Mark schemes

1 (a) (i) 230 × √2 = 325 (V) ✓

(2 × 325 =) 650 to 651 V ✓

allow doubling their incorrect peak voltage (162.6 × 2) by use of $\sqrt{2}$
2 as an attempt to find peak-to-peak for 1 mark but not just 2 × 230

2

(ii) *(use of $P = V^2/R$)*

$P = 230^2/12$ ✓

$P = 4.4 \times 10^3$ (W)✓ cao

2 sig. figs. Incorrect answer must be supported by working ✓

Allow their incorrect answer (a)(i)^2 ÷ 12

Or *325^2 ÷ 12 as a use of for 1 mark*

Alternative

For first mark

$I = \frac{V}{R}$ ***and*** *P=VI allowing their incorrect answer*

(a)(i) or 325 as sub for V for 1 mark

Answers 8.8 kW (325V) and 35 kW (650V)

3

(b) (i) there is a pd / voltage across the cable ✓

pd / voltage across cooker is 230 V minus this pd / voltage ✓

2nd mark depends on 1st mark in all

The current is lower due to the resistance of cable / The current is lower as circuit resistance increases ✓

pd across oven is lower since V=I × Resistance of element ✓

or

Resistance of the cable is in series with element ✓

Voltage splits (in ratio) across these resistances ✓

2

(ii) resistance of cable = 2 × 3.15 × 0.0150 = 0.0945 ✓

Allow power 10 error here

$V = \frac{12}{12 + R_{cable}} \times 230$ ✓

Or $I = \frac{230}{12 + R_{cable}}$ **and** $V = \left(\frac{230}{12 + R_{cable}}\right) \times 12$

=228 V ✓ cao

Allow their incorrect R_{cable} correctly substituted for 2nd marking

3

(iii) 230 − their (b) (ii) or 19 (A) quoted for current or equivalent seen in equation (230 / 12.0945) ✓

(P =) 34.2 to 42.3(W) ✓ correct working

ecf as P = (230- (b)(ii))^2 / their R_{cable}

2

(iv) minimise power loss / maximise efficiency of oven / ensure element gets as hot as possible ✓
avoid overheating / fires ✓

not just to carry a large current / larger pd across element

Either order

2

[14]

2 (a) (i) graph showing two pulses one at start and the other at the end with no emf between the pulses

Positive and negative pulses shown

Similar shaped 'curved' pulses : negative between 0 and 0.22 ± 0.02 s and positive pulse 0.58 ± 0.02 and 0.8

3

(ii) emf induced when the flux is changing or induced emf depends on the rate of change of flux

emf induced when flux changes between 0 and 0.2(2) s and / or between 0.6(0.58)s and 0.8 s
OR
no change in flux between 0.2 and 0.6 so no induced emf

Induced emf / current produces a field to oppose the change producing it.

Flux linking bracelet increases as the bracelet enters the field produced by C and decreases as it leaves so opposite emfs

4

(b) (Takes 0.21 s or 0.22 s for flux to change from 0 to maximum so)
diameter = 0.28 × 0.21 = 0.059 (0.588) (m)
or 0.28 × 0.22 = 0.062 (0.616) (m)

must be to at least 2sf

1

(c) Area of bracelet = 3.14×0.031^2

$B = 1120 \times 10^{-6} / (3.14 \times 0.031^2) = 0.38$ (T)
B = 0.40 T if 3 cm used for radius

Condone incorrect power of 10

Allow answers in range 0.38T to 0.41 T (depends on value used for r)

2

(d) Use of steepest gradient of graph or tangent drawn on Figure 2
Correct data from tangent or points on the steepest part of the graph
10 to 11 mV

3

[13]

3 (a) (i) meter deflects then returns to zero ✓
current produces (magnetic) field / flux ✓
change in field / flux through Q induces emf ✓
induced emf causes current in Q (and meter) ✓

Deflection to right (condone left) then zero is equivalent to 1st mark.

Accept momentary deflection for 1^{st} point.

"Change in field / flux <u>induces</u> current in Q" is just ✓ from the last two marking points.

max 3

(ii) meter deflects in opposite direction (or to left, or ecf) ✓
field / flux through P is reduced ✓
induces emf / current in opposite direction ✓

Ignore references to magnitude of deflection.

max 2

(b) (i) flux linkage ($= n\Phi = nBA$) $= 40 \times 0.42 \times 3.6 \times 10^{-3}$
$= 6.0(5) \times 10^{-2}$ ✓

Unit mark is independent.

Allow 6×10^{-2}.

Wb turns ✓

Accept 60 mWb turns if this unit is made clear.

Unit: allow Wb.

2

(ii) change in flux linkage = $\Delta(n\Phi)$= 6.05 × 10^{-2} (Wb turns) ✓

induced emf $\left(=\frac{\Delta(n\phi)}{\Delta t}\right)=\frac{6.05\times10^{-2}}{0.50}$ = 0.12(1) (V) ✓

Essential to appreciate that 6.05 × 10^{-2} is change in flux linkage for 1st mark. Otherwise mark to max 1.

2

[9]

4 (a) emf = Δ*(BAN) / t*
Change in flux = *A* × Δ*B* or 12 × (23 − 9) seen

C1

Substitution ignoring powers of 10

C1

1.2 V

A1

3

(b) Reduced

M0

Magnet will move (with the case)

A1

Increased

M0

Flux <u>linkage increases</u> or emf is proportional to *N*

A1

2

(c) (i) Formula used

$2\pi\sqrt{\frac{8\times10^{-3}}{2.6}}$ seen

B1

0.348 / 0.349 seen to at least 3 sf

B1

2

(ii) Period consistent at 0.35 s or V_o = 8 V

B1

Shape shows decreasing amplitude

M1

At least 3 cycles starting at 8 V

A1

3

[10]

5 (a) (i) force acts towards left or in opposite direction to field lines ✓
because ion (or electron) has negative charge
(∴ experiences force in opposite direction to field) ✓

Mark sequentially.
Essential to refer to negative charge (or force on + charge is to right) for 2^{nd} mark.

2

(ii) (use of *W* = *F* s gives) force $F = \dfrac{4.0 \times 10^{-16}}{63 \times 10^{-3}}$ ✓

$= 6.3(5) \times 10^{-15}$ (N) ✓

*If mass of ion m is used correctly **using algebra** with F = ma, allow both marks (since m will cancel). If numerical value for m is used, max 1.*

2

(iii) electric field strength $E\left(=\dfrac{F}{Q}\right)=\dfrac{6.35 \times 10^{-15}}{3 \times 1.6 \times 10^{-19}}$ = 1.3(2) ✓ 10^4 (N C^{-1}) ✓

[**or** $\Delta V\left(=\dfrac{\Delta W}{Q}\right)=\dfrac{4.0 \times 10^{-16}}{3 \times 1.60 \times 10^{-19}}$ (833 V)

$E\left(=\dfrac{\Delta V}{d}\right)=\dfrac{833}{63 \times 10^{-3}}$ = 1.3(2) ✓ 10^4 (V m^{-1}) ✓]

Allow ECF from wrong F value in (ii).

1

(b) (i) (vertically) downwards on diagram ✓
reference to Fleming's LH rule **or** equivalent statement ✓

Mark sequentially.
1^{st} point: allow "into the page".

2

(ii) number of free electrons in wire = $A \times l \times$ number density

$= 5.1 \times 10^{-6} \times 95 \times 10^{-3} \times 8.4 \times 10^{28} = 4.1\ (4.07) \times 10^{22}$ ✓

Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).

1

(iii) $B\left(=\frac{F}{Qv}\right)=\frac{1.4\times10^{-25}}{1.60\times10^{-19}\times5.5\times10^{-6}}$ ✓ = 0.16 (0.159) (T) ✓

[**or** $B\left(=\frac{F}{Il}\right)=\frac{1.4\times10^{-25}\times4.07\times10^{22}}{0.38\times95\times10^{-3}}$ ✓ = 0.16 (0.158) (T) ✓]

In 2nd method allow ECF from wrong number value in (ii).

2

[10]

6 (a) (i) 128 V✓

1

(ii) 64 V

CE from (i)

1

(iii) V_{rms}= 64 / √2 ✓=45.3 V ✓

CE from (ii)

2

(iv) frequency = 1 / 0.01✓= 100 ✓ Hz ✓

do not accept kHz for unit mark unless correct for candidate value
if use 10 s instead of 10 ms then can score second two marks

3

(b) horizontal line✓
through y = 45 (44 − 48) x =0 ✓

CE from (a)(iii)+ / - half square
straight line must extend to at least to 6.0 ms

2

(c) connect to *y-input*✓
adjust / change time base ✓
so that each division is 2.0 ms OR 20 ms across screen ✓
reference to y-gain / sensitivity ✓

if inappropriate numbers quoted for y gain then lose last mark

3max

[12]

7 **B**

[1]

8 **B**

[1]

9 **C**

[1]

10 B

[1]

Examiner reports

1 Most students were able to determine the peak voltage of 325 V in part (a)(i). Unfortunately a considerable proportion of students neglected to double this value to determine the peak-to-peak voltage.

In part (b)(ii), students were told that the rms voltage across the heating element was less than 230 V and asked to explain why this was the case. Many weaker responses restated information that had been given without adding any new detail. Others would state that there was a voltage drop across the connecting cable without developing this point to explain why this meant that the rms voltage would be lower across the element. Better responses were able to produce a two stage argument to support their explanation.

The calculation in (b)(ii) was challenging for most students. The working seen was often unclear with students carrying forward non-relevant data from (a)(i) and (a)(ii). Grade A students generally produced work that was well laid out and direct in approach. Some students used incorrect methods for determining the current such as dividing 230 V by 12 ohms or dividing 4400 W by 230 V, neither of these approaches took account of the new resistance in the circuit and how this would impact on the current value.

Similarly, part (b)(iii) caused problems for all but the most able students. Many students took the answer to part (b)(ii) and substituted this into $P = \frac{V^2}{R}$ with no clear appreciation of the task. This perhaps indicated a mechanical approach to calculations by some students in which preceding parts are blended to get the final answer without really understanding the nuances of the task.

2 (a) (i) A difficult question for most students who did not realise the emf pulses occur as the bracelet enters and leaves the magnetic flux of the coil.

(ii) Since most of the graphs for (a)(i) were incorrect it was difficult or impossible to explain the shape correctly. However, marks were awarded for correct statements of the Faraday and Lenz laws.

(b) Few students knew how to tackle this one marker. Many incorrect times were chosen.

(c) Some did not read the graph scale correctly, others used $area = \pi d^2$ and there were many power of 10 errors. A final answer of 0.4 T (1 sf) was penalised.

(d) The vast majority of answers incorrectly used the average emf for the first 0.22 s, instead of using the gradient of the steepest part of the graph to find the maximum emf.

3 The topic of electromagnetic induction continues to challenge the understanding of A level students, as well as their ability to describe a sequence of processes systematically. Part (a) was set in the context of two coils linked by an iron bar, where the first coil acts as an electromagnet and the second is subject to magnetic flux changes produced by current changes in the electromagnet. Relatively few students stated in part (i) that the centre-zero meter would deflect *and then return to zero* when the current in coil P was switched on. There were frequent references to current flowing through the iron bar from P to Q and also to “ac batteries” and alternating currents. Only the best students described the processes sequentially and coherently: current in P produces magnetic flux, change in flux induces emf in Q, emf causes current in Q and meter, current falls to zero when flux becomes steady.

In part (a)(ii) more answers attempted to address the magnitude of the induced current than its direction. The effect on the magnitude could not in fact be determined, because there is no indication in the question of how rapidly the slider of the resistance is moved. What could be deduced is that a reduction in the electromagnet’s current would reduce the flux linkage and that this change would induce an emf in the opposite direction. This would cause a momentary deflection of the ammeter in the opposite direction to that in part (i).

Most students found the calculation of flux linkage in part (b)(i) to be routine. Both marks were usually awarded. The unit of flux linkage caused problems for some. The accepted unit for flux linkage is Wb turns. Some text books omit “turns” (which anyway is a dimensionless quantity) and quote flux linkage values in Wb. Either Wb turns or Wb were therefore considered to be acceptable; derived units such as T m^2 were not. Calculation of the emf induced when the coil was rotated by 90° was required in part (b)(ii). This tempted many students to attempt their solution by using the equation in the data booklet for a uniformly rotating coil, $\varepsilon = BAN\omega \sin\omega t$, which does not apply in this case. Correct solutions should have started from $\varepsilon = \Delta(N\Phi) / \Delta t$, and it should therefore have been clear that the induced emf is derived from the change in flux linkage rather than just one value of flux linkage. Almost inevitably, a few students confused flux with flux linkage.

4

(a) Many candidates omitted the area in the formula, and there was some confusion over powers of 10.

(b) Very few candidates were able to give a satisfactory reason for the reduced emf when the spring stiffness increased. Of those who mentioned the magnet, most stated that it would move less, seemingly unaware that previously it did not move at all.

(c) (i) Well done by most.

(ii) Apart from some poor scripts where no scale was attempted, most answers gained at least 2 marks. The commonest errors were to start the graph at 0 instead of 8V and to draw fewer than 3 cycles.

5 The direction of the force on the negatively charged ion in part (a)(i) was mainly correct. Explanations of the direction of the force were good and marks for this part were high.

At A2 level the students are expected to have retained a comprehensive knowledge of earlier work, which is tested by synoptic components within the questions. Part (a)(ii) was an example of this, because the simplest solution followed directly from "energy gained = work done = force × distance". This eluded most students, many of whom were completely defeated. Many of them became successful after taking a very roundabout route, involving calculation of the pd from $V = W / Q$, the field strength from $E = V / d$ and the force from $F = EQ$. Others produced answers based on the uniform acceleration equations and $F = ma$. When this was done using algebra the mass m of the ion could be cancelled and the answer was accepted. When a numerical value was chosen for m the mark that could be awarded was limited to 1 out of 2. There were fewer difficulties in part (a)(iii), where $E = F / 3e$ gave the most direct answer but where $E = V / d$ offered an alternative method. Incorrect force values from part (a)(ii) were permitted for full credit in part (a)(iii).

In part (b)(i) the successful application of Fleming's left hand rule readily showed the majority that the magnetic force on the wire would be downwards (or into the page). Most students gained both marks. It seemed that some students who thought too deeply about the direction of this force eventually got it wrong: their line of thought was that the force due to the current was downwards, but electrons carry a negative charge so the force on them must act upwards. It had not occurred to them that the force on the complete wire has to act in the same direction as the force on all of the free electrons within it.

The simple calculation that led to the number of free electrons in the section of wire was almost always worked out correctly in part (b)(ii). This was a "show that" question, so students should have realised that a more precise answer than 4×10^{22} (such as 4.07×10^{22}) would be expected before the mark became available. Part (b)(iii) offered two approaches to the value of the flux density B. By considering the average force on a single electron, $F = BQv$ could be used. Alternatively, by considering the force on the section of wire, $F = BIl$ could be used. In the latter method many got into difficulty by forgetting to consider the number of electrons in the wire.

6 This question on alternating currents was generally very well done. There were few major problems with part (a) although a minority did leave the rms voltage in surd form thus not completing the calculation.

Part (b) was also well answered and most candidates drew their line with care, using a ruler.

Part (c) however, was answered poorly and it is apparent that a significant proportion of candidates were not clear on how to use an oscilloscope. Reference to the time base was seen more often than reference to *y – gain or y – sensitivity* but frequently neither of these was mentioned. It was also quite common for candidates to assume that the vertical scale only needed to cover the peak voltage and not the peak to peak voltage i.e. eight divisions covered 64 V rather than 128 V.

On the other hand a far greater proportion was able to deduce that each horizontal division needed to represent 2.0 ms.