

# **Principle of Electric Generator**

**Dennis Law, 08.06.2024**

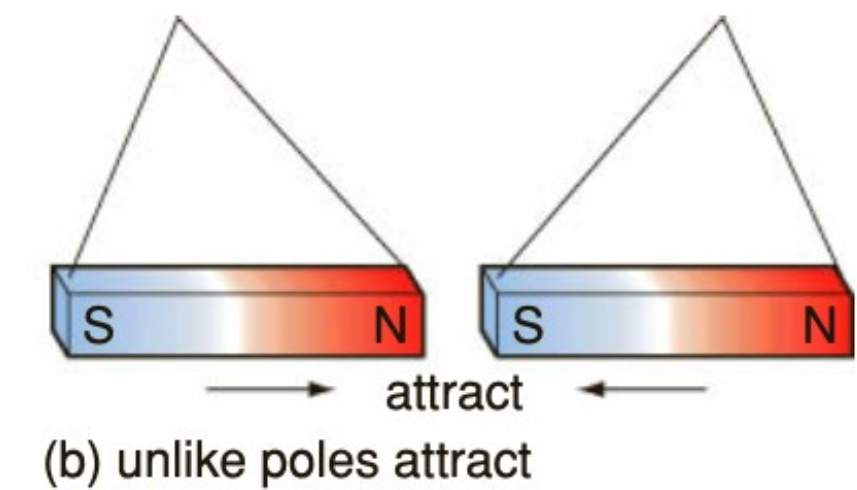
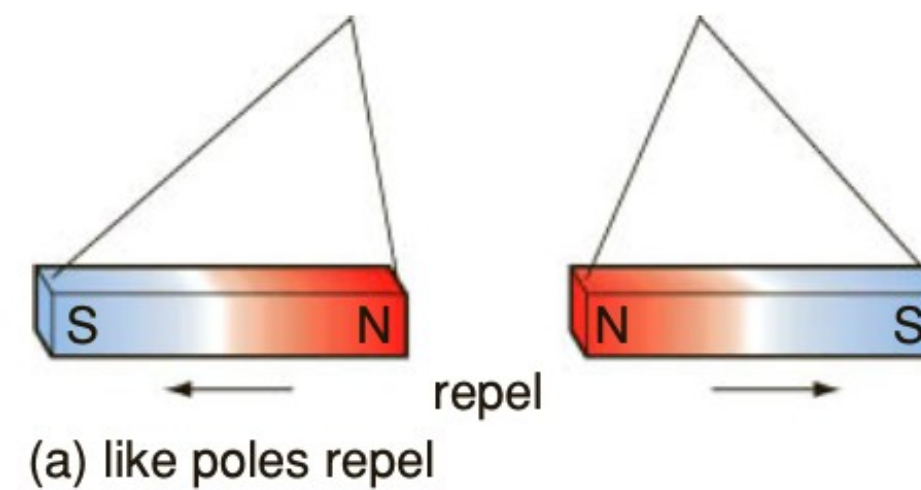
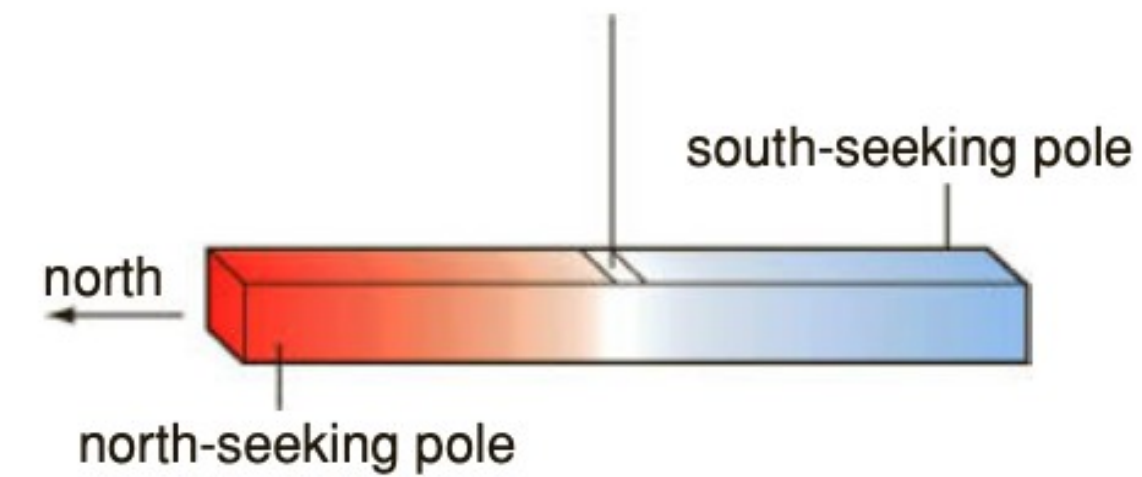
# Overview

- A electrical generator is a device which converts mechanical energy to electrical energy.
- Principle: Electromagnetic induction
- Requires: magnetic fields, coil of wire

# Magnetic Field

## Magnets

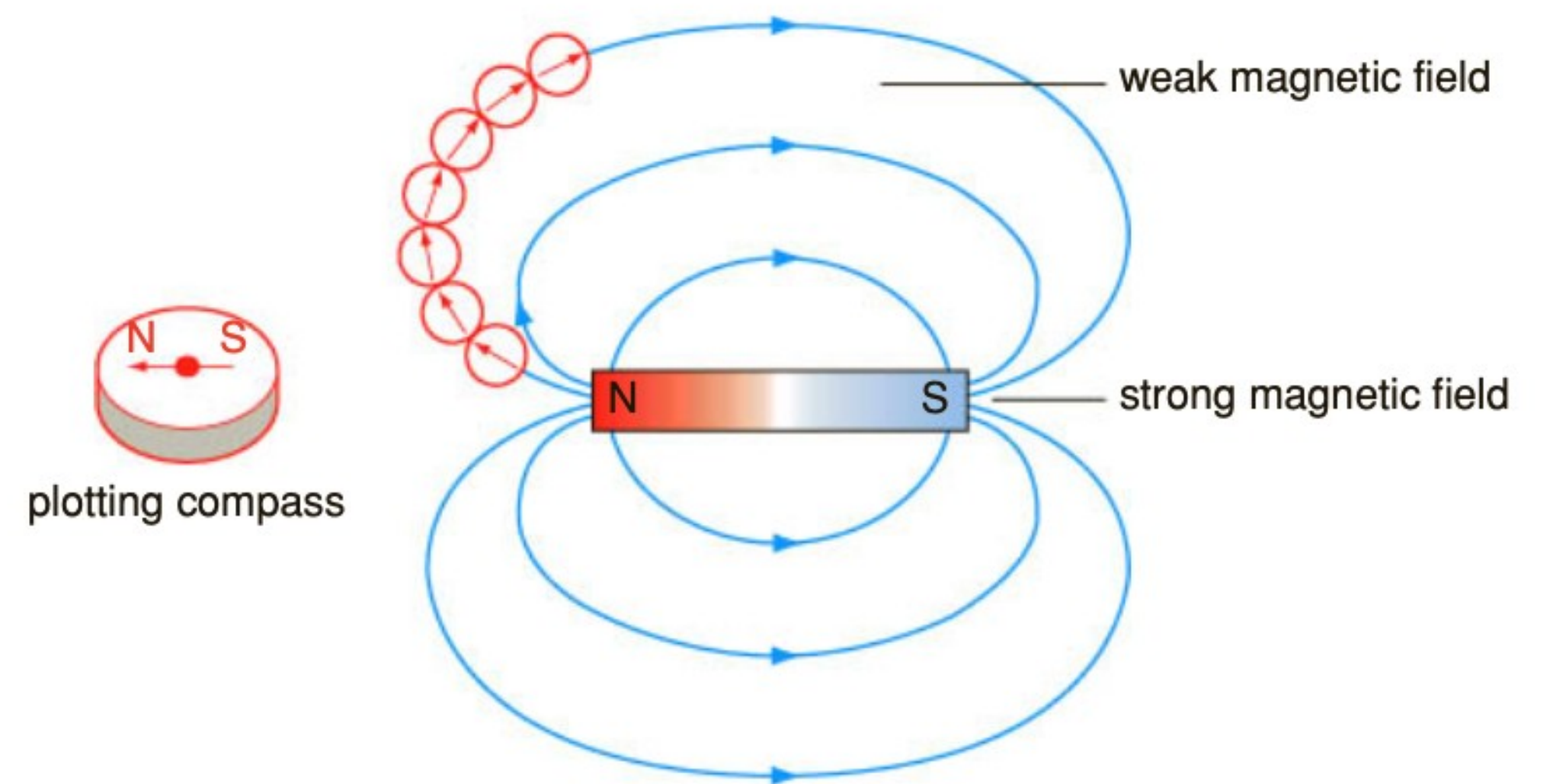
- Magnets have two poles:  
North pole and South Pole
- Unlike poles attract each other.
- Like poles repel each other.



# Magnetic Field

## Describing magnetic field with field lines

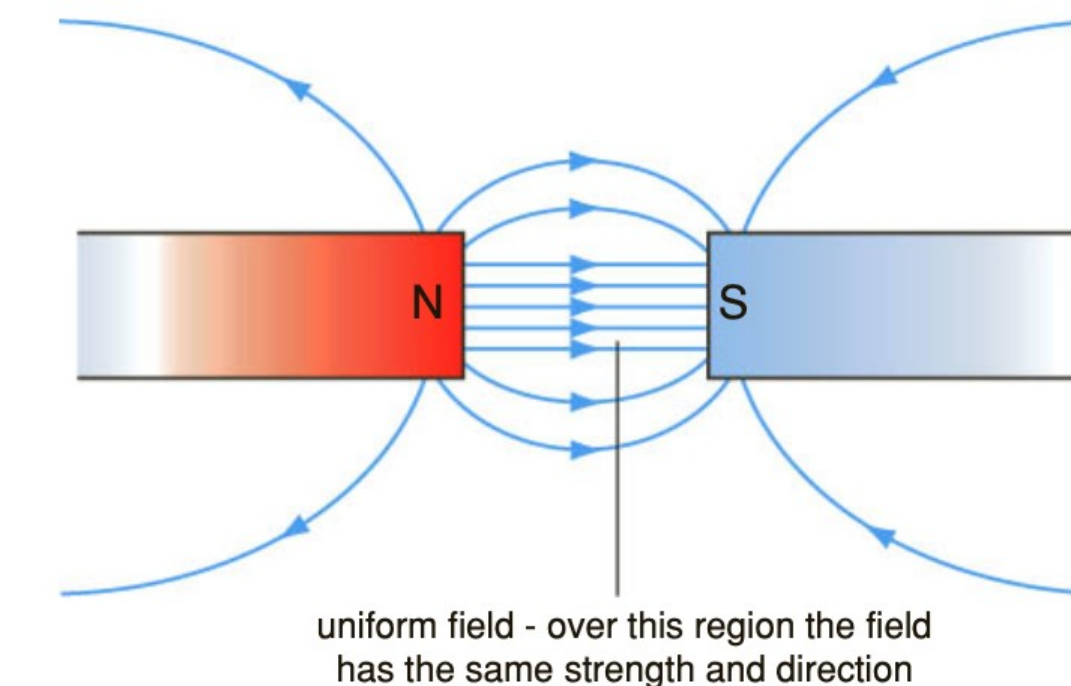
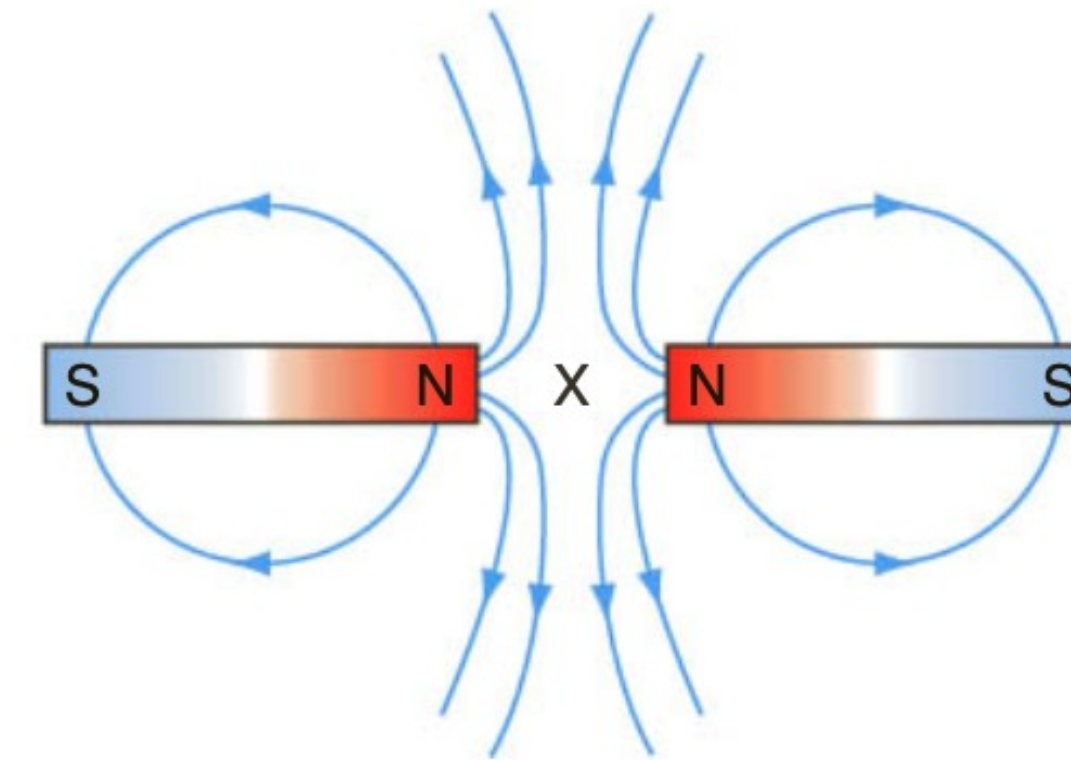
- Magnetic field describes the strength of the Influence of the magnets.
- The direction of field lines can be found by using small compasses.
- Compass needles always align with the field.
- Strength of magnetic field often described by the **density** of magnetic field lines.
- The stronger the magnetic field, the stronger is the magnetic force.
- Magnetic field starts from north pole and ends in south pole.
- Magnetic field lines repel each other, so they can never cross each other.



# Magnetic Field

## Magnetic field around magnets with field lines

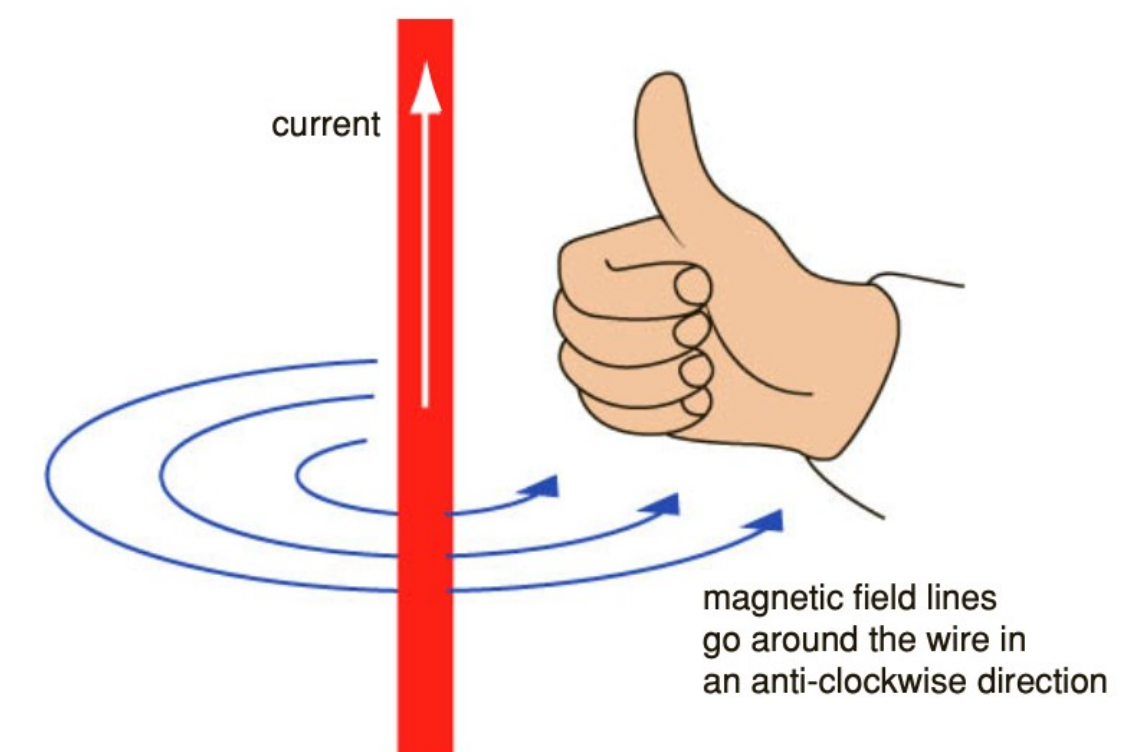
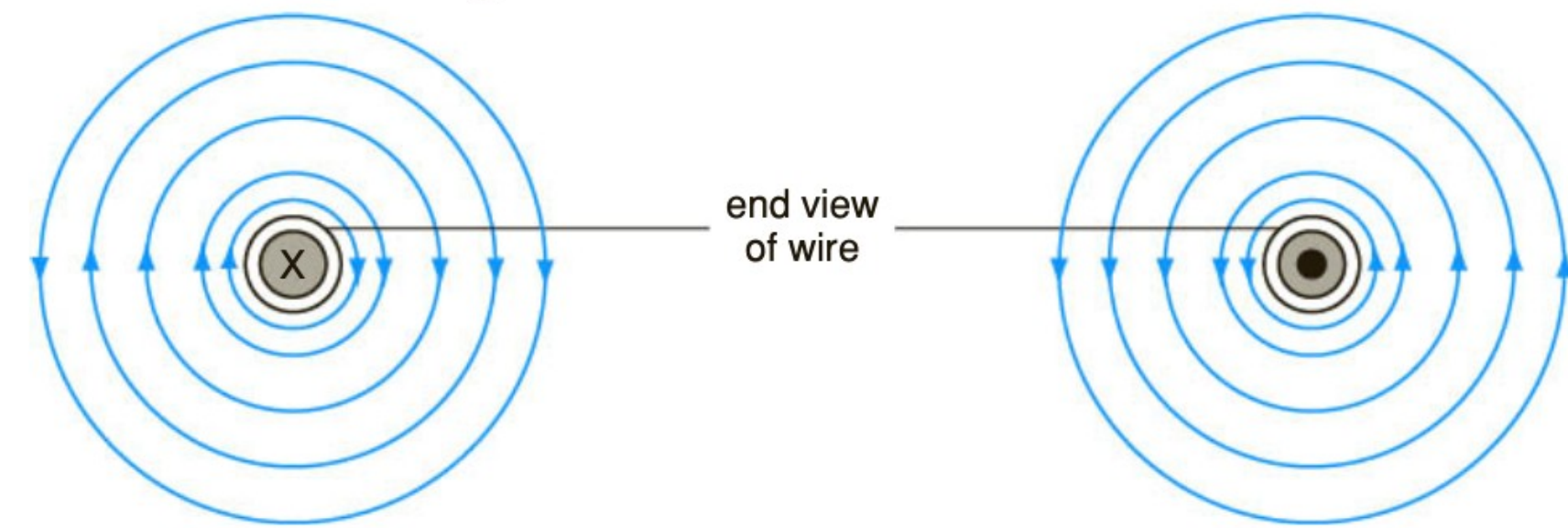
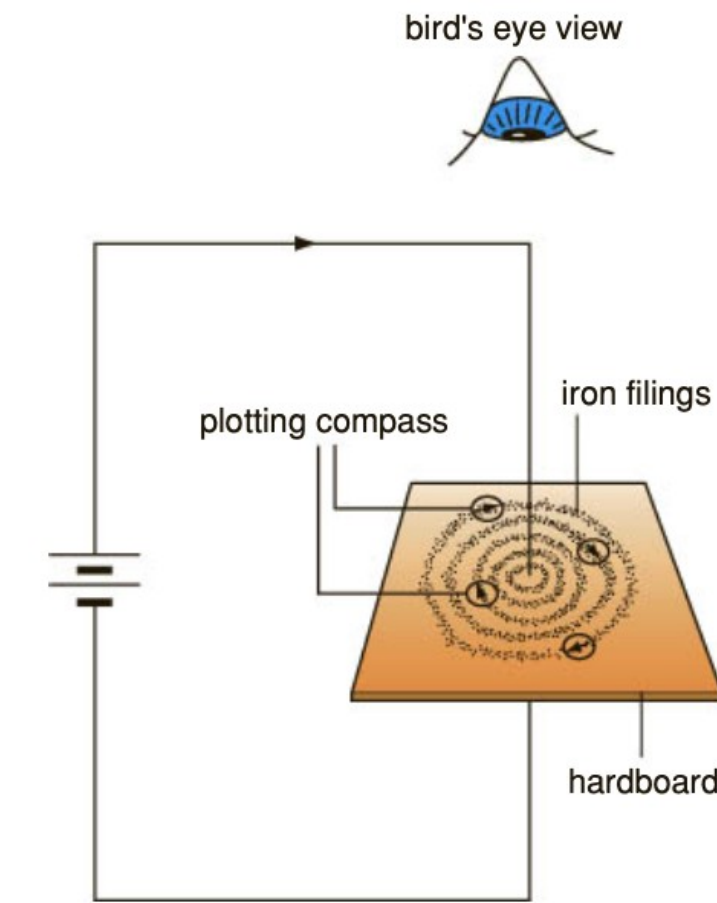
- Field lines repel each other, so they never cross.
- Magnetic fields from two magnets combine.
- When two like poles are brought close to each other, there is a point X (neutral point) at which the two fields cancel.
- When two unlike poles are brought close to each other, there is a region of uniform field.
- This uniform magnetic field finds applications in motors and generators.



# Magnetic Field

## Magnetic field due to a current

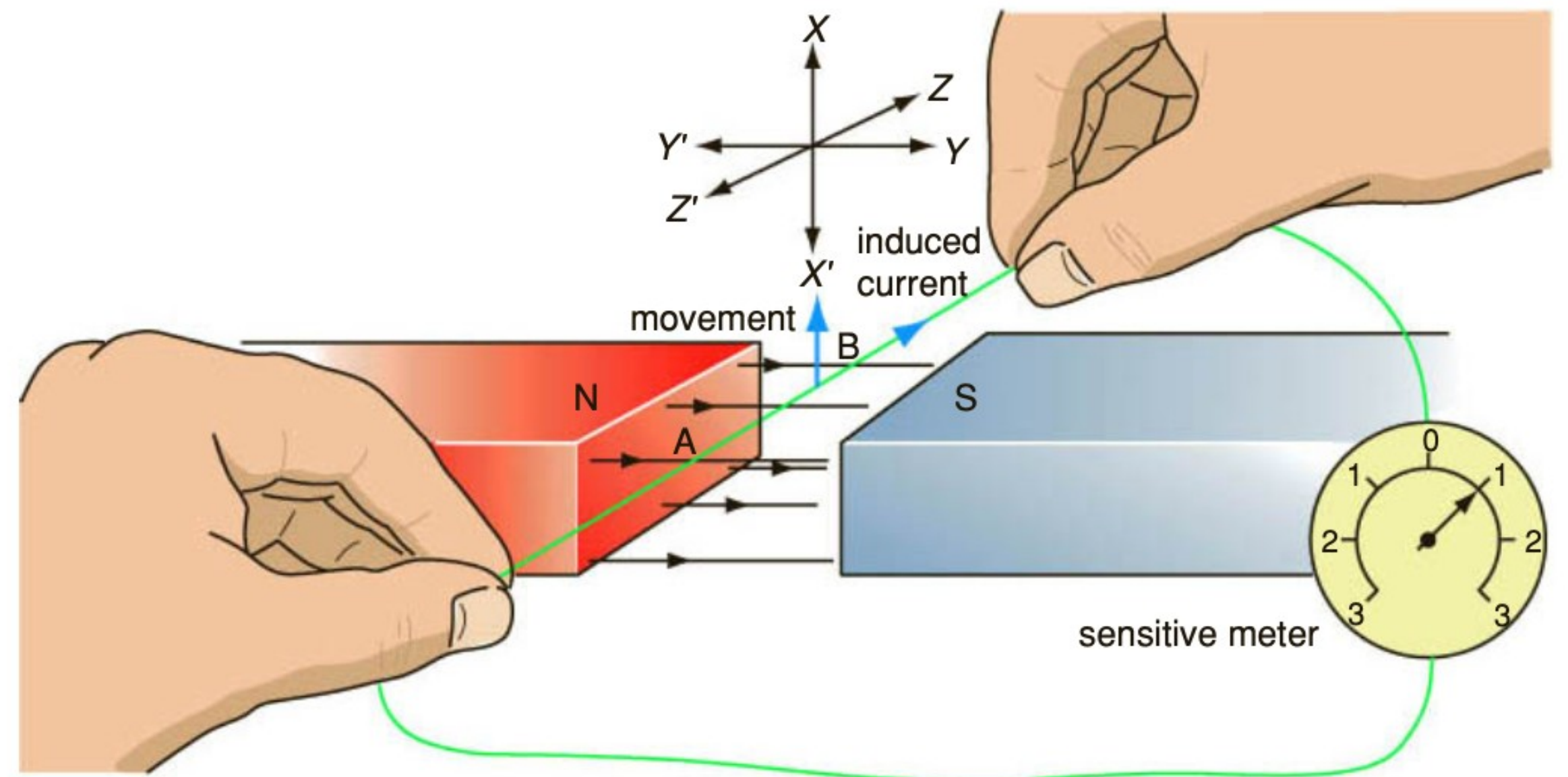
- A current-carrying wire produces magnetic field around it.
- Strength of the magnetic field proportional to the current in the wire
- Magnetic field strength decreases with the distance from the wire.
- Direction of the magnetic field can be found by the right-hand rule



# Electromagnetic Induction

## Magnetic field around a current carrying wire

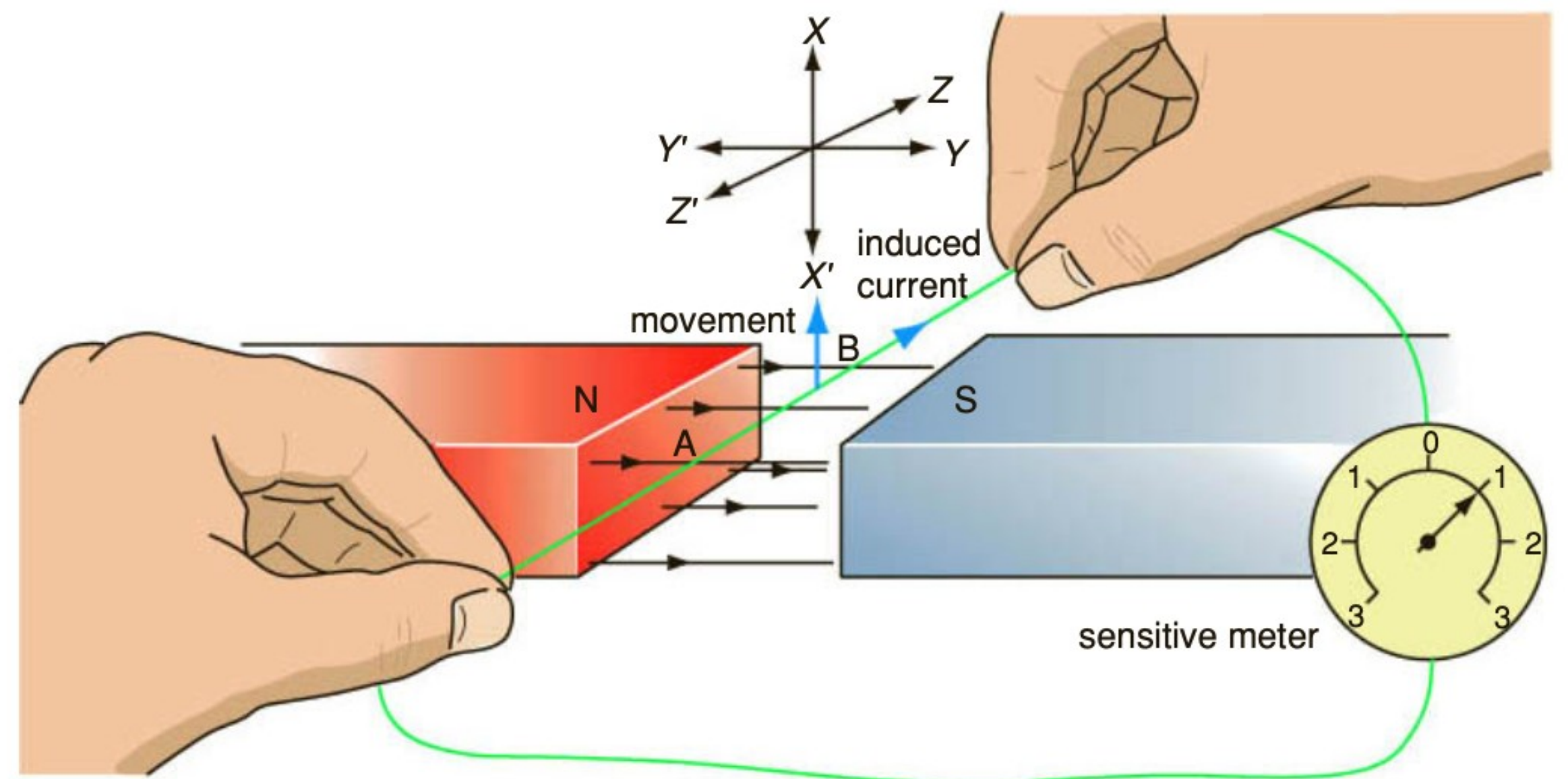
- Move the wire in the directions  $XX'$ ,  $YY'$  and  $ZZ'$ .
- No voltage is induced if the wire moves in the  $YY'$  and  $ZZ'$  direction.
- Voltage is induced and current is detected only when the wire is moved in the  $XX'$  direction.
- Reason: The wire does not cut magnetic field lines if they move in the  $YY'$  and  $ZZ'$  direction.



# Electromagnetic Induction

## Magnetic field around a current carrying wire

- Reversing the direction of movement of the wire reverses the direction of the induced voltage/ induced current.
- Reversing the direction of magnetic field also reverses the direction of the voltage.

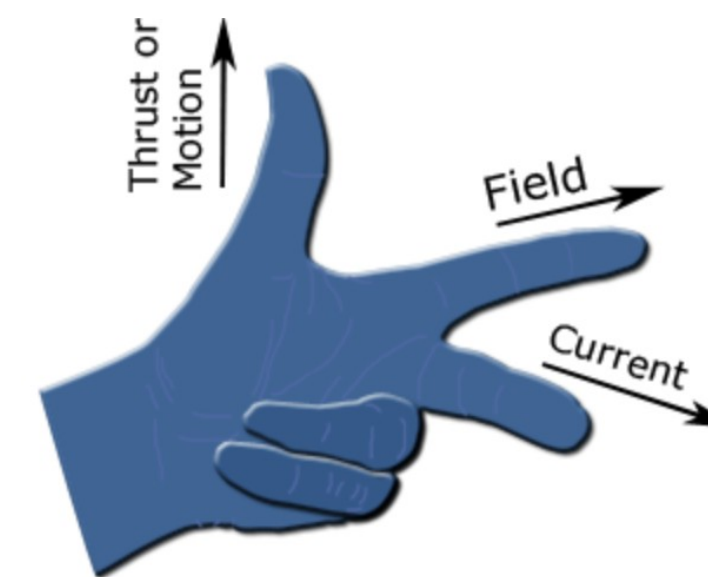
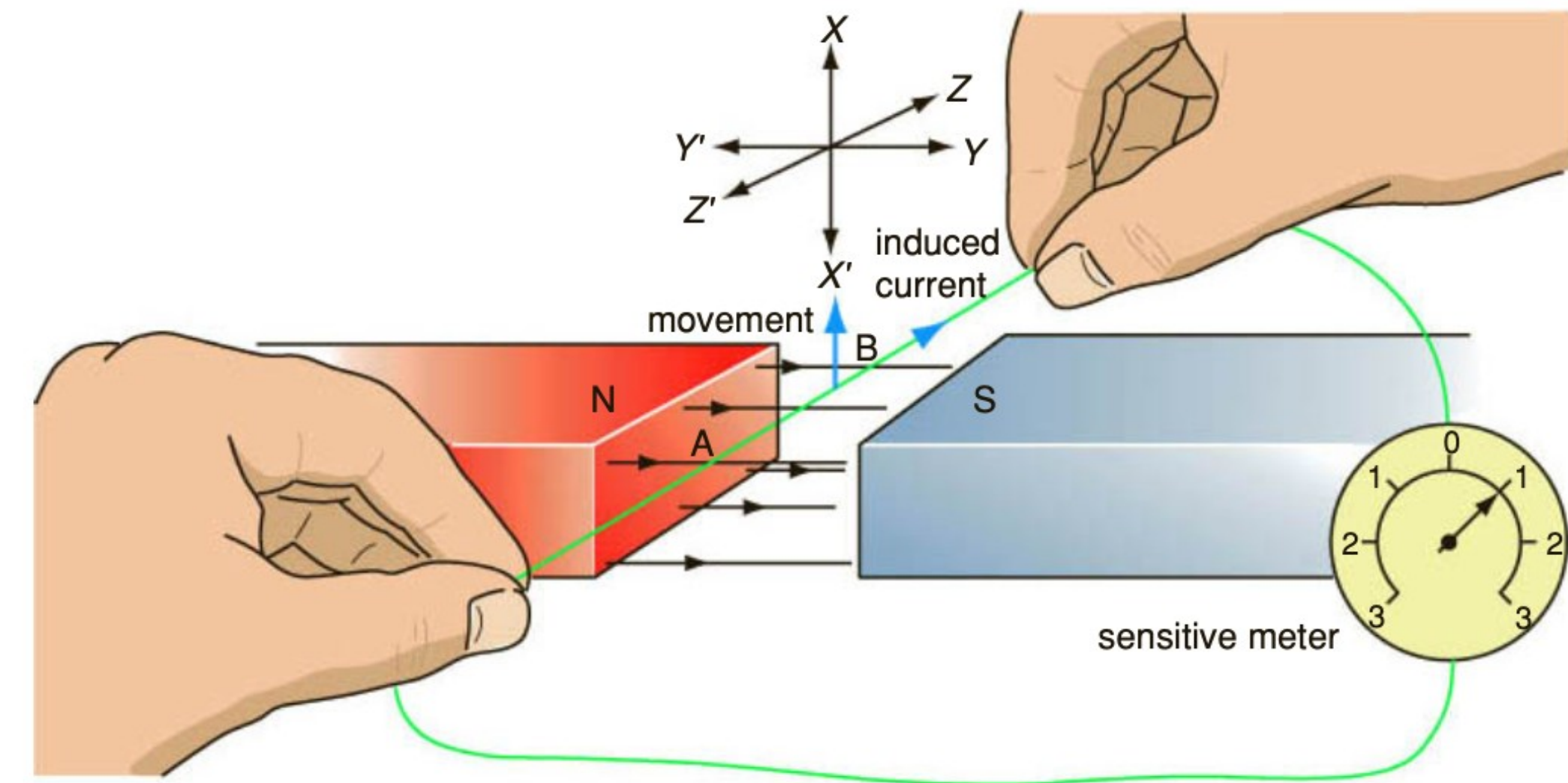


# Lenz's law

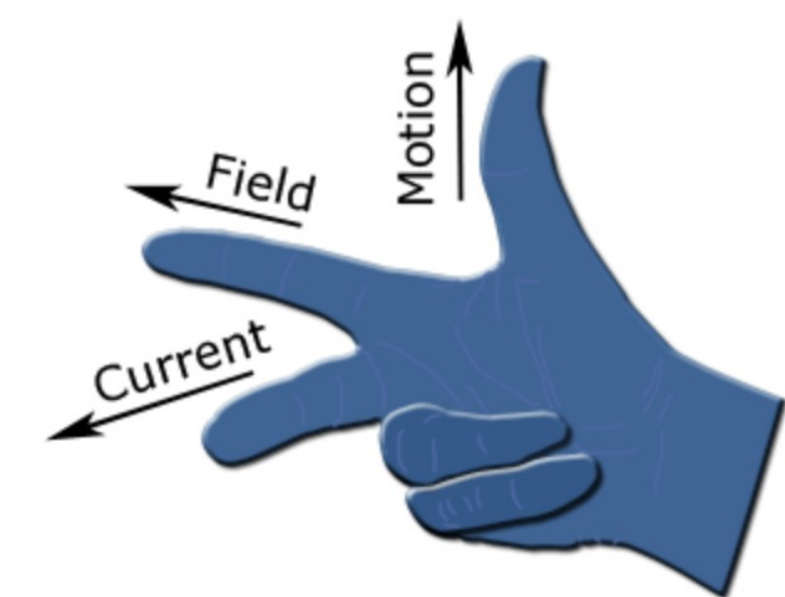
Direction of the induced current can be inferred by **Fleming's right hand rule: current into the page**

Direction of the thrust due to induced current can be inferred by **Fleming's left-hand rule: downward thrust**

**Opposes the upward motion of the wire!**



Fleming's left hand rule for direction of force on a current-carrying wire in the magnetic field



Fleming's right hand rule for direction of current due to the motion of wire in the magnetic field

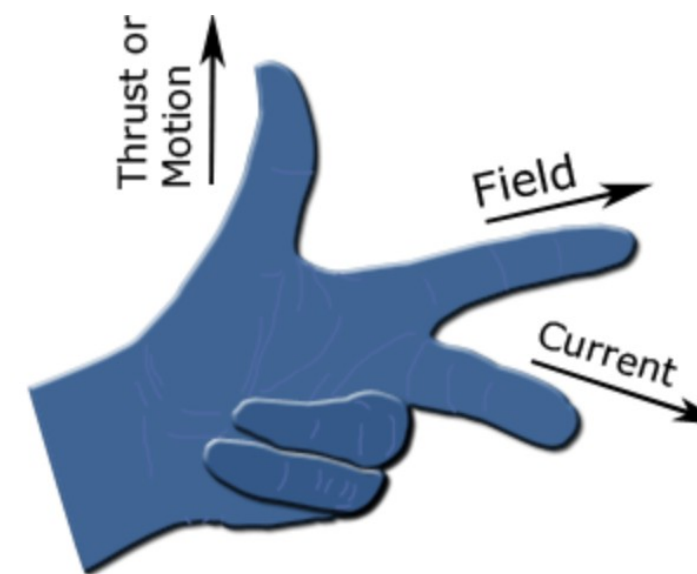
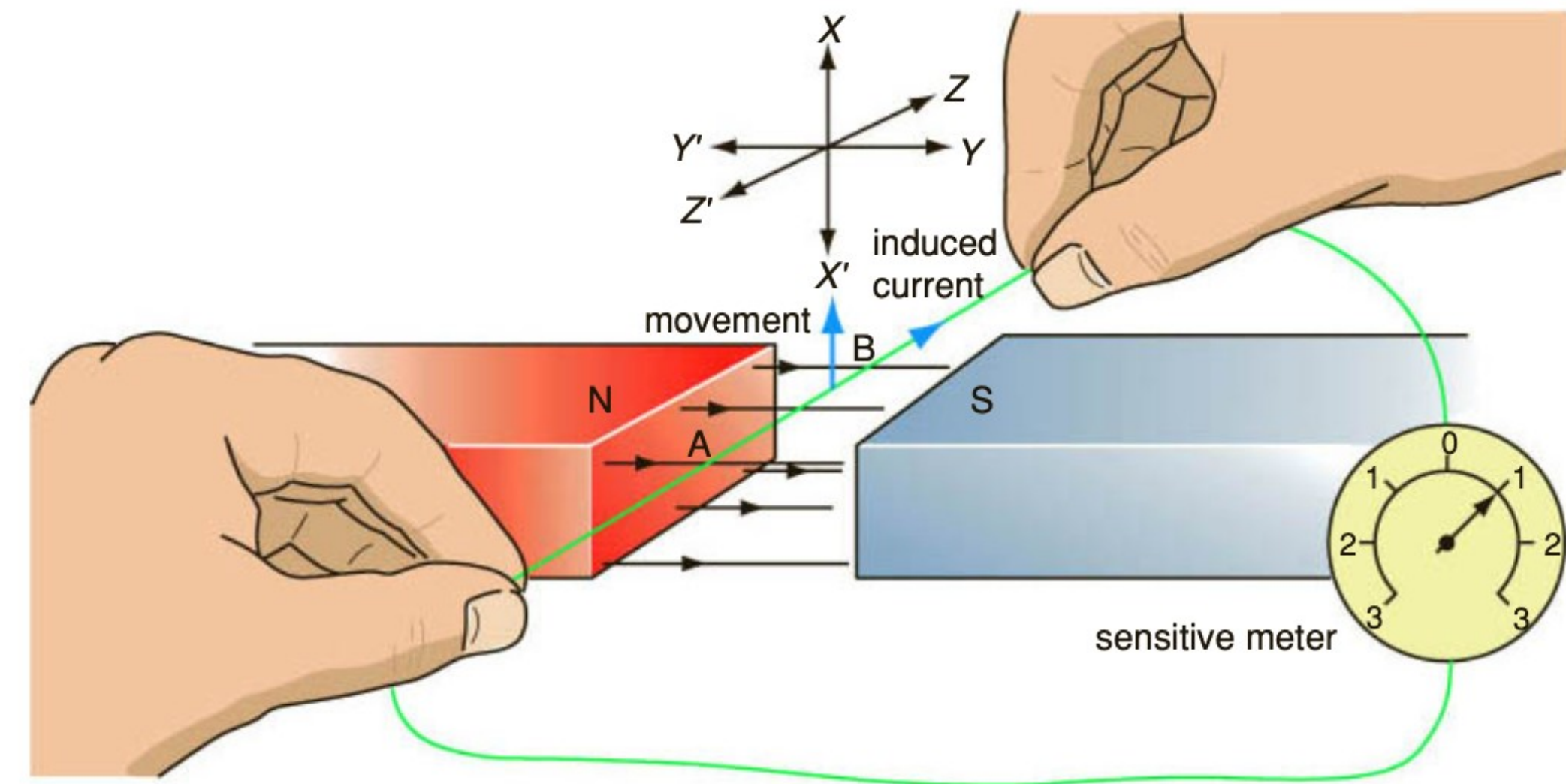
# Lenz's law

## Lenz law:

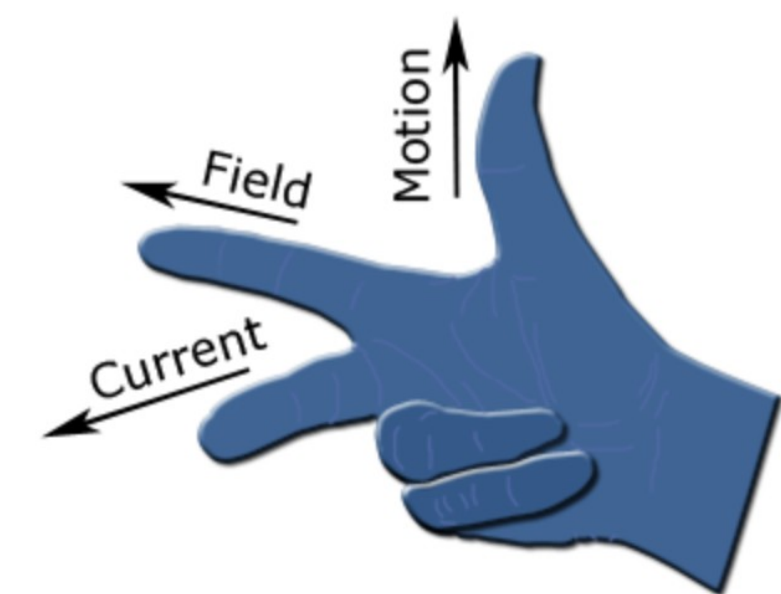
*The induced voltage generates an electric current whose magnetic field opposes the original change in field.*

The magnetic field due to the induced current resists the motion of the wire.

This ensures energy is not created out of nothing: Kinetic energy of wire is converted to electrical energy



Fleming's left hand rule for direction of force on a current-carrying wire in the magnetic field

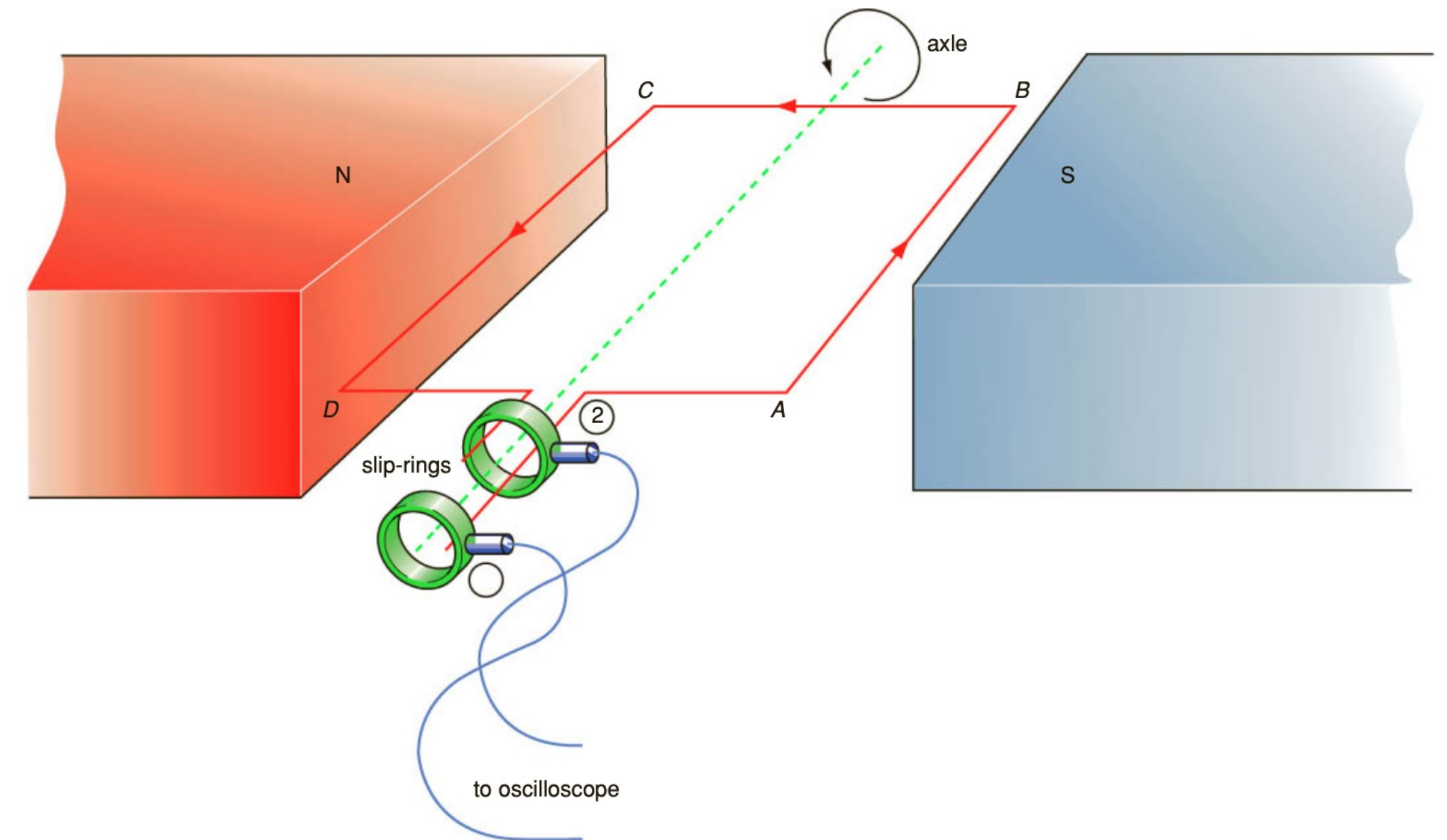


Fleming's right hand rule for direction of current due to the motion of wire in the magnetic field

# Electrical a.c. Generator

## Set-up

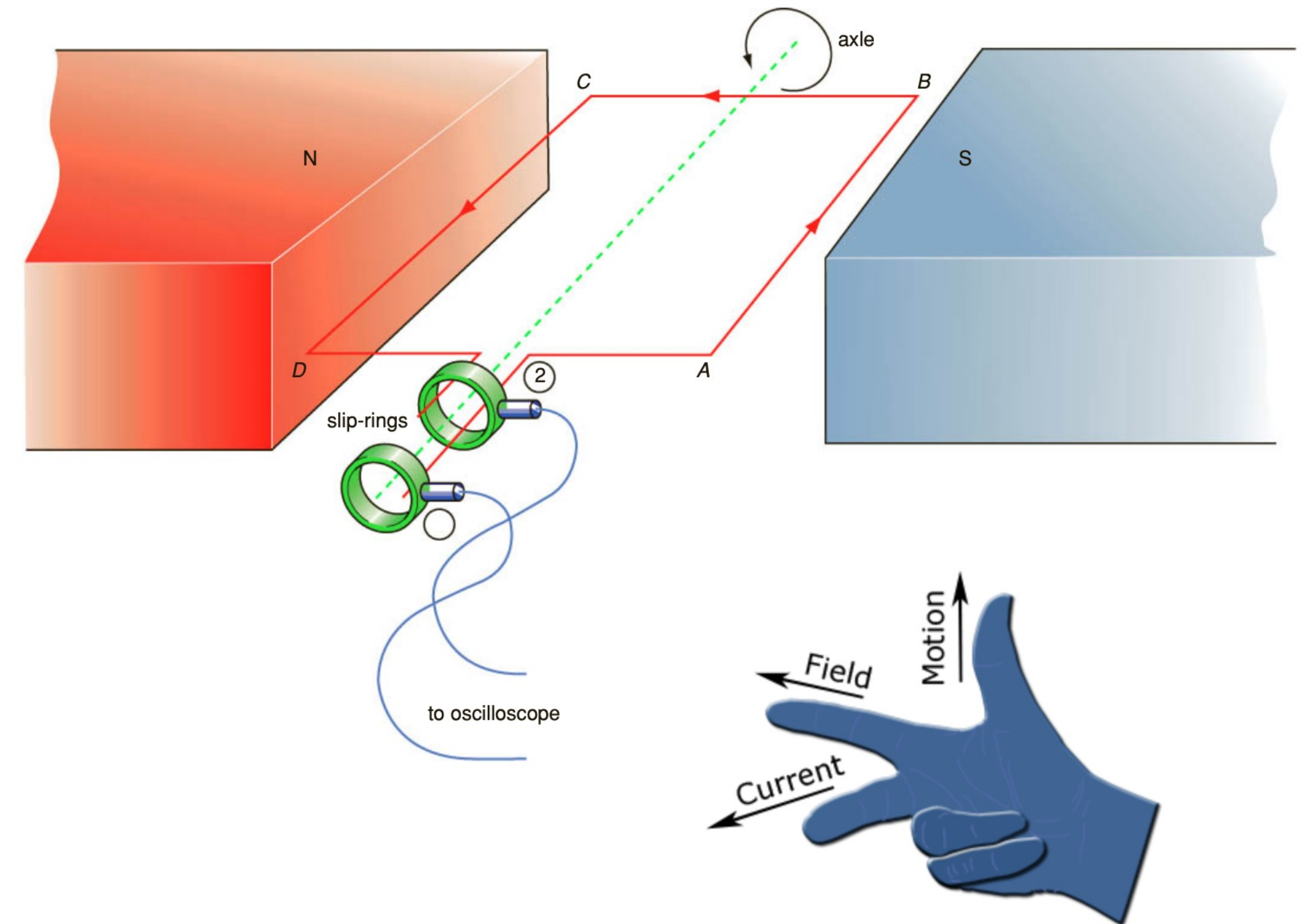
- Use large magnets so that the field in the region between them is roughly uniform
- Place the coil of wire in this region of uniform magnetic field.
- The wire are connected to two slip-rings to allow continuous rotation motion and connection to oscilloscope at the same time.
- The oscilloscope monitors the induced current.



# Electrical a.c. Generator

## Induced current

- Rotate the coil anti-clockwise in this uniform magnetic field by turning the axle.
- The motion of coil induces voltage in sections AB and CB
- Fleming's right-hand rule can be applied to deduce the direction of induced current
- AB: Current flows from A to B
- CD: Current flows from C to D



# Electrical a.c. Generator

## Induced voltage waveform

(i) Motion of wires parallel to magnetic field.

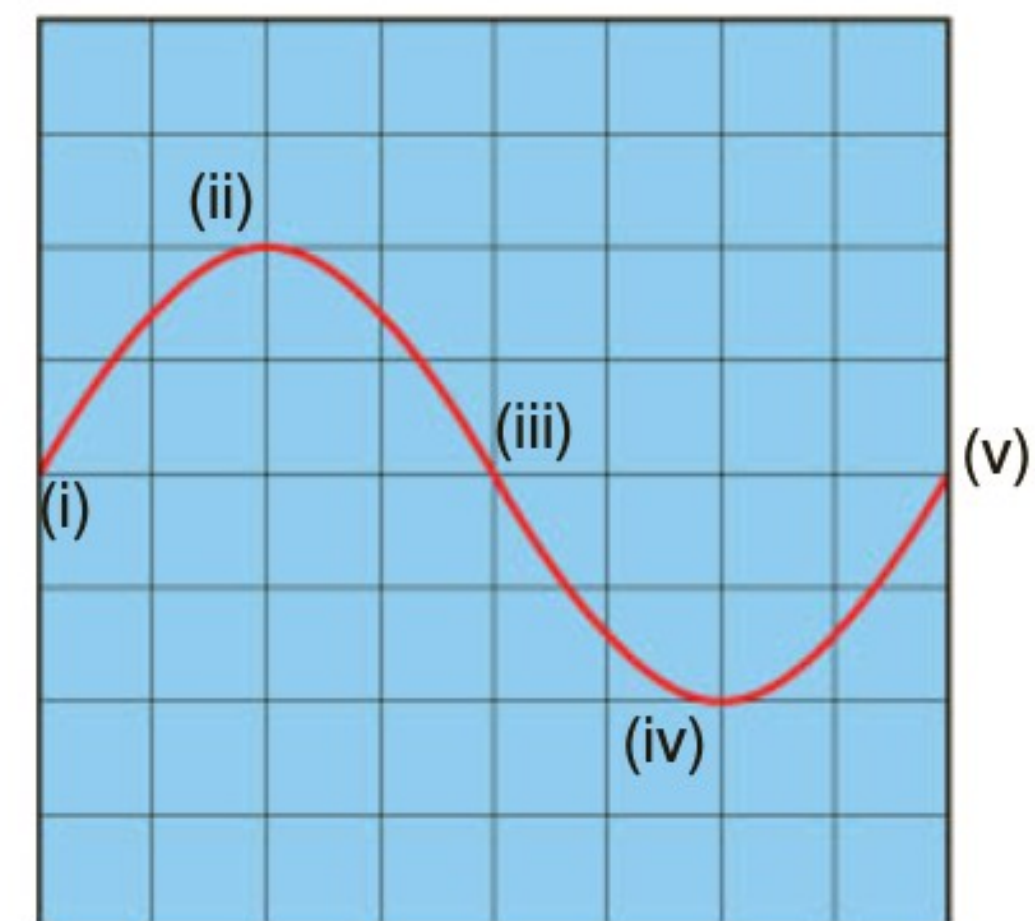
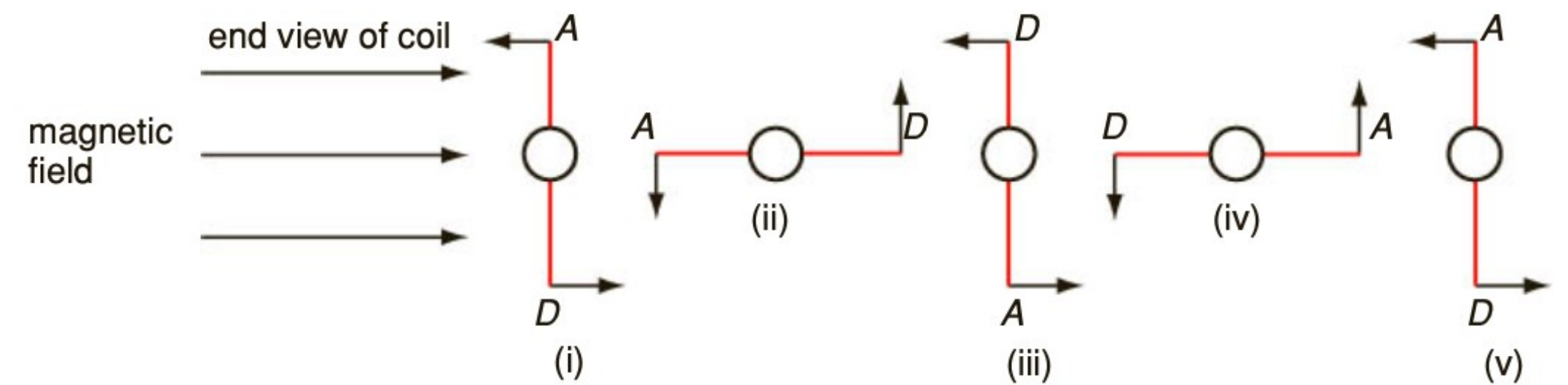
No magnetic field line is cut.

No voltage is induced

(ii) Motion of wires perpendicular to magnetic field.

Max number of magnetic field lines are cut.

Max voltage induced.



# Electrical a.c. Generator

## Induced voltage waveform

(iii) Same situation as (i).

Motion of wires parallel to magnetic field.

No magnetic field line is cut.

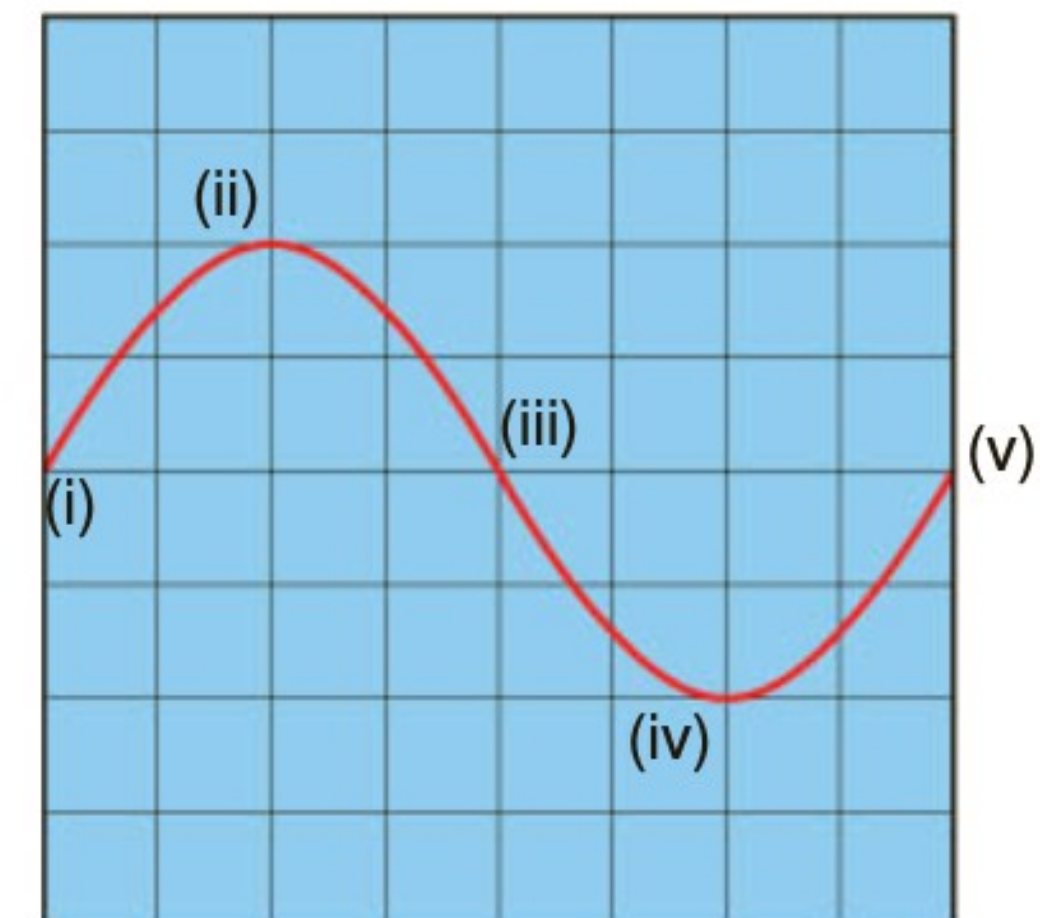
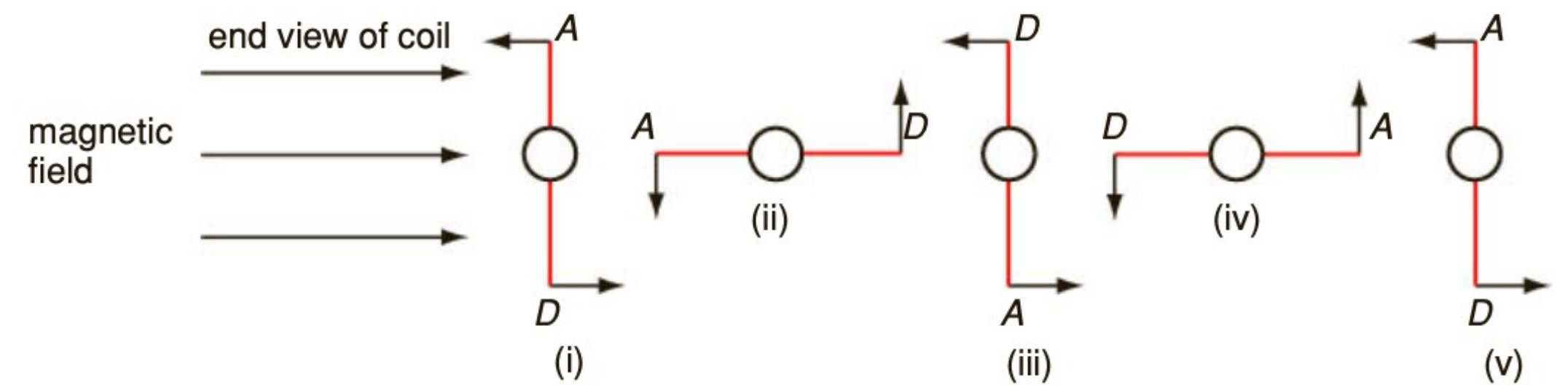
No voltage is induced

(iv) Motion of wires perpendicular to magnetic field as in (ii).

Max number of magnetic field lines cut in opposite direction

(A moving up).

Max voltage induced but with opposite sign as in (ii).

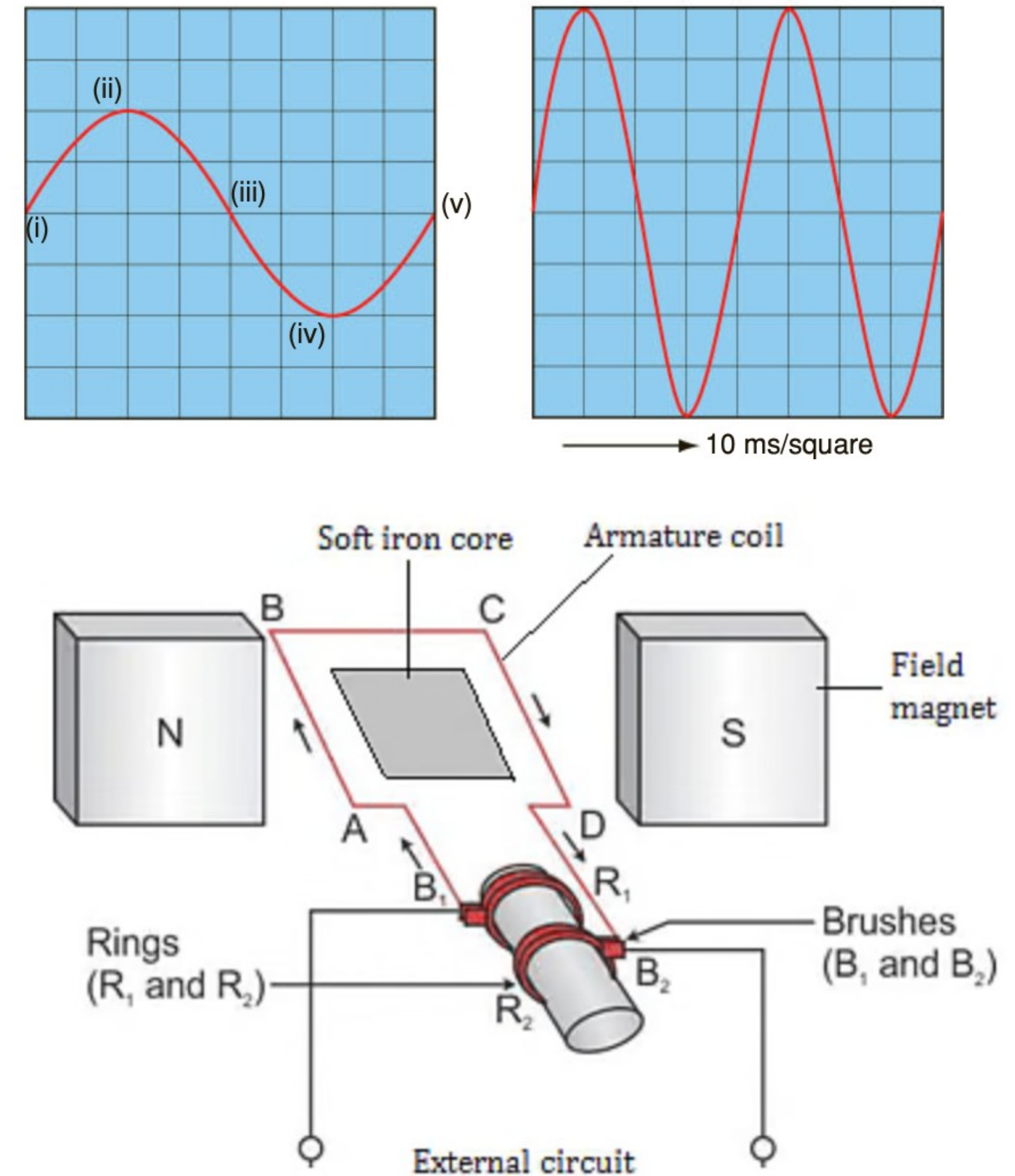


# Electrical a.c. Generator

## Factors affecting the size of induced voltage

The size of the induced voltage can be increased by

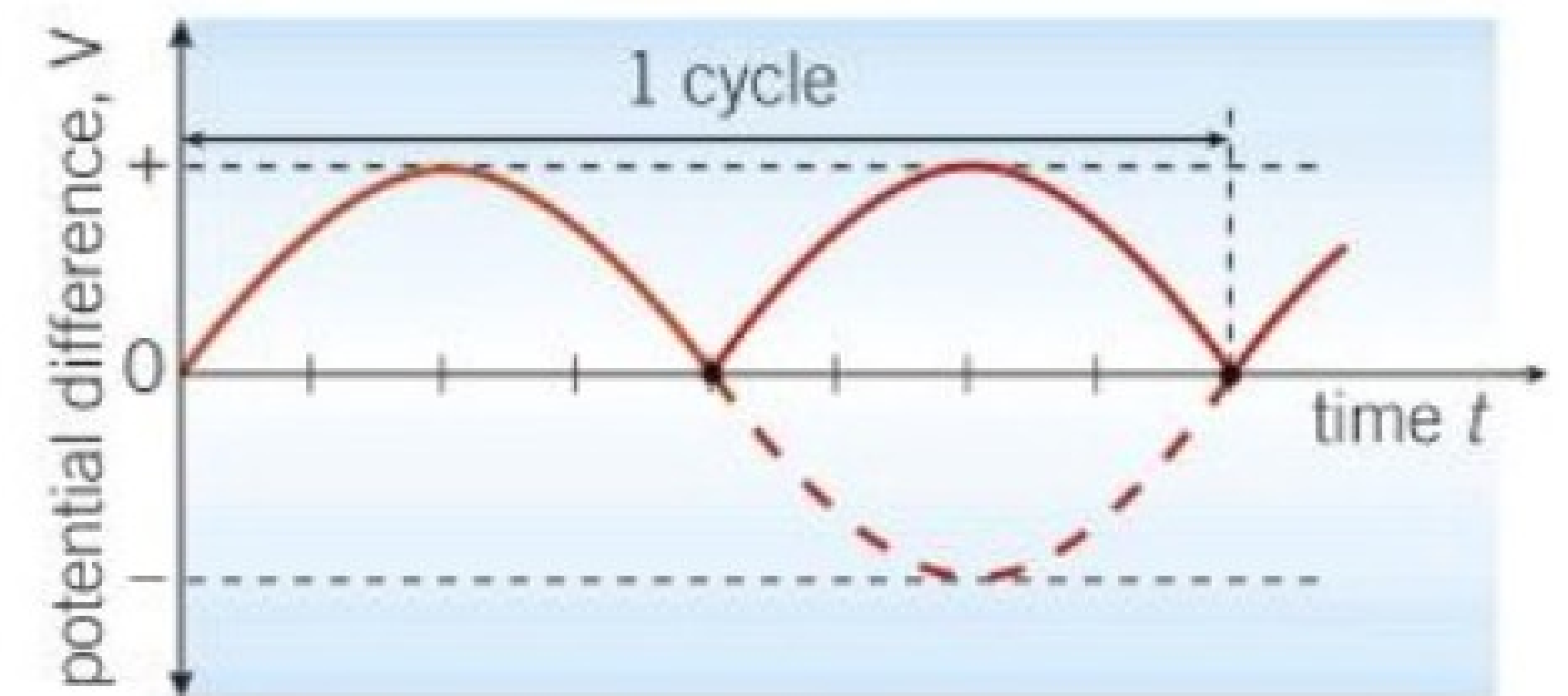
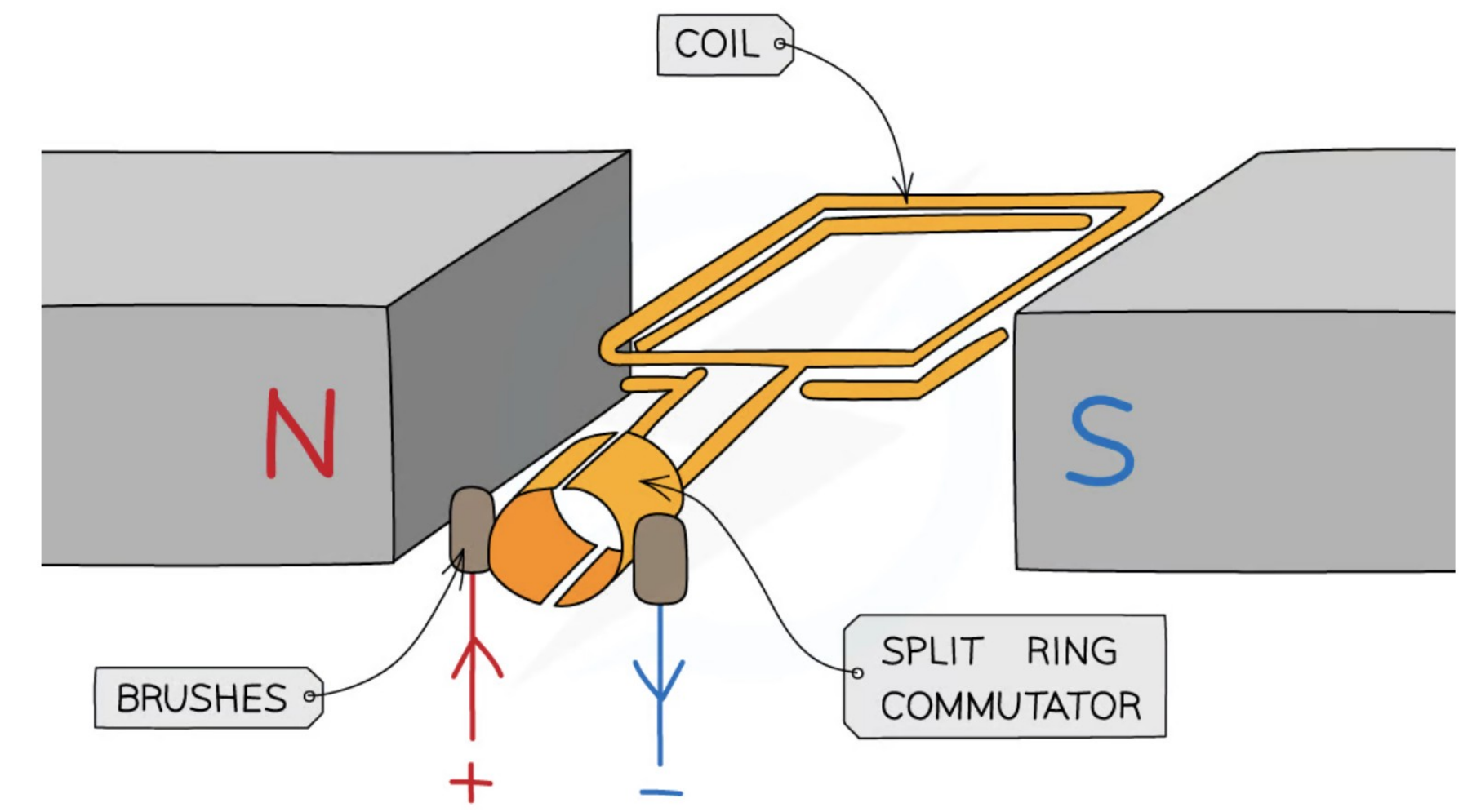
1. rotating the coil faster
2. using stronger magnets
3. using more turns of wires
4. wrapping the wire around a soft-iron core



# Electrical d.c. Generator

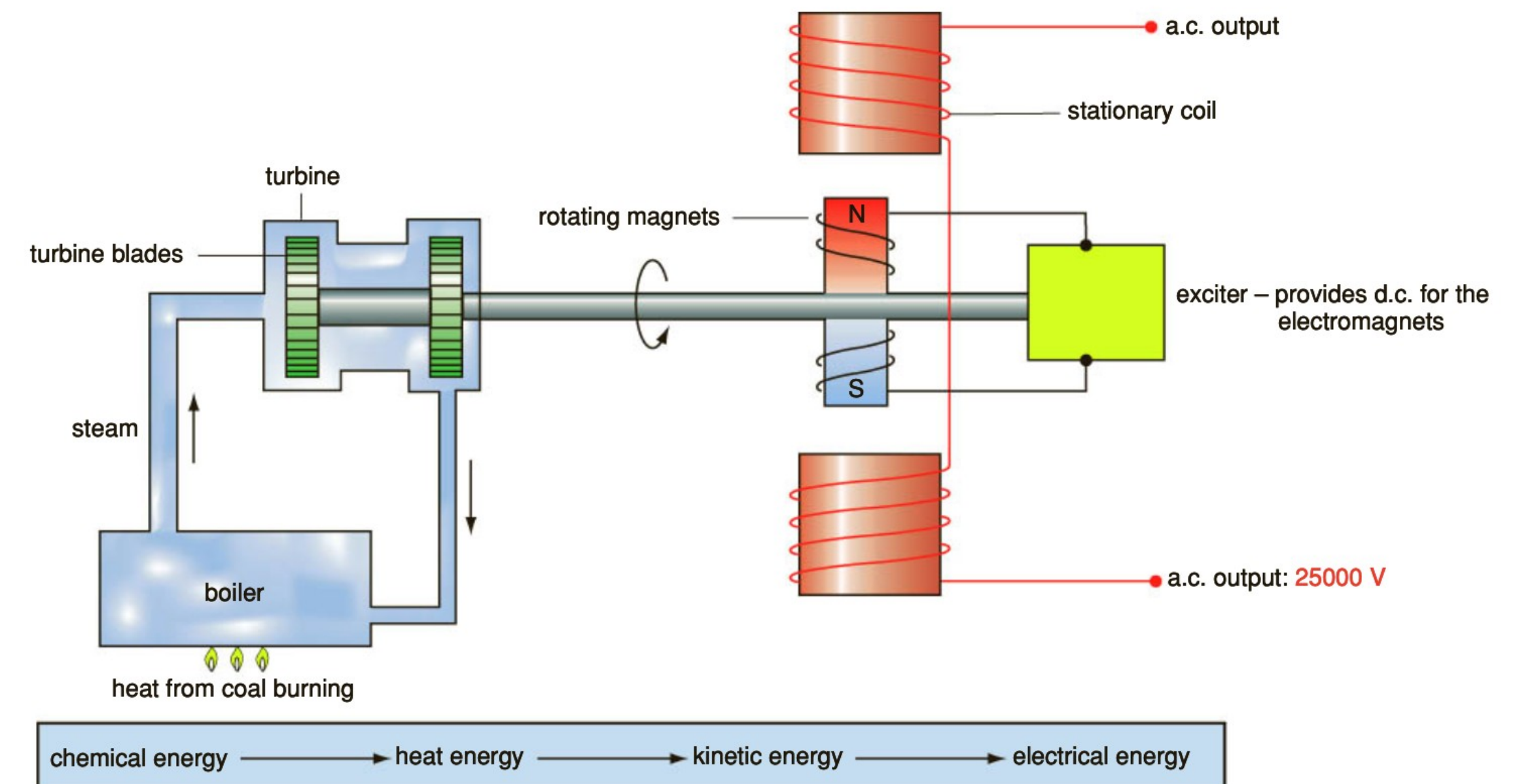
## Difference between a.c. and d.c. generators

- The set-ups are virtually identical except that split rings instead of slip rings are used in d.c. generators.
- The split ring reconnects the coil the opposite way every half turn - when the coil is perpendicular to the magnetic field lines.
- The induced current does not reverse direction.



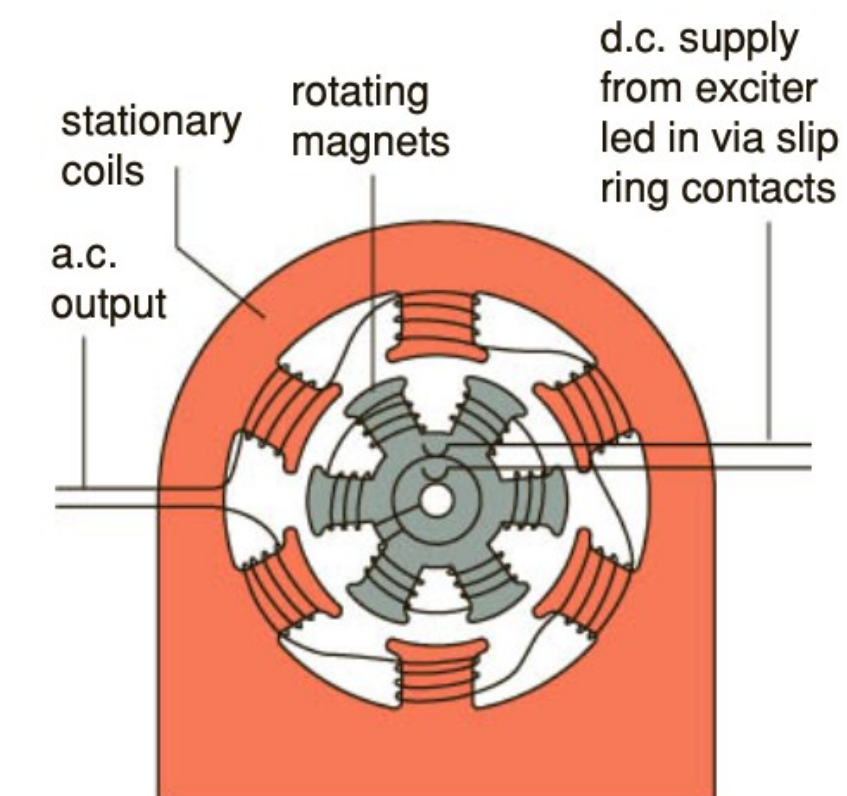
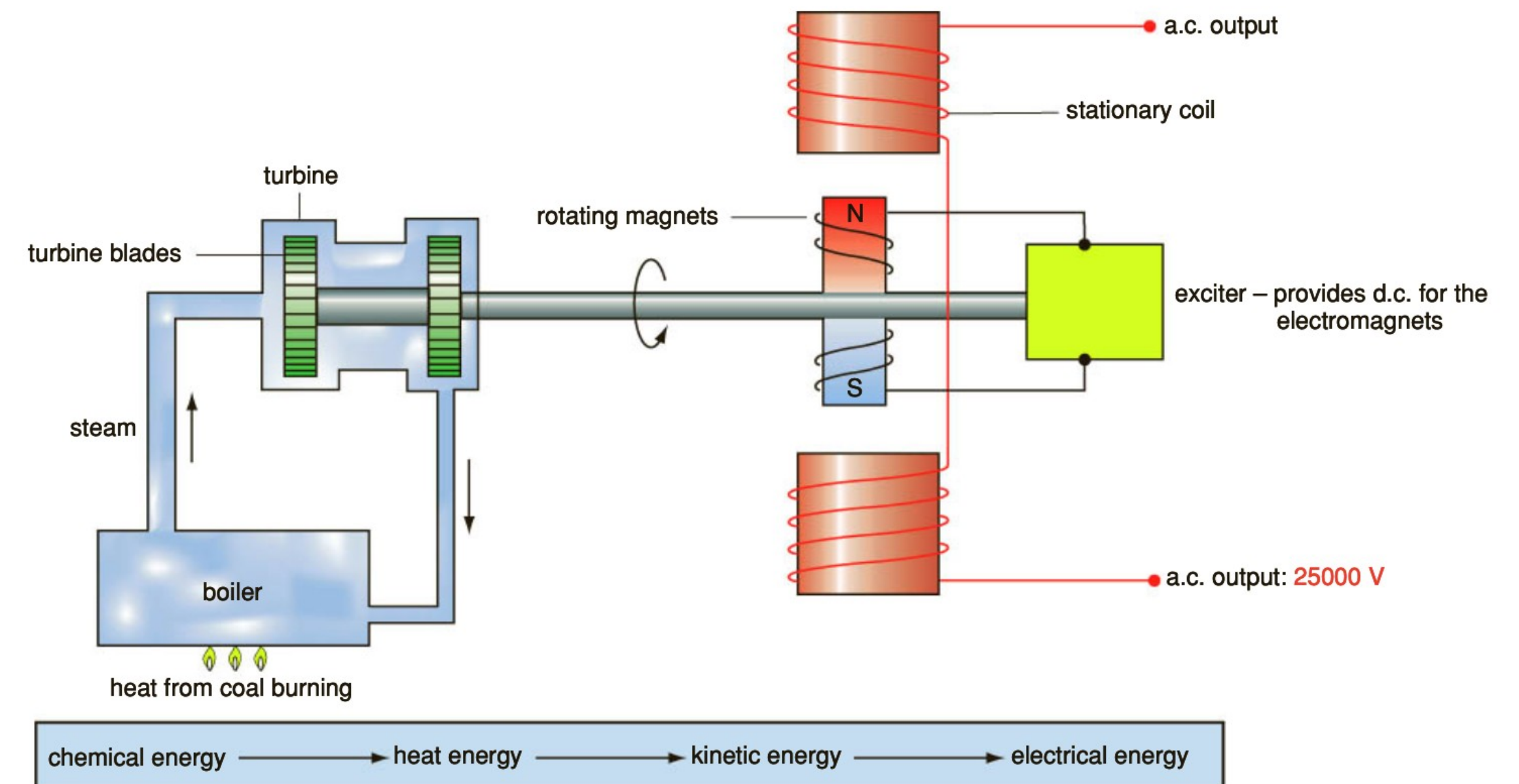
# Power Production on a Large Scale

- The work principle is slightly different.
- Instead of having a rotating coil and a stationary magnet, large generators use rotating electromagnets and stationary coils.
- Advantage: No moving part is needed for current collection.



# Power Production on a Large Scale

- Coal is burnt to boil water
- High-pressure steam is used to turn the turbine.
- The drive shaft is connected to the generator electromagnet, which rotates close to the stationary coil.
- The turbine's drive shaft also powers the exciter, which is a d.c. generator producing direct current for the electromagnet.



# Power Production on a Large Scale

Energy change:

1. Chemical energy in fuel
2. Heat energy in steam
3. Kinetic energy of turbine
4. Electrical energy in the wire.

Note that energy is lost at each stage of the conversion.

