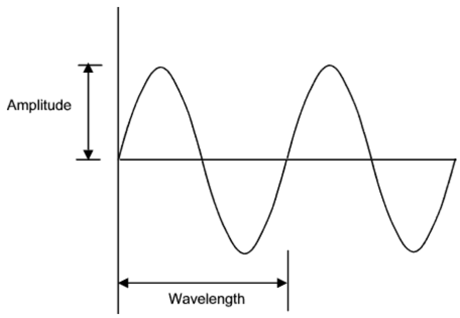
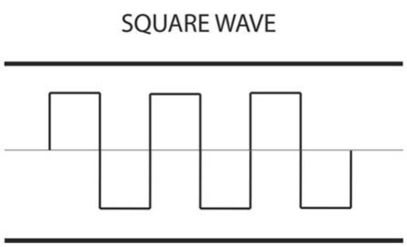
AC Theory and Electronics

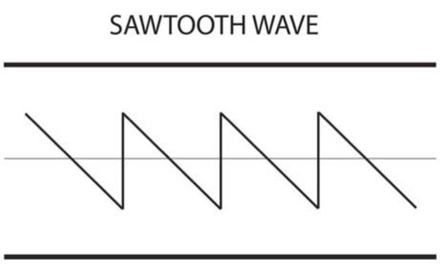
An Alternating Current (AC) or Voltage is one whose amplitude is not constant, but varies with time about some mean position (value). Some examples of AC variation are shown below:



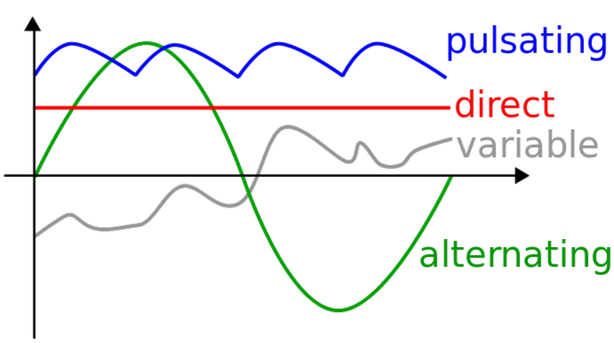
Sinusoidal wave form (Sine wave)



Square wave variation



Square wave variation



Other Variations

For alternating currents, since the currents in a circuit are driven back and forth through the circuit, alternating currents wave form must have a positive and a negative part of the wave form.

Definitions

Peak Value and Peak – Peak Value

Let us look at the sinusoidal wave form in the graph from above.

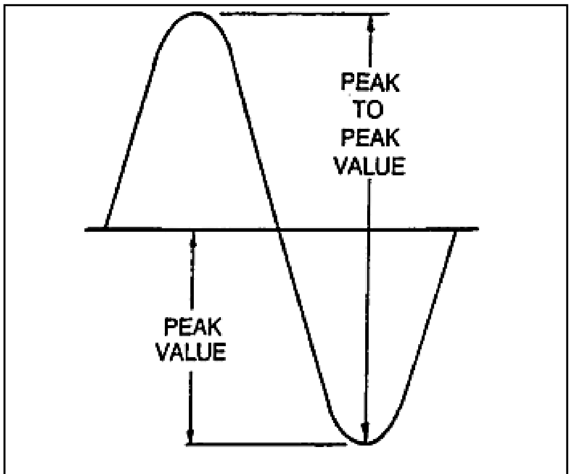


FIGURE 5-14. Peak and Peak-to-Peak Values.

Immediately we can start indicating properties on the waveform. Notice that this waveform is also a sinusoidal wave form. The peak value of this wave form is simply the amplitude of the wave. The peak – peak value of this waveform is the distance from maximum displacement on the positive y-axis to the maximum displacement on the negative y-axis.

Now from mathematics, we know that the formula for any sinusoidal wave is:

$x = A\sin\theta$

Where A is some constant. But this is alternating values of current which we represent in angular representation and not on some angle in one plane. Thus the formula for the wave above becomes:

$$x = A \sin \omega t$$

$$\text{where } \omega = \frac{2\pi}{T}$$

Time Period

This wave will have another property referred to as the time period or simply … a period. The period refers to the time it takes to complete one full oscillation.

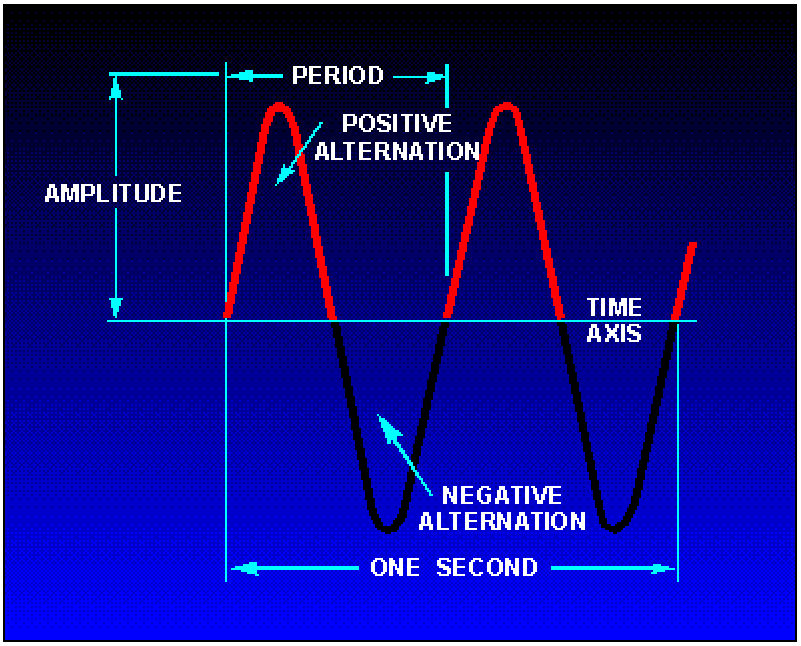
$$T = \frac{1}{f}$$

Frequency

This wave form will also have another property associated with it. This property is referred to as frequency. Simply put, frequency refers to the number of complete oscillations that the waveform makes n one second

$$f = \frac{1}{T}$$

Please fill out the information that is asked for below.



Wavelength

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Amplitude

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Crest

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Trough

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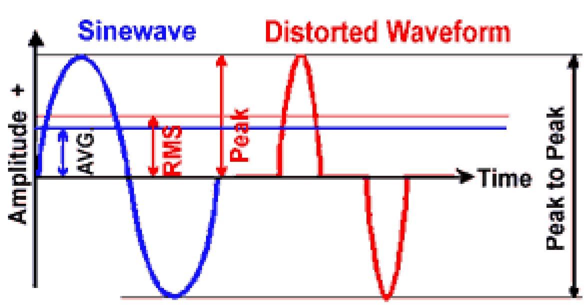
Mean Power and Peak Power

The Mean power refers to the average power supplied to a resistor in one complete cycle in an AC circuit. If the *Peak Power* or amplitude is I_0 then the peak power supplied is $I_0{}^2$ R. Now the *Mean power* refers to the area under the graph for both cycles. The area under the power x time graph is some constant. We know this because when we calculate the area under the curve using some mathematical formula, we obtain some value. This value is the true representation of what a DC circuit would have to mimic in order to supple the same power to the resistor that the AC circuit was powering. Now I know that you do not like complex mathematics, so I wrote the formula for peak power and mean power below:

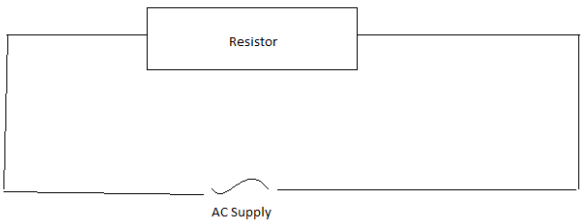
Peak Power $(P_{peak}) = I_0^2 R$

Mean Power or Average power (AVG) $(P_{mean}) = \frac{1}{2} I_0^2 R$



The Root mean Square (r.m.s)

This is the effective *alternating current or voltage* that would allow a *direct current or voltage* to *supply the same power* in a given resistor.



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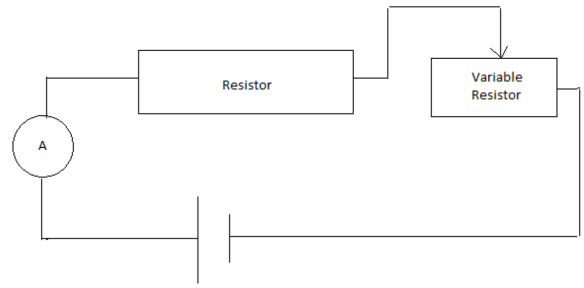


Diagram A

Diagram B

Practical Comparison of Diagram A and B:

- Measure the rate at which heat is produced in the circuit A
- Adjust the variable resistor in diagram B until the rate of energy produced in the heater is the same as in circuit A.
- The current in circuit B which produces the rate of heating is the **rms** value of the AC supply of circuit A

Proof

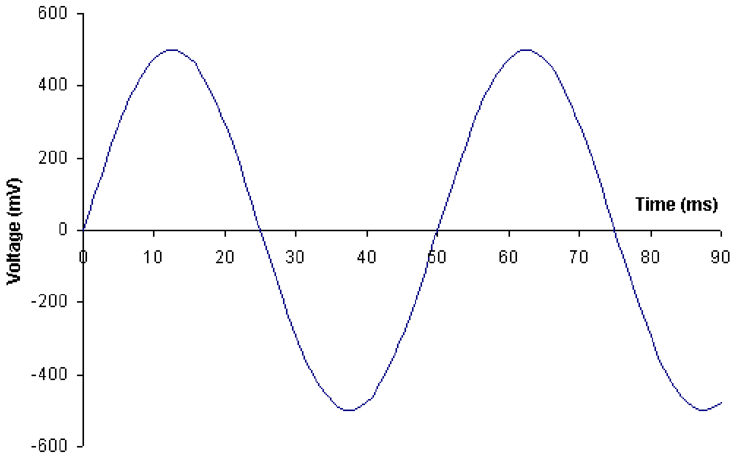
Calculate the r.m.s of values of the numbers given below:

1+2+3+4+5

1. Square the individual values:
   1^2 , 2^2, 3^2,4^2, 5^2
2. Sum the squared values
   1+4+9+16+25=55
3. Calculate the mean of the squares
   55/5 = 11
4. Finally square root the mean
   $\sqrt{11} = 3.3$

   Hence the r.m.s value is 3.3

Calculation of rms for a sinusoidal waveform variation (continuous variation)

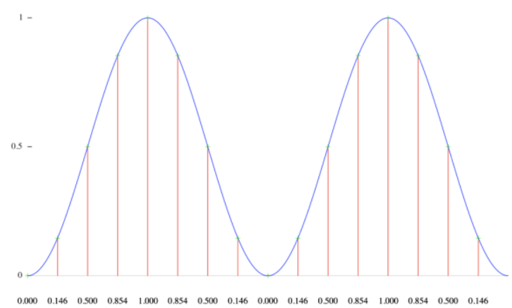


The equation which represents the graph above is

$$v = V_0 \sin \omega t$$

Where V_0 is the peak value of the waveform.

1. Square the graph



2. Sum the area highlighted red under the graph
3. Mean of squares

$$\frac{\textit{Area under graph}}{\textit{One period}}$$

4. Square root – mean

$$\sqrt{\frac{\textit{Area under graph}}{\textit{One period}}}$$

The rms value for a sinusoidal is always 0.707* V_0 which is the same thing as

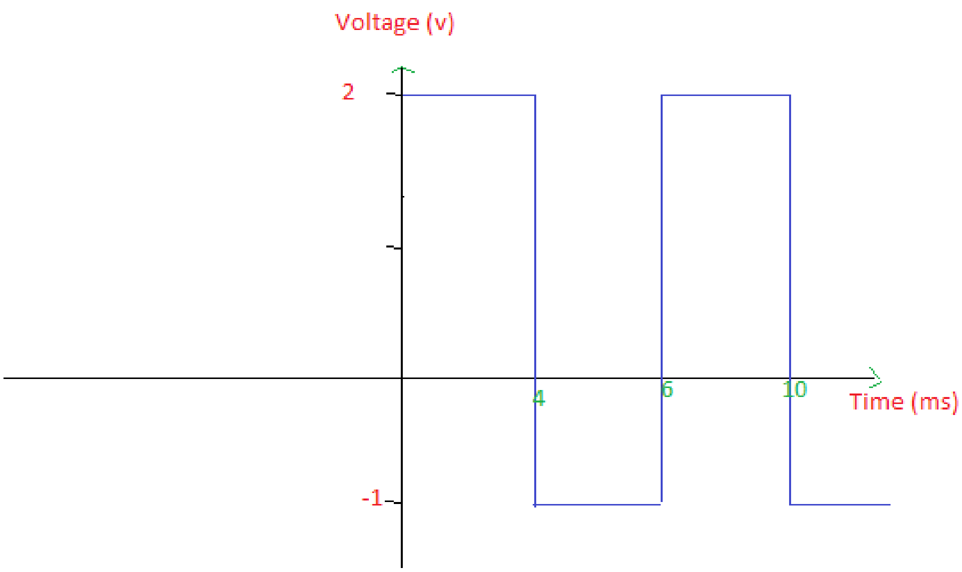
$$\text{r.m.s value} = \frac{1}{\sqrt{2}} \times V_{peak}$$

or

$$\text{r.m.s value} = \frac{1}{\sqrt{2}} \times I_{peak}$$

Example

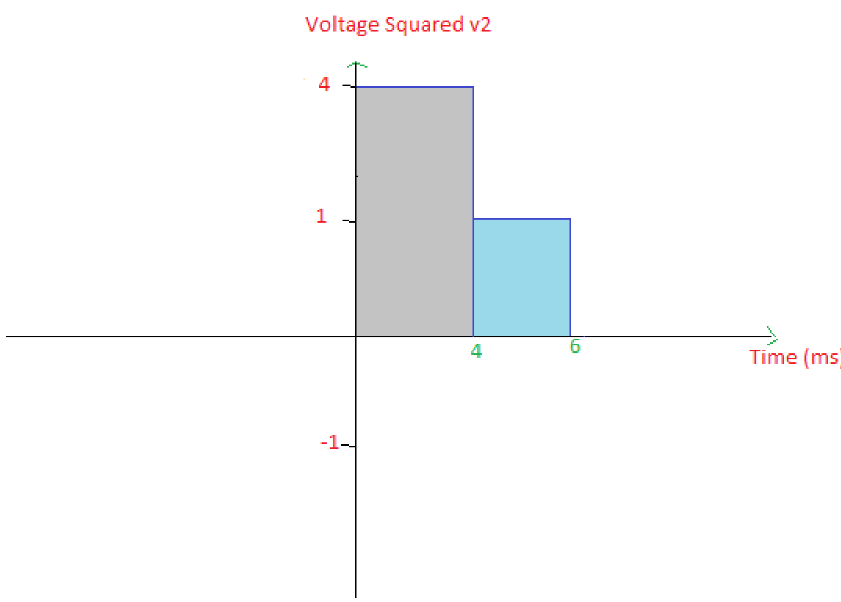
Calculate the rms value of the variation shown below:



Observations:

- Period = 6ms

1. Square the function



Area under curve:

4 * 4x10-3

And

1*2x10-3

2. Sum the area under the curve

$(4 * 4x10^{-3}) + (1*2x10^{-3})$
18 x10-3 v^2s

3. Mean :

$$\frac{18*10-3}{6*10-3}$$

4. Rms:

$\sqrt{3}v^2$

∴ rms = 1.7 v

Exercise

1. Calculate the mean and r.m.s values given below:

1 , 2, 3,4, 5, -3, -4, -5, -2, -1

2. A sinusoidal a.c. has a peak value of 3.0A
   a. What is the rms value of the current?
   b. How much heat is produced every second in a resistor of 2Ω?

3. An AC voltage produces 60J of heat energy every second in a resistor of magnitude 10Ω. What is the peak value of the voltage?

4. Use the equations $V = Vo \sin \omega t$ and $I = Io \sin \omega t$ for the following:

An alternating voltage of frequency 50 Hz has a peak value of 110v. Calculate the time when the voltage has reached -80v.

5. An alternating voltage with a peak value of 200v and a frequency of 100Hz changes from 110v to 180v within the same cycle. Calculate the time over which this change occurred.

Transmission of Alternating Current in Industry

Draw the path of electricity as it leaves the power station, via a step up transformer and then across some wires until it reaches the step down transformer close to your home and then onto your house.

Benefits of Alternating Current*:* Alternating Current is used because:

1. It can easily be produced by generators
2. It can be stepped up and down by transformers
3. It can be easily converted into direct current
4. We are able to generate 3 – phased electrical currents using AC. This allows us to transmit three separate voltages or currents within the same wire 120 degrees out of phase with each other.

Rectification

Rectification is the process of converting AC to DC (Direct current) by the use of a rectifier. A rectifier is a device which has a resistance to the flow of current in one direction by a very high resistance in the other direction. A semiconductor diode is an example of a rectifier.

Diagram 1: A semiconductor diode in an AC circuit (AC supply, conductors, load resistor and diode)

Schematic diagram

Waveform Voltage vs Time

HALF WAVE RECTIFICATION

Diagram 2: Bridge rectification (Diode Bridge, AC Supply, load resistor)

Schematic Diagram

Waveform (Voltage vs Time)

FULL WAVE RECTIFICATION

Full wave rectification alone is not enough to convert from AC to DC, we need other components to smooth out the fluctuating voltage and currents. Thus we add a filter capacitor, which charges as the voltages increases. As soon as the voltage begins to dip, the capacitor discharges and essentially helps to maintain the voltage at the maximum/peak level. A close examination of the waveform will show slight drop off. Draw the schematic for the circuit with a filter capacitor and the resultant waveform:

SMOOTHING FULL WAVE RECTIFICATION

In your own words, explain why a capacitor is present in the diagram above. Mention discharge time, recharge time and the direction of charge on the capacitor plates in relation to the supplied current/voltage. Also does the discharge time constant of the capacitor make a difference?

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EXERCISES

UNDERSTANDING PHYSICS PG 508 - 509

END OF AC THEORY