**Topic 11.1 & 11.2: Electromagnetic induction & Power generation and transmission**

1. A conductor in the shape of a solid square is moving with constant velocity in a region of magnetic field as shown in the diagram below.

   ![Diagram of a conductor moving in a magnetic field]

   The direction of the field is into the plane of the page.

   Which of the following diagrams correctly represents the separation of the induced charges?

   A. ![Diagram A]
   B. ![Diagram B]
   C. ![Diagram C]
   D. ![Diagram D]

2. A uniform magnetic field of strength $B$ completely links a coil of area $S$. The field makes an angle $\phi$ to the plane of the coil.

   ![Diagram of a coil with magnetic field]

   The magnetic flux linking the coil is

   A. $BS$
   B. $BS \cos \phi$
   C. $BS \sin \phi$
   D. $BS \tan \phi$

3. Faraday’s law of electromagnetic induction states that the induced emf 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.
4. The magnetic flux \( \Phi \) through a coil having 500 turns varies with time \( t \) as shown below.

The magnitude of the emf induced in the coil is

A. 0.25 V.        B. 0.50 V.     C. 250 V.     D. 1 000 V.  

5. The variation with time \( t \) of the magnetic flux \( \Phi \) through a coil is shown below.

Which of the following diagrams best shows the variation with time \( t \) of the emf \( E \) induced in the coil?

A.  

B.  

C.  

D.  

A. \( \Phi \) \( t \)  

B. \( \Phi \) \( t \)  

C. \( \Phi \) \( t \)  

D. \( \Phi \) \( t \)  

(1)
6. 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.

7. The north pole of a permanent bar magnet is pushed along the axis of a coil as shown below. 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
8. The diagram below shows two concentric loops lying in the same plane.

The current in the inner loop is clockwise and increases with time as shown in the graph below.

![Diagram of two concentric loops](image)

The current in the inner loop is clockwise and increases with time as shown in the graph below.

The induced current in the outer loop is

A. constant in the clockwise direction.
B. constant in the anticlockwise direction.
C. variable in the clockwise direction.
D. variable in the anticlockwise direction.

9. The diagram shows a coil of wire wound on an iron core.

![Diagram of a coil with a battery and ammeter](image)

When the switch is closed, the ammeter reading gradually increases from zero to a maximum value.
What is the explanation for this gradual growth of current?

A. An e.m.f. is induced in the coil.
B. The e.m.f. of the battery is increasing.
C. The iron core has a very low resistance.
D. The battery has a large internal resistance.
10. 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. $2V_0 I_0$.

(1)

11. A lamp of resistance $R$ is connected in series to a source of alternating voltage. The rms value of the voltage is 20 V. The variation with time $t$ of the power $P$ dissipated in the light bulb is shown below.

![Graph showing power variation with time](image)

The best estimate for the value of the resistance of the filament of the lamp is

A. 4.0 Ω.  
B. 4.0$\sqrt{2}$ Ω.  
C. 8.0 Ω.  
D. 8.0$\sqrt{2}$ Ω.

(1)

12. The diagram below shows the variation with time $t$ of the emf $E$ generated in a coil rotating in a uniform magnetic field.

![Diagram showing emf variation with time](image)

What is the root-mean-square value $E_{rms}$ of the emf 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>
</tr>
<tr>
<td>$\frac{e}{\sqrt{2}}$</td>
<td>$\frac{1}{T}$</td>
</tr>
</tbody>
</table>

(1)
13. The graph below shows the variation with time $t$ of the current $I$ in a resistor.

Which of the following is the root-mean-square value of the current $I$?

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

14. The rms voltages across the primary and secondary coils in an ideal transformer are $V_p$ and $V_s$ respectively. The currents in the primary and secondary coils are $I_p$ and $I_s$ respectively.

Which one of the following statements is always true?

A. $V_s = V_p$  B. $I_s = I_p$

C. $V_s I_s = V_p I_p$  D. $\frac{V_s}{V_p} = \frac{I_s}{I_p}$

15. The diagram below shows an ideal transformer.

The transformer has $n$ turns on the primary coil and $2n$ turns on the secondary coil. The waveform produced on the screen of a cathode-ray oscilloscope (cro), when the cro is connected to the primary coil, is shown below.

Which of the following diagrams shows the waveform displayed on the cro when it is connected to the secondary coil? The settings of the cro remain unchanged.
16. The variation with time of the current in the primary coil of an ideal transformer is shown below. 

At which time will the magnitude of the induced e.m.f. in the secondary coil be maximum?

A. A           B. B
C. C           D. D

17. A transformer has a primary coil with \( N_p \) turns and a secondary coil with \( N_s \) turns. An alternating voltage supply of frequency \( f \) and r.m.s. value \( V_p \) is connected to the primary coil.

Which of the following correctly gives the frequency and r.m.s. voltage in the secondary coil?

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. ( \frac{N_s}{N_p} f )</td>
<td>( \frac{N_p}{N_s} V_p )</td>
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<tr>
<td>B. ( f )</td>
<td>( \frac{N_p}{N_s} V_p )</td>
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<tr>
<td>C. ( \frac{N_p}{N_s} f )</td>
<td>( \frac{N_s}{N_p} V_p )</td>
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<tr>
<td>D. ( f )</td>
<td>( \frac{N_s}{N_p} V_p )</td>
</tr>
</tbody>
</table>
18. High voltages are used for the transmission of electric power over long distances because
   A. high voltages can be stepped down to any required value.
   B. larger currents can be used.
   C. power losses during transmission are minimized.
   D. transformers have a high efficiency.

19. A power station generates electrical energy at a potential difference $V$ and current $I$. The resistance of the transmission lines between the power station and the consumer is $R$.

![Diagram of power station and transmission lines]

The power lost in the transmission lines is

A. 0. B. $\frac{V^2}{R}$. C. $RI^2$. D. $VI$.

20. Electrical conduction and induced currents
   (a) The diagram below shows a copper rod inside which an electric field of strength $E$ is maintained by connecting the copper rod in series with a cell. (Connections to the cell are not shown.)

![Diagram of copper rod with electric field]

Describe how the electric field enables the conduction electrons to have a drift velocity in a direction along the copper rod.

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(3)
(b) A copper rod is placed on two parallel, horizontal conducting rails PQ and SR as shown below.

The rails and the copper rod are in a region of uniform magnetic field of strength $B$. The magnetic field is normal to the plane of the conducting rods as shown in the diagram above.

A conducting wire is connected between the ends P and S of the rails. A constant force, parallel to the rails, of magnitude $F$ is applied to the copper rod in the direction shown. The copper rod moves along the rails with a decreasing acceleration.

(i) On the diagram, draw an arrow to show the direction of induced current in the copper rod. Label this arrow with the letter I.

(ii) Explain, by reference to Lenz’s law, why the induced current is in the direction you have shown in (i).

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(2)

(iii) By considering the forces on the conduction electrons in the copper rod, explain why the acceleration of the copper rod decreases as it moves along the rails.

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(3)

(c) The copper rod in (b) eventually moves with constant speed $v$. The induced emf $\varepsilon$ in the copper rod is given by the expression

$$\varepsilon = Bvl$$

where $l$ is the length of copper rod in the region of uniform magnetic field.
(i) State Faraday’s law of electromagnetic induction.

........................................................................................................................................ (1)

(ii) Deduce that the expression is consistent with Faraday’s law.

........................................................................................................................................ (3)

(iii) The following data are available:

\[ F = 0.32 \text{ N} \]
\[ l = 0.40 \text{ m} \]
\[ B = 0.26 \text{ T} \]

resistance of copper rod = 0.15 \( \Omega \)

Determine the induced current and the speed \( v \) of the copper rod.

Induced current: .............................................................................................................. (4)

Speed \( v \): .................................................................................................................... (4)

(Total 17 marks)

21. Electromagnetic induction

(a) State Lenz’s law.

........................................................................................................................................ (1)

(b) A long solenoid is connected in series with a battery and a switch \( S \). Several loops of wire are wrapped around the solenoid close to its midpoint as shown below.

![Diagram of solenoid with loops wrapped around it]
The ends of the wire are connected to a high resistance voltmeter V that has a centre zero scale (as shown in the inset diagram). The switch S is closed and it is observed that the needle on V moves to the right and then drops back to zero.

Describe and explain, the deflection on the voltmeter when the switch S is re-opened.

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Explanation: ...........................................................................................................
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(4) (Total 5 marks)

22. This question is about an ideal transformer.

(a) State Faraday’s law of electromagnetic induction.
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(b) The diagram below shows an ideal transformer.

(i) Use Faraday’s law to explain why, for normal operation of the transformer, the current in the primary coil must vary continuously.
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(ii) Outline why the core is laminated.

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(2)

(iii) The primary coil of an ideal transformer is connected to an alternating supply rated at 230V. The transformer is designed to provide power for a lamp rated as 12V, 42W and has 450 turns of wire on its secondary coil. Determine the number of turns of wire on the primary coil and the current from the supply for the lamp to operate at normal brightness.

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(3) (Total 9 marks)

23. 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 small coil near a current-carrying wire]

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

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

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(1)
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.
(1)

(ii) Construct, on the axes provided, a sketch-graph to show the variation with time $t$ of the emf induced in the coil.
(2)

(iii) State and explain the effect on the maximum emf induced in the coil when the coil is further away from the wire.
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(2)

(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: ................................................................................................................................
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Disadvantage: ................................................................................................................................
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(Total 10 marks)
24. This question is about a diode bridge rectification circuit.
   In the following rectifier circuit, the output voltage is less than half of the secondary winding’s rated voltage (12 volts)

   (a) Explain the reason.
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   (1)

   (b) Determine and explain whether this is a half-wave or a full-wave rectifier circuit.
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   (2)

   (c) Suggest how to change the circuit to make it a different rectifier from your answer in (b).
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   (1)

   (Total 4 marks)
Topic 11.3: Capacitance

1. A capacitor is charged to 6 V and then isolated from the battery. The plates are then pulled apart so their separation is twice as big.

   The p.d. between the plates will now be
   
   A. 12 V   B. 6 V   C. 3 V   D. 1.5 V

2. A parallel plate capacitor of capacitance 10 pF is charged by connecting to a 6 V battery. Plates are now pushed closer together. Which of the following statements is true

   A. More charge flows onto the capacitor.
   B. Charge flows off the capacitor.
   C. Charge flows across the capacitor plates.
   D. No charge flow.

3. The two plates of a capacitor hold +2500 $\mu$C and −2500 $\mu$C of charge, respectively, when the potential difference is 850 V. Calculate the capacitance.

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4. Calculate the capacitance of a pair of circular plates with a radius of 5.0 cm separated by 3.2 mm of mica ($\varepsilon=7\varepsilon_0$).

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5. An electric field of $8.50 \times 10^5$ V/m is desired between two parallel plates, each of area $35.0 \text{ cm}^2$ and separated by 2.45 mm of air. What charge must be on each plate?

6. 650 V is applied to a 2200-pF capacitor. How much energy is stored?

7. A homemade capacitor is assembled by placing two 23 cm. pie pans 5 cm apart and connecting them to the opposite terminals of a 9-V battery. Estimate
   (a) the capacitance,
   (b) the charge on each plate,
   (c) the electric field halfway between the plates,
   (d) the work done by the battery to charge the plates.
(e) Which of the above values change if a dielectric is inserted?

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8. How does the energy stored in a capacitor change if

(a) the potential difference is doubled,

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(b) the charge on each plate is doubled, as the capacitor remains connected to a battery.

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9. (a) Six 4.7-\(\mu\)F capacitors are connected in parallel. What is the equivalent capacitance?

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(b) What is their equivalent capacitance if connected in series?

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10. Determine the equivalent capacitance of the circuit shown below.

\[ \begin{array}{c}
 & C_1 \\
C_2 & & C_3 \\
 & V \\
\end{array} \]

11. A 185-pF capacitor is connected in series with an unknown capacitance, and as a series combination they are connected to a battery with an emf of 25.0 V. If the 185-pF capacitor stores 125 pC of charge on its plates, what is the unknown capacitance?
12. Electrocardiographs are often connected as shown below.

The leads are said to be capacitively coupled. A time constant of 3.0 s is typical and allows rapid changes in potential to be recorded accurately. If $C = 3.0 \mu F$, what value must $R$ have? [Hint: consider each leg as a separate circuit.]

13. The $RC$ circuit has $R = 6.7 \, k\Omega$ and $C = 3.0 \, \mu F$. The capacitor is at voltage $V_0$ at $t = 0$, when the switch is closed. How long does it take the capacitor to discharge to 1.0% of its initial voltage?