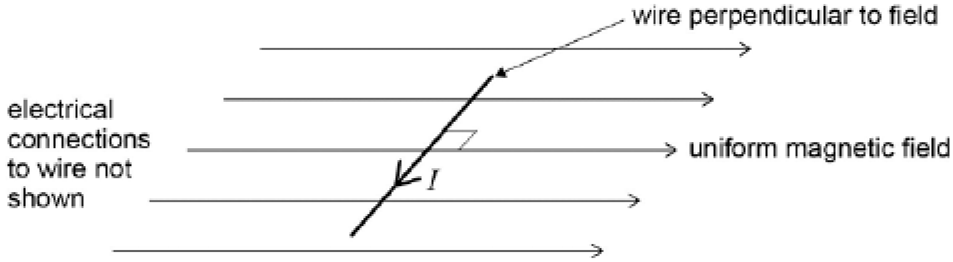
1 A horizontal straight wire of length 0.30 m carries a current of 2.0 A perpendicular to a horizontal uniform magnetic field of flux density 5.0×10^{-2} T. The wire 'floats' in equilibrium in the field.



What is the mass of the wire?

A 8.0×10^{-4} kg

B 3.1×10^{-3} kg

C 3.0×10^{-2} kg

D 8.2×10^{-1} kg

(Total 1 mark)

2 Charged particles, each of mass m and charge Q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B.
Which expression gives the frequency of rotation of a particle in the beam?

A $\frac{BQ}{2\pi m}$

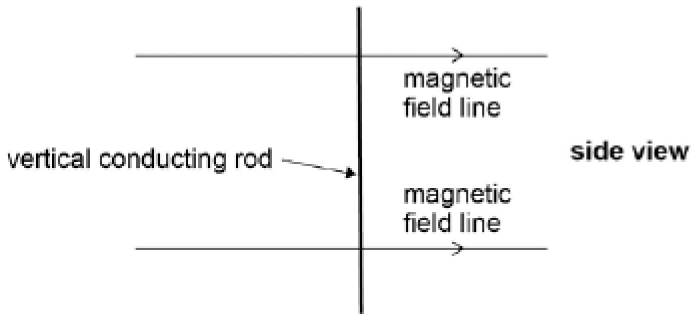
B $\frac{BQ}{m}$

C $\frac{BQ}{\pi m}$

D $\frac{2\pi BQ}{m}$

(Total 1 mark)

3 A vertical conducting rod of length l is moved at a constant velocity v through a uniform horizontal magnetic field of flux density B.

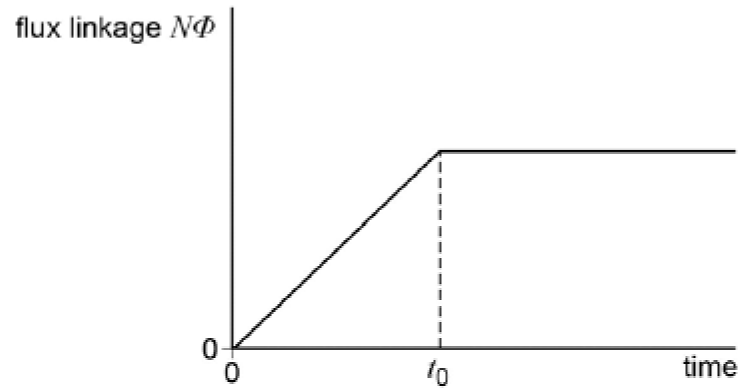


Which of the rows gives a correct expression for the induced emf between the ends of the rod for the stated direction of the motion of the rod?

	Direction of motion	Induced emf	
A	Vertical	$\frac{B}{lv}$	⬭
B	Horizontal at right angles to the field	Blv	⬭
C	Vertical	Blv	⬭
D	Horizontal at right angles to the field	$\frac{B}{lv}$	⬭

(Total 1 mark)

4 The graph shows how the flux linkage, $N\Phi$, through a coil changes when the coil is moved into a magnetic field.



The emf induced in the coil

A decreases then becomes zero after time t_0.

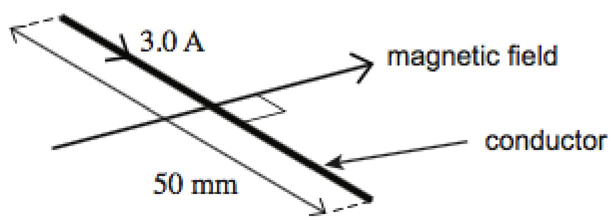
B increases then becomes constant after time t_0.

C is constant then becomes zero after time t_0.

D is zero then increases after time t_0.

(Total 1 mark)

5 The diagram shows a horizontal conductor of length 50 mm carrying a current of 3.0 A at right angles to a uniform horizontal magnetic field of flux density 0.50 T.

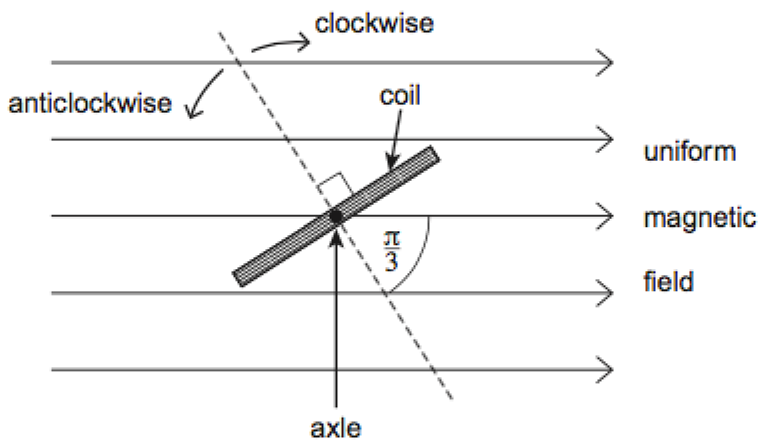


What is the magnitude and direction of the magnetic force on the conductor ?

A 0.075 N vertically upwards
B 0.075 N vertically downwards
C 75 N vertically upwards
D 75 N vertically downwards

(Total 1 mark)

6 The diagram shows a coil placed in a uniform magnetic field. In the position shown, the angle between the normal to the plane of the coil and the magnetic field is $\frac{\pi}{3}$ is rad.



Which line, **A** to **D**, in the table shows the angles through which the coil should be rotated, and the direction of rotation, so that the flux linkage becomes (i) a maximum, and (ii) a minimum?

Angle of rotation / rad		
	(i) for maximum flux linkage	**(ii) for minimum flux linkage**
A	$\frac{\pi}{6}$ clockwise	$\frac{\pi}{3}$ anticlockwise
B	$\frac{\pi}{6}$ anticlockwise	$\frac{\pi}{3}$ clockwise
C	$\frac{\pi}{3}$ clockwise	$\frac{\pi}{6}$ anticlockwise
D	$\frac{\pi}{3}$ anticlockwise	$\frac{\pi}{6}$ clockwise

(Total 1 mark)

7 A train is travelling at 20 m s^{-1} along a horizontal track through a uniform magnetic field of flux density 4.0×10^{-5} T acting vertically downwards.

What is the emf induced between the ends of an axle 1.5 m long?

A 3.0×10^{-6}V

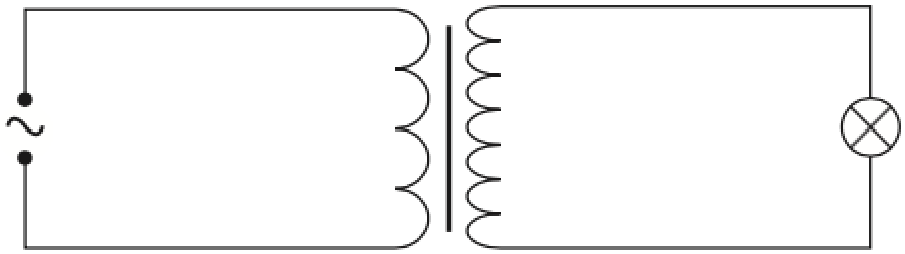
B 5.3×10^{-4}V

C 1.2×10^{-3}V

D 7.5×10^{5}V

(Total 1 mark)

8 The primary coil of a step-up transformer is connected to a source of alternating pd. The secondary coil is connected to a lamp.

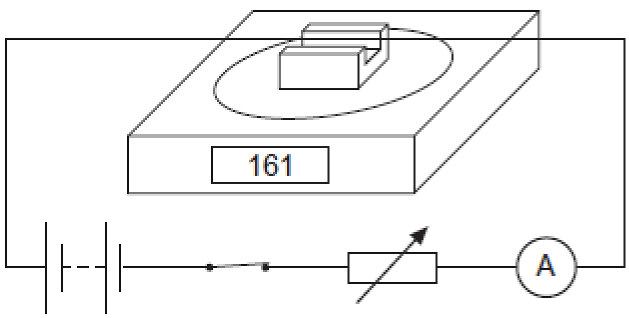


Which line, **A** to **D**, in the table correctly describes the ratios of flux linkages and currents through the secondary coil in relation to the primary coil?

	$\frac{\textbf{Secondary magnetic flux linkage}}{\textbf{Primary magnetic flux linkage}}$	$\frac{\textbf{Secondary current}}{\textbf{Primary current}}$
A	< 1	< 1
B	> 1	< 1
C	> 1	> 1
D	< 1	> 1

(Total 1 mark)

9 The diagram shows a rigidly-clamped straight horizontal current-carrying wire held mid-way between the poles of a magnet on a top-pan balance. The wire is perpendicular to the magnetic field direction.



The balance, which was zeroed before the switch was closed, read 161 g after the switch was closed. When the current is reversed and doubled, what would be the new reading on the balance?

A −322 g

B −161 g

C zero

D 322 g

(Total 1 mark)

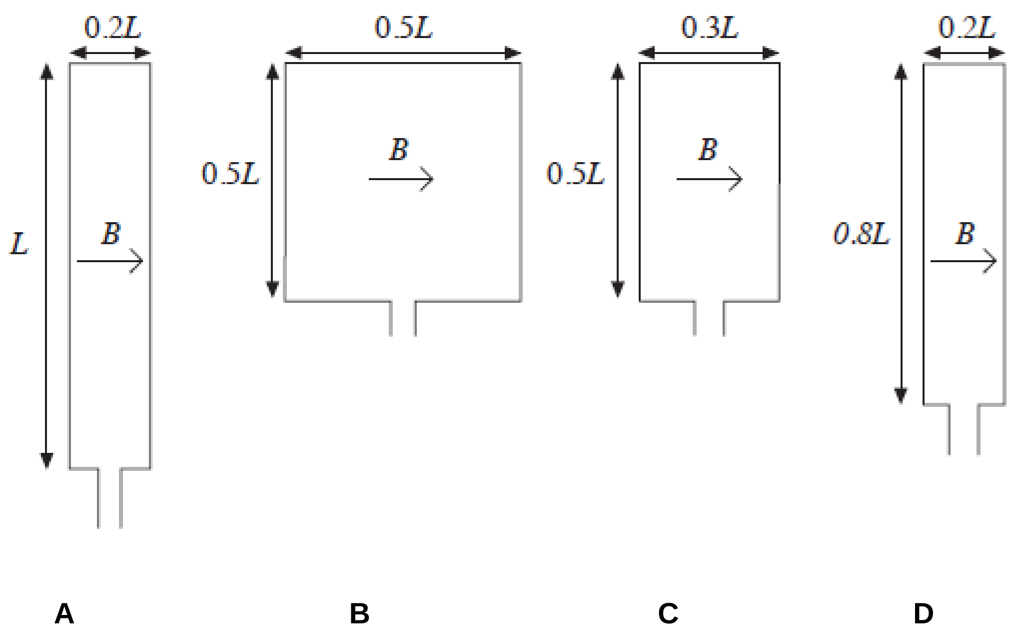
10 Which one of the following statements is the main reason for operating power lines at high voltage?

A Transformers are never perfectly efficient.
B High voltages are required by many industrial users of electricity.
C Electrical generators produce alternating current.
D For a given amount of transmitted power, increasing the voltage decreases the current.

(Total 1 mark)

11 Four rectangular loops of wire **A**, **B**, **C** and **D** are each placed in a uniform magnetic field of the same flux density B. The direction of the magnetic field is parallel to the plane of the loops as shown.

When a current of 1 A is passed through each of the loops, magnetic forces act on them. The lengths of the sides of the loops are as shown.
Which loop experiences the largest couple?



(Total 1 mark)

12 Which one of the following statements is correct?

An electron follows a circular path when it is moving at right angles to

A a uniform magnetic field.

B a uniform electric field.

C uniform electric and magnetic fields which are perpendicular.

D uniform electric and magnetic fields which are in opposite directions.

(Total 1 mark)

13 Two electrons, X and Y, travel at right angles to a uniform magnetic field.
X experiences a magnetic force, F_X, and Y experiences a magnetic force, F_Y.

What is the ratio $\frac{F_X}{F_Y}$ if the kinetic energy of X is half that of Y?

A $\frac{1}{4}$

B $\frac{1}{2}$

C $\frac{1}{\sqrt{2}}$

D 1

(Total 1 mark)

14 A lamp rated at 12 V 60 W is connected to the secondary coil of a step-down transformer and is at full brightness. The primary coil is connected to a supply of 230 V. The transformer is 75% efficient.
What is the current in the primary coil?

A 0.25 A

B 0.35 A

C 3.75 A

D 5.0 A

15 The path followed by an electron of momentum p, carrying charge $–e$, which enters a magnetic field at right angles, is a circular arc of radius r.

What would be the radius of the circular arc followed by an α particle of momentum $2p$, carrying charge $+2e$, which entered the same field at right angles?

A $\frac{r}{2}$

B r

C $2r$

D $4r$

(Total 1 mark)

16 In which one of the following applications does electromagnetic induction **not** take place?

A the generators at a nuclear power station

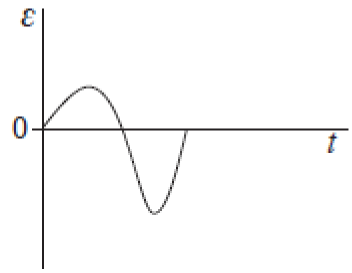
B the ac power adapter for a laptop computer

C the wings of an aircraft cutting through the Earth's magnetic field

D the back up capacitor of an electric timer

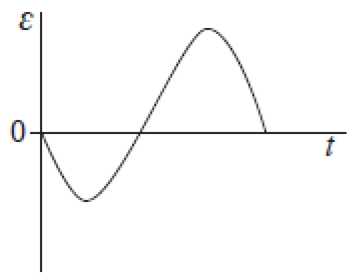
(Total 1 mark)

17 When a magnet is dropped through an aluminium ring an emf is induced. A data logger connected to the ring records the variation of the induced emf ε with time t as shown below.

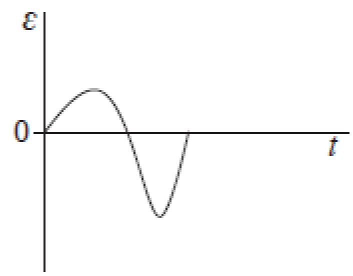


In a second experiment, the magnet is dropped from a greater height.

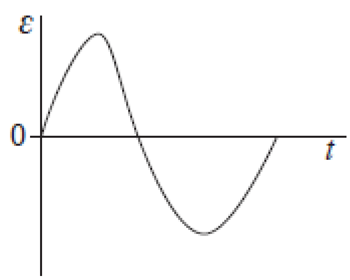
Which one of the following graphs best represents the induced emf in the second experiment?



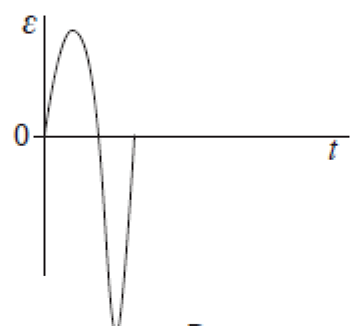
A



B



C

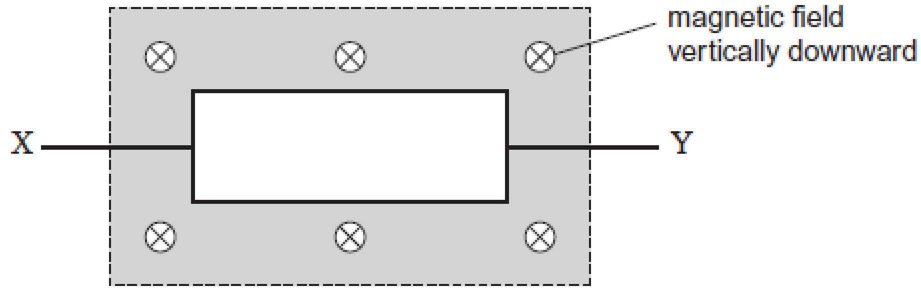


D

(Total 1 mark)

18 A rectangular coil of area A has N turns of wire. The coil is in a uniform magnetic field, as shown in the diagram.

When the coil is rotated at a constant frequency f about its axis XY, an alternating emf of peak value ε_0 is induced in it.



What is the maximum value of the magnetic flux linkage through the coil?

A $\dfrac{\varepsilon_0}{2\pi f}$

B $\dfrac{\varepsilon_0}{\pi f}$

C $\pi f \varepsilon_0$

D $2\pi f \varepsilon_0$

(Total 1 mark)

19 A transformer has 1150 turns on the primary coil and 500 turns on the secondary coil. The primary coil draws a current of 0.26 A from a 230 V ac supply. The current in the secondary coil is 0.50 A. What is the efficiency of the transformer?

A 42%

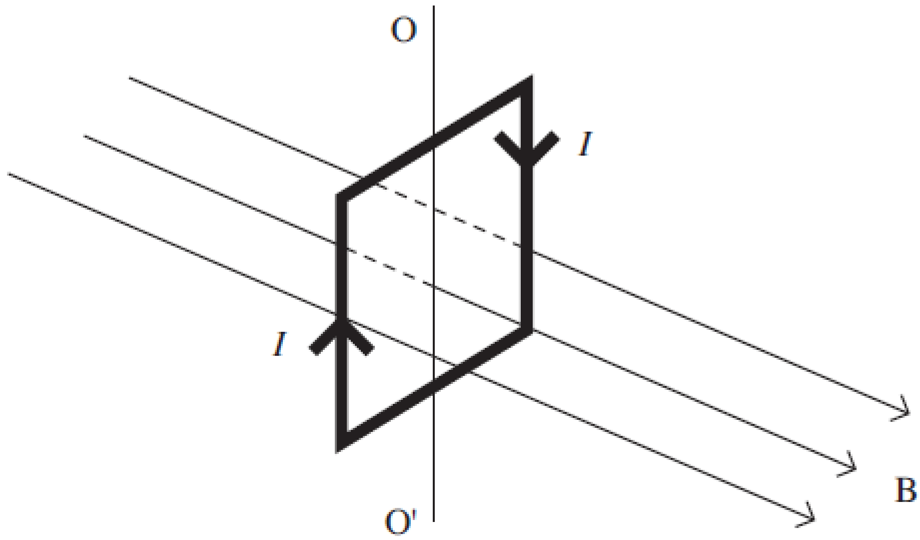
B 50%

C 84%

D 100%

(Total 1 mark)

20 The diagram shows a vertical square coil whose plane is at right angles to a horizontal uniform magnetic field B. A current, I, is passed through the coil, which is free to rotate about a vertical axis OO'.



Which one of the following statements is correct?

A The forces on the two vertical sides of the coil are equal and opposite.

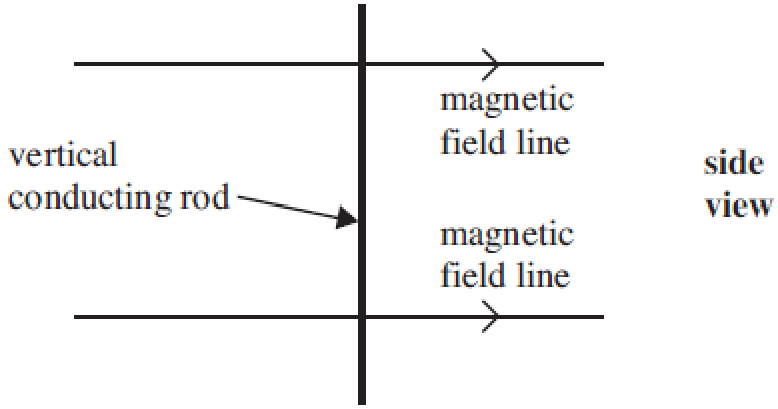
B A couple acts on the coil.

C No forces act on the horizontal sides of the coil.

D If the coil is turned through a small angle about OO' and released, it will remain in position.

(Total 1 mark)

21 A vertical conducting rod of length l is moved at a constant velocity v through a uniform horizontal magnetic field of flux density B.



Which line, **A** to **D**, in the table gives a correct expression for the induced emf for the stated direction of the motion of the rod?

	direction of motion	induced emf
A	vertical	$\frac{B}{lv}$
B	horizontal at right angles to the field	Blv
C	vertical	Blv
D	horizontal at right angles to the field	$\frac{B}{lv}$

(Total 1 mark)

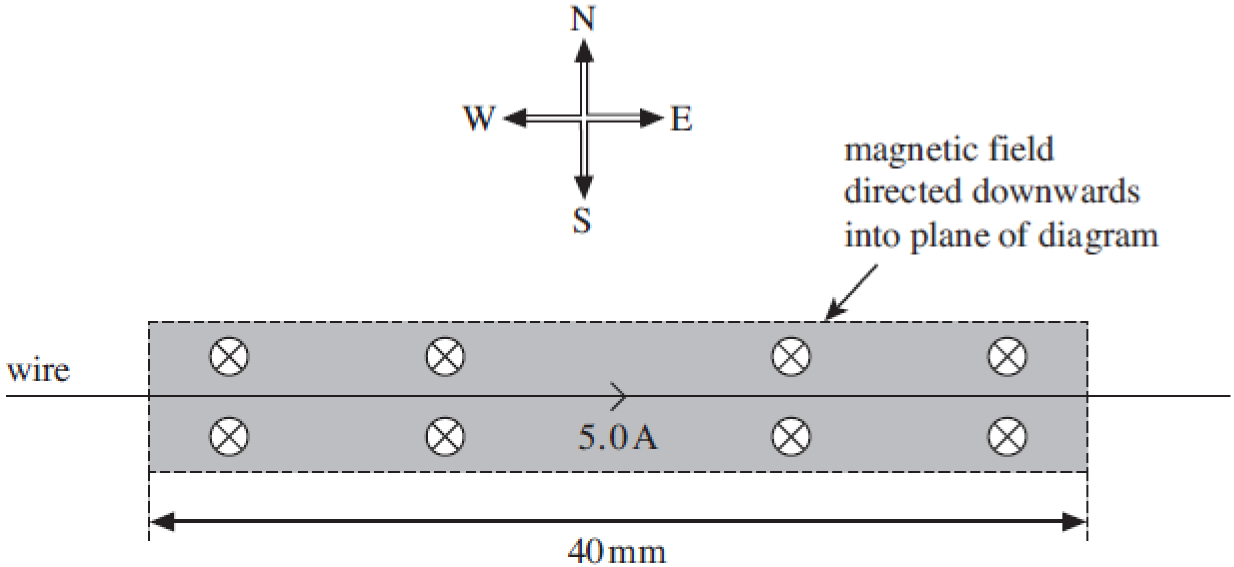
22 A transformer, which is not perfectly efficient, is connected to a 230 V rms mains supply and is used to operate a 12 V rms, 60 W lamp at normal brightness. The secondary coil of the transformer has 24 turns.

Which line, **A** to **D**, in the table is correct?

	number of turns on primary coil	rms current in primary coil
A	92	less than 0.26 A
B	92	more than 0.26 A
C	460	less than 0.26 A
D	460	more than 0.26 A

(Total 1 mark)

23 A horizontal straight wire of length 40 mm is in an east-west direction as shown in the diagram. A uniform magnetic field of flux density 50 mT is directed downwards into the plane of the diagram.



When a current of 5.0 A passes through the wire from west to east, a horizontal force acts on the wire. Which line, **A** to **D**, in the table gives the magnitude and direction of this force?

	magnitude / mN	direction
A	2.0	north
B	10.0	north
C	2.0	south
D	10.0	south

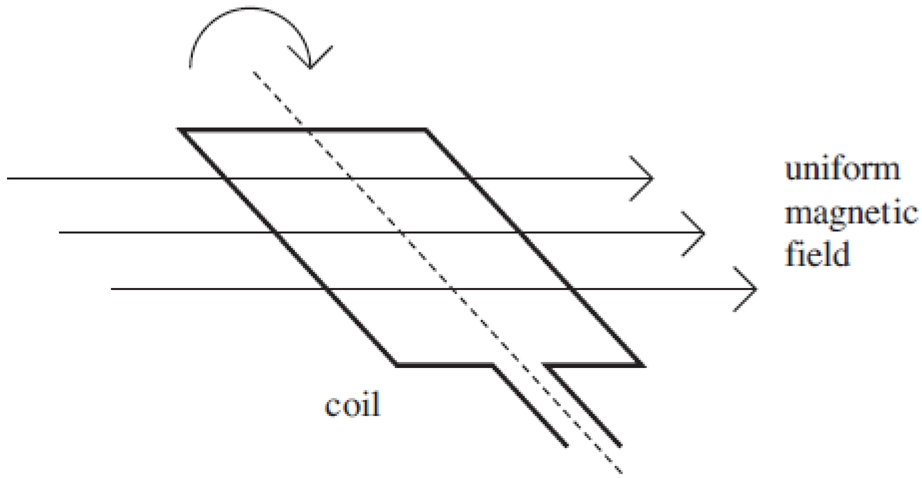
(Total 1 mark)

24 Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	uniform magnetic field
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

25 A rectangular coil is rotated in a uniform magnetic field.



When the coil is rotated at a constant rate, an alternating emf ε is induced in it. The variation of emf ε, in volts, with time t, in seconds, is given by

$$\varepsilon = 20 \sin (100 \pi t)$$

Which line, **A** to **D**, in the table gives the peak value ε_0 and the frequency f of the induced emf?

	ε_0 / V	f / Hz
A	10	50
B	10	100
C	20	50
D	20	100

(Total 1 mark)

26 The magnetic flux through a coil of 5 turns changes uniformly from 15×10^{-3} Wb to 7.0×10^{-3} Wb in 0.50 s. What is the magnitude of the emf induced in the coil due to this change in flux?

A 14 m V

B 16 m V

C 30 m V

D 80 m V

(Total 1 mark)

27 Which one of the following statements concerning power losses in a transformer is **incorrect**?

Power losses can be reduced by

A laminating the core.

B using high resistance windings.

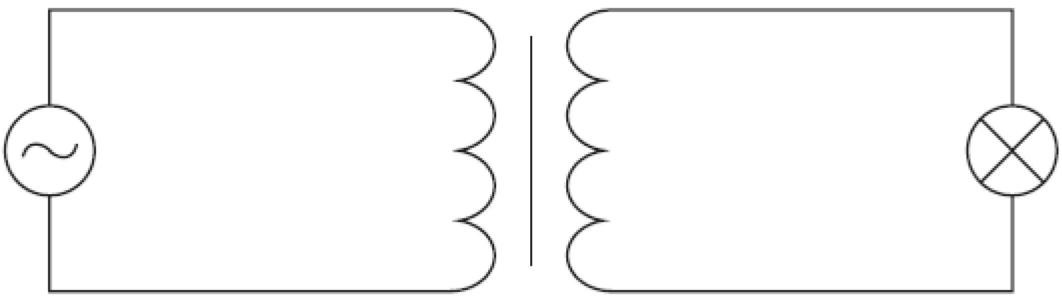
C using thick wire.

D using a core made of special iron alloys which are easily magnetised.

(Total 1 mark)

28 A transformer with 3000 turns in its primary coil is used to change an alternating pd from an rms value of 240 V to an rms value of 12 V.

When a 60 W, 12 V lamp is connected to the secondary coil, the lamp lights at normal brightness and a rms current of 0.26 A passes through the primary coil.



Which line, **A** to **D**, in the table gives correct values for the number of turns on the secondary coil and for the transformer efficiency?

	number of turns on the secondary coil	**efficiency**
A	150	96%
B	60 000	96%
C	150	90%
D	60 000	90%

(Total 1 mark)

29 A section of current-carrying wire is placed at right angles to a uniform magnetic field of flux density *B*. When the current in the wire is I, the magnetic force that acts on this section is *F*.

What force acts when the same section of wire is placed at right angles to a uniform magnetic field of flux density 2*B* when the current is 0.25 I?

A $\frac{F}{4}$

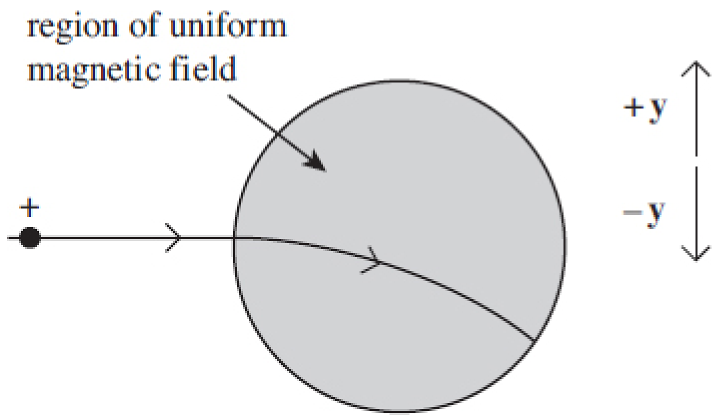
B $\frac{F}{2}$

C *F*

D *2F*

(Total 1 mark)

30 A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.



What is the direction of the magnetic field?

A out of the page and perpendicular to it

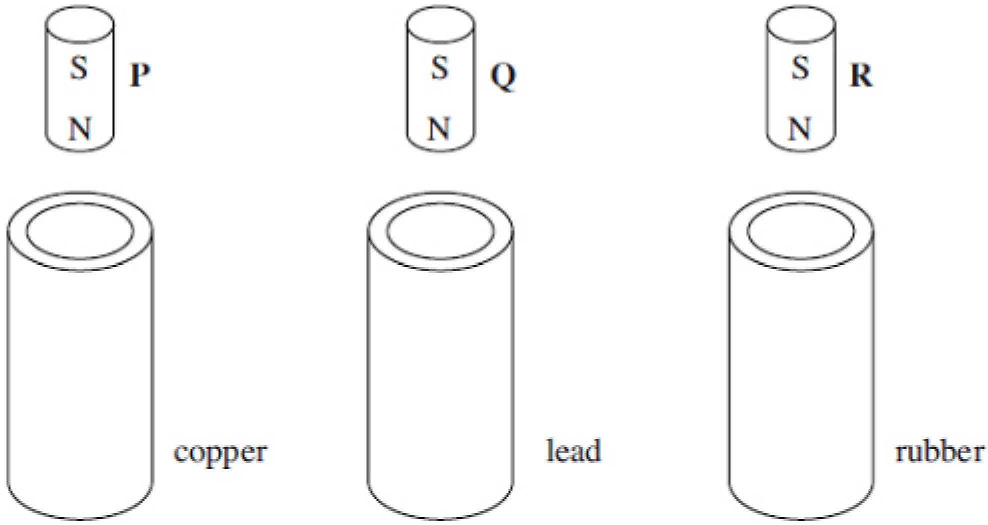
B into the page and perpendicular to it

C in the direction indicated by +*y*

D in the direction indicated by -*y*

(Total 1 mark)

31 Three vertical tubes, made from copper, lead and rubber respectively, have identical dimensions. Identical, strong, cylindrical magnets **P**, **Q** and **R** are released simultaneously from the same distance above each tube. Because of electromagnetic effects, the magnets emerge from the bottom of the tubes at different times.



Which line, **A** to **D**, in the table shows the correct order in which they will emerge?

resistivity of copper = 1.7×10^{-8} Ωm

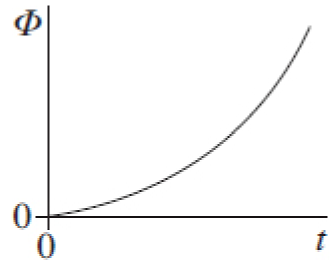
resistivity of lead = 22×10^{-8} Ωm

resistivity of rubber = 50×10^{13} Ωm

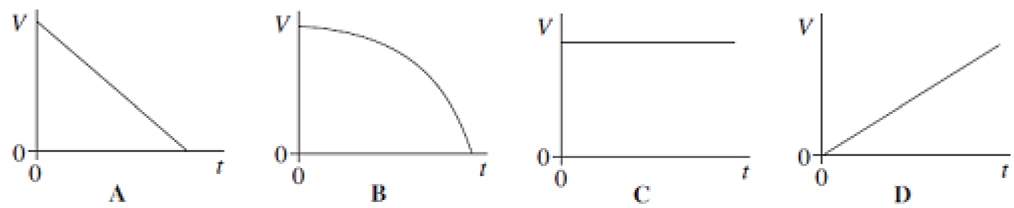
	emerges first	**emerges second**	**emerges third**
A	**P**	**Q**	**R**
B	**R**	**P**	**Q**
C	**P**	**R**	**Q**
D	**R**	**Q**	**P**

(Total 1 mark)

32 The graph shows how the magnetic flux, Φ, passing through a coil changes with time, t.

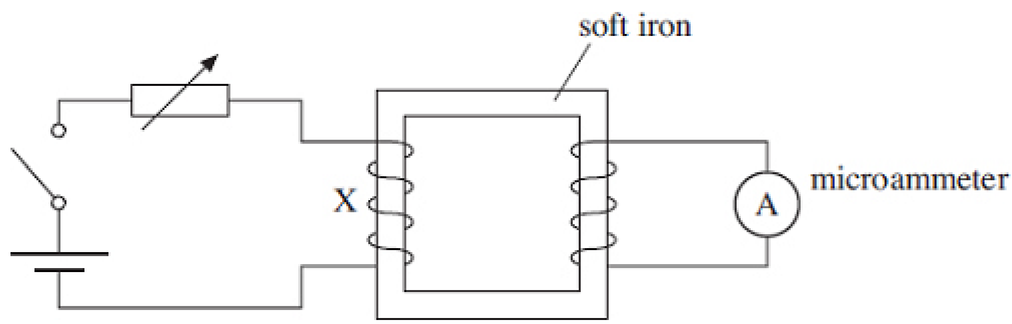


Which one of the following graphs could show how the magnitude of the emf, V, induced in the coil varies with t?



(Total 1 mark)

33 Using the circuit shown, and with the switch closed, a small current was passed through the coil X. The current was slowly increased using the variable resistor. The current reached a maximum value and was then switched off.



The maximum reading on the microammeter occurred when

A the small current flowed at the start.

B the current was being increased.

C the current was being switched off.

D the current in X was zero.

(Total 1 mark)

34 When a mobile phone is being recharged, the charger heats up. The efficiency of the transformer in the charger can be as low as 15% when drawing a current of 50 mA from a 230 V mains supply. If the charging current required is 350 mA, what is the approximate output voltage at this efficiency?

A 4.9 V

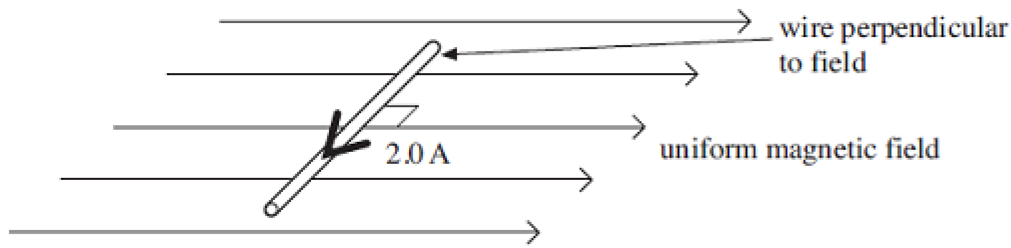
B 11 V

C 28 V

D 33 V

(Total 1 mark)

35 A horizontal straight wire of length 0.30 m carries a current of 2.0 A perpendicular to a horizontal uniform magnetic field of flux density 5.0×10^{-2} T. The wire 'floats' in equilibrium in the field.



What is the mass of the wire?

A 8.0×10^{-4} kg

B 3.1×10^{-3} kg

C 3.0×10^{-2} kg

D 8.2×10^{-1} kg

(Total 1 mark)

Mark schemes

1 B

[1]

2 A

[1]

3 B

[1]

4 C

[1]

5 **A**

[1]

6 **D**

[1]

7 **C**

[1]

8 **B**

[1]

9 A

[1]

10 **D**

[1]

11 B

[1]

12 A

[1]

13 C

[1]

14 B

[1]

15 B

[1]

16 D

[1]

17 D

[1]

18 A

[1]

19 C

[1]

20 A

[1]

21 B

[1]

22 D

[1]

23 B

[1]

24 A

[1]

25 C

[1]

26 D

[1]

27 B

[1]

28 A

[1]

29 B

[1]

30 A

[1]

31 D

[1]

32 D

[1]

33 C

[1]

34 A

[1]

35 B

[1]

Examiner reports

5 This question, concerning the magnitude and direction of the force acting on a current-carrying wire in a uniform magnetic field, was the easiest question (facility 88%). Evidently the application of $F = B\,I\,l$ together with Fleming's left hand rule caused few problems.

6 This question required students to decide through what angle (in rad), and in which direction, a coil should be rotated in order to achieve maximum and minimum values of flux linkage. 66% of them were successful. Distractor A, which was almost the exact opposite of the correct answer, was the most popular incorrect response.

7 A straightforward calculation of the emf induced in a moving straight conductor (using $\varepsilon = B\,l\,v$) was all that was needed. 68% of the students did this correctly. One in five of them selected distractor B, which could follow from an incorrect formula or substitution ($\varepsilon = B\,v/\,l$).

8 This question tested students' knowledge of the flux linkages and currents in the primary and secondary windings of a step-up transformer. The same question had been used in an earlier examination. The facility this time was 54%, up from 46% when used previously.

9 In this question the students needed to know that reversing the current in a wire placed in a magnetic field would reverse the direction of the force on it, and that doubling the current would double the force. 60% of the responses were correct, up from 41% the last time this question appeared in an examination. The most common incorrect answer was distractor D (22%), where the force would be doubled but not reversed.

10 This question, with a facility of 86%, was one of the easiest questions in this test. Students readily appreciated that the real reason that power lines are operated at high voltage is that this reduces the current, hence lowering joule heating losses from the cables.

11 This question gave the most surprising outcome because, although its facility of 54% was satisfactory, it was a very poor discriminator between the strongest and weakest students. The physics of the question is clear enough: the couple on the coil is proportional to its cross-sectional area. The puzzling outcome may have arisen because 39% of the answers were for distractor A. The ratios of the areas are actually 0.20, 0.25, 0.15 and 0.16 respectively, so why so many students selected 0.20 remains a mystery. Maybe they were put off by the greater length of the long side of the rectangle.

12 This question required students to understand the trajectory of an electron moving in electric and / or magnetic fields. 73% gave a correct response.

13 Calculation of the force acting on electrons moving in magnetic fields in relation to their kinetic energies was the basis of this question. Because the kinetic energy of X is half that of Y, it follows that $v_x = v_y / \sqrt{2}$ and that the ratio of the forces is $1 / \sqrt{2}$. The facility of this question was 54%; 18% of the students gave distractor A and 23% gave B.

14 This question was a transformer calculation that caused few problems. Its facility was 78% and it discriminated very well.

15 This question, which had been used in an earlier examination, had a facility of 60% in 2014. On the previous occasion its facility was 55%. It may be readily seen that the radius of the path of a moving charged particle in a magnetic field is proportional to momentum p and inversely proportional to charge Q. When both p and Q are doubled, the charge will continue in a path of the same radius. Incorrect responses were evenly spread between distractors A, C and D. This was the most discriminating question in the test.

16 This question required students to show an understanding of the meaning of the term *electromagnetic induction*. 69% were able to do so. Careful reading of the question was needed again here, because students had to choose an application where electromagnetic induction does not take place. 13% of the students considered that electromagnetic induction does *not* take place in power station generators (distractor A) – probably because they had mis-read the question.

17 The majority of the students knew that a faster moving magnet would induce a greater emf, and would pass through a vertical coil more rapidly, in this question. The facility of this question was 65%. One fifth of the answers selected distractor C, where the emf was greater but the time unchanged.

18 This question could be answered by knowing that the emf generated in a coil rotating in a magnetic field is given by $\varepsilon = BAN\omega \sin \omega t$, that and that $\omega = 2\pi f$. The maximum emf $\varepsilon_0 = BAN\omega$, which is (maximum flux linkage) × $2\pi f$. 59% of the answers were correct.

19 It is possible that the values chosen for three of the distractors in this question, on transformer efficiency, were so obviously wrong that there was no need for the students to perform any calculation. However, only 54% gave the correct response when the question was pre-tested in 2009. The 2014 A level students made amends for this, because the facility of the question was 87% this time.

20 This question has been used to test candidates in earlier years. The former one showed an improvement in facility and the latter one a deterioration. This question was about the magnetic forces that act on a coil which is free to rotate in a uniform magnetic field. 58% of the responses were correct. The most popular incorrect answer was distractor B. Candidates who chose this response had not spotted the fact that when the coil lies with its plane perpendicular to the field, the two forces on its sides act in opposite directions along the same straight line. Therefore they do not constitute a couple.

21 By far the majority of the students realised that the induced emf would be $B\,l\,v$. It was the direction of motion of the rod that caused a problem for the 30% who chose distractor C; evidently they did not realise that the rod would not cut field lines if it were to move vertically.

22 The question showed that most of the candidates were able to apply the turns ratio equation correctly, because over 80% of them selected $N_p = 460$. A simple conservation of power calculation would also show them that the primary current would be 0.26 A if the transformer was perfectly efficient. Since this transformer has an efficiency of less than 100%, the better candidates (51%) realised that the primary current had to be greater than 0.26 A.

23 This question dealt with various aspects of electromagnetism. The question required the application of $F = B\,I\,L$ together with Fleming's left hand rule. The facility was 75% and the most common incorrect response was distractor D – from those who could not decide the correct direction.

24 This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

25 This question tested the candidates' understanding of the peak voltage and frequency terms in the equation $\varepsilon = \varepsilon_0 \sin(2\pi f t)$ for a coil rotating at constant speed in a uniform magnetic field. This equation was not understood as well as might have been expected, because the facility was less than 60%. Common misapprehensions seem to have been that ε_0 represents the peak-to-peak voltage (because distractors A and B each attracted more than 10% of the responses) and that $2f$ represents the frequency (because distractor D attracted 17% of responses).

26 This question, which involved the direct application of $\varepsilon = \Delta N\Phi / \Delta t$, probably required less thought before committing a response. The facility of the question was 74%, an improvement of 10% over the last occasion when it appeared in an examination. Thinking that the induced emf is equal to the rate of change of *flux*, instead of *flux linkage*, probably caused 16% of the candidates to select distractor B.

27 This qestion was about transformers. Causes of power loss were well known in this question, where three quarters of the candidates evidently saw that using windings with higher resistance would have a detrimental effect.

28 This question tested both the turns ratio equation and efficiency; again there were few problems and the facility was 72%.

29 This question was a test of $F = BIl$ that, with a facility of 86%, proved to be the least demanding question in this Section A. When the question was pre-tested just over half of the students selected the correct response.Fleming's left hand rule, as applied to a beam of positive ions

30 This question 61% of the students could apply the rule correctly, but almost one quarter of them chose distractor B, where the magnetic field would have acted "down" into the page instead of "up" out of it.

31 This question on the emf generated by a moving magnet and the consequences of Lenz's law, had been used in a previous examination. The facility of 67% this time was slightly better than when it was last used. Curiously, the most common incorrect response was distractor A (chosen by 18%), where the order in which the magnet would emerge is the exact opposite of the correct order.

32 This question was a graphical test of the relationship between an induced emf and the rate of change of magnetic flux causing it. 59% of the students saw that the increasing gradient of the original graph had to imply that the emf would increase, and that therefore only graph D *could* be correct. 24% of the responses were for distractor B, where the emf is shown to decrease at an increasing rate.

33 This question needed students to spot that the most rapid change of flux in a transformer circuit occurs when a current is suddenly interrupted, leading to a maximum emf and (in this case) the largest current in the secondary circuit. A conventional car ignition system, now increasingly rare, illustrates this principle most effectively. The facility of the question was 43%, with 25% of the students opting for distractor B (when the primary current is steadily increased).

34 This question amounted to a traditional transformer efficiency question, but it was set in the context of a mobile phone charger circuit with low efficiency. The facility of the question was 71%. There was no strong distractor, and the question discriminated much better than it had done when pre-tested.

35 In this question the correct answer could be found by equating the weight of a section of wire to the magnetic force that acts on it when the wire carries a current at right angles to magnetic field. This was answered correctly by 75% if the students. Distractor C, where the mass was approximately 9.8 times the expected mass, was the choice of almost one in five. This suggests that the students involved equated the mass of the wire with the magnetic force, forgetting *g*.