T11 *[101 marks]*

1. Faraday's law of electromagnetic induction states that the electromotive force (emf) induced in a conductor is proportional to *[1 mark]*

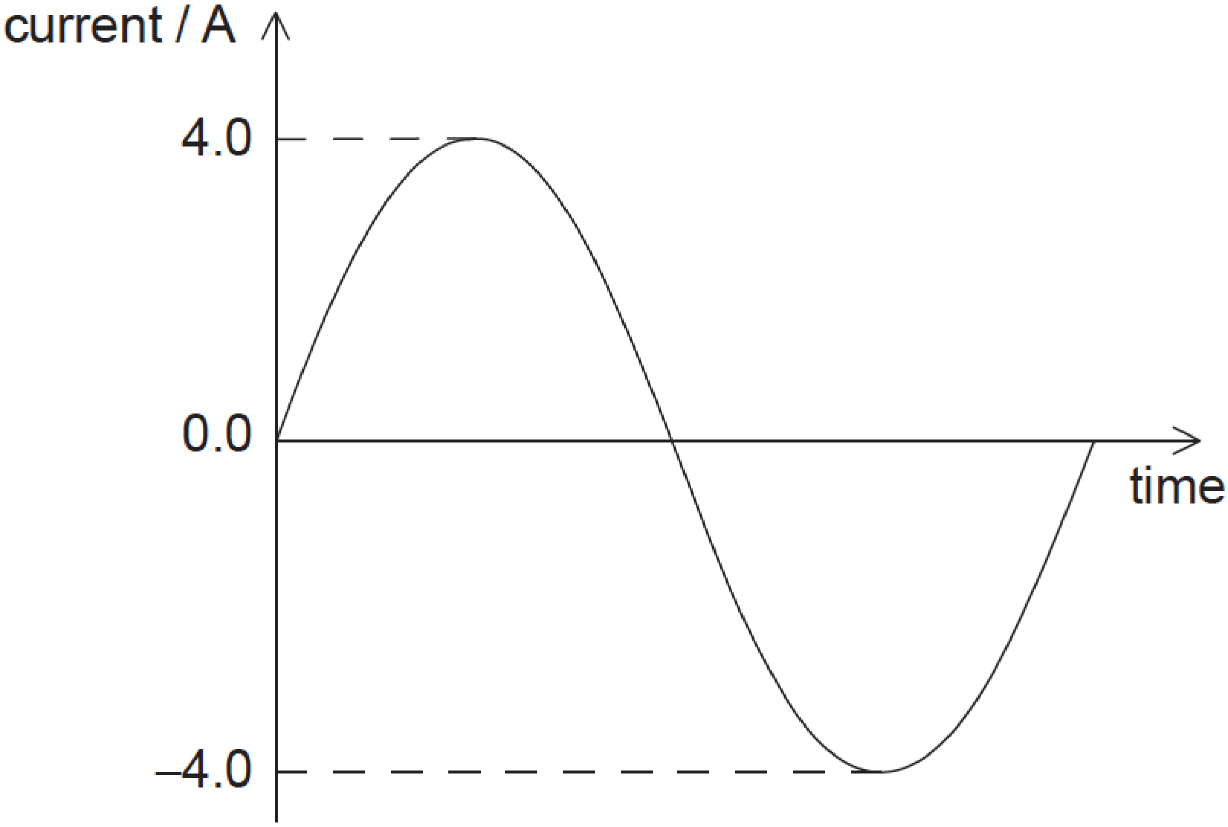
   A. the change of magnetic flux density.

   B. the change of magnetic flux linkage.

   C. the rate of change of magnetic flux density.

   D. the rate of change of magnetic flux linkage.

2. The graph below shows the variation with time of an alternating current in a resistor of resistance 2.0 Ω. *[1 mark]*



   What is the average power dissipated in the resistor?

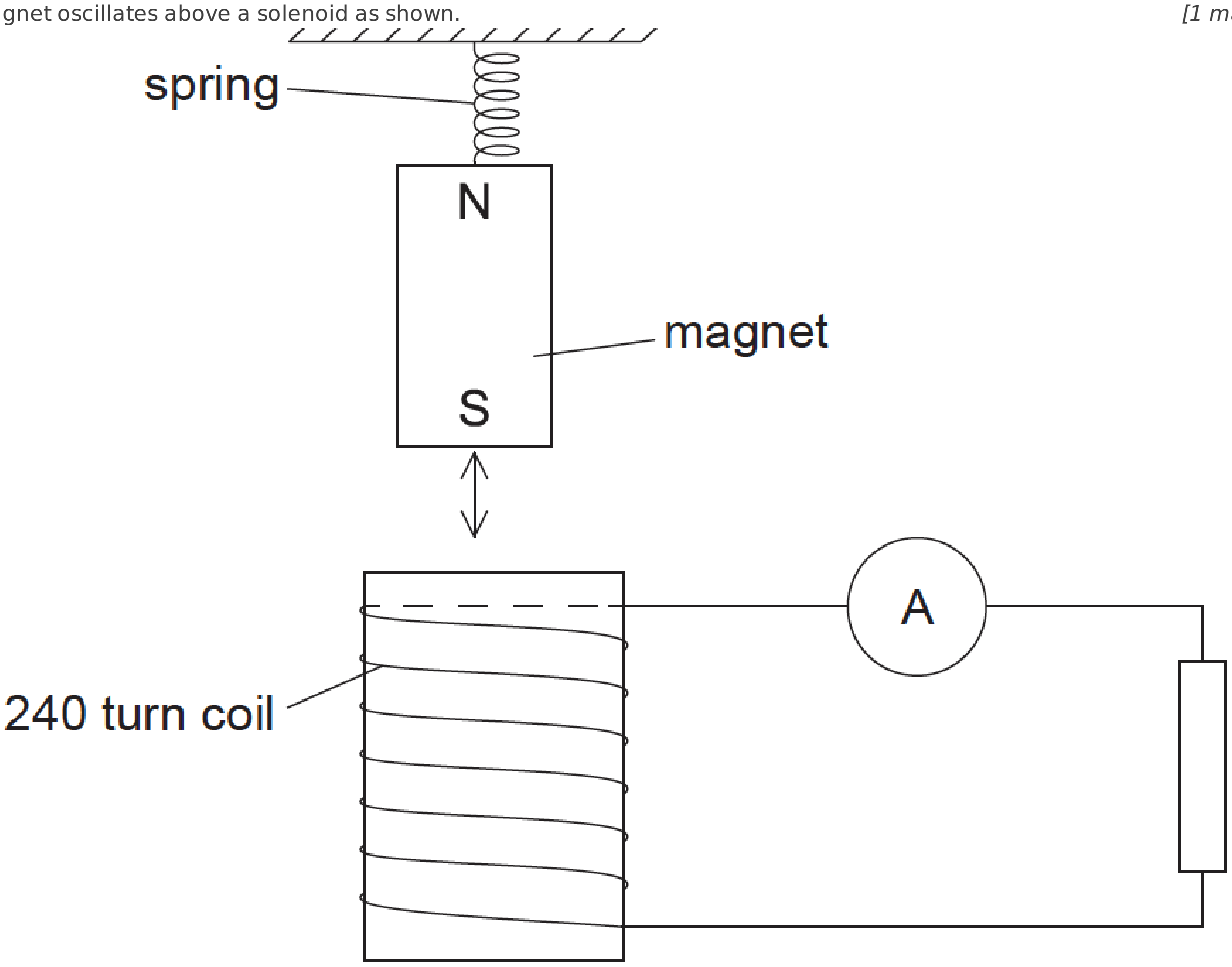
   A. 0.25 W

   B. 8.0 W

   C. 16 W

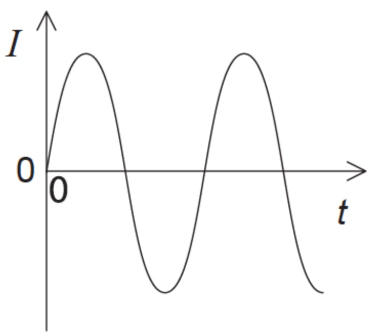
   D. 32 W

3. A magnet oscillates above a solenoid as shown. *[1 mark]*

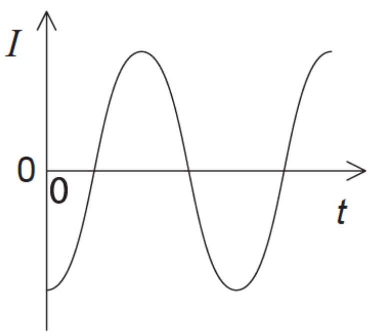


The magnet is displaced vertically and released from its highest position at time t=0. Which graph shows the variation with time t of the current I in the resistor?

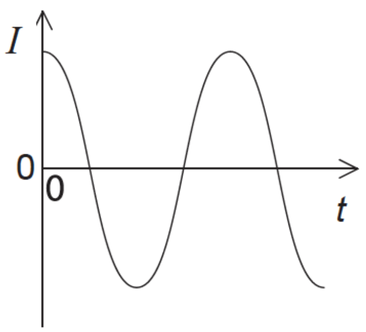
A.



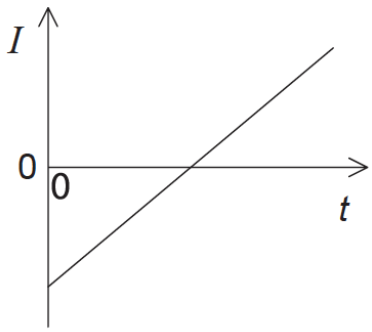
B.



C.



D.



4. Two identical resistors R are connected in series to an alternating current (ac) power supply. The power supply has a root mean squared (rms) voltage of V and an rms current of I. What is the maximum power developed in **one** of the resistors in the circuit? *[1 mark]*

A. $\sqrt{2}\,VI$

B. VI

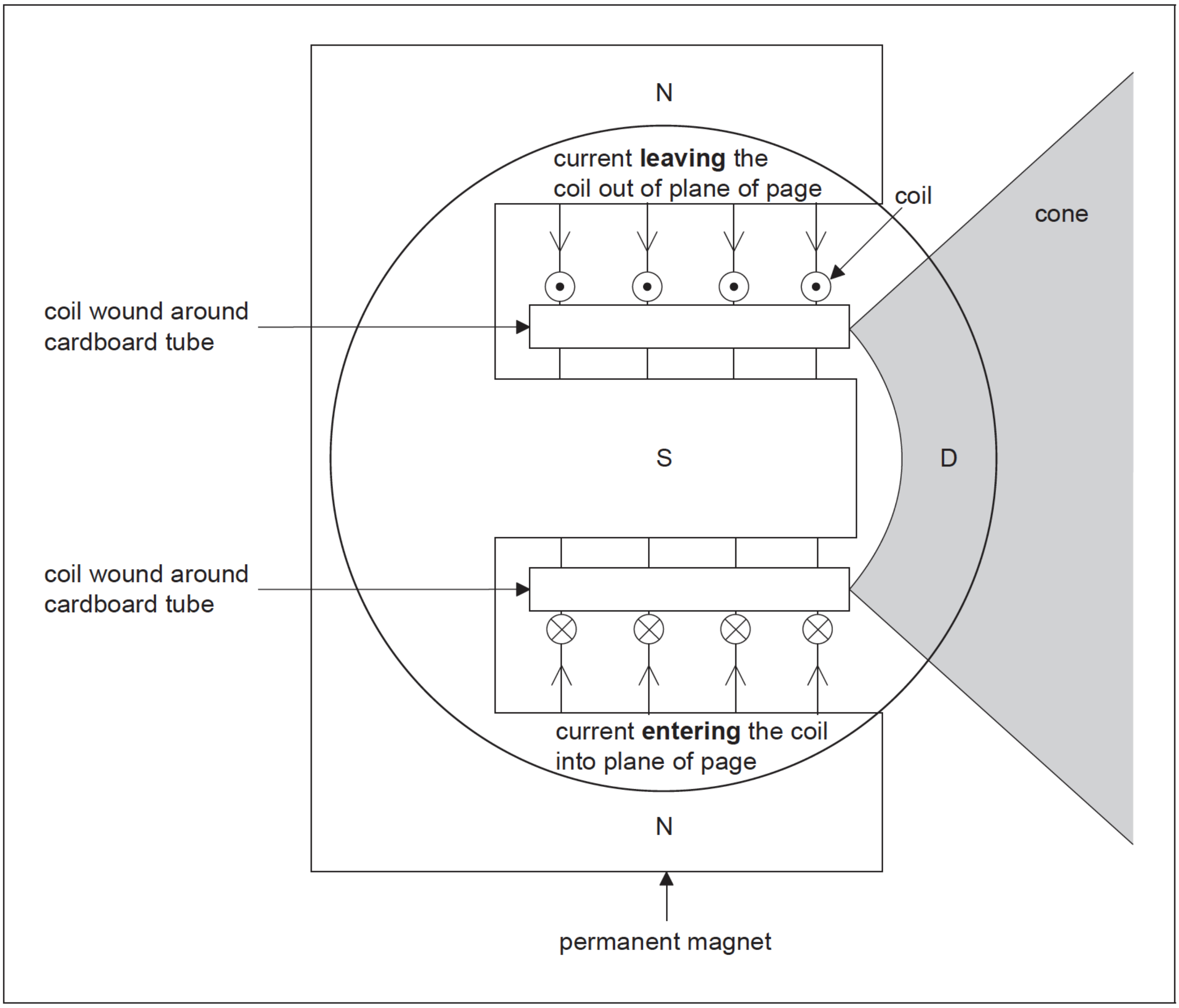
C. $2\,VI$

D. $\frac{VI}{\sqrt{2}}$

This question is in two parts. **Part 1** is about the electrical and magnetic characteristics of a loudspeaker. **Part 2** is about vibrations and waves.

Part 1 Electrical and magnetic characteristics of a loudspeaker

The diagram shows the main features of a loudspeaker L. A current-carrying coil is positioned within the magnetic field provided by a permanent magnet. The diagram also shows the directions of the magnetic field and of the current in the coil at a particular instant. The dust cap D prevents dust from blocking the gap between the cardboard tube and the south pole of the magnet.



The coil consists of 150 turns, each of average diameter 2.5 cm. The magnetic field of the permanent magnet has strength 0.40 mT. The peak current in the coil is 0.45 mA.

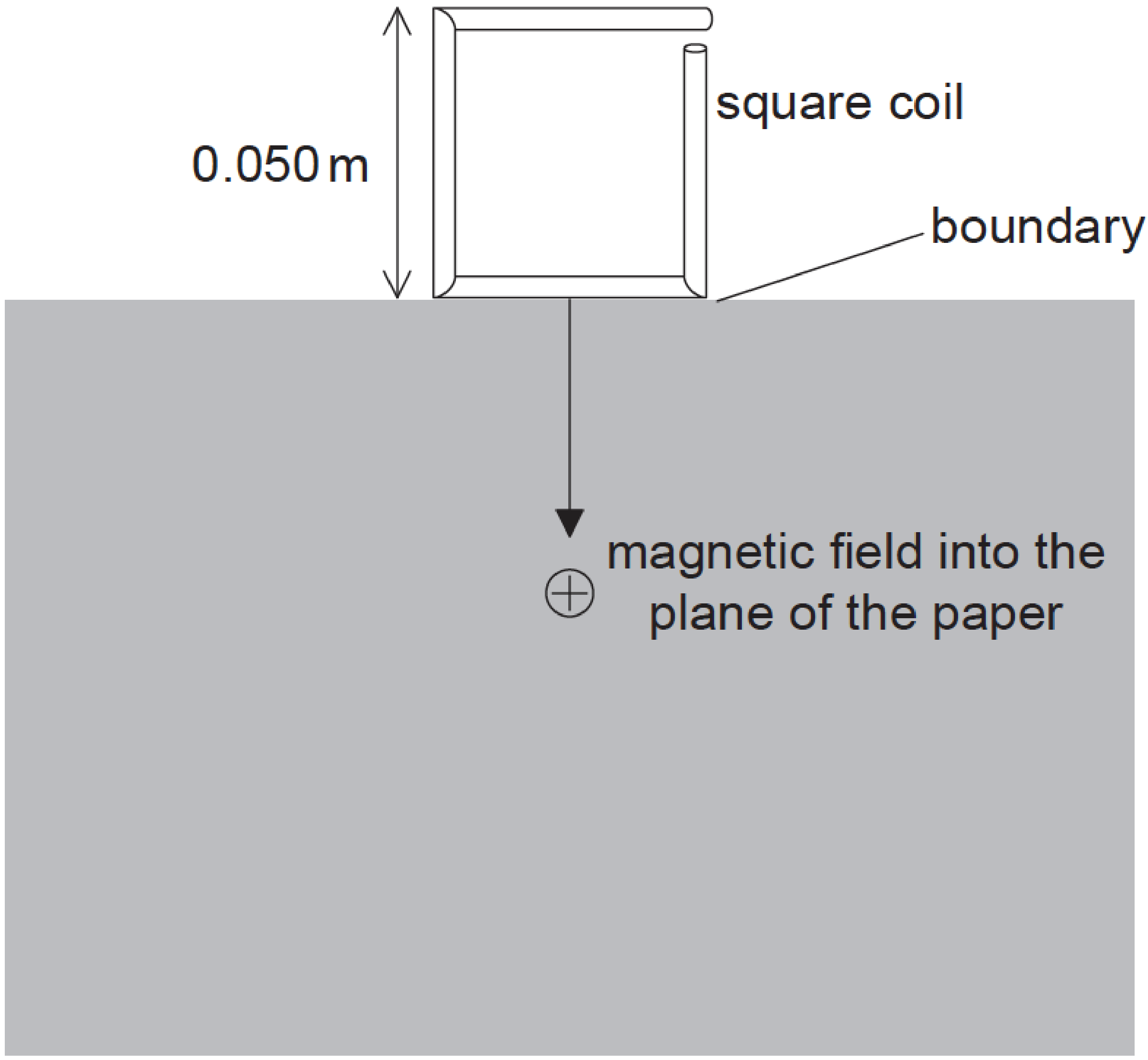
5a. Identify, **on the diagram**, the direction of the force on the coil with the current directions shown. *[2 marks]*

5b. Calculate the maximum magnetic force acting on the coil. *[3 marks]*

5c. Explain, with reference to electromagnetic induction, the effect of the motion of the coil on the current. *[3 marks]*

This question is about changing magnetic fields.

A single-turn conducting square coil is released and falls vertically from rest. At the instant it is released, the coil is at the boundary of a region of a uniform horizontal magnetic field directed into the plane of the paper as shown. The ends of the coil are not joined together.



Each side of the coil is 0.050 m long. The dimensions of the magnetic field region are greater than that of the coil. The magnetic field strength is 25 mT.

6a. Calculate the electromotive force (emf) induced in the coil at the instant just before the whole of the coil enters the magnetic field. *[3 marks]*

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6b. Suggest why the time taken for the whole of the coil to enter the magnetic field increases if the coil is a continuous loop. *[3 marks]*

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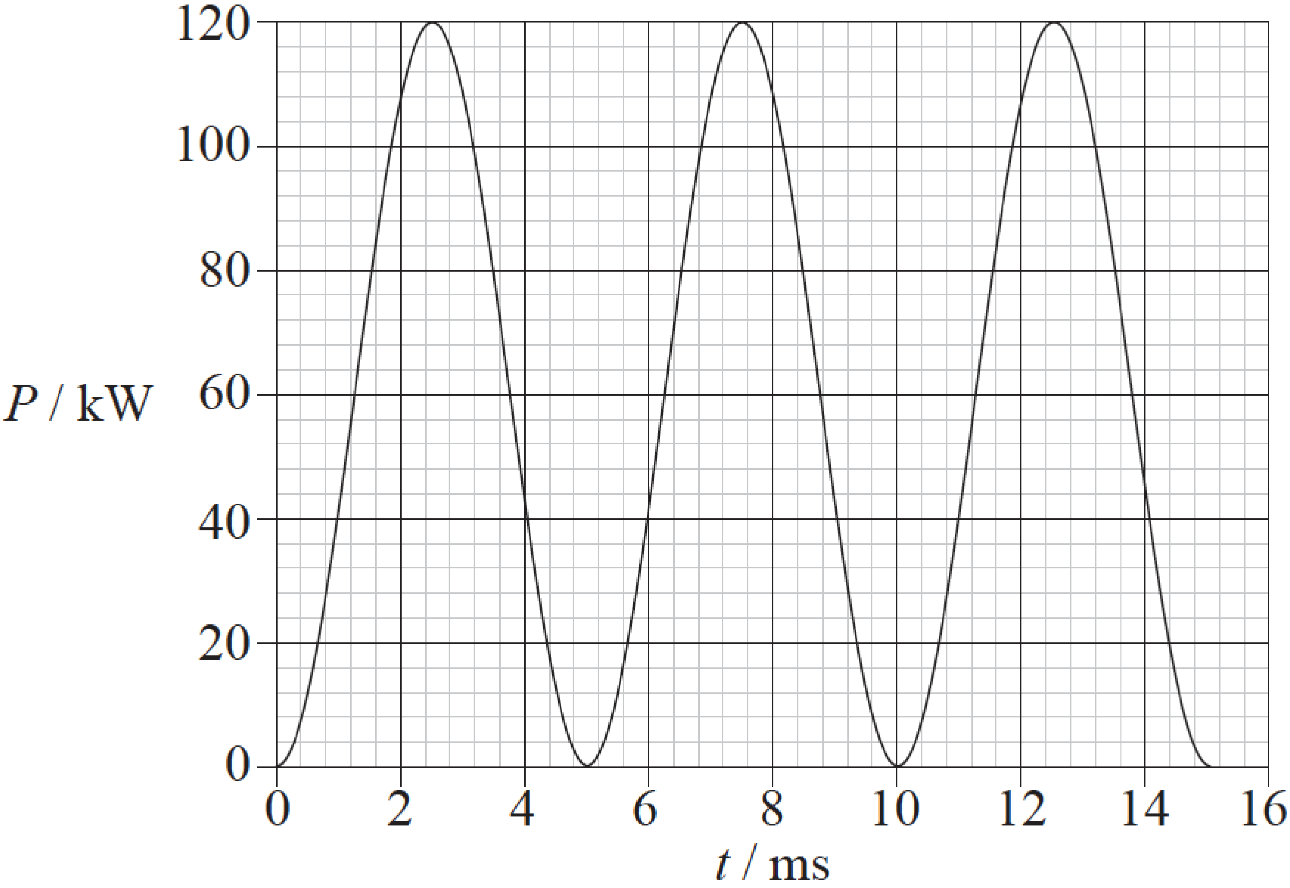
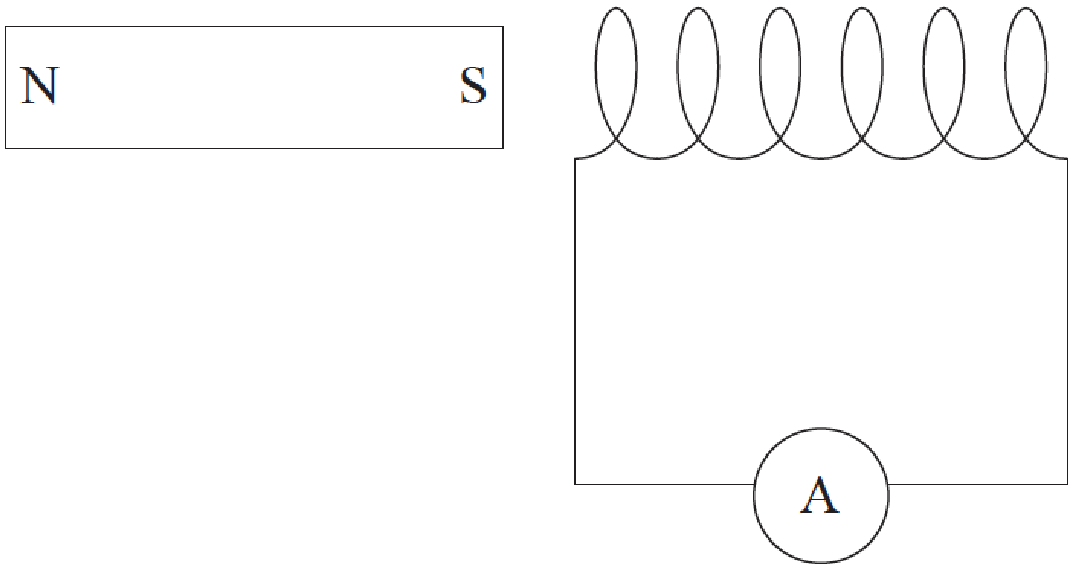
7. The graph shows the variation with time t of the power P produced in a coil that is rotating in a region of uniform magnetic field. *[1 mark]*



Which of the following describes the average power produced and the period of rotation of the coil?

	Average power	Period
A.	60 kW	5.0 ms
B.	60 kW	10 ms
C.	$\frac{120}{\sqrt{2}}$ kW	5.0 ms
D.	$\frac{120}{\sqrt{2}}$ kW	10 ms

8. A bar magnet is close to a coil. No other magnetic fields are present. An ammeter is connected to the coil. *[1 mark]*



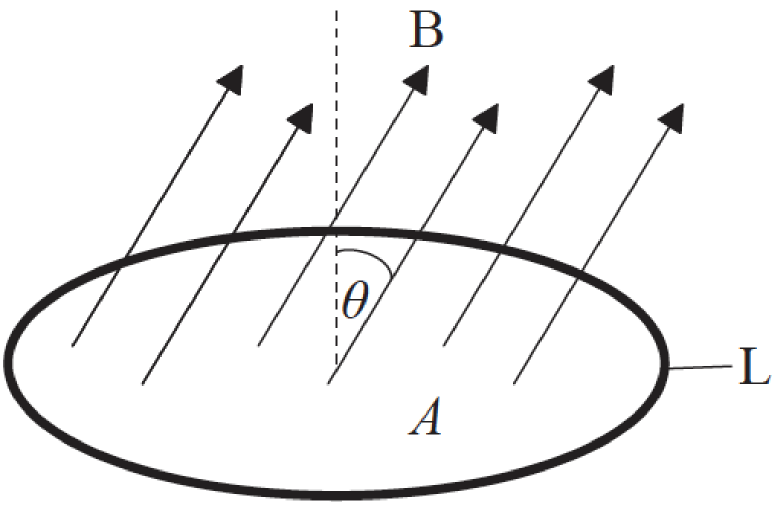
The magnet and the coil are moved in the following ways.

I. The magnet and the coil both move to the right with the same speed.
II. The magnet is stationary and the coil moves to the left.
III. The coil is stationary and the magnet moves to the right.

In which of the following will the ammeter indicate a current?

A. I and II only
B. I and III only
C. II and III only
D. I only

9. The diagram shows a loop L of wire in a uniform magnetic field B. *[1 mark]*



The loop encloses an area A and the field is directed at an angle θ to the normal to the plane of the loop. The strength of B is increasing at a uniform rate R. What is the emf induced in L?

A. $\frac{RA}{\cos\theta}$

B. $RA\cos\theta$

C. $\frac{RA}{\sin\theta}$

D. $RA\sin\theta$

10. The voltage output of a particular power station is stepped up by a factor of 10^3. As a result the power loss in the transmission cables is reduced by a factor of *[1 mark]*

A. 10^3.

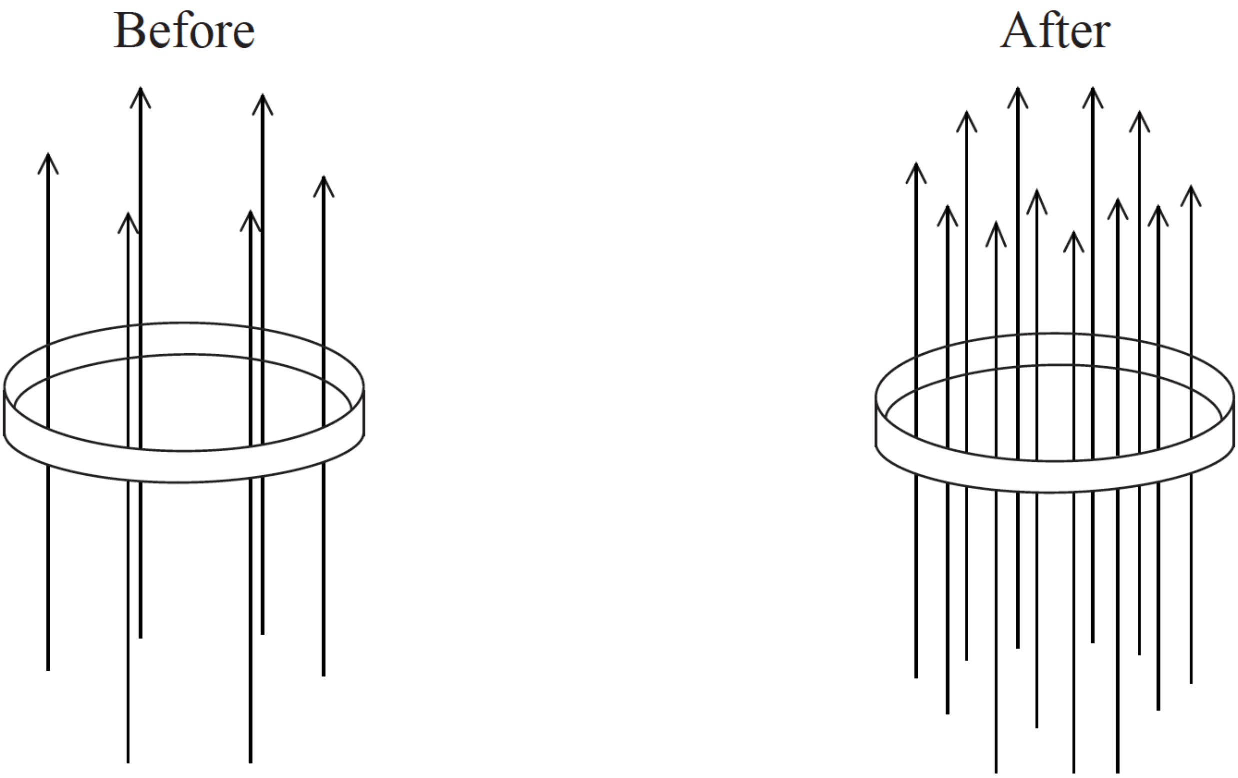
B. 10^6.

C. 10^9.

D. 10^{12}.

This question is about electromagnetic induction.

A metal ring is placed in a magnetic field which is directed upwards. The magnetic flux through the ring increases over a time interval.



11a. State and explain the direction of the current induced in the ring during this change. *[3 marks]*

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11b. The following data are available. *[3 marks]*

Resistance of ring = $3.0\times10^{-3}\Omega$
Initial magnetic flux = 1.2×10^{-5}Wb
Final magnetic flux = 2.4×10^{-5}Wb
Time interval = 2.0×10^{-3}s

Calculate the average current induced in the ring.

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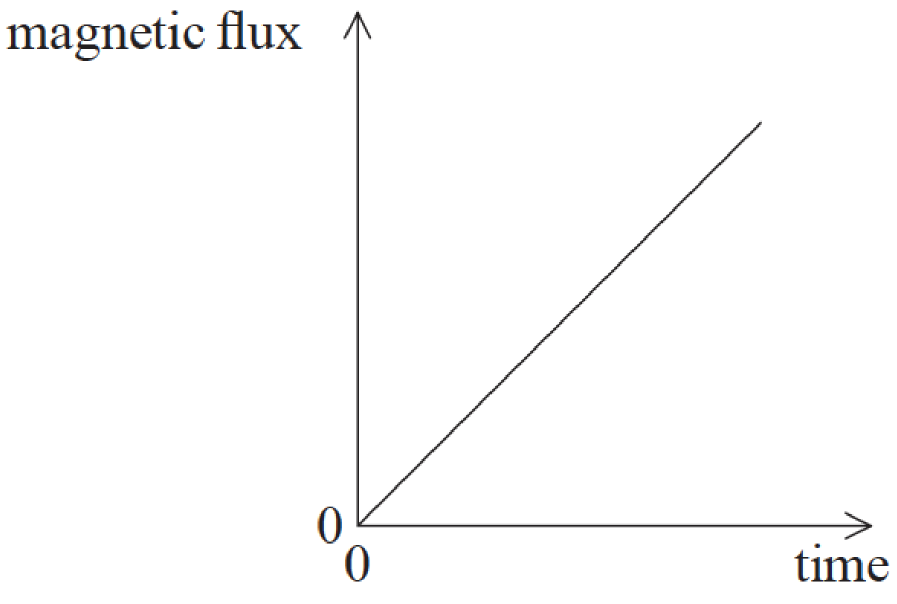
12. A flat coil with *N* turns has a cross-sectional area *A*. The coil has a flux density of *B* in a direction of 90º to the plane of the coil. *[1 mark]*

What is the magnetic flux linkage?

A. 0
B. *BA*
C. *NB*
D. *NBA*

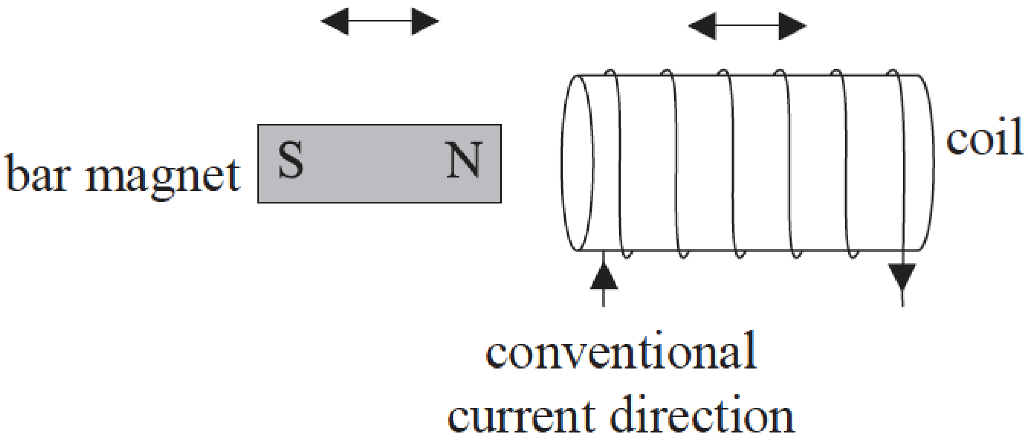
13. The graph shows the variation with time of a magnetic flux passing through a loop of wire. *[1 mark]*



What is the magnitude of the emf induced in the coil?

A. The area between the graph and the time axis
B. The area between the graph and the magnetic flux axis
C. The gradient of the graph
D. The inverse of the gradient of the graph

14. A coil and a magnet can move horizontally to the left or to the right at the same speed. *[1 mark]*



In which of the following will a conventional current be induced in the direction shown in the diagram when both the magnet and the coil are moving?

	direction of motion of magnet	direction of motion of coil
A.	to the left	to the right
B.	to the left	to the left
C.	to the right	to the right
D.	to the right	to the left

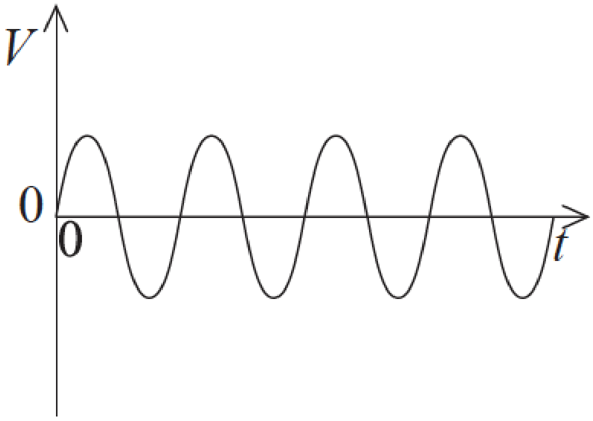
15. In an ideal transformer *[1 mark]*

I. the power output exceeds the power input
II. the magnetic flux produced by the primary coil entirely links the secondary coil
III. there are more turns on the secondary coil than on the primary coil.

Which of the above statements **must** be true?

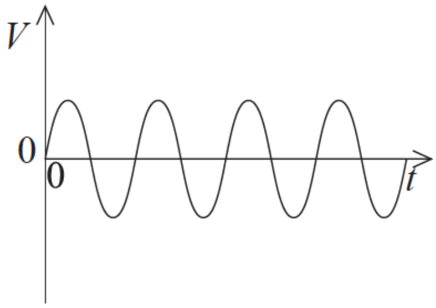
A. I and II only
B. I and III only
C. II only
D. III only

16. The graph shows the variation with time *t* of the output voltage *V* of a generator. *[1 mark]*

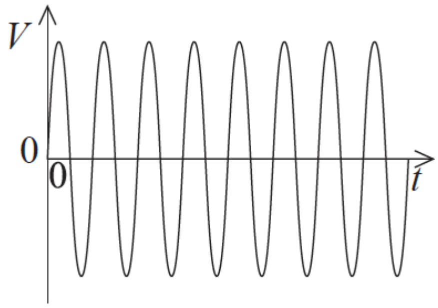


Assuming all graph scales are identical, which graph shows the output when the speed of rotation is doubled?

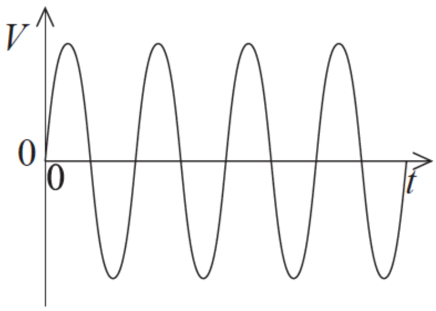
A.



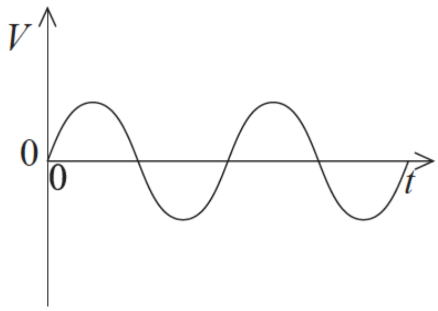
B.



C.



D.



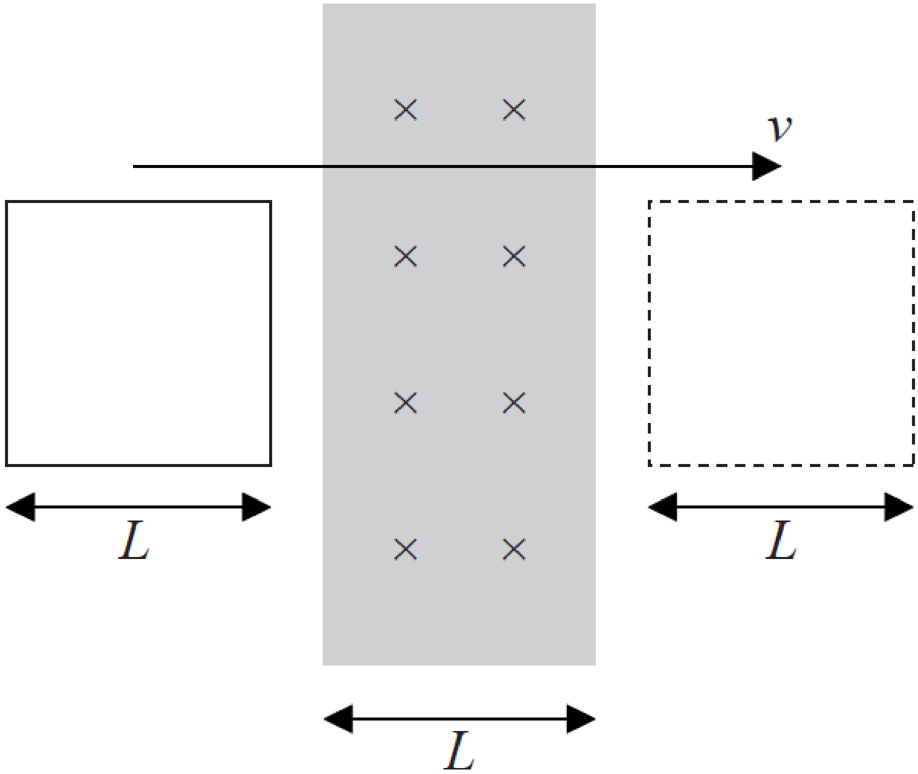
17. The capacitance of a device is defined as the *[1 mark]*

A. charge stored by the device.
B. energy stored by the device.
C. charge stored by the device for a potential difference of 1V across the device.
D. energy stored by the device for a potential difference of 1V across the device.

18. Capacitance of a capacitor is defined as the *[1 mark]*

A. ability to store electrical charge.
B. ratio of charge stored to potential difference.
C. ratio of potential difference to charge stored.
D. ratio of work done to charged stored.

19. A uniform magnetic field directed into the page occupies a region of width *L*. A conducting coil of width *L* moves at constant speed *v*, from left to right, through the field. *[1 mark]*



From the instant that the coil enters the field until the instant that the coil leaves the field, which of the following best describes the direction of the current induced in the coil?

A. Anti-clockwise

B. Clockwise

C. Anti-clockwise then clockwise

D. Clockwise then anti-clockwise

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20. An ideal transformer has 200 turns of wire on the primary coil and 600 turns on the secondary coil. There is an alternating potential difference of frequency f and of peak value V across the primary coil. Which of the following best describes the emf across the secondary coil? *[1 mark]*

	Peak emf	**Frequency**
A.	less than V	less than f
B.	less than V	equal to f
C.	greater than V	greater than f
D.	greater than V	equal to f

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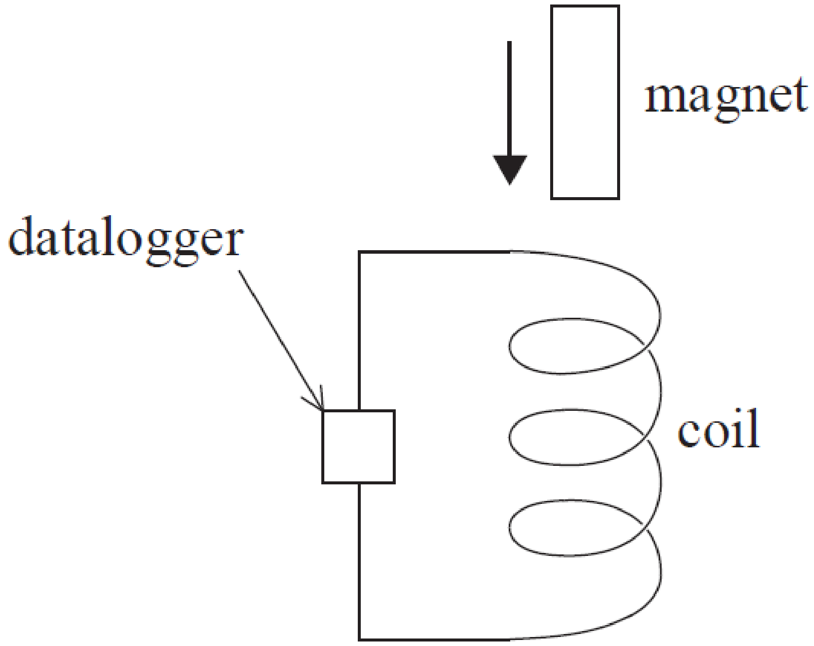
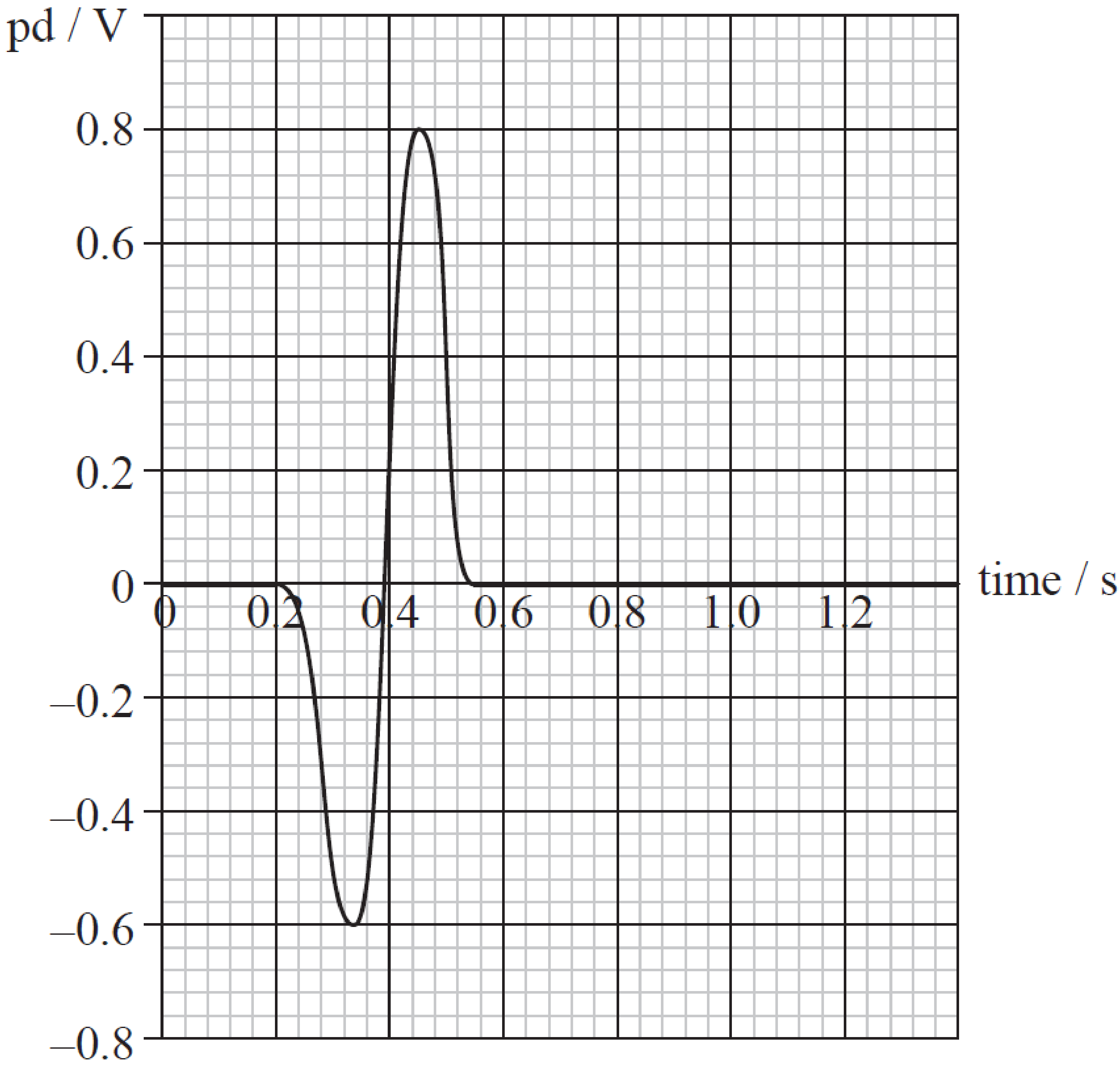
This question is in **two** parts. **Part 1** is about electromagnetic induction. **Part 2** is about nuclear fusion.

Part 1 Electromagnetic induction

21a. A bar magnet falls vertically from rest through a coil of wire. The potential difference (pd) across the coil is recorded by a datalogger. *[6 marks]*



The graph shows the variation with time of the pd across the coil.



(i) Explain, with reference to Faraday’s and Lenz’s laws, the shape of the graph.

(ii) The coil has 1500 turns. Calculate the magnitude of the maximum rate of change of magnetic flux.

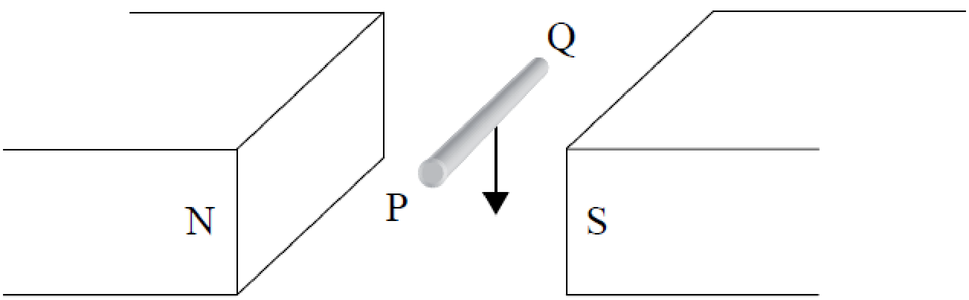
21b. The magnet is now suspended from a spring. The magnet is displaced vertically and starts to oscillate in and out of the coil. A sinusoidal alternating current of rms value 280 nA is induced in the coil. *[5 marks]*

(i) State in words how the rms value of the alternating current relates to a direct current of 280nA.

(ii) The coil has a resistance of 1.5MΩ. Calculate the peak voltage across the coil.

(iii) Explain what effect the generation of the current has on the oscillation of the magnet.

22. A length of copper wire PQ is moved downwards through the poles of two horizontal bar magnets as shown below. *[1 mark]*



Compared to end Q, end P will have

A. fewer electrons.
B. more electrons.
C. fewer protons.
D. more protons.

23. The rms voltage of a sinusoidal electricity supply is 110V. The maximum potential difference during one cycle is *[1 mark]*

A. 220 V.
B. 156 V.
C. 110 V.
D. 55 V.

24. An ideal transformer has a primary coil with N_p turns and a secondary coil with N_s turns. The electrical power input to the primary is *P*. Which of the following is the power output from the secondary? *[1 mark]*

A. $\left(\frac{N_p}{N_s}\right) P$

B. *P*

C. $\left(\frac{N_s}{N_p}\right) P$

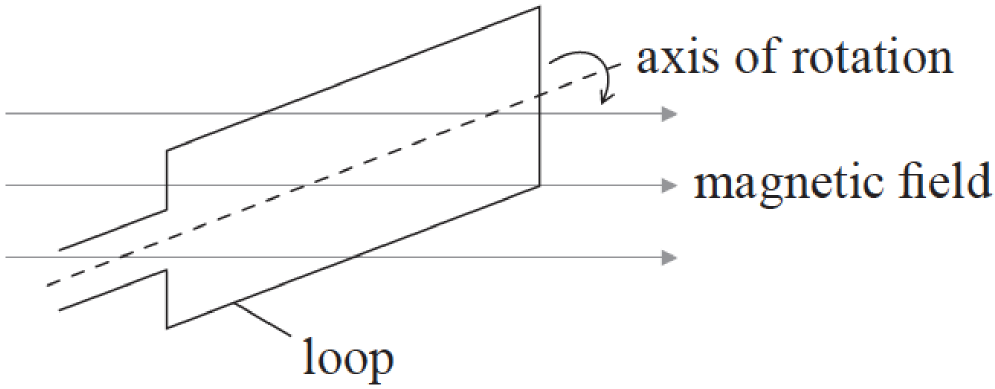
D. $\frac{1}{P}$

25. An alternating current generator produces a root mean squared (rms) emf of ε at a frequency *f*. The rotational speed of the coil in the generator is doubled. Which of the following correctly identifies the new output rms emf and the new frequency? *[1 mark]*

	emf	Frequency
A.	2ε	$2f$
B.	$\sqrt{2}\varepsilon$	$2f$
C.	2ε	$\frac{f}{2}$
D.	$\sqrt{2}\varepsilon$	$\frac{f}{2}$

This question is about induced electromotive force (emf).

26a. A loop of copper wire in a region of uniform magnetic field is rotated about a horizontal axis. *[4 marks]*



The magnitude of the magnetic field strength is B and the area of the loop is A.

(i) State the minimum value and the maximum value of the magnetic flux linking the loop.

(ii) Outline with reference to Faraday's law why, if the speed of rotation of the loop is increased, the maximum emf induced in the loop is increased.

26b. The loop in (a) is connected in series with a resistor of resistance 15 Ω. The root mean squared (rms) value of the sinusoidal current in the resistor is 2.3 mA. *[4 marks]*

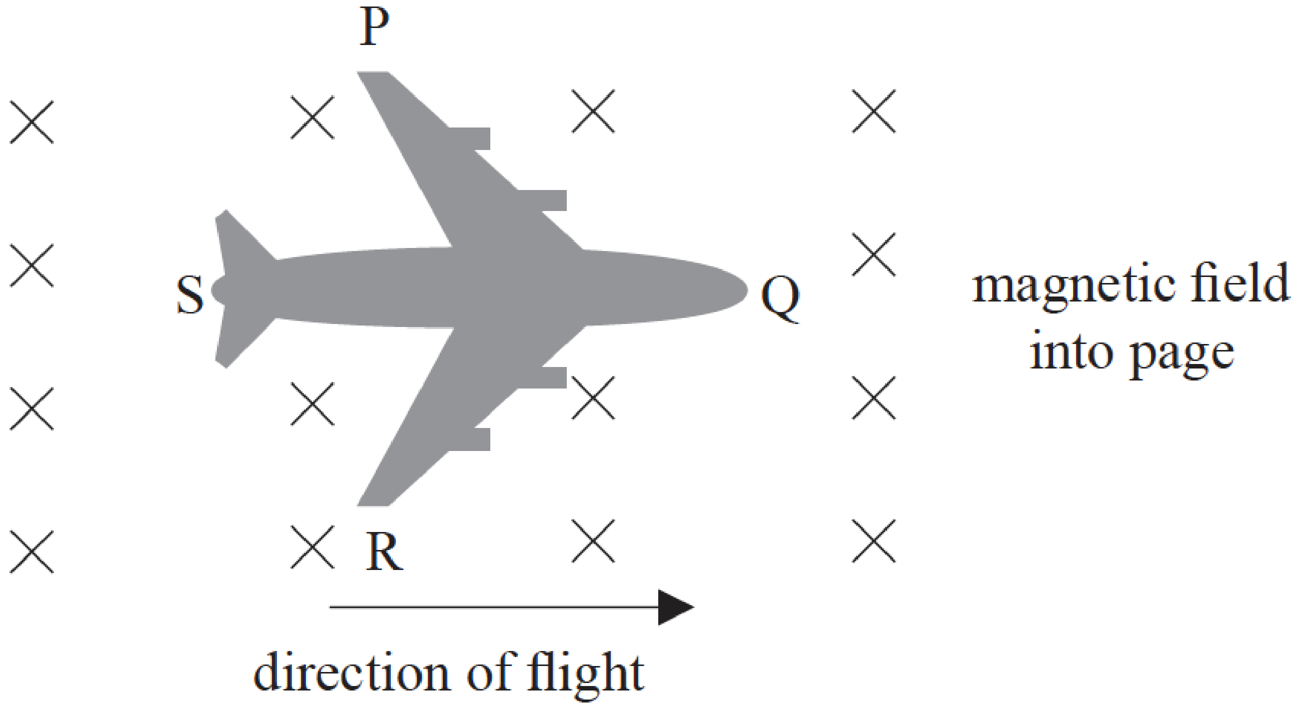
(i) Explain what is meant by the rms value of a sinusoidal current.

(ii) Determine the maximum power dissipated in the resistor.

27. The peak value of an alternating sinusoidal potential difference is 100V. The approximate rms value of the potential difference will be *[1 mark]*

A. 50V.
B. 70V.
C. 140V.
D. 200V.

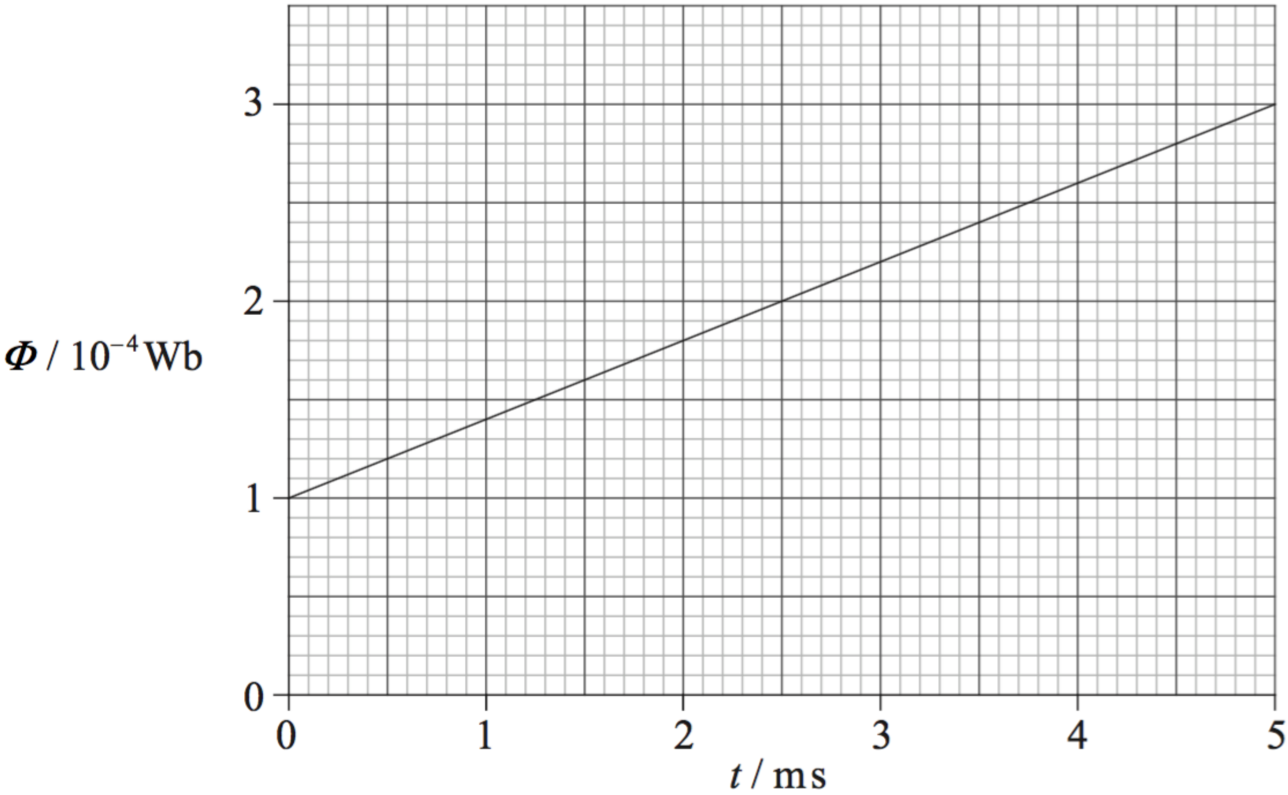
28. The diagram shows the view from above as an airplane flies horizontally through the Earth's magnetic field. The airplane is made of conducting material. *[1 mark]*



The direction of the induced emf will be from

A. P to R.
B. R to P.
C. S to Q.
D. Q to S.

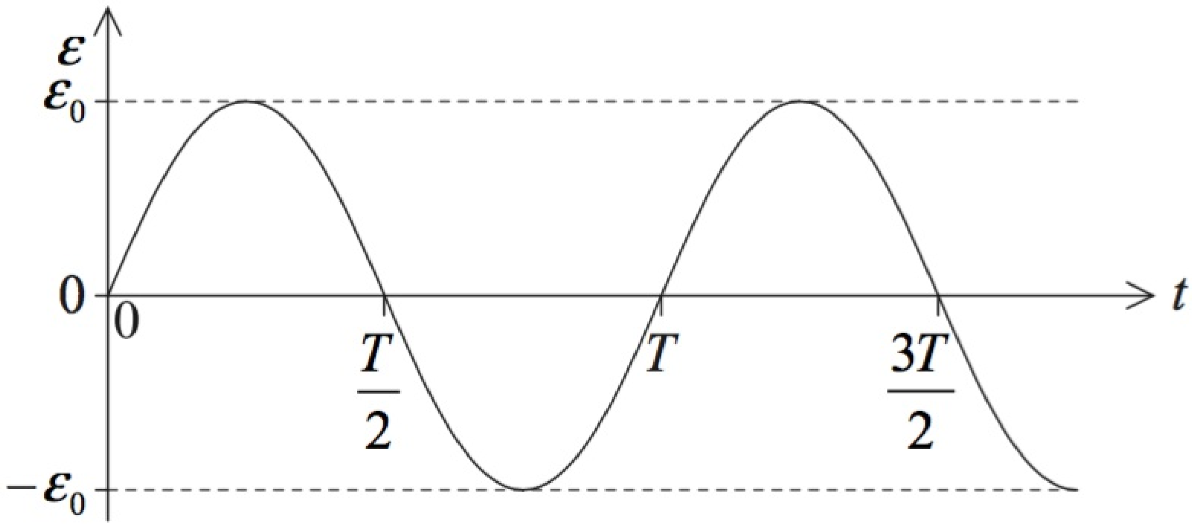
29. The magnetic flux Φ through a coil with 1000 turns varies with time t as shown in the graph. *[1 mark]*



What is the magnitude of the emf produced in the coil?

A. 0.04 V
B. 0.06 V
C. 40 V
D. 60 V

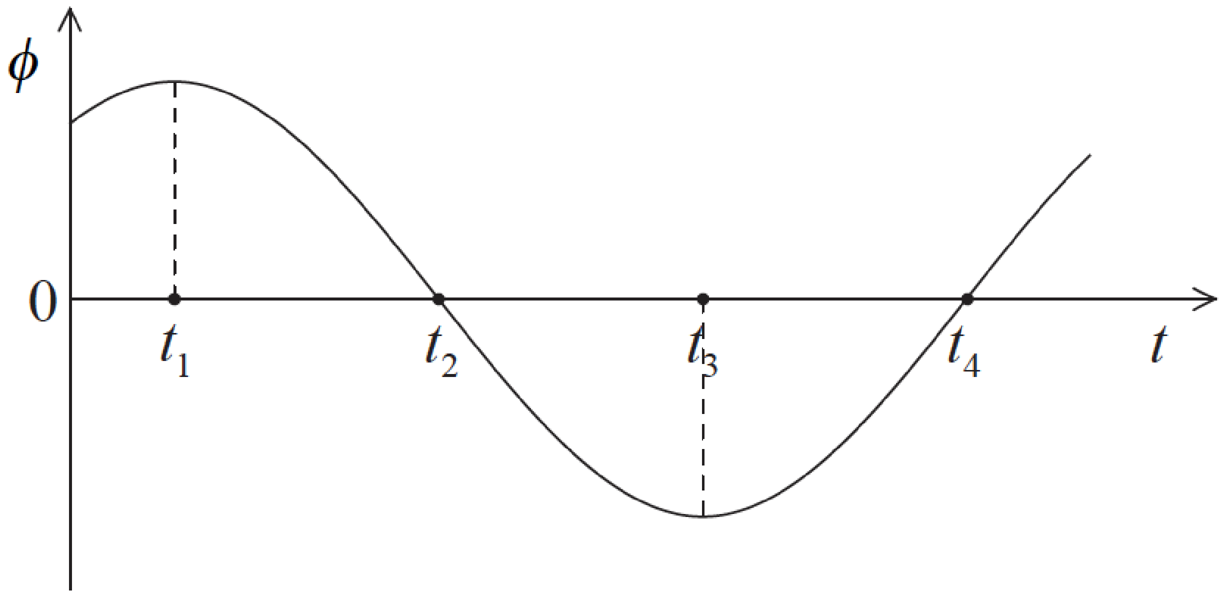
30. A coil rotates in a magnetic field. The emf ε produced in the coil varies sinusoidally with time t as shown. *[1 mark]*



Which of the following correctly gives the rms value of the emf and the frequency of rotation of the coil?

	rms value of emf	Frequency of rotation
A.	$\varepsilon_0\sqrt{2}$	$\frac{1}{T}$
B.	$\frac{\varepsilon_0}{\sqrt{2}}$	$\frac{2}{T}$
C.	$\varepsilon_0\sqrt{2}$	$\frac{2}{T}$
D.	$\frac{\varepsilon_0}{\sqrt{2}}$	$\frac{1}{T}$

31. The graph shows the variation with time t of the magnetic flux φ through a coil that is rotating in a uniform magnetic field. *[1 mark]*



The magnitude of the emf induced across the ends of the coil is maximum at time(s)

A. t_1 and t_3.

B. t_2 and t_4.

C. t_3 only.

D. t_4 only.

32. The rms current rating of an electric heater is 4A. What direct current would produce the same power dissipation in the electric heater? *[1 mark]*

A. $\frac{4}{\sqrt{2}}\mathrm{A}$

B. 4A

C. $4\sqrt{2}\mathrm{A}$

D. 8A

This question is about the emf induced in a coil.

33a. Define *magnetic flux*. *[2 marks]*

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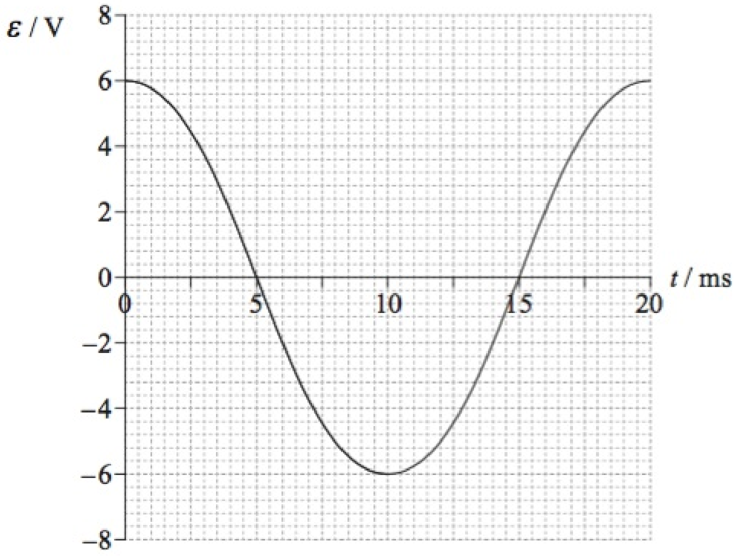
33b. A coil is rotated at constant speed in a region of uniform magnetic field. *[3 marks]*

The graph shows the variation with time t of the emf ε induced in the coil for one cycle of rotation.



(i) On the graph label, with the letter T, a time at which the flux linkage in the coil is a maximum.

(ii) Use the graph to determine the rate of change of flux at t=4.0ms. Explain your answer.

(iii) Calculate the root mean square value of the induced emf.

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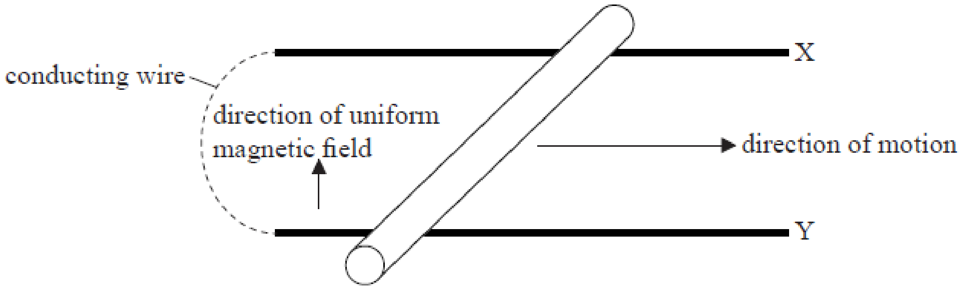
This question is about induced electromotive force (emf).

34a. A rod made of conducting material is in a region of uniform magnetic field. It is moved horizontally along two parallel conducting rails X and Y. The other ends of the rails are connected by a thin conducting wire. *[4 marks]*



The speed of the rod is constant and is also at right angles to the direction of the uniform magnetic field.

(i) Describe, with reference to the forces acting on the conduction electrons in the rod, how an emf is induced in the rod.

(ii) An induced emf is produced by a rate of change of flux. State what is meant by a rate of change of flux in this situation.

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34b. The length of the rod in (a) is 1.2 m and its speed is 6.2 m s^{-1}. The induced emf is 15 mV. *[4 marks]*

(i) Determine the magnitude of the magnetic field strength through which the rod is moving.

(ii) Explain how Lenz's law relates to the situation described in (a).

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This question is about electromagnetic induction.

35a. State Lenz’s law. *[1 mark]*

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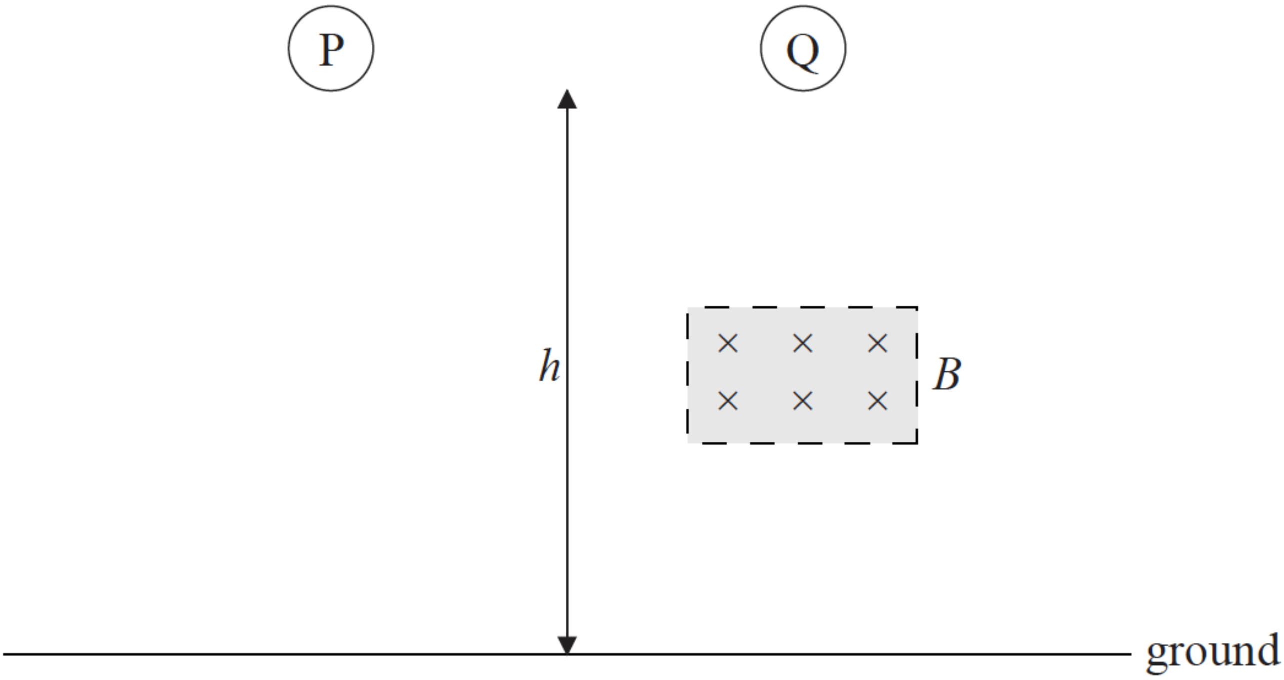
35b. Two identical aluminium balls are dropped simultaneously from the same height. Ball P falls through a region with no magnetic field. Ball Q falls through a region of uniform horizontal magnetic flux density *B*. *[4 marks]*



Explain why ball Q takes longer than ball P to reach the ground.

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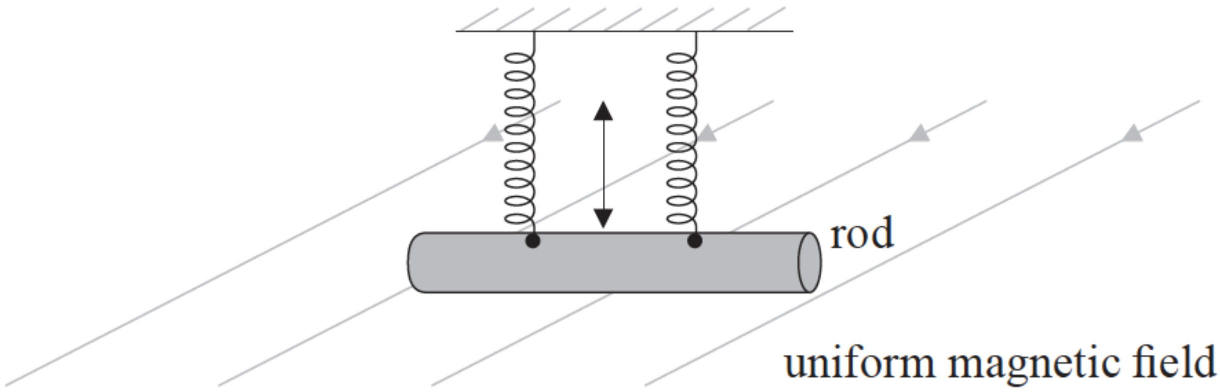
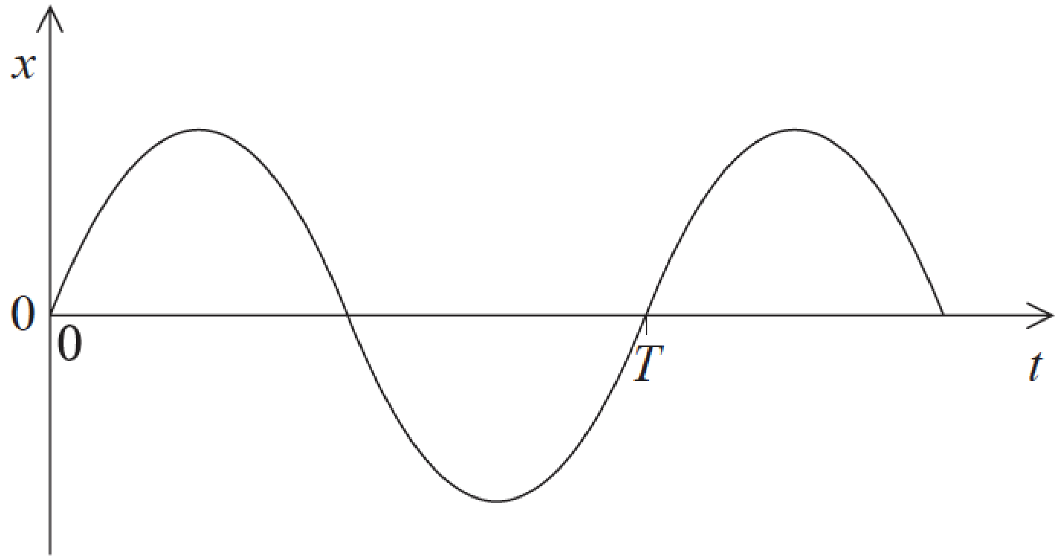
Part 2 Electromagnetic induction

The diagram shows a horizontal metal rod suspended by two vertical insulated springs.



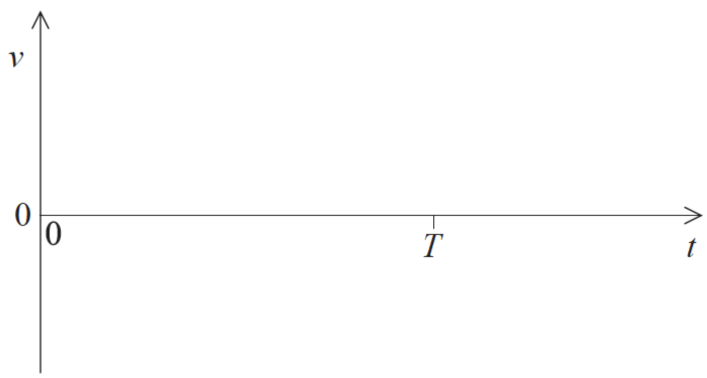
The rod moves vertically up and down with simple harmonic motion with a time period *T* at right angles to a uniform magnetic field.

The diagram shows the variation with time *t* of the vertical displacement *x* of the rod.

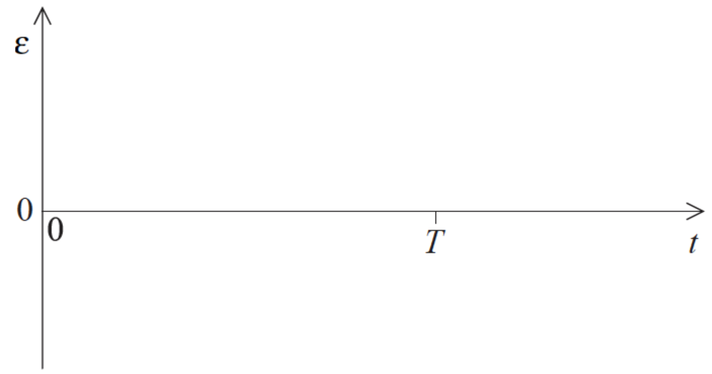


36a. On the axes provided, draw a graph to show *[3 marks]*

(i) the variation with time *t* of the vertical velocity *v* of the rod.



(ii) the variation with time *t* of the emf generated between the ends of the rod.



36b. The length of the rod is 0.18 m and the magnitude of the magnetic field is 58 μT. The frequency of the simple harmonic motion is 2.5 Hz. The amplitude of the motion is 8.2×10^{-2} m. *[3 marks]*

Determine the magnitude of the maximum emf ε_{max} between the ends of the rod.

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36c. The frequency of the motion is doubled without any change in the amplitude of the motion. *[4 marks]*

State and explain the changes to the variation with time *t* of the emf *ε* generated as a result of this change in frequency.

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37. A coil of wire has a large number of turns. It is moved relative to a fixed magnetic field. The emf generated will be equal to the *[1 mark]*

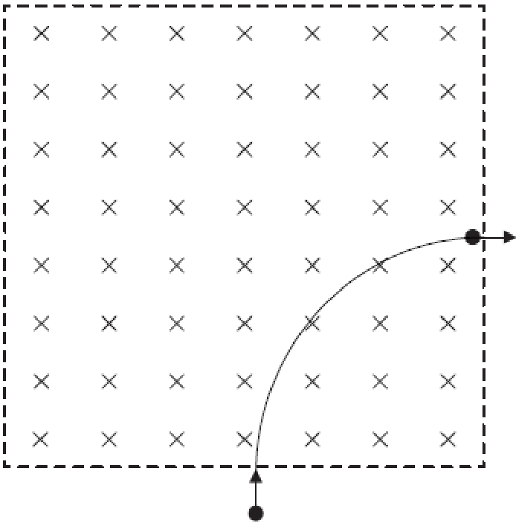
A. rate of change of magnetic flux linkage.
B. rate of change of the magnetic flux through the coil.
C. change of magnetic flux linkage.
D. change of the magnetic flux through the coil.

38. A sinusoidal ac power supply has rms voltage *V* and supplies rms current *I*. What is the maximum instantaneous power delivered? *[1 mark]*

A. $2VI$
B. $\sqrt{2}VI$
C. VI
D. $\frac{VI}{2}$

This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.



39a. The electron's path while in the region of magnetic field is a quarter circle. Show that the time the electron spends in the region of magnetic field is 7.5×10^{-11}s. *[1 mark]*

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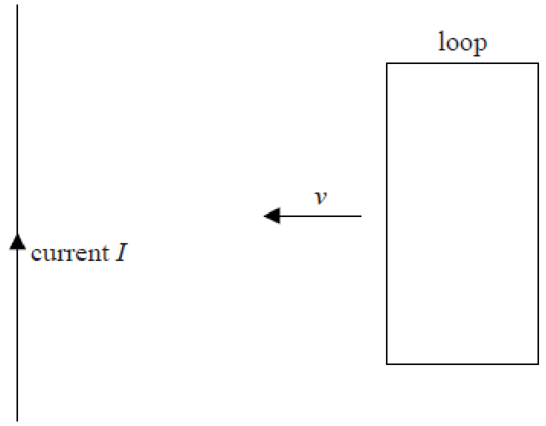
39b. A square loop of conducting wire is placed near a straight wire carrying a constant current *I*. The wire is in the same plane as the loop. *[4 marks]*



The loop is made to move with constant speed *v* towards the wire.

(i) Explain, by reference to Faraday's and Lenz's laws of electromagnetic induction, why work must be done on the loop.

(ii) Suggest what becomes of the work done on the loop.

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