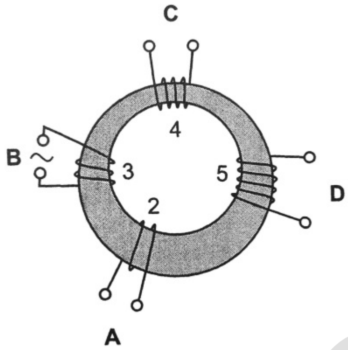
ELECTROMAGNETIC INDUCTION

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

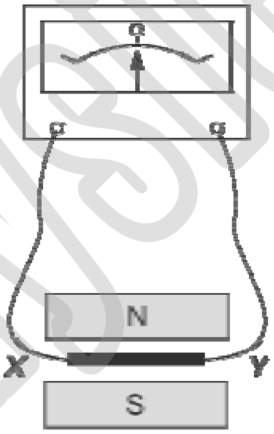
1 A soft-iron ring of variable cross-section has four coils wound round it at the positions shown. The coils have 2, 3, 4 and 5 turns. The 3-turn coil is connected to an a.c. supply.

In which coil does the magnitude of the magnetic flux density have the least variation?



2 A conducting wire XY moves between the magnets as shown in the diagram.

Which of the following motions of XY will make the galvanometer deflect the most?



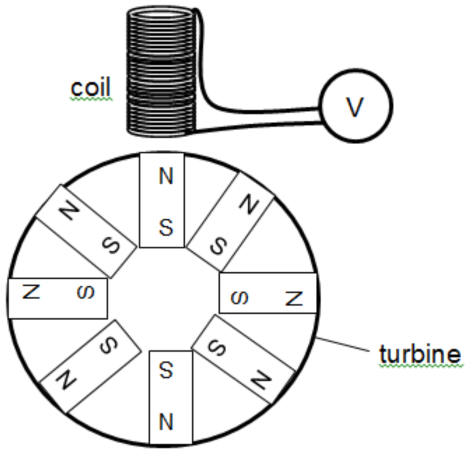
A It moves sideways along the magnetic field quickly.

B It moves sideways along the magnetic field slowly.

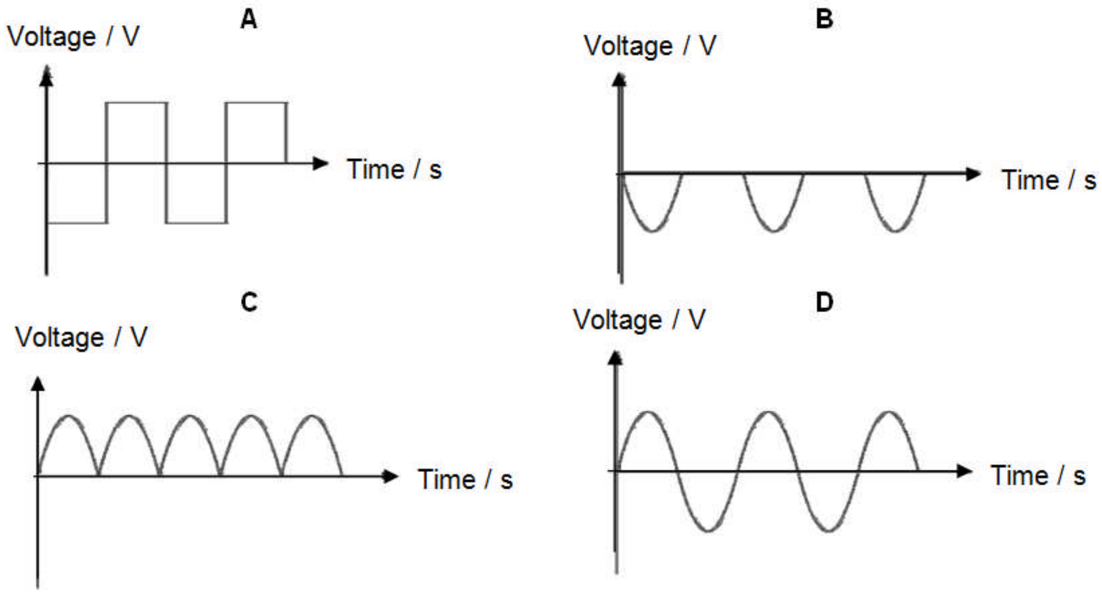
C It moves perpendicular to the magnetic field quickly.

D It moves perpendicular to the magnetic field slowly.

3 A flowmeter is used in many industries to measure the volume of liquid passing through a pipe per unit time about the axis of the turbine. When the liquid flows through the turbine, the 8 magnets attached on it rotate.



Which of the following voltage-time graphs shows the signal detected by the coil?

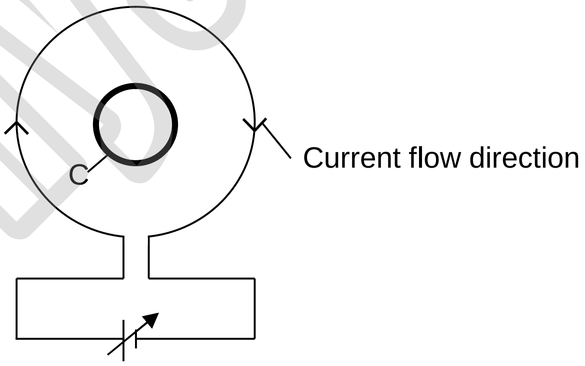


4 A flat circular coil of diameter 40.0 mm has 600 turns and is placed so that the plane of the coil is perpendicular to a uniform magnetic field of flux density 30.0 mT. The magnetic flux density first reduces to zero and then increases to 30.0 mT in the opposite direction at a constant rate. The time taken for the whole operation is 60.0 ms.

What is the average value of the e.m.f induced in the coil?

A 0.00 V **B** 0.377 V **C** 0.754 V **D** 3.02 V

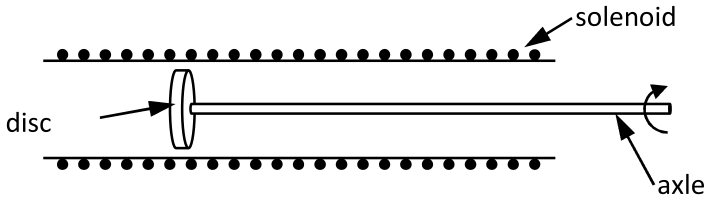
5 A flexible conductor loop, C is placed in the centre of a larger metal coil that is connected to a variable power supply as shown in the figure below. The plane of the flexible conductor loop is parallel to the plane of the larger metal coil. Initially, the current in the larger metal coil is kept constant and flows clockwise.



When the current in the larger metal coil is suddenly switched off, what is the direction of the induced current and the change in the area of the flexible conductor loop at that instance?

	Direction	Area
A	clockwise	increase
B	clockwise	decrease
C	anticlockwise	increase
D	anticlockwise	decrease

6 A small copper disc spins on an axle lie along the centre of a long solenoid. An induced e.m.f. is generated between the axle and the circumference of the disc.



Which of the following changes does **not** result in a larger magnitude of induced e.m.f.?

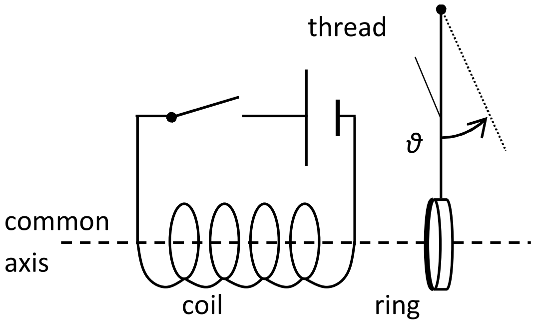
A placing a soft iron core to the left of the disc.

B spinning the axle with a larger angular speed.

C increasing the current in the solenoid.

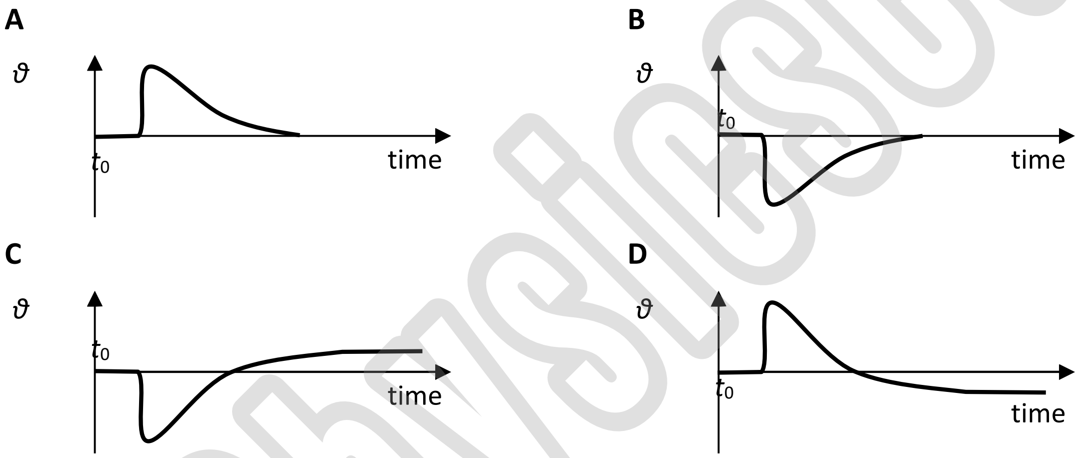
D cooling the copper disc.

7 An soft-iron ring hangs vertically from a thread and has its axis aligned with a coil.

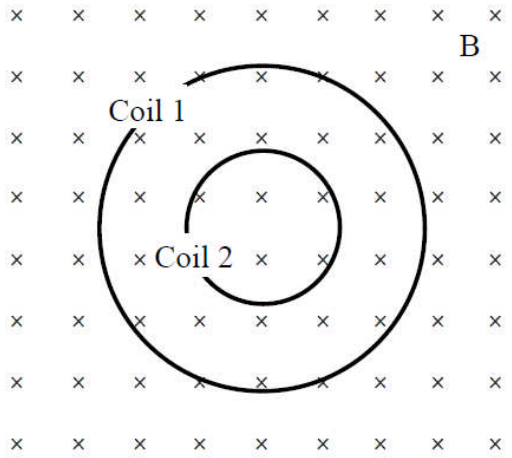


The current in the coil is switched on at time t_0.

Which of the following graphs shows a possible variation of the angular displacement that the thread makes with the vertical, ϑ, with time?



8 Two coils of different diameters are in the same uniform magnetic field *B*.



If the magnitude of the magnetic field is increasing with time,

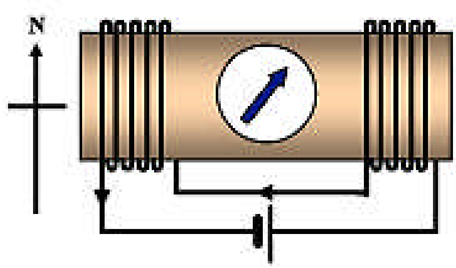
A the induced emf is the same in each coil.

B the induced emf in coil 1 is greater.

C the induced emf in coil 2 is greater.

D the induced emfs in the two coils is in opposite directions.

9 The diagram below shows a compass placed inside a solenoid with current flowing in the direction as shown.



What will happen to the compass needle if the current in the coil is increased?

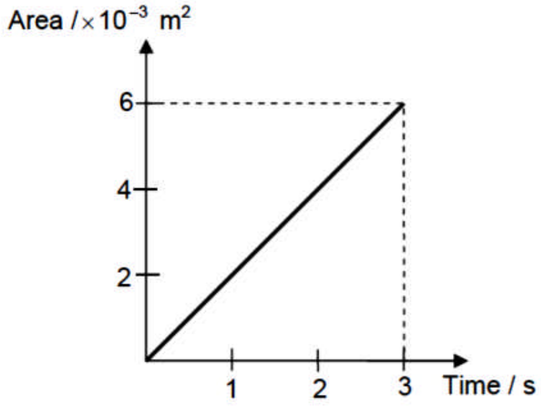
A The needle will turn more to the right.

B The needle will turn more to the left.

C The needle will remain in the same position.

D The needle will oscillate about the original position.

10 A single circular loop of wire is placed in a uniform magnetic field of 12 mT that is normal to the plane of the loop. The area of the loop varies with respect to time as shown in the graph below.



What is the e.m.f. induced?

A 24 V **B** 0.24 V **C** 24 mV **D** 24 μV

11 A magnet is dropped from rest, with its North pole at the bottom, from a height of 2.0 cm above the end of a coil. When the magnet is entering the coil, the maximum deflection of the needle in the galvanometer connected to the coil is 10 units to the right.

The same magnet is again dropped from rest but with its South pole at the bottom and from a height of 4.0 cm above the end of the same coil. What is the maximum deflection of the needle in the galvanometer when the magnet is entering the coil again?

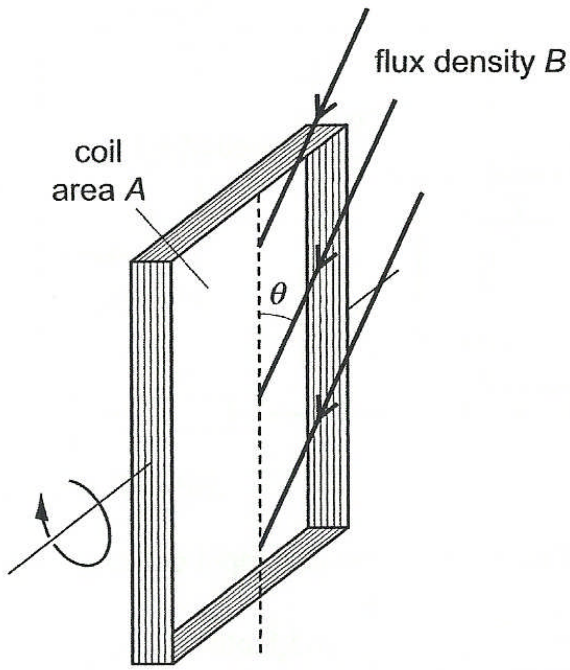
A Less than 10 units to the left

B Less than 10 units to the right

C More than 10 units to the left

D More than 10 units to the right

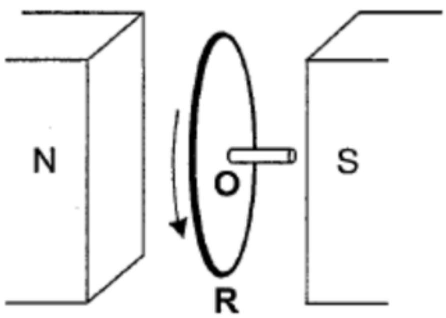
12 A coil has area A and n turns.
A uniform magnetic field of flux density B acts at an angle θ to the plane of the coil, as shown.



What is the decrease in magnetic flux linkage when the coil rotates so that angle θ is reduced to zero?

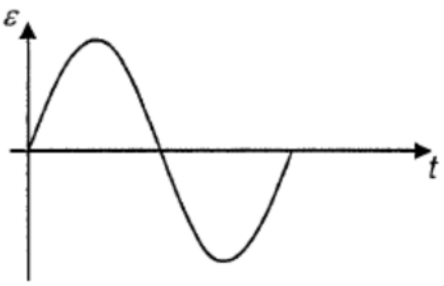
A $BAn\cos\theta$ **B** $BAn\sin\theta$ **C** $2BAn\cos\theta$ **D** $2BAn\sin\theta$

13 The figure below shows a copper disc rotating at a constant rate about its centre O in a uniform magnetic field between two bar magnets. The magnetic field is acting perpendicularly to the disc.

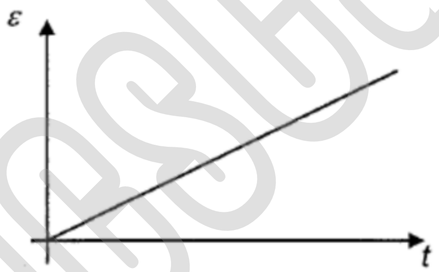


Which of the following graphs correctly shows the variation of the induced e.m.f. between the centre O and a point R on the rim of the disc with time *t*?

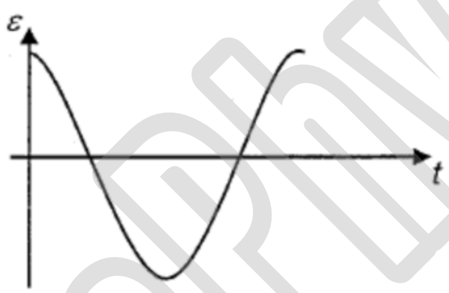
A



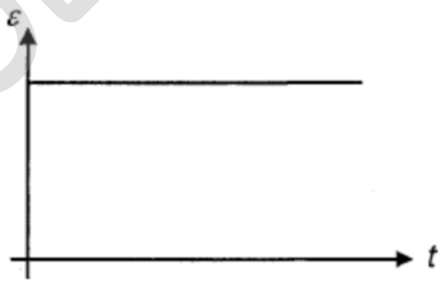
B



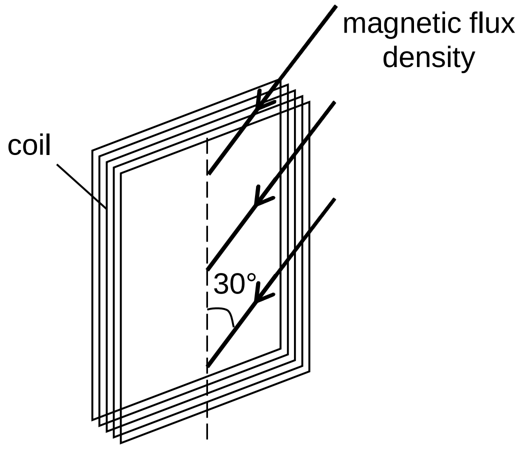
C



D



14 A flat circular coil of 850 turns, each of area 0.055 m^2, is placed with its plane aligned at 30° to a uniform magnetic field as shown below. The flux density of the field is changed steadily from 80 mT to 30 mT over a period of 4.0 s.



What is the average e.m.f. induced in the coil during this time?

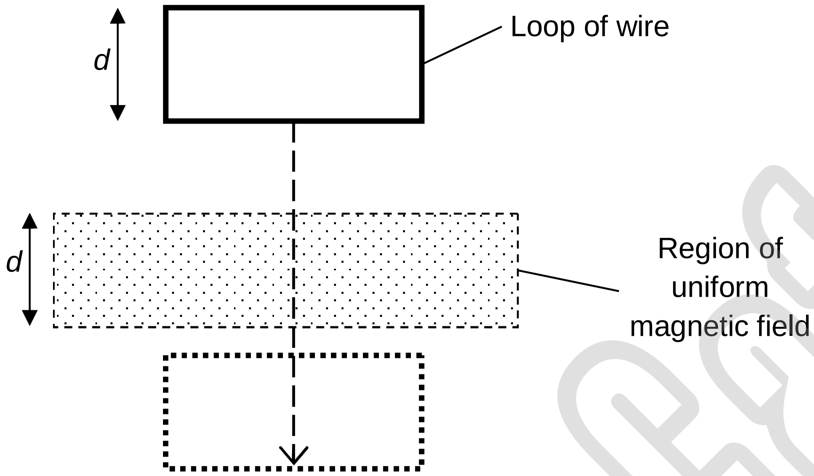
A 0.29 V

B 0.34 V

C 0.51 V

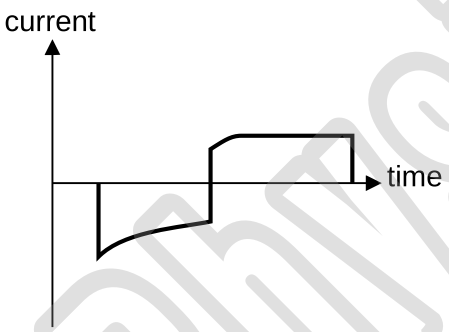
D 0.58 V

15 A rectangular loop of wire is released from rest and falls vertically through a region of uniform magnetic field under the influence of gravity. The loop and the region of magnetic field has the same height *d* as shown in the figure below.

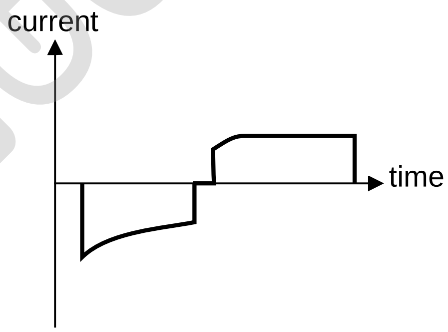


Which of the following graphs shows the flow of the current in the loop of the wire as it falls and passes through the region of magnetic field?

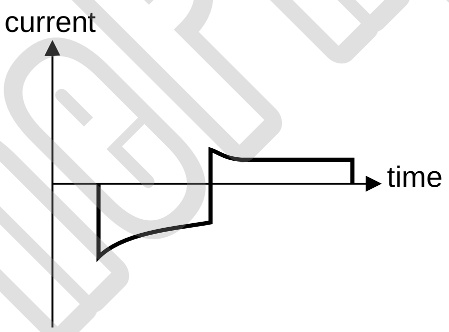
A



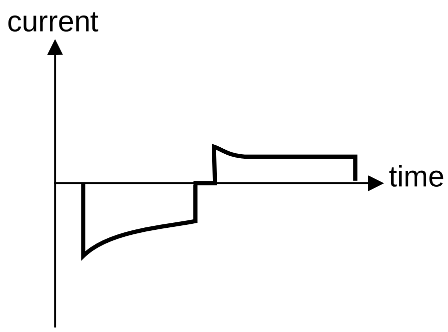
B



C



D



EMI

WORKED SOLUTIONS

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1 Ans: **A**

Since magnetic flux $\phi = BA$

magnetic flux density, $B = \frac{\phi}{A}$

Magnetic flux ϕ is the same throughout the core assuming no leakage.
Since section (A) has the biggest cross-sectional area, it has the smallest magnetic flux density B.

Note that as N is the smallest for A, it also has the smallest flux linkage, hence A is the region with the least variation of magnetic flux density.

2 Ans: **C**

For the galvanometer to deflect the most, the rate of change of magnetic flux linkage in the wire is to be the largest. Hence, the wire moving perpendicular to the magnetic field quickly will give a larger induced emf than moving perpendicular slowly. For A & B, wire is moving sideways along magnetic field, this will not induce any emf.

3 Ans: **D**

When each magnet approaches the coil, there is an increase in the flux linkage in the coil. The maximum flux linkage in the coil occurs when the magnet is closest to the coil. The increase in flux linkage with respect to time results in an induced emf. When that magnet moves away from the coil, there is a decrease in the flux linkage in the coil. The minimum flux linkage in the coil occurs when the coil is at equidistant from the 2 magnets that are closest to the coil. Thus, the decrease in flux linkage with respect to time results in having an induced emf in the opposite direction.

4 Ans: **C**

$E=\frac{\Delta\varphi}{\Delta t}$

$E=\frac{\Delta NBA}{\Delta t}=NA\frac{\Delta B}{\Delta t}$

$E=600\times\pi(0.0200)^2\times\frac{[30-(-30)]\times10^{-3}}{60\times10^{-3}}$

$E = 0.754$ V

5 Ans: **A**

The current in the larger outer loop generates a magnetic field into the page, within the loop where the smaller loop is.

When the current is switched off, the magnetic flux density pointing into the page decreases.

An e.m.f is generated in the flexible tube due to the change in magnetic flux linkage through the loop as predicted by Faraday's law. The current is induced in the closed loop.

According to Lenz’s law, the induced current would want to reinforce the reduced magnetic field into the page, hence the direction of the induced current is clockwise.

In addition, since the magnetic flux decreases as the current is switched off, the flexible loop would increase the area as a way to oppose that change.

6 Ans: **D**

7 Ans: **D**

8 Ans: **B**

9 Ans: **A**

In the absence of the current, the compass needle would point northwards. With the current turned on, the magnetic field due to the solenoid points to the right. Combining the two components, the compass needle points toward the right. With a further increased in the current in the same direction, the magnetic field set up in the solenoid is even larger and hence, the needle points even more to the right.

10 Ans: **D**

$$E = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{(B)(\Delta A)}{\Delta t} = \frac{(12\times10^{-3})}{} \times \frac{6\times10^{-3}}{3}$$

$= 24\ \mu V$

11 Ans: **C**

The magnet will enter the coil at a faster speed if it is dropped from rest at a greater height above the coil. This increases the rate of change of flux linkage through the coil, resulting in higher induced e.m.f. and/or induced current thus the maximum needle movement will be more than 10 units. Since the magnet had been flipped so that it is the other pole entering the coil, the direction of the induced e.m.f. and/or induced current will also flip so the needle will move to the left.

12 Ans: **B**

Initially,
$\Phi = nBA\cos\alpha$, where α is the angle between the magnetic field and normal to the plane.

$\Phi = nBA\cos(90° - \theta)$
$\Phi = nBA\sin\theta$

As θ becomes zero, $\Phi = 0$. Hence the decrease is $nBA\sin\theta$.

13 Ans: **D**

Since the angular velocity is constant, the rate of cutting of magnetic flux by the disc is constant, hence constant induced e.m.f.

14 Ans: **A**

$$\Delta(BAN\sin\theta) = (AN\sin\theta)(\Delta B)$$
$$= 0.055\times850\times(\sin30°)\times(30-80)\times10^{-3}$$
$$= 1.17\ \text{Wb}$$

$$\text{e.m.f.} = \frac{\Delta\Phi}{\Delta t} = \frac{1.17}{4.0} = 0.29\ \text{V}$$

15 Ans: **C**

By Lenz's law, an induced current will flow in the loop such that it opposes the increase in the magnetic flux linkages producing it. When loop starts to enter the region of magnetic field, loop experiences an upwards retarding force larger than its weight and hence decelerate.
By Faraday's law, the induced emf is proportionate to the rate of cutting of magnetic flux. As the loop decelerates, the induced emf decreases and given that resistance is constant, induced current decreases in magnitude.
When the loop is leaving the region of magnetic field, the magnetic flux linkages through the loop decreases, hence the induced current is such that it opposes the decrease in the magnetic flux linkages. → induced current is now in the opposite direction but force is still upwards.
As the upwards force is still larger than its weight, it continues to decelerate and magnitude of induced current will decrease.
When the upwards magnetic force and weight become equal and opposite, the loop experience zero net force and reaches terminal velocity. Thus the rate of cutting of magnetic flux linkage and the induced current is constant.