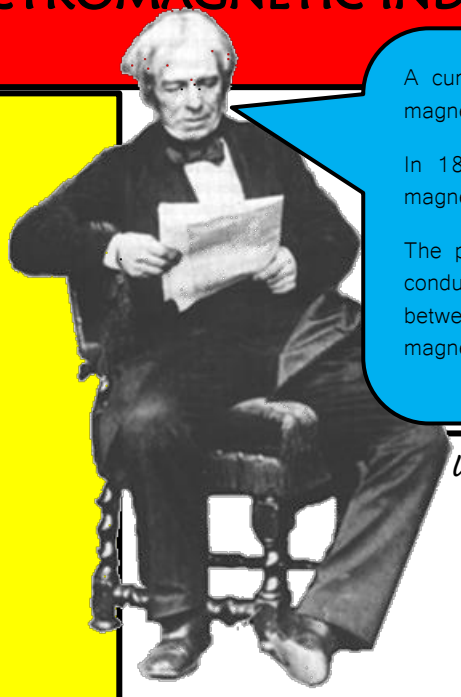
Week 1

LESSON 1: ELECTROMAGNETIC INDUCTION

Lesson objectives

At the end of the lesson, I will be able to:



A current produces a magnetic field. But can a magnetic field produce a current?

In 1831, I passed a conductor through a magnetic field and voila! current was produced.

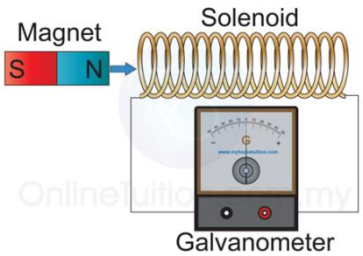
The production of electric current or voltage in a conductor whenever there is a *relative motion* between the conductor and a magnetic field (or magnet) is called *electromagnetic induction*.

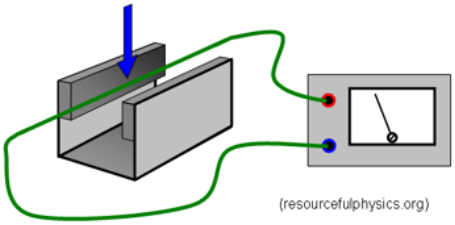
Michael Faraday
(1791-1867)

What is Electromagnetic Induction?

Let's Experiment:

Grab a partner; let's try out what Faraday did





Activity A

Wind the copper wire into a coil of 20 turns. Connect it to the meter. Hold the coil still and push the North Pole of the magnet into the coil. Record what happens. Now try the same with the South Pole. Try moving it fast and then slowly. Now hold the magnet still and move the coil. Watch carefully as the meter movements will be small. Record the size and direction of the current on the meter in the Worksheet table.

Action	Size of Current	Direction of Current
North Pole of Magnet in Coil		

Name:_____ Class:_____

Activity B

Connect the wire to the meter as shown in the diagram. Move it downwards between the two magnets, record what happens on the meter. Now move it upwards. Now move the wire sideways between the magnets and then from end to end. Watch carefully as the meter movements will be small. Record the size and direction of the current on the meter in the Worksheet table.

Action	Size of Current	Direction of Current

How do these readings compare with those you got in the first activity? _____

Activity C

Repeat Activity A but this time use the large mounted coil.

Action	Size of Current	Direction of Current

From the experiment we can conclude that the induced EMF (and current) can be increased by:

1. _____
2. _____
3. _____

The above results are summed up by the 1st Law of electromagnetic induction: Faraday's Law

In simple form, this law can be stated as follows:

The EMF induced in a conductor is proportional to the rate at which magnetic field lines are cut by the conductor.

Faraday's Law of Electromagnetic induction states that when there is a change in the magnetic lines of force (or flux), an e·m·f· is induced, the strength of which is proportional to the rate of change of the magnetic flux linked with the circuit·

Name:_____ Class:_____

Explain Faraday's Law of Electromagnetic Induction in your own words

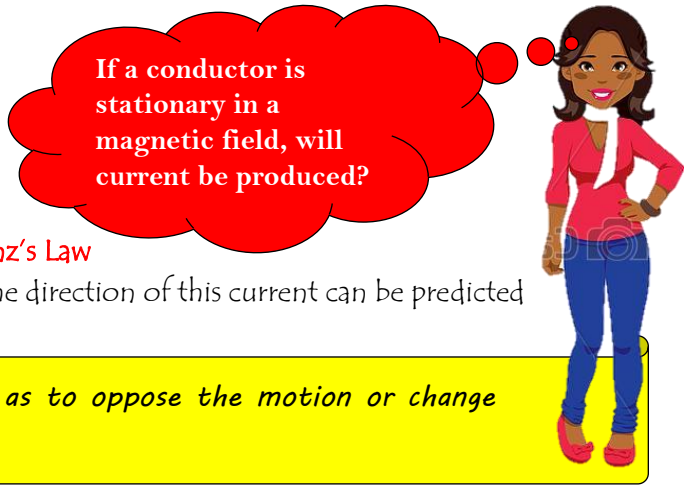
From activity a, b, and c, what will reverse the direction of the induced EMF and current?

1. _____
2. _____

From the activities carried out, the following observations/results were made/derived.

1. If the magnet is pulled out of the coil, _____.
2. If the S pole of the magnet, rather than the N pole, is pushed into the coil, _____.
3. If the magnet is held still, so no field lines are cut, _____.

   The induced EMF (and current) can be increased by:
4. Moving the magnet faster
5. _____
6. _____



How do we find the direction of the induced current?

We find the direction using the 2nd Law of Electromagnetic Induction: Lenz's Law

If a magnet is moved in or out of a coil, a current is induced in the coil. The direction of this current can be predicted using Lenz's law. Lenz's law is an example of conservation of energy.

Lenz law states that the induced e·m·f is in such a direction as to oppose the motion or change producing it·

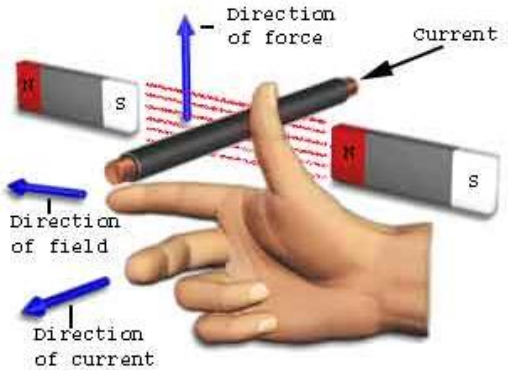
$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

Where $\mathcal{E}$ is the electromotive force (E.M.F) and Φ_B is the magnetic flux.

FLEMING'S RULES

Another way to predict the direction of the induced e.m.f. is by using Fleming's Right Hand Rule

If a straight conductor is moving at right angles to a magnetic field, the direction of the induced current can be found using Fleming's right- hand rule, as shown:



This rule states "Hold out the right hand with the first finger, second finger and thumb at right angle to each other· If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current·

NOTE:

- When a current causes motion, the left-hand rule applies
- When motion causes a current, the right-hand rule applies

Name:_____ Class:_____

Eddy Currents

When a solid metallic sheet swings in a magnetic field, it cuts through the magnetic field lines. Consequently, according to Lenz's law, an e.m.f is induced in the sheet which opposes this movement of the sheet. Hence the sheet quickly comes to rest and its motion is said to be damped. The induced e.m.f. that brings this about produces an induced current in the sheet. This induced current is known as Eddy Current. Eddy currents generate heat in the material leading to wastage of energy in most electrical devices. The oscillation of the solid sheet is much less damped if the sheet is laminated (i.e. cut into slots). This is because the eddy currents cannot flow across the gaps between the slots even though an e.m.f is still induced to oppose motion. Eddy current are desirable in moving coil instruments because of the resulting damping known as electromagnetic damping

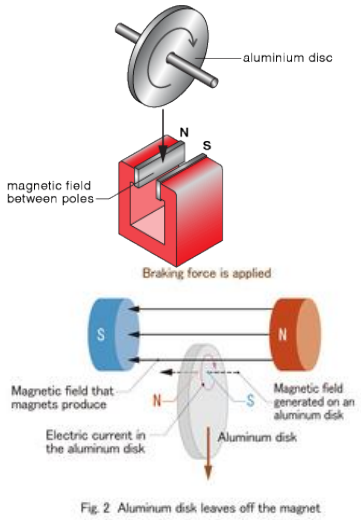


Fig. 2 Aluminum disk leaves off the magnet

Explain Eddy currents in your own words and state two applications

SUMMARY EXERCISE

1. What is electromagnetic induction? ……

   ……

2. An induced e.m.f. is always produced in a circuit whenever there is ……

   ……

3. The induced current can be increased by:

   (a) ……

   (b) ……

   (c) ……

   (d) ……

4. Faraday's law states that ……

   ……

5. Lenz's law states that ……

   ……

6. Eddy currents occur wherever …… are in a changing ……

   ……

Name:_____ Class:_____

Week 1

Lesson 2: Generators

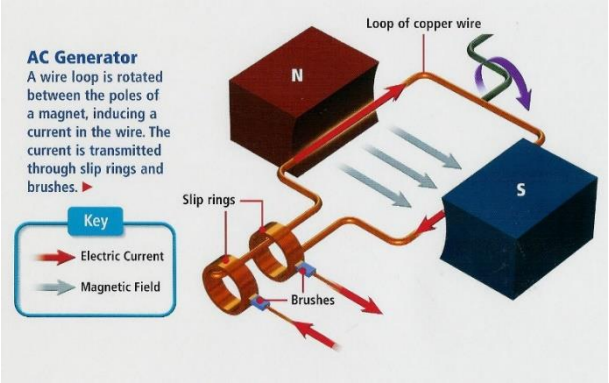
Lesson Objectives

By the end of this lesson, I will be able to:

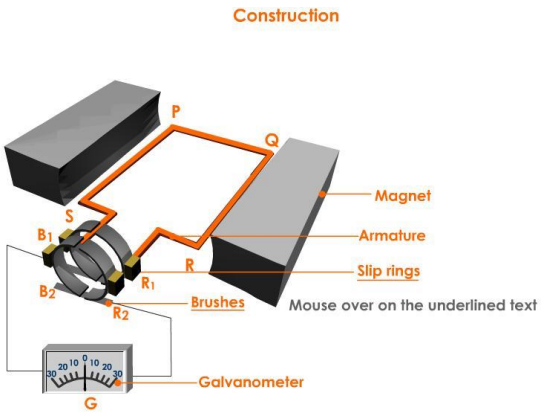
Generators

Most of our electricity comes from huge generators in power stations. There are smaller generators in cars and on some bicycles. These generators, or dynamos, all use electromagnetic induction. When turned on, they induce an E.M.F (Voltage) which can make current flow. Most generators give out alternating current (A.C). A.C generators are also called alternators.

A Simple AC Generator



The diagram shows a simple A.C. generator. The coil is made of insulated copper wire and is rotated by turning the shaft. The slip rings are fixed to the coil and rotate with it. The brushes are two contacts which rub against the slip rings and keep the coil connected to the outside part of the circuit. They are usually made of carbon.



When the coil is rotated, it cuts magnetic field lines, so an EMF is generated. This makes a current flow. As the coil rotates, each side travels upwards, downwards, upwards, downwards and so on, through the magnetic field. So the current flows backwards, forwards and so on. In other words, it is alternating.

When will the current be at a maximum ……

Why? ……

……

When will the current be at a minimum? ……

Why? ……

……

The following all increase the maximum EMF (and the current)

1. ……
2. ……
3. ……
4. ……

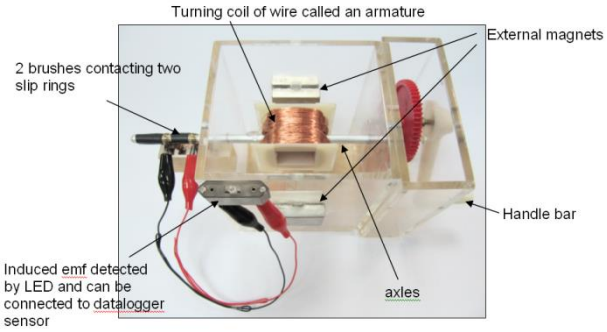
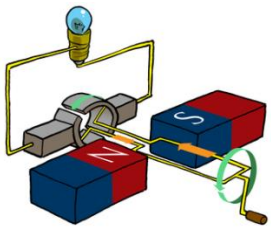


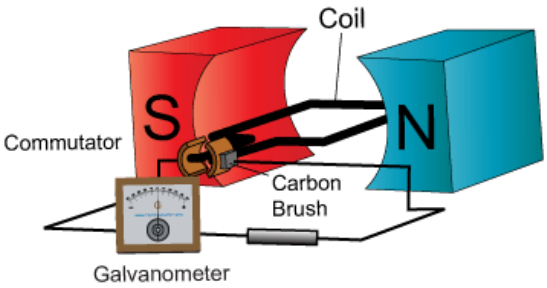
Figure 2: Real-life AC customized demonstration set by Scientist Dr Tan Kah Chye (2010)

Name:_____ Class:_____

Direct Current (D.C.) Generators



A direct current is 'one-way' current like that from a battery. DC generators are similar in construction to DC motors, with a fixed magnet, rotating coil, brushes, and a commutator (spilt ring) to reverse the connections to the outside circuit every half-turn. When the coil is rotated, current is generated. However, the action of the commutator means that the current in the outside circuit always flow the same way – in other words, it is direct.

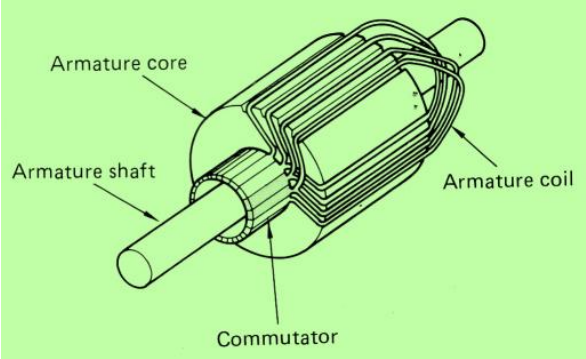


PRACTICAL GENERATOR

A practical generator needs to produce a larger emf.

To produce a larger e.m.f. in practical a.c. or d.c generators:

1. the armature is constructed with a large number of turns in the coil
2. the coil is wound on a soft iron core so as to increase the magnetic flux through the coil
3. the strength of the magnetic field is made as high as possible
4. The armature is made to rotate at a fast rate.



Summary Exercise

Do the following without flipping through your notes

1. Describe a simple generator ……
   ……...
   ……...
2. Distinguish between a.c and d.c generator

AC generator	DC generator

3. Distinguish between simple generator and practical generator

Simple Generator	Practical Generator

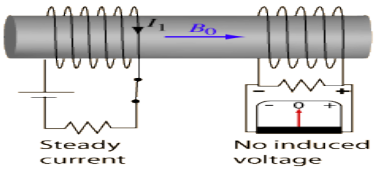
Name:_____ Class:_____

Lesson 3: Transformers

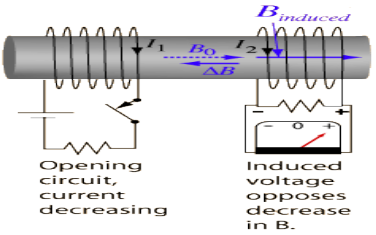
Lesson Objectives

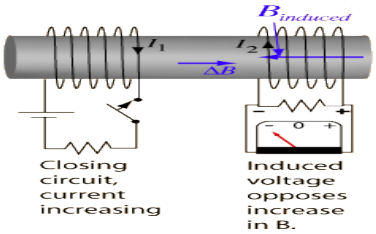
By the end of this lesson, I will be able to:

A moving magnetic field can induce an EMF (Voltage) in a conductor. A changing magnetic field can have the same effect.



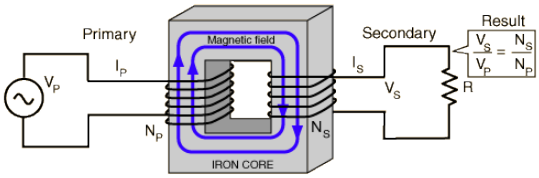
As the electromagnet in the diagram is switched on, an EMF is induced in the other coil, but only for a fraction of a second. The effect is equivalent to pushing a magnet towards the coil very fast. With a steady current through the electromagnet, no EMF is induced because the magnetic field is not changing. As the electromagnet is switched off, an EMF is induced in the opposite direction. The effect is equivalent to pulling a magnet away from the coil very fast.





When coils are magnetically linked, as above, so that a changing current in one causes an induced EMF in the other, this is called mutual induction.

What do you understand by mutual Induction?



A SIMPLE TRANSFORMER

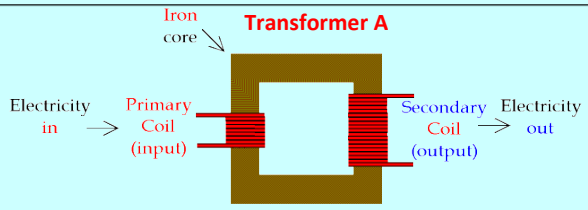
AC voltage can be increased or decreased using a transformer. A simple transformer is shown in the diagram. It works by mutual induction. When alternating current flows through the primary (input) coil, it sets up an alternating magnetic field in the core and, therefore, in the secondary (output) coil. This changing field induces an alternating voltage in the output coil.

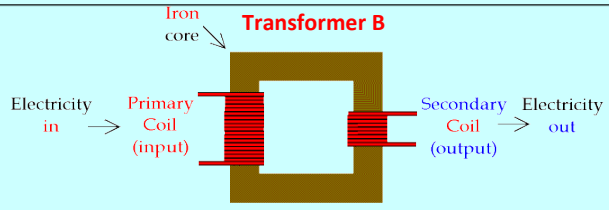
If all the field lines pass through both coils and the coil wastes no energy because of heating effects, the following equation

$$\frac{\textit{Output voltage}}{\textit{input voltage}} = \frac{\textit{turns on output coil}}{\textit{turns on input coil}} \rightarrow \frac{V_2}{V_1} = \frac{n_2}{n_1}$$

Spot the Difference in the 2 transformers and fill in the table below

Transformer A	Transformer B





Name:_____ Class:_____

Step-up Transformers: Step-up transformers have more turns on the output than on the input coil, so their output voltage is more than the input voltage.

Step-down transformers: Step-down transformers have fewer turns on the output coil than on the input coil, so the output voltage is less than the input voltage. In battery chargers, computers and other electronic equipment, they reduce the voltage of the AC mains to the much lower levels needed for the circuits.

What kind of transformer is Transformer A? ……

What kind of transformer is Transformer B?……..

Both types of transformer work on AC, but not on DC. Unless there is a changing current in the input coil, no voltage is induced in the output coil. Connecting a transformer to DC supply can damage it. A high current flows through the input coil, which can make it overheat.

ENERGY LOSSES IN PRACTICAL TRANSFORMERS: The relationship $\frac{V_2}{V_1} = \frac{n_2}{n_1}$ apply to an ideal transformer where there are no energy losses, and the transformer efficiency is 100%. In practical transformer however, there are energy losses.

Cause of Energy Loss	Description	Reduction
1. Eddy Currents	Energy is lost as heat in the iron core due to eddy currents	Lamination of core reduces eddy currents by breaking up their path of flow
2. Hysteresis Loss	Energy is wasted energy due to reversing the magnetization of core. The core is made to go through a cycle of magnetization during each alternating cycle of the primary current.	It is reduced by the use of special alloys in the core of the primary coil, or by the use of soft iron cores.
3. I^2R (or Heat) Loss:	Because the primary and secondary coils have resistance, some energy is lost in the form of Heat (I^2R) in the coils.	This heat loss can be reduced by using thick wires, or low resistance coils
4. Leakage of magnetic flux:	Some energy is lost due to leakage of magnetic flux. This arises because not all the lines of induction due to current in the primary coil pass entirely through the iron core to the secondary coil.	This loss is reduced by special forms of coil winding

Efficiency of a transformer is given by: $E = \frac{\textit{Output Power}}{\textit{Input Power}} \times 100\%$

Classwork 1: A transformer has 500 turns in the primary coil and 300 turns in the secondary coil. If the primary coil is connected to a 220V mains, what voltage will be obtained from the secondary coil? What type of transformer is this?

Classwork 2: A transformer supplies 15V from a 220V mains. If the transformer takes 0.7A from the mains when used to light three lamps connected in parallel and each rated 15V, 40W, calculate

(i) the efficiency of the transformer

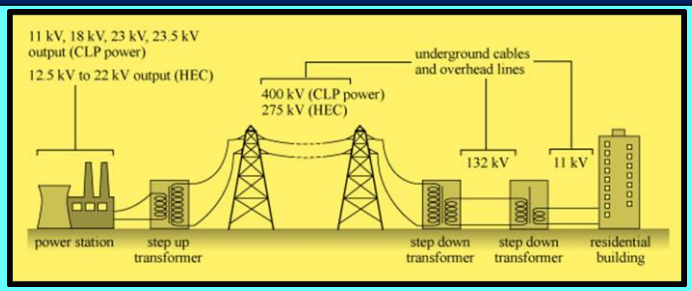
(ii) the cost of using it for 24hrs at 30k per kWh

Name:_____ Class:_____

POWER TRANSMISSION

Ever get this message in the middle of the most interesting conversation?

So what really happens when you plug your phone in?



Power from the socket is generated in power stations, transmitted through long-distance cables, and then distributed to consumers.

The cables feed power to a nationwide supply network called a grid. Power from the grid is distributed by a series of substations. These contain step-down transformers which reduce the voltage in stages to levels needed by consumers. Depending on the country, this might be between 110V and 240V for home consumers, although industries normally use a higher voltage.

Alternating current (AC) is used for the mains (household electrical supply). On a large scale, it can be generated more efficiently than direct current (DC). However, the main advantage of AC is that voltages can be stepped up or down using transformers. Transformers will not work with DC.

Should transmission be done in high or low voltage?

Transmission cables are good conductors, but they still have significant resistance – especially when they are hundreds of kilometers long. This means that energy is wasted because of the heating effect of the current. By using transformer to increase the voltage, the current is reduced, so thinner, lighter, and cheaper cables can be used.

SUMMARY EXERCISE

1. Define Transformer

   ……

   ……

   ……

2. Describe how a transformer works

   ……

   ……

   ……

3. Energy is lost in a transformer by the following:

   (a) ……

   (b) ……

   (c) ……

   (d) ……

4. What role do transformers play in the high voltage transmission of electricity?

   ……

   ……

   ……

   ……

5. State the main advantage of high voltage transmission?

   ……

   ……

   ……

6. What are substations for?

   ……

   ……

   ……

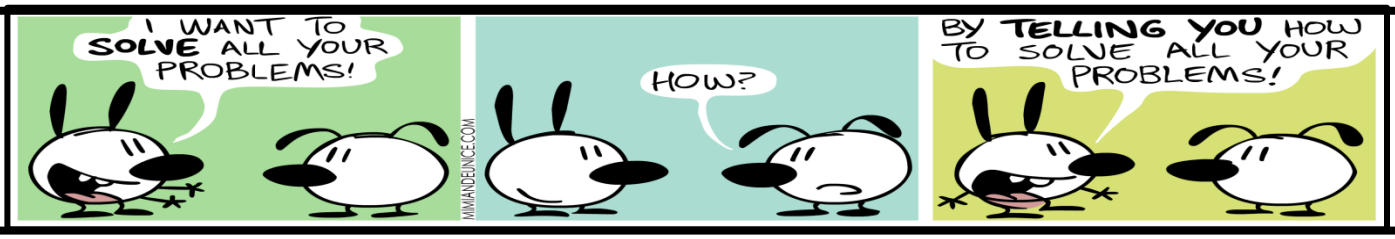
Name:_____ Class:_____

Electromagnetic Induction Prep Questions

Question from this section may appear in your CA classwork or Resumption Tests

Fill in the blanks

1. Induced current can be increased by moving the wire ……
2. Induced current can be …… using a stronger magnet.
3. Induced current can be …… by increasing the length of the wire in the magnetic field
4. The direction of the induced current can be reversed by …… ……
   ……...
5. The EMF induced in a conductor is proportional to the …… ….cut by the conductor.
6. An induced current always flows in a direction such that it ……...the change
   ……...
7. Eddy current can be reduced by ……
8. When a current causes motion, Fleming's …….. applies.
9. When motion causes a current, the Fleming's …… applies.
10. AC generators are also called ……..
11. Generator transform …… energy into…….. energy
12. A device called a …… changes AC output to DC.
13. Direct current is ……
14. Transformer works on the principle of ……..
    ……
15. AC voltage can be increased or decreased using a ……
16. ……transformers have more turns on the output coil than on the input coil.
17. …… have fewer turns on the output coil than on the input coil.
18. Hysteresis loss is wasted energy due to ……..
19. Energy loss by eddy current can be reduced by ……
20. An alternating current is ……



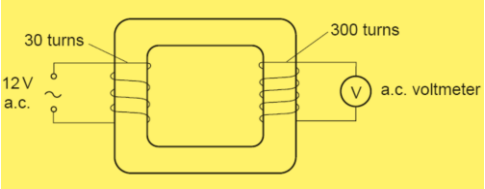
Accelerated Questions

Questions from this section may appear in your CA quizzes or examination

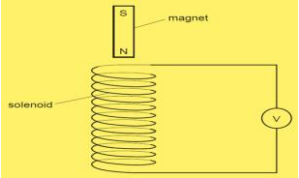
1. State two essential differences between a moving coil galvanometer and a d.c. generator.
2. Explain the term eddy current and state two devices in which the currents are applied.
3. Draw a simple labeled diagram illustrating the principle of a step-down transformer and explain how it works.
4. If a transformer is used to light a lamp rated at 60W,220V from a 4400V a.c. supply, calculate the;
   i. ratio of the number of turns of the primary coil to the secondary coil in the transformer
   ii. Current taken from the main circuit if the efficiency of the transformer is 95%.
5. State three methods by which higher e.m.f could be obtained from a generator

Name:_____ Class:_____

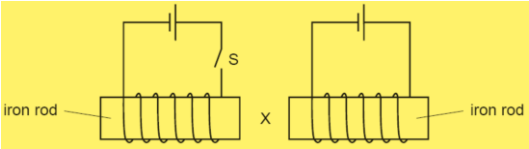
1. An ideal step-down transformer steps up
   A. Power
   B. energy
   C. current
   D. voltage
2. The diagram below shows a transformer



   What is the voltmeter reading?
   A. 1.2V
   B. 12V
   C. 120V
   D. 1200V
3. The diagram shows a solenoid connected to a sensitive voltmeter.



   Which of the following would give a zero reading on the voltmeter?
   A. holding the magnet stationary inside the solenoid
   B. moving the magnet away from the solenoid
   C. moving the magnet towards the solenoid
   D. moving the solenoid towards the magnet
4. Two circuits are set up as shown. The iron rods are placed close together, and are free to move.



   What happens to the size of the gap at X when switch S is closed?
   A. It decreases.
   B. It decreases then increases.
   C. It increases.
   D. It does not change.
5. The current produced by a simple dynamo is not steady because
   A. a back e.m.f opposes the induced voltage
   B. eddy currents oppose the motion which induces them, and absorbs energy from the current
   C. the magnetic field produced by the magnet is not sufficiently uniform
   D. the induced current opposes the motion which causes it, in accordance with Lenz's law
   E. the rate of change of flux varies with the position of the coil of the dynamo

Name:_____

WEEK 1 MORNING PREP PHYSICS DRILL

1. Induced current depends on the
   (i) Number of turns in the coil
   (ii) Strength of the magnet
   (iii) Speed with which the magnet is plunged into the coil

   Which of these is/are false?

   A. I only
   B. II only
   C. II and III only
   D. III only
   E. None of the above
2. To convert an alternating current dynamo into a direct current dynamo, the
   A. number of turns in the coil is increased
   B. strength of the field magnet is increased
   C. slip rings are replaced with split ring commutator
   D. coil is wound on a soft iron armature
3. Which of the following operations will not lead to an increase in the induced e.m.f in a coil of wire rotating between the poles of a magnet? Increasing the
   A. Area
   B. Strength of the magnet
   C. Gap between the poles of the magnet
   D. number of turns in the coil
   E. speed of rotation of the coil
4. Which of the following statements about a generator is not correct?
   A. It can produce direct current
   B. It can produce alternating current
   C. It requires an external supply of energy to rotate the coil
   D. It requires an external supply of current to the coil
   E. It may require the use of a commutator
5. Which of the following devices would be used on its own in the working of a petrol-driven motor car engine for obtaining a high voltage from a low one?
   A. Induction coil
   B. A.C. dynamo
   C. D.C. generator
   D. The transformer
   E. The electric motor

Class:_____