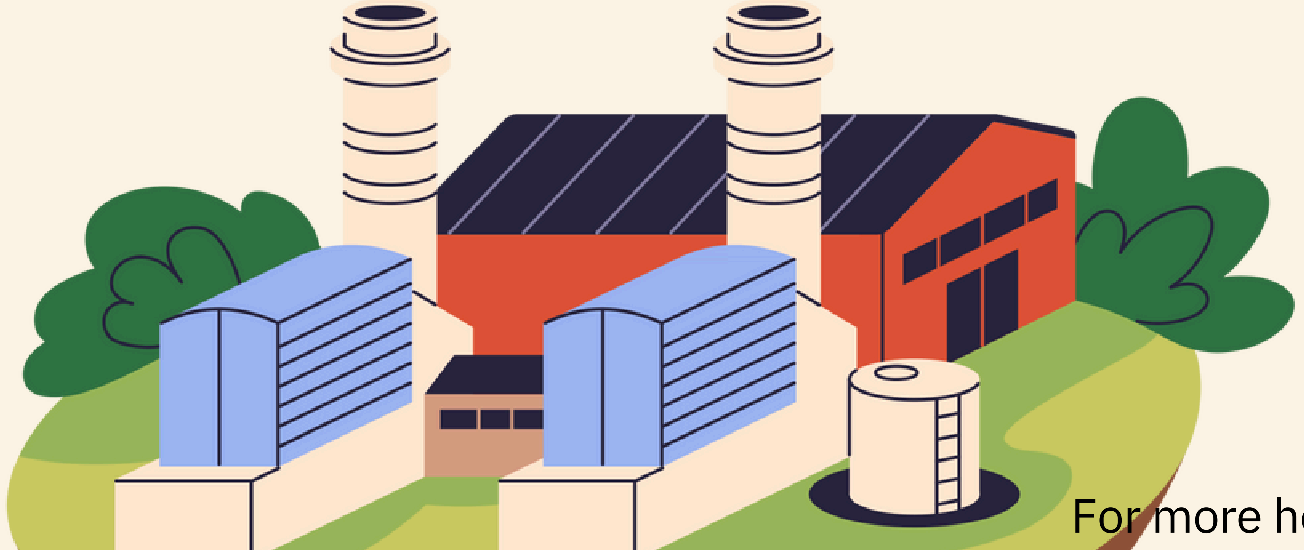
CIE IGCSE PHYSICS for board 0625 and 0972

(For exam 2025+)

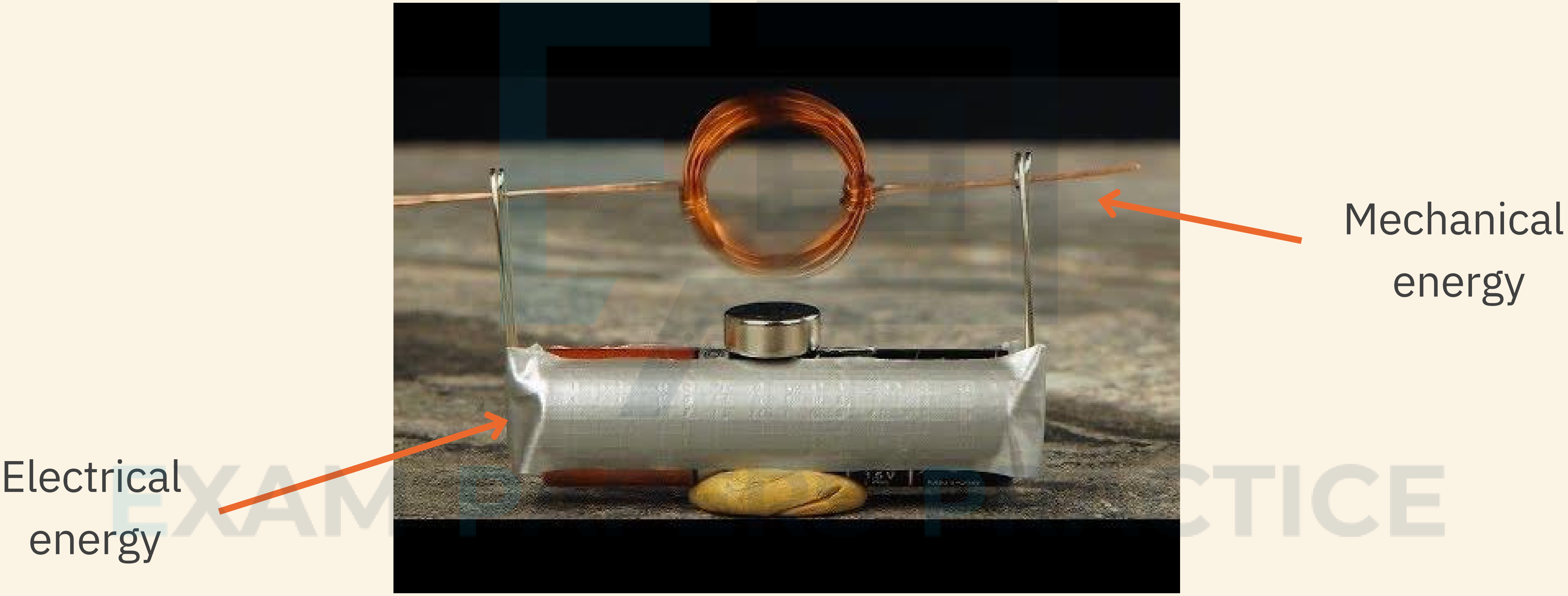
ELECTROMAGNETIC INDUCTION

Chapter 21



RECAP

[redacted]
mechanical energy (movement).

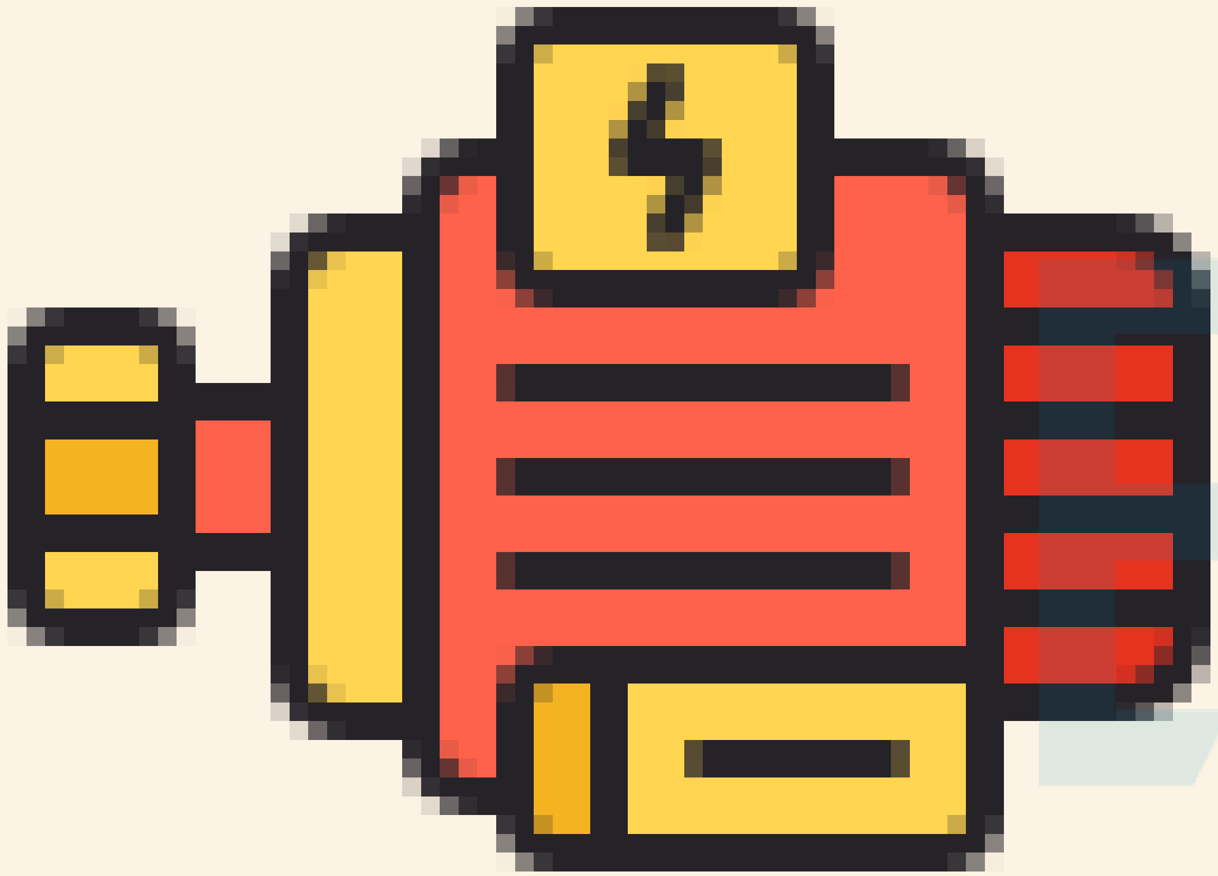


21.1 Generating electricity

[redacted]
flow) into electric energy.

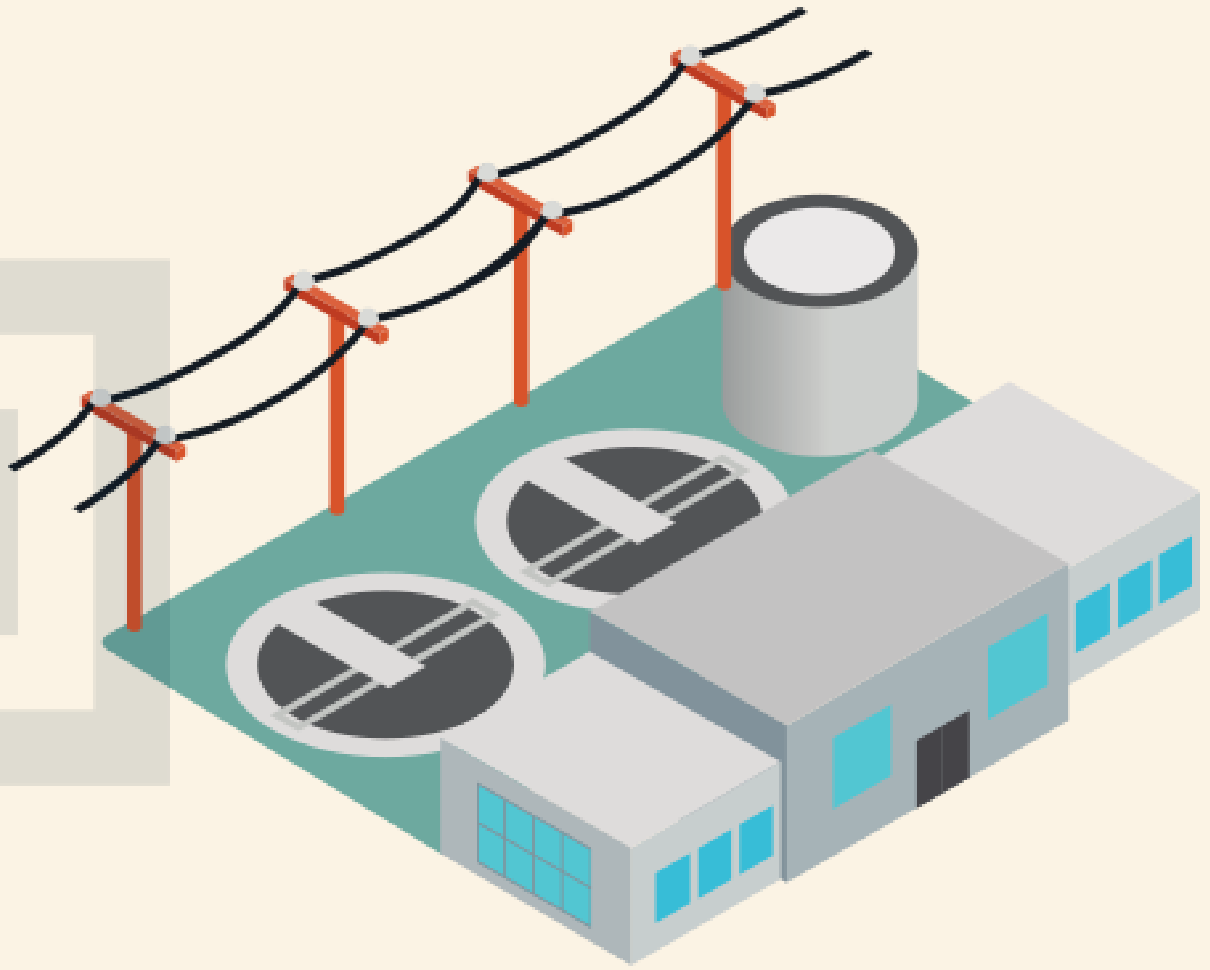
21.1 Generating electricity

DIFFERENT TYPES OF GENERATOR



Dynamo

An electrical generator used in bicycle for powering the light



Power Station Generator

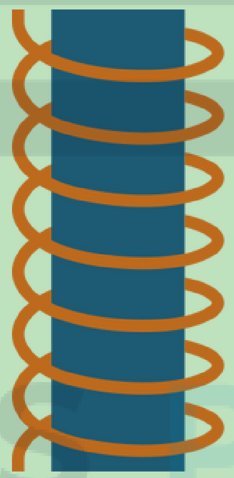
21.1 Generating electricity

HOW DOES POWER GENERATORS WORK?

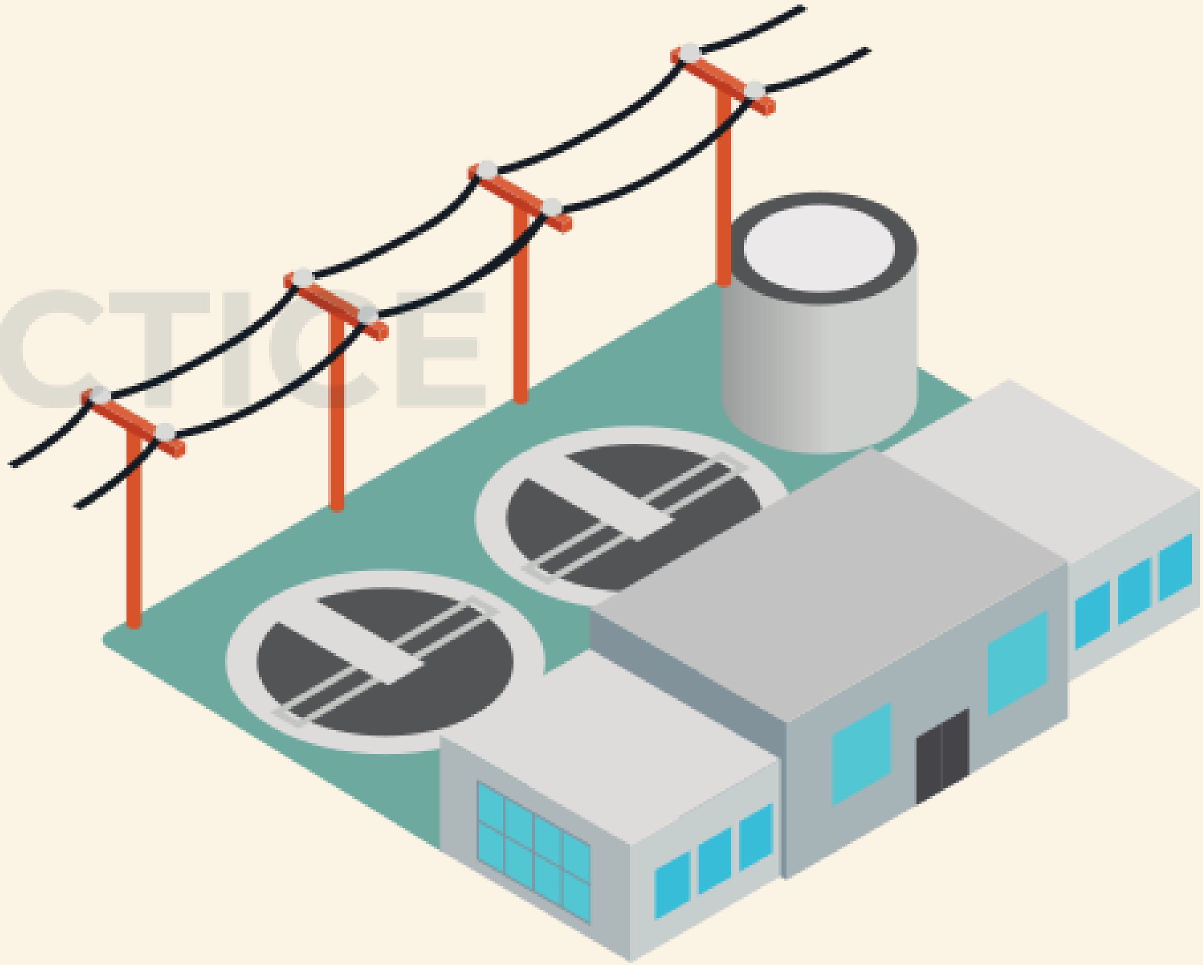
The turbines are driven to spin by the high-pressure steam from the boiler.

The generator shares the same axle as the turbine, causing it to spin as well.

Inside the generator, a coil rotates within fixed electromagnets, generating a magnetic field.



As a result, a large current is induced in the rotating coil, which is the current supplied by the power station to consumers.



Power Station Generator

ALL THESE GENERATORS HAVE 3 THINGS IN COMMON

A magnetic field
(provided by magnets or electromagnets)

A coil of wire

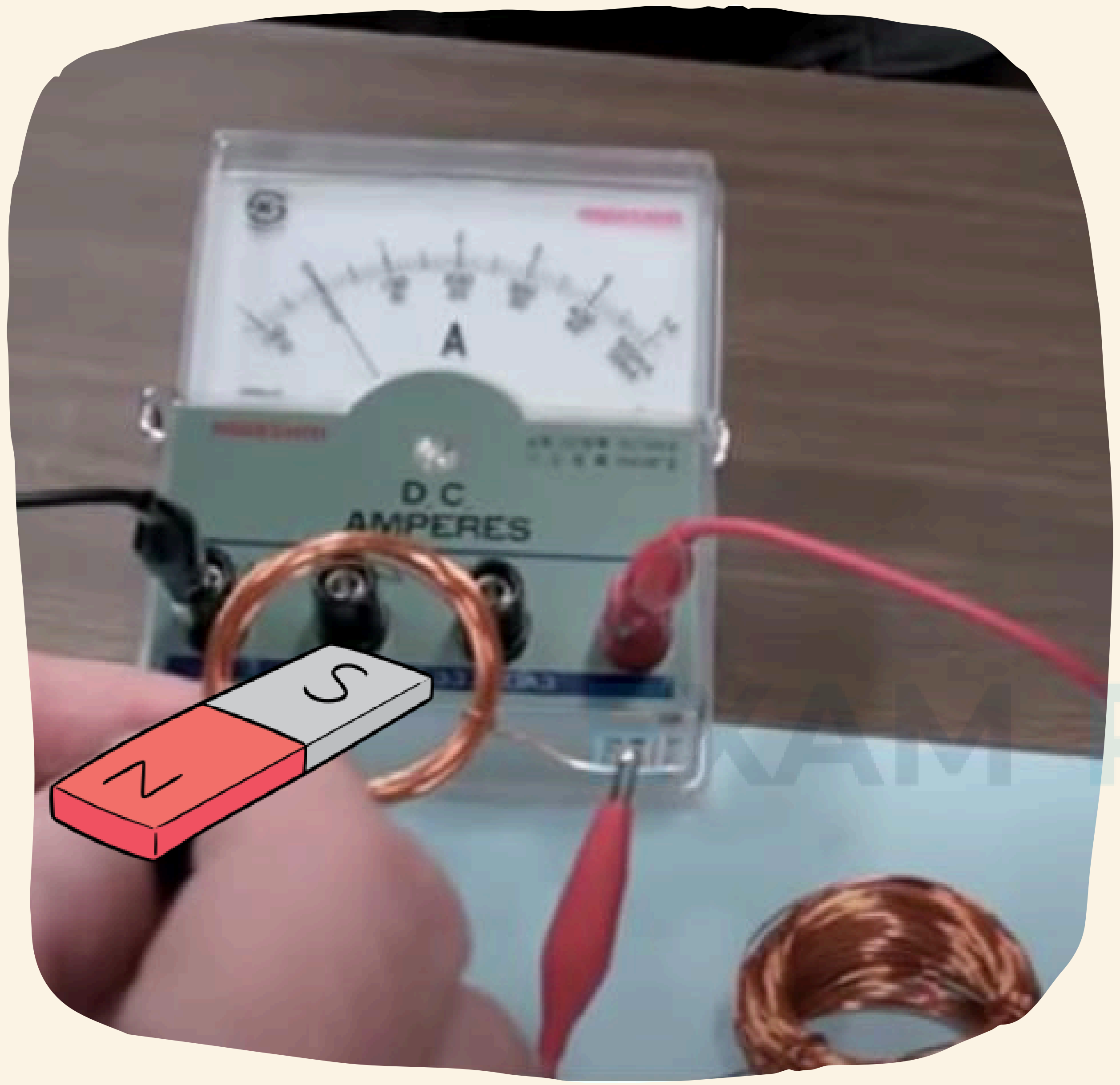
Movement

ELECTROMAGNETIC INDUCTION

> Electromagnetic induction is the process where a changing magnetic field induces an electromotive force (emf) and consequently an electric current in a nearby conductor.

21.2 The principles of electromagnetic induction

ILLUSTRATION ON E.I



Observation

a. When a magnet is inserted into and removed from the coil, current is induced, as indicated by the ammeter.

b. The faster the movement of the magnet, the greater the induced current.

c. Increasing the number of turns in the coils results in a larger induced current.

d. Reversing the magnet to use the opposite pole causes the current to flow in the opposite direction.

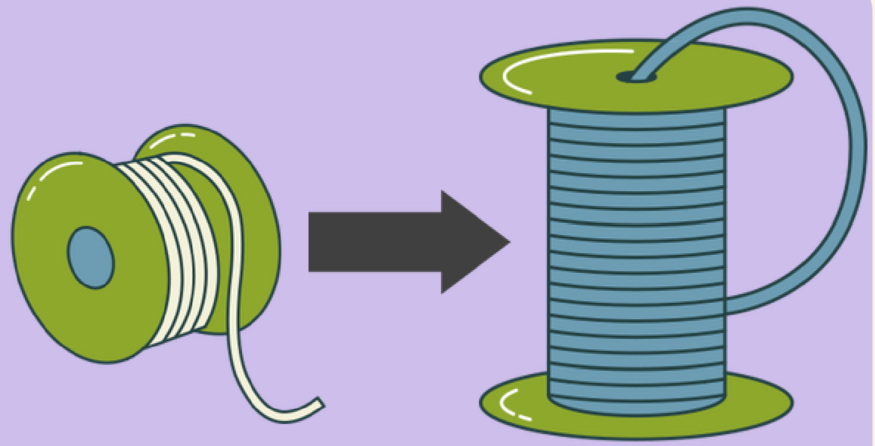
e. If the magnet is held stationary relative to the wire or coil, no current flows.

ALL THESE GENERATORS HAVE 3 THINGS IN COMMON

Use a stronger magnet

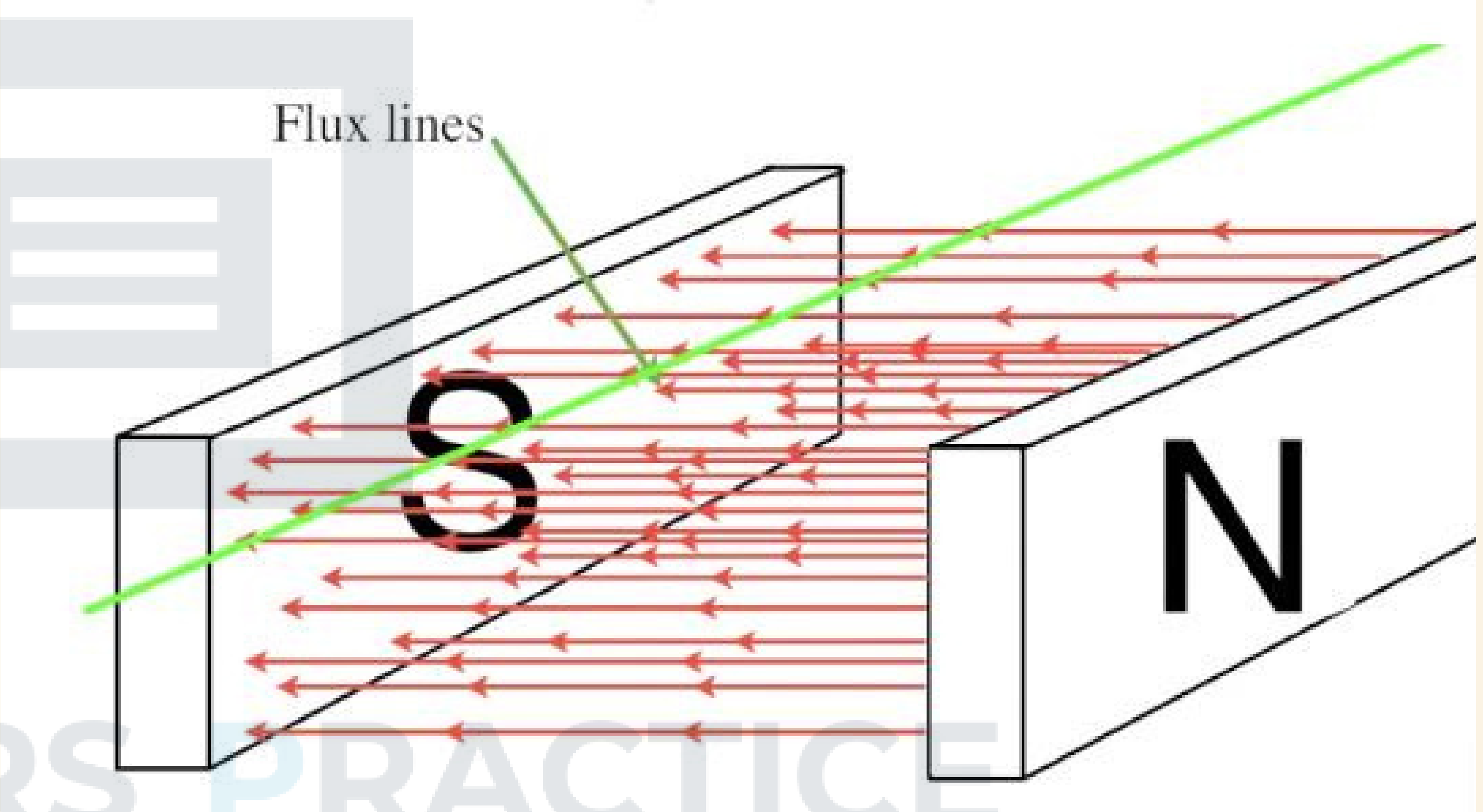
Increase the speed at which the wire or coil moves relative to the magnet.

Utilize a coil with a greater number of turns of wire. Each turn of wire induces an electromotive force (e.m.f.), and these combine to produce a larger overall e.m.f.



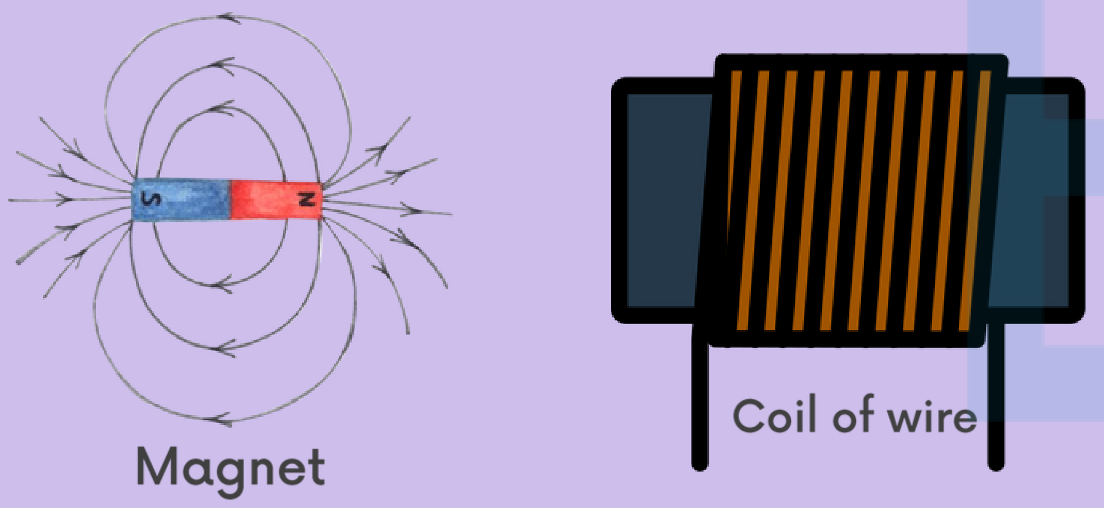
UNDERSTANDING ELECTROMAGNETIC INDUCTION

> As the wire moves downward between the poles of the magnet, it intersects and cuts across the magnetic field lines. This cutting action induces an electromotive force (e.m.f.) in the wire.

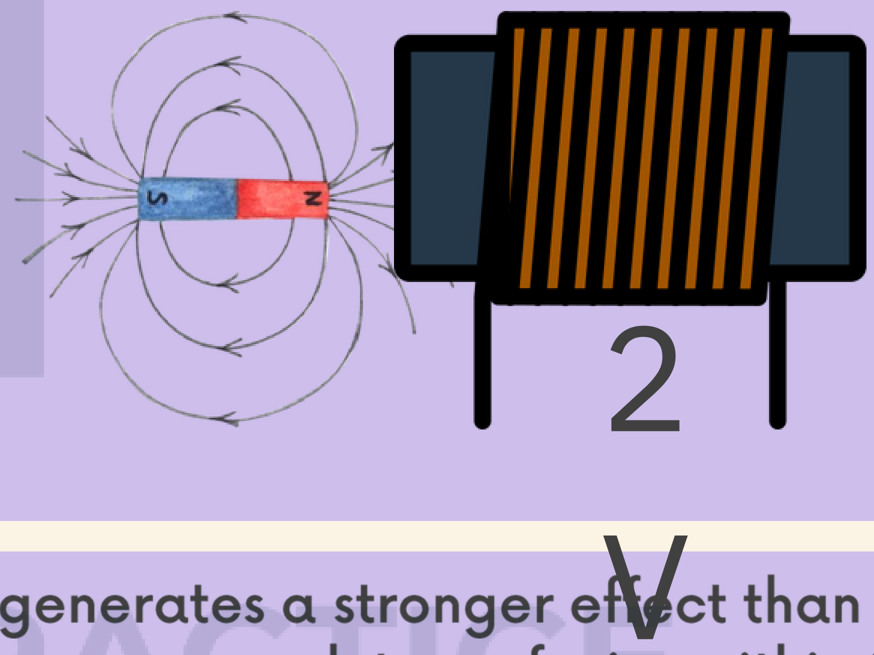


UNDERSTANDING ELECTROMAGNETIC INDUCTION

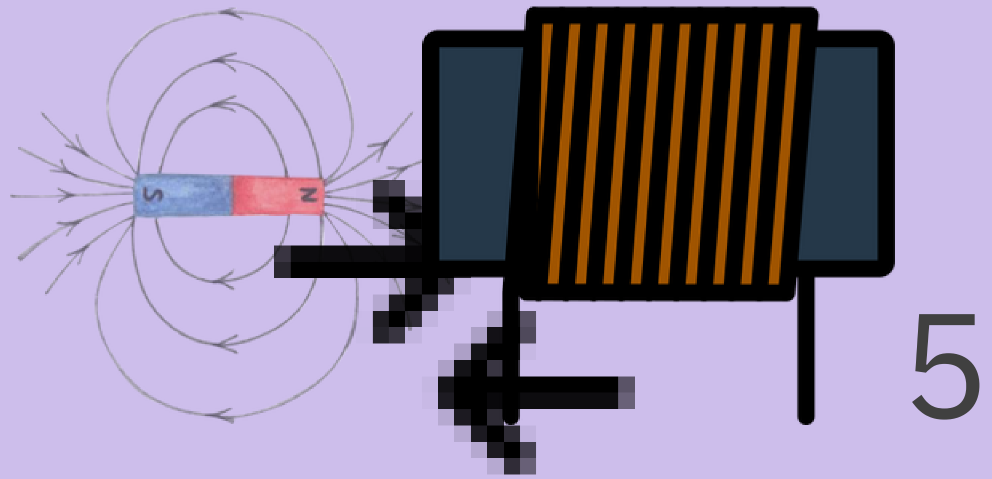
1 When the magnet is stationary, there is no movement to cut the magnetic field lines, resulting in no induced e.m.f.



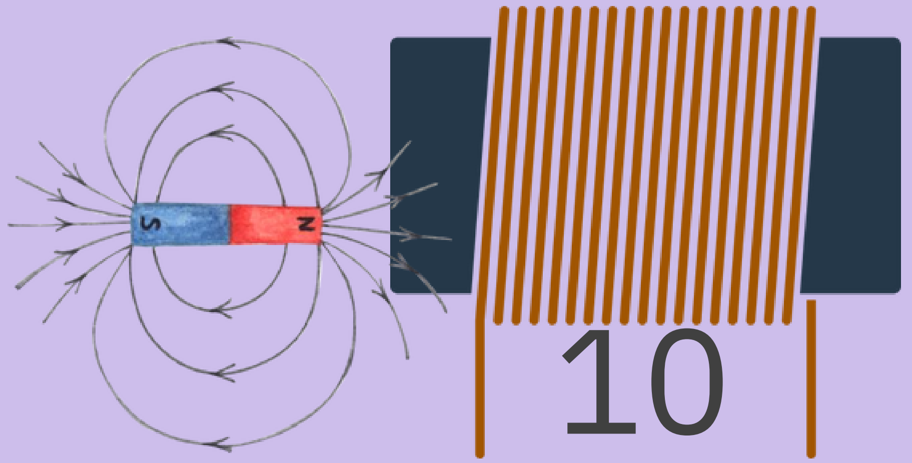
2 If the magnet is farther from the wire, the magnetic field lines are more widely spaced, resulting in fewer lines being cut and thus a smaller induced e.m.f.



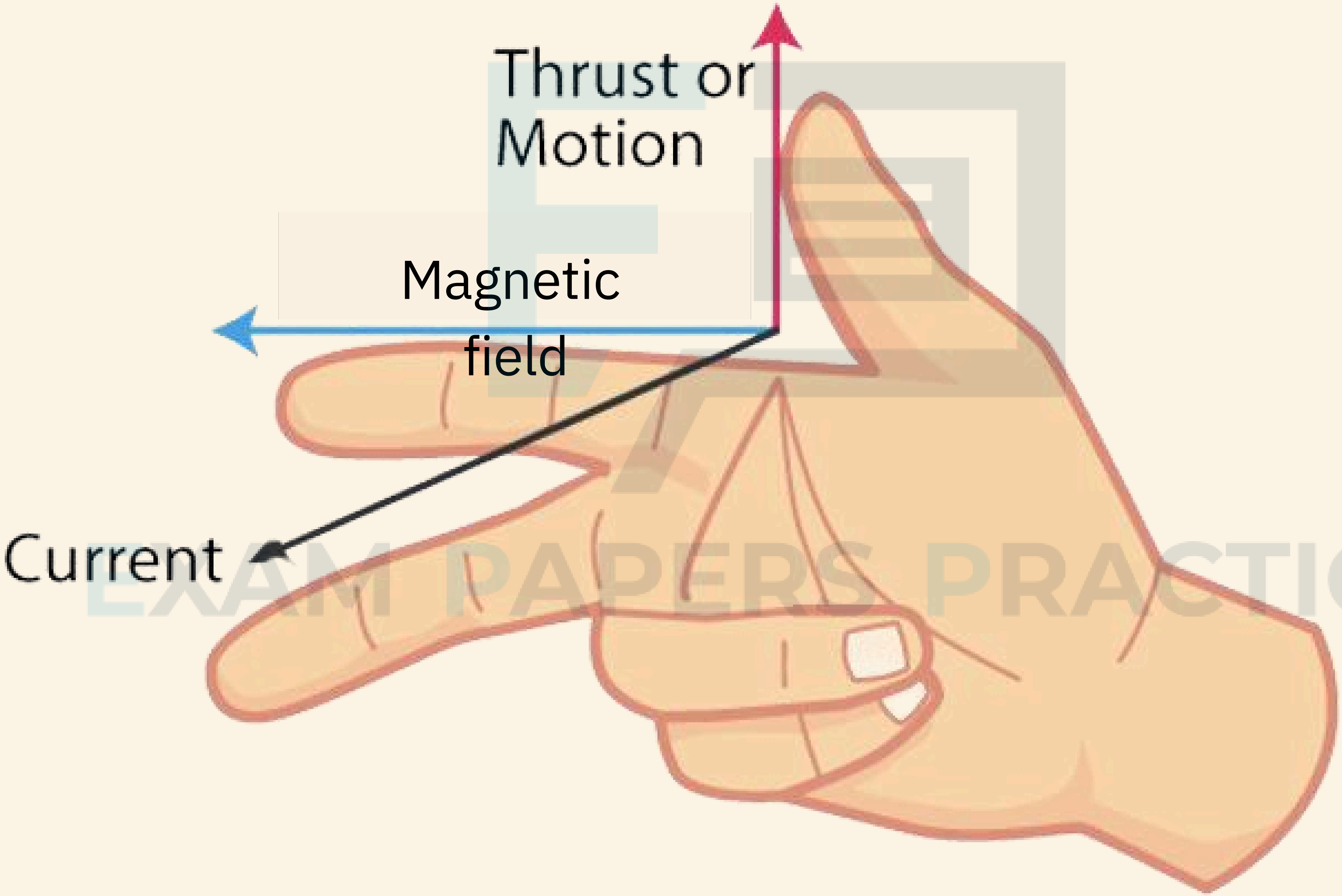
3 Moving the magnet quickly increases the rate at which the magnetic field lines are cut, leading to a larger induced e.m.f.



4 A coil generates a stronger effect than a single wire because each turn of wire within the coil cuts across the magnetic field lines, contributing to the total induced e.m.f.



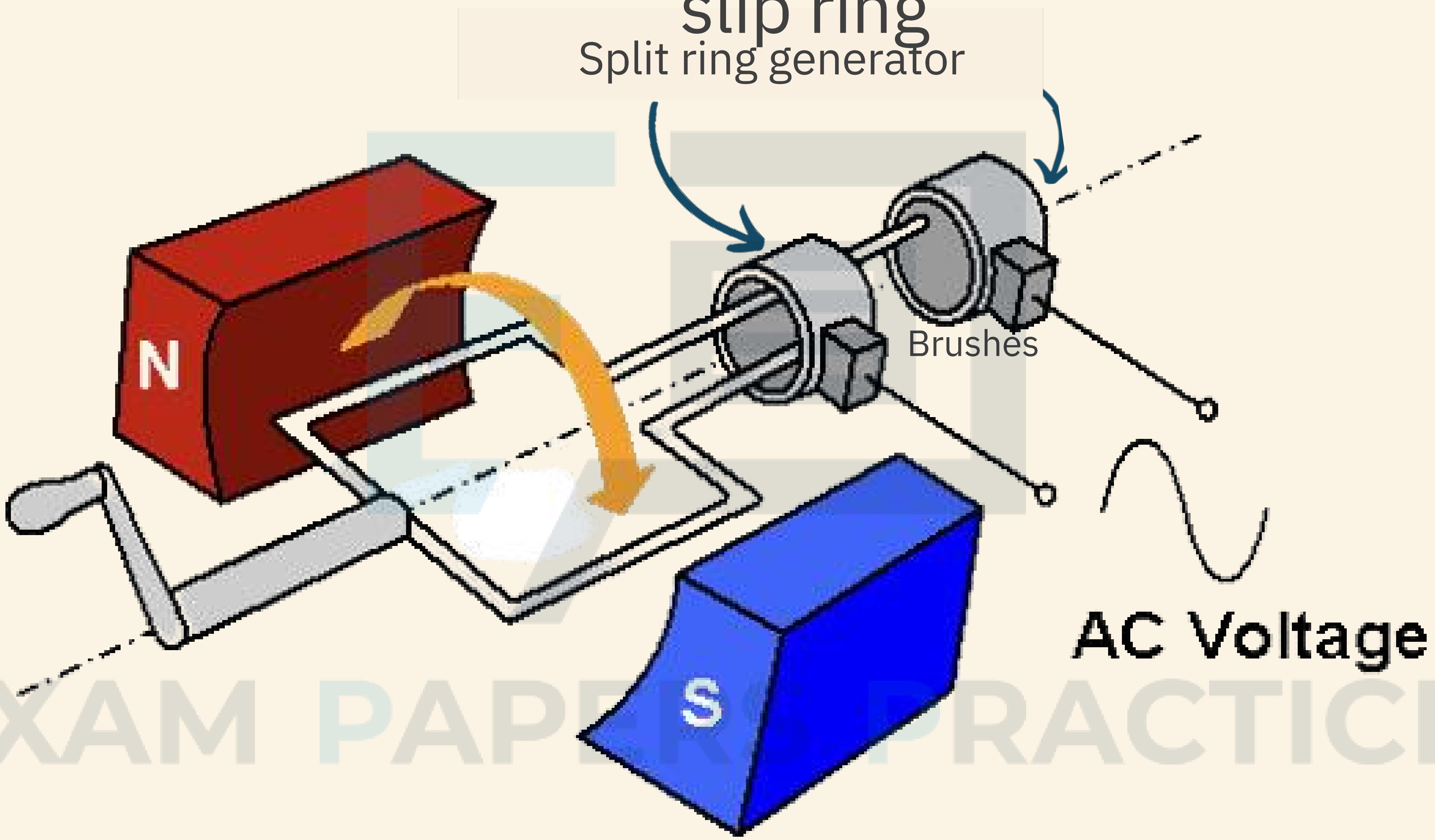
FLEMING'S RIGHT-HAND RULE –HELP IDENTIFY THE DIRECTION OF CURRENT GENERATED



EXAM PAPERS PRACTICE

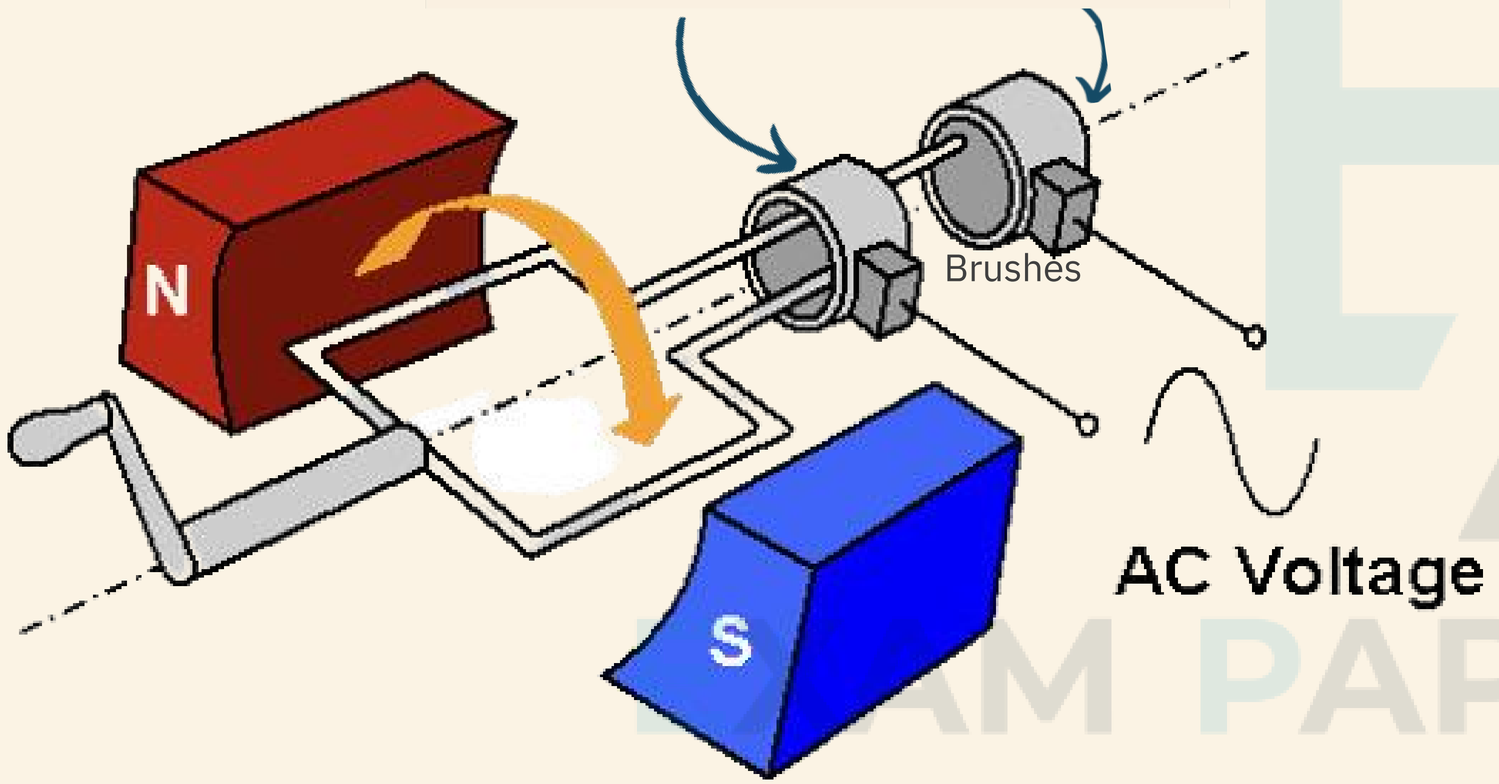
ALTERNATING CURRENT GENERATOR

slip ring



21.3 a.c generator

ALTERNATING CURRENT GENERATOR



The axle is rotated, causing the coil to spin within the magnetic field, inducing a current.

The induced current in the coil is connected to the external circuit.

An alternating current (AC) generator utilizes slip rings, which rotate along with the coil.

Brushes make contact with the slip rings, allowing them to pick up the same electromotive force (e.m.f.) as the sides of the rotating coil.

21.3 a.c generator

FOUR WAYS TO INCREASETHE VOLTAGE GENERATED BY AN A.C. GENERATOR:

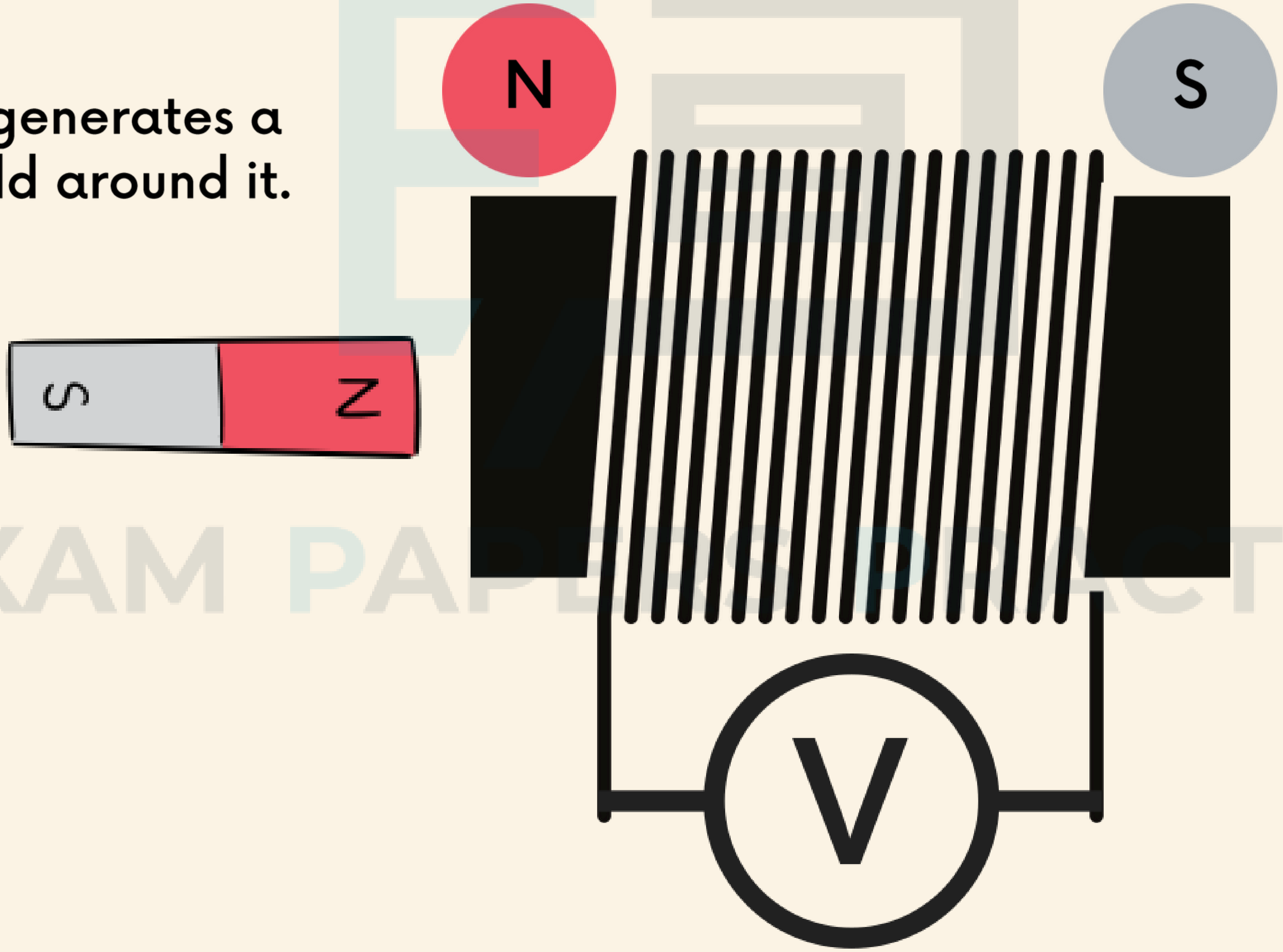
- Turn the coil more rapidly
- Use a coil with more turns of wire
- Use a coil with a bigger area
- Use stronger magnets

21.3 a.c generator

LENZ LAW

Lenz's Law states that the direction of the induced electromotive force (emf) and hence the induced current in a conductor will be such that it opposes the change in magnetic flux that caused it, thereby obeying the conservation of energy principle.

1 The magnet generates a magnetic field around it.

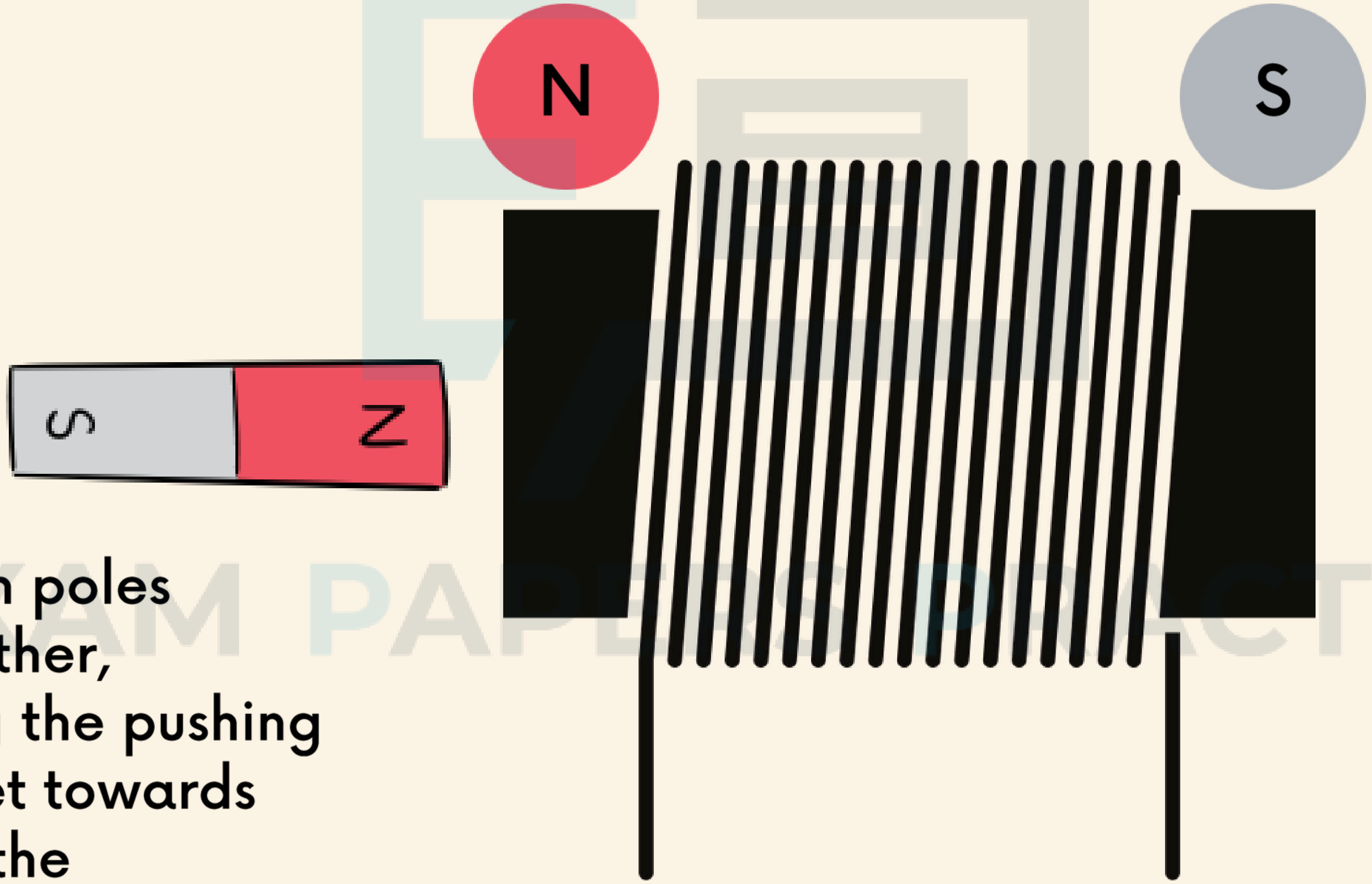


3 When the magnet's north pole approaches the coil, the induced current flows to create a north pole at the end of the coil nearest to the magnet.

2 This magnetic field always exerts a force in opposition to the field inducing the current.

LENZ LAW

Lenz's Law states that the direction of the induced electromotive force (emf) and hence the induced current in a conductor will be such that it opposes the change in magnetic flux that caused it, thereby obeying the conservation of energy principle.



4

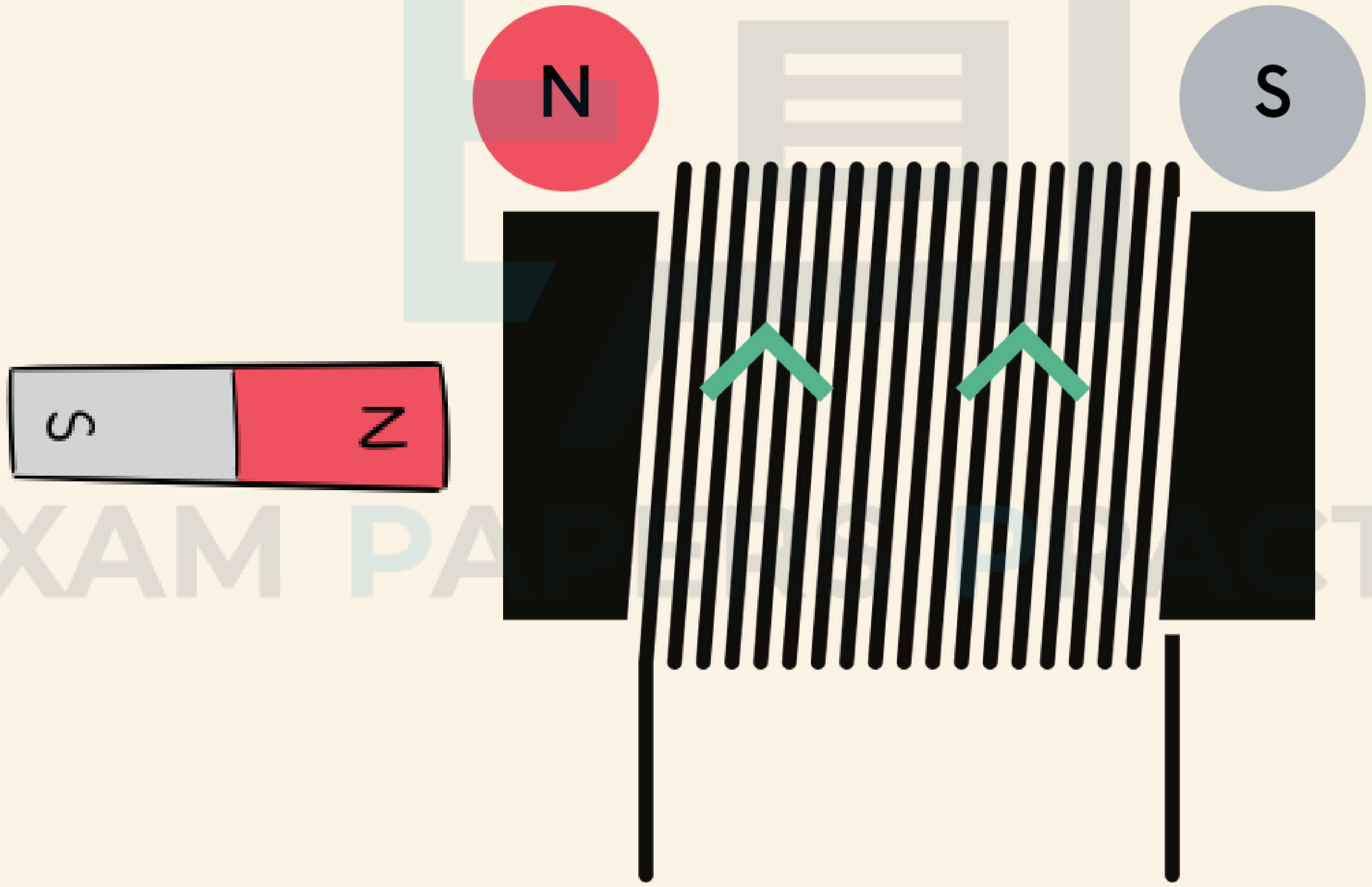
The two north poles repel each other, necessitating the pushing of the magnet towards the coil and the expenditure of energy (work).

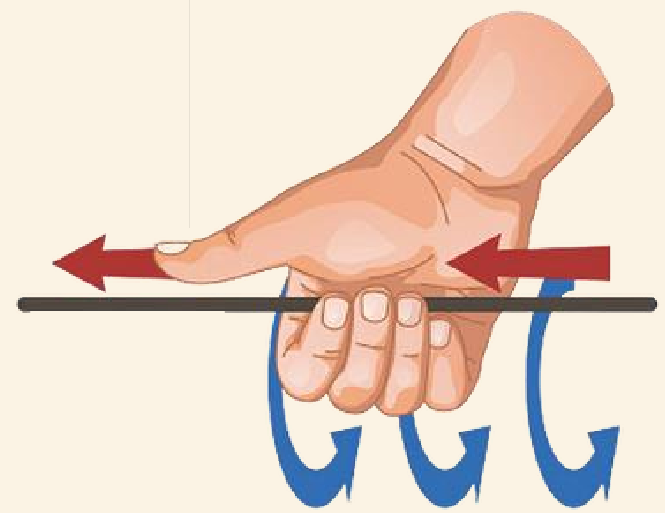
5

The energy expended in pushing the magnet is transferred to the current induced in the coil.

LENZ LAW

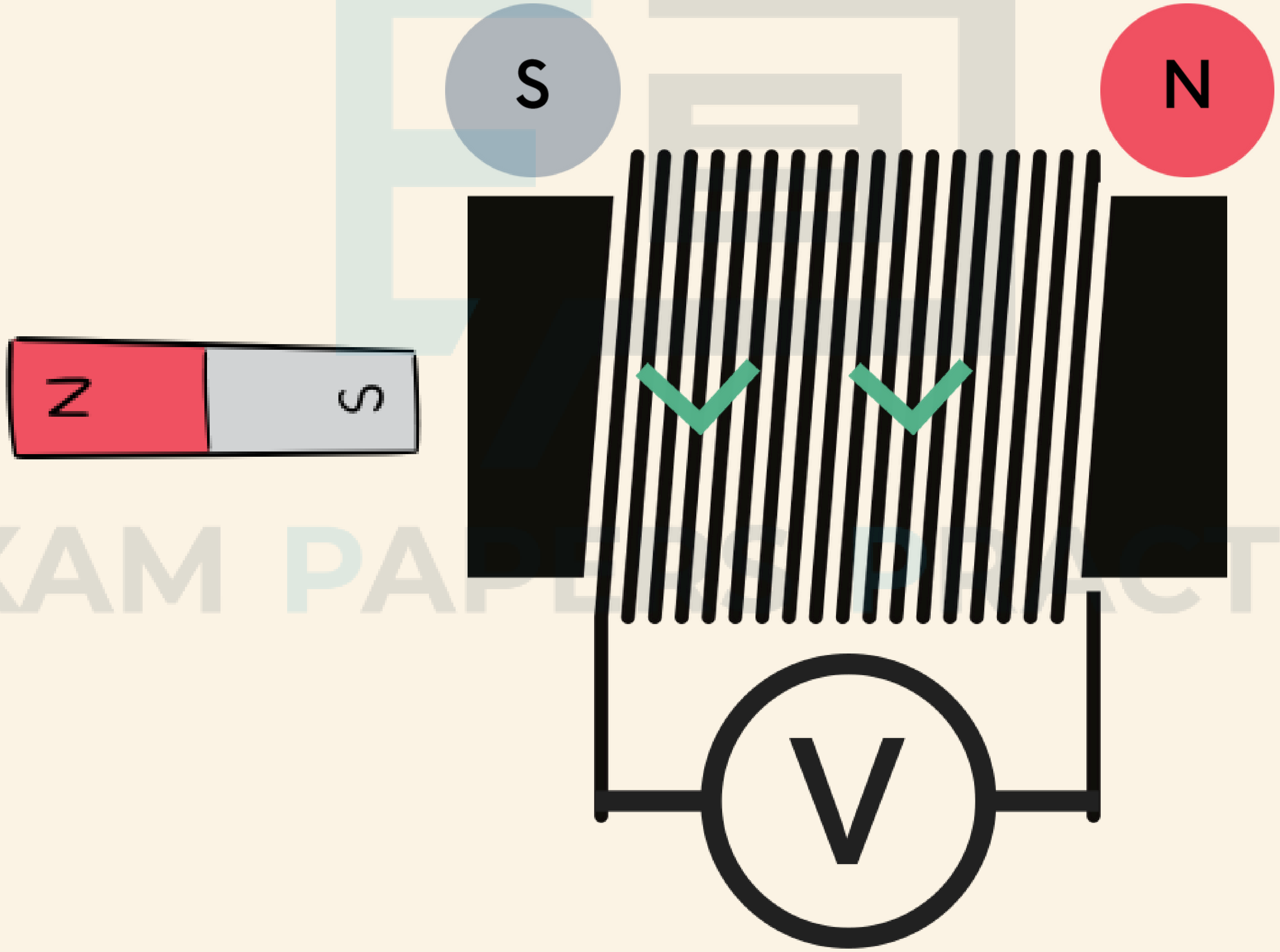
We now know the pole of the magnetic field of the induced current, we can find out the the direction of current flow using right hand grip rule.

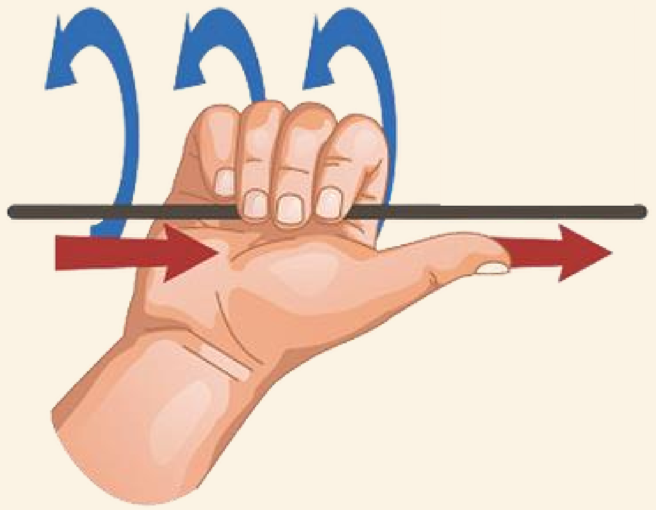




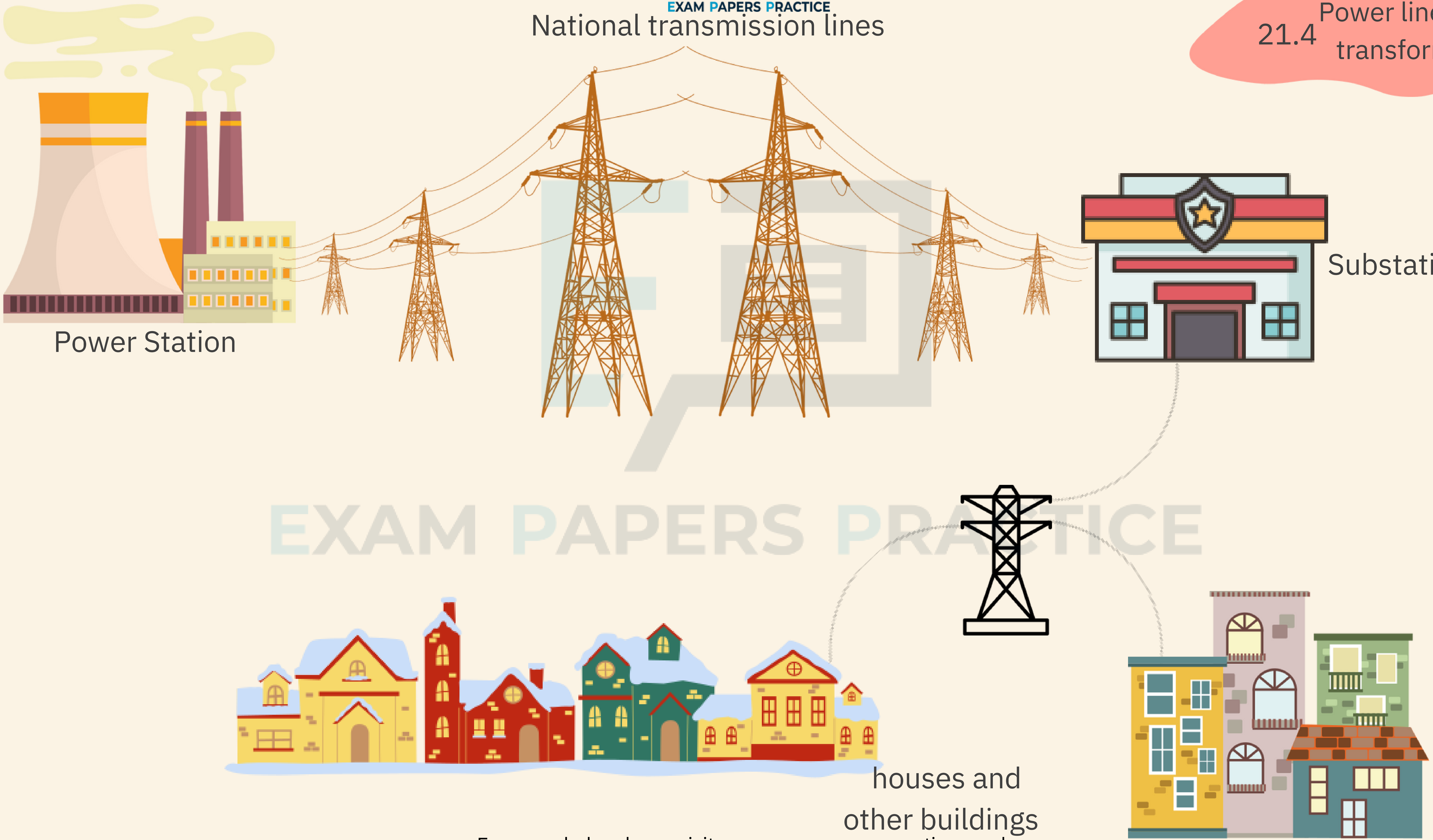
LENZ LAW

Reversing the direction of the magnet

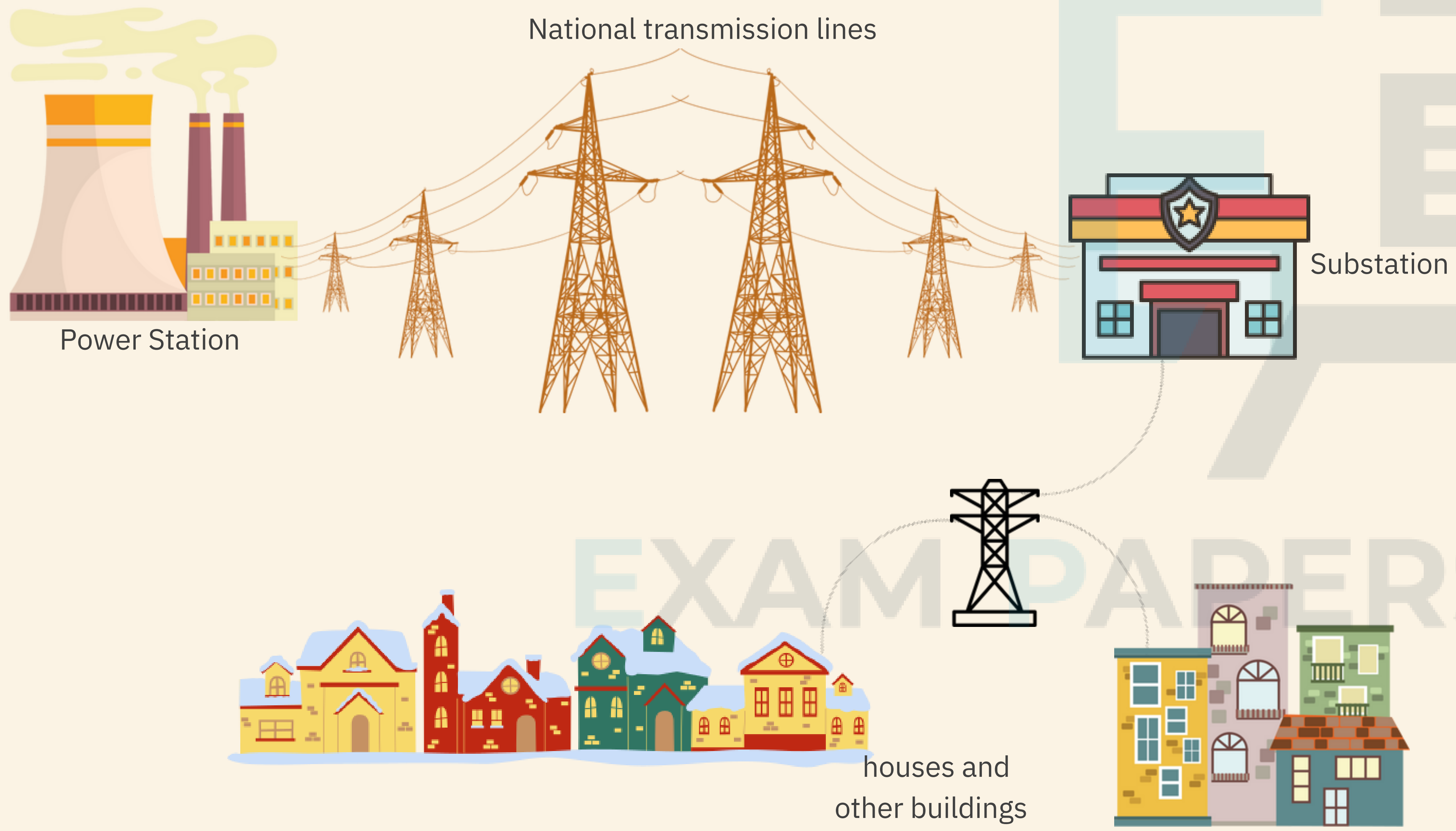




21.4 Power lines and transformer



21.4 Power lines and transformer



High-voltage electricity departs from the power station.

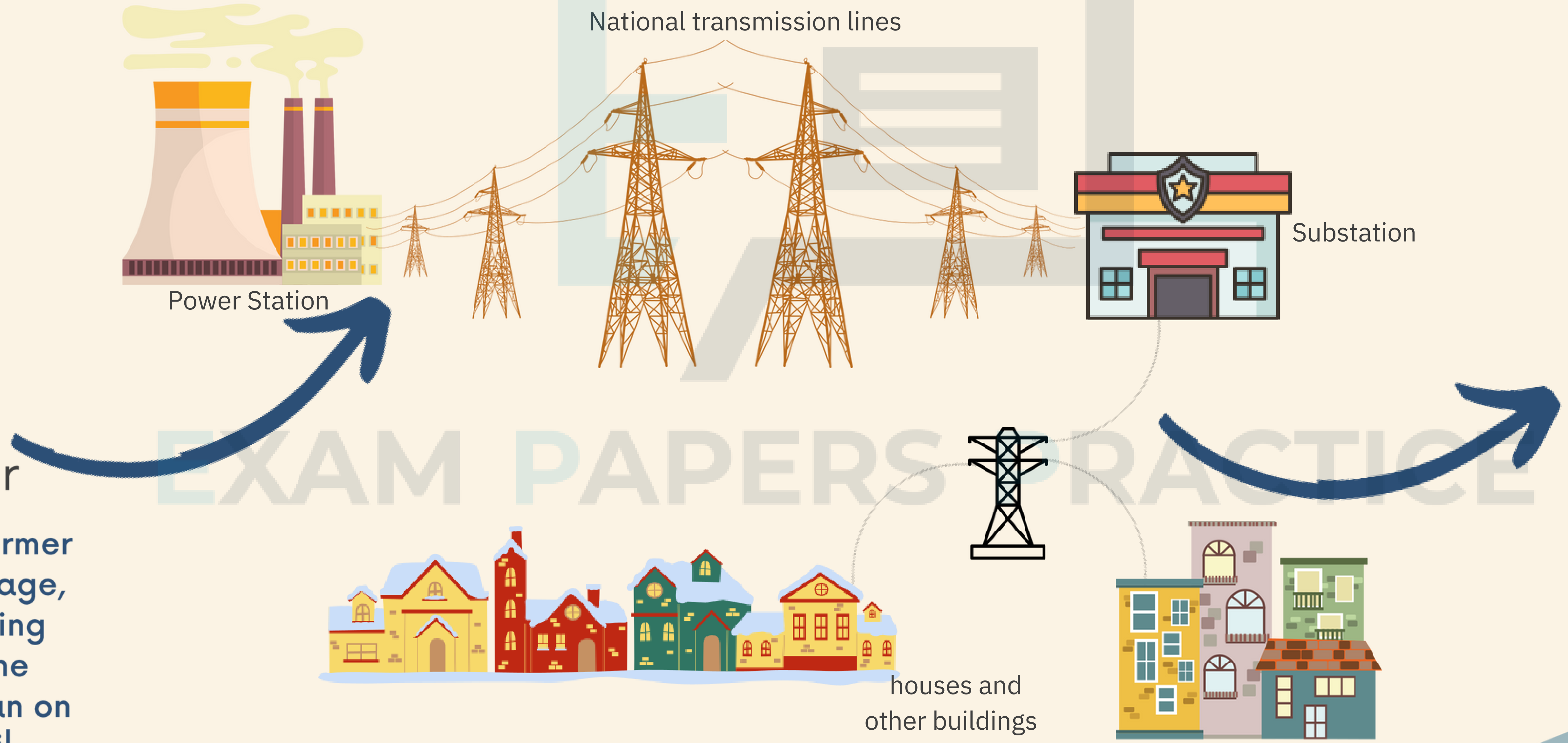
To mitigate risks to people, this electricity is typically transmitted through cables known as power lines, which are suspended high above the ground between tall pylons.

Networks of pylons carry these power lines across the countryside, directing electricity toward urban and industrial areas where it is needed.

As the power lines approach the areas of consumption, they enter local distribution centers. Here, the voltage is decreased to a safer level, and the electricity is transmitted through additional cables to local substations.

Within the substation, the voltage is further reduced to the standard local supply voltage, typically around 230 V.

TRANSFORMER



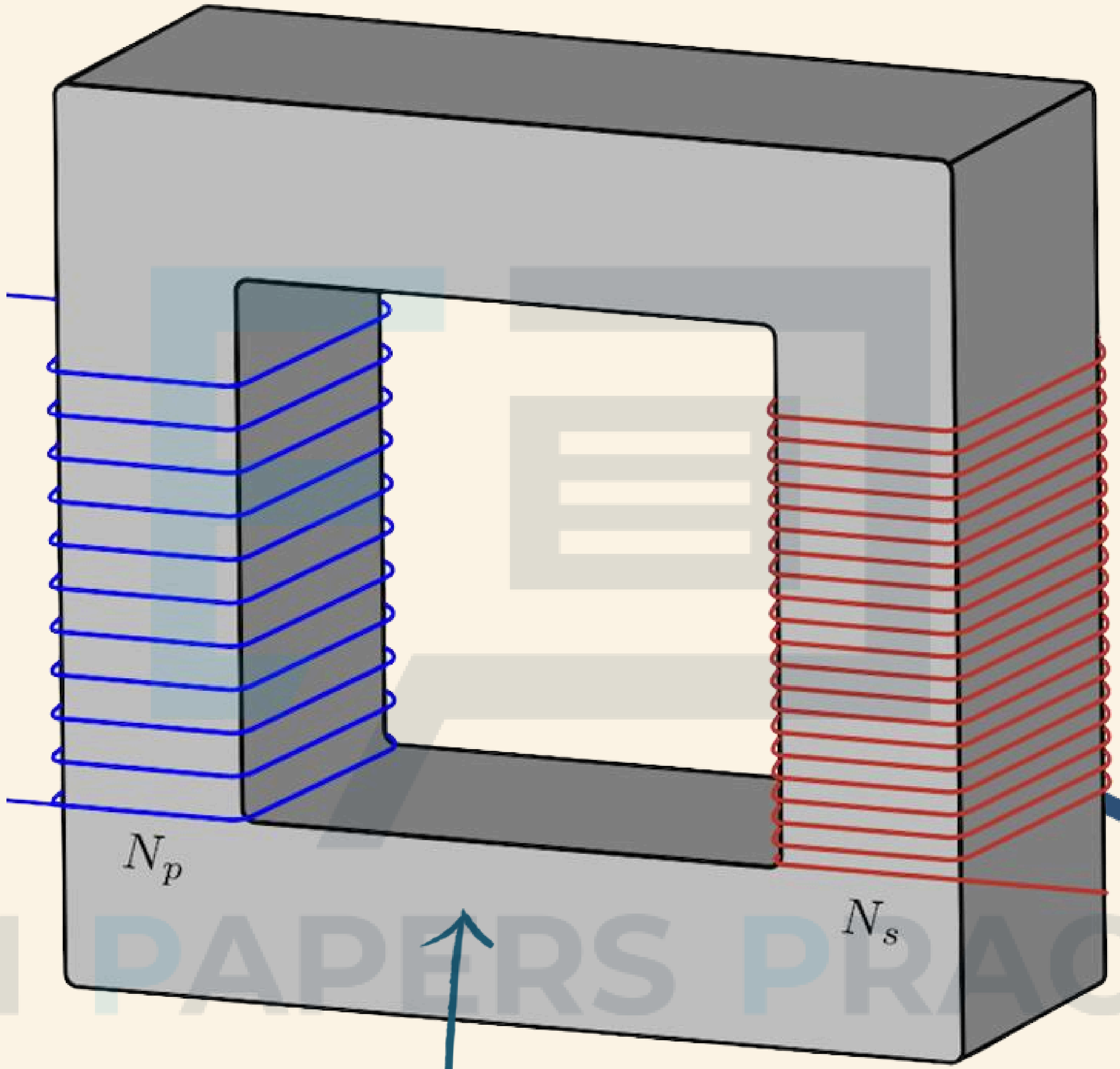
Step up transformer

Step down transformer

•A step-up transformer increases the voltage, achieved by having more turns on the secondary coil than on the primary coil.

21.5 Transformer

STRUCTURE OF A TRANSFORMER



Primary coil

The incoming voltage Vp is connected across this coil.

Secondary coil

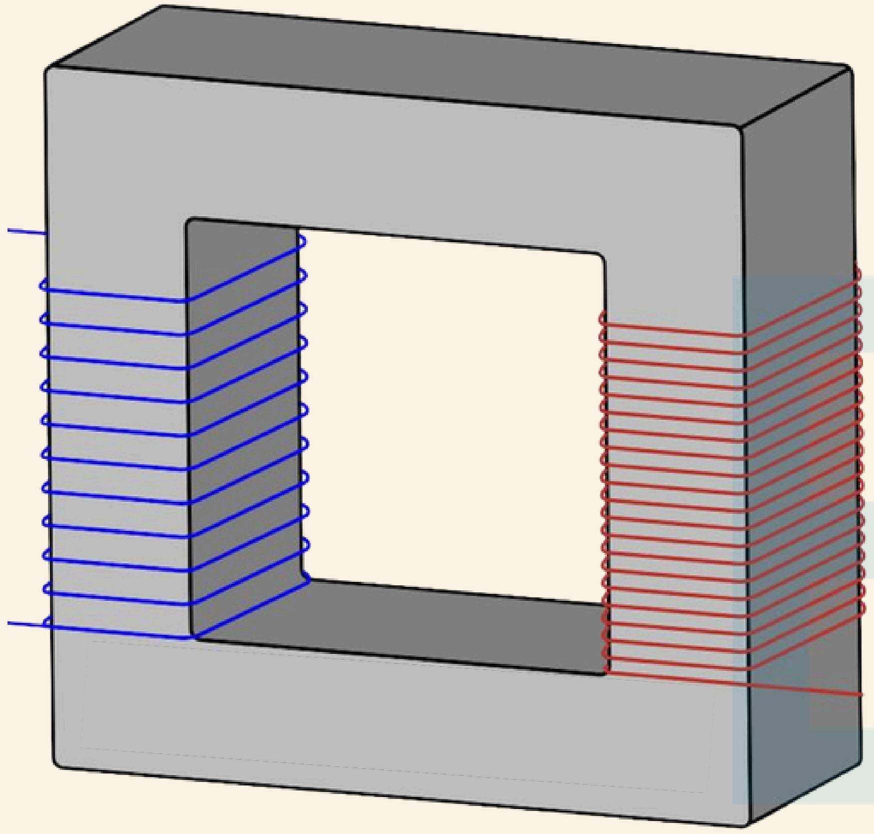
This provides the voltage Vs to the external circuit.

Iron Core

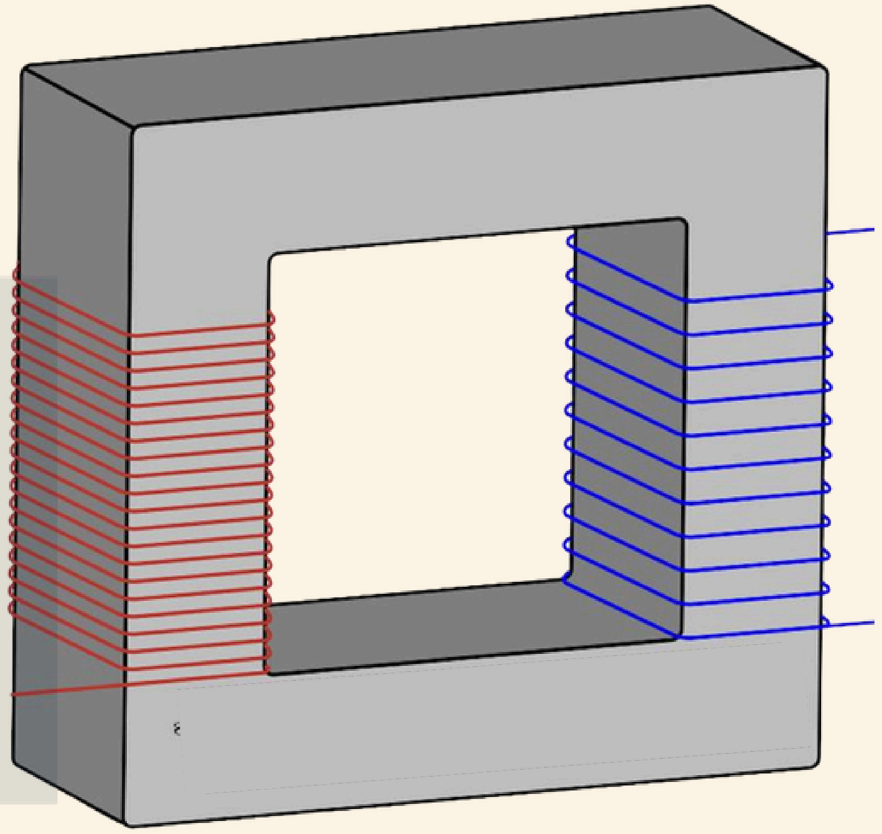
This links the two coils.

21.5 Transformer

TYPES OF TRANSFORMERS



Step up transformers



Step down transformers

Increases the voltage, achieved by having more turns on the secondary coil than on the primary coil.

Decreases the voltage, accomplished by having fewer turns on the secondary coil than on the primary coil.

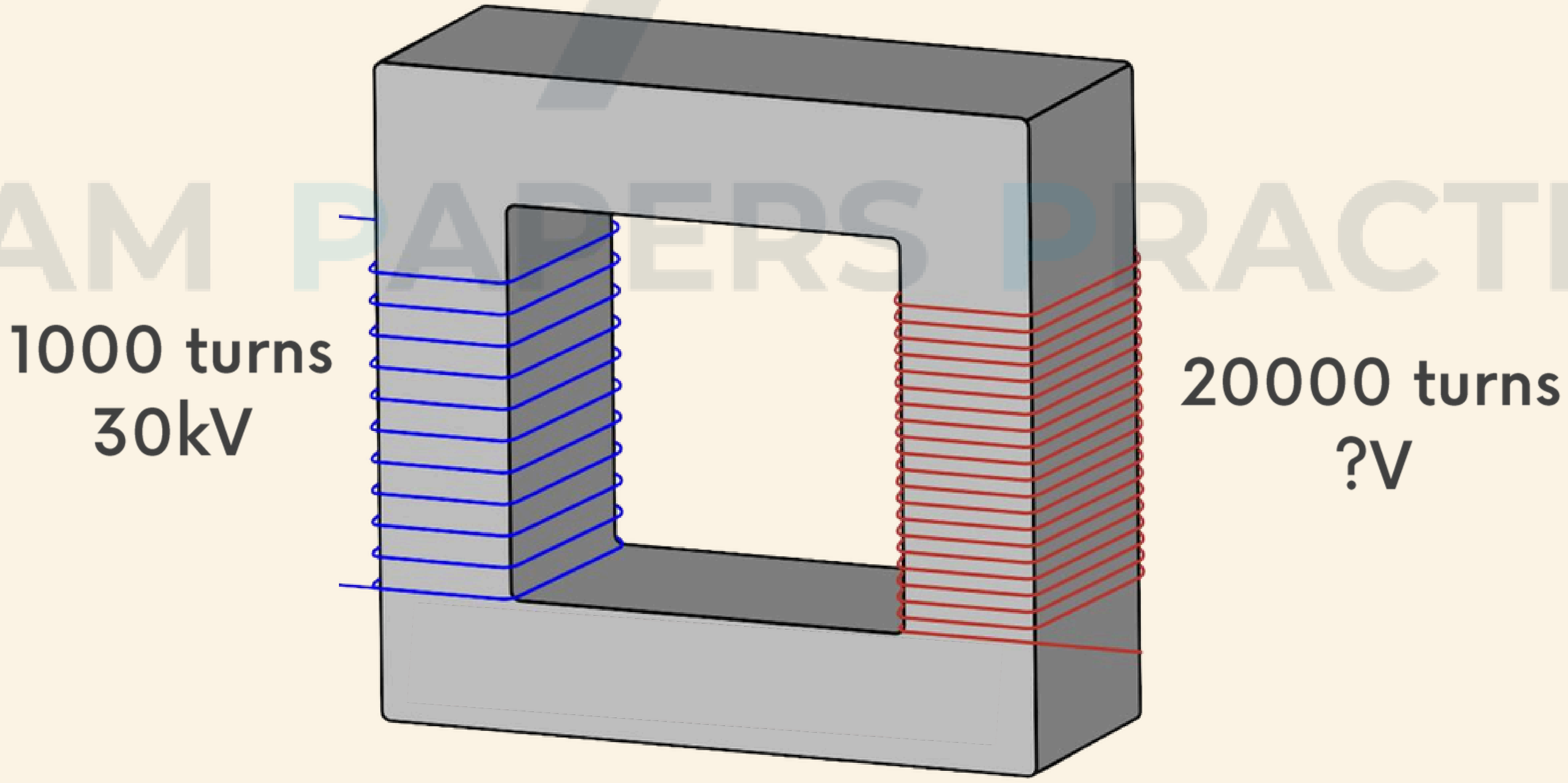
EQUATION RELATING VOLTAGES AND NUMBER OF TURNS IN EACH COIL:

$$\frac{Vp}{Vs} = \frac{Np}{Ns}$$

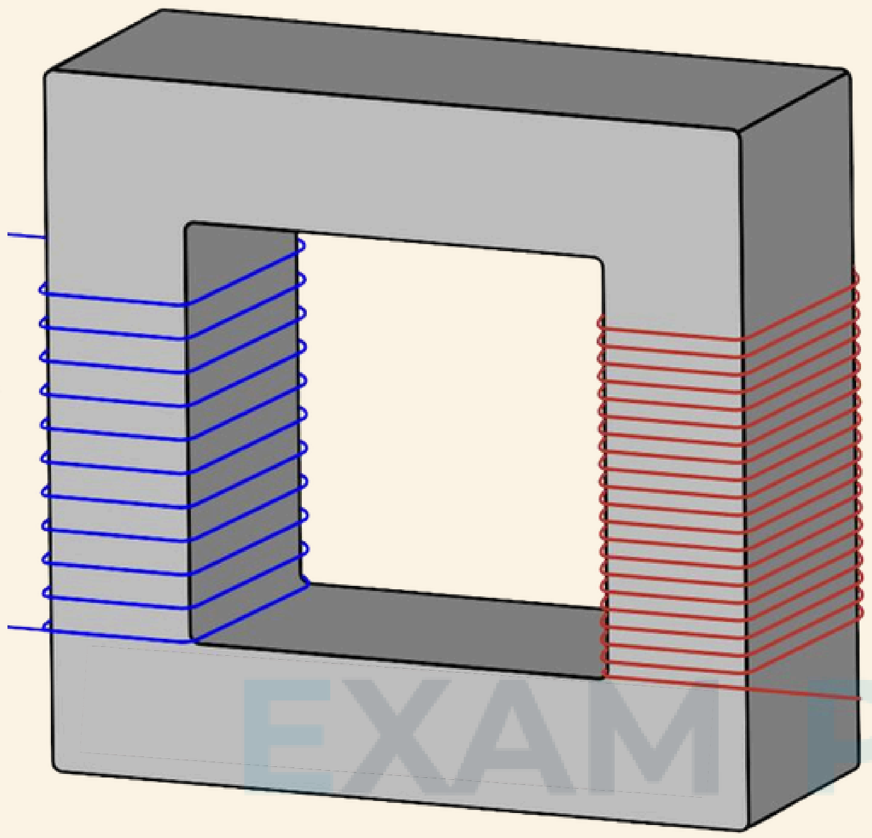
WORKED EXAMPLE

[redacted]
across its primary coil is 30 kV.

a. State what type of transformer this is.
b. Calculate the voltage across its secondary coil.



SOLUTION



a.

Step up transformer

b.

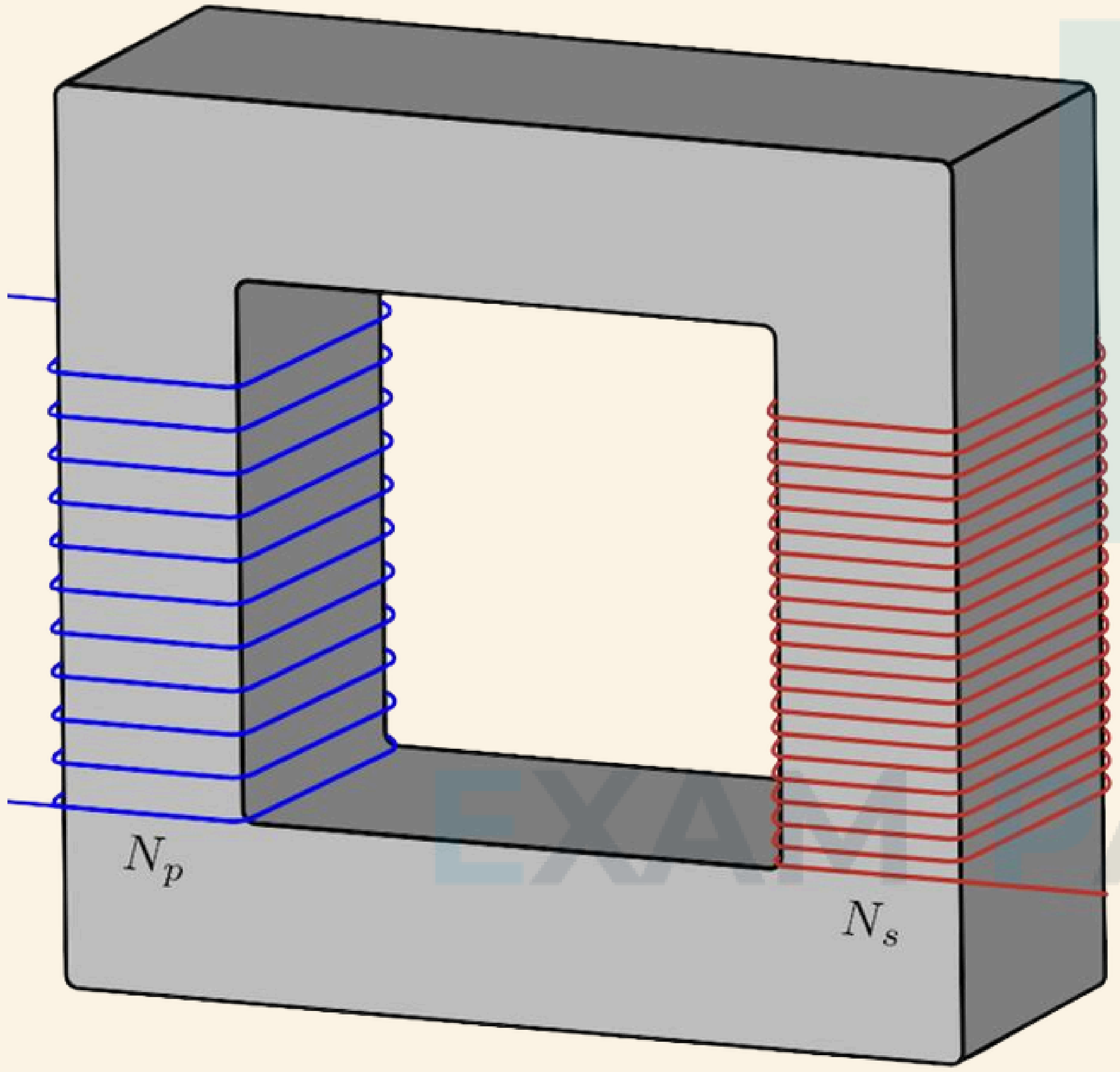
1000 / 20000 = 30000 / V

V = 30000 / 0.05

= 600,000 V

worked example

HOW DOES A TRANSFORMER WORK?



The primary coil carries alternating current, creating an electromagnet with an alternating magnetic field. The core conducts this alternating magnetic field to the secondary coil. The secondary coil, being in a changing magnetic field, becomes a conductor. This induces a current in the secondary coil.

occurs because the magnetic field produced by the primary coil remains constant. Without a changing magnetic field passing through the secondary coil, no voltage is induced in it.

POWER FORMULA RECAP

$P = VI$

Using high voltages reduces the current flow in the wire.

ENERGY LOST FORMULA

NEW

$P = I^2R$

Reducing the current flow in the wire will result in lower power lost.

21.6 calculating power loss

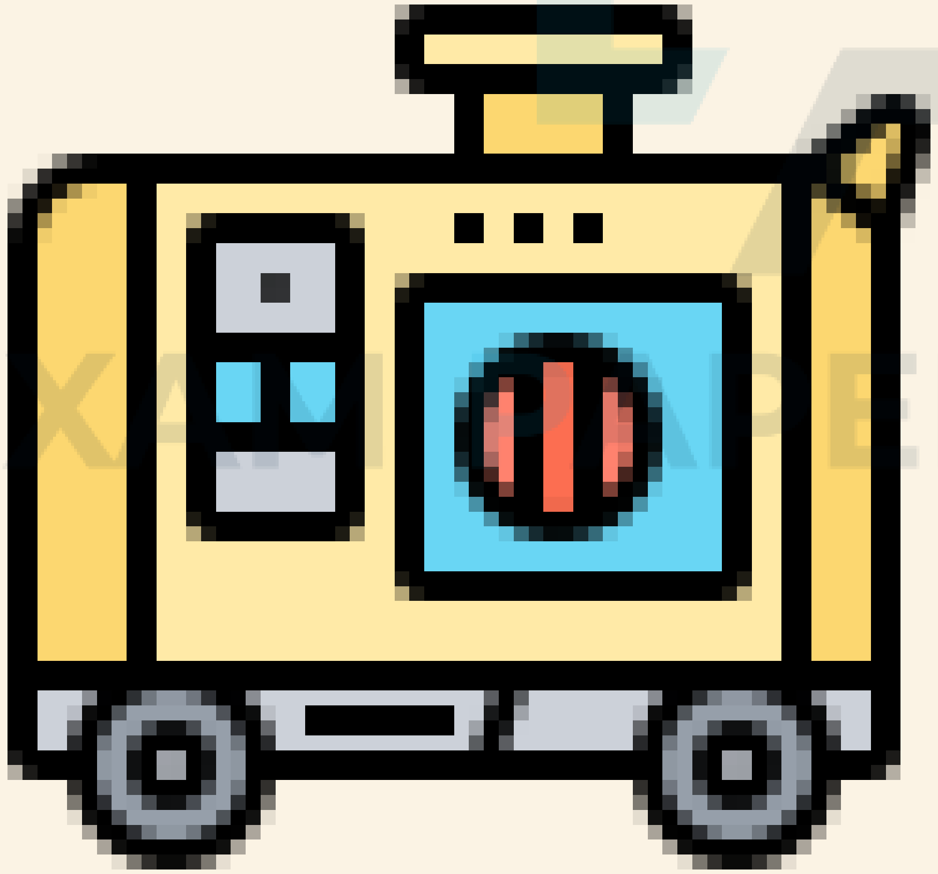
WORKED EXAMPLE

[redacted]
using cables with a resistance of 25 ohms. Calculate:

a. The power lost in the cables.

[redacted]
assuming the power output remains constant.

$P = I^2R$



calculating power loss

SOLUTION

[redacted]
using cables with a resistance of 25 ohms. Calculate:

a. The power lost in the cables.

[redacted]
assuming the power output remains constant.

$P = I^2R$

a.

$P = VI$

$15000 = 6000\,I$

$I = 2.5a$

$P = I^2R$

$p = (2.5) \times (2.5) \times (25)$

$= 156.25$ W

calculating power loss

SOLUTION

[redacted]

using cables with a resistance of 25 ohms. Calculate:

a. The power lost in the cables.

[redacted]

assuming the power output remains constant.

B.

$P = VI$

$15000 = 15000\,I$

$I = 1a$

$P = I^2 R$

$p = 1 \times (25)$

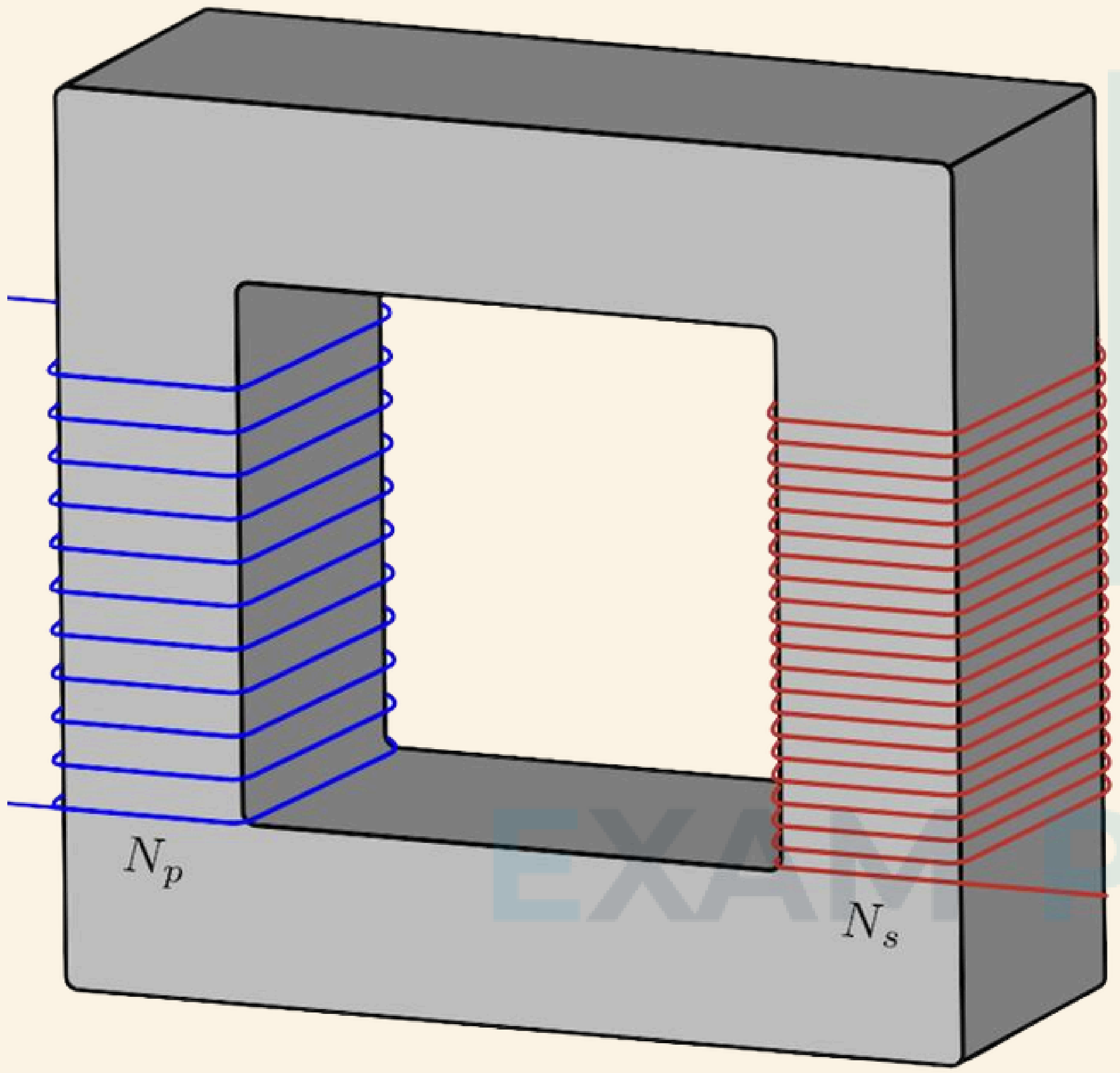
$= 25\ W$

power lost reduces by 131.25 W.

$P = I^2 R$

calculating power loss

EXAM PAPERS PRACTICE



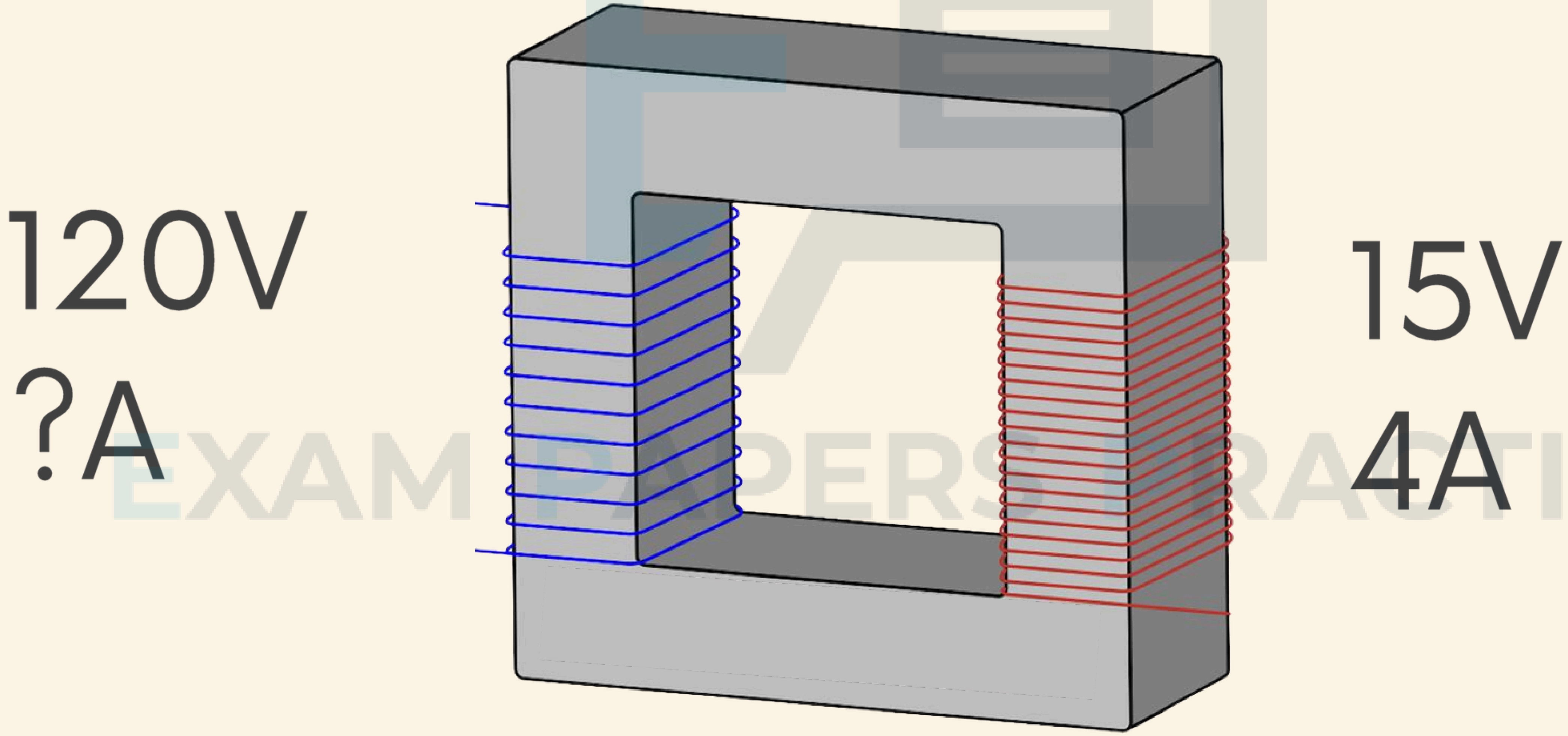
If a transformer is 100% efficient, no power is lost in its coils or core. Well-designed transformers typically waste only about 0.1% of the power transferred through them. This efficiency allows us to establish an equation linking the primary and secondary voltage to the primary and secondary current.

$$V_p I_p = V_s I_s$$

WORKED EXAMPLE

A laboratory power supply unit provides an **output voltage of 15 V**. It is connected to a **120 V mains supply**. The unit utilizes a transformer. The output current from the power [redacted]

$$P = I^2R$$



calculating power loss

WORKED EXAMPLE

A laboratory power supply unit provides an **output voltage of 15 V**. It is connected to a **120 V mains supply**. The unit utilizes a transformer. The output current from the power [redacted]

$P = I^2R$

$$V_pI_p = V_sI_s$$

$$120\,I = 15 \times 4$$

$$I = 60 / 120$$

$$= 0.5\ A$$

calculating power loss

Fig. 10.1 shows the basic parts of a transformer.

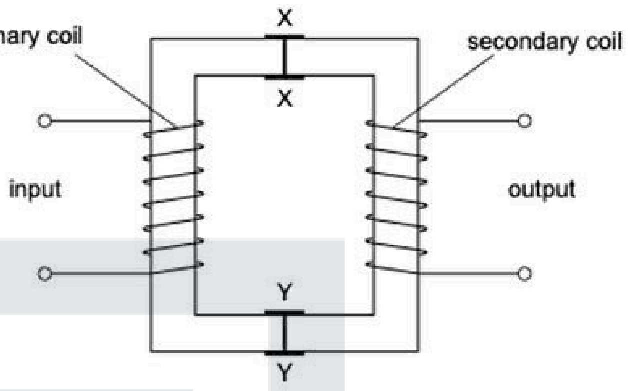


Fig. 10.1

(a) Use ideas of electromagnetic induction to explain how the input voltage is transformed into an output voltage. Use the three questions below to help you with your answer.

What happens in the primary coil?

....

....

....

....

What happens in the core?

....

....

What happens in the secondary coil?

....

....

.... [5]

(b) State what is needed to make the output voltage higher than the input voltage.

.... [1]

(c) The core of this transformer splits along XX and YY. Explain why the transformer would not work if the two halves of the core were separated by about 30 cm.

....

.... [1]

(d) A 100% efficient transformer is used to step up the voltage of a supply from 100 V to 200 V. A resistor is connected to the output. The current in the primary coil is 0.4 A.

Calculate the current in the secondary coil.

current = ... [2]

2	(a (i)	a.c. input causes constantly changing current through co magnetic field formed in or around coil constantly changing magnetic field	B1 B1 B1	[M2]
	(ii)	(changing) magnetic field transferred to secondary coil	B1	
	(iii)	(changing) magnetic field cuts secondary coil induces e.m.f.	B1 B1	[3]
	(b)	more turns on secondary (than on primary)	B1	[1]
	(c)	no transfer of magnetic field from primary to secondary	B1	[1]
	(d)	Vp.Ip = Vs. Is or 100 x 0.4 = 200 x Is Is = 0.2 A	C1 A1	[2] Total [9]

PYQ 2

Electromagnetic induction can be demonstrated using a solenoid, a magnet, a sensitive ammeter and connecting wire.

(a) In the space below, draw a labelled diagram of the apparatus set up to demonstrate electromagnetic induction. [2]

(b) State one way of using the apparatus to produce an induced current.

....

....[1]

(c) Explain why your method produces an induced current.

....

....

....[2]

(d) Without changing the apparatus, state what must be done to produce

(i) an induced current in the opposite direction to the original current,

....

....

(ii) a larger induced current.

....

....
[2]

[Total : 7]

(a)		Solenoid ends connected to meter, both labelled	B1	
		One magnet in correct position to enter / leave solenoid, labelled	B1	2
(b)		Push magnet into coil / pull out / move near end of coil	B1	1
(c)		(magnet has / produces) magnetic lines of force / magnetic field	B1	
		lines cut (coils of) solenoid / coils / wires	B1	2
(d)	(i)	Pull magnet out of coil / reverse effect to answer (b)	B1	
	(ii)	Move magnet faster or effect in (a) faster	B1	2
				[7]