Chapter 21. Electromagnetic Induction

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20.2 Power lines and Transformers

Dynamo发电机 national grid国家电网 power lines 输电线

4.5.1 Electromagnetic induction

Core

1 Know that a conductor moving across a magnetic field or a changing magnetic field linking with a conductor can induce an e.m.f. in the conductor

2 Describe an experiment to demonstrate electromagnetic induction

3 State the factors affecting the magnitude of an induced e.m.f.

Supplement

4 Know that the direction of an induced e.m.f. opposes the change causing it

5 State and use the relative directions of force, field and induced current

4.5.2 The a.c. generator

Core

Supplement

1 Describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings and brushes where needed

2 Sketch and interpret graphs of e.m.f. against time for simple a.c. generators and relate the position of the generator coil to the peaks, troughs and zeros of the e.m.f.

4.5.6 The transformer

Core

1 Describe the construction of a simple transformer with a soft iron core, as used for voltage transformations

2 Use the terms primary, secondary, step-up and step-down

3 Recall and use the equation

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

where p and s refer to primary and secondary

4 Describe the use of transformers in high-voltage transmission of electricity

5 State the advantages of high-voltage transmission

Supplement

6 Explain the principle of operation of a simple iron-cored transformer

7 Recall and use the equation for 100% efficiency in a transformer

$$I_p V_p = I_s V_s$$

where p and s refer to primary and secondary

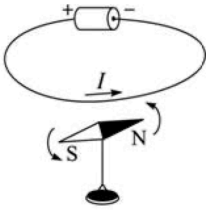
8 Recall and use the equation

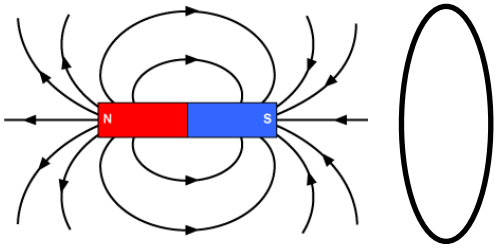
$$P = I^2 R$$

to explain why power losses in cables are smaller when the voltage is greater

20.1 Generating Electricity

Introduction





current (moving charge) => magnetic field

magnetic field(moving) => current?

The principles of electromagnetic induction

Electromagnetic induction: the production of an e.m.f. across an electrical conductor when conductor moves across magnetic field or magnetic flux through conductor changes

1. **Induction by (cutting field lines)**

What kind of motion can induce a current?

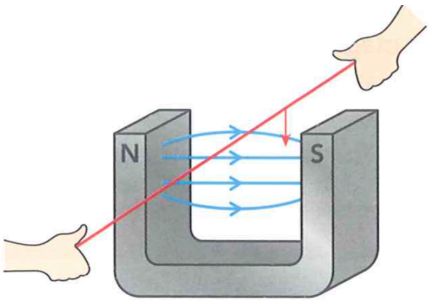
1. Keep magnet stationary, Move wire up btw poles => current flow in one direction
2. Keep magnet stationary, Move wire down btw poles => current flow in opposite direction
3. Keep wire stationary, move magnets up around wire => current flow as in situation 2
4. Keep wire stationary, move magnets down around wire => current flow as in situation 1

Cutting field lines → Current/e.m.f.

How to increase the induced current?

Use stronger magnet
Move wire/magnetic quickly relative to each other
Add more turns of wire

==>cutting more field lines

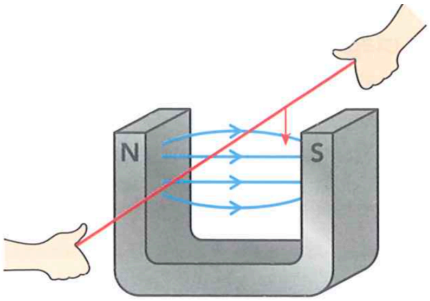


***Why cutting filed lines can induce a current/e.m.f.?

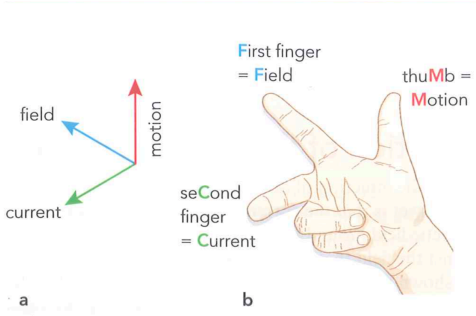
Movement of wire can be seen as movement of electrons in the wire, which causes a current, current in a magnetic field produces a force (ampere's force/lorentz's force) on the current/electrons, causing electron to move which is current

According to the explanation above can you draw the direction of current of following situation?

Electrons moving into the paper
Out of the paper



Determine direction of current (high potential -> low potential) => Fleming right hand rule



Exercise 21.0:

Fig. 9.1 shows a thin, straight rod XY placed in the magnetic field between the poles of a magnet. The wires from the ends of XY are connected to a centre-zero voltmeter.

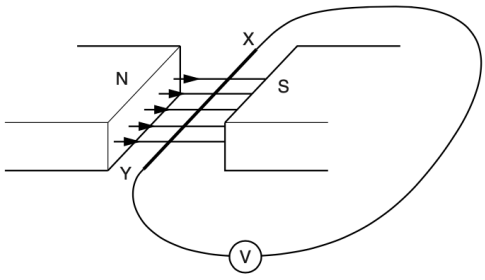


Fig. 9.1

(a) When XY is moved slowly upwards the needle of the voltmeter shows a small deflection.

(i) State how XY must be moved to produce a larger deflection in the opposite direction.

.....

..... [2]

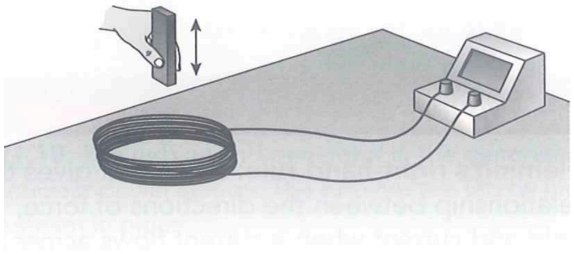
(ii) XY is now rotated about its central point by raising X and lowering Y. Explain why no deflection is observed.

.....

.....

..... [2]

2. Induction by (moving a magnet relative to a coil:)

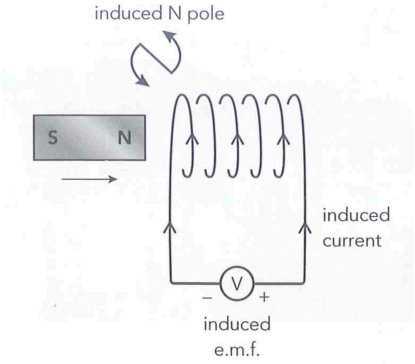


What kind of motion can induce a current?
Relative movement btw wire and magnet

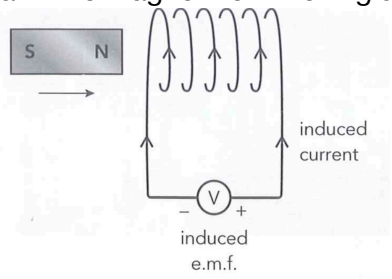
Increase the induced current e.m.f,?

Cutting field lines/ change flux/linkage inside coil → Current/e.m.f.

Determine direction of current => Lenz's law:
The direction of an induced current always opposes the change in the circuit or the magnetic field that produce it.



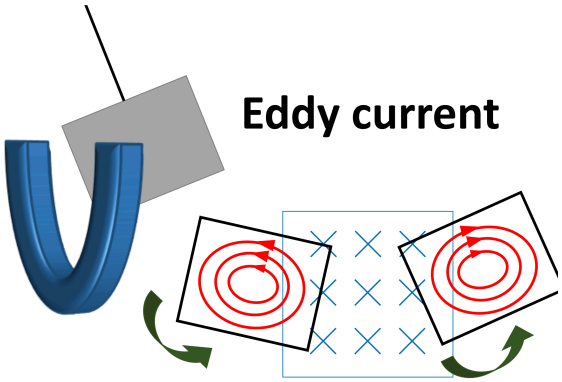
What if the magnet now moving away?



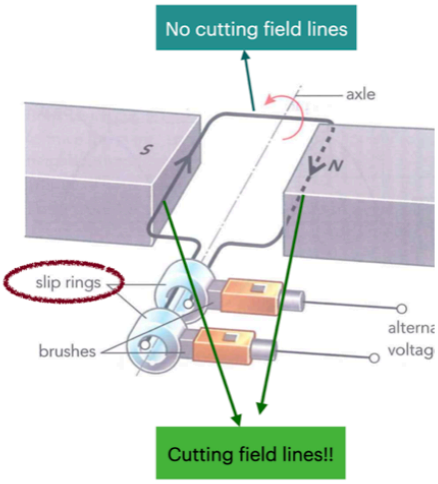
Understanding Lenz's law in the point of view of **Energy:** the generated current always opposes the change of magnetic field, a external force needed to make the B continue to do the change/ extra work need to be done => transfer to electrical energy in the generated current

Why does the movement btw magnet and coil induce a e.m.f or current?
When moving a coil closer to the magnet, the wire of the coil cuts the magnetic field lines of the magnet.
Or
The change of magnet field flux is changing

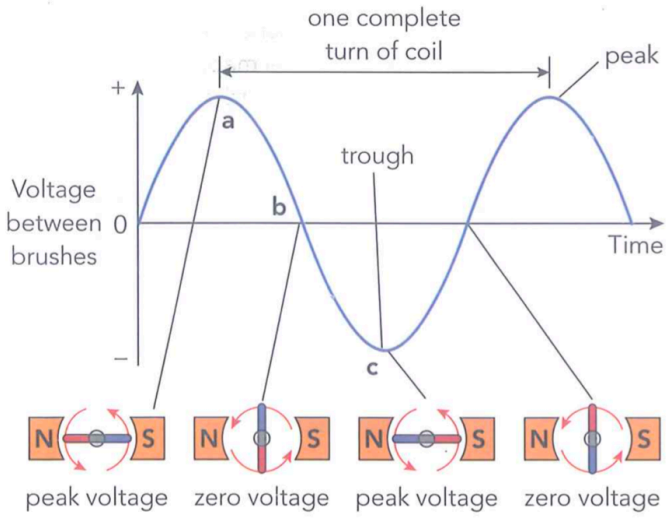
Eddy current



a.c. generator

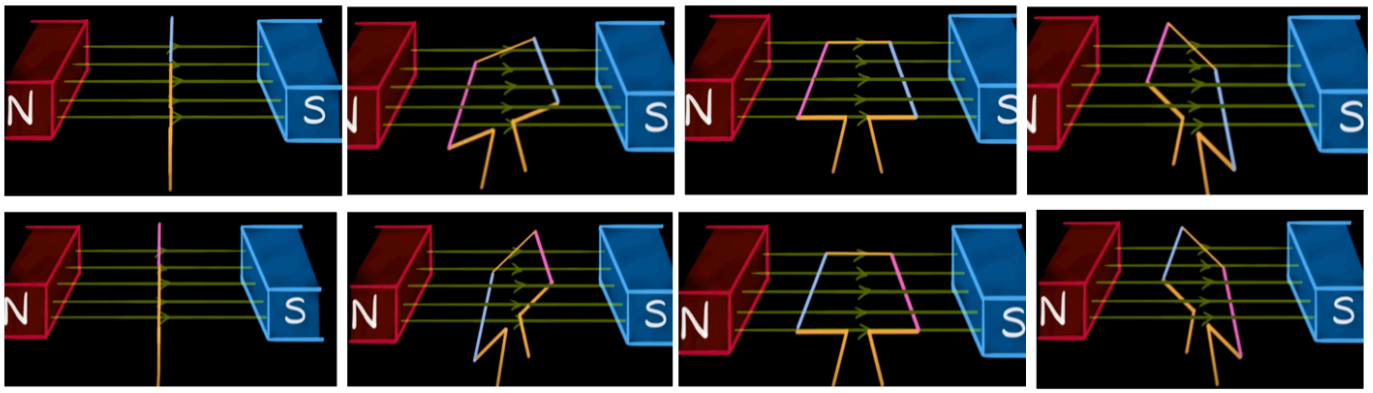


Why generator produces alternating current?



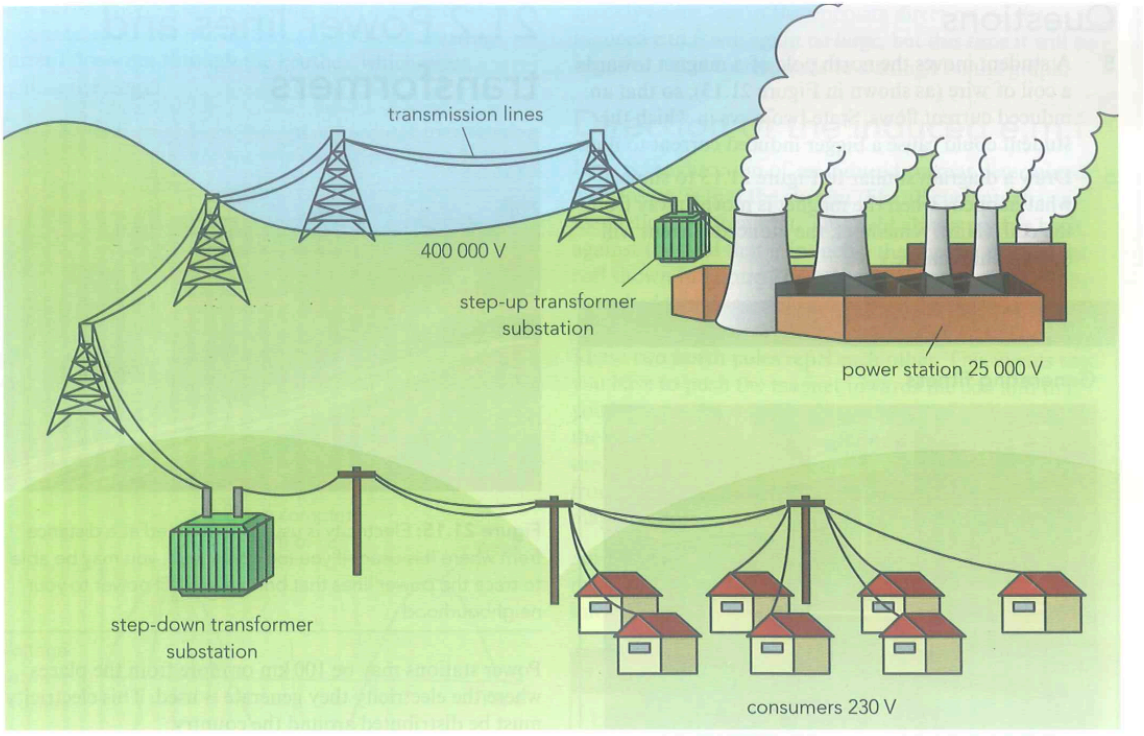
Increase generated voltage?

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



20.2 Power lines and Transformers

National grid:



Why use high voltage?

To reduce power loss by reducing current in transmission line;
(Reduce cost due to less metal use in cable)

Power loss:

$$P_{loss} = I^2 R$$

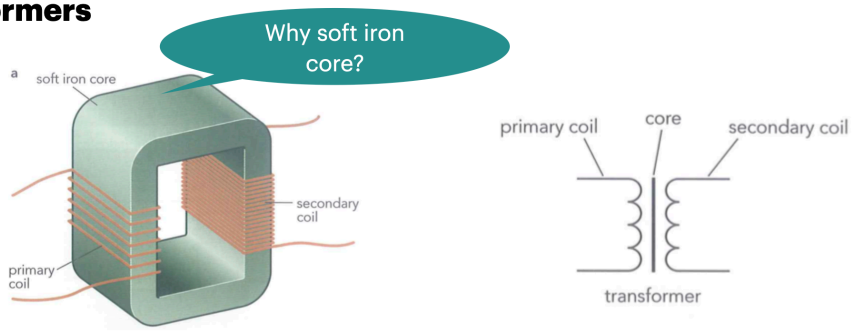
Current in transmission line: $I = P_{tot}/V$

Exercise 21.2:

A 20kW generator gives an output of 500V. This is transmitted to a workshop by cables with a resistance of 20 ohms. Calculate:
A. the power loss in the cables.
B. If the output is increased somehow to 20kV, calculate the power loss in this case.

How to get high/low voltage?

➔ **transformers**



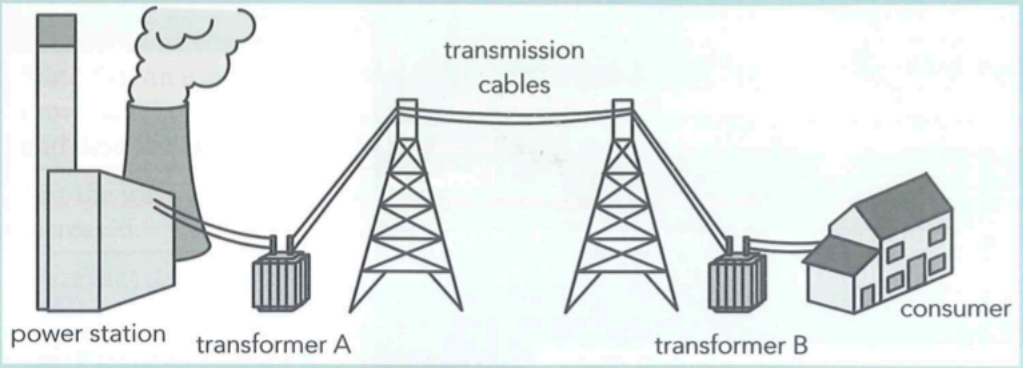
$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

Step-up transformer: A transformer which increases the voltage of an a.c. supply; $N_P < N_S$

Step-down transformer: A transformer which decreases the voltage of an a.c. supply; $N_P > N_S$

Exercise 21.3:

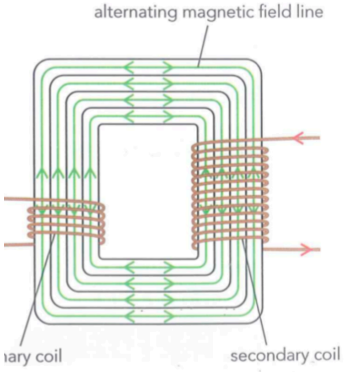
7 a Transformers are used in the national grid to change the voltage of the supply. For transformers A and B, state whether the transformer is step-up or step-down, and explain why the voltage change is necessary. [4]



b A transformer in the national grid has 800 turns on the primary coil and 16 000 on the secondary. The primary voltage is 25 kV. Calculate the secondary voltage. [2]

[Total: 6]

How transformers work?



Power in ideal transformer(100% efficiency):

$(P_{in} = P_{out})$

$V_P I_P = V_S I_S$

Possible reasons for efficiency less than 100%:

Magnetic field leakage

Heat in coils

Eddy current in core

Sound from coil/core

Only a.c. current can use transformer

1. **Alternating/changing current** in **primary coil** produces a **changing magnetic field**
2. This changing magnetic field transfers to **second coil** through **iron core**
3. Causes **changing magnetic flux** in second coil/ **cut** by secondary coil
4. Which **induces alternating current** in second coil

Why use soft iron core?

iron core is a soft magnetic material, so it can be easily magnetized; using it will make it easy to transfer magnetic field

Exercise 21.4:

A school power pack has an output voltage of 9 V. It is plugged in to the 230 V mains supply. The power pack contains a transformer. The output current of the power pack is 3 A. Calculate the current supplied to the primary coil of the transformer in the power pack. Assume there are no energy losses in the transformer.