

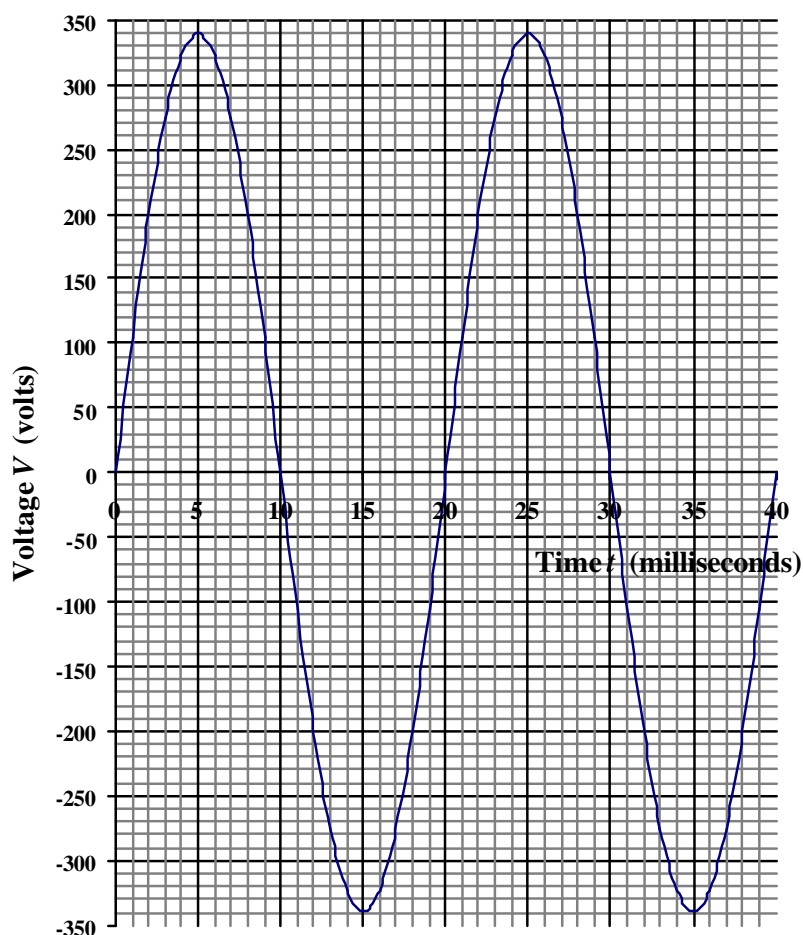
Power to the People

Electricity is produced at power stations located around the country and is then transmitted across the country to businesses and houses.

The electricity is transmitted as an alternating current with a frequency of 50 cycles per second. When it reaches your house its voltage is 240 volts. This value is what is known as the root mean square of the voltage. In fact the voltage varies periodically as shown in the graph below.



Domestic power supply



The root mean square, V_{RMS} , of the supply voltage is related to the amplitude, V_A , by the equation:

$$V_{RMS} = \frac{V_A}{\sqrt{2}}$$

The root mean square value of the voltage is used to represent the supply because it is the voltage of a direct current that would give the same power.

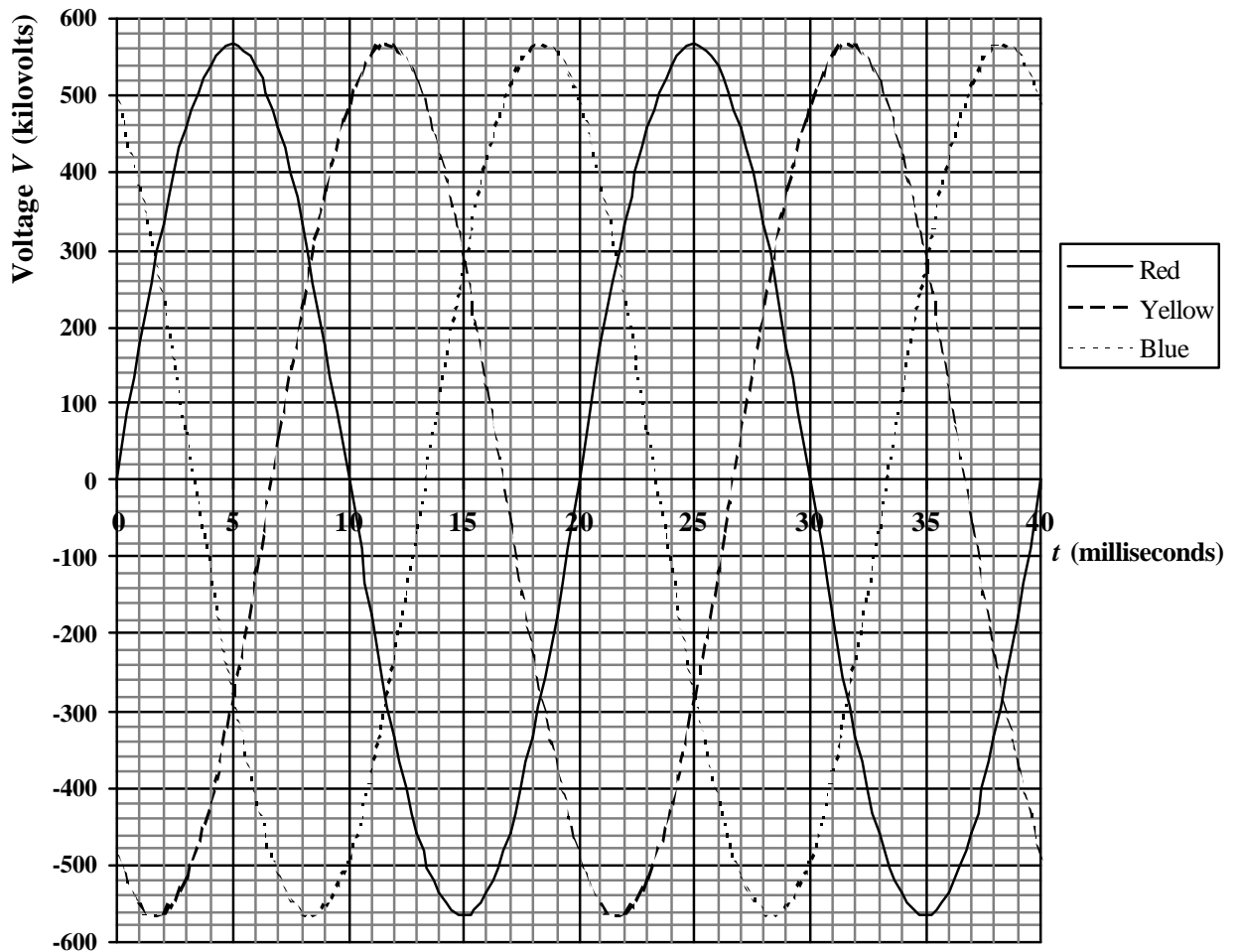
The function shown in the graph above is $V = 240\sqrt{2} \sin(18t)^\circ$ where V represents the voltage in volts and t the time in milliseconds.



Power is the product of voltage and current. To transmit a given amount of power you could use a high voltage and a low current or a low voltage and a high current. High currents require large cables and switchgear and power losses are greater with higher currents, so it is more efficient to use a high voltage and a low current. The 'supergrid' that transmits power in bulk across the country runs largely at 400 kilovolts (i.e. 400 000 volts).

The supergrid distributes electricity as a three-phase supply. The three phases of voltage supply, often called after the colours red, yellow and blue, are shown in the graph below.

Three phase power supply



These three phases of voltage supply are given by the functions:

$$V_1 = 400\sqrt{2} \sin 18\left(t - \frac{20}{3}\right)^\circ, \quad V_2 = 400\sqrt{2} \sin(18t)^\circ \quad \text{and} \quad V_3 = 400\sqrt{2} \sin 18\left(t + \frac{20}{3}\right)^\circ$$

where V represents the voltage in kilovolts and t the time in milliseconds.

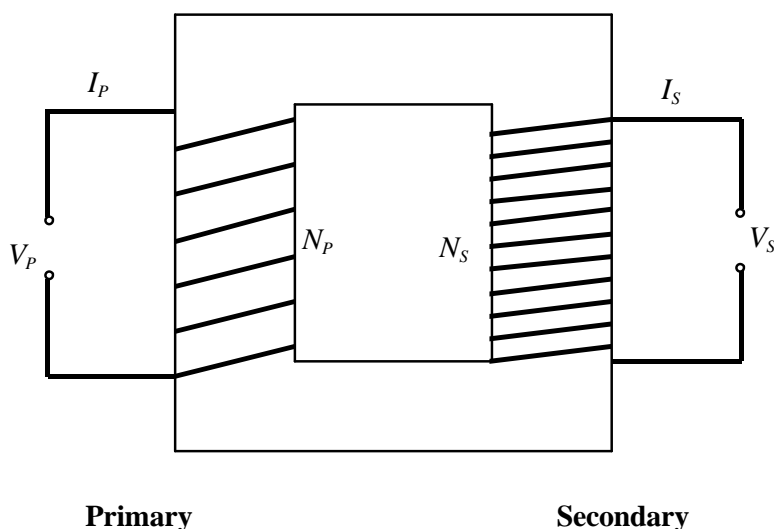
For any value of t , the resultant (i.e. total) voltage is zero.



Some parts of the grid system operate at other voltages. National Grid transmits electricity at 275 kilovolts as well as at 400 kilovolts, regional electricity companies carry electricity at 132 kilovolts, large industrial customers often receive supplies at 33 kilovolts and smaller industrial users at 11 kilovolts. Then, of course, there are all the residential users requiring a domestic supply at 240 volts.

Transformers at substations are used to change voltages from one value to another.

In essence a transformer consists of two coils of wire, called the primary and secondary windings, that are insulated from each other and linked by a common magnetic field. Passing an alternating current through the primary winding causes an induced current to flow in the secondary winding.



V_p = primary voltage
 V_s = secondary voltage

I_p = primary current
 I_s = secondary current

N_p = number of turns in
 primary coil

N_s = number of turns in
 secondary coil

The primary and secondary voltages, V_p and V_s , are related by the equation $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

where N_p is the number of turns in the primary coil and N_s is the number of turns in the secondary coil.

The primary and secondary currents, I_p and I_s , are related by the equation $\frac{I_s}{I_p} = \frac{N_p}{N_s}$

It has been stated above that domestic supply voltage in this country is 240 volts. From 1st January 1995 the nominal voltage of domestic supply across Europe has been 'harmonised' at 230 volts. However The Electricity Safety, Quality and Continuity Regulations 2002 which came into force on 31st January 2003 allow UK domestic supply voltage tolerances of 230 volts – 6% to + 10%. On this basis there is no need at present to change the domestic supply voltage from its present value of 240 volts.



Comprehension Questions

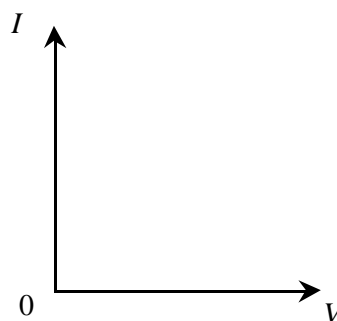
- 1 a The period, T seconds, of a sine wave is related to its frequency, f cycles per second, by $T = \frac{1}{f}$.
Use this formula to find the period in milliseconds of a voltage supply whose frequency is 50 cycles per second. (2 marks)
- b Explain how this is confirmed by the graph on page 1. (1 mark)

- 2 a The article states that:
'The root mean square, V_{RMS} , of the supply voltage is related to the amplitude, V_A , by the equation: $V_{RMS} = \frac{V_A}{\sqrt{2}}$.'
The root mean square of domestic supply voltage is 240 volts.
Calculate the amplitude of domestic supply voltage, giving your answer to the nearest volt. (2 marks)
- b Explain how you can check this value from the graph. (1 mark)

- 3 The statement 'Power is the product of voltage and current.' can be written as $P = IV$ where P represents the power in watts, I the current in amps and V the voltage in volts.

On these axes sketch a graph of I against V for a constant power P .

(2 marks)



- 4 a Look at the graph on page 2. Which of the three functions
 $V_1 = 400\sqrt{2} \sin 18\left(t - \frac{20}{3}\right)^\circ$, $V_2 = 400\sqrt{2} \sin(18t)^\circ$ and $V_3 = 400\sqrt{2} \sin 18\left(t + \frac{20}{3}\right)^\circ$
gives the curve labelled as Red in this graph, which gives Yellow and which gives Blue? (3 marks)
- b Describe completely the geometric transformation of the curve $y = \sin t$ that would give the Red curve. (4 marks)
- c (i) Find the values of V_1 , V_2 and V_3 when $t = 8$, giving your answers to 3 significant figures. (4 marks)
(ii) Hence show that the resultant voltage is zero for this value of t .
- 5 A transformer is needed to change a voltage from 132 kilovolts to 240 volts.
Find the ratio of the turns in the secondary coil to the turns in the primary coil. (3 marks)
- 6 Use calculations to show why there is no need at present to change the domestic supply voltage of 240 volts as a result of The Electricity Safety, Quality and Continuity Regulations 2002. (2 marks)

(Total 24 marks)



Teacher Notes

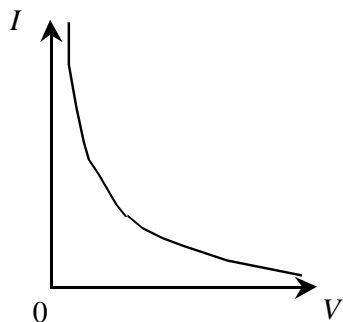
Unit Advanced Level, Applying mathematics

Notes

This is intended as a practice comprehension that students can attempt near the end of their AS level course. It is recommended that students are given the comprehension to study in their own time prior to attempting the questions based on it. The questions are similar to the type of questions that they are likely to meet in Applying Mathematics Paper 1. They are allocated marks that total 24, again to reflect the mark total in that paper.

Answers

- 1 a 20 milliseconds
 b Time for one complete wave on graph = 20 milliseconds
- 2 a 339 volts (nearest volt)
 b This is the maximum value shown on the graph.
- 3



- 4 a Red V_2 , Yellow V_1 , Blue V_3
 b One way stretch in the y direction (vertically) with scale factor $400\sqrt{2}$
 One way stretch in the t direction (horizontally) with scale factor $\frac{1}{18}$ (either order)
 c (i) $V_1 = 230$, $V_2 = 333$, $V_3 = -563$ (to 3 sf) (ii) $230 + 333 - 563 = 0$
- 5 1 : 550
- 6 Domestic supply voltage must be in the range $230\text{V} - 6\%$ to $230\text{V} + 10\%$ i.e. 216.2V to 253V
 240V is between these values and therefore acceptable.

Marks

The comprehension has a total of 24 marks.

As noted above this reflects the number of marks available in the comprehension paper (Paper 1) for Applying Mathematics.

There are another 6 marks available for mathematics presented:

- accurately using correct notation
- logically and clearly.

