

Exercise walk-through

12.4

Electromagnetic Induction and Faraday's Law

AP Physics 2

Electromagnetic induction

A **changing** magnetic **flux** through a loop induces a voltage:

Flux and Faraday's law

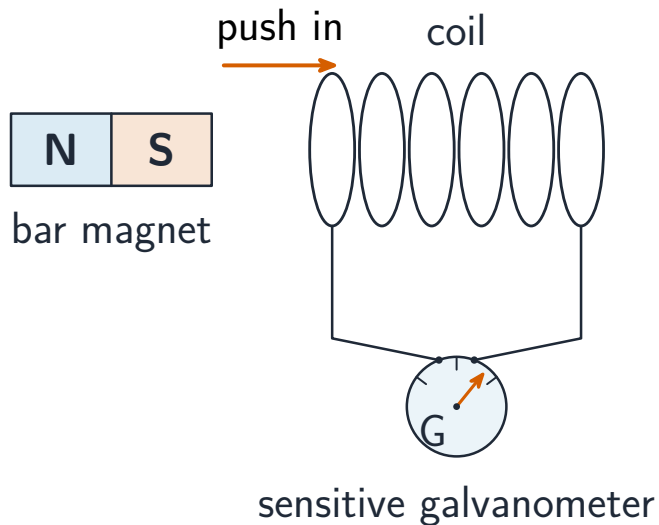
$$\Phi = BA \cos \theta, \quad \varepsilon = - \frac{\Delta \Phi}{\Delta t}$$

Lenz's law (the minus sign): the induced current **opposes the change** – energy conservation.



Induction moves energy between coils

Electromagnetic Induction and Faraday's Law



Moving a magnet into a coil induces an e.m.f. that drives a current

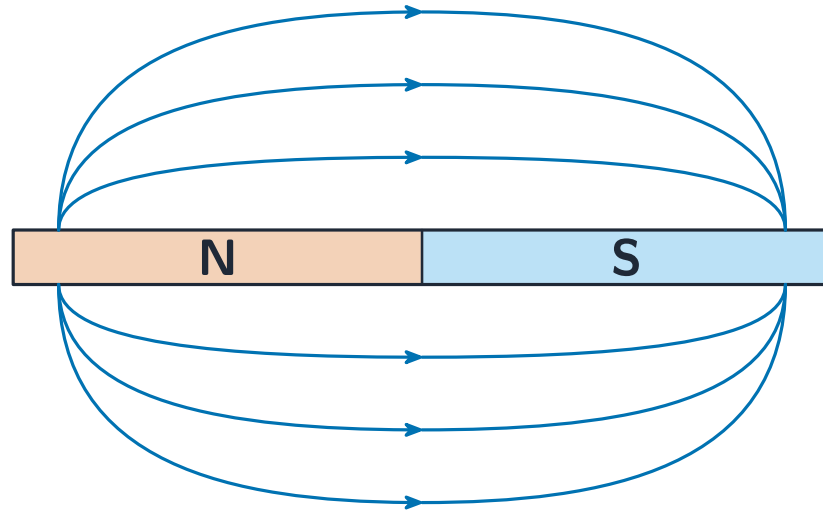
Worked example – an average induced emf

The flux through a single loop drops from 0.020 Wb to 0.008 Wb in 0.030 s. Find the average emf.

- $\varepsilon = -N \frac{\Delta\Phi}{\Delta t}$, with $N = 1$
- $= - \frac{0.008 - 0.020}{0.030} = \frac{0.012}{0.030}$
- $= 0.40 \text{ V}$

The minus sign is **Lenz's law**: the induced current opposes the change that caused it. Quote the magnitude, then say which way the current flows and why.

Magnetic Fields, continued



Field lines run from N to S outside a bar magnet, closer where the field is stronger

How three kinds of material answer a magnetic field

ferromagnetic

iron, nickel, cobalt – domains align *with* the field, strongly, and can **stay** aligned as a permanent magnet

paramagnetic

a **weak** alignment with the field, lost as soon as the field is removed

diamagnetic

present in **all** materials – a usually weak alignment *opposite* to the field

permeability

the measure of the response; free space has the constant $\mu_0 = 4\pi \times 10^{-7} \text{ T m/A}$

Diamagnetism is universal but weak, so it only shows when nothing stronger is present. The other two are extra effects on top of it.

Exercises 2.1-2.3

2.1 Find the magnetic flux through a 0.20 m^2 loop lying face-on in a 0.50 T field. [2]

2.2 State what is needed to induce an emf in a coil. [1]

2.3 State Lenz's law. [1]

Exercises 2.1-2.3

2.1 Find the magnetic flux through a 0.20 m^2 loop lying face-on in a 0.50 T field. [2]

2.1

- $\Phi = BA \cos 0^\circ = 0.50 \times 0.20 = 0.10 \text{ Wb}$

2.2 State what is needed to induce an emf in a coil. [1]

2.2

- a changing magnetic flux through the coil

2.3 State Lenz's law. [1]

2.3

- the induced current opposes the change in flux that produces it

Exercises 3.1-3.2

3.1 Magnetic flux is

[1]

☐

A $BA \cos \theta$

B $BI\ell$

C qvB

D $\frac{\mu_0 I}{2\pi r}$

3.2 The rule that an induced current opposes the change that causes it is

[1]

☐

A Ohm's law

B Faraday's law

C Lenz's law

D Kirchhoff's law

Exercises 3.1·3.2

3.1 Magnetic flux is

[1]

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A $BA \cos \theta$

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3.1 A

- $BA \cos \theta$.

3.2 The rule that an induced current opposes the change that causes it is

[1]

☐

A Ohm's law

B Faraday's law

C Lenz's law

D Kirchhoff's law

3.2 C

- Lenz's law.

Exercise 3.3 (a)

3.3 The flux through a coil falls from 0.40 Wb to 0.10 Wb in 0.20 s .

(a) Find the size of the induced emf.

[3]

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3.3 The flux through a coil falls from 0.40 Wb to 0.10 Wb in 0.20 s.

(a) Find the size of the induced emf.

[3]

(a)

- $|\varepsilon| = \left| \frac{\Delta\Phi}{\Delta t} \right| = \frac{0.40 - 0.10}{0.20} = 1.5 \text{ V}$

Exercise 3.3 (b)

3.3 The flux through a coil falls from 0.40 Wb to 0.10 Wb in 0.20 s.

(b) Name the law used.

[1]

Exercise 3.3 (b)

3.3 The flux through a coil falls from 0.40 Wb to 0.10 Wb in 0.20 s.

(b) Name the law used.

[1]

(b)

- Faraday's law