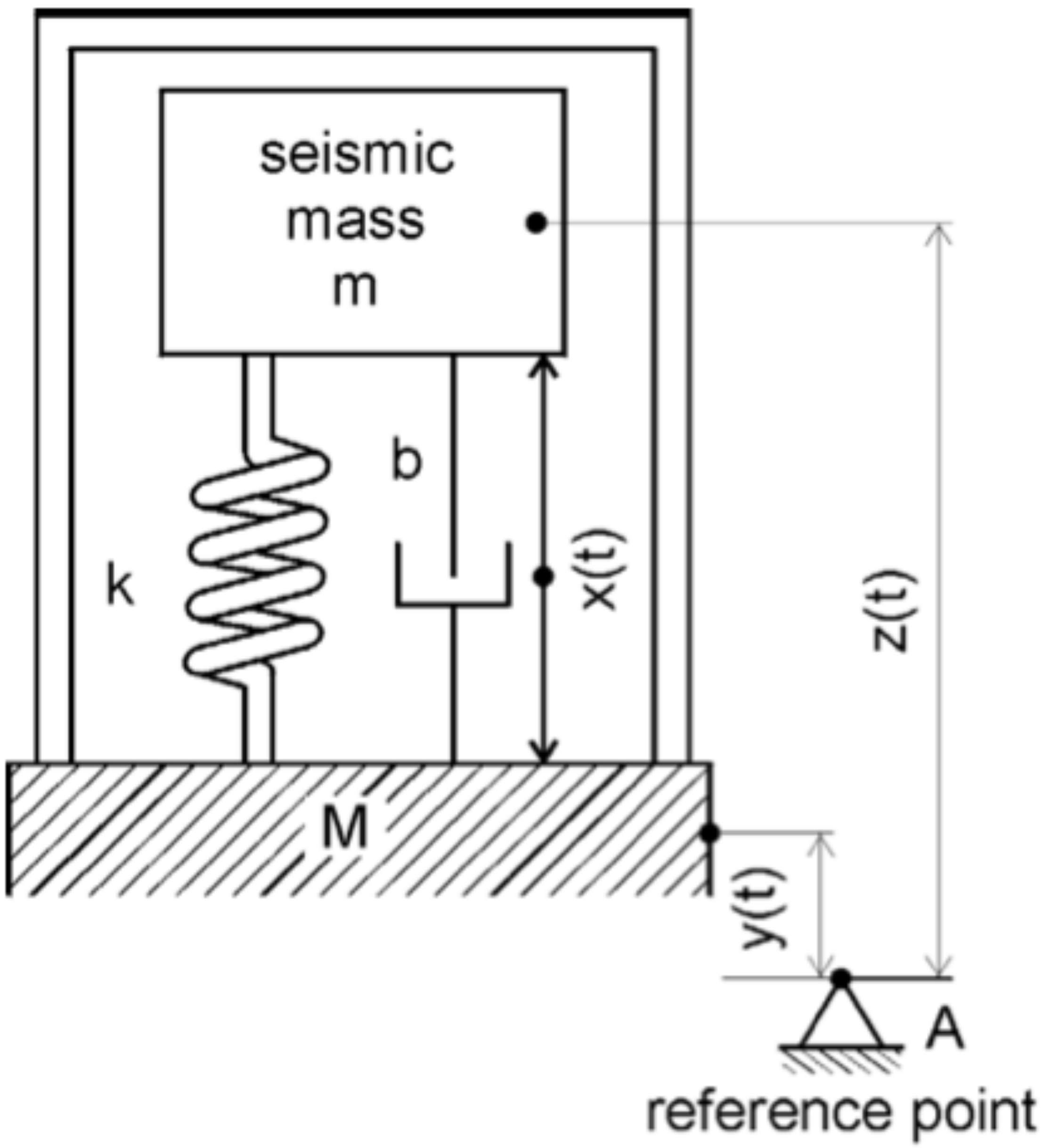
Total Resistance: 5000 Ohms ± 20%
Linearity: ±1% S
Hysteresis: ±0.001" (0.025 mm)
Repeatability: ±0.0005" (0.012 mm)
Incremental Sensitivity: 0.00005"
Power Rating: 0.75 watts/stroke inch
Temp. Range: -65 to 105°C (-85 to 221°F)
Operating Force: 450 grams (1 Lb) maximum
Shaft: 0.236" (6 mm) diameter with 1¼4-28 threaded end adapter
Life: 100 million operations up to 12" stroke-derated proportionally for longer units (standard rate of travel 2"/sec)

Omega

MEMS accelerometers



Absolute sensors of vibrations



Equation of motion of mass-spring system

$$m\frac{d^2z}{dt^2} + b\frac{dx}{dt} + kx = 0$$

$$z(t) = x(t) + y(t)$$

$$\boxed{m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = -m\frac{d^2y}{dt^2}}$$

inertial force

spring force

damping

presumption:

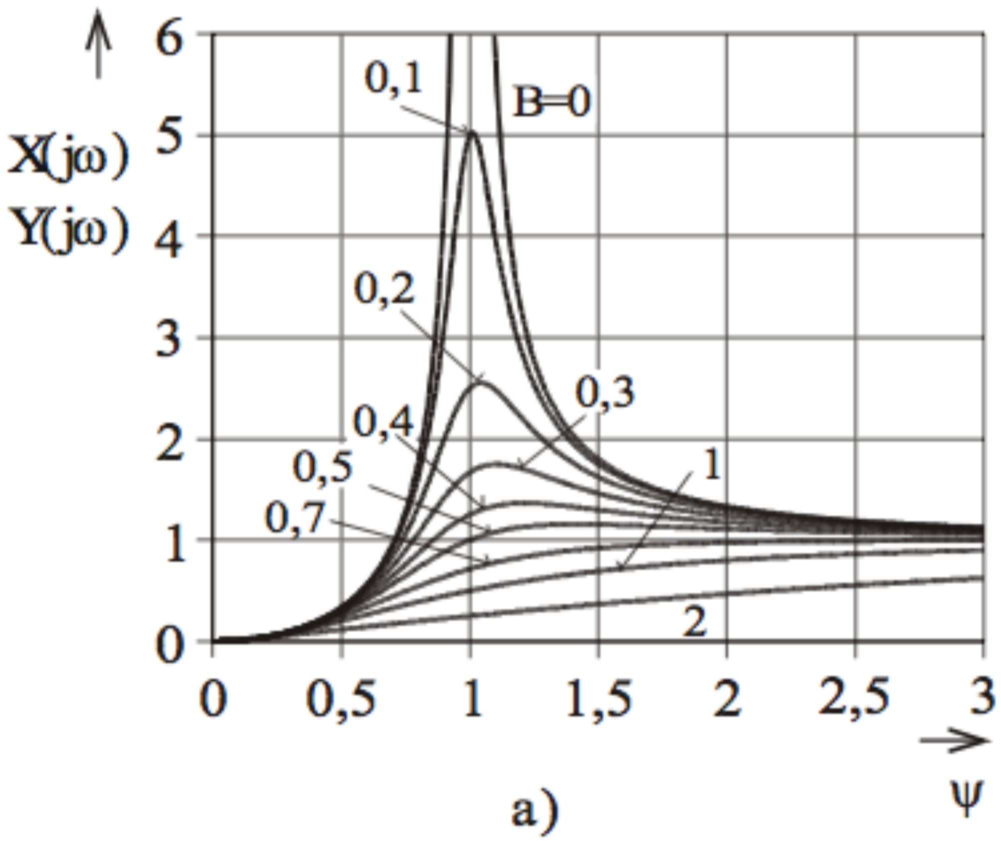
$$y(t) = Y(j\omega)e^{j\omega t}$$

Solution:

$$\boxed{x(t) = X(j\omega)e^{j(\omega t-\varphi)}}$$

m - mass
k - stiffness (spring constant)
b – viscous friction coefficient

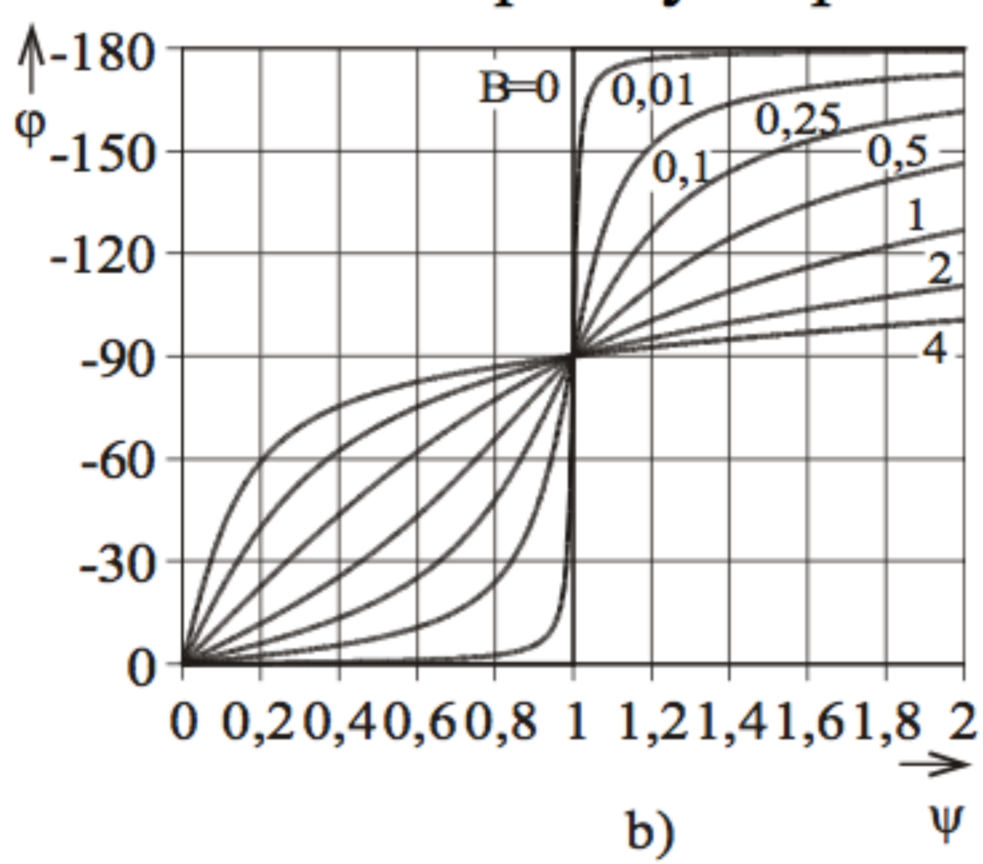
Amplitude frequency response:



a)

$$\left|\frac{X(j\omega)}{Y(j\omega)}\right| = \frac{\Psi^2}{\sqrt{(1-\Psi^2)^2 + (2B\Psi)^2}}$$

Phase frequency response



b)

$$\varphi = \operatorname{arctg} \frac{-2B\Psi}{1-\Psi^2}$$

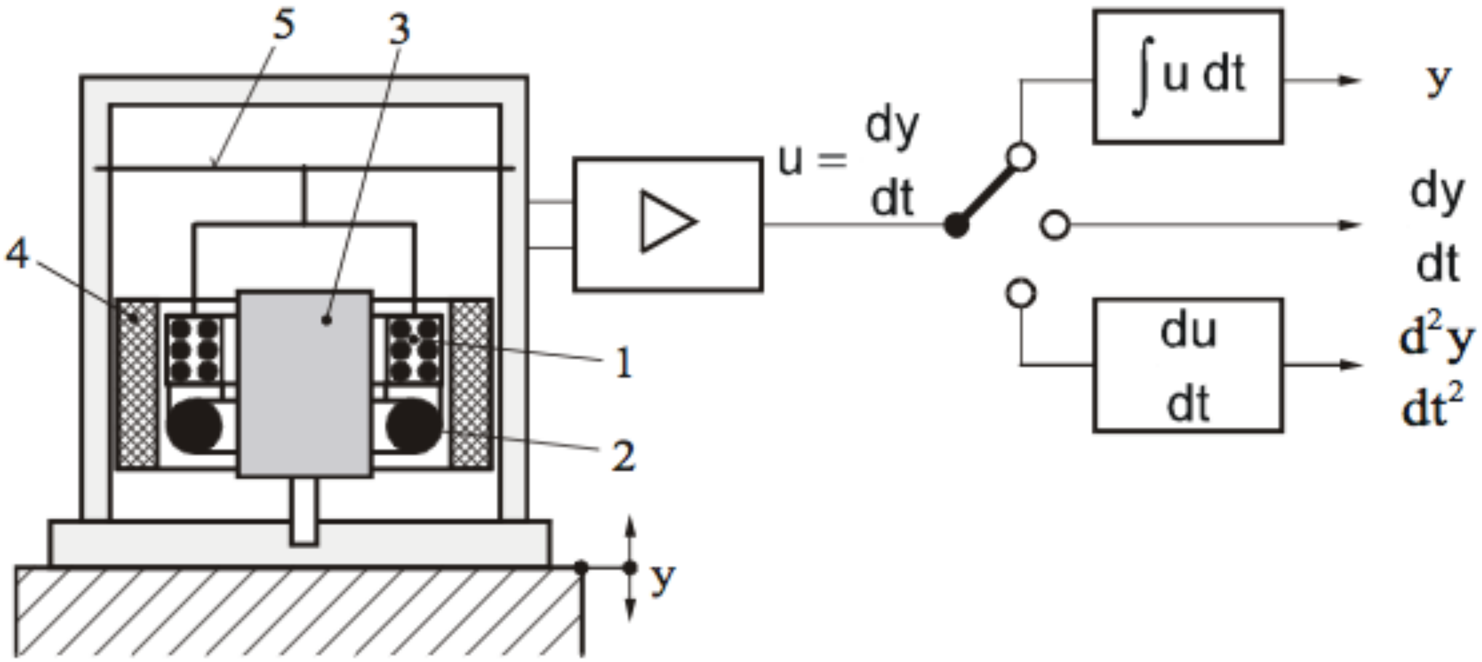
where: $\Psi = \frac{\omega}{\omega_0}$ - normalised frequency (referenced to resonance freq.)

$B = \frac{b}{b_{kr}}$ - damping ratio

$b_{kr} = 2m\omega_0$ - critical damping ratio

$\omega_0 = \sqrt{\frac{k}{m}}$ - resonant frequency

Electrodynamic sensor of vibration



1 - pick-up coil
2 – damping winding
3 – cylindrical part of mg. circuit
4 – permanent magnet
5 - membrane

- seismic mass = mass of coil 1 + mass of winding 2
- viscous damping – due to currents induced in winding 2
- induced voltage $u = \frac{d\Phi}{dt}$ proportional to the *velocity* of coil

☺ - universality

GEOPHONE

- application: vibrations of machines, buildings, occupancy detection

☺ - cheap $f_r = 1 .. 100$ Hz, $m = 20g .. 5$ kg