WJEC England A-Level Physics

3.10 Electromagnetic Induction

Flashcards

What is magnetic flux? (Quantitative)

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What is magnetic flux? (Quantitative)

$$\Phi = BA$$

Flux = Flux Density x Area

Where B is normal to A

What is flux linkage?

What is flux linkage?

$N\Phi$ = The number of turns cutting the flux at one time.

What is the flux linkage of a rectangular coil rotating through a magnetic field?

What is the flux linkage of a rectangular coil rotating through a magnetic field?

$$N\Phi = BAN\cos\theta$$

What is Faraday's Law?

What is Faraday’s Law?

The induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage.

What is Lenz’s Law?

What is Lenz's Law?

The direction of the induced e.m.f. is such as to oppose the change that induces it.

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

What happens when you move a straight conductor through a magnetic field?

What happens when you move a straight conductor through a magnetic field?

The electrons experience a force pushing them to one end of the conductor creating an emf across the conductor. The rod obey Faraday's law - it is changing flux as it moves through the field hence an EMF is induced.

What would be the EMF produced when rotating a coil at a constant rate in a magnetic field?

What would be the EMF produced when rotating a coil at a constant rate in a magnetic field?

$$\varepsilon = BAN\omega \sin(\omega t)$$

Where ω is the angular velocity of the rotating coil.

How do you work out the shape of the field around a current-carrying wire?

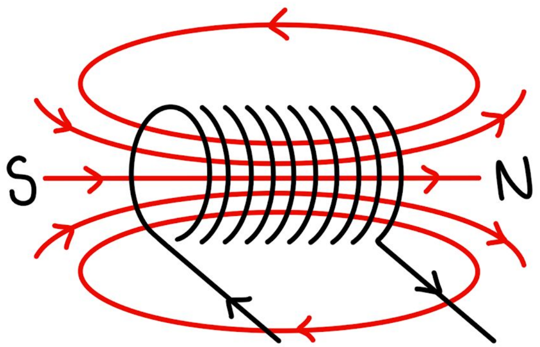
How do you work out the shape of the field around a current-carrying wire?

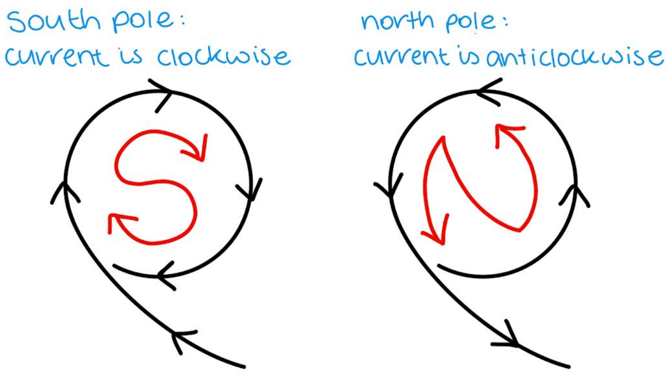
The right-hand thumb rule: take your right hand and make a thumbs-up shape. Point your thumb in the direction of the (conventional) current and the field goes around the wire in the direction of your fingers (from palm to tip).

How do you work out the shape of the field around a solenoid?

How do you work out the shape of the field around a solenoid?

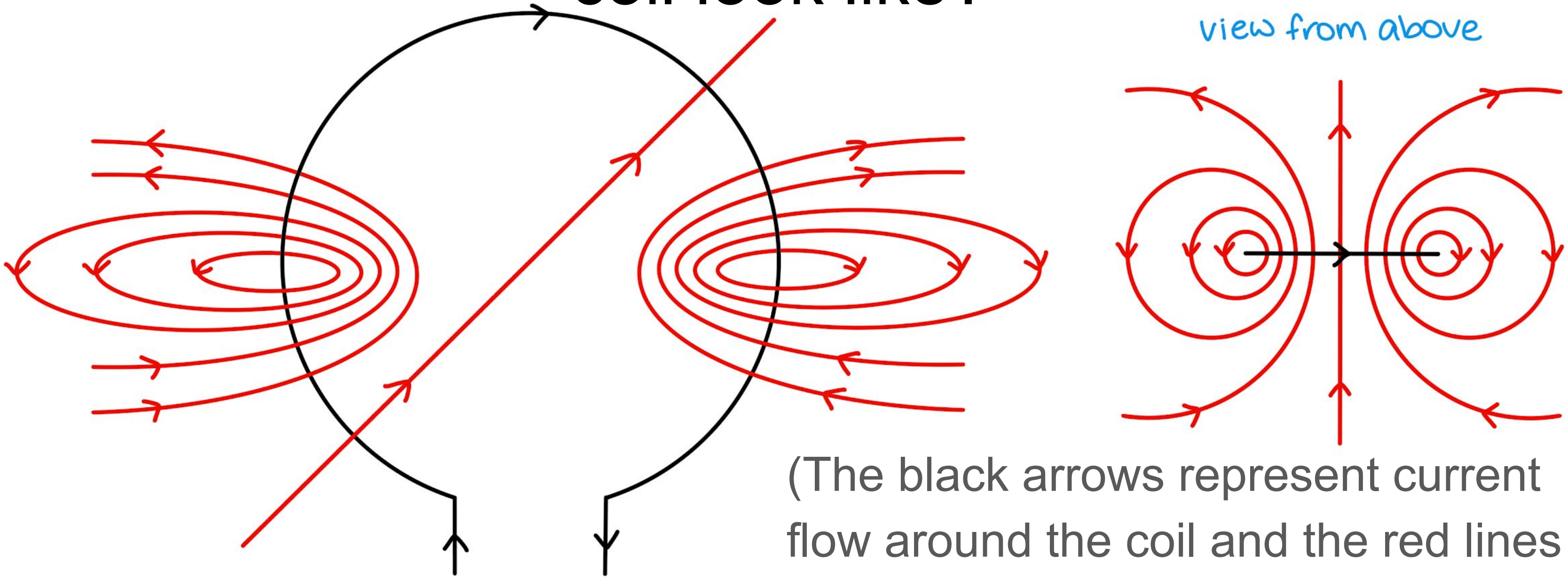
Where the current is going **anticlockwise** around the coil is the north pole. At the south pole, the current goes clockwise. The shape of the field is then similar to a bar magnet. A good way to remember it is by the shapes of the letters:





What does the magnetic field around a flat, circular coil look like?

What does the magnetic field around a flat, circular coil look like?



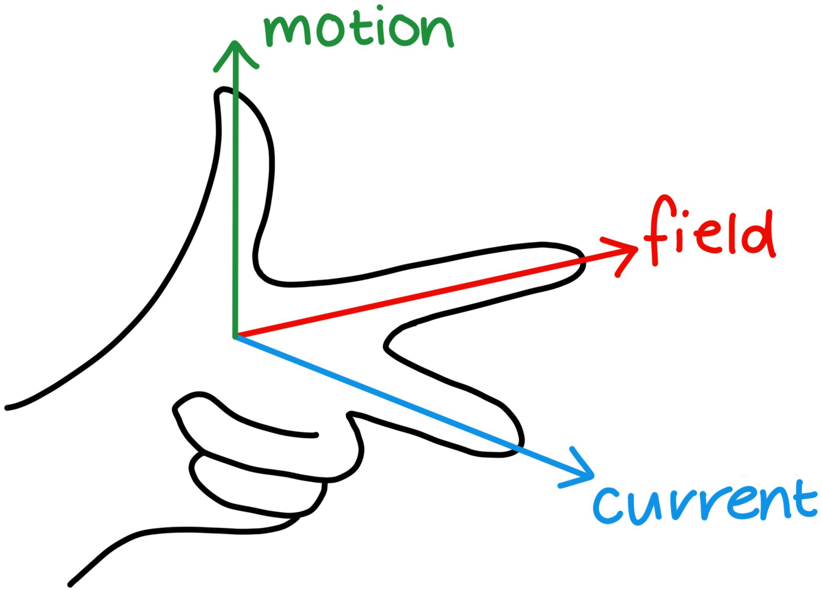
(The black arrows represent current flow around the coil and the red lines are the field lines)

How can you predict which direction the force will push the conductor? (motor effect)

How can you predict which direction the force will push the conductor?

Using Fleming's left-hand rule:

- **F**irst finger: **F**ield lines
- Se**c**ond finger: **C**urrent (conventional)
- Thu**m**b: **M**otion



Give the formula relating magnetic force, flux density, current, length and angle between the field and the conductor.

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$$F = BIL\sin\theta$$

F = Magnetic force (N)

B = Magnetic flux density (T)

I = Current in the conductor (A)

L = Length of conductor in the field (m)

θ = Angle between the field lines and the conductor (º or rad)

Describe an experiment to measure flux density.

Describe an experiment to measure flux density.

1. Place a horseshoe magnet on a digital balance and zero it.
2. Connect a rigid piece of straight wire to a DC supply, variable resistor and ammeter (in series).
3. Align the wire so the force on it acts upwards (so there will be a downward force on the magnet – Newton's 3rd law).
4. Measure the length of the wire in the field.
5. Record extra mass on the balance and use this to calculate force ($F = mg$).
6. Plot a graph of current against mass – gradient gives BL/g.
   a. Since L and g are both known, B can be calculated.

What does the previous experiment setup look like?

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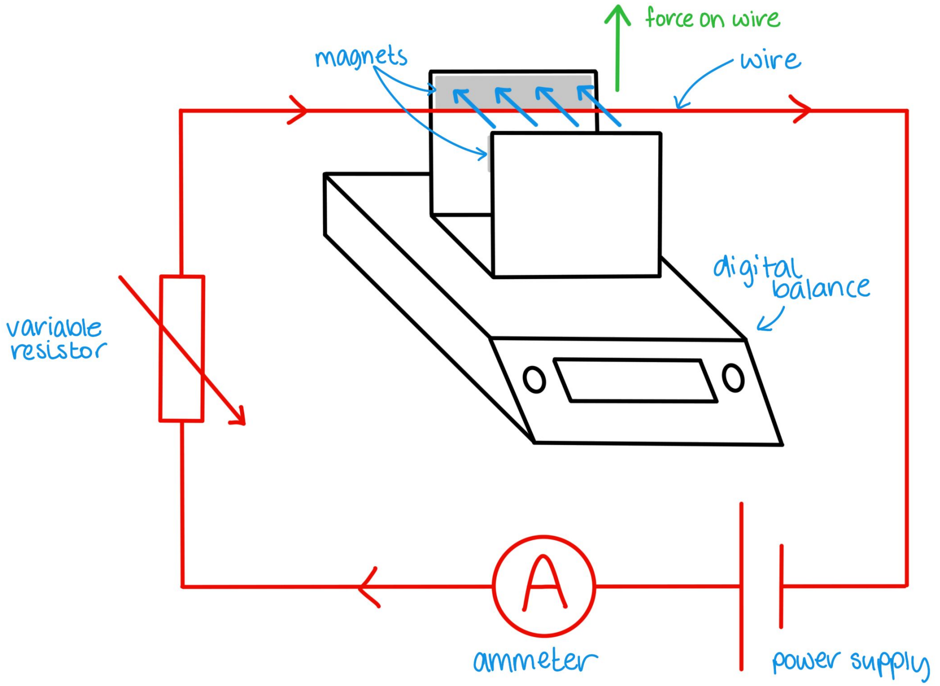


What is the formula for magnetic force on a moving charge at 90° to the field lines?

What is the formula for magnetic force on a moving charge at 90º to the field lines?

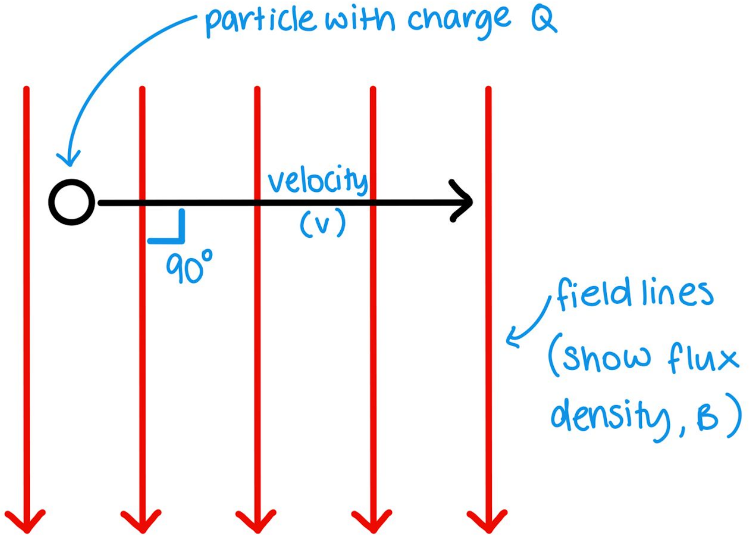
$F = BQv$

F = Force (N)

B = Magnetic flux density (T)

Q = Charge of particle (C)

v = Velocity of particle (ms^{-1})



How is $F = BQv$ derived?

How is F = BQv derived?

From F = BIL (for magnetic force on a conductor at 90° to field lines).

Use I = Q/t and L = vt (distance = speed x time).

F = BQvt/t

The t cancels out, leaving F = BQv

Why do charged particles move in a circular orbit in a magnetic Field?

Why do charged particles move in a circular orbit in a magnetic field?

The magnetic force is always perpendicular to the velocity of the particle, so it will end up being forced in a circular orbit. The particles undergo a centripetal acceleration, with the centripetal force being the magnetic force.

How can you derive the formula for the radius of the circular orbit?

How can you derive the formula for the radius of the circular orbit?

Equating the formula for centripetal force and the formula for magnetic force (since they are the same thing in this context), you get $mv^2/r = BQv$.

Rearrange this and you get $r = mv / BQ$

Using r = mv / BQ, explain how changing the mass, velocity, flux density and charge affects the radius of the orbit.

Using $r = mv / BQ$, explain how increasing the mass, velocity, flux density and charge affects the radius of the orbit.

Increasing mass or velocity will increase the radius.

Increasing flux density or charge will decrease the radius.

What is the purpose of a velocity selector?

What is the purpose of a velocity selector?

They isolate particles of a specific velocity. This is useful for things like mass spectrometry.

Define magnetic flux.

Define magnetic flux.

The product of the magnetic flux density and the area perpendicular to the field lines. Magnetic flux is represented by the Greek letter Phi, ϕ.

What is the unit for magnetic flux?

What is the unit for magnetic flux?

Weber (Wb), where $1Wb = 1Tm^2$

What is the formula for magnetic flux?

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What is the formula for magnetic flux?

$$\phi = BA\cos\theta$$

ϕ = Magnetic flux (Wb)

B = Magnetic flux density (T)

A = Area perpendicular to the field (in a coil this is the cross-sectional area) (m^2)

θ = angle between the normal to the coil and the field lines (° or rad)

Define magnetic flux linkage.

Define magnetic flux linkage.

The magnetic flux of an entire coil of wire. This is the product of the magnetic flux and the number of turns on the coil.

Flux linkage is also measured in Wb, and it is represented as $N\phi$.

Explain Lenz's Law in terms of energy.

Explain Lenz's Law in terms of energy.

Lenz's law follows the principle of the conservation of energy. If the induced emf was in a direction that aided the change which caused it, it would be creating electrical energy from nowhere.

For example, if the north pole of a bar magnet was pushed into a solenoid and that end became a south pole, it would then pull the magnet into the coil faster and field would get stronger, pulling the magnet in faster still, etc.

What is the formula that links Faraday’s Law and Lenz’s Law?

What is the formula that links Faraday's Law and Lenz's Law?

$$\varepsilon = -\frac{(\Delta N \phi)}{\Delta t}$$

change of flux linkage (Wb)

induced emf (V)

change in time (s)

negative because emf acts in the opposite direction to the change that caused it → Lenz's Law