4.5 Electromagnetic effects

Name: _____ Class: _____ Date: _____ **Total: 35 marks**

0 Vocabulary

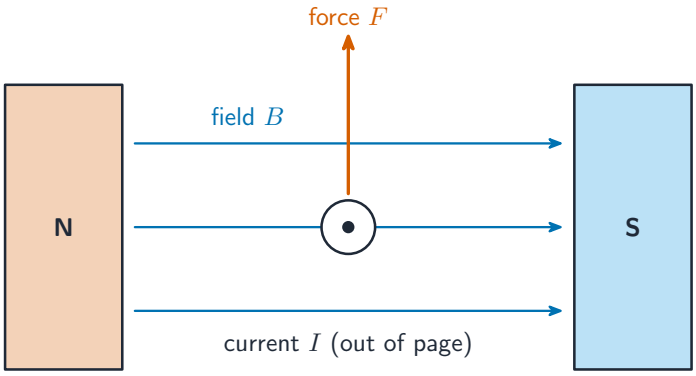
Word	Example
soft iron /sɒft 'aɪən/ 软铁	**Soft iron** is easy to magnetise and loses its magnetism quickly. **软铁**容易被磁化，也会很快失去磁性。
conductor /kən'dʌktə/ 导体	Copper is a good **conductor** of electricity. 铜是良好的电**导体**。
coulomb /'ku:lɒm/ 库仑	The **coulomb** is the unit of charge. **库仑**是电荷量的单位。
ampere /'æmpeə/ 安培	The **ampere** is the unit of electric current. **安培**是电流的单位。
direct current 直流电 /daɪ'rekt 'kʌrənt/	A battery gives **direct current**. 电池提供**直流电**。
volt /vəʊlt/ 伏特	The **volt** is the unit of potential difference. **伏特**是电势差的单位。
electrical power 电功率 /ɪ'lektrɪkl 'paʊə/	**Electrical power** is current times voltage. **电功率**等于电流乘以电压。
motor /'məʊtə/ 电动机	An electric **motor** turns the fan. **电动机**带动风扇转动。
transformer /træns'fɔ:mə/ 变压器	A **transformer** changes the voltage. **变压器**改变电压。
coil /kɔɪl/ 线圈	Wrap the wire into a **coil**. 将导线绕成**线圈**。
electromagnetic induction 电磁感应 /ɪˌlektrəʊməg'netɪk ɪn'dʌkʃn/	Moving a magnet in a coil causes **electromagnetic induction**. 在线圈中移动磁铁会产生**电磁感应**。
Fleming's right-hand rule 弗莱明右手定则 /'flemɪŋz raɪt hænd ru:l/	**Fleming's right-hand rule** gives the direction of the induced current. **弗莱明右手定则**可以确定感应电流的方向。

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Word	Example
a.c. generator 交流发电机 /ˌeɪ ˈsiː ˈdʒenəreɪtə/	An **a.c. generator** gives a current that changes direction. **交流发电机**产生方向不断改变的电流。
slip rings /slɪp rɪŋz/ 滑环	**Slip rings** connect the spinning coil to the outside wires. **滑环**将旋转的线圈连接到外部导线。
brushes /ˈbrʌʃɪz/ 电刷	Carbon **brushes** press against the slip rings. 碳制**电刷**紧贴滑环。
Fleming's left-hand rule 弗莱明左手定则 /ˈflemɪŋz left hænd ruːl/	Use **Fleming's left-hand rule** to find the force on the wire. 用**弗莱明左手定则**确定导线受到的力。
deflect /dɪˈflekt/ 偏转	A magnet can **deflect** a beam of electrons. 磁体可以使电子束**偏转**。
turning effect /ˈtɜːnɪŋ ɪˈfekt/ 转动效应	A longer spanner gives a bigger **turning effect**. 更长的扳手会产生更大的**转动效应**。
d.c. motor /ˌdiː ˈsiː ˈməʊtə/ 直流电动机	A **d.c. motor** spins a coil in a magnetic field. **直流电动机**使线圈在磁场中旋转。
split-ring commutator 换向器 /splɪt rɪŋ ˈkɒmjuːteɪtə/	The **split-ring commutator** reverses the current every half-turn. **换向器**每转半圈就改变一次电流方向。
soft-iron core /sɒft ˈaɪən kɔː/ 软铁芯	A **soft-iron core** makes an electromagnet stronger. **软铁芯**能增强电磁铁的磁性。
primary coil /ˈpraɪməri kɔɪl/ 原线圈	The **primary coil** is joined to the input supply. **原线圈**与输入电源相连。
secondary coil 副线圈 /ˈsekəndəri kɔɪl/	The **secondary coil** gives the output voltage. **副线圈**提供输出电压。
step-up /step ʌp/ 升压	A **step-up** transformer raises the voltage. **升压**变压器使电压升高。
step-down /step daʊn/ 降压	A **step-down** transformer lowers the voltage. **降压**变压器使电压降低。
high-voltage transmission 高压输电 /haɪ ˈvəʊltɪdʒ trænˈsmɪʃn/	**High-voltage transmission** wastes less energy in the cables. **高压输电**能减少电缆中的能量损失。

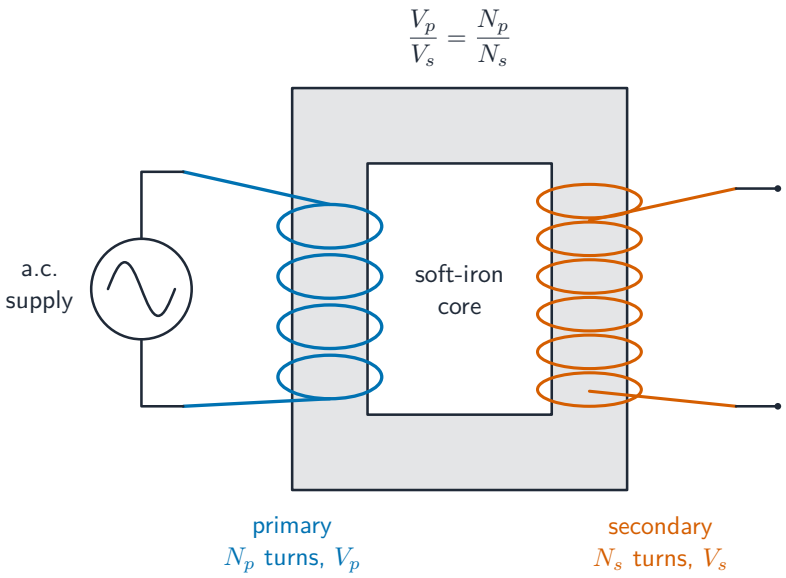
1 Key knowledge and worked examples

■ Motor effect & transformer



F, B and I are all at $90°$ (Fleming's left-hand rule)

A current-carrying wire in a magnetic field feels a force; reverse the current or field to reverse the force



$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$ – *the voltage ratio equals the turns ratio*

$N_p = 1200$, $N_s = 100$, $V_p = 240$ **V:** $V_s = 240 \times \dfrac{100}{1200} = 20$ V (step-down).

■ Induction, the generator and the transformer

An e.m.f. is **induced** 感应 whenever a conductor cuts across a magnetic field or the field through a coil changes. The induced e.m.f. is larger with a **stronger magnet**, a **faster movement**, or **more turns** on the coil, and it always opposes the change causing it. Find the direction of the induced current with **Fleming's right-hand**

rule 弗莱明右手定则 (thumb = motion, first finger = field, second finger = current); for the force on a current-carrying wire use the left-hand rule instead.

In an **a.c. generator** 交流发电机 a coil spins in a magnetic field, and **slip rings** 滑环 with brushes carry the current out. The e.m.f. is largest when the coil is flat, because its sides then cut the field fastest, and zero when the coil is upright, because its sides move along the field. So the e.m.f.-time graph is a sine curve: peak, zero, opposite peak, zero for each turn.

A **transformer** 变压器 has a **primary coil** 原线圈 and a **secondary coil** 副线圈 wound on a laminated **soft-iron core** 软铁芯. The a.c. in the primary makes a changing field in the core; the core carries that field to the secondary, where it induces an alternating e.m.f. It works only on a.c., because a steady current makes no change of field.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \qquad I_p V_p = I_s V_s \text{ (at 100\% efficiency)}$$

Worked example (transmission). A power station sends 2.0 MW along cables of total resistance 5.0 Ω. Compare the loss at 10 kV and at 400 kV.

1. At 10 kV: $I = \dfrac{P}{V} = \dfrac{2.0 \times 10^6}{10\,000} = 200$ A, so the loss is $I^2R = 200^2 \times 5.0 = 200\,000$ W, a tenth of the power sent.
2. At 400 kV: $I = \dfrac{2.0 \times 10^6}{400\,000} = 5.0$ A, so the loss is $5.0^2 \times 5.0 = 125$ W.

That is why a step-up transformer raises the voltage for transmission and a step-down transformer lowers it again for homes: the same power at a higher voltage needs a smaller current, and the heating loss I^2R falls with the square of the current.

2 Practice

2.1 State two ways to increase the force on a current-carrying wire in a magnetic field. [2]

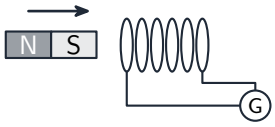


2.2 State what a step-up transformer does to the voltage. [1]

step-up transformer

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2.3 State three ways to increase the e.m.f. induced in a coil by a moving magnet. [3]



2.4 State the two parts that carry the current out of a spinning generator coil, and state where in the turn the e.m.f. is zero. [2]



2.5 Describe the construction of a simple transformer. [3]

transformer

3 Exam-style questions

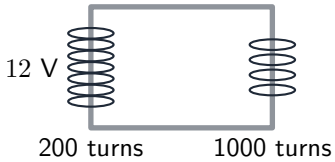
3.1 Reversing the current in a wire in a magnetic field: [1]



- **A** removes the force
- **B** reverses the force
- **C** doubles the force
- **D** has no effect

3.2 A transformer has 200 turns on the primary and 1000 turns on the secondary. The primary voltage is 12 V.

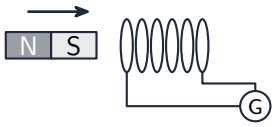
(a) Find the secondary voltage. [3]



(b) State whether this is a step-up or step-down transformer. [1]

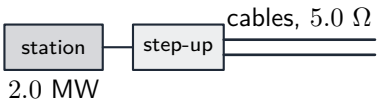
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3.3 Describe how an e.m.f. is induced when a magnet is moved into a coil, and state two ways to make the induced e.m.f. larger. [3]



3.4 A power station generates 2.0 MW of electrical power, transmitted through cables of total resistance 5.0 Ω.

(a) A step-up transformer raises the voltage to 400 kV. Calculate the current in the cables. [2]



(b) Calculate the power wasted as heat in the cables. [2]

(c) Explain why much more power would be wasted if the voltage were only 10 kV. [2]

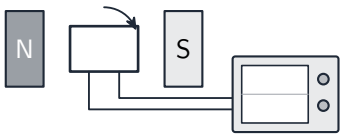
(d) The step-up transformer has 500 turns on its primary and the generator supplies 20 kV. Calculate the number of turns on the secondary. [3]

(e) Explain why a transformer cannot be used with a direct current. [1]

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3.5 A student spins a coil between the poles of a magnet and connects it to an oscilloscope.

(a) Sketch the e.m.f. against time for two complete turns of the coil. [2]



(b) Explain, by referring to the position of the coil, why the e.m.f. is zero twice in each turn. [2]

(c) The student spins the coil faster. State two changes to the trace. [2]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- increase the current
- use a stronger magnetic field

2.2

- it increases (steps up) the voltage

2.3

- any three of: use a stronger magnet; move the magnet or coil faster; use more turns on the coil; use a coil of larger area

2.4

- slip rings and carbon brushes
- the e.m.f. is zero when the coil is upright, so its sides move along the field instead of cutting across it

2.5

- two coils, a primary and a secondary
- wound on a soft-iron core
- that links the coils magnetically but is not electrically connected to them

3.1 B

- reversing the current reverses the direction of the force

3.2

(a) $V_\text{p}/V_\text{s} = N_\text{p}/N_\text{s}$

$$\frac{12\ \text{V}}{V_\text{s}} = \frac{200}{1000} \Rightarrow V_\text{s} = (12\ \text{V}) \times 5 = \mathbf{60}\ \text{V}$$

(b) step-up (more turns on the secondary)

3.3

- moving the magnet changes the magnetic field through the coil, which induces an e.m.f.
- make it larger by moving the magnet faster
- use a stronger magnet or more turns on the coil

3.4

(a) $I = P/V$

$$I = \frac{2.0 \times 10^6\ \text{W}}{400\,000\ \text{V}} = \mathbf{5.0}\ \text{A}$$

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(b) $P = I^2R$

$$P = (5.0\text{ A})^2(5.0\ \Omega) = \mathbf{125}\text{ W}$$

(c) at 10 kV the current would be 200 A, forty times larger

- the loss is I^2R, so it would be about 1600 times larger, roughly 200 kW

(d) $V_\text{p}/V_\text{s} = N_\text{p}/N_\text{s}$

$$\frac{V_\text{p}}{V_\text{s}} = \frac{N_\text{p}}{N_\text{s}}: \quad \frac{20\,000\text{ V}}{400\,000\text{ V}} = \frac{500}{N_\text{s}} \Rightarrow N_\text{s} = \mathbf{10\,000}$$

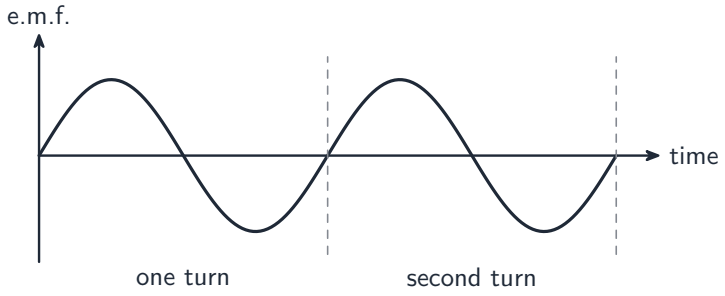
turns

(e) a direct current gives a steady magnetic field in the core, and a field that does not change induces no e.m.f. in the secondary

3.5

(a) a sine-shaped curve

- crossing zero twice per turn, with two complete cycles shown



(b) the e.m.f. is zero when the coil is upright

- because its sides are then moving parallel to the field lines and cut none of them

(c) the peaks are higher

- and the cycles are closer together, so the frequency is higher

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