1 When a β particle moves at right angles through a uniform magnetic field it experiences a force F. An α particle moves at right angles through a magnetic field of twice the magnetic flux density with velocity one tenth the velocity of the β particle. What is the magnitude of the force on the α particle?

A 0.2 F

B 0.4 F

C 0.8 F

D 4.0 F

(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 500 turn coil of cross-sectional area 4.0×10^{-3} m^2 is placed with its plane perpendicular to a magnetic field of flux density 7.5×10^{-4} T. What is the value of the flux linkage for this coil?

A 3.0×10^{-6} Wb turns

B 1.5×10^{-3} Wb turns

C 0.19 Wb turns

D 94 Wb turns

(Total 1 mark)

4 The output electromotive force (emf) of a simple ac generator can be increased by any of the four factors listed.

Which one of these factors should **not** be changed if the frequency of the output is to remain unaffected when the emf is increased?

A the area of the coil
B the number of turns on the coil
C the speed of rotation
D the strength of the magnetic field

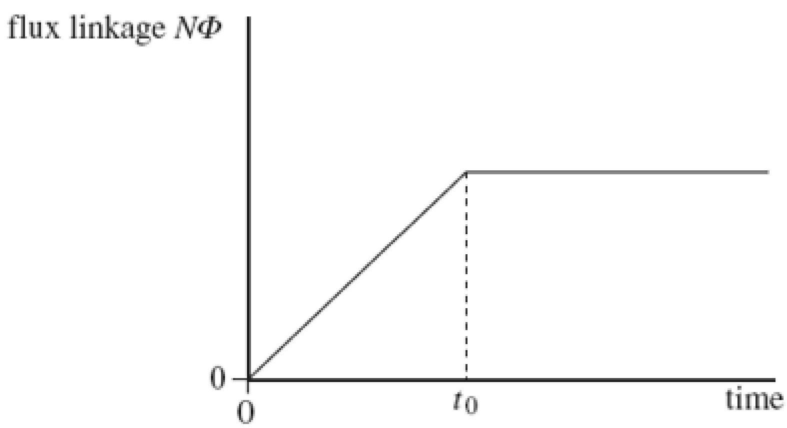
(Total 1 mark)

5 Which one of the following would **not** reduce the energy losses in a transformer?

A using thinner wire for the windings
B using a laminated core instead of a solid core
C using a core made from iron instead of steel
D using a core that allows all the flux due to the primary coil to be linked to the secondary coil

(Total 1 mark)

6 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 increases then becomes constant after time t_0.

B is constant then becomes zero after time t_0.

C is zero then increases after time t_0.

D decreases then becomes zero after time t_0.

(Total 1 mark)

7 Two charged particles, P and Q, move in circular orbits in a magnetic field of uniform flux density. The particles have the same charge but the mass of P is less than the mass of Q. T_P is the time taken for particle P to complete one orbit and T_Q the time for particle Q to complete one orbit. Which one of the following is correct?

A $T_P = T_Q$

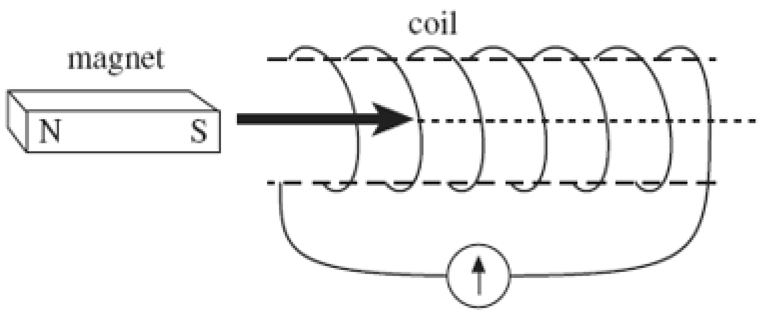
B $T_P > T_Q$

C $T_P < T_Q$

D $T_P - T_Q = 1$

(Total 1 mark)

8 A bar magnet is pushed into a coil connected to a sensitive ammeter, as shown in the diagram, until it comes to rest inside the coil.



Why does the ammeter briefly show a non-zero reading?

A The magnetic flux linkage in the coil increases then decreases.

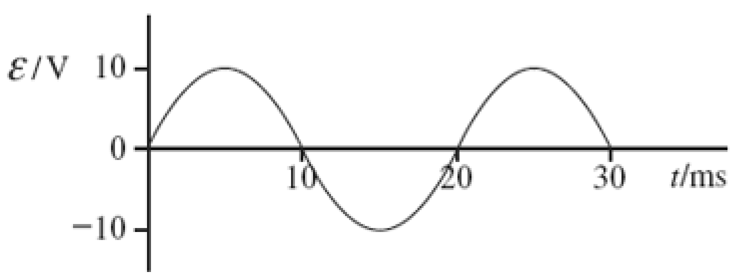
B The magnetic flux linkage in the coil increases then becomes constant.

C The magnetic flux linkage in the coil decreases then increases.

D The magnetic flux linkage in the coil decreases then becomes constant.

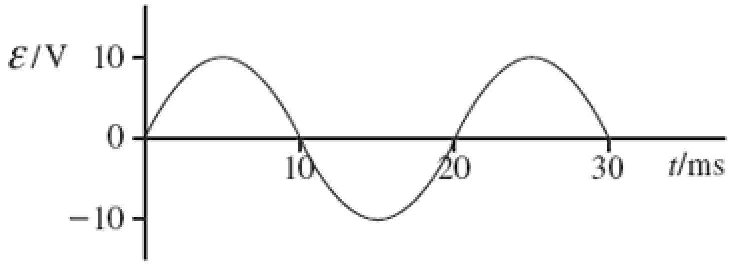
(Total 1 mark)

9

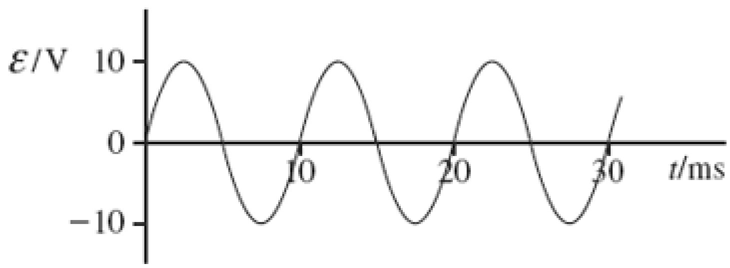


The above graph shows how the output emf, ε, varies with time, t, for a coil rotating at angular speed ω in a uniform magnetic field of flux density B. Which one of the following graphs shows how ε varies with t when the same coil is rotated at angular speed 2ω in a uniform magnetic field of flux density 0.5 B?

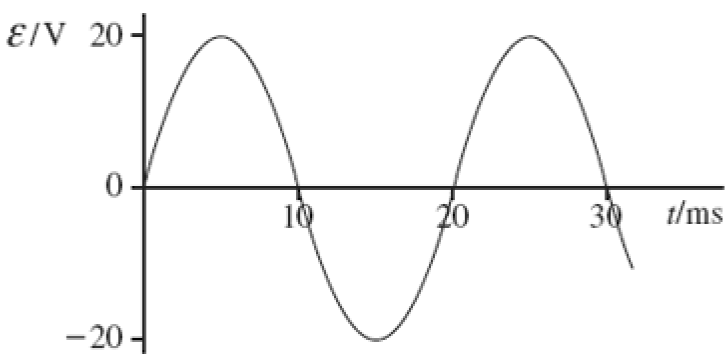
A



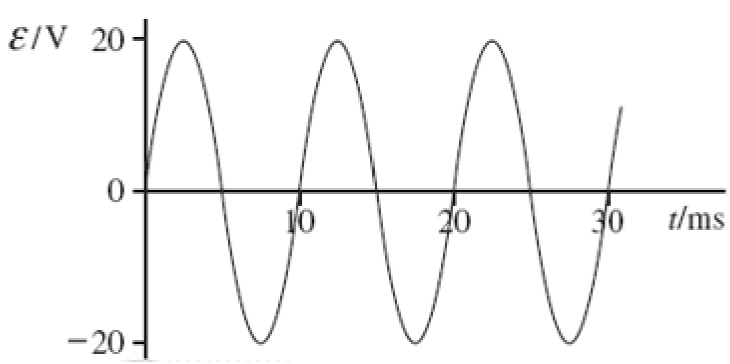
B



C



D



(Total 1 mark)

10 Which one of the following is **not** a cause of energy loss in a transformer?

A good insulation between the primary and secondary coil

B induced currents in the soft iron core

C reversal of magnetism in the soft iron core

D resistances in the primary and secondary coil

(Total 1 mark)

11 A negatively charged particle moves at right angles to a uniform magnetic field. The magnetic force on the particle acts

A in the direction of the field.

B in the opposite direction to that of the field.

C at an angle between 0° and 90° to the field.

D at right angles to the field.

(Total 1 mark)

12 An electron moving with a constant speed enters a uniform magnetic field in a direction perpendicular to the magnetic field. What is the shape of the path that the electron would follow?

A parabolic

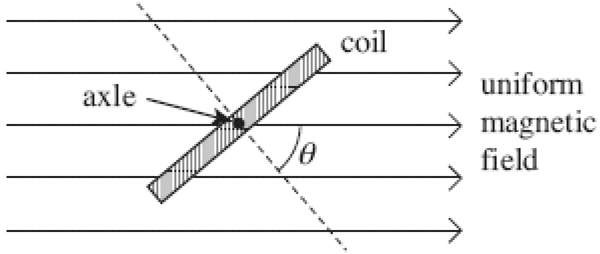
B circular

C elliptical

D a line parallel to the magnetic field

(Total 1 mark)

13



A coil of 50 turns has a cross-sectional area of 4.2×10^{-3} m^2. It is placed at an angle to a uniform magnetic field of flux density 2.8×10^{-2} T, as shown in the diagram, so that angle $\theta = 50°$.

What is the change in flux linkage when the coil is rotated anticlockwise until $\theta = 0°$?

A The flux linkage decreases by 2.1×10^{-3} Wb turns.

B The flux linkage increases by 2.1×10^{-3} Wb turns.

C The flux linkage decreases by 3.8×10^{-3} Wb turns.

D The flux linkage increases by 3.8×10^{-3} Wb turns.

(Total 1 mark)

14 An aircraft, of wing span 60 m, flies horizontally at a speed of 150 m s^{-1}. If the vertical component of the Earth's magnetic field in the region of the plane is 1.0×10^{-5} T, what is the magnitude of the magnetic flux cut by the wings in 10 s?

A 1.0×10^{-5} Wb

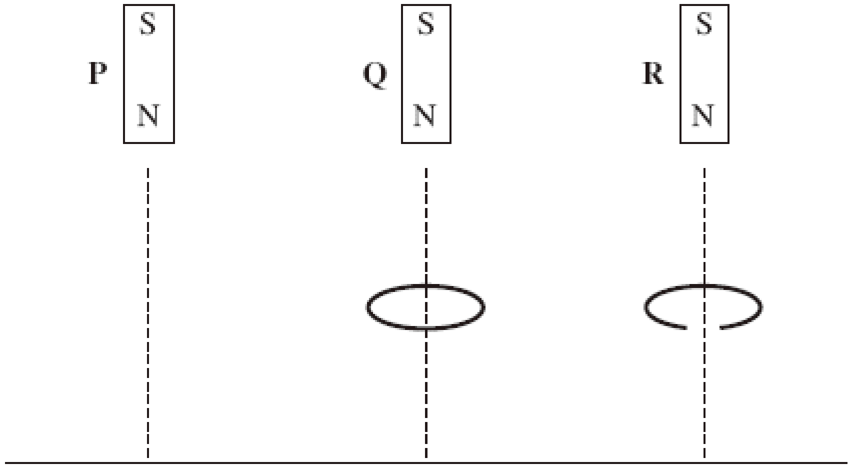
B 1.0×10^{-4} Wb

C 9.0×10^{-2} Wb

D 9.0×10^{-1} Wb

(Total 1 mark)

15



Three identical magnets **P**, **Q** and **R** are released simultaneously from rest and fall to the ground from the same height. **P** falls directly to the ground, **Q** falls through the centre of a thick conducting ring and **R** falls through a ring which is identical except for a gap cut into it. Which one of the statements below correctly describe the sequence in which the magnets reach the ground?

A **P** and **R** arrive together followed by **Q**.

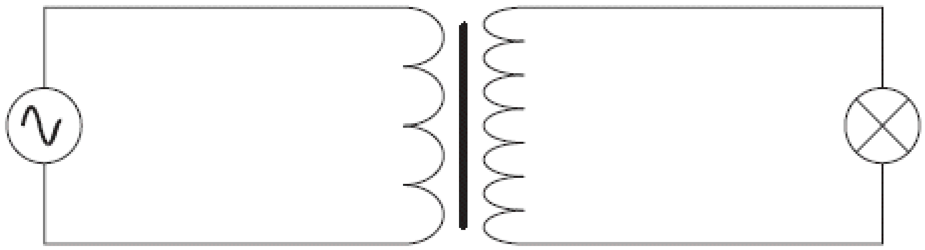
B **P** and **Q** arrive together followed by **R**.

C **P** arrives first, follow by **Q** which is followed by **R**.

D All three magnets arrive simultaneously.

(Total 1 mark)

16 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 flux linkage and current through the secondary coil in relation to the primary coil?

	$\frac{\text{secondary magnetic flux linkage}}{\text{primary magnetic flux linkage}}$	$\frac{\text{secondary current}}{\text{primary current}}$
A	>1	<1
B	<1	<1
C	>1	>1
D	<1	>1

(Total 1 mark)

17 A transformer has 1200 turns on the primary coil and 500 turns on the secondary coil. The primary coil draws a current of 0.25 A from a 240 V ac supply. If the efficiency of the transformer is 83%, what is the current in the secondary coil?

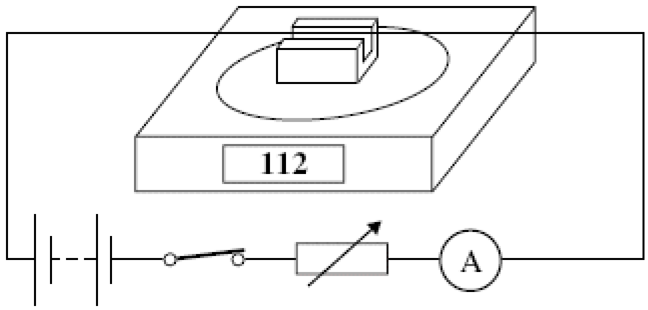
A 0.10 A

B 0.21 A

C 0.50 A

D 0.60 A

18 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, reads 112 g after the switch is closed. If the current is reversed and doubled, what will be the new reading on the balance?

A –224 g

B –112 g

C zero

D 224 g

(Total 1 mark)

19 An electron moving with a constant speed enters a uniform magnetic field in a direction at right angles to the field. What is the subsequent path of the electron?

A A straight line in the direction of the field.

B A straight line in a direction opposite to that of the field.

C A circular arc in a plane perpendicular to the direction of the field.

D An elliptical arc in a plane perpendicular to the direction of the field.

(Total 1 mark)

20 Which one of the following could **not** be used as a unit of force?

A A T m

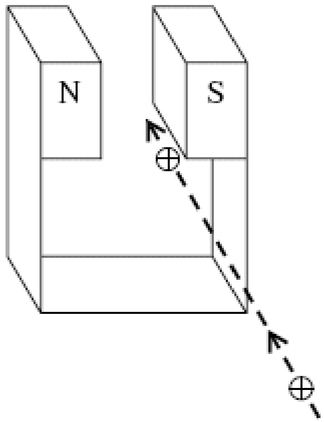
B W s^{-2}

C kg m s^{-2}

D J m^{-1}

(Total 1 mark)

21 A jet of air carrying positively charged particles is directed horizontally between the poles of a strong magnet, as shown in the diagram.



In which direction are the charged particles deflected?

A upwards

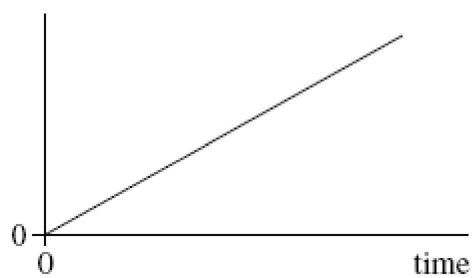
B downwards

C towards the N pole of the magnet

D towards the S pole of the magnet

(Total 1 mark)

22 The graph shows how the magnetic flux passing through a loop of wire changes with time.



What feature of the graph represents the magnitude of the emf induced in the coil?

A the area enclosed between the graph line and the time axis

B the area enclosed between the graph line and the magnetic flux axis

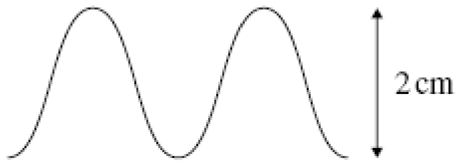
C the inverse of the gradient of the graph

D the gradient of the graph

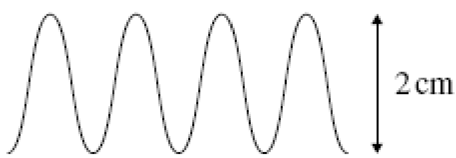
(Total 1 mark)

23 A coil rotating in a magnetic field produces the following voltage waveform when connected to an oscilloscope.

With the same oscilloscope settings, which one of the following voltage waveforms would be produced if the coil were rotated at twice the original speed?

A 

B 

C 

D 

(Total 1 mark)

24 A 230 V, 60 W lamp is connected to the output terminals of a transformer which has a 200 turn primary coil and a 2000 turn secondary coil. The primary coil is connected to an ac source with a variable output pd. The lamp lights at its normal brightness when the primary coil is supplied with an alternating current of 2.7 A.

What is the percentage efficiency of the transformer?

A 3%

B 10%

C 97%

D 100%

(Total 1 mark)

25 An electron moves due North in a horizontal plane with uniform speed. It enters a uniform magnetic field directed due South in the same plane. Which one of the following statements concerning the motion of the electron in the magnetic field is correct?

A It accelerated due West.

B It slows down to zero speed and then accelerates due South.

C It continues to move North with its original speed.

D It is accelerated due North.

(Total 1 mark)

26 Particles of mass *m*, each carrying charge *Q* and travelling with speed *v*, enter a magnetic field of flux density *B* at right angles. Which one of the following changes would produce an increase in the radius of the path of the particles?

A an increase in *Q*

B an increase in *m*

C a decrease in *v*

D an increase in *B*

(Total 1 mark)

27 The magnetic flux through a coil of *N* turns is increased uniformly from zero to a maximum value in a time *t*. An emf, *E*, is induced across the coil.
What is the maximum value of the magnetic flux through the coil?

A $\frac{Et}{N}$

B $\frac{N}{Et}$

C $E\,t\,N$

D $\frac{E}{Nt}$

(Total 1 mark)

28 An aircraft, of wing span 60 m, flies horizontally at a speed of 150 m s^{-1}, If the vertical component of the Earth's magnetic field in the region of the plane is 1.0×10^{-5} T, what emf is induced across the wing tips of the plane?

A 0.09 V

B 0.90 V

C 9.0 V

D 90 V

(Total 1 mark)

29 Particles of mass *m* carrying a charge *Q* travel in a circular path of radius *r* in a magnetic field of flux density *B* with a speed *v*. How many of the following quantities, if changed one at a time, would change the radius of the path?

- *m*
- *Q*
- *B*
- *v*

A one

B two

C three

D four

(Total 1 mark)

30 Protons, each of mass *m* and charge *e*, follow a circular path when travelling perpendicular to a magnetic field of uniform flux density *B*. What is the time taken for one complete orbit?

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

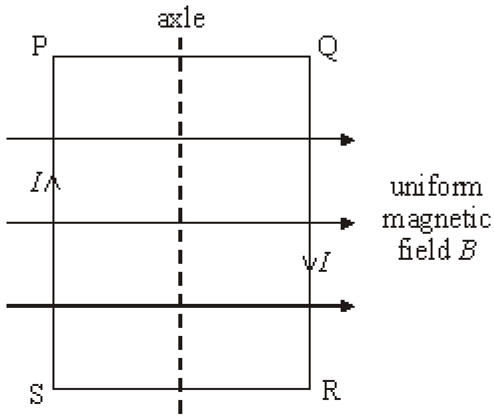
B $\frac{m}{2\pi eB}$

C $\frac{eB}{2\pi m}$

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

(Total 1 mark)

31



A coil, mounted on an axle, has its plane parallel to the flux lines of a uniform magnetic field *B*, as shown. When a current *I* is switched on, and before the coil is allowed to move,

A there are no forces due to *B* on the sides PQ and RS.

B there are no forces due to *B* on the sides SP and QR.

C sides SP and QR attract each other.

D sides PQ and RS attract each other.

(Total 1 mark)

32 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 $\frac{r}{2}$

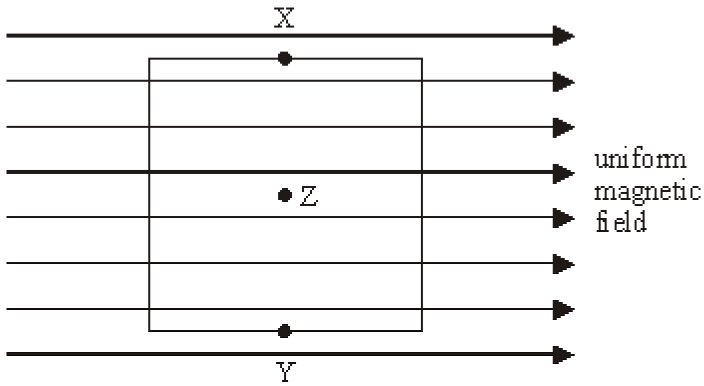
B r

C $2r$

D $4r$

(Total 1 mark)

33



The diagram shows a square coil with its plane parallel to a uniform magnetic field. Which one of the following would induce an emf in the coil?

A movement of the coil slightly to the left

B movement of the coil slightly downwards

C rotation of the coil about an axis through XY

D rotation of the coil about an axis perpendicular to the plane of the coil through Z

(Total 1 mark)

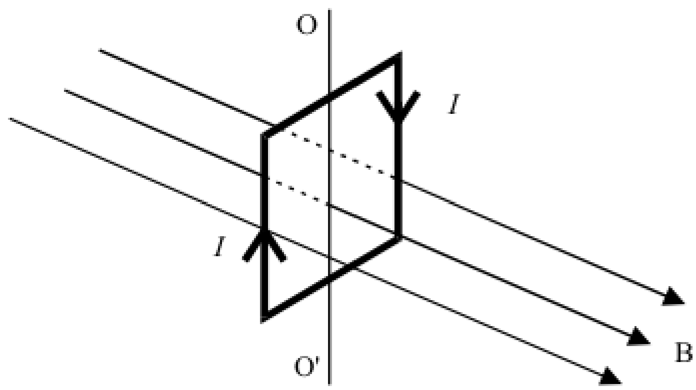
34

Which line, **A** to **D**, correctly describes the trajectory of charged particles which enter, at right angles, (a) a uniform electric field, and (b) a uniform magnetic field?

	(a) uniform electric field	(b) uniform magnetic field
A	circular	circular
B	circular	parabolic
C	parabolic	circular
D	parabolic	parabolic

(Total 1 mark)

35 The diagram shows a vertical square coil whose plane is at right angles to a horizontal uniform magnetic field B. A current, *I*, flows in the coil, which can 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', it will remain in position.

(Total 1 mark)

Mark schemes

1 B **[1]**

2 A **[1]**

3 B **[1]**

4 C **[1]**

5 A **[1]**

6 B **[1]**

7 C **[1]**

8 B **[1]**

9 B **[1]**

10 A **[1]**

11 D **[1]**

12 B **[1]**

13 B **[1]**

14 D **[1]**

15 A **[1]**

16 A **[1]**

17 C **[1]**

18 A [1]

19 C [1]

20 B [1]

21 B [1]

22 D [1]

23 C [1]

24 C [1]

25 C [1]

26 B [1]

27 A [1]

28 A [1]

29 D [1]

30 B [1]

31 A [1]

32 B [1]

33 C [1]

34 C [1]

35 A [1]

Examiner reports

1 This question had the unusual outcome that one of the distractors (A) was slightly more popular than the correct answer (B). This had not happened when the question was pre-tested. No doubt the mistake made by students who chose distractor A was to forget that the charge of an α particle is +2e, not +e. The question had a facility of 44%.

2 This question was a fairly standard test of the algebraic equations which govern the motion of a charged particle as it moves through a magnetic field at right angles, but involving the frequency of rotation around the circle. Almost 70% of the students selected the correct response.

3 The remaining three questions all tested aspects of electromagnetism.This question which, with a facility of 89% was the easiest in the test, was a straightforward calculation of flux linkage for a coil in a magnetic field.

4 This question which were each correctly answered by just over three-quarters of the students, respectively tested the rotating coil and energy losses in a transformer.

5 This question which were each correctly answered by just over three-quarters of the students, respectively tested the rotating coil and energy losses in a transformer.

6 This question required candidates to know that an induced emf is proportional to the rate of change of flux linkage. Almost one-third of the candidates considered it to be proportional to the flux linkage, distractor A. 56% of the responses were correct, whilst very few chose alternatives C or D.

7 This question concerned the time period of charged particles moving in a circular orbit in a magnetic field. Its facility was 55% but distractors A and B were each selected by more than 20% of candidates. Successful solutions required $mv^2/r = BQv$ to be combined with $T = 2\pi r / v$.

8 In this question a large proportion of candidates did not realise that the flux linkage increases to a constant value once the magnet is at rest inside the coil, and therefore selected the incorrect distractor A. 43% gave the correct response.

9 Electromagnetic induction continued to cause difficulty in this question, which had a facility of 40%. Candidates should have noticed that, although the speed of rotation of the coil was doubled, the flux density was halved. This has the net effect of leaving the peak emf unchanged whilst the frequency is doubled. 30% of the candidates realised that the frequency would be doubled but thought the peak emf would also double (distractor D).

10 The facts about energy losses in transformers were well known in this question, where 73% of candidates gave the correct answer. The strongest incorrect distractor was C, suggesting that the energy losses caused by magnetic hysteresis are not always recognised.

11 This question, with facilities of 67%, was about charged particles moving at right angles to a magnetic field. Relatively few candidates chose any one of the incorrect responses in the question.

12 This question, with facilities of 62%, was about charged particles moving at right angles to a magnetic field. Distractor A (parabolic path) attracted 29% of the responses.

13 This was the most demanding question in the test, about the change in flux linkage when a coil is rotated in a magnetic field. 40% of the responses to this question were correct. Distractors C and D were each selected by almost a quarter of the candidates; this is probably because they considered the flux linkage to be zero when the plane of the coil was perpendicular to the magnetic field.

14 The most common incorrect response was distractor C, which accounted for 25% of the answers. This wrong choice is likely to have been caused by trying to work out the emf across the wing tips of a moving aircraft using the equation $E = B L v$, rather than finding the magnetic flux cut by the wing of a moving aircraft, as required by the question. However, 59% of the candidates chose the correct answer. This question discriminated well between the most able and the least able candidates.

15 This question had been used in a previous examination. Its facility in 2011 was 82%, an improvement on the previous result of over 10%. Evidently, the candidates this time readily recognised that the falling magnet would lose energy to the conducting ring only when the ring was complete, enabling the emf induced in it to cause a current.

16 A fairly demanding test of candidates' knowledge of transformers; slightly fewer than half of them selected the correct answer. Among the incorrect responses, distractor C was a common choice (23%), showing that the flux linkage ratio was better understood than the current ratio.

17 Transformers were also the subject under test, where 68% of the responses were correct. This was a fairly straightforward calculation involving transformer efficiency.

18 This question involved a basic current balance and assumed familiarity with $F = B I l$. The simple idea here was that reversing the current and doubling it would produce a force in the opposite direction that would be twice the original. This eluded so many of the candidates that only 41% of them could select the correct response, whilst many of them chose distractors C or D.

19 The principles of the magnetic deflection of an electron beam by a magnetic field were well understood in this question, where 73% of the candidates made the correct choice. Almost one in five candidates chose distractor D, an obvious confusion over the shape of the curved path.

20 This question contained a synoptic element, because two of the unit combinations quoted were mechanical. The facility of the question was 44%.

Overlooking the word not in the stem of the question presumably caused 34% of the candidates to choose distractor A, where $F = B I l$ ought to have shown that A T m is a correct unit of force.

21 This question could be answered by applying Fleming's left hand rule to a beam of positive ions. Around half of the responses were correct, but a quarter were for distractor A (which was upwards, instead of downwards).

22 This question was easy, with a facility of 73%. It was a direct test of $\varepsilon = N (\Delta\Phi/\Delta t)$ in a graphical context. The most common incorrect answer was distractor A.

23 A coil which was rotating in a magnetic field was the subject being tested in this question. This was successfully answered by 57% of the candidates. Incorrect answers were almost equally divided between distractors A and B, with very few for distractor D.

24 Knowledge of the efficiency of a transformer was tested in this question, which had a facility of 58%. The output power from the transformer must have been 60 W, because the lamp was lit at its normal brightness. The turns ratio indicated that the primary voltage was 23 V, whilst the question stated that the primary current was 2.7 A. Hence the input power could be found using $2.7 \times 23 = 62.1$ W. 25% of the candidates chose the incorrect distractor B.

25 The magnetic force on a moving electron was tested in this question, but this time qualitatively instead of quantitatively. Since this electron was moving anti-parallel to the magnetic field through which it was travelling, it would experience no magnetic force. Therefore, its motion would not be affected by the *B* field. 45% of candidates appreciated this (answer C), but 21% thought it would grind to a halt and set off in the opposite direction (distractor B) whilst 18% thought it would accelerate in its original direction (distractor D). Confusion with the effects of electric fields is evident in these incorrect responses.

26 This question looked at factors that might increase the radius of curvature of charged particles following a circular arc in a *B* field. The facility of this question was 63%, and incorrect responses were fairly equally spread.

27 This question moved on to electromagnetic induction and tested $E = N\,\Delta\Phi/\Delta t$ for a uniform rate of change of magnetic flux. 72% of the responses were correct. Like questions 22 and 23, this question was a very good discriminator.

28 The uniform rate of change of flux experienced by an aircraft wing in steady horizontal flight, leading to an emf across the wing tips, was considered in this question. This had a facility of 71%. No doubt arithmetical errors were the cause of 13% of the candidates choosing distractor B, and 11% choosing distractor C.

29 This question required candidates to be familiar with the factors that affect the radius of the path followed by a charged particle in a magnetic field. 58% of the candidates spotted that all four factors would change the radius, but 27% thought that only three would matter (distractor C). This question was the best discriminator in the test.

30 Difficulties over rearrangement of the algebra no doubt caused 20% of the candidates to choose distractor A and 13% distractor C in this question, but the facility was still 55%. This was another two-stage calculation, where Bev, mv^2/r and $2\pi r/v$ were all to be combined to find the time for one orbit of a proton in a magnetic field.

31 This question was correctly answered by 61% of the candidates. It involved the topic, familiar from previous tests, of the forces acting on the sides of a current-carrying coil when in a uniform magnetic field. This is another question that had been re-banked after use in an earlier PA04 test, when the facility had been only 53%. Evidently, a greater majority were able this time to spot that sides PQ and RS would experience no forces when *I* and *B* are parallel, but distractors C and B were chosen by 18% and 15% respectively.

33 This question was answered correctly by 60% of the candidates. Electromagnetic induction involves three-dimensional thinking, and it is likely that the 24% who chose distractor D experienced difficulty in visualising the meaning of the words in the statement for this distractor.

34 Trajectories of charged particles as they pass through electric and magnetic fields ought to be a fairly simple topic, but the facility of this question improved only slightly, from 55% to 57%, between pre-test and examination. Candidates who did not understand these topics were attracted in almost equal numbers to distractors B and D.

35 This question, on the forces which act on a current-carrying coil in a magnetic field, had a facility of 63%, which was a substantial improvement on the pre-examination facility. It was not a particularly effective discriminator.