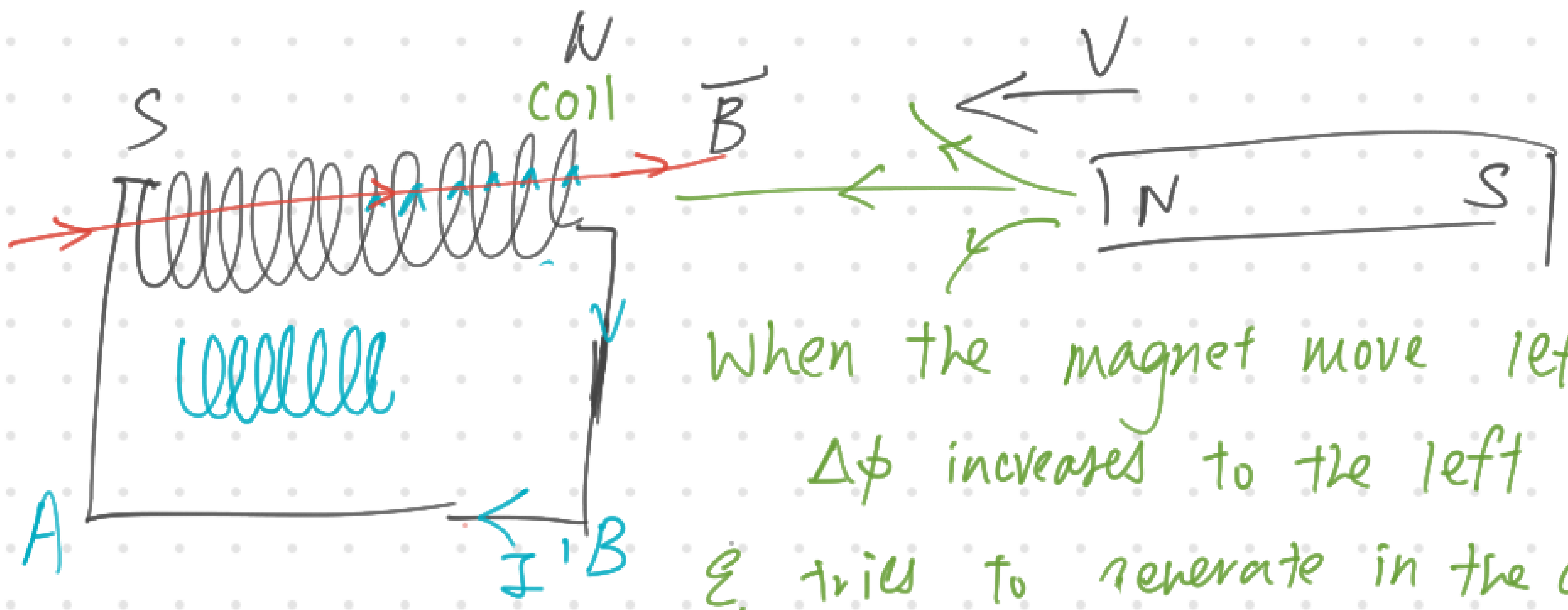
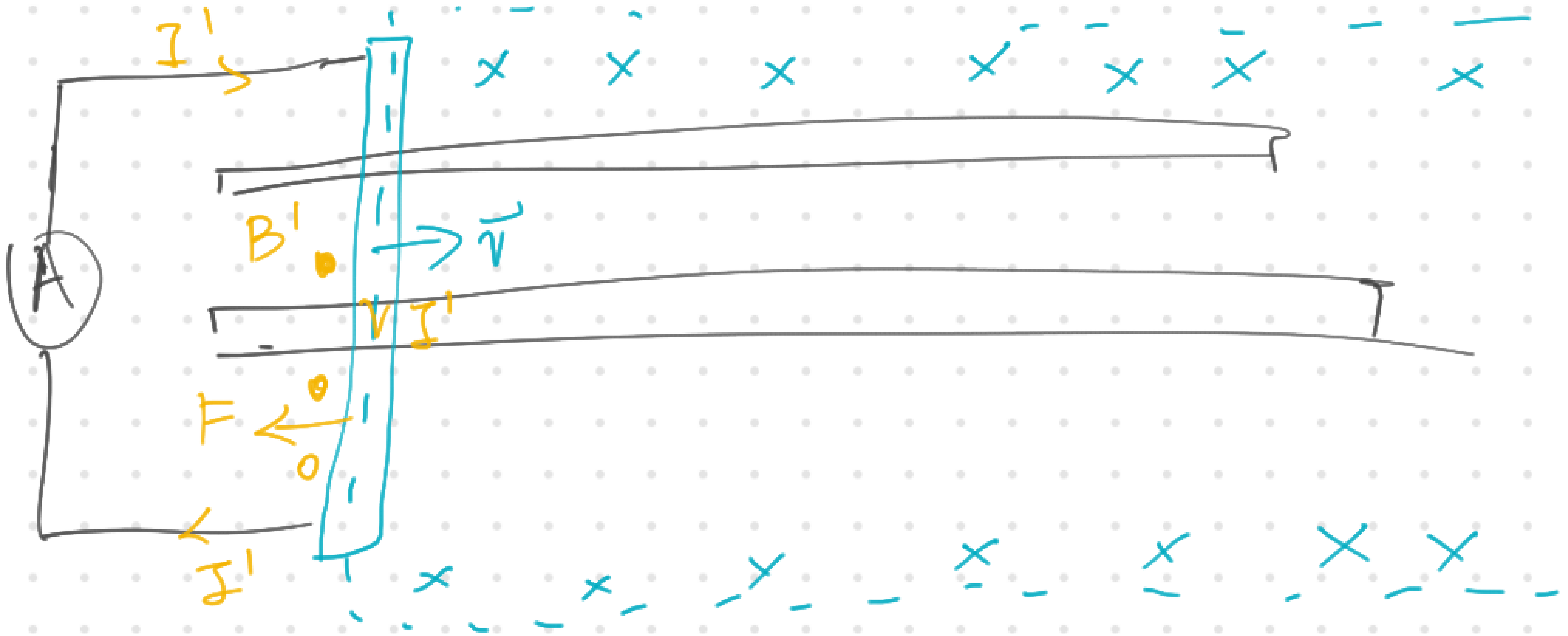
When is there induced current?

- There is a $\Delta\phi$ through the coil.
- By Lenz law, there is an induced emf in the coil to oppose $\Delta\phi$.
- Closed circuit, current flows

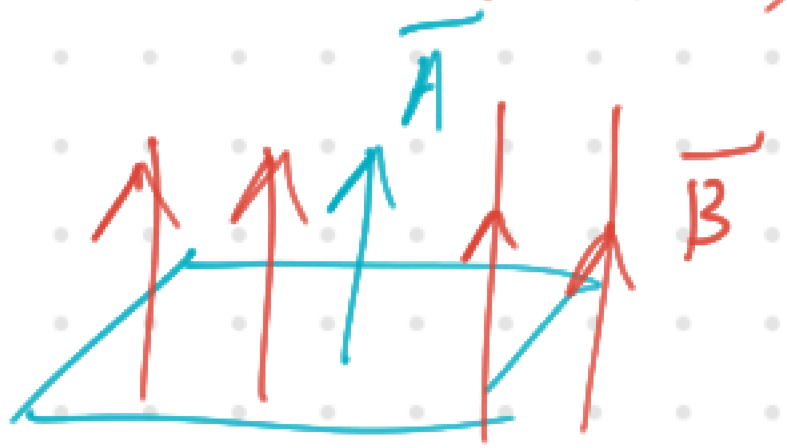


When the magnet move left
$\Delta\phi$ increases to the left
$\mathcal{E}$ tries to generate in the coil to the right



When the goes right, ϕ ~~ϕ~~ through the loop increases.

$$\phi = BA \ (Tm^2 / Wb) \qquad \phi = \vec{B} \cdot \vec{A}$$



$$= \phi = BA$$

$$B = Wb\,m^{-2} = T$$

$$\phi = BA\cos 45^\circ$$
$$= B \cdot \vec{A}$$

$$\mathcal{E} = -\frac{d\phi}{dt}$$

5 A bar magnet is suspended vertically from the free end of a helical spring, as shown in Fig. 5.1.

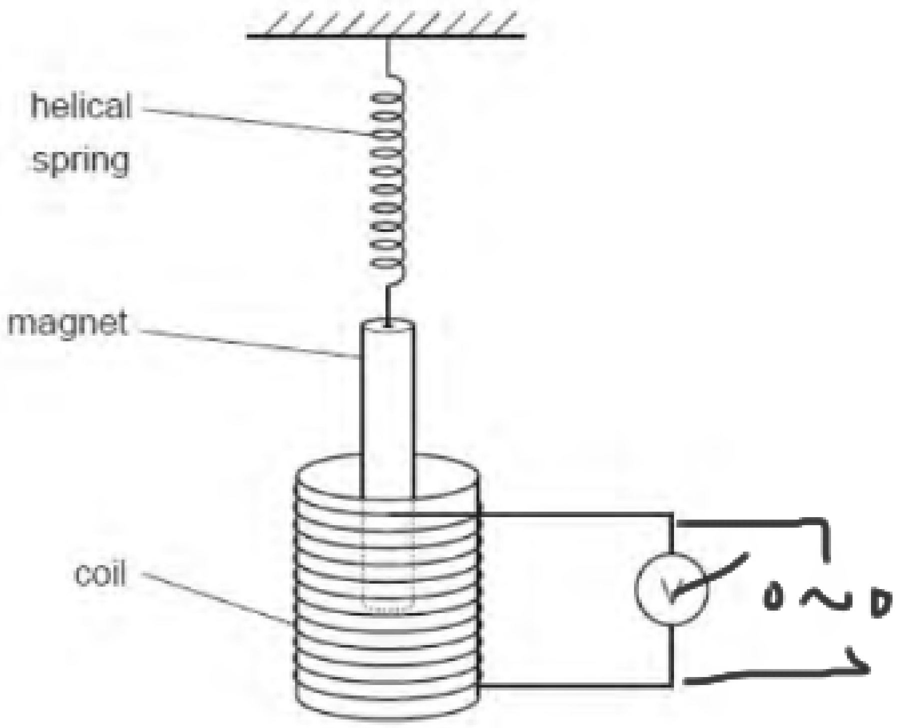


Fig. 5.1

One pole of the magnet is situated in a coil. The coil is connected in series with a high-resistance voltmeter.
The magnet is displaced vertically and then released.
The variation with time t of the reading V of the voltmeter is shown in Fig. 5.2.

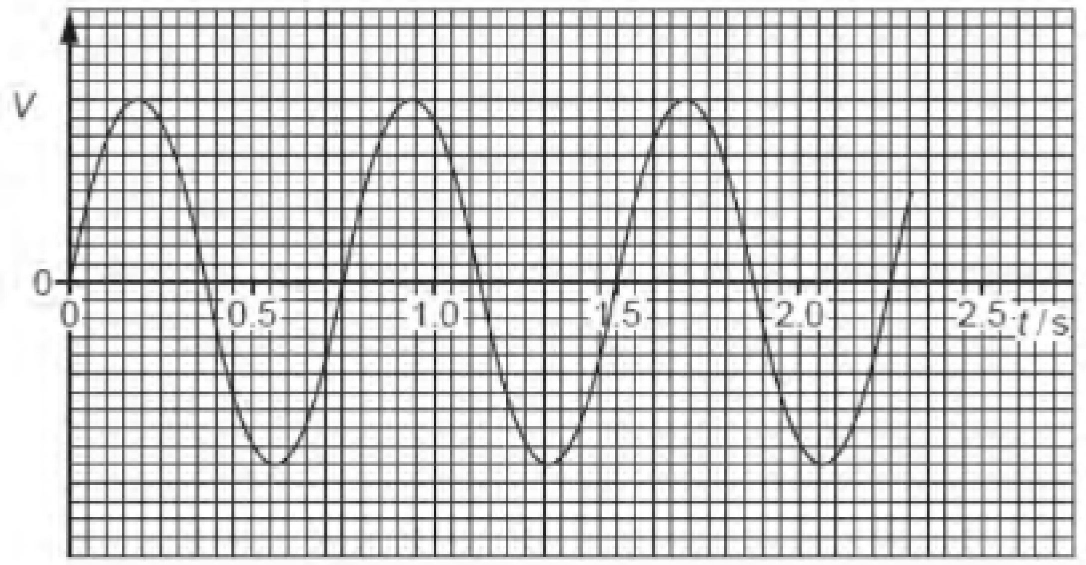


Fig. 5.2

(a) (i) State Faraday's law of electromagnetic induction.

emf induced equal the rate of change of magnetic flux, The direction of emf induced will oppose $\Delta\phi$ [2]

(ii) Use Faraday's law to explain why

1. there is a reading on the voltmeter,

when the magnet moves, the coil experience $\Delta\phi$, $\rightarrow \varepsilon = -\frac{d\phi}{dt}$ # [1]

(ii) Use Faraday's law to explain why

1. there is a reading on the voltmeter,

[1]

2. this reading varies in magnitude,

The magnet oscillates at a varying speed, therefore the rate of change of magnetic flux experienced by the coil is different at different times. [1]

3. the reading has both positive and negative values.

The coil travels both into and out of the coil, so the coil experiences both positive and negative change in magnetic flux, so emf induced has both positive and negative values. [1]

(b) Use Fig. 5.2 to determine the frequency f_0 of the oscillations of the magnet.

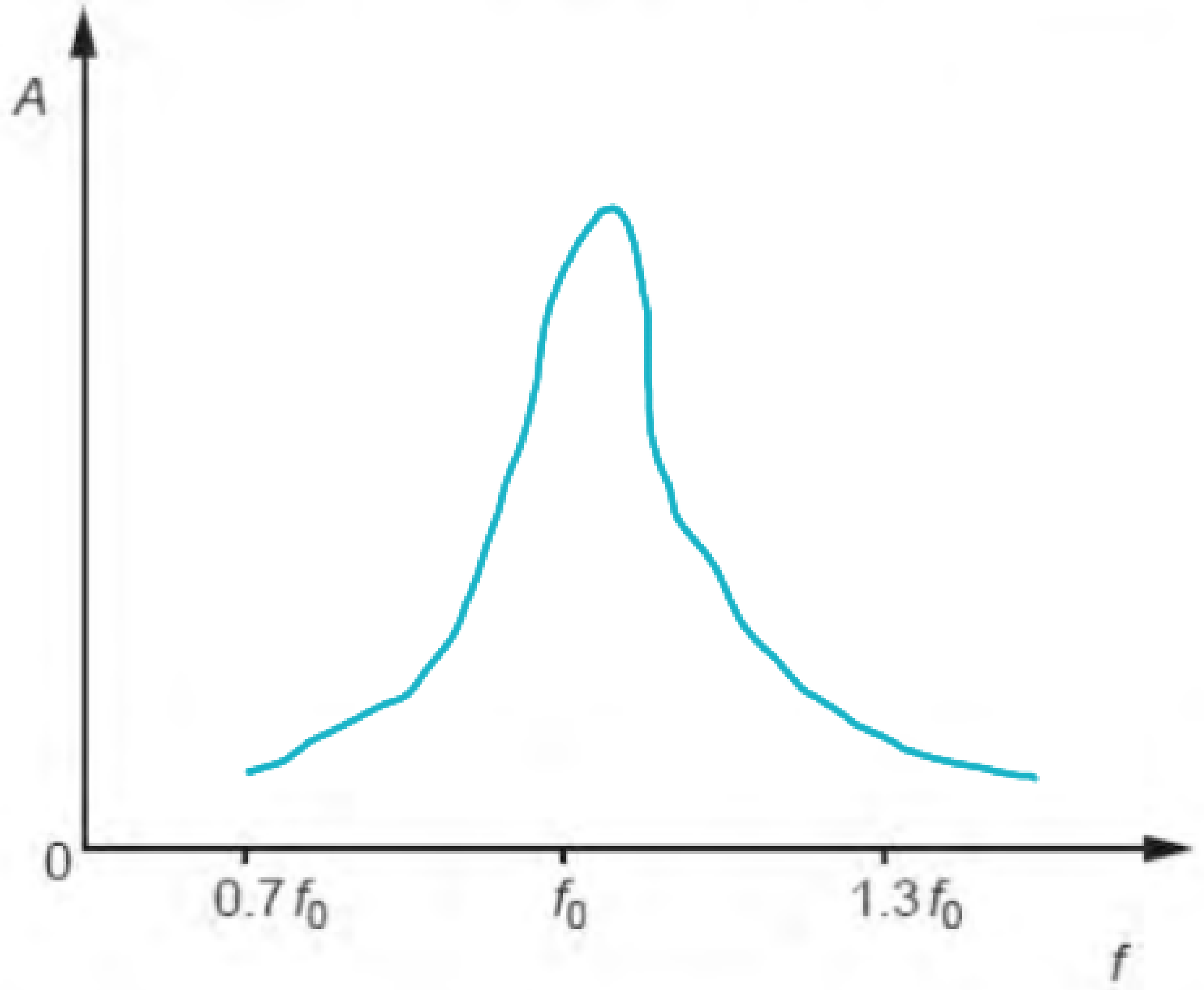
$T = 0.75\,s$

$f_0 = \frac{1}{T}$

$= 1,33\,Hz$

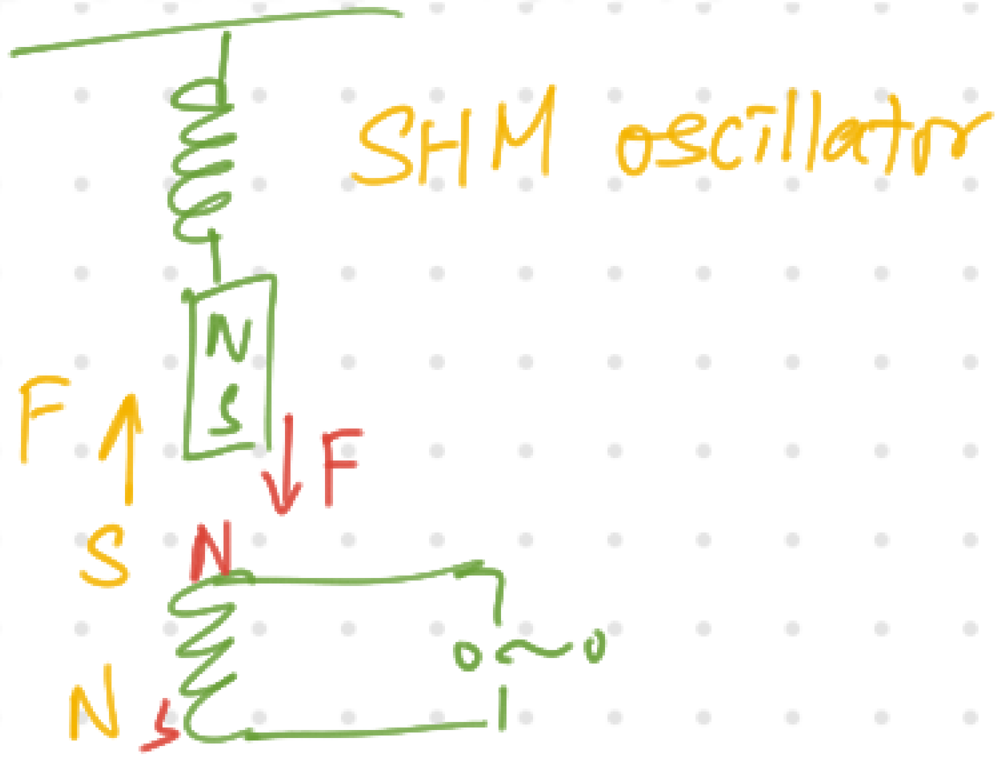
f_0 = ... Hz [2]

(c) The magnet is now brought to rest and the voltmeter is replaced by a variable frequency alternating current supply that produces a constant r.m.s. current in the coil.
The frequency of the supply is gradually increased from $0.7f_0$ to $1.3f_0$, where f_0 is the frequency calculated in **(b)**.
On the axes of Fig. 5.3, sketch a graph to show the variation with frequency f of the amplitude A of the new oscillations of the bar magnet.



[2]

Fig. 5.3



(d) (i) Name the phenomenon illustrated on your completed graph of Fig. 5.3.

Resonance .... [1]

(ii) State one situation where the phenomenon named in **(i)** is useful.

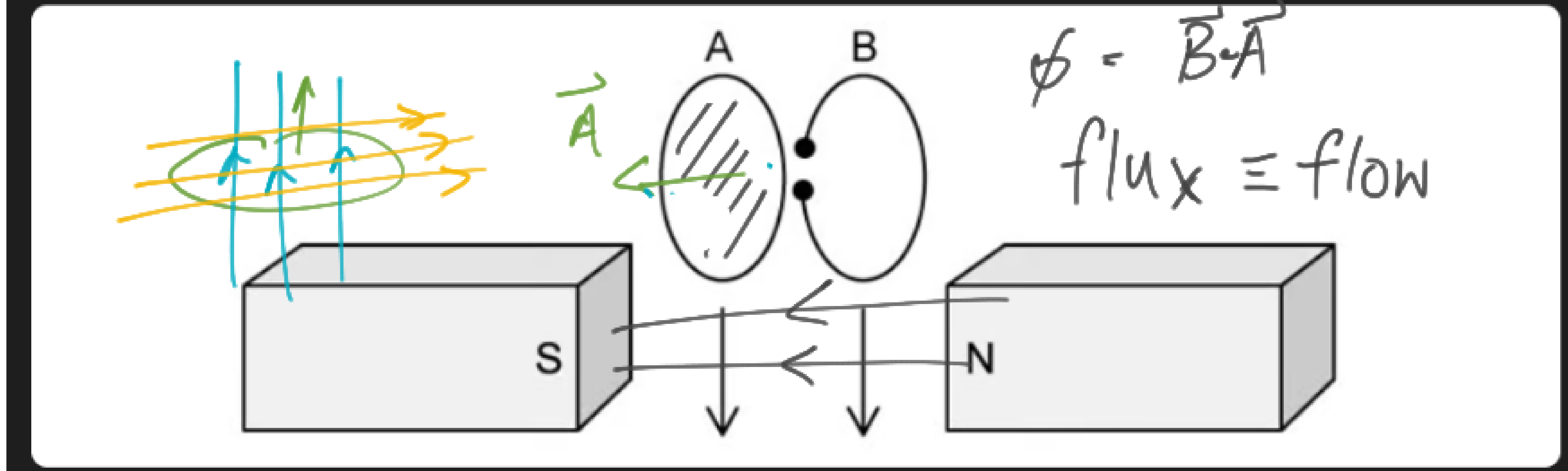
....

.... [1]

As part of an introductory lesson to electromagnetic induction, a physics teacher plans a series of experiments for her students to carry out.

In experiment 1, two metal rings **A** and **B** are dropped from the same height between two magnets, as shown in **Figure 1**. They are identical, apart from a small slit cut in **B** as shown.

Figure 1



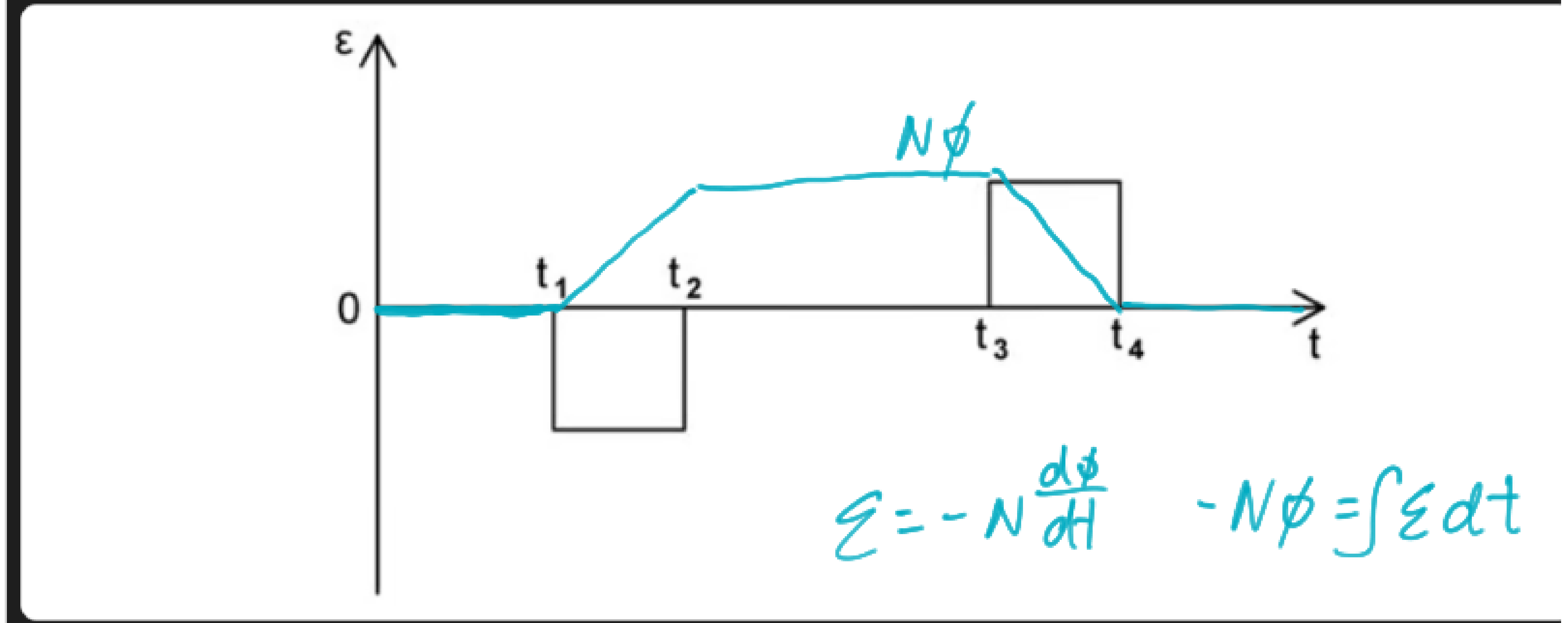
The teacher asks her students to observe the motion of the two metal rings as they fall between the magnets.

Describe and explain the motion of **A** and **B** as they fall between the magnets.

You may wish to include sketches in your answer.

Experiment 2 is designed as a thought experiment. The physics teacher displays a sketch of the variation of induced emf ε in a coil with time. This is shown in **Figure 2a**.

Figure 2a



The students are asked to use discuss the properties of the graph shown in **Figure 2** to determine how it might be reproduced.

Use the axes provided in **Figure 2b** to sketch a graph of the magnetic flux linkage $N\phi$ through the coil between $t = 0$ to $t = t_4$.

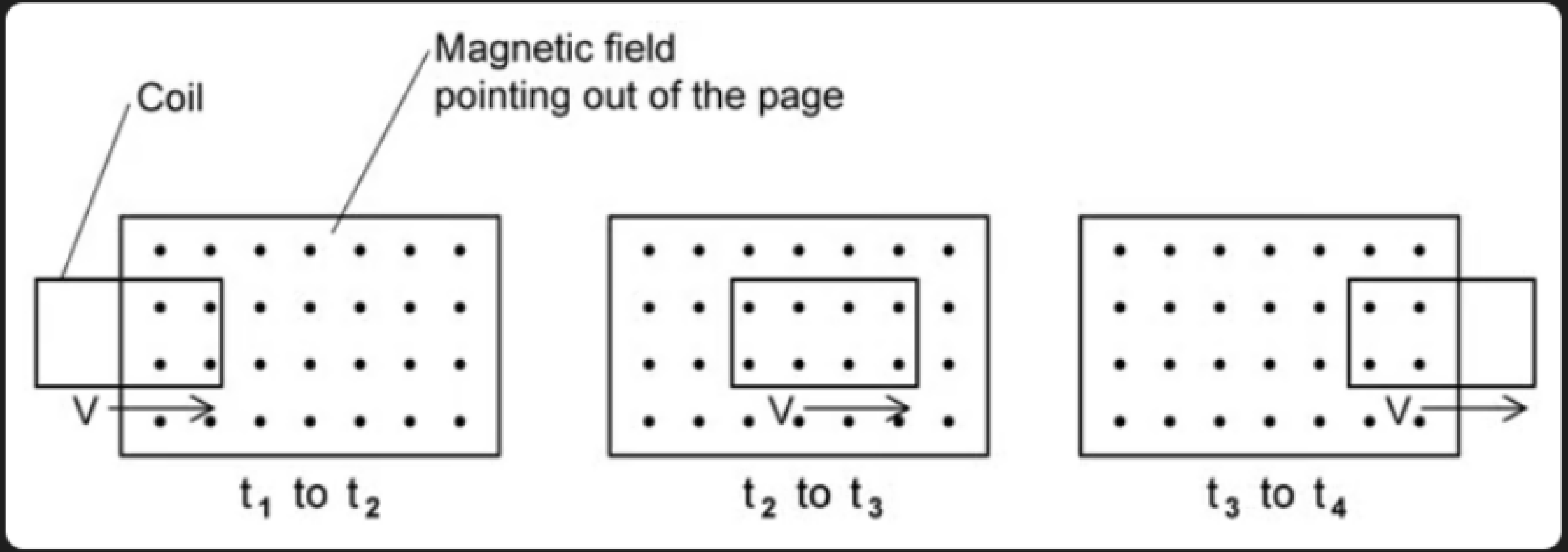
Both A & B experience gravitation force → a ↓

As A passes through the 2 magnets, it experiences $\Delta\phi$. By Lenz law, there is an induced emf which opposes $\Delta\phi$. Since A is a closed loop, an induced current flows in A and generates an upward ~~Fb~~ ~~mag~~ force. A drops slower.

B experiences same $\Delta\phi$. But B is not a closed loop. Even if there's induced $\mathcal{E}$, no I flows in B so it cannot generate an upward force like A
↳ B drops faster

The physics teacher reveals that the graph shown in **Figure 2a** was produced by a coil moving at a constant speed into and out of a uniform magnetic field. They draw a sketch of this motion in three stages, as shown in **Figure 3**:

Figure 3



A student disagrees, saying that while the coil is moving across the magnetic field between t_2 to t_3 as shown in **Figure 3**, magnetic field lines are being cut, so there must be an induced emf in the coil.

Suggest how the teacher should explain what happens within the coil during time t_2 to t_3 to improve the student's understanding.

when the the loop is passing through a uniform $\vec{B}$ in $t_2 \to t_3$, the magnetic flux of the loop remain constant.

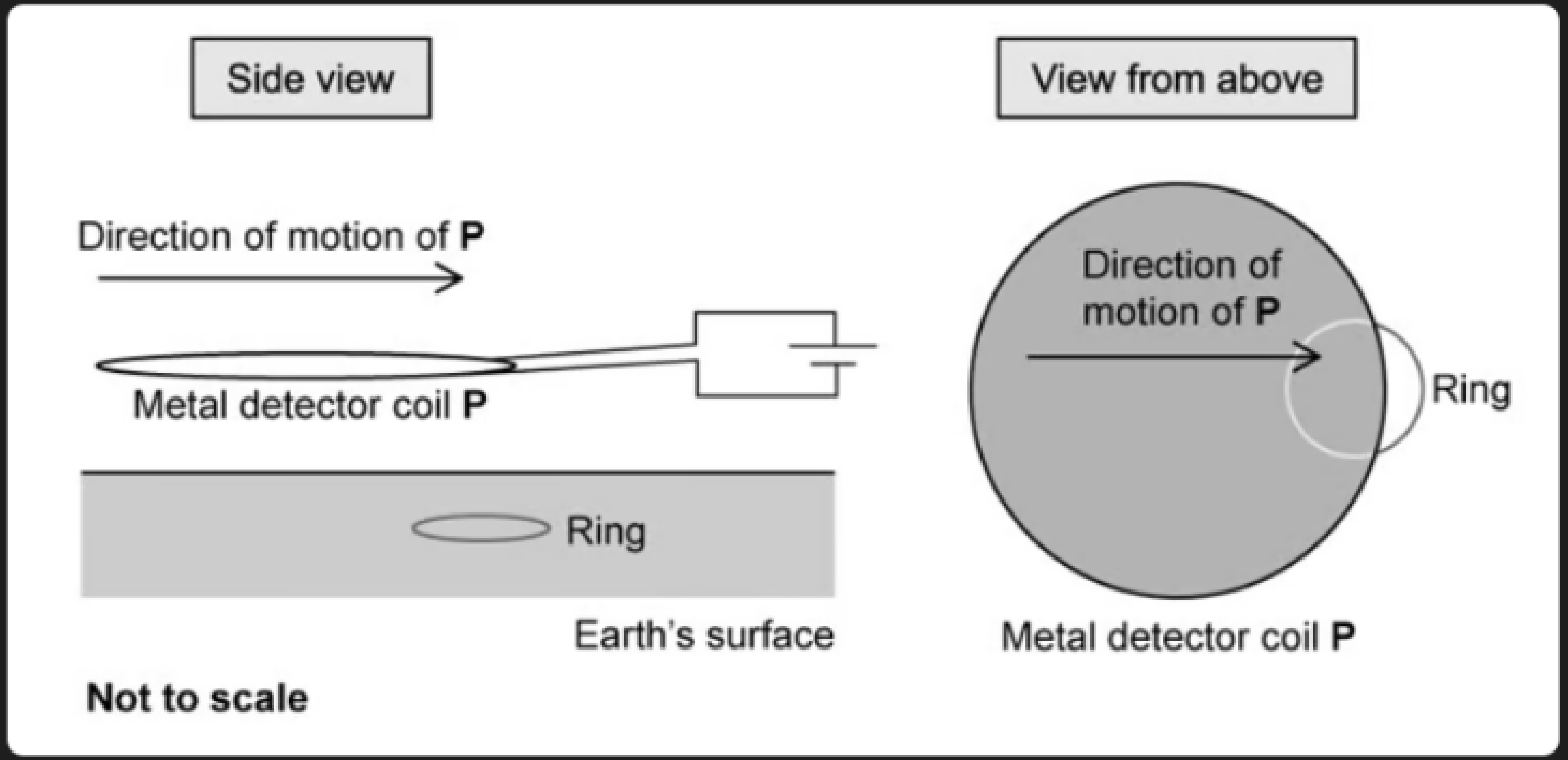
$\frac{d\phi}{dt} = 0$, by Faraday's law /

$\varepsilon = -N\frac{d\phi}{dt} \Rightarrow \varepsilon = 0$

A metal detector is moved horizontally at a constant speed just above the Earth's surface to search for buried metal objects

Figure 1 shows the coil **P** of a metal detector moving over a circular ring of diameter 3.0 cm and made from a single band of metal. The planes of the coil and the ring are both horizontal.

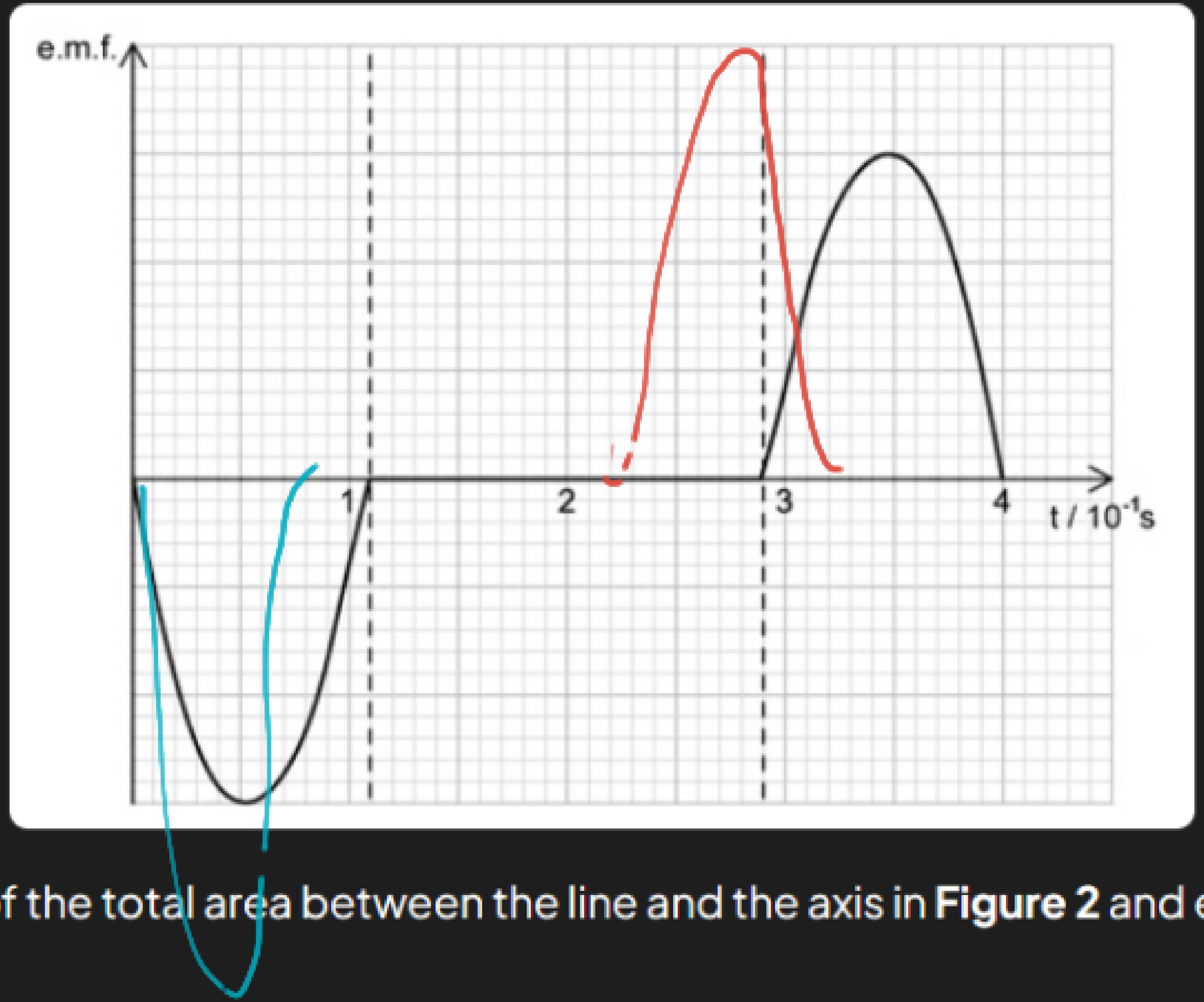
Figure 1



In this metal detector, **P** carries a direct current so that the magnetic flux produced by **P** does not vary. The ring is just below the surface, so the flux is perpendicular to the plane of the ring. The field is negligible outside the shaded region of **P**.

Figure 2 shows how the induced emf in the ring varies with time when **P** is moving at a constant velocity.

Figure 2



State the value of the total area between the line and the axis in **Figure 2** and explain what it represents.

Ch Magnetic flux linkage through the ring

3b

4 marks

Calculate the magnitude of the flux through the ring when the field strength due to **P** is 1.3 T.

Give an appropriate unit with your answer.

$\phi = BA \cos \theta$

$\phi = (1.3)\, \pi\, (0.015)^2 = 9.19 \cdot 10^{-4}$ Wb

3c

2 marks

Describe and explain the effect on the emf induced in the ring if the velocity at which **P** moves increases.

ε amplitude increases

$\because$ v increases $\left(\frac{d\phi}{dt}\right)$

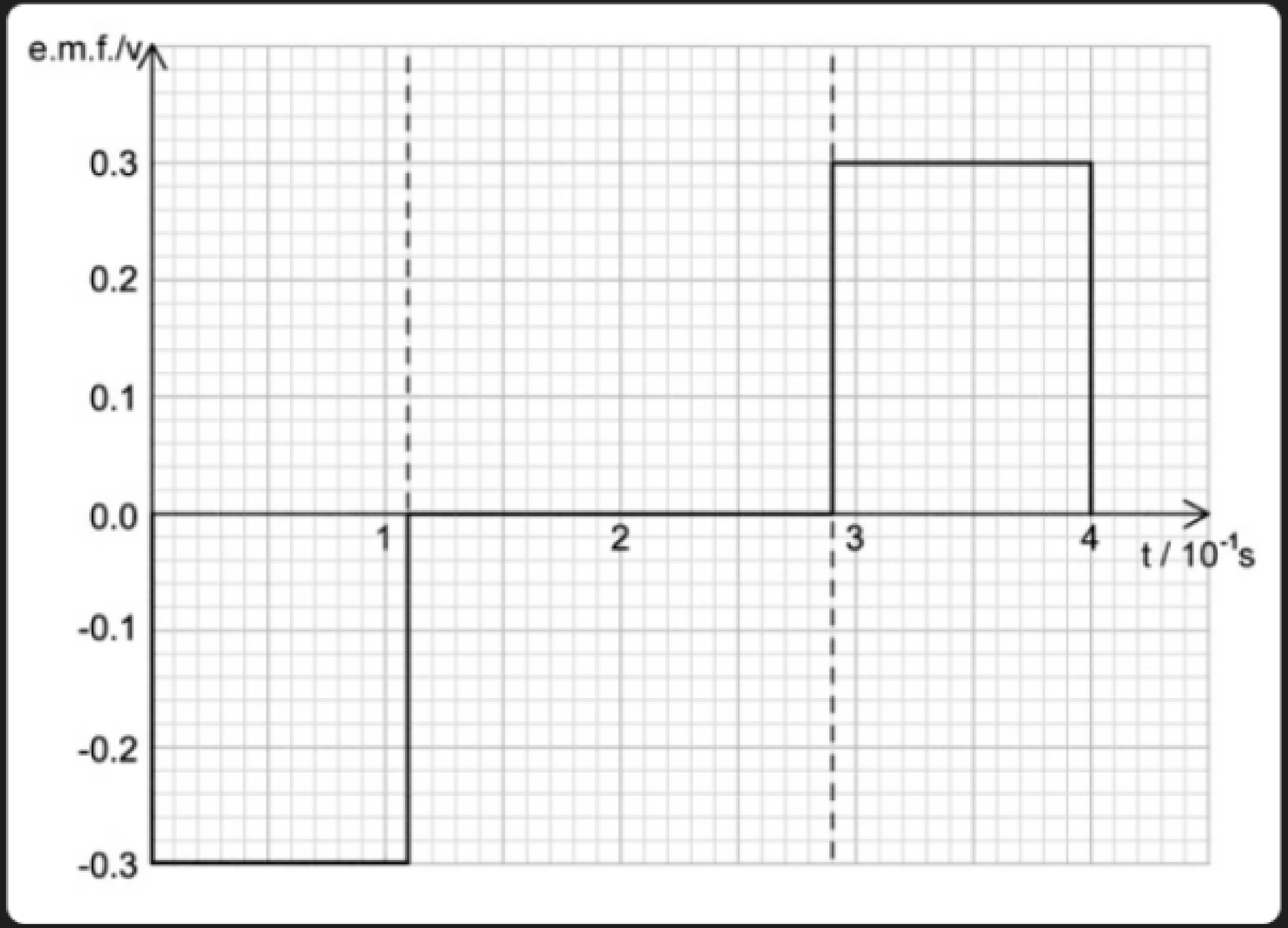
$\therefore$ Rate of change of ϕ increases

• ε increase (by Faraday's law)

The metal detector **P** is replaced with a rectangular metal detector **Q** and the process repeated as shown in **Figure 1**. The planes of the coil and the ring remain horizontal.

Figure 3 shows how the induced emf in the ring varies with time when **Q** is moving at a constant velocity.

Figure 3



linkage

Show that the magnitude of the change in flux through the ring in the first 1.1×10^{-1} s is equal to 0.03 Wb

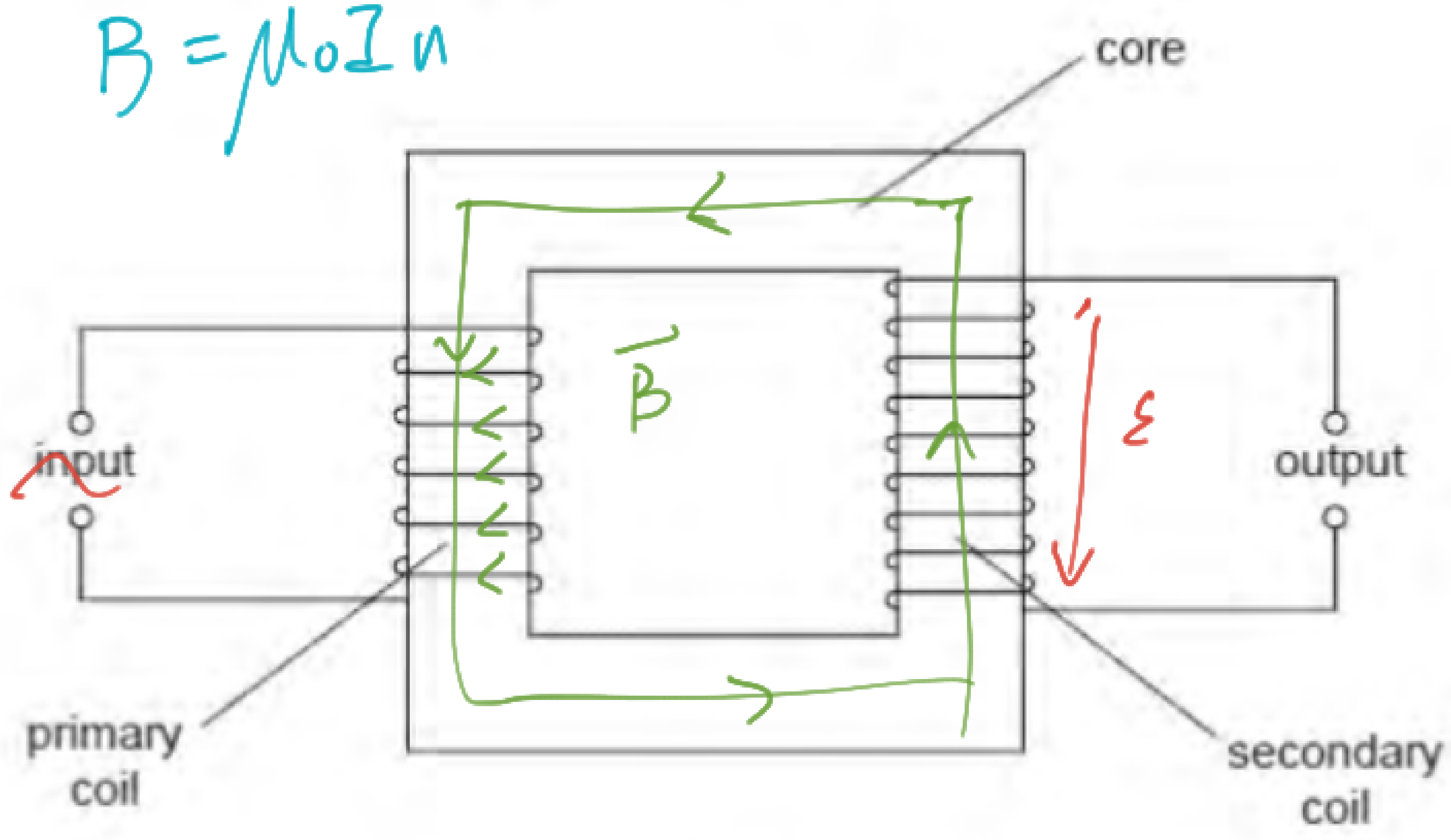
$$\left|\frac{\Delta\phi}{\Delta t}\right| = |-\varepsilon|$$

$$|\Delta\phi| = (0.3)(1.1 \cdot 10^{-1})$$

$$= 0.033 \text{ Wb}$$

6 An ideal iron-cored transformer is illustrated in Fig. 6.1.

$B = \mu_0 I n$



$\phi = BA$

$\varepsilon = -\frac{d\phi}{dt}$

Fig. 6.1

(a) Explain why

(i) the supply to the primary coil must be alternating current, not direct current,

$\varepsilon = -\frac{d\phi}{dt}$

When DC is used, B generated in primary coil = constant → No $\Delta\phi$ in secondary coil

No output voltage

Pin Is↓ when Vs↑

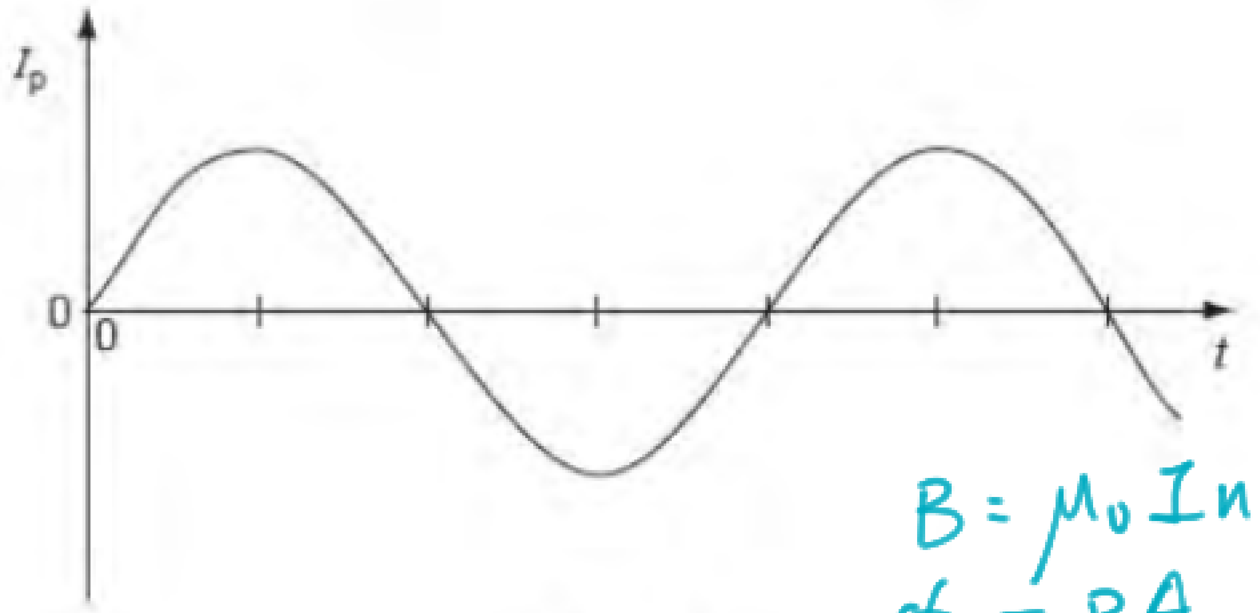
(ii) for constant input power, the output current must decrease if the output voltage increases.

$P_{in} = P_{out}$ $P_{out} = V_{out} I_{out} = Const$

V_{out} increase, I_{out} must decrease and vice versa [2]

(b) Fig. 6.2 shows the variation with time t of the current I_p in the primary coil. There is no current in the secondary coil.

Use



$B = \mu_0 I n$

$\phi = BA$

Fig. 6.2

sin

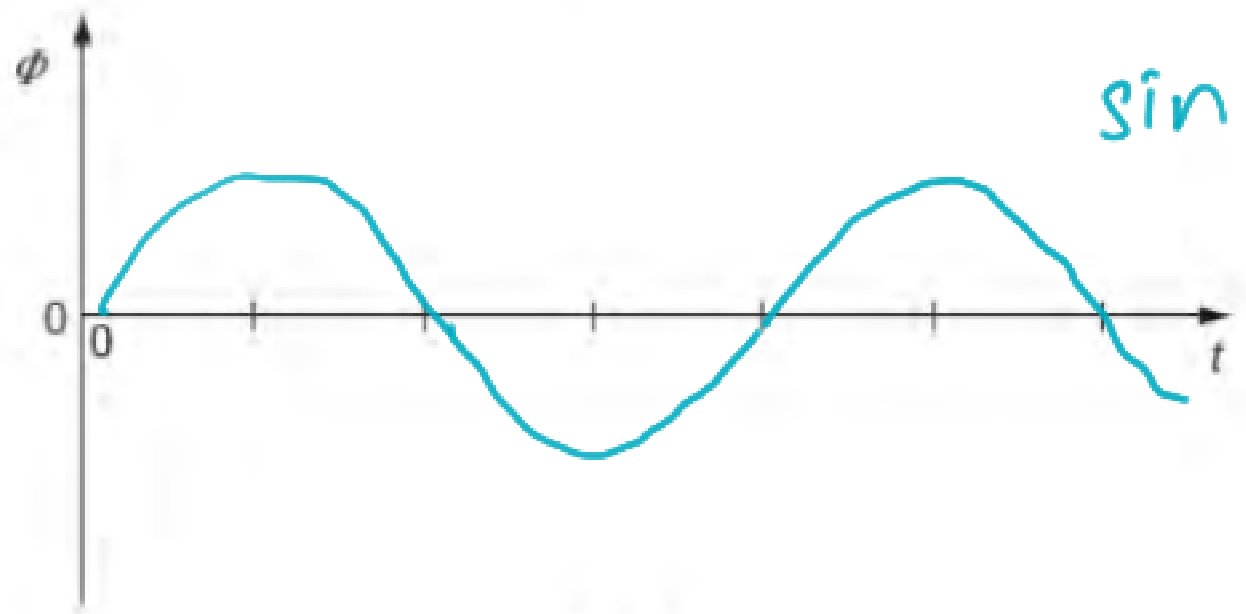


Fig. 6.3

$\phi = C\sin(\omega t)$

$\mathcal{E} = -\omega C\cos(\omega t)$

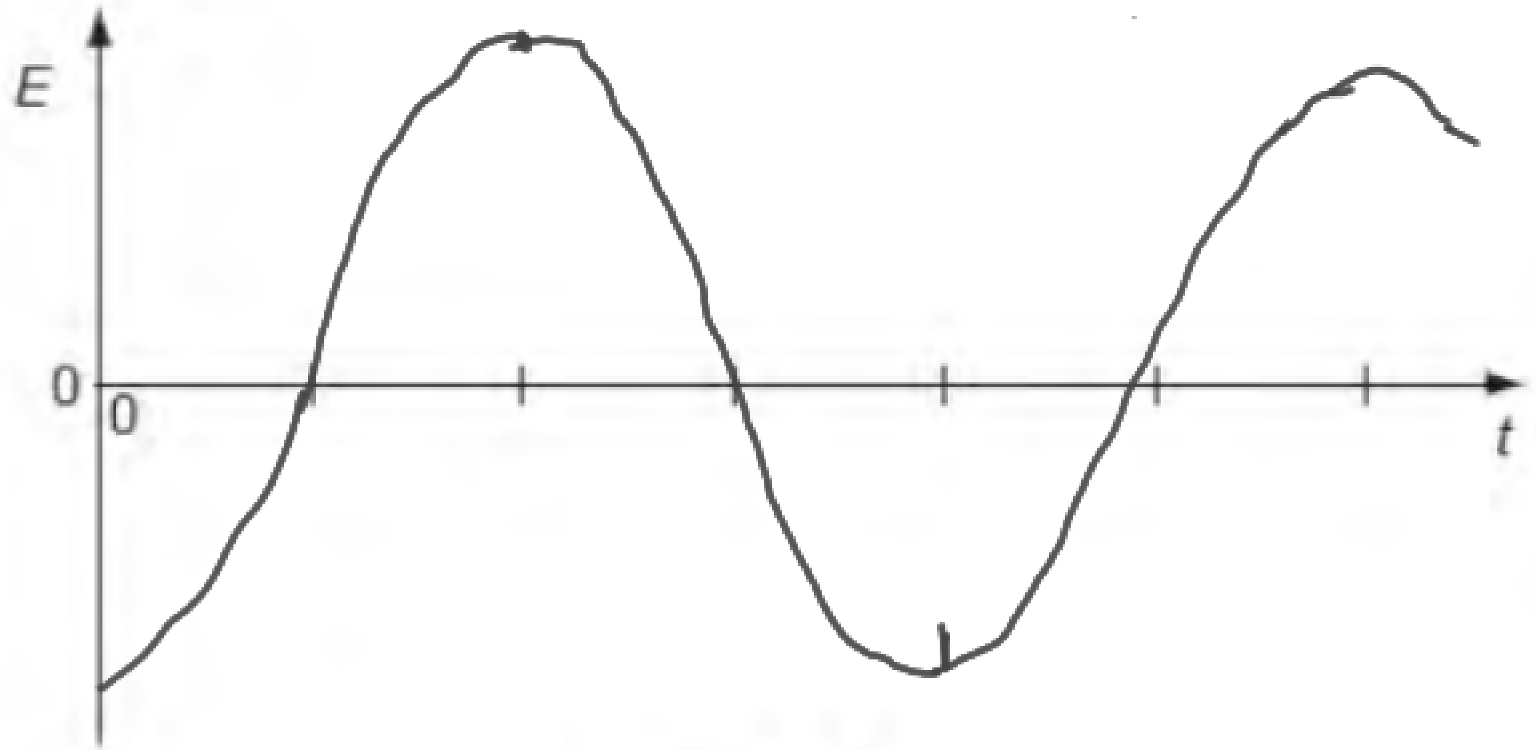


Fig. 6.4

(i) Complete Fig. 6.3 to show the variation with time t of the magnetic flux Φ in the core. [1]

(ii) Complete Fig. 6.4 to show the variation with time t of the e.m.f. E induced in the secondary coil. [2]

(iii) Hence state the phase difference between the current I_p in the primary coil and the e.m.f. E induced in the secondary coil.

phase difference = $\frac{\pi}{2}$ rad [1]