42 – Physics

magnetic flux. Figure 3(a) shows a rectangular loop of wire of area A in a field at right angles to the loop of magnetic flux density B. The magnetic flux Φ is given by

$\Phi = BA$

In Figure 3(b) a side view of the same situation is shown but with the rectangular loop at an angle θ to its original position. Here less of the flux passes through the loop. The new value of the magnetic flux Φ' through the area is

$\Phi' = BA \cos\theta$

When the loop is parallel to the field, θ will be 90°, and since cos 90° = 0, the magnetic flux will be zero. Be careful with this angle. It is not the angle between the flux and the area, but the angle the loop has turned through. Make sure you have things the right way around.

The unit of magnetic flux is the **weber**. One weber (Wb) is the magnetic flux when a magnetic field of magnetic flux density one tesla passes at right angles through an area of one square metre.

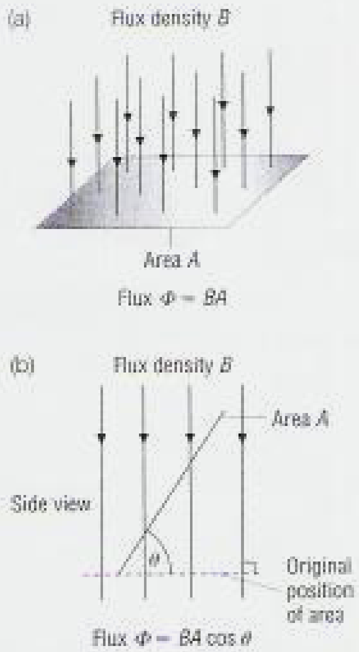

Figure 3 **(a)** Here the loop of area A is at right angles to the field of flux density B so $\theta = 0$, $\cos\theta = 1$ and the flux through the loop is BA; **(b)** here the loop of area A has been rotated through an angle θ from its original position, so the flux through the loop is $BA\cos\theta$

Magnetic flux linkage

In many motors and generators, coils of many turns of wire are used, so it is useful to know not just the flux through one coil but the product of this and the number of turns N. This quantity is called the **flux linkage** and is defined by the equation

flux linkage = $N\Phi$

is simply measured in weber turns, Wb turns.

Worked example

A rectangular coil of 400 turns of wire has length 8.9 cm and width 6.4 cm. It rotates in a magnetic field of flux density 0.045 T. Calculate the flux through the coil and the flux linkage when the plane of the coil is **(a)** at right angles to the field, **(b)** has moved through an angle of 40° and **(c)** has moved through 90° so that it is parallel to the field, as shown in Figure 4.

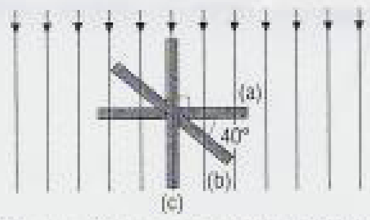

Figure 4 Rectangular coil

Answer

The flux is always given by $\Phi = BA\cos\theta$, and the flux linkage by ΦN.
The area A of the coil is 0.089 m × 0.064 m = 5.7×10^{-3} m². Answers are tabulated so that the pattern is clear.

	(a) Coil at 90° to field	(b) Coil moved by 40°	(c) Coil parallel to field
Flux Φ $= BA\cos\theta$	$0.045 \times 5.7 \times 10^{-3} \cos 0$ $= 2.56 \times 10^{-4}$ Wb	$2.56 \times 10^{-4} \times \cos 40$ $= 1.96 \times 10^{-4}$ Wb	$2.56 \times 10^{-4} \times \cos 90$ $= 0$
Flux linkage $= \Phi N$	$2.56 \times 10^{-4} \times 400$ = 0.102 Wb turns	$1.96 \times 10^{-4} \times 400$ = 0.078 Wb turns	0

Key definitions

Magnetic flux through an area A is defined as the product of the magnetic flux density B and the projection of area A onto a surface at right angles to the flux. It is given the symbol Φ.

$\Phi = BA\cos\theta$

where θ is the angle between the plane of the area and the projection surface.

The unit of magnetic flux is the weber. One weber (Wb) is the magnetic flux when a magnetic field of magnetic flux density one tesla passes at right angles through an area of one square metre.

Magnetic **flux linkage** for a coil equals the magnetic flux through the coil multiplied by the number of turns on the coil.

Questions

✓ 1 Show that a Tesla, T, is a Weber per square metre, Wb m⁻².

✓ 2 A long coil or solenoid wound on an iron rod has 300 turns of cross-sectional area 4.0×10^{-5} m². When it carries a certain current the flux linkage of the coil is 6.0×10^{-4} Wb turns.

(a) Calculate **(i)** the flux linking one turn of the coil and **(ii)** the flux density in the iron rod.

(b) Why is it not possible to answer this question when the coil is wound on a wooden dowel?