Detect Sensor (6B)

- Eddy Current Sensor

Please send corrections (or suggestions) to youngwlim@hotmail.com.

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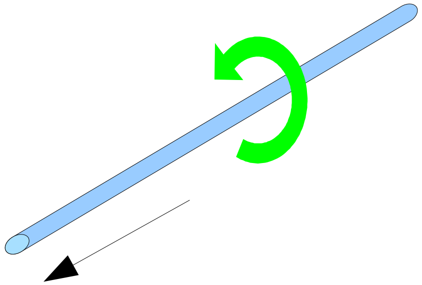
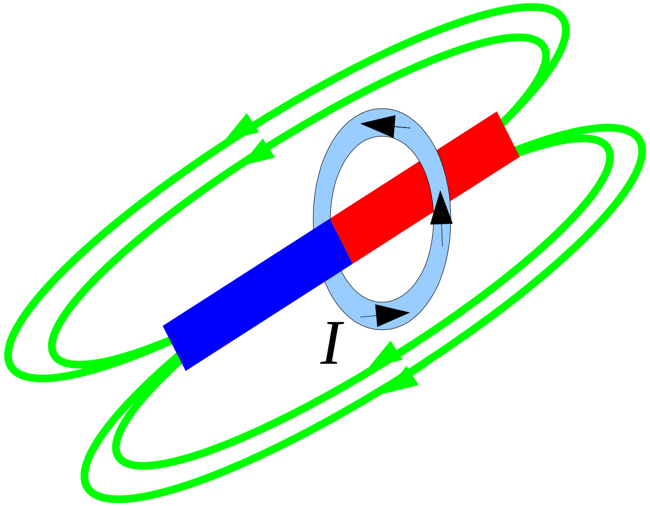
Induction

Electromagnetic Induction



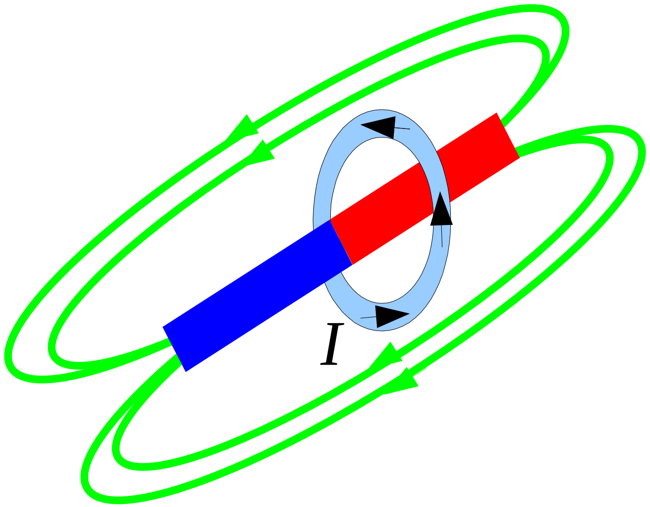
Current $\rightarrow$ *Magnetic Field*

Faraday's Law of Induction



Magnetic Field $\rightarrow$ *Current*

Faraday's Law of Induction



Magnetic Field → *Current*

Changing Magnetic Field

→ electric current

→ induced emf

The amount of induced voltage

is proportional to

the **rate of change** of the magnetic field

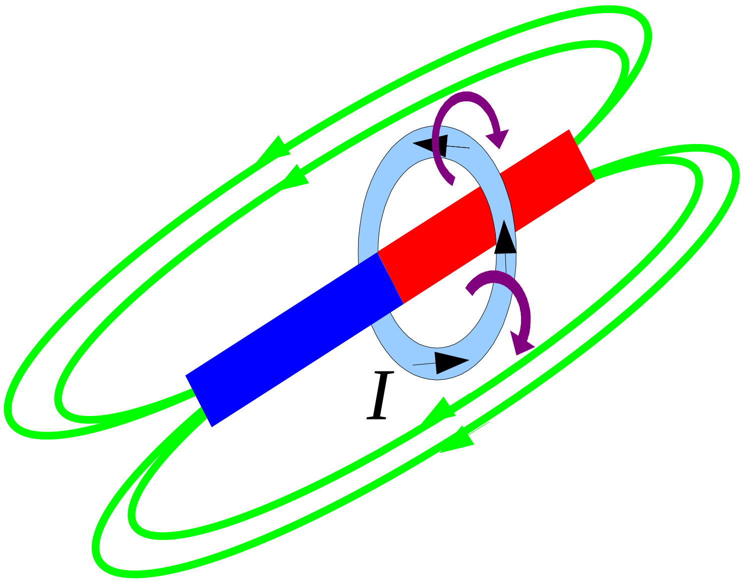
$$\epsilon = -\frac{d\Phi}{dt}$$

$$\boxed{\epsilon = -N\frac{d\Phi}{dt}}$$

N turns in a coil

Lenz's Law of Induction

$$\epsilon = -\frac{d\Phi}{dt}$$



Opposite signs (–)

- induced emf
- change in flux

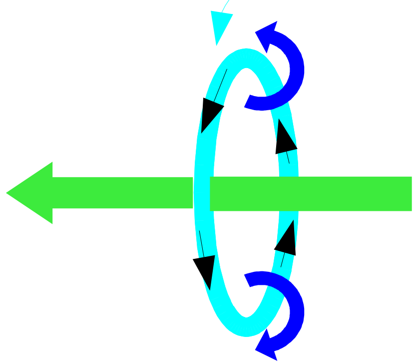
The induced current is in the direction
that creates a magnetic field
that ***opposes*** **the change** in magnetic flux

$Magnetic\ Field \quad \rightarrow \quad EMF$

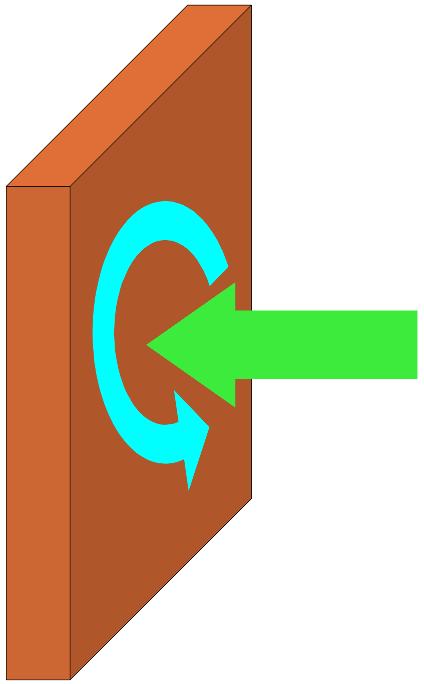
the polarity of the induced EMF :
opposing the change

Eddy Current

induced secondary <u>magnetic field</u>
that ***opposes*** **the change** in magnetic flux



$$\epsilon = -\frac{d\Phi}{dt}$$



Changing magnetic flux induces

- emf
- current

in a circuit (loop, coil)

Changing magnetic flux

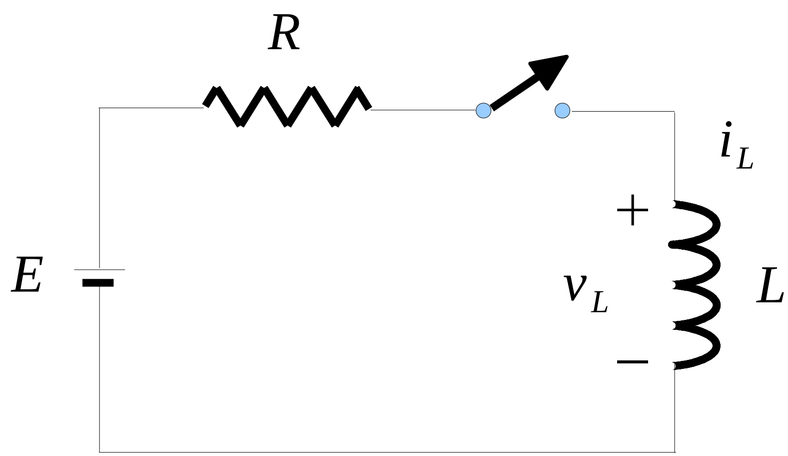
in bulk pieces of metal

induces **circulating currents**

eddy currents

Self-induction

The current i_L does <u>not immediately</u> increase from **0** to the max value ***E/R***



As the current i_L increases

- the <u>magnetic flux</u> increases
- **emf** and **current** are induced
- the <u>secondary</u> magnetic field is created, which **opposes** the <u>change</u> in the <u>original</u> magnetic field

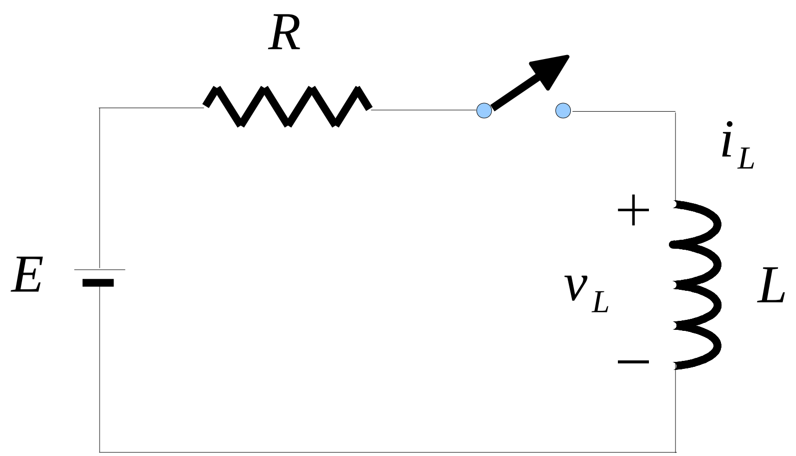
Back EMF (the induced v_L)

opposite direction to the battery ***E***

Self Induction:
changing flux in a circuit
→ the induced emf in the same circuit

Inductance (1)

The current i_L does not immediately increase from **0** to the max value ***E/R***



The induced emf v_L

- equals to the negative of change rate of the magnetic flux
- magnetic flux ← magnetic field ← the current i_L

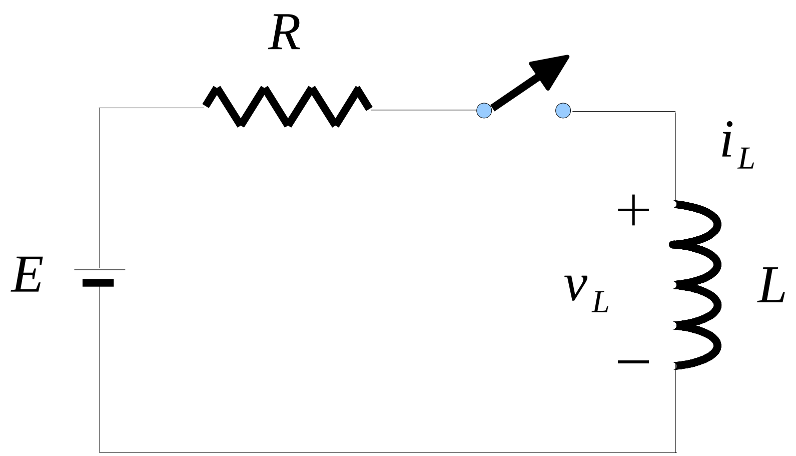
$$\epsilon = -L\frac{dI}{dt}$$

Inductance is
a measure of ability to induce voltage
because of the change in its current

The direction of induced voltage is
to oppose the change in its current

Inductance (2)

The current $\mathbf{i_L}$ does not immediately increase from **0** to the max value ***E/R***



Self-Inductance

$$\epsilon = -L\frac{dI}{dt}$$

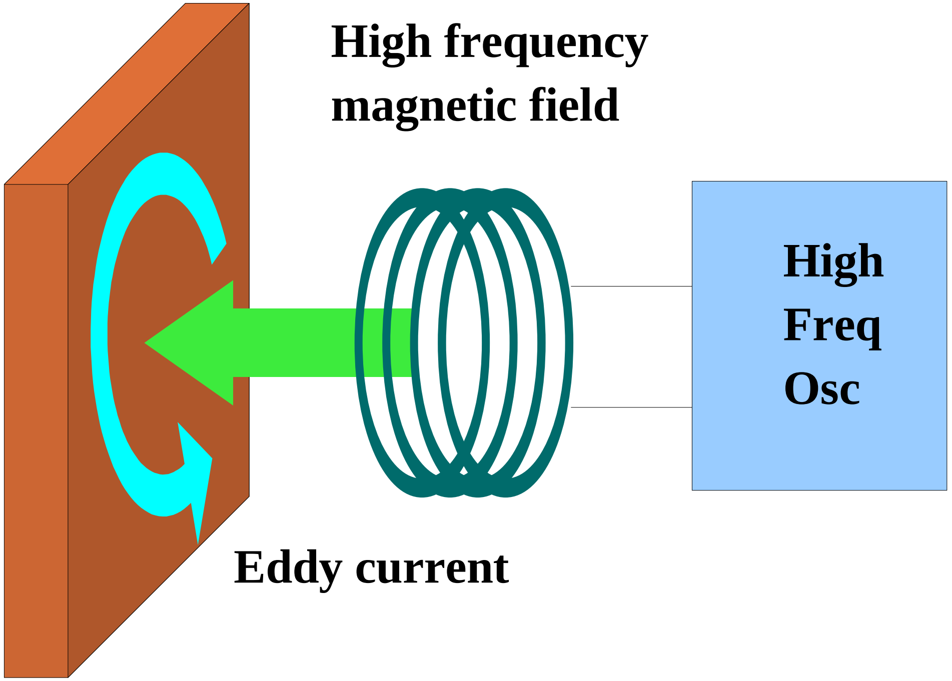
Faraday's Law of Induction

$$\epsilon = -N\frac{d\Phi}{dt}$$

$$\epsilon = -L\frac{dI}{dt} = -N\frac{d\Phi}{dt}$$

$$LI = N\Phi$$

Eddy Current Sensor (1)



When metal target is present

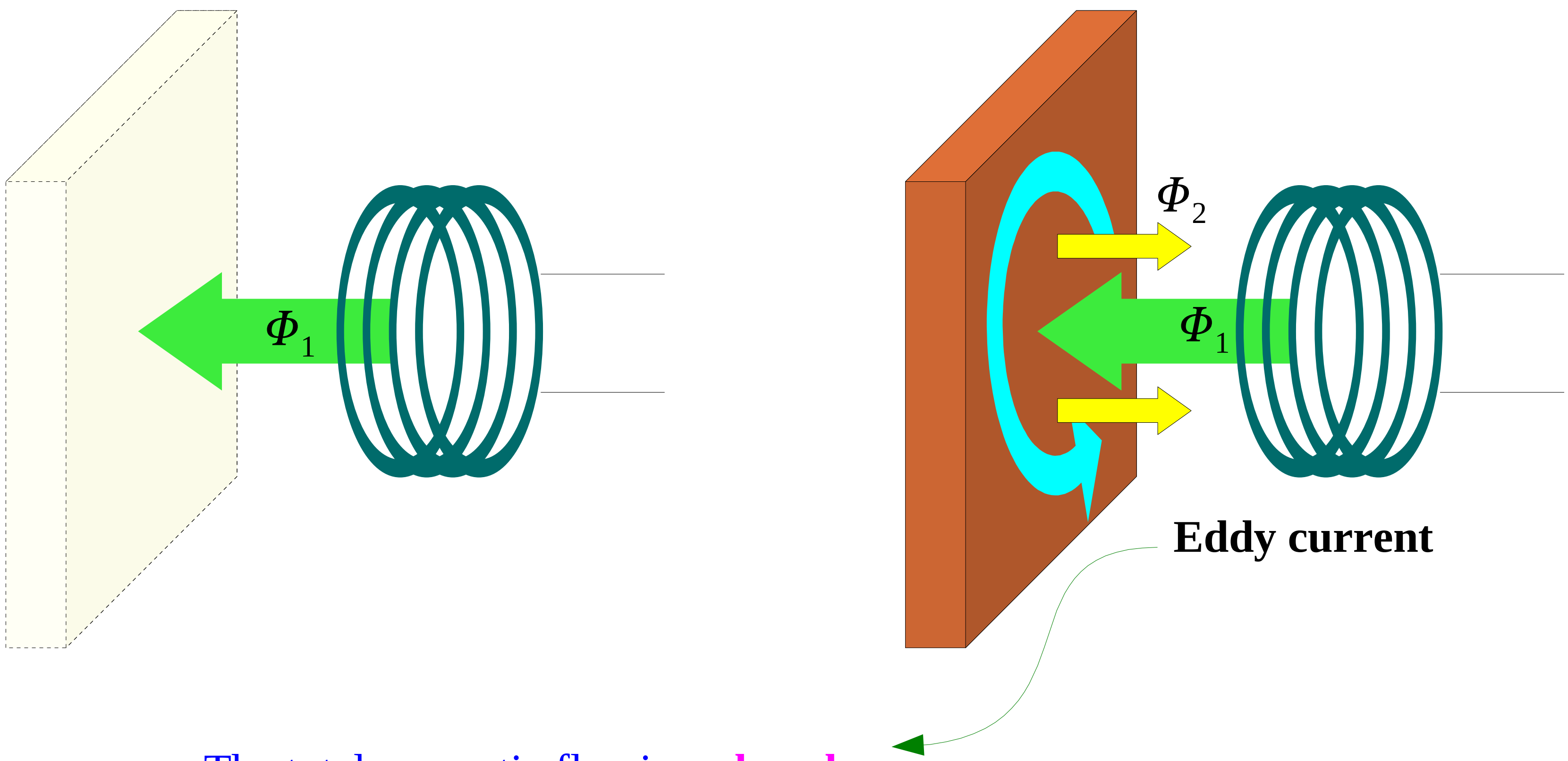
- Eddy current induced
- Secondary magnetic field is created to oppose the original magnetic field
- The inductance of sensor coil is reduced

As a target approaches,
the oscillation **amplitude** becomes smaller
the **phase difference** becomes larger

Detecting changes in amplitude and phase

Eddy Current Sensor (2)

No target present | **Metal target present**



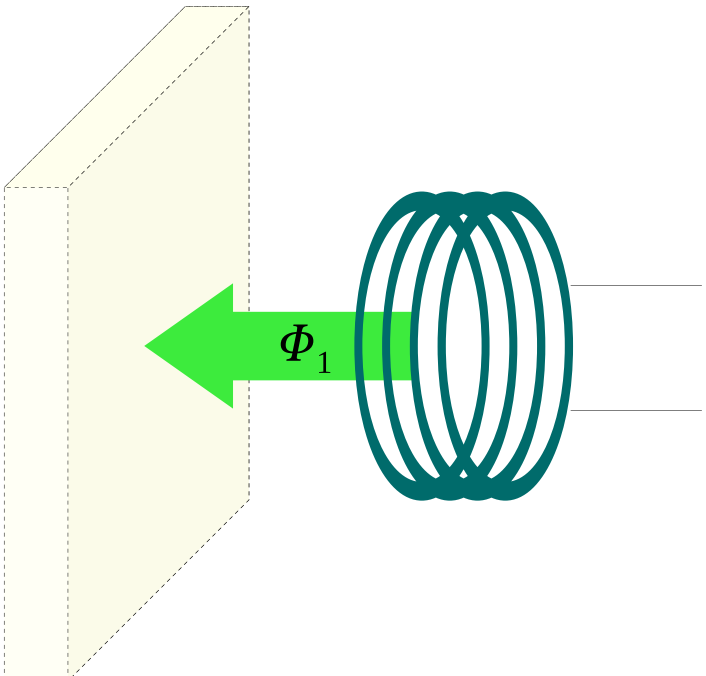
The total magnetic flux is **reduced**

- Because of <u>the opposing magnetic field</u> that is induced by the eddy current

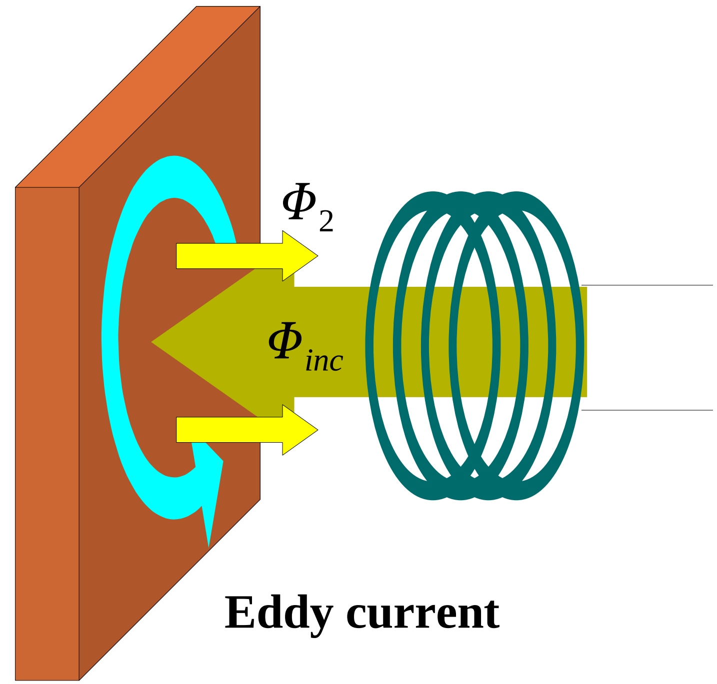
$$\Phi_{net} = \Phi_1 - \Phi_2$$

Eddy Current Sensor (2)

No target present



Metal target present



To get the same magnetic

$$\Phi_1 = \Phi_{net} = \Phi_{inc} - \Phi_2$$

Eddy Current Sensor (3)

No target present

Φ_1

Metal target present

$$\Phi_1 = \Phi_{net} = \Phi_{inc} - \Phi_2$$

magnetic flux ← magnetic field ← current i_L

To increase magnetic flux

the current must be increased

The effective inductance is decreased

$$L = \frac{N\Phi}{I}$$

To get the same magnetic flux, Φ_1
the current must be increased.

Because the increased magnetic flux Φ_{inc}
is obtained by increasing the current

$$L\,I = N\,\Phi$$

References

[1] http://en.wikipedia.org/
[2] Nam Ki Min, Sensor Electronics, Dong-il Press
[3] R. A. Serway, J. W. Jewett, Jr., Physics for scientists and Engineers with Modern Physics, Thomson Brooks/Cole
[4] Thomas L Floyd, Electric Circuit Fundamentals
[5] http://www.sensorcentral.com/