Voltmeters and ammeters

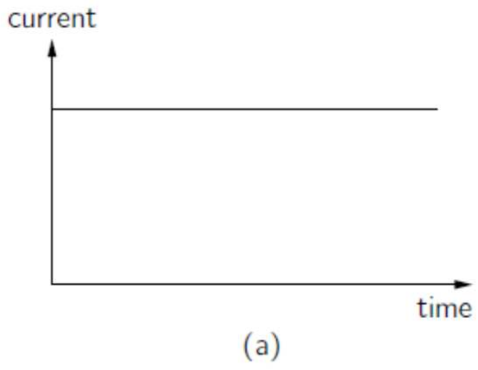
A voltmeter measures the potential difference in a circuit. It is always connected **across** (in **parallel** with) a resistor or cell. It has **infinite resistance** to prevent of current.

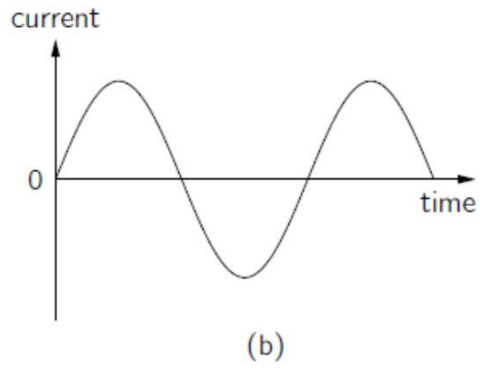
Ammeter measures the current in a circuit. It is always connected in **series** with a resistor or cell. It should have **zero internal resistance**.

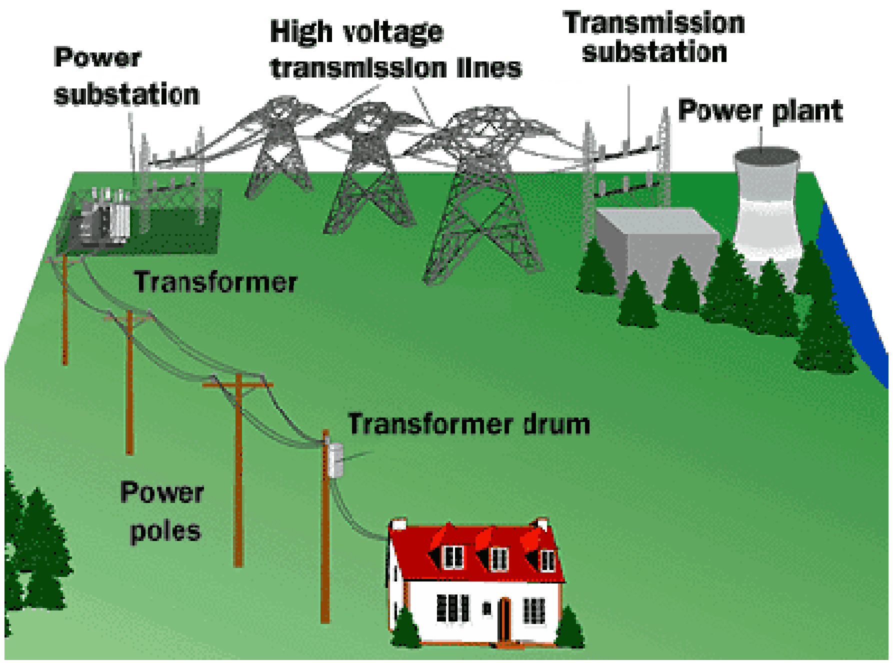
Digital multimeter is an instrument that could be used as an ammeter, a voltmeter, an ohmmeter

Alternating current

When a battery or a power supply is connected to a circuit, the current flows steadily in one direction. This current is called **direct current (dc).** However, the current produced by generators at power station reverses direction many per second, this is called **alternating current (ac)**. The diagram on the right shows how the current varies with time.







The advantage of ac over dc is that in ac, voltage can be **changed whenever is needed**. At a power plant at Eskom the terminal voltage ranges from 115 kV to 650 kV. Power substation reduces it to 7.2 kV. The transformer in the city reduces it further to 230 V as required by household appliances.

Alternating current does not lose (much) energy to heat over large distances.

Alternating current

The voltage generated at a power station is sinusoidal and so the current it produces is also sinusoidal. We can write the voltage V as a function of the time t as

$$V = V_o \sin(2\pi f\ t)$$

where V_o is called the peak voltage and f is the frequency. Note the following:

1. V oscillates between $+V_o$ and $-V_o$.
2. f gives a number of times a voltage changes between $+V_o$ and $-V_o$. It is measured in Hertz (Hz) or (s^{-1}).

From Ohm's law $\left(R = \frac{V}{I}\right)$, if an alternating voltage that exists across a resistance R is known, the current I can be found from

$$I = \frac{V}{R} = \frac{V_o}{R}\sin(2\pi f\ t)$$

$$\mathrm{I} = I_o \sin(2\pi f\ t)$$

where $I_o = V_o/R$ is the peak current.

f gives a number of times a current changes direction.

The main voltage provide by Eskom is V_o = 333 V at a frequency $f = 50\ Hz$.

Power

The power delivered to a resistor R at any instant is given by

$$P = I^2 R = I_o^2 R \sin^2(2\pi f\, t)$$

Because the current is squared, the power is always positive. The quantity $\sin^2(2\pi f\, t)$ varies between 0 and 1 and its average value is $\frac{1}{2}$. Therefore the **average power** is given by

$$\bar{P} = \tfrac{1}{2} I_o^2 R$$

Since power can also be written

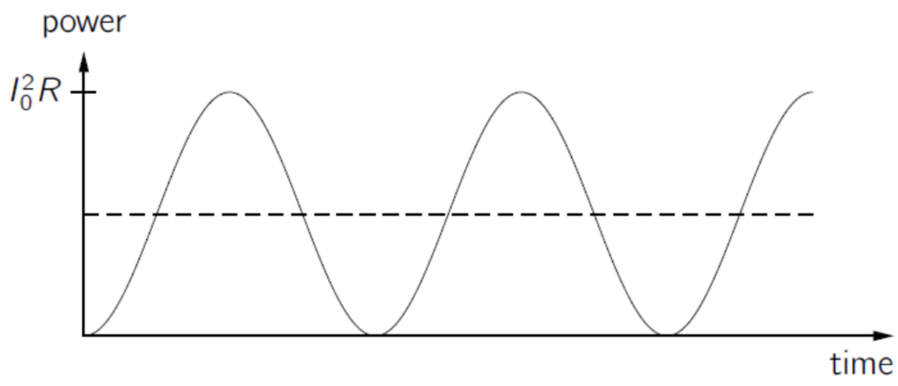
$$\mathrm{P} = V^2/R = (V_o^2/R)\sin 2(2\pi f\, t)$$

we can similarly show that the average power is

$$\bar{P} = \frac{1}{2}\frac{V_o^2}{R}$$

The two equations for P above can be written as

$$\bar{P} = \left(\frac{I_o}{\sqrt{2}}\right)^2 R = \frac{\left(V_o/\sqrt{2}\right)^2}{R}$$



We **define** the **root-mean-square** (rms) current and voltage as

$$I_{rms} = \frac{I_o}{\sqrt{2}} \text{ and } V_{rms} = \frac{V_o}{\sqrt{2}}$$

Then

$$\bar{P} = I_{rms}^2 R = \frac{V_{rms}^2}{R}$$

Voltage supplied by Eskom has

$$V_o = 333V$$
$$F = 50\, Hz$$
$$V_{rms} = 220 - 240\, V$$