

ALTERNATING CURRENT

23 JULY 2013

Lesson Description

In this lesson we:

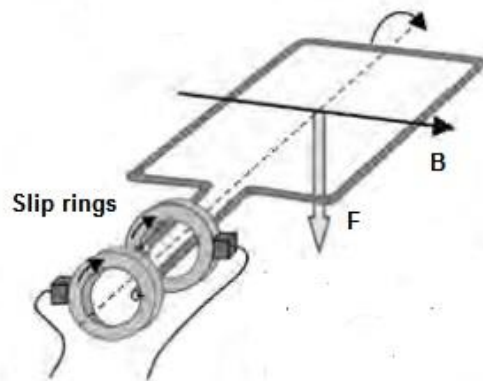
- Provide a brief revision on how generators work
- Discuss and explain the difference between Direct Current (DC) and Alternating Current (AC) generators.
- Introduce AC circuits and explain the root mean square values

Key Concepts

Alternating Current (AC) Generator

All Generators convert mechanical energy into electrical energy.

The diagram below shows a simple AC generator with slip rings. AC generators are also called alternators.

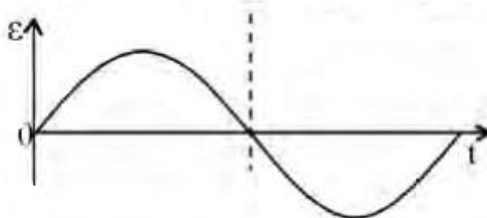


(Adapted from Macmillan Physical Sciences for All Grade 12, Chapter 2, Figure 21, pg 76)

In an AC generator, the induced current changes in magnitude and direction as the coil is turned in the magnetic field. The graph below shows how the induced emf changes as the coil is rotated in the magnetic field.



The top part of the diagram shows the direction of magnetic field, the position of the coil (side view) and the direction of rotation

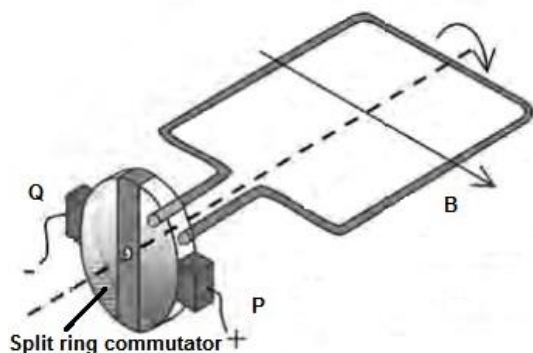


The graph shows the induced emf in relation to the position of the coil above for one cycle of rotation. In South African power stations, the turbines rotate at 50 cycles per second or 50 Hz.

(Adapted from Macmillan Physical Sciences for All Grade 12, Chapter 2, Figure 22, pg 76)

Direct Current (DC) Generator

A DC generator is made from the same components a DC motor except there is no battery or cell.

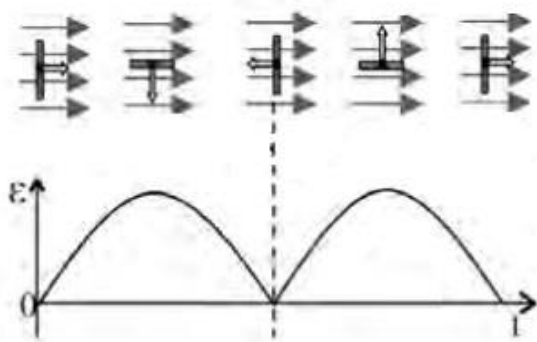


A source of mechanical energy is used to turn the coil inside the permanent magnetic which induces an emf across the ends of the coil. The split ring commutator ensures that the current passing through the coil, moves in one direction only. This means that terminal P is always positive and Q is always negative.

However, the magnitude of the induced emf changes during each rotation.

(Adapted from Macmillan Physical Sciences for All Grade 12, Chapter 2, Figure 23, pg 76)

The graph below shows how the induced emf changes with each rotation:



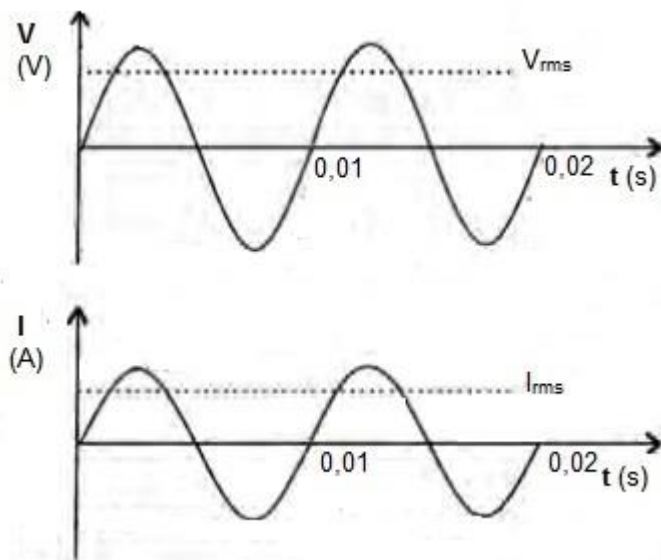
(Adapted from Macmillan Physical Sciences for All Grade 12, Chapter 2, Figure 23, pg 76)

Comparison of the using alternating current compared to direct current:

1. Batteries and cells are the main source of direct current. These are too expensive to provide large amounts of current.
2. Direct current cannot be transformed. Even when using a DC generator, transformers are less effective than when transforming current from an AC generator.
3. The potential difference of AC can be changed by using step up or step down transformers. Step up transformers are usually used at power stations where AC is generated. In this way we minimise the lost of energy due to heat and make it possible for current to be carried over large distances at high voltage and low current.
4. Step down transformers are used at substations to allow municipalities to distribute electricity to consumers at low voltage and high currents.

Root mean square values for potential difference and current

In alternating current circuits both the potential difference and the current continuously fluctuate between the negative and positive maximums over a period of time. The graphs below show how this occurs:



Even though both the potential difference and current are changing, we need a way to measure these values. If we took an average potential difference or average current, this will equal zero, since the values of the graphs above the time axis are exactly equal to the values below the axis.

To overcome this problem we square the values, making them all positive, divide by 2 and then take the square root. This is called the root mean square (rms). This special average is shown on the graph as a dotted line.

In most South African households the potential difference delivered across the terminals of a wall plug is 220V. This is the V_{rms} value that appliances operate on. It is not the maximum value.

Root mean square values for potential difference and current are found using the following formulae;

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

AC motors

Most household appliances like fridges, washing machines and vacuum cleaners have AC motors. These have the same components as an AC generator, except that we use a source of electricity to turn the coil in a magnetic field and so do work for us.

Questions

Question 1

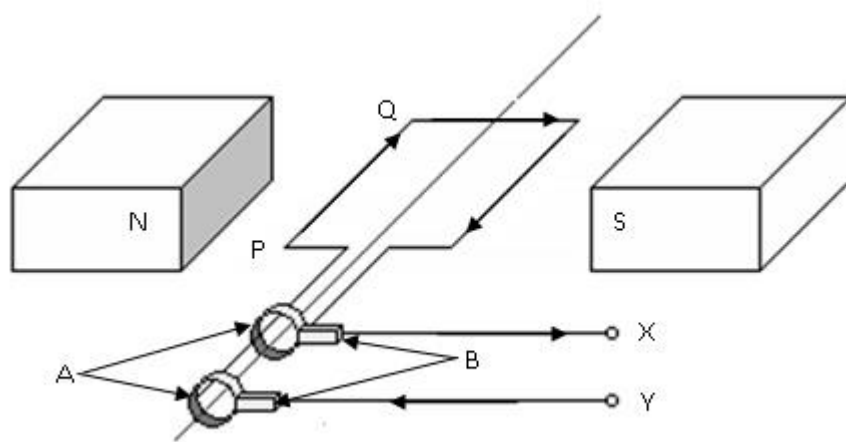
- 1.1 Which physics principle forms the basis in which generators function?
 1.2 State the energy conversion that occurs when a generator is operating.

Question 2

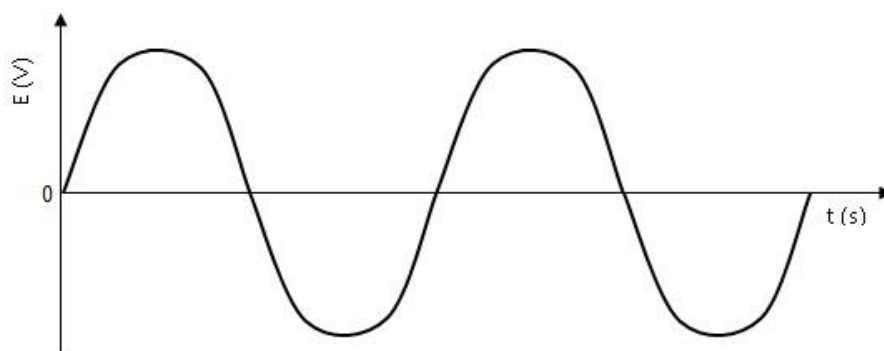
The root mean square value for voltage as supplied to consumers in South Africa is 220 V.
 Calculate the maximum potential difference of the electricity supply in South Africa.

Question 3

The simplified sketch below shows the principle of operation of the alternating current (AC) generator.



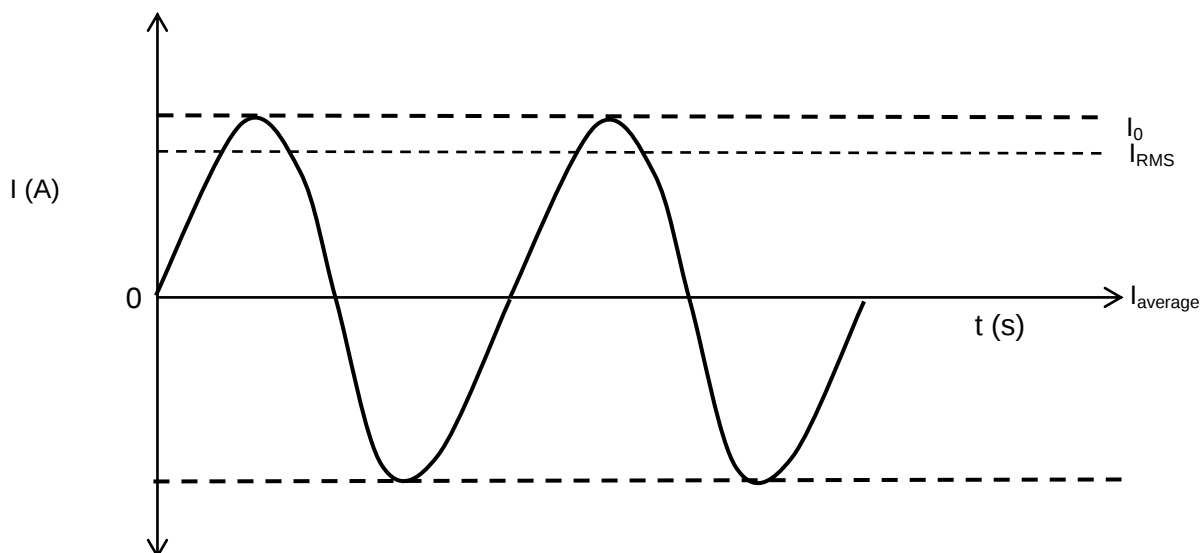
- 3.1 Name the parts labelled A and B respectively.
 3.2 In which direction does segment PQ of the coil have to be rotated in order to cause the current direction as shown in the diagram? Write down only clockwise or anticlockwise
 3.3 Write down TWO changes that can be brought about to improve the output of the generator.
 3.4 What changes must be made to the AC generator to make it function as a direct-current (DC) motor?
 3.5 The induced emf versus time graph for an AC generator is shown below.



Sketch a graph to show how the above waveform changes, if at all, after changing this generator into a DC generator.

Question 4

The sine waveform shown below represents the variation of current (I) with time (t) for a generator used by a man to light his home. The current alternates between a maximum and a minimum.



In the diagram, I_0 = the peak current

I_{RMS} = root mean square current

I_{average} = average value of the current

- 4.1 Write down a formula which represents the relationship between the maximum peak current (I_0) and the root mean square current (I_{RMS}).
- 4.2 The frequency of the AC generated by Eskom is 50 Hz. A substation supplies 240 V (RMS) to a house. Calculate the peak voltage at a wall socket.
- 4.3 Explain why it is of greater value to use RMS current than the average current.