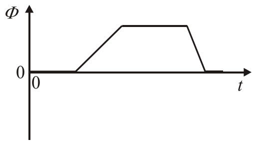
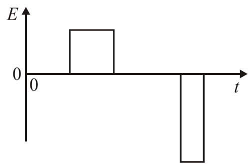
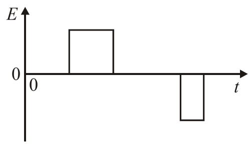
# Electromagnetic Induction: IB Questions

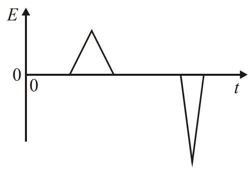
**1.** The variation with time $t$ of the magnetic flux $\Phi$ through a coil is shown below.

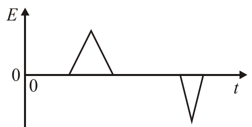



Which of the following diagrams best shows the variation with time $t$ of the emf $E$ induced in the coil?

A.


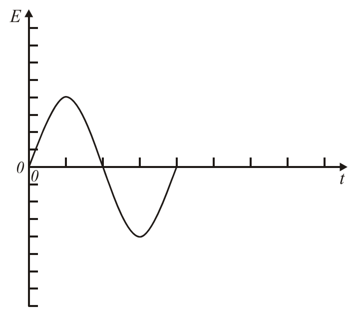

B.



C.



D.


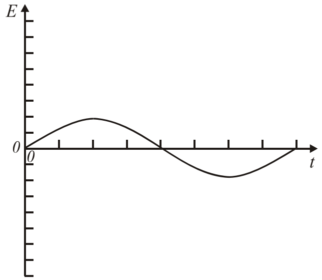

**(1)**

**2.** When a coil is rotated in a uniform magnetic field at a certain frequency, the variation with time $t$ of the induced emf $E$ is as shown below.

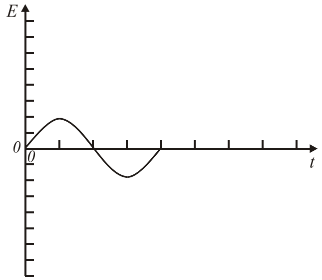


The frequency of rotation of the coil is reduced to **one half** of its initial value. Which **one** of the following graphs correctly shows the new variation with time $t$ of the induced emf $E$?

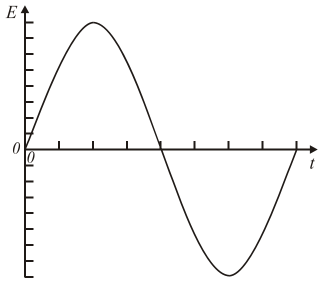
A.



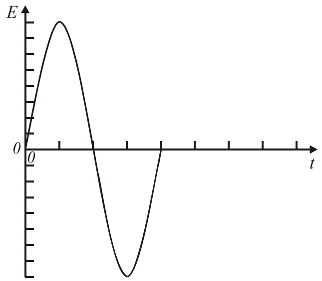

B.




C.

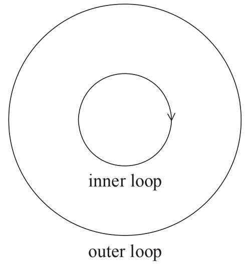



D.

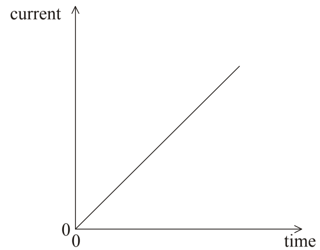



**(1)**

**3.** 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.




The induced current in the outer loop is

A. constant in the clockwise direction.

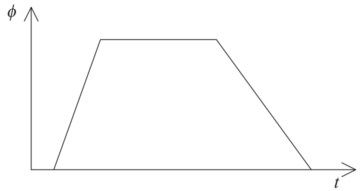
B. constant in the anticlockwise direction.

C. variable in the clockwise direction.

D. variable in the anticlockwise direction.

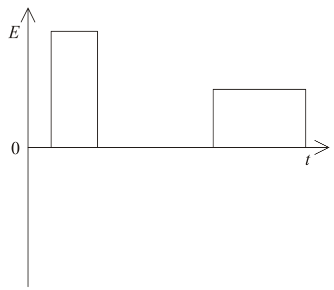
**(1)**

**4.** The magnetic flux $\phi$ in a coil varies with time $t$ as shown below.

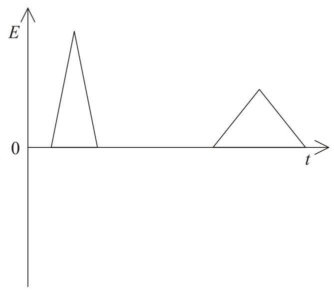



Which graph best represents the variation with time $t$ of the emf $E$ induced in the coil?

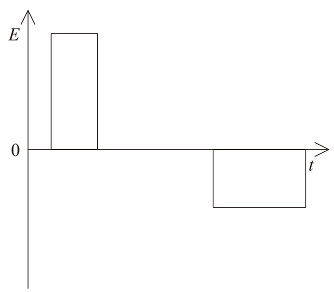
A.



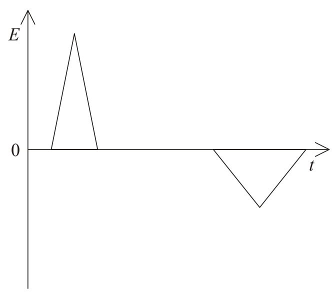

B.




C.

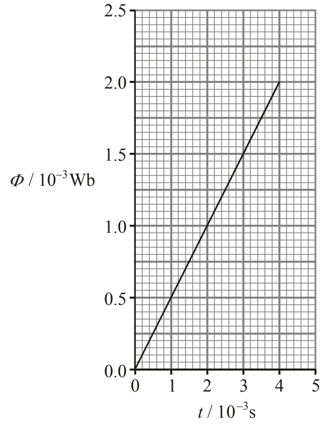



D.




**(1)**

**5.** 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.

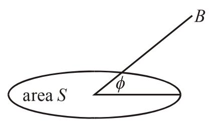
B. 0.50 V.

C. 250 V.

D. 1 000 V.

**(1)**

**6.** 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.



The magnetic flux linking the coil is

A. *BS*.

B. *BS* cos $\phi$.

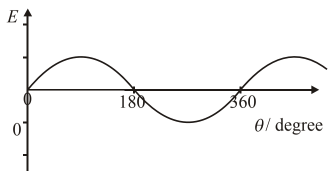
C. *BS* sin $\phi$.

D. *BS* tan $\phi$.

**(1)**

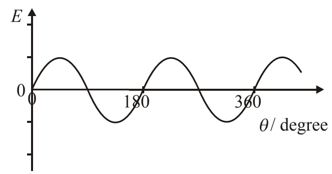
**7.** A coil rotates at a constant rate in a uniform magnetic field. The angle of rotation of the coil from its starting position is $\theta$.

The variation with angle $\theta$ of the emf $E$ generated in the coil is shown below.

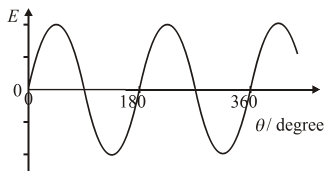



Which **one** of the following graphs best shows the variation with $\theta$ from the starting position of the emf $E$ when the rate of rotation of the coil is doubled?

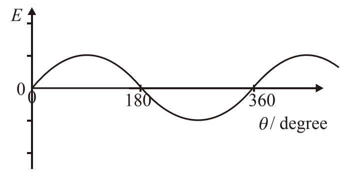
A.



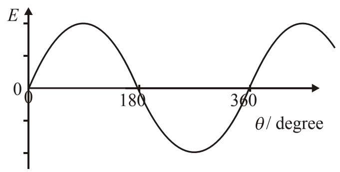

B.




C.




E.




**(1)**

**8.** A thin copper ring encloses an area $S$. The area is linked by magnetic flux that is increasing. The rate of change of the magnetic flux from time $t = 0$ to time $t = T$ is $R$.

The emf induced in the copper ring during the time $t = 0$ to time $t = T$ is

A. *R*.

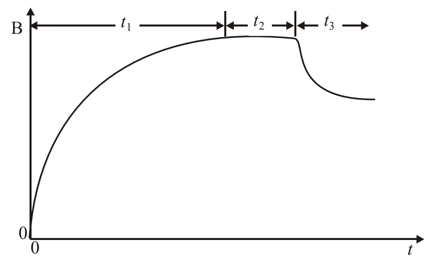
B. *RS*.

C. *RST*.

D. $\frac{RS}{T}$.

**(1)**

**9.** 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.

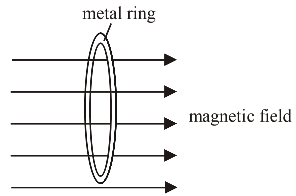
B. $t_2$ only.

C. $t_2$ and $t_3$ only.

D. $t_1$ and $t_3$ only.

**(1)**

**10.** A metal ring has its plane perpendicular to a magnetic field.




The magnetic flux through the ring increases at a constant rate by $4.0 \times 10^{-5}$ Wb in 5.0 s.

During this change the e.m.f. induced in the ring

A. remains constant at 8μV.

B. remains constant at 20μV.

C. increases from zero to 8μV.

D. increases from zero to 20μV.

**(1)**

**11.** Faraday's law of electromagnetic induction states that the induced emf is

A. proportional to the change in magnetic flux linkage.

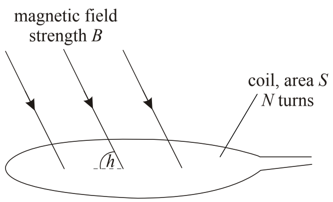
B. proportional to the rate of change of magnetic flux linkage.

C. equal to the change in magnetic flux linkage.

D. equal to the change of magnetic flux.

**(1)**

**12.** A coil of area $S$ has $N$ turns of wire. It is placed in a uniform magnetic field of strength $B$ so that its plane makes an angle $\theta$ with the direction of the magnetic field as shown.




The magnetic flux linkage is

A. $BSN \sin \theta$.

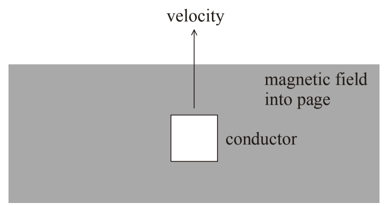
B. $BSN \cos \theta$.

C. $BSN \tan \theta$.

D. $BSN$.

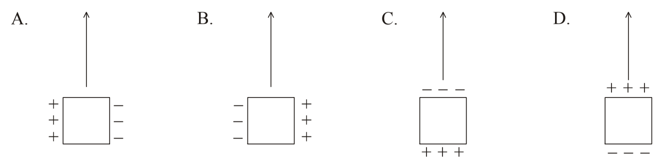
**(1)**

**13.** 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.



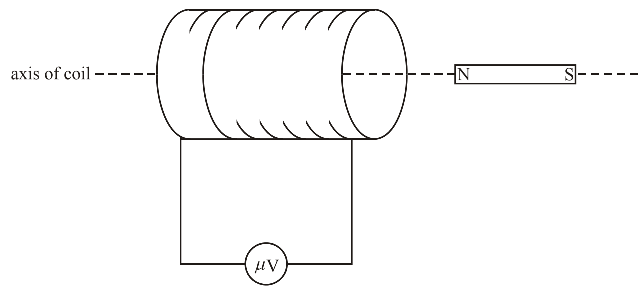

The direction of the field is into the plane of the page.

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




**(1)**

**14.** 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

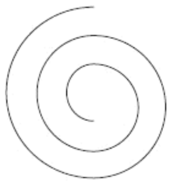
B. 8 units to the left

C. 16 units to the right

D. 16 units to the left

**(1)**

**15.** An electron is moving in air at right angles to a uniform magnetic field. The diagram below shows the path of the electron. The electron is slowing down.



region of magnetic field

Which of the following correctly gives the direction of motion of the electron and the direction of the magnetic field?

| | Direction of motion | Direction of magnetic field |
|---|---|---|
| A. | clockwise | into plane of paper |
| B. | clockwise | out of plane of paper |
| C. | anti-clockwise | into plane of paper |
| D. | anti-clockwise | out of plane of paper |

**(1)**

**16.** Electromagnetic induction

(a) State Lenz's law.

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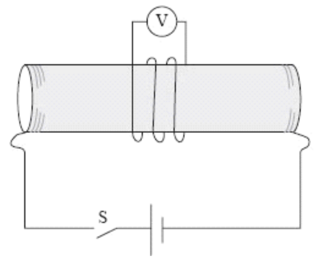
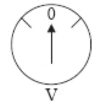
**(1)**

(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.




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.

Description: ..........................................................................................................

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Explanation: ..........................................................................................................

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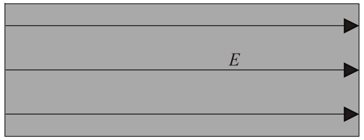
**(4)**
**(Total 5 marks)**

**17.** 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.)




copper rod

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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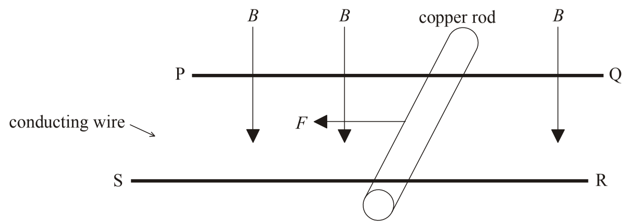
**(3)**

(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.

**(1)**

(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.

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**(1)**

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

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**(3)**

(iii) The following data are available:

$F = 0.32$ N
$l = 0.40$ m

$B = 0.26$ T

resistance of copper rod = 0.15 Ω

Determine the induced current and the speed $v$ of the copper rod.

Induced current: ..........................................................................................

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Speed $v$: ..........................................................................................

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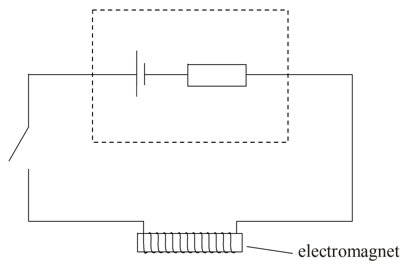
**(4)**
**(Total 17 marks)**

**18.** This question is about electrical energy and associated phenomena.

**Electromagnetism**




The current in the circuit is switched on.

(i) State Faraday's law of electromagnetic induction and use the law to explain why an emf is induced in the coil of the electromagnet.

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**(3)**

(ii) State Lenz's law and use the law to predict the direction of the induced emf in (i).

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**(3)**

(iii) Magnetic energy is stored in the electromagnet. State and explain, with reference to the induced emf, the origin of this energy.

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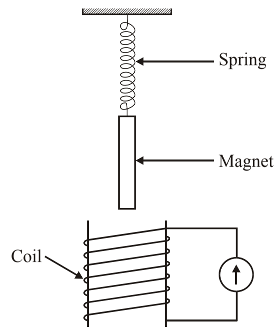
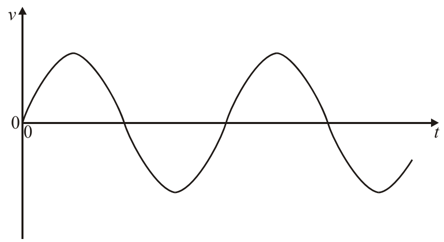
**(2)**
**(Total 8 marks)**

**19.** A bar magnet is suspended above a coil of wire by means of a spring, as shown below.




The ends of the coil are connected to a sensitive high resistance voltmeter. The bar magnet is pulled down so that its north pole is level with the top of the coil. The magnet is released and the variation with time $t$ of the velocity $v$ of the magnet is shown below.




(a) On the diagram above,

(i) mark with the letter M, one point in the motion where the reading of the voltmeter is a maximum;

(ii) mark with the letter Z, one point where the reading on the voltmeter is zero.

**(2)**

(b) Explain, in terms of changes in flux linkage, why the reading on the voltmeter is alternating.

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**(2)**
**(Total 4 marks)**

**1.** A **[1]**

**2.** A **[1]**

**3.** B **[1]**

**4.** C **[1]**

**5.** C **[1]**

**6.** C **[1]**

**7.** D **[1]**

**8.** A **[1]**

**9.** D **[1]**

**10.** A **[1]**

**11.** B **[1]**

**12.** A **[1]**

**13.** A **[1]**

**14.** D **[1]**

**15.** D **[1]**

**16.** Electromagnetic induction

(a) the induced emf is induced in such a direction that its effect is to oppose the change to which it is due / *OWTTE*; 1

(b) *description*:
on opening the switch, the reading on the voltmeter will deflect to the left and then drop to zero;

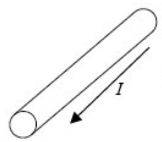
*explanation:*
when the switch is opened the field drops to zero – so again a time changing flux;
which will induce an emf in the opposite direction as the emf will now be such as to oppose the field falling to zero / Lenz's law;
when the current reaches zero, there will no longer be a flux change; 4

**[5]**

**17.** Electrical conduction and induced currents

(a) the force on the electrons produced by the electric field causes them to accelerate along the direction of the rod;
however, they will (soon) collide with a lattice ion but after collision will again be accelerated (along the rod) before making another collision / *OWTTE*;
hence the electrons gain a drift / net velocity in the direction of the wire / in the (opposite) direction to the field even though they still have random velocities / *OWTTE*; 3

(b) (i)




; 1

(ii) Lenz's law says that the direction of the induced current is such as to oppose change;
therefore, to produce a (magnetic) force that opposes $F$ the current must be in direction shown / reference to left / right hand rule / *OWTTE*; 2

(iii) the force on the electrons is given by $Bev$;
as $v$ increases so does this force and therefore, so does the induced current;
therefore, net force on rod decreases / *OWTTE*; 3

(c) (i) the induced <u>emf</u> is equal / proportional to the rate of change / cutting of (magnetic) flux; 1

(ii) if the rod moves a distance $\Delta x$ in time $\Delta t$ then area swept out by rod = $l\Delta x$;
flux = $Bl\Delta x$;

rate of change of flux = $\dfrac{Bl\Delta x}{\Delta t} = Blv = \varepsilon$; 3

(iii) *induced current:*

$I = \dfrac{F}{Bl}$;

substitute to give $I = 3.1\text{A}$;

*speed v*:

$\varepsilon = IR = 0.47$;

$\varepsilon = Bvl$ substitute to give $v = 4.5\ (4.4)\ \text{ms}^{-1}$; 4

**[17]**

**18.** (i) (induced) e.m.f. proportional to rate of change of magnetic flux (linkage);

*(do not allow induced current)*

as current increases, magnetic field in coil increases;
thus change in flux linkage and e.m.f. induced; 3

(ii) direction of (induced) e.m.f. such as to tend to oppose;
the change producing it;
induced e.m.f. must oppose e.m.f. of battery / growth of current in circuit; 3

(iii) energy is supplied by the battery;
in making charge move against the induced e.m.f.; 2

**[8]**

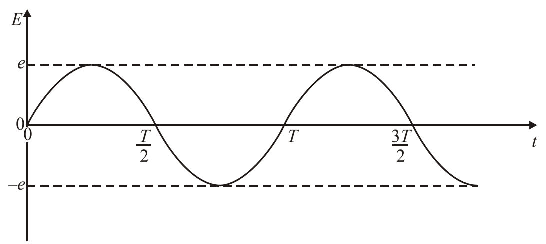
**19.** (a) (i) M shown at peak or trough; 1

(ii) Z shown on $t$-axis; 1

(b) by Lenz's law, emf (or current) must change direction as flux cutting changes direction;
as magnet oscillates, flux is cut in opposite directions; 2

**[4]**

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




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

| | $E_{rms}$ | $f$ |
|---|---|---|
| A. | $e$ | $\frac{2}{T}$ |
| B. | $e$ | $\frac{1}{T}$ |
| C. | $\frac{e}{\sqrt{2}}$ | $\frac{2}{T}$ |
| D. | $\frac{e}{\sqrt{2}}$ | $\frac{1}{T}$ |

**(1)**

**2.** A resistor of resistance $R$ is connected in series with a sinusoidal alternating supply having a maximum value of emf $V_0$.

The best estimate for the average power dissipated in the resistor during one cycle of the alternating current is

A. $\frac{2V_0^2}{R}$.

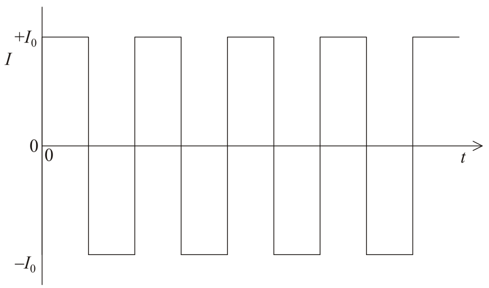
B. $\sqrt{2}\frac{V_0^2}{R}$.

C. $\frac{V_0^2}{\sqrt{2}R}$.

D. $\frac{V_0^2}{2R}$.

**(1)**

**3.** 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. $\frac{I_0}{\sqrt{2}}$

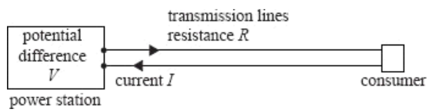
**(1)**

**4.** An alternating supply of constant r.m.s. current and constant r.m.s. potential difference is connected to the primary coil of an ideal transformer. Which **one** of the following describes the effect, if any, on the r.m.s. current and on the r.m.s. power in the circuit of the secondary coil when the number of turns on the secondary coil is increased?

| | **r.m.s. current** | **r.m.s. power** |
|---|---|---|
| A. | no change | increases |
| B. | no change | no change |
| C. | decreases | increases |
| D. | decreases | no change |

**(1)**

**5.** 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 $R$.




The power lost in the transmission lines is

A. 0.

B. $\frac{V^2}{R}$.

C. $RI^2$.

D. $VI$.

**(1)**

**6.** 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)**

**7.** An AC generator produces a voltage of **peak** value $V$. The frequency of rotation of the coil of the generator is doubled. The **rms** value of the voltage produced is

A. $\frac{V}{2\sqrt{2}}$.

B. $\frac{V}{\sqrt{2}}$.

C. $V\sqrt{2}$.

D. $2V\sqrt{2}$.

**(1)**

**8.** 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. $V_s = V_p$

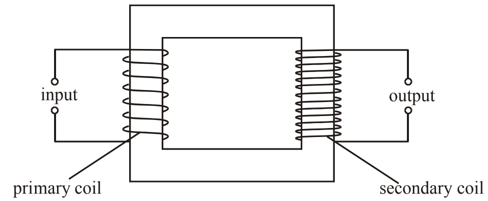
B. $I_s = I_p$

C. $V_sI_s = V_pI_p$

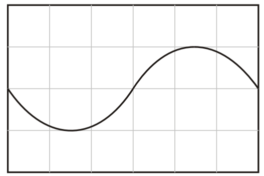
D. $\frac{V_s}{V_p} = \frac{I_s}{I_p}$.

**(1)**

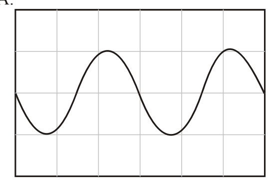
**9.** The diagram below shows an ideal transformer.

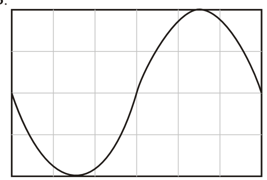


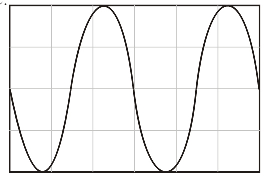

The transformer has $n$ turns on the primary coil and $2n$ turns on the secondary coil. The waveform produced on the screen of a cathode-ray oscilloscope (cro), when the cro is connected to the primary coil, is shown below.

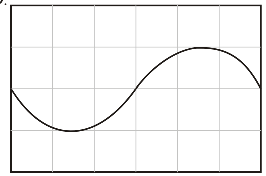


Which of the following diagrams shows the waveform displayed on the cro when it is connected to the secondary coil? The settings of the cro remain unchanged.

A.


B.


C.


D.


**(1)**

**10.** A light bulb is connected to an ac supply. The variation with time of the current is sinusoidal having a maximum value of 0.50 A. The rms. current is

A. $\frac{0.50}{2}$ A.

B. $\frac{0.50}{\sqrt{2}}$ A.

C. 0.50 A.

D. $0.50\sqrt{2}$ A.

**(1)**

**11.** An ideal transformer has $N_p$ turns on the primary coil and $N_s$ turns on the secondary coil. The input power of the primary coil is *P*. The output power at the secondary coil is

A. *P*.

B. $\left(\frac{N_p}{N_s}\right)P$.

C. $\left(\frac{N_s}{N_p}\right)P$.

D. $\left(1-\frac{N_s}{N_p}\right)P$.

**(1)**

**12.** This question is about an ideal transformer.

(a) State Faraday's law of electromagnetic induction.

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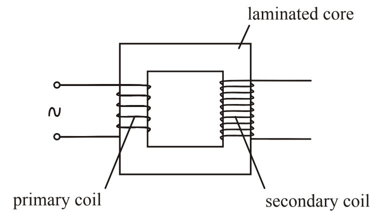
**(2)**

(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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**(2)**

(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)**

**13.** The maximum value of a sinusoidal alternating current in a resistor of resistance $R$ is $I_0$. The maximum current is increased to $2I_0$.

Assuming that the resistance of the resistor remains constant, the **average** power dissipated in the resistor is now

A. $\frac{1}{2}I_0^2R$.

B. $I_0^2R$.

C. $2I_0^2R$.

D. $4I_0^2R$.

**(1)**

**1.** D **[1]**

**2.** D **[1]**

**3.** B **[1]**

**4.** D **[1]**

**5.** C **[1]**

**6.** A **[1]**

**7.** C **[1]**

**8.** C **[1]**

**9.** B **[1]**

**10.** B **[1]**

**11.** A **[1]**

**12.** (a) e.m.f. induced proportional to/equal to;
rate of change of flux (linkage) / rate of flux cutting; 2

(b) (i) for e.m.f./current to be induced in secondary, flux must be changing in the core;
changing flux is caused by varying current in primary; 2

(ii) induced currents in core are kept small; (*do not allow reduced/ prevented*) to reduce heating/energy losses;
(*do not allow mere "eddy current losses"*) 2

(iii) use of $\frac{N_S}{N_P} = \frac{V_S}{V_P}$;
to give $N_P = 8600$ turns;
and $I_P \left( = \frac{42}{230} \right) = 180$ mA; 3

**[9]**

**13.** C **[1]**