Practical Physics

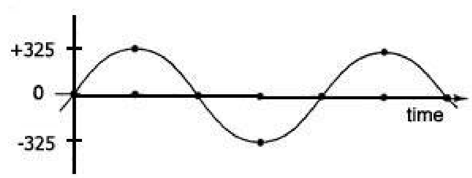
Practical activities designed for use in the classroom with 11- to 19-year-olds.

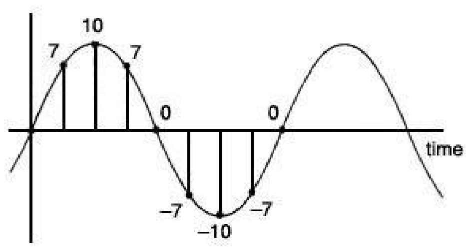
In partnership with IOP Institute of Physics

Explaining rms voltage and current

There are many ways of explaining root mean square (rms) voltage and current at different levels of complexity, to advanced level students.

1 For the simplest level, say that you sample the current (or potential difference) at tiny intervals of time. Square each value, add up the squares (which are all positive) and divide by the number of samples to find the average square or mean square. Then take the square root of that. This is the 'root mean square' (rms) average value.





For example: suppose there are 8 time intervals as shown in the diagram above:

	Values	7	10	7	0	-7	-10	-7	0	
	Squares	49	100	49	0	49	100	49	0	

Sum of squares = 396

Average of squares = 396/8 = almost 50

Square root ~ 7

With more intervals the rms average turns out to be (*peak value*) / √2 = *peak value*/1.41 = 0.707*peak value*

2 For those who are familiar with the graphs of sine and cosine functions, then the following algebraic method can be attempted.

$I = I_o \sin \omega t$ and $I^2 = I_o^2 \sin^2 \omega t$

The heating effect depends on I^2R, and so an average of I^2 is needed and not an average of I.

To find the rms value, you need the average value of $\sin^2$ as time runs on and on.

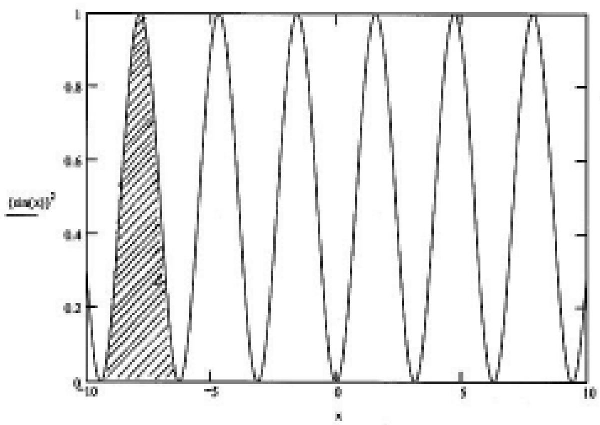
The graph of $\sin\omega t$ and the graph of $\cos\omega t$ look the same, except for a shift of origin. Because they are the same pattern, $\sin^2\omega t$ and $\cos^2\omega t$ have the same average as time goes on.

But $\sin^2\omega t + \cos^2\omega t = 1$. Therefore the average values of either of them must be 1/2.

Therefore the rms value of $I_o \sin\omega t$ must be $I_o / \sqrt{2}$

The rms value is 0.707 times the peak value, and the peak value is 1.41 times the value the voltmeter shows. The peak value for 230 V mains is 325 V.

3 Alternatively: Plot a graph of $\sin^2\theta$. Cut the graph in half and turn one half upside down, or copy onto a transparency and fit together. The two halves fit together exactly, showing that the mean value is 1/2.



4 Note that, when using *unsmoothed* rectified AC from a simple power supply, the estimate of the power obtained by multiplying the readings of a moving coil DC voltmeter and a moving coil ammeter is likely to be nearly 20% too low. This is because each moving coil meter measures the simple time-average of the half-cycle humps, not the rms average.

The rms values of current and voltage multiplied together give the actual power. This is a vital fraction when trying to do quantitative power and energy experiments such as specific thermal capacity. The values are only 80 % of the value at best

$$I^2_{mean} = \frac{I_0^2}{2}$$

$$\therefore \quad I_{mean} = \frac{I_0}{\sqrt{2}}$$

This leads us to:

Peak value current $= I_0$	Peak value voltage $= V_0$
R.M.S value current $= \frac{I_0}{\sqrt{2}}$	R.M.S. value voltage $= \frac{V_0}{\sqrt{2}}$
Time average current $= \frac{2I_0}{\pi}$	Time average voltage $= \frac{2V_0}{\pi}$

The equivalent d.c. power is $V_{RMS} \times I_{RMS} = \frac{V_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} = \frac{V_0 I_0}{2}$

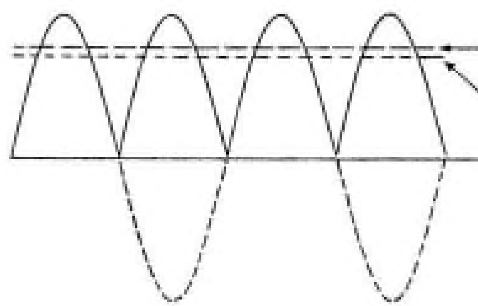
With unsmoothed d.c. then

ammeter reading (DC meter) x voltmeter reading (DC meter)

$$= \frac{2I_0}{\pi} \times \frac{2V_0}{\pi} = \frac{4}{\pi^2} I_0 V_0$$

$\therefore$ d.c .meter readings $= \frac{8}{\pi^2}$ x equivalent DC power

= 0.8 x equivalent DC power



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