Nelson Mandela Metropolitan University
for tomorrow

GRADE 12

Video Series

CAPS Physical Science

ELECTRICITY AND MAGNETISM

Lesson 5: Alternating Current

Nelson Mandela Metropolitan University
for tomorrow

Video Series

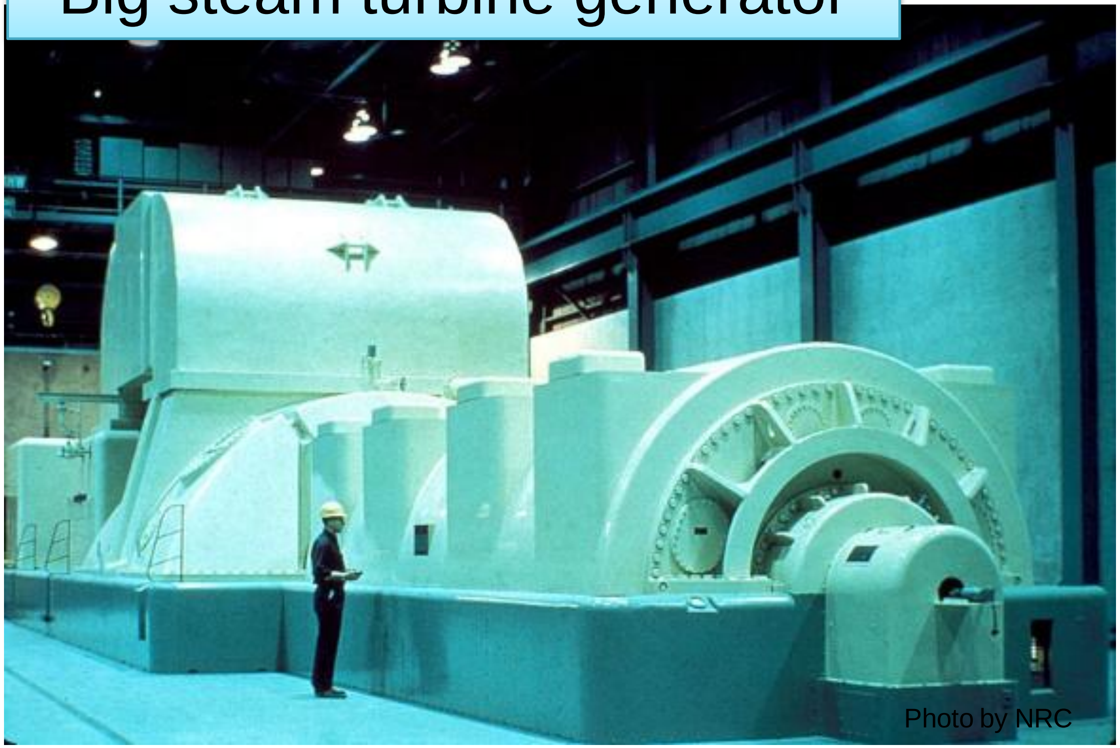
GRADE 12

CAPS Physical Science

Electrodynamics

To Recap

Big steam turbine generator



Power used in industry and in our homes is generated by **power stations** using AC generators.

Business of other facilities like hospitals that cannot afford power failures usually have their own AC generators for backup power.

Electricity can be supplied almost anywhere (e.g. at building sites) by using a portable AC generator.

Power Supply

In South Africa electrical power is supplied by Eskom.

- This power is AC,
- AC is easier to generate than DC
  - by means of AC generators
- The current changes direction 50 times per second (f= 50 Hz)
- Frequency is monitored to avoid damage to electrical equipment.

One big advantage of alternating current is that the **emf can be stepped up or stepped down** through the use of **transformers**.

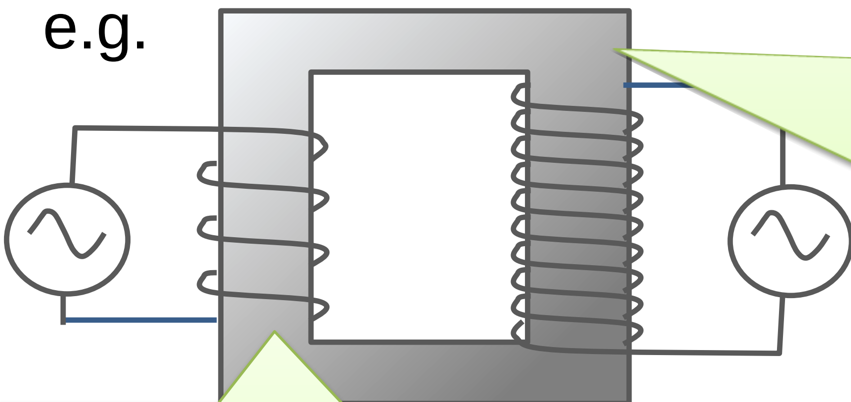
Transformers make use of mutual induction which requires alternating current.

Transformers

Not CAPS

A **transformer** is an electrical device that uses the principle of induction between the primary coil and the secondary coil to either step-up or step-down the voltage

e.g.



Secondary coil with 10 windings.

$V_s = V_p \times \frac{10}{4}$

$I_s = I_p \times \frac{4}{10}$

Delivers AC again.

Primary coil with 4 windings. Powered by AC supply

This is a Step-UP transformer:

While voltage is **increased**, current is **de**creased.

Energy Loss

In an ideal situation, the conducting wire in an electric circuit does not resist the flow of charge.

- That, however, is not the case in reality.
- The problem that needs to be solved, is how to transport the power generated by a power station to the consumer, without loosing big amounts of energy due to the resistance of the connecting cables.

To reduce resistance in power cables,
electrical energy is transported with
high voltage and low current
(from Ohm's Law: $R = \frac{V}{I}$)

Heating Effect

Considering again the equations of power:

$P = \frac{W}{t}$

$P = VI$

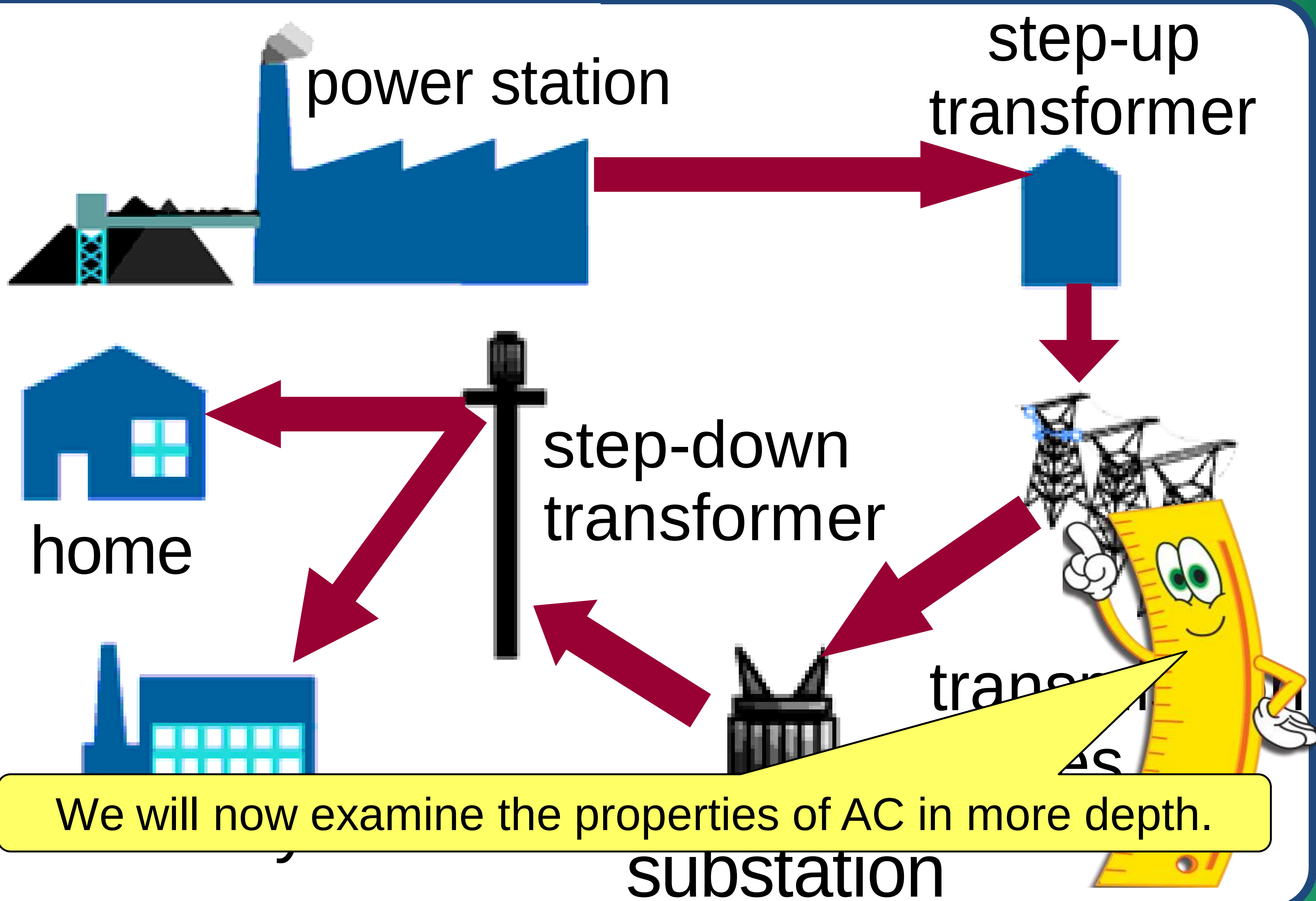
$P = \frac{V^2}{R}$

$P = I^2R$

The rate of energy transfer to a resistance is directly proportional to I^2

- If energy was transferred using **high current and low voltage** …
  - **Loss of energy** will be high
  - High **temperature rises** in connecting wires will occur.

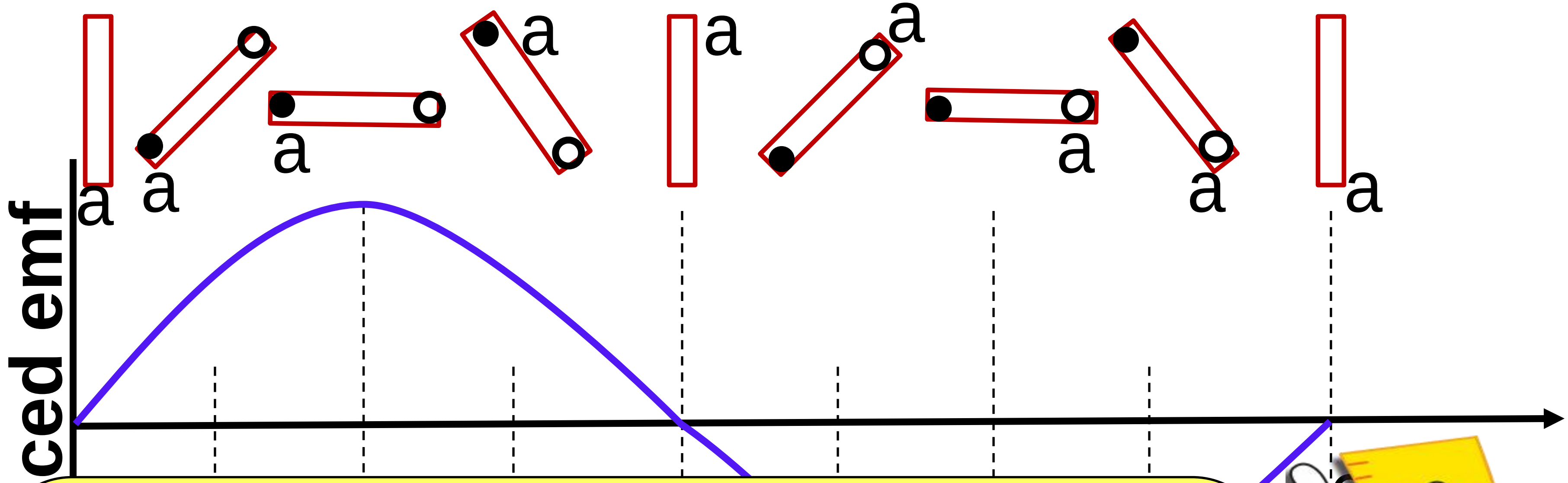
Distribution of Energy



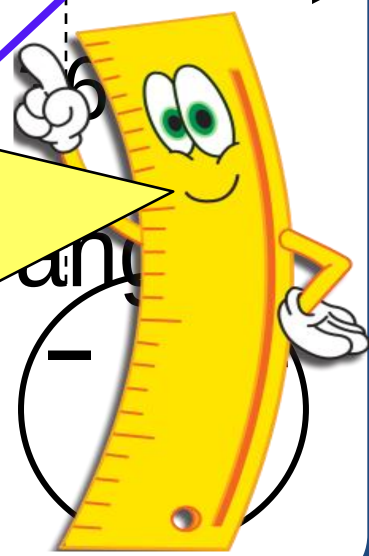
Emf Graph

This graph of an AC generator was drawn:

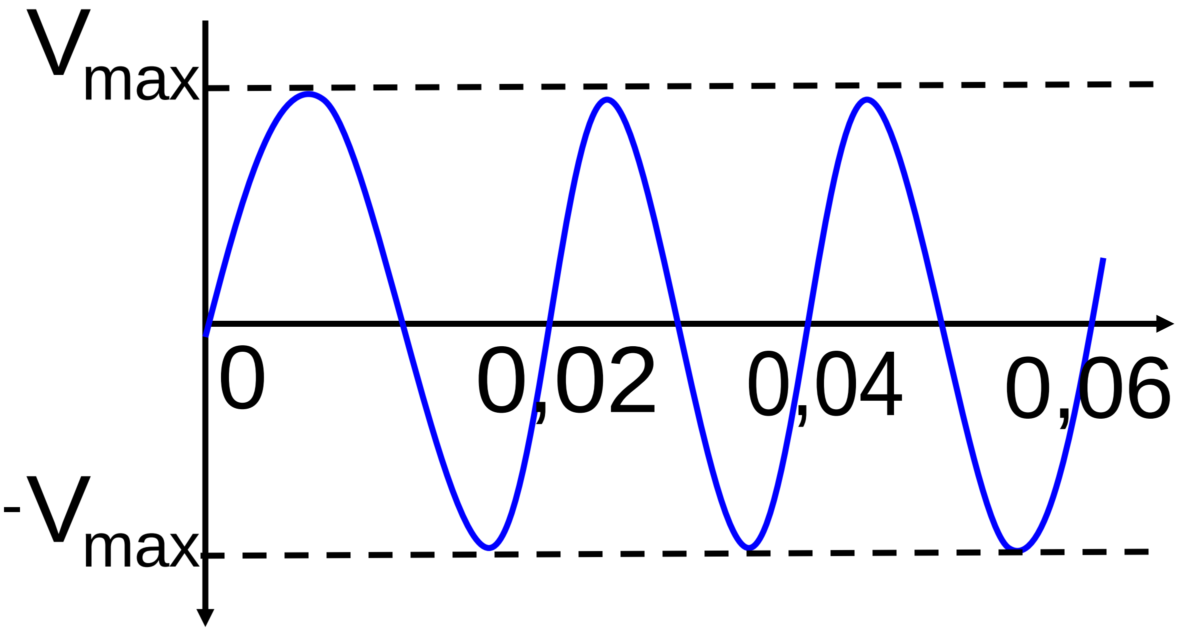
● Current coming out of screen ○ Current going into screen



The induced emf (and current) reverses at every half cycle;
The induced emf (and current) fluctuates between minimum and maximum values.
Different emf (and current) values are associated with different degrees of rotation.



AC Voltage



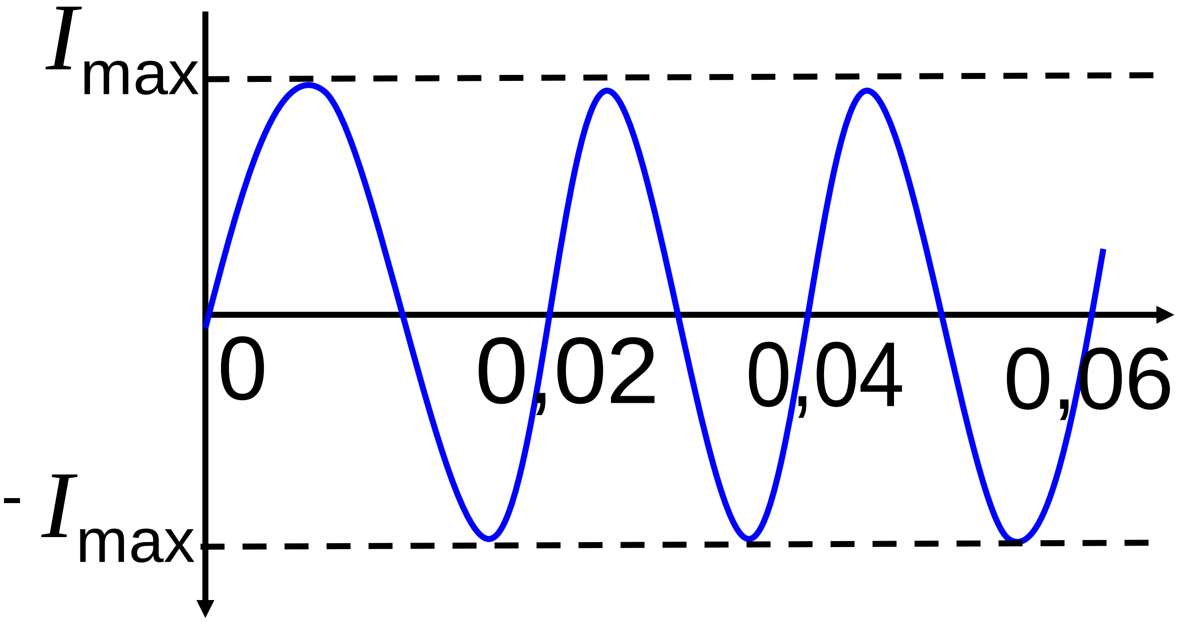
If the armature completes 50 full cycles in one second:

- f = 50 Hz
- $T = \frac{1}{f} = \frac{1}{50} = 0{,}02$ s

The voltage at different degrees of rotation can be expressed as: $V = V_{max} \cos\theta$

Note that the voltage generated **fluctuates** between $+V_{max}$ and $–V_{max}$, with smaller + and – values in between.
The **average value** of the voltage for one cycle is zero.

AC Current



Similarly, AC current can be expressed as:

$$I = I_{max} \cos\theta$$

The current generated **fluctuates** between $+I_{max}$ and $-I_{max}$, with smaller + and – values in between.
The **average value** of the current for one cycle is zero.

Characteristics of AC

Alternating … in the wires

because … ic field.

The resu…

- Some …

  appli… peak

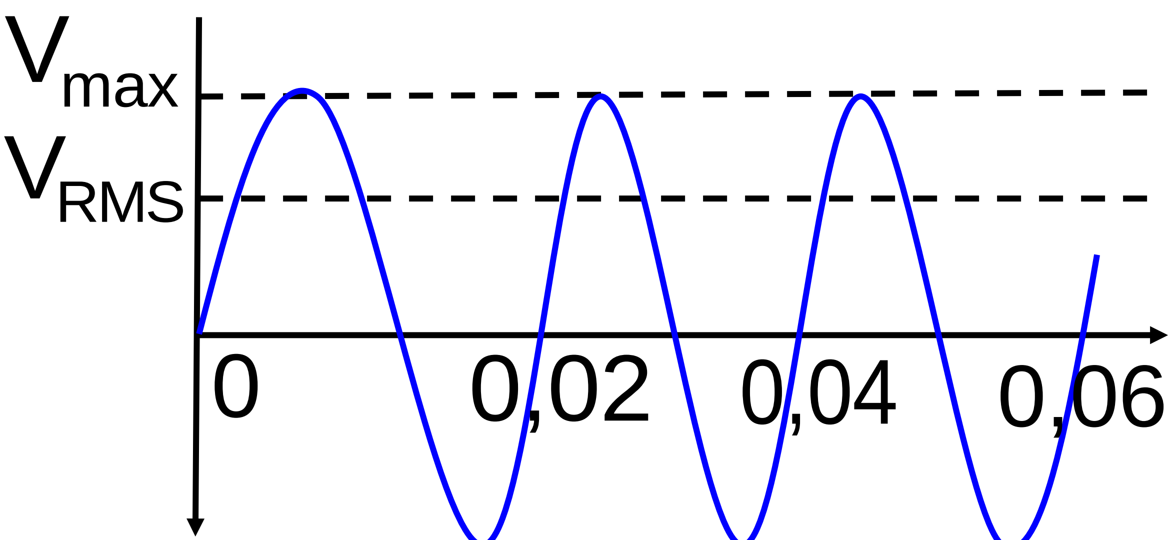
  value supplied;

While electrical appliances in South Africa works at

V_{rms} = 240 V,

the voltage generated by the power station

V_{max} = ± 311 to 325 V



- This **lower maximum voltage** is known the **root-mean-square (RMS) value**.

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

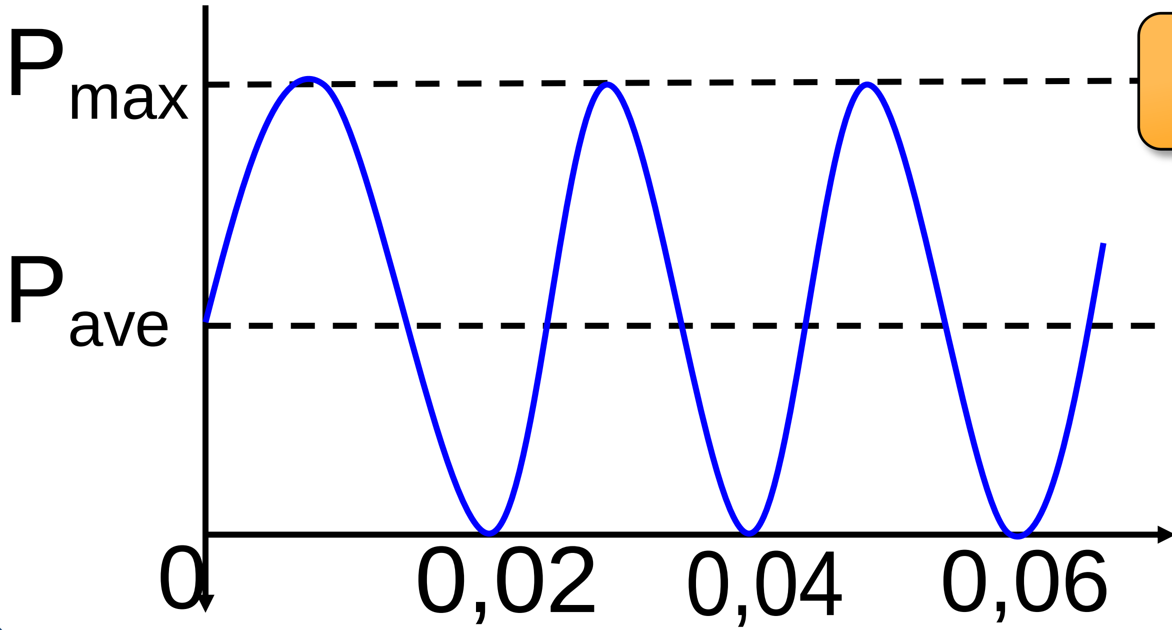
RMS

The RMS value of a supply is what its DC equivalent would be.

The RMS current formula is:

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

Since $P = I^2R = \frac{V^2}{R}$, current as well as voltage are squared, and the power generated in an AC generator is always positive, although it varies with time …



$$P_{average} = V_{rms} \cdot I_{rms}$$

$$P_{average} = \frac{V_{rms}^2}{R}$$

$$P_{average} = I_{rms}^2 R$$

Example

The frequency of the AC generated by Eskom is 50 Hz. A substation supplies 240 V (RMS) to the house.

1. Calculate the peak voltage at a wall socket.

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

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

$$= 339{,}41 \text{ V}$$

2. If an electrical appliance should function at an average power of 100 W, calculate the current supplied to the appliance.

$$P_{average} = V_{rms} \cdot I_{rms}$$

$$I_{rms} = \frac{100W}{240V}$$

$$= 0{,}42 \text{ A}$$

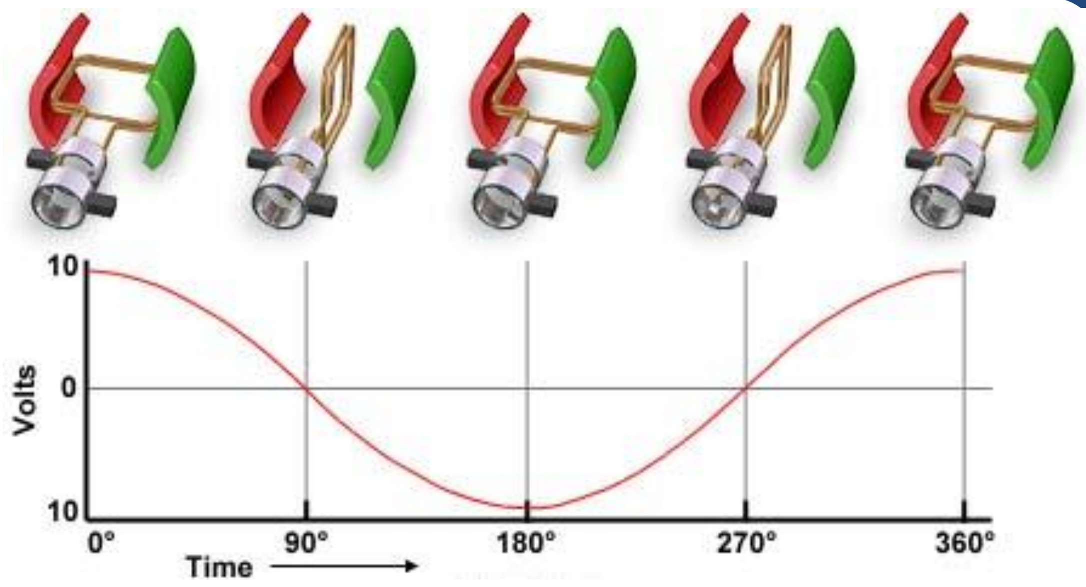
3. What is the maximum current supplied by the power station?

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

$$= 0{,}59 \text{ A}$$

Class Exercise 1/1

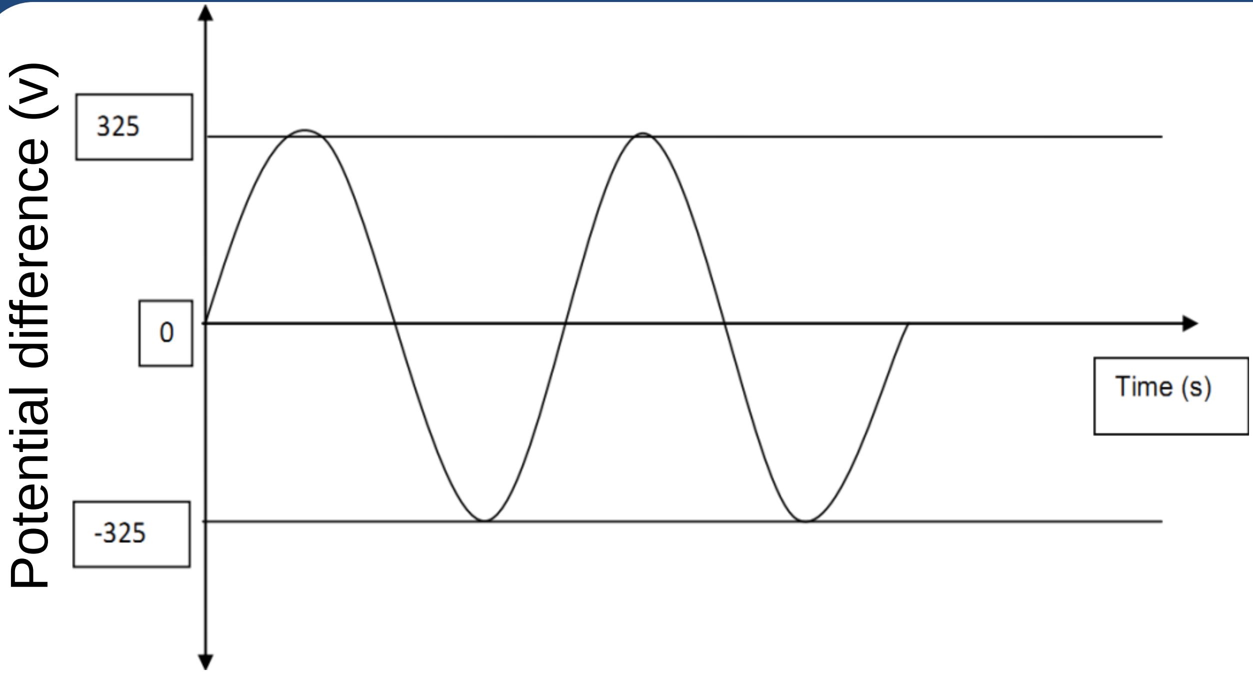
1. Name the device shown here.
   AC generator.
2. Explain the fluctuating property displayed in the graph.



A coil cutting through a basic magnetic field in a clockwise direction will at first result in a emf with positive polarity, but as it cuts across the same field in the opposite direction during the second half of its turn, the polarity becomes negative.

Note the **slip rings** – slip rings identify a generator or motor **as AC** rather than DC

Class Exercise 1/2

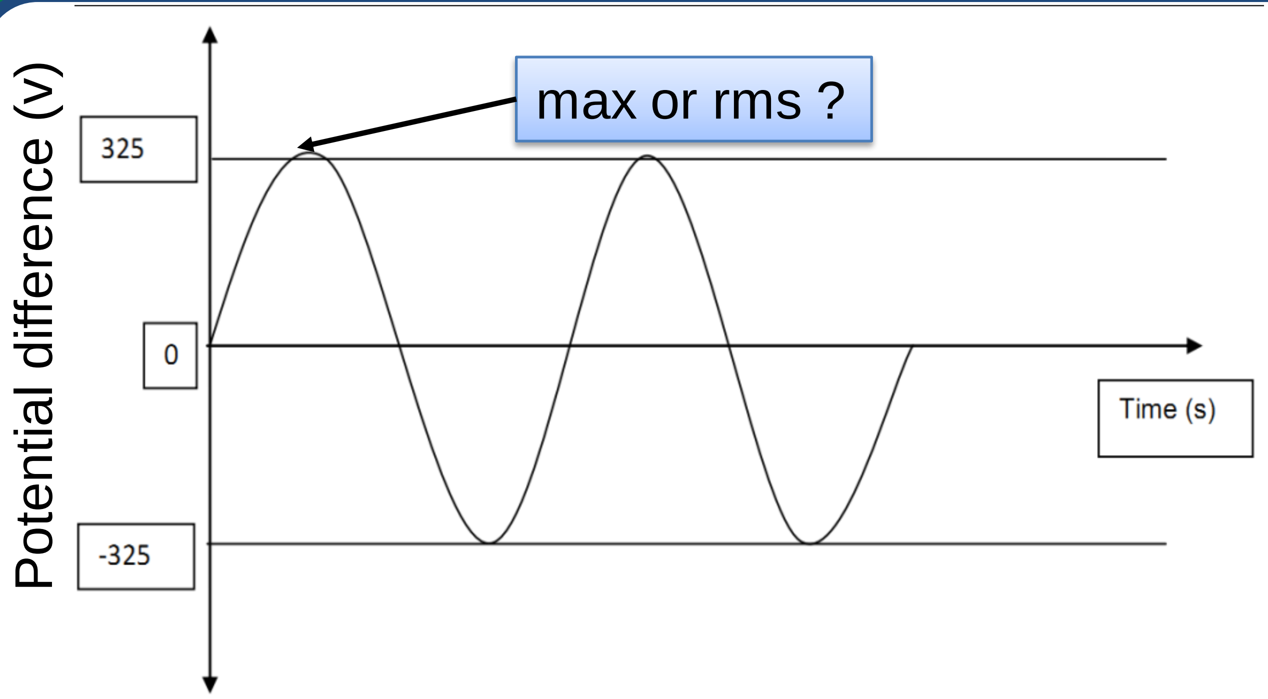


3. The waveform is a graphical representation of the variation of voltage (V) vs time (t) for an AC current.

3.1. Explain the advantage of using alternating current at power stations.

The voltage can be altered by using transformers. Transformers only operate on AC current. Electrical energy can be transmitted over long distances at low current, and experience low energy loss.

Class Exercise 1/3



3. The waveform is a graphical representation of the variation of voltage (V) vs time (t) for an AC current.

3.2. Calculate the average power dissipated by this generator if the rms current produced is 13 A.

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

$= 325 / \sqrt{2}$

$= 230$ V

$P_{ave} = V_{rms} \times I_{rms}$

$= 230 \times 13$

$= 2990$ W.

Class Exercise 1/4

4. A certain generator operates at a maximum voltage of 340 V. A 120 W appliance is connected to the generator. Calculate the resistance of the appliance.

$$P_{average} = \frac{V_{rms}^{2}}{R}$$

$$120 = 240{,}42^2 / R$$

$$R = 240{,}42^2 / 120$$

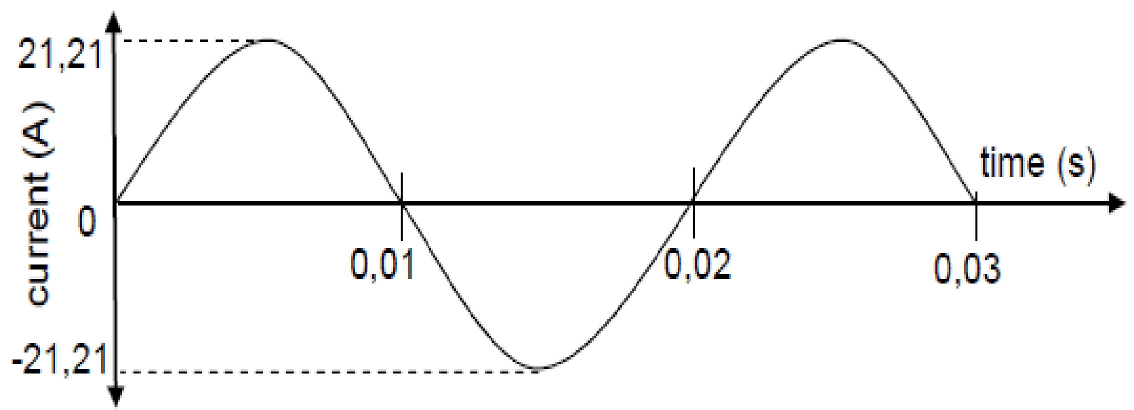
$$= 481{,}68\ \Omega$$

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

$$= 340 / \sqrt{2}$$

$$= 240{,}42\ V$$

5. Calculate the frequency with which this device is turning.



$T = 0{,}02$ s $f = \frac{1}{T} = 50$ Hz

Class Exercise 1/5

6. If the generator produces a max. potential difference of 311 V, calculate its average power output.

$P_{ave} = V_{rms} \times I_{rms}$

$= 219{,}91 \times 15$

$= 3\,298{,}65$ W.

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

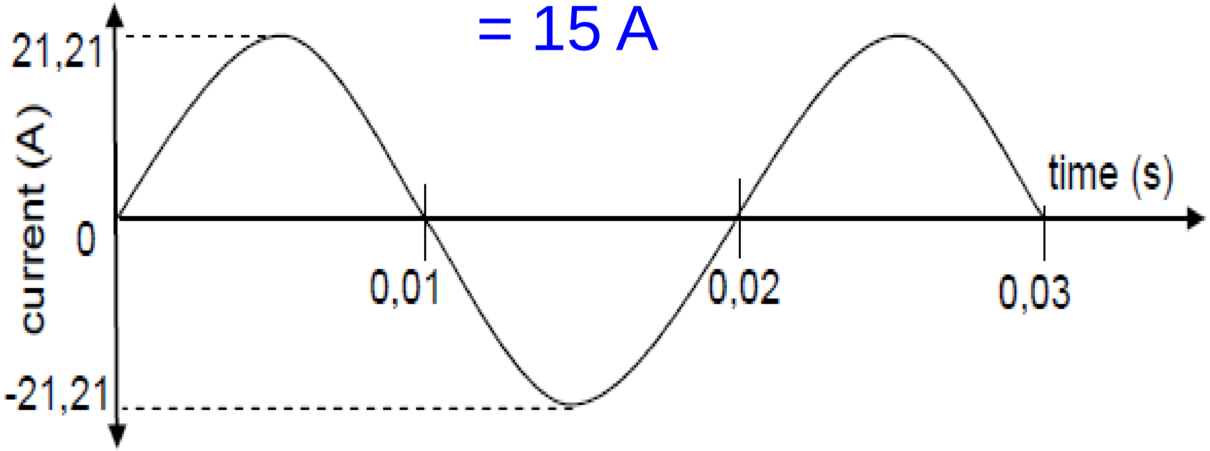
$= 311 / \sqrt{2}$

$= 219{,}91$ V

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

$= 21{,}21 / \sqrt{2}$

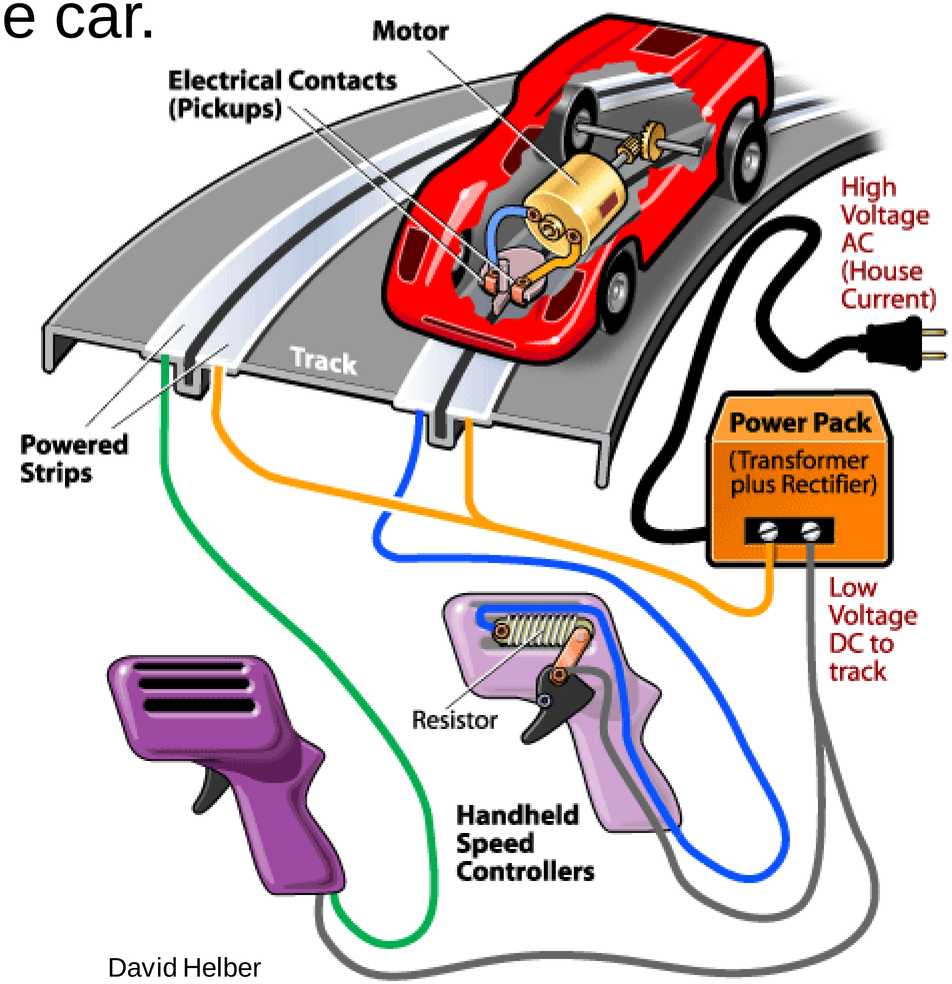
$= 15$ A



Class Exercise 1/6

7. Examine this drawing of a slot car-setup and explain how electricity is supplied to the car.

High voltage AC is supplied by plugging into the main power;
The high voltage AC is changed to low voltage DC by a transformer;
The circuit is completed when the speed controller is pressed;
The current is fed into the powered strips and picked up by the electrical contacts of the small electrical motor.



Key Concepts 1

Our **power stations** produce alternating current and the current that we get from the plug points in our homes is AC. The frequency of alternating current in South Africa is 50Hz.

Advantages of AC

- We can use transformers to step up the voltage and step down the current. This enables the distribution of electricity on the national power grid with low energy loss;
- It is easier and cheaper to convert AC to DC;
- AC motors can produce a higher power output that DC motors.

Key Concepts 2

Calculations for AC

- The **potential difference** varies between 0 V and 311 V. This has the same effect as a constant value of 220 V. We call this the **root mean square** voltage.

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

- The **current** also fluctuates with time.

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

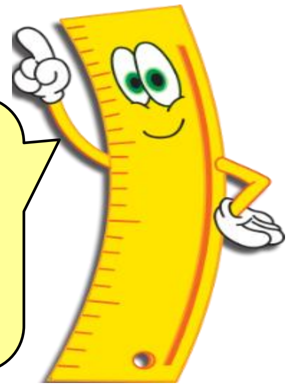
- The RMS value of AC is the DC potential difference / current which dissipates the same amount of energy as AC.
- The **average power** in an AC circuit is calculated by using

$$P_{average} = V_{rms} \cdot I_{rms} = \frac{V_{rms}^2}{R} = I_{rms}^2 R$$

Isigama

- **Memorise** the various definitions
- **Review** the exercises you had difficulty with …
- and do some **additional exercise** …
  - as given in your **workbooks** that accompany this video series or from your school textbook

Continue your learning by watching the **next video lesson** in this series:
Lesson 1: Photoelectric Effect



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