This question is about electromagnetic induction.

In 1831 Michael Faraday demonstrated three ways of inducing an electric current in a ring of copper. One way is to move a bar magnet through the stationary copper ring.

(a) Describe briefly a way that a current may be induced in the copper ring using a stationary bar magnet. 

You are given the following apparatus: copper ring, battery, variable resistor, lengths of insulated copper wire with connecting terminals at each end.

(b) Describe how you would use all of this apparatus to induce a current in the copper ring.

In the diagram below, a magnetic field links a circular copper ring. The field is uniform over the area of the ring and its strength is increasing in magnitude at a steady rate.

(c) (i) State Faraday’s law of electromagnetic induction as it applies to this situation.

(ii) Draw on the diagram, an arrow to show the direction of the induced current in the copper ring. Explain how you determined the direction of the induced current.

(iii) The radius of the copper ring is 0.12 m and its resistance is $1.5 \times 10^{-2} \, \Omega$. The field strength is increasing at rate of $1.8 \times 10^{-3} \, T \, s^{-1}$. Calculate the value of the induced current in the copper ring.

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(Total 13 marks)
2. A circular coil of wire of radius \( r \) is placed in a uniform magnetic field of flux density \( B \). The angle between the plane of the coil and the magnetic field is \( \theta \).

The magnetic flux linking the coil is

A. \( \pi r^2 B \).
B. \( \pi r^2 B \sin \theta \).
C. \( \pi r^2 B \cos \theta \).
D. \( \pi r^2 B \).

3. A magnetic force acts on an electric charge in a magnetic field when

A. the charge is not moving.
B. the charge moves in the direction of the magnetic field.
C. the charge moves in the opposite direction to the magnetic field.
D. the charge moves at right angles to the lines of the magnetic field.
4. This question is about the force between current-carrying wires.

Diagram 1 below shows two long, parallel vertical wires each carrying equal currents in the same direction. The wires pass through a horizontal sheet of card. Diagram 2 shows a plan view of the wires looking down onto the card.

(a) Draw on diagram 2 the magnetic field pattern due to the currents in the wire.

(b) Outline how two current carrying conductors may be used to define the ampere.

(c) The card is removed and one of the two wires is free to move. Describe and explain, the changes in the velocity and in acceleration of the moveable wire.

(Total 8 marks)

5. A charged particle of mass $m$ and charge $q$ is travelling in a uniform magnetic field with speed $v$ such that the magnetic force on the particle is $F$. The magnetic force on a particle of mass $2m$, charge $q$ and speed $2v$ travelling in the same direction in the magnetic field is

A. $4F$.

B. $2F$.

C. $F$.

D. $\frac{1}{2}F$.

(1)
6. (a) On the diagram below, draw the magnetic field pattern around a long straight current-carrying conductor.

![Diagram of a current-carrying wire](image)

The diagram below shows a coil consisting of two loops of wire. The coil is suspended vertically.

![Diagram of a coil with two loops](image)

Each loop has a diameter of 6.0 cm and the separation of the loops is 0.20 cm. The coil forms part of an electrical circuit so that a current may be passed through the coil.

(b) (i) State and explain why, when the current is switched on in the coil, the distance between the two loops changes.

When there is a current \( I \) in the coil, a mass of 0.10 g hung from the free end of the coil returns the separation of the loops to the original value of 0.20 cm. The circumference \( C \) of a circle of radius \( r \) is given by the expression \( C = 2\pi r \).

(ii) Calculate the current \( I \) in the coil. You may assume that each loop behaves as a long straight current-carrying wire.

(Total 11 marks)

7. The definition of the unit of current, the ampere, is based on

A. the force per unit length on a conductor in a uniform magnetic field.
B. the force per unit length on parallel current-carrying conductors.
C. the charge per unit time delivered by a cell of e.m.f. 1.0 V.
D. the charge passing a point per unit time in an electrical circuit.

(1)
8. Two long, vertical wires X and Y carry currents in the same direction and pass through a horizontal sheet of card.

Iron filings are scattered on the card. Which one of the following diagrams best shows the pattern formed by the iron filings? *(The dots show where the wires X and Y enter the card.)*

A.  

B.  

C.  

D.  

(1)
9. The diagram shows a coil of wire that can rotate between the poles of a magnet about the axis XY.

A current is passed through the coil by means of a commutator connected to the ends of the coil. What is the position of the coil in the magnetic field so that its turning effect is a maximum and what is the position of the coil when the current is reversed so that the coil rotates continuously?

<table>
<thead>
<tr>
<th>plane of coil for maximum turning effect</th>
<th>plane of coil for reversal of current</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. parallel to direction of field</td>
<td>parallel to direction of field</td>
</tr>
<tr>
<td>B. normal to direction of field</td>
<td>parallel to direction of field</td>
</tr>
<tr>
<td>C. parallel to direction of field</td>
<td>normal to direction of field</td>
</tr>
<tr>
<td>D. normal to direction of field</td>
<td>normal to direction of field</td>
</tr>
</tbody>
</table>

(1)

10. When a coil is rotated in a uniform magnetic field at a certain frequency, the variation with time \( t \) of the induced e.m.f. \( E \) is as shown below.

![Graph showing E vs t]

The frequency of rotation of the coil is reduced to one half of its initial value. Which one of the following graphs correctly shows the new variation with time \( t \) of the induced e.m.f. \( E \)?
11. The magnetic flux $\Phi$ through a coil having 500 turns varies with time $t$ as shown below.

The magnitude of the e.m.f. induced in the coil is
A. 0.25 V.
B. 0.50 V.
C. 250 V.
D. 1000 V.

12. A resistor is connected in series with an alternating current supply of negligible internal resistance. The peak value of the supply voltage is $V_0$ and the peak value of the current in the resistor is $I_0$. The average power dissipation in the resistor is

A. $\frac{V_0 I_0}{2}$
B. $\frac{V_0 I_0}{\sqrt{2}}$
C. $V_0 I_0$
D. $2V_0 I_0$.

13. A magnetic field links a closed loop of metal wire. The magnetic field strength $B$ varies with time $t$ as shown.

A current is induced in the loop during the time period

A. $t_1$ only.
B. $t_2$ only.
C. $t_2$ and $t_3$ only.
D. $t_1$ and $t_3$ only.
14. Faraday’s law of electromagnetic induction states that the induced e.m.f. is
   A. proportional to the change in magnetic flux linkage.
   B. proportional to the rate of change of magnetic flux linkage.
   C. equal to the change in magnetic flux linkage.
   D. equal to the change of magnetic flux.

15. The diagram below shows the variation with time $t$ of the e.m.f. $E$ generated in a coil rotating in a uniform magnetic field.

What is the root-mean-square value $E_{rms}$ of the e.m.f. and also the frequency $f$ of rotation of the coil?

<table>
<thead>
<tr>
<th>$E_{rms}$</th>
<th>$f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e$</td>
<td>$\frac{2}{T}$</td>
</tr>
<tr>
<td>$e$</td>
<td>$\frac{1}{T}$</td>
</tr>
<tr>
<td>$\frac{e}{\sqrt{2}}$</td>
<td>$\frac{2}{T}$</td>
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<tr>
<td>$\frac{e}{\sqrt{2}}$</td>
<td>$\frac{1}{T}$</td>
</tr>
</tbody>
</table>

(1)
16. The north pole of a permanent bar magnet is pushed along the axis of a coil as shown below.

![Diagram of a coil with a magnet](image)

The pointer of the sensitive voltmeter connected to the coil moves to the right and gives a maximum reading of 8 units. The experiment is repeated but on this occasion, the south pole of the magnet enters the coil at twice the previous speed.

Which of the following gives the maximum deflection of the pointer of the voltmeter?

A. 8 units to the right
B. 8 units to the left
C. 16 units to the right
D. 16 units to the left

17. This question is about electromagnetic induction.

A small coil is placed with its plane parallel to a long straight current-carrying wire, as shown below.

![Diagram of a coil and a current-carrying wire](image)

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

(ii) Use the law to explain why, when the current in the wire changes, an e.m.f. is induced in the coil.

The diagram below shows the variation with time \( t \) of the current in the wire.
(b)  
(i) Draw, on the axes provided, a sketch-graph to show the variation with time $t$ of the magnetic flux in the coil. 

(ii) Construct, on the axes provided, a sketch-graph to show the variation with time $t$ of the e.m.f. induced in the coil. 

(iii) State and explain the effect on the maximum e.m.f. induced in the coil when the coil is further away from the wire. 

(c) Such a coil may be used to measure large alternating currents in a high-voltage cable. Identify one advantage and one disadvantage of this method. 

Advantage: 

Disadvantage: 

(Total 10 marks)