KeyQ's 3, 4, 7, 9, 13, 15, 23, 29 Chapter 26 Magnetism and Electromagnetism

1. **Electromagnetic induction** is the process of producing an EMF in a conductor by changing magnetic flux. **Faraday's Law** states that when the magnetic field in the region of a conductor changes, an EMF is induced across the endo of the conductor. **Lenz's Law**: The current induced in a conductor by a changing magnetic field is in such a direction that its own induced magnetic field opposes the change that produces it. **Induced voltage** is voltage produced in a conductor by a changing magnetic field.

2. (a)

$$EMF = BLv$$
$$= 3.6 \times 10^{-2} \times 0.55 \times 12$$
$$= \underline{0.24\ V}$$

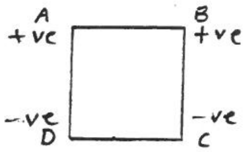
(b)

$$EMF = BLv \sin 30$$
$$= 3.6 \times 10^{-2} \times 0.55 \times 12 \sin 30$$
$$= \underline{0.12\ V}$$

3. (a) $V_{AB} = V_{DC} = 0$ since these wires have no component of their length at right angles to the field.

$$V_{AD} = V_{BC} = BLv$$
$$= 150 \times 10^{-3} \times 0.05 \times 8.5$$
$$= \underline{6.4 \times 10^{-2}\ V}$$

(b) There will be no induced current since V_{BC} opposes V_{AD}:



Draw bottom of small solenoid just inside large one.

4. When the switch is closed, current flows in the small inside solenoid. A magnetic field begins to form around this solenoid. The solenoid has a North pole at the top and a South pole down inside the large solenoid. The build up of the magnetic field in the small solenoid has the same effect on the larger solenoid as would be obtained by moving the South pole of a permanent magnet into the larger solenoid.

Current will flow in the larger solenoid to oppose this change: it will flow from

4 continued ...

the bottom of the larger coil to the top (Lenz's Law).

When the current in the smaller solenoid is switched off, the reverse happens: the field in the solenoid begins to decay. This is like removing the South pole of a permanent magnet from the larger solenoid. Current now flows in the larger solenoid from top to bottom. Switching the current in the smaller solenoid on and off repeatedly would produce an alternating current in the larger solenoid.

5. The DC generator has an almost identical make-up to the alternator (AC generator) in older models. The major difference is that the DC generator has a split ring commutator.

In newer models the two are exactly the same. A rectifier changes AC to DC if required.

6. We could assume that the primary voltage is relatively high already, since it is being stepped-down. Connecting this voltage across the secondary windings would increase it, probably to levels that the transformer was not designed to handle. This could be dangerous.

7. Both have coils spinning between poles of a magnet

Motor	Generator
Input: current	Input: motion
Output: motion	Output: current
Use RH Motor Rule	Use LH Generator rule

8.

$$EMF = \frac{-\Delta BA}{\Delta t} = \frac{-2.5 \times 10^{-2} \times (0.08)^2}{0.1}$$
$$\therefore |EMF| = \underline{1.6 \times 10^{-3}\ \text{Volts}}$$

9. STEP UP

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{240\ V}{12\,000\ V} = \frac{1}{50}$$

$\therefore$ Ratio of $N_P : N_S = 1 : 50$ to obtain 12 kV from a 240 V input.

10. Not covered in this course.

11. AC is more efficient to transport long distances, which we have in Australia. It is transmitted at high voltage and relatively low current. However, it must be converted to DC before use in electric motors.

In countries with large populations in small areas electricity can be transported as DC. The saving in not needing devices to change AC to DC outweighs the loss of power by transmission as DC.

12. (a) There are few people awake at 6:00am. Around 7:00 am people are up and using electricity for showers, cooking etc. Factories are starting up. (b) Heating of homes etc. (c) At this time factories and offices are shutting down. People are on their way home and so electricity use is reduced.

13. $P = VI \quad \therefore \quad I = \frac{P}{V}$

For 11 kV transmission:

$I = \frac{600 \text{ kW}}{11 \text{ kV}} = \frac{600}{11} \text{ A}$

$\therefore$ Power loss $= I^2 R = \left(\frac{600}{11}\right)^2 \times 120$

$= \underline{3.6 \times 10^5 \text{ W}}$

For 66 kV transmission:

$I = \frac{600 \text{ kW}}{66 \text{ kV}} = \frac{600}{66} \text{ A}$

$\therefore$ Power loss $= I^2 R = \left(\frac{600}{66}\right)^2 \times 120$

$= \underline{9.9 \times 10^3 \text{ W}}$

14. $EMF = \frac{-\Delta BA}{\Delta t} = \frac{-2.4(0.55 - 0.15)}{0.4}$

$\therefore |EMF| = 2.4 \text{ V}$

NB. Q14 and 15 show that $\phi = BA$

15. $EMF = \frac{-\Delta \phi}{\Delta t} = \frac{-(0.15 - 0.03)}{0.02} \times 15 \text{ turns}$

$\therefore |EMF| = 90 \text{ Volts}$

16. This is a simple proportion:

New voltage $= 200 \text{ V} \times \frac{80}{60}$

$= \underline{270 \text{ Volts}}$

17. If the induced current flowed in such a direction to <u>assist</u> the motion producing the current, we would be getting electrical energy for nothing. This contravenes the Law of Conservation of Energy.

18. The soft iron cores increase the magnetic field. Domains become aligned in the soft iron core and become magnets themselves.
In inductance using any soft iron core, alternating current induces a voltage in the soft iron core. This voltage causes a current in the soft iron core called the eddy current (because it flows in a circular path in the cross section of the core). Eddy currents cause wasted power dissipation as heat in the core. Using insulated laminations in the core increase resistance in the cross section of the core. This reduces eddy current.

19. $\frac{V_P}{V_S} = \frac{N_P}{N_S} \quad \therefore N_S = N_P \times \frac{V_S}{V_P}$

$= 2000 \times \frac{6.3}{240}$

$= \underline{53 \text{ turns}}$

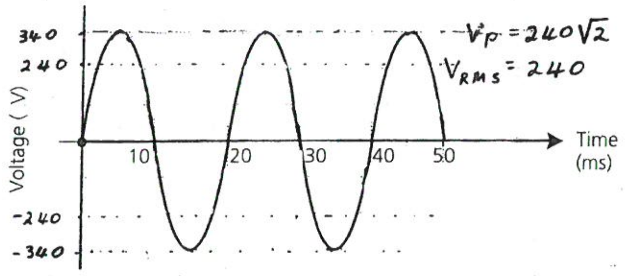
20. DC does not produce a changing magnetic flux except at switch on and switch off. AC, because it is continuously changing, produces a continuously changing magnetic flux.

21 (a) A thermal power station produces electricity by burning fossil fuels
(b) A turbine-driven generator gets it movement from a turbine: a rotatin[g] device, often driven by steam
(c) A brownout occurs when supply volta[ge] reduces. Machines, lights etc can st[ill] operate, but at lower levels than usu[al]
(d) A power surge is a sudden increase in voltage. (e) The base load is that supplied by larger, often coal fired, generators

22. Leave out $E_0 = NAB\omega$

23. As the left hand magnet is dropped, a current is induced in the left hand coi[l]. This current moves DOWN the coil, thus making the TOP of this coil a NORTH pole. This opposes the motion of the dropped magnet.
The current enters the right hand coil at the bottom, making the TOP of the coil NORTH. This <u>attracts</u> the RH magnet.

24. $V_P = \underline{240\sqrt{2}} = 339 \text{ V} \quad V_{RMS} = \frac{V_P}{\sqrt{2}} = \frac{240\sqrt{2}}{\sqrt{2}} = \underline{240 \text{ V}}$



25. Leave out

26. $V_S = V_{output} = V_P \times \frac{N_S}{N_P}$

Output voltage depends on input voltage and the number of turns in the primary and secondary coils.
Energy is lost via eddy currents (see Q18)

27. $E = \frac{-\Delta BA}{\Delta t} = \frac{20 \times 10^{-3} \text{ T} \times 50 \times 10^{-4} \text{ m}^2}{0.023} \times 200$

$= 1 \text{ volt}$

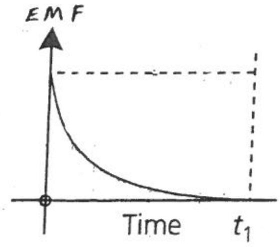
$R = 20 + 5 = 25 \ \Omega$

$I = \frac{V}{R} = \frac{1}{25} = \underline{0.04 \text{ A}}$

28.(a) $EMF = -\frac{\Delta(BA)}{\Delta t}$

$\therefore |EMF| = \frac{\Delta B}{\Delta t} \times A$

Since A (area) remains constant, EMF depends on $\frac{\Delta B}{\Delta t}$. The more change in B (magnetic flux density) per unit time, the greater is the EMF, ie where the slope of the B vs t graph is steep, EMF is large.



(b)

$|EMF| = \frac{\Delta BA}{\Delta t}$

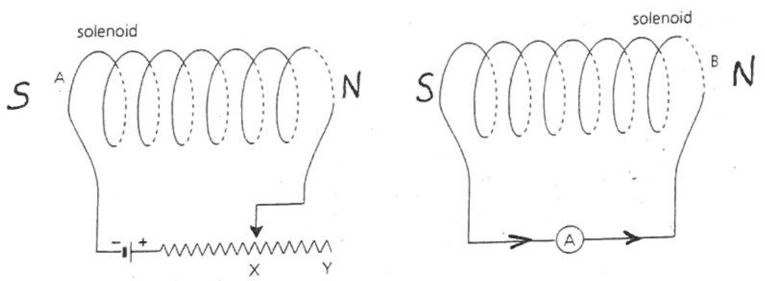
$= \frac{0{\cdot}04 \times 0{\cdot}6}{2{\cdot}0} \frac{m^2}{s} \frac{V\text{-}s}{m^2}$

$= 0{\cdot}012$ Volts

29. As the resistor is varied from position X to Y the resistance increases so the current decreases.

As the current decreases, the North pole of coil A becomes less strong. To coil B, this has the same effect as you would get if you were moving coil A to the left.

Lenz's Law tells us that the induced current in B would flow in a direction which would oppose the percieved motion of coil A. That is, a South pole would be nduced at the left hand end of coil B. Therefore the current in coil B would flow from left to right in coil B, as shown by the arrows on coil B below:



30(a) Power $= 40$ kW
Voltage $= 250$ V } use this to calculate the current flowing

$\therefore P = VI$

$\therefore I = \frac{P}{V} = \frac{40\,000}{250}$

$= 160$ Amps

See P.456: when current flows through a resistor some power is converted to heat:

Power loss $= P = I^2R = (160)^2 \times 0{\cdot}2$

$= 5120$ watts

30(b) Power remaining $= 40\,000 - 5120 = VI$

$\therefore$ Voltage $= \frac{\text{Power remaining}}{I}$

$= \frac{40\,000 - 5120}{160}$

$= 218$ Volts

Normal 240 V appliances would possibly work.

(c) Power loss $= I^2R = (160)^2 \times 1{\cdot}0$

$= 25\,600$

$\therefore$ Voltage $= \frac{\text{Power remaining}}{I}$

$= \frac{40\,000 - 25\,600}{160}$

$= 90$ V { 240 V appliances would not work

(d) Power $= 40\,000$ W
Voltage $= 10\,000$ volts

Power $= VI$

$\therefore I = \frac{P}{V} = \frac{40000}{10\,000} \frac{J}{s} \frac{C}{J}$

$= 4$ A $(= C\,s^{-1})$

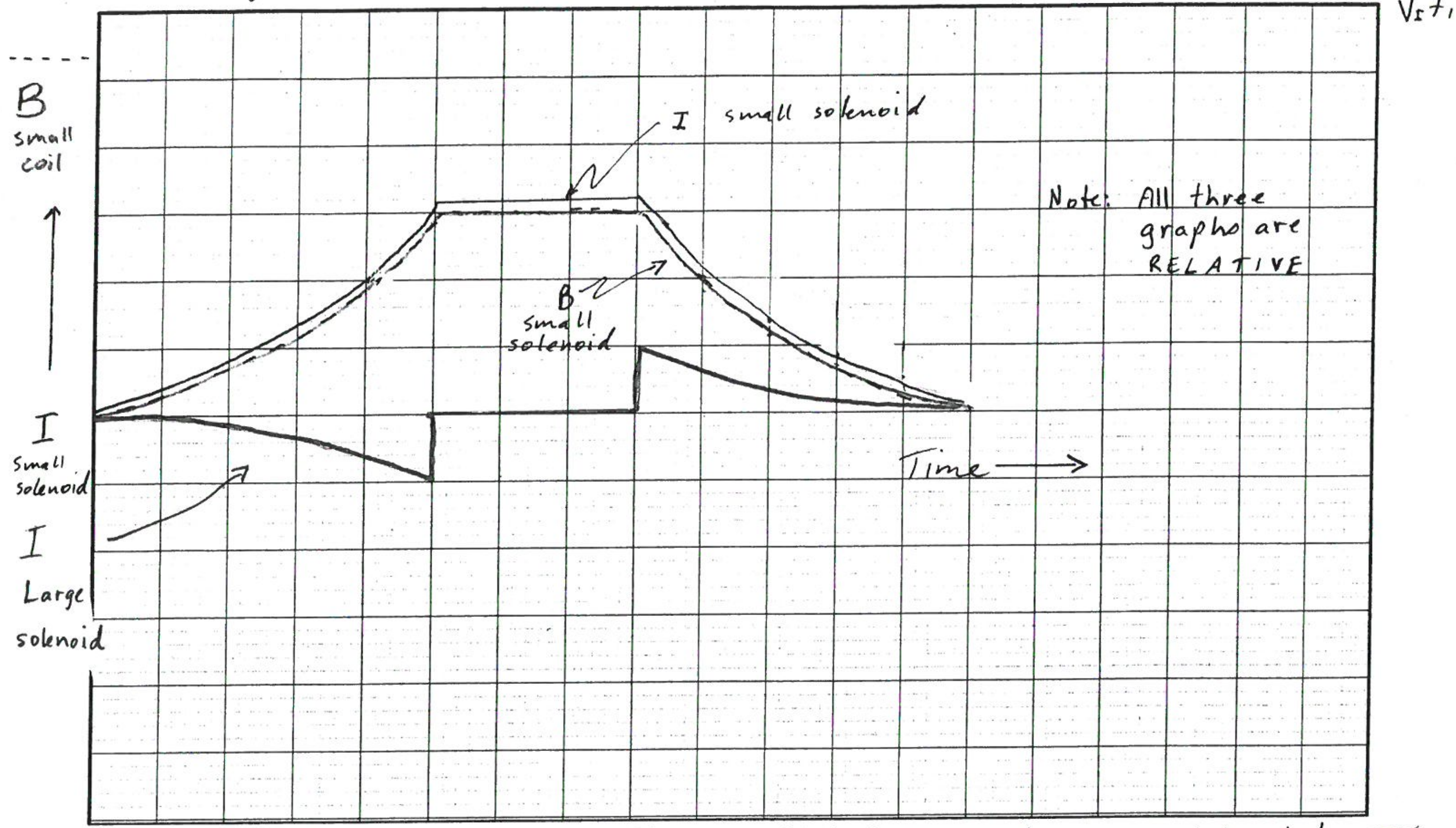
$\therefore$ Power loss $= I^2R$ $(R = 0{\cdot}2\,\Omega)$

$= 4^2 \times 0{\cdot}2$

≈ 3 Watts

Q4 chapter 26

The switch in question 4 is turned on, left on for a short time, then turned off. On the same piece of graph paper, draw graphs for (a) magnetic field strength, B, in the small coil (b) I in the small coil and (c) I in the large coil. All gr... Vs t...



In Question 4 the small solenoid is switched ON then some time later OFF

Faraday's Law

$$EMF = \frac{-\Delta\phi}{\Delta t} = \frac{-\Delta(BA)}{\Delta t}$$

$$\therefore \quad I \propto EMF = -\frac{\Delta B \times A}{\Delta t}$$

$\therefore$ current in the large coil is the TANGENT to the B Vs t graph since $B = \frac{2\pi K N I}{L}$, $B \propto I$

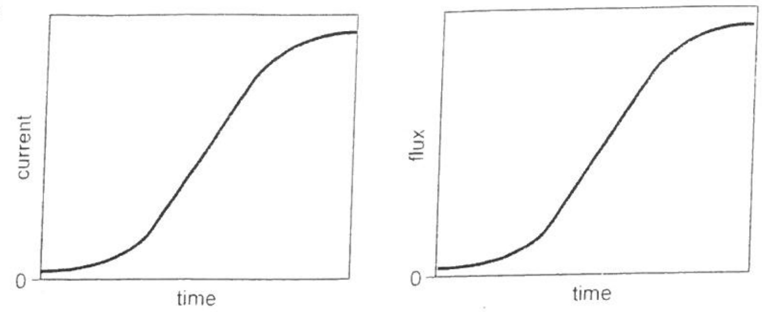
In the above, the − sign denotes the fact that the induced EMF acts to oppose any change in the magnetic flux density.

Graphs of changing flux and emf

Flux produced by a current

straight wire

1\.



The formulae which relate to the field around a current carrying wire are:

wire

1\. $B = \frac{KI}{r}$ or $B = \frac{K}{r} \times I$ (const.)

ie $B \propto I$

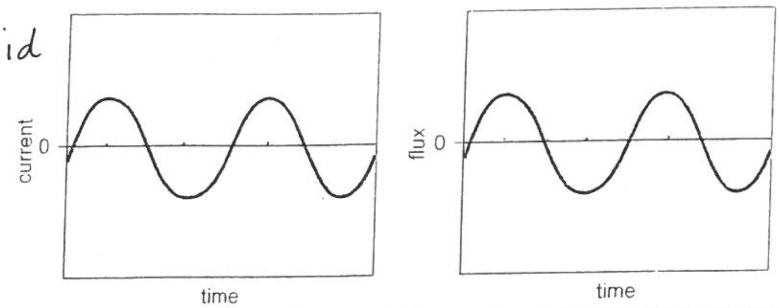
Solenoid

2\. $B = \frac{2\pi KNI}{L}$ or $B = \frac{2\pi KN}{L} \times I$

ie $B \propto I$

Solenoid

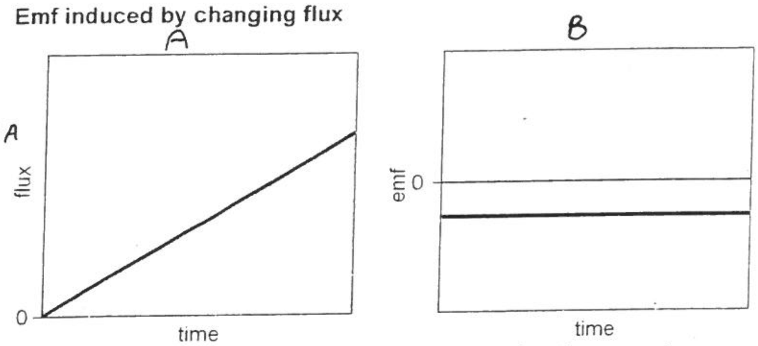
2\.



If the flux is proportional to the current, the graphs of changing flux and changing current have the same form.

Emf induced by changing flux

3



A steadily increasing flux produces a constant emf, acting so as to oppose the change of flux producing it.

The formula which relates to these graphs is:

For a wire loop} $EMF = -\frac{\Delta(BA)}{\Delta t}$

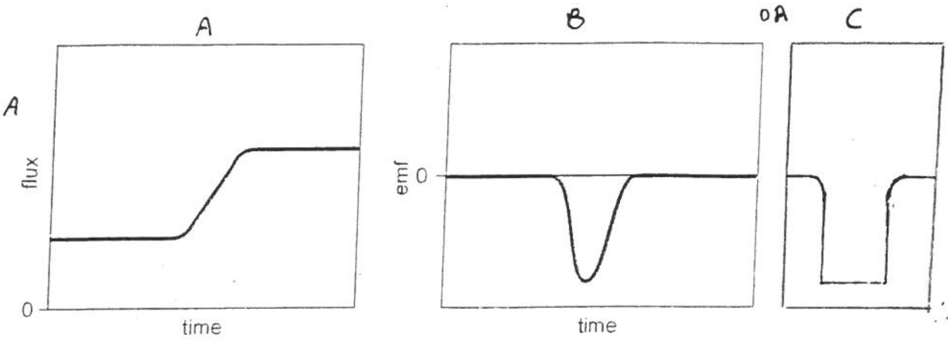
We are changing B and assume that A is unchanged

$\therefore EMF = -\frac{\Delta B}{\Delta t} \times A$

the sign indicates that the induced EMF acts to oppose any change in the magnetic flux: Faraday

Since $\frac{\Delta BA}{\Delta t}$ is the SLOPE of a BA Vs time graph: $\therefore$ EMF $\propto$ − SLOPE

4

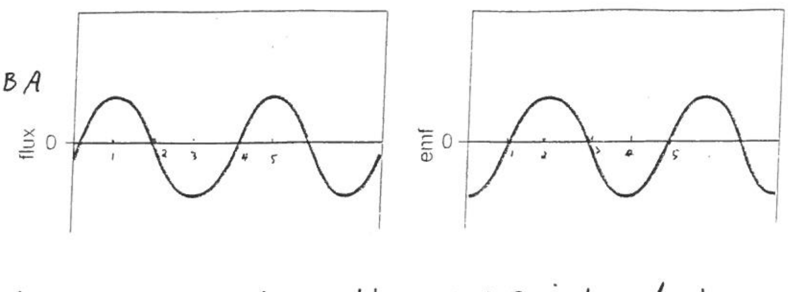


A sharp increase of flux produces a pulse of emf, acting so as to oppose the change of flux producing it.

Note that Graph 3 A has a constant, positive slope. Graph 3 B shows a negative (oppositional) EMF which is CONSTANT.

With this in mind, we may wish to relook at Graph 4 A which has a large straight section. Thus 4 C may be a more accurate graph than 4 B.

5



Graph 5 shows how the EMF induced by a changing field opposes the change that produced it. This oppositional nature of the induced EMF is shown by the −ve sign in $EMF = -\frac{\Delta B}{\Delta t} \times A$

EC Revision question Semester III 2017

Morgan collects two samples of soft iron, steel (not magnetised), an iron based permanent magnet and neodymium magnet (a very strong magnet).

All of the samples look the same. He knows that each piece of each pair is the same. For example soft iron is with soft iron, and neodymium is with neodymium. However he does not know which sample is soft iron, and which is steel etc.

He labels the samples A, B, C, D and then gathers some results into a table.

What happens when he brings the materials near each other is entered on the first line of each square. The sample's alignment and ability to pick up paper clips is entered on the second line. If the test has already been done he enters "-" in the table.

		A	B	C	D
A	1 2	One Y P	Two	Two	Two
B	1 2	- Y P	One	Two	Two
C	1 2	- N NP	-	No	No
D	1 2	- N NP	-	-	No

KEY

One = attracts one end and repels other Two = attracts both ends No = no attraction

Y = aligns north–south when suspended N= does not align north-south

P = picks up paper clips NP = does not pick up paper clips

After Morgan has collected the above results, he again suspends a sample of each material to check its alignment. To his surprise, sample D now aligns itself north-south and while A still aligns itself, it does so more slowly than at the start. The other samples act the same as they did at the start of the experiment.

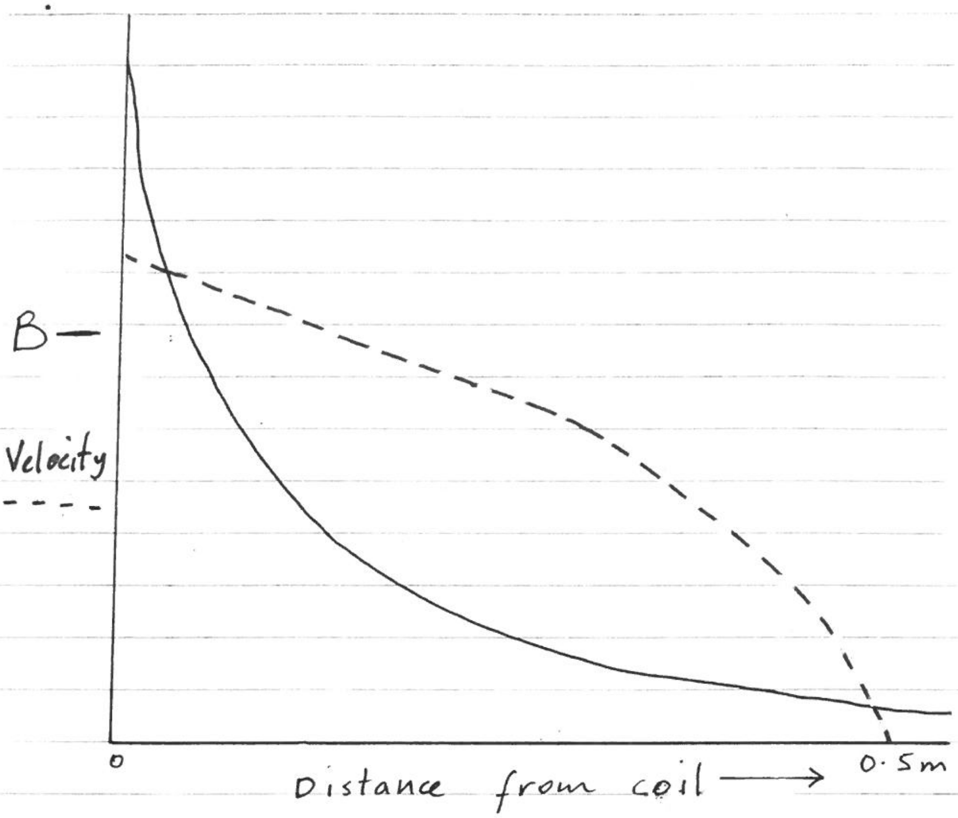
What is the make up of samples A, B, C, and D? Justify your conclusions.

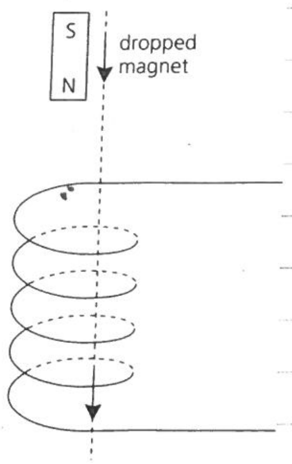
A and B are magnetic 1 because - they align with earth's field, 1
- pick up paper clips 1 - attract at one end & repel the other 1

B is neodymium 1 since A has lost some magnetism 1 due to B's high strength

D is steel 1 since it retains its magnetism 1

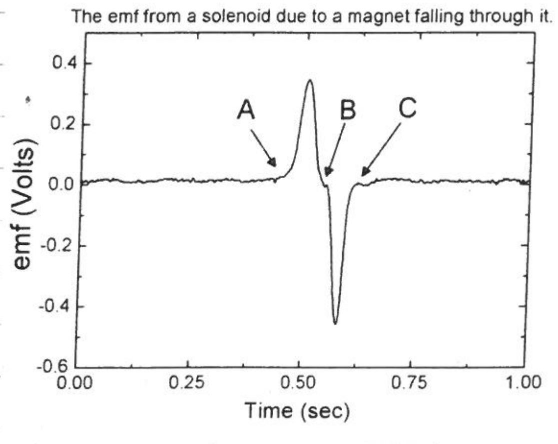
C is soft iron 1 since it does not retain its magnetism 1

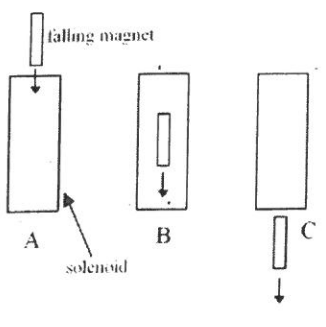




The strength of the magnetic field threading through the solenoid increased exponentially as the magnet got closer to to the coil. In addition, the velocity of the falling magnet increased the closer the magnet got to the solenoid.

The net effect of these changes means that the induced voltage in the solenoid will increase exponentially as the distance of the magnet from the solenoid decreases. It will fall off at the same rate.





The A, B, and C positions are indicated on the graph. There are a couple of features to note:

(a) The sign of the emf as the magnet enters the solenoid is opposite to that when the magnet exits.

(b) The two peaks are not the same width because the magnet is falling freely and thus accelerating, so the induced emf occurs more quickly as the magnet nears the other end of the solenoid.

(c) There is zero emf when the centre of the magnet corresponds to the centre of the solenoid.

(d) The graphs and text at the top of this page explain the exponential growth and falling off of induced EMF.

(e) We could expect a larger. flat (= zero volts) section for B, and a quicker drop of in A