# A screenshot of a computer Description automatically generated**05/01/2025 6.3.3 Flux and Flux Linkage**

# *DO Now:*

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1. Sketch the direction of force on the particle in both chambers.
2. Which chamber has the greater magnetic field?
3. If the particle is positive, state the direction of the magnetic field.
4. State and explain the velocity of the particle as it leaves the second chamber.

# *Magnetic Flux, φ*

Magnetic flux is a measure of how many magnetic field lines are passing through an area of *A* m2.

The magnetic flux through an area *A* in a magnetic field of flux density *B* is given by: 

This is when *B* is ***perpendicular*** to *A*, so the normal to the area is in the same direction as the field lines.

**Magnetic Flux is measured in Webers, Wb**

The more field pass through area *A*, the greater the concentration and the stronger magnetic field.

This is why a magnet is strongest at its poles; there is a high concentration of field lines.

A diagram of a circle with arrows and a circle with a circle

Description automatically generatedWe can see that the amount of flux flowing through a loop of wire depends on the angle it makes with the field lines. The amount of flux passing through the loop is given by: 

*θ* is the angle that the normal to the loop makes with the field lines.

# *Magnetic Flux Density*

We can now see why *B* is called the magnetic flux density. If we rearrange the top equation for *B* we get:

 So *B* is a measure of how many flux lines (field lines) passes through each unit area (per m2).

A flux density of 1 Tesla is when an area of 1 metre squared has a flux of 1 Weber.

# *Flux Linkage*

We now know that the amount of flux through one loop of wire is: 

If we have a coil of wire made up of *N* loops of wire the total flux is given by: 

The total amount of flux, , is called the *Magnetic Flux Linkage*; this is because we consider each loop of wire to be linked with a certain amount of magnetic flux.

Sometimes flux linkage is represented by , so  which makes our equation for flux linkage 

**Flux Linkage is measured in Webers, Wb**

# *Rotating Coil in a Magnetic Field*

If we have a rectangle of wire that has an area of *A* and we place it in a magnetic field of flux density *B*, we have seen that the amount of flux flowing through the wire depends on the angle between it and the flux lines.

The flux linkage at an angle *θ* from the perpendicular to the magnetic field is given by: 

From circular motion we established that the angular speed is given by  which can be rearranged to and substituted into the equation above to transform it into: 

When *t* = 0 the wire is perpendicular to the field so there is a maximum amount of flux.

A diagram of a diagram

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At 1 the flux linkage is a maximum in one direction. There is the lowest rate of change at this point.

At 2 the flux linkage is zero. There is the biggest rate of change at this point

At 3 the flux linkage is maximum but in the opposite direction. The lowest rate of change occurs here too.

At 4 the flux linkage is zero. There is the biggest rate of change at the point too but in the opposite direction.

**Next lesson we will be looking at inducing an e.m.f. using a wire and a magnetic field. The size of the e.m.f. depends on the rate of change of flux linkage.**

**Worked Example:**

1. A square coil is placed in a uniform magnetic field of flux density 40 mT.

Diagram of a diagram of a wire

Description automatically generatedThe plane of the coil is normal to the magnetic field. The coil has 200 turns and the length of each side of the coil is 3.0 cm.

1. Calculate
2. the magnetic flux Φ through the coil;
3. the magnetic flux linkage for the coil.
4. The plane of the coil is turned through 90°. What is the change in the magnetic flux linkage for the coil?

**Your Turn**

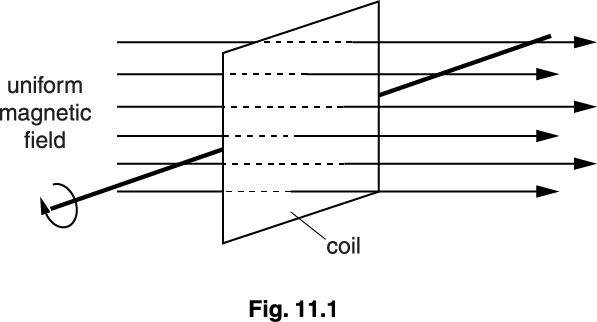
A diagram of a wire with arrows

Description automatically generated with medium confidence

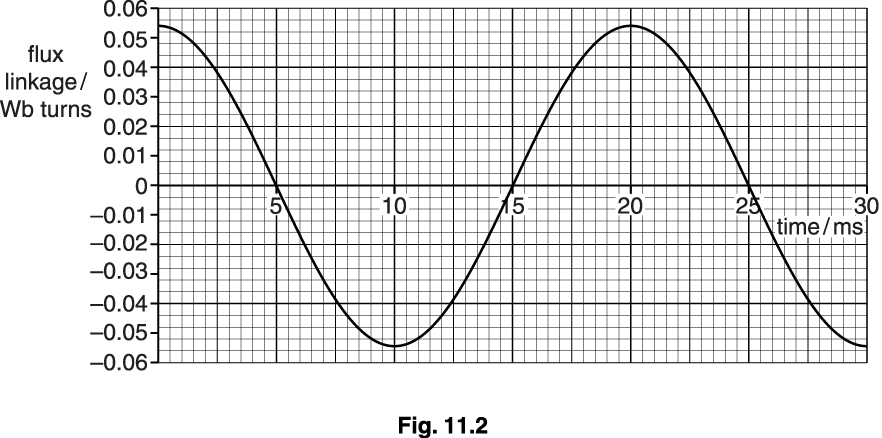
1. A coil of cross-sectional area 4.0 × 10–4 m2 and 70 turns is placed in a uniform magnetic field.
2. The plane of the coil is at right angles to the magnetic field. Calculate the magnetic flux density when the flux linkage for the coil is 1.4 × 10–4 Wb.
3. The coil is placed in a magnetic field of flux density 0.50 T. The normal to the coil makes an angle of 60˚ to the magnetic field, as shown in the diagram. Calculate the flux linkage for the coil.

A diagram of a wire

Description automatically generated

1. The diagram shows a coil of radius 4.0cm and 1000 turns placed in a uniform magnetic field of flux density 0.060 T. The place of the coil is at right-angles to the magnetic field. Determine the magnetic flux Φ through the coil and the magnetic flux linkage.
2. The diagram shows a square coil initially perpendicular to a uniform magnetic field.

The graph below shows how the flux linkage through the coil changes as it rotates in the field.



The coil has 200 turns. The magnetic field has a flux density of 7.5 × 10-2 T.  
  
Use these data and data from the graph to calculate the length of a side of the square coil.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Tokens at start of Q** | **A** | **B** | **C** | **D** | **Tokens after Question** |
| **1** | **100** |  |  |  |  |  |
| **2** |  |  |  |  |  |  |
| **3** |  |  |  |  |  |  |
| **4** |  |  |  |  |  |  |

**Q1.** A 500 turn coil of cross-sectional area 4.0 × 10–3 m2 is placed with its plane perpendicular to a magnetic field of flux density 7.5 × 10–4 T. What is the value of the flux linkage for this coil?

**A**        3.0 × 10–6 Wb turns

**B**       1.5 × 10–3 Wb turns

**C**       0.19 Wb turns

**D**       94 Wb turns

**Q2.** An aircraft, of wing span 60 m, flies horizontally at a speed of 150 m s–1. If the vertical component of the Earth’s magnetic field in the region of the plane is 1.0 × 10–5 T, what is the magnitude of the magnetic flux cut by the wings in 10 s?

**A**       1.0 × 10–5 Wb

**B**       1.0 × 10–4 Wb

**C**       9.0 × 10–2 Wb

**D**       9.0 × 10–1 Wb

A diagram of a clock

Description automatically generated**Q3.** The diagram shows a coil placed in a uniform magnetic field. In the position shown, the angle between the normal to the plane of the coil and the magnetic field is  is rad.

Which line, **A** to **D**, in the table shows the angles through which the coil should be rotated, and the direction of rotation, so that the flux linkage becomes (i) a maximum, and (ii) a minimum?

|  |  |  |
| --- | --- | --- |
| **Angle of rotation / rad** | | |
|  | **(i) for maximum flux linkage** | **(ii) for minimum flux linkage** |
| **A** | clockwise | anticlockwise |
| **B** | anticlockwise | clockwise |
| **C** | clockwise | anticlockwise |
| **D** | anticlockwise | clockwise |

**Q4.**

A diagram of a square with lines and text

Description automatically generatedA rectangular coil of area *A* has *N* turns of wire. The coil is in a uniform magnetic field of flux density *B* with its plane parallel to the field lines.

The coil is then rotated through an angle of 30° about axis **PQ**.

What are the correct initial value and correct final value of the magnetic flux linkage?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Initial magnetic flux linkage** | **Final magnetic flux linkage** |  |
| **A** | 0 | *BAN* |  |
| **B** | 0 | *BAN* |  |
| **C** | *BAN* | *BAN* |  |
| **D** | *BAN* | *BAN* |  |

**Q5.**

A rectangular coil measuring 20 mm by 35 mm and having 650 turns is rotating about a horizontal axis which is at right angles to a uniform magnetic field of flux density 2.5 × 10–3 T.  
The plane of the coil makes an angle *θ* with the vertical, as shown in the diagrams.

A drawing of a rectangular object

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(a)     State the value of *θ* when the magnetic flux through the coil is a minimum.

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(b)     Calculate the magnetic flux passing through the coil when *θ* is 30°.

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(c)     What is the maximum *flux linkage* through the coil as it rotates?

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**(2)**