

Exercise walk-through

13.1

Magnetic Flux

AP Physics C: Electricity and Magnetism

Magnetic flux and Faraday's law

Flux, then Faraday

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = BA \cos \theta$$

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

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

Motional emf: $\varepsilon = BLv$; a coil of N turns: $\times N$.



Motor rotor

Flux, and the three ways it changes

Magnetic flux measures how much field passes through a surface. For a uniform field through a flat loop it is a dot product, so the **area vector** – normal to the surface – sets the sign:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$$

- B changes – a stronger or weaker field
- A changes – the loop grows, shrinks or leaves the field
- θ changes – the loop rotates

Any one of the three induces an e.m.f.
A generator uses the third.

The sliding rod on rails

$$L = 0.20 \text{ m at } 3.0 \text{ m/s across } 0.50 \text{ T}$$

$$\varepsilon = BLv = 0.50(0.20)(3.0) = 0.30 \text{ V}$$

The rod sliding on conducting rails, closed by a resistor, is the setup every question is built from: the growing loop area changes the flux.

Once a current flows, the field pushes back on it ($\vec{F} = \int I d\vec{l} \times \vec{B}$), and by Lenz's law that force always **resists the motion** that caused it. Push harder, get more current, feel more drag – the mechanical work is what becomes electrical energy.

Faraday's law is also the third of **Maxwell's equations** :
a changing magnetic flux creates a **circulating electric field**.

Exercises 2.1-2.3

2.1 Find the flux through a 0.10 m^2 loop placed face-on in a 0.30 T field. [2]

2.2 State three ways to change the flux through a loop. [2]

2.3 State what a changing magnetic flux produces. [1]

Exercises 2.1-2.3

2.1 Find the flux through a 0.10 m^2 loop placed face-on in a 0.30 T field. [2]

2.1

- $\Phi_B = BA = 0.30 \times 0.10 = 0.030 \text{ Wb}$

2.2 State three ways to change the flux through a loop. [2]

2.2

- change the field strength B , the area A , or the angle θ

2.3 State what a changing magnetic flux produces. [1]

2.3

- an induced emf

Exercise 3.1

3.1 Magnetic flux is

[1]

☐ **A** $\int \vec{B} \cdot d\vec{A}$

B $\int \vec{E} \cdot d\vec{A}$

C BIL

D qvB

Exercise 3.1

3.1 Magnetic flux is

[1]

☐ A $\int \vec{B} \cdot d\vec{A}$

B $\int \vec{E} \cdot d\vec{A}$

C BIL

D qvB

3.1 A

• $\int \vec{B} \cdot d\vec{A}.$

Exercise 3.2

3.2 The flux through a loop is greatest when its plane is

[1]

☐

A parallel to the field

B perpendicular to the field

C at 45° to the field

D irrelevant to the field

Exercise 3.2

3.2 The flux through a loop is greatest when its plane is

[1]

☐

A parallel to the field

B perpendicular to the field

C at 45° to the field

D irrelevant to the field

3.2 B

- the plane perpendicular to the field means the loop faces it

Exercise 3.3 (a)

3.3 A 0.050 m^2 coil sits in a 0.40 T field.

(a) Find the flux when the coil faces the field.

[2]

Exercise 3.3 (a)

3.3 A 0.050 m^2 coil sits in a 0.40 T field.

(a) Find the flux when the coil faces the field.

[2]

(a)

- $\Phi_B = BA = 0.40 \times 0.050 = 0.020 \text{ Wb}$

Exercise 3.3 (b)

3.3 A 0.050 m^2 coil sits in a 0.40 T field.

(b) Find the flux when the field lies in the plane of the coil.

[1]

Exercise 3.3 (b)

3.3 A 0.050 m^2 coil sits in a 0.40 T field.

(b) Find the flux when the field lies in the plane of the coil.

[1]

(b)

- zero ($\theta = 90^\circ$)