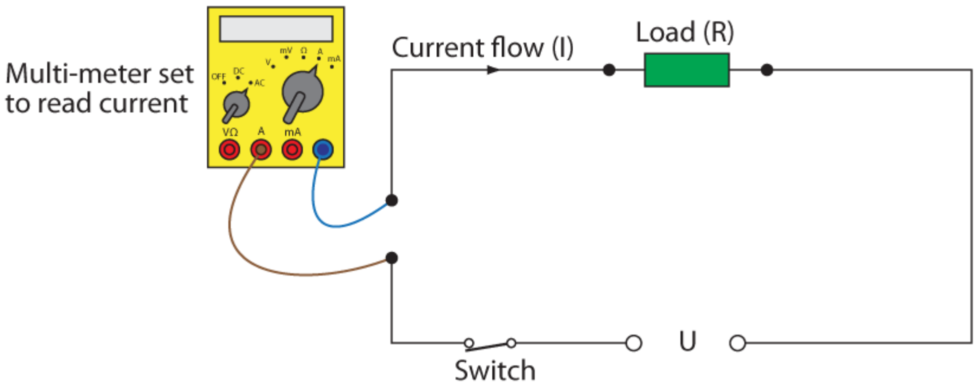
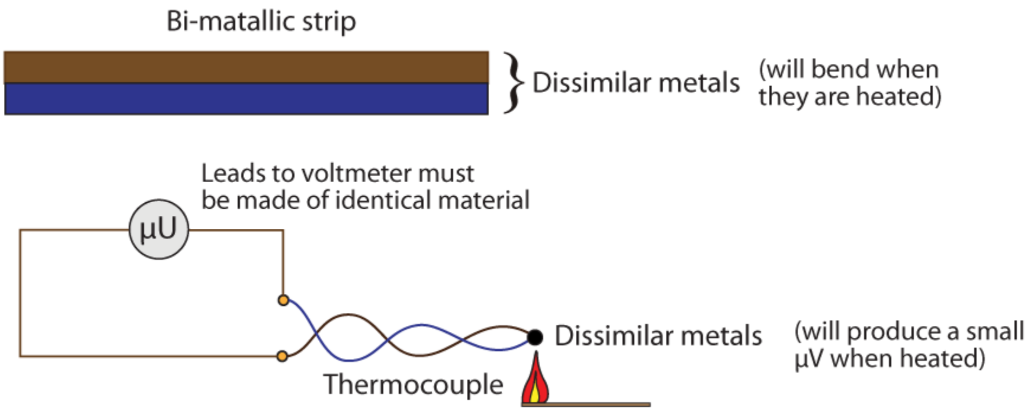
Level 3 Diploma
in
Installing Electrotechnical Systems & Equipment

associates ltd

C&G 2357

Unit 309-2 Standard units of measurement used in electrical installation, maintenance and design work.





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Learning Materials for the Electrical Industry

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Disclaimer

Every effort has been made to ensure accuracy and up-to date information but no responsibility can be accepted for any errors, misleading information or omissions.

The documents and presentations that make up this learning package do not constitute either fully or partially the full and final information on all aspects of the City and Guilds Level 3 NVQ Diploma in Installing Electrotechnical Systems and Equipment (Buildings, Structures and the Environment) (2357-13/91). They do not show full representation of Health and Safety aspects or full knowledge of any job descriptions.

By the end of this study book you will have had:

- Identify the use of internationally recognised SI units of measurement for general variables
- Identify and determine values of basic SI units which apply specifically to electrical variables
- Identify appropriate electrical instruments for the measurement and calculation of different electrical values.

Range:

- Units of measurement
- Basic SI units
- Electrical values

1: Fundamental SI units and their multiples

In this session the student will:

- Gain an understanding of the fundamental and derived SI units.
- Reinforce an understanding of multiples of units using engineering standard form.

Over the years it has become increasingly obvious that when trying to understand one another it is better that a common form of expression is adopted, particularly when engineers, scientists etc. need to communicate.

If there were no common understanding, there would be a large number of different standards adopted by different countries, which makes conversion more difficult. It was with this in mind that a common ***system*** was adopted with some exceptions, the United States being one of those exceptions.

This system of common identification of units and terms is called the **Système Internationale d'Unities**. Thankfully, this has been abbreviated so that it is now simply called the **SI units.**

There are ***seven fundamental physical quantities***. These quantities are:

- mass
- length
- time
- electric current
- temperature
- luminous intensity
- mole *(this is used extensively in chemistry)*

Each of these physical quantities has a ***symbol*** and this should not be confused with their unit name. This will become more apparent as they are used in formulae and equations throughout your course.

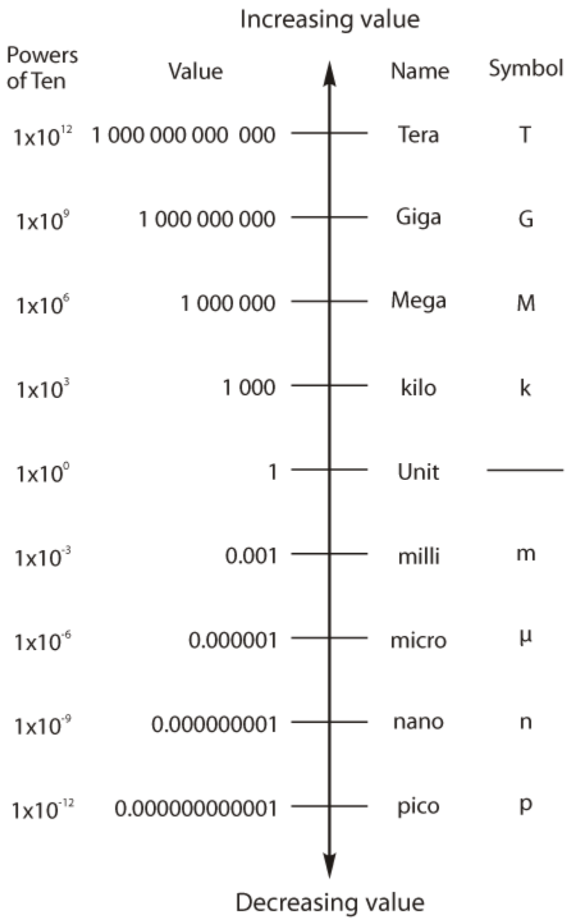
Below is a **table** showing the seven fundamental quantities, their symbols and units.

Quantity	Length	*Mole*	Intensity	Mass	Current	Time	Temperature
Symbol	l	*N*	I	m	I	t	θ
Units	Metres (m)	*Mol*	Candela (cd)	Kilogram (Kg)	Amperes (amps) (A)	seconds	Kelvin (K)

We will not need to look at moles as this relates to quantity of a substance.

All units are derived from these fundamental quantities, and all of the above units cannot be broken down into smaller elements.

To allow more convenient use of these units; ***prefixes*** are used to describe the quantity or size of the unit. In the diagram below most of the common engineering multiples can be seen.



There are more prefixes than these shown above but these are the most commonly used in engineering. It is important that you are familiar with these terms.

Follow the examples and then try some for yourself.

Revision

Note that the common thing is that they are all based on the ***power 10***. This is usually written as:

$$m \times 10^n$$

$$\text{Where} \quad m = \text{any number}$$

$$n = \text{any power}$$

Notice how easy it is to change the decimal point and to add the power or to use the prefix (Remember that the prefix is the letter used to signify the amount.)

A number written with one digit (**one and only one digit**) to the left of the decimal point, multiplied by ten which is then raised to some power is said to be written in ***standard form.*** When we look at engineering units we use engineering form which can be slightly different.

So:-

i). $5837 = 5.837 \times 10^3 = 5.837k$

ii). $0.0415 = 41.5 \times 10^{-3} = 41.5m$

iii). $39400 = 39.4 \times 10^3 = 39.4k$

The number of decimal points moved is the number used for the index. If the decimal point is moved towards the right then we have a negative number, and if we move it to the left, we have a positive index.

Don't get confused between standard form and the prefixes and numbers that we use in engineering. With standard form, we have only one number in front of the decimal point. With engineering form, we often have more than one number in front of the decimal point.

Let's have a look at a few more examples.

With each of the examples shown, convert the number to its whole number.

i). 22kW; ii). 340mm; iii). 220µΩ.

i). $22\text{kW} = 22 \times 10^3\,\text{W} = 22000\text{W}$ **;**

ii). $340\text{mm} = 340 \times 10^{-3}\,\text{m} = 0.34\text{m}$ **;**

iii). $220\mu\Omega = 22 \times 10^{-6}\,\Omega = 0.00022\Omega$ **.**

Remember that each of the prefixes, the letters, have a meaning. Familiarity comes with practice. It may be a good idea to get into the habit of writing out the table of values each time you come to a session as a revision aid.

Complete the table.

Name	pico				Giga	milli	
Letter		k		M			n
Multiplier			$\times 10^{-6}$				

Exercise 1.

1) Convert the following numbers into common engineering units.

a). 2 500 000 VA b). 0.000 047 F c). 2.5 A

d). 0.000 000 008 8 H e). 23 492 W f). 825 000 W.

2) Convert the following into whole numbers.

a). 8.8 µF b). 975 kVA c). 2.5 mH

d). 470 pF e). 3 MW f). 55 TWh.

3) What is measured using the following units?

a). Tesla b). Celsius c). Kelvin

d). Voltage e). Hertz f). second

g). Watts h). metre I). Newtons.

All other units within the international system of measurement are based on the units given to the seven base physical quantities considered in the first section.

Remember. these base units are:

- mass
- length
- time
- electric current
- temperature
- luminous intensity
- mole (amount of a substance).

When considering other units of measurement it is relatively easy in many instances to recognise where they derive from. In this section we will look at the units that will have to be considered throughout this course of study.

The table over the page details the derived SI units.

Quantity	Symbol	Unit	Unit symbol
Area	A	Square metre	(m^2)
Volume	V	Cubic metre	m^3
Density	D	Kilogram per cubic metre	kgm^{-3} or kg/m^3
Velocity/Speed	v	Metre per second	ms^{-1} or m/s
Acceleration	a or g	Meter per second per second	ms^{-2} or m/s^2
Force	F	Newton	N
Resistance	R	Ohm	Ω
Resistivity	ρ	Ohm metre	Ωm
Power	P	Watt or Joule per second	W or J/s
Frequency	f	Hertz	Hz
Voltage	U	Volt	V
Energy	W	Joule or Newton metre	J or Nm
Magnetic flux	ϕ	Weber	Wb
Magnetic flux density	B	Tesla or Wb/m^2 or Wbm^{-2}	T
Impedance	Z	Ohm	Ω
Inductance	L	Henry	H
Inductive reactance	X_L	Ohm	Ω
Capacitance	C	Farad	F
Capacitive reactance	X_L	Ohm	Ω
Power factor	pf	A ratio therefore no units	
True power	P	Watt	W
Reactive power	Q	Volt ampere reactive	VAr
Apparent power	S	Volt ampere	VA

There are a range of non-SI units that are often used, and it is worthwhile being aware of some of them.

Quantity	Symbol	Name	Derived from
Time	min	minute	$1\text{min} = 60s$
Time	hr	hour	$1\text{hr} = 60\text{min} = 3600s$
Time	day	day	$1\text{day} = 24\text{hr} = 1440\text{min} = 86400s$
Volume	l	Litre	$1l = 1000ml = 0.001m^3$
Mass	t	Tonne	$1t = 1000kg$

Exercise 2.

1) Convert the following numbers into their SI unit.

a).	2.5 hours	b).	3hr 12min	c).	0.5 days
d).	1000l	e).	4.7t	f).	1day 2hr 14min.

2: Instruments

In this session the student will:

- Gain an understanding of instruments used to measure electrical values

In this session we are going to look at how electrical instruments are connected into a circuit so that measurement of the following values can be made.

- Resistance
- Power
- Frequency
- Current
- Voltage
- Energy
- Impedance

Resistance

As an electrician, knowing the value of resistance of things is important. If a cable had too high a value of resistance then a circuit might not work in the way it was designed. At the completion of an installation a test sheet must be completed where the electrician is to record the values of conductor resistance and insulation resistance. This will be explained in more detail in a later outcome. Electrical heaters have a resistance value which would enable the electrician to work out how much current the circuit would draw, and then what size cable was needed to supply the heater. The instrument used to measure resistance is called an ohmmeter. Many digital multimeters in use today have a scale marked ohms. In electrical testing, the ohmmeter is often called a continuity tester.

The drawings below show two types of ohmmeter; an electrical test instrument and a typical multimeter.

Figure 1 Test instrument

Figure 2 Typical multimeter

To measure the resistance of something, it could be a conductor in a cable or a heater element. The meter is simply connected across the ends of the cable etc. without any power being connected. The current for the meter is drawn from the batteries inside the meter. On a technical level, digital multimeters are best because they do not add resistance to the circuit.

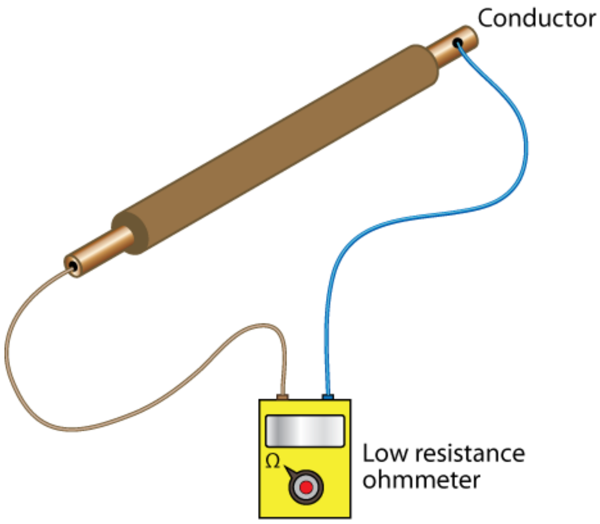


Figure 3 The resistance of a conductor being measured

Current

This value tells the electrician much about a circuit, such as is the installed cable suitable, or what size overcurrent protective device (fuse), is needed. Quite often, the current consumption is shown on the equipment along with the voltage and power.

However, there are times when an electrician will need to measure what the actual value of current is flowing. To do this an ammeter is used. This can be one of two types; a tong tester which is also commonly called a clamp meter and a multimeter having an ammeter setting.

The advantage of the tong tester is that the circuit does not need to be broken; it is simply clamped around the conductor. A typical tong/clamp meter is shown in Fig. 4.

Figure 4Tong tester

Using a multimeter, the circuit has to be **broken** and the ammeter placed in **series** with the load, i.e. whatever is drawing the current.

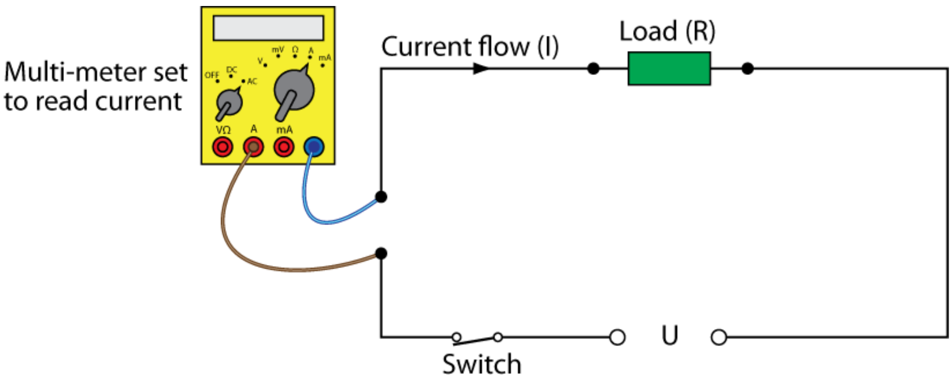


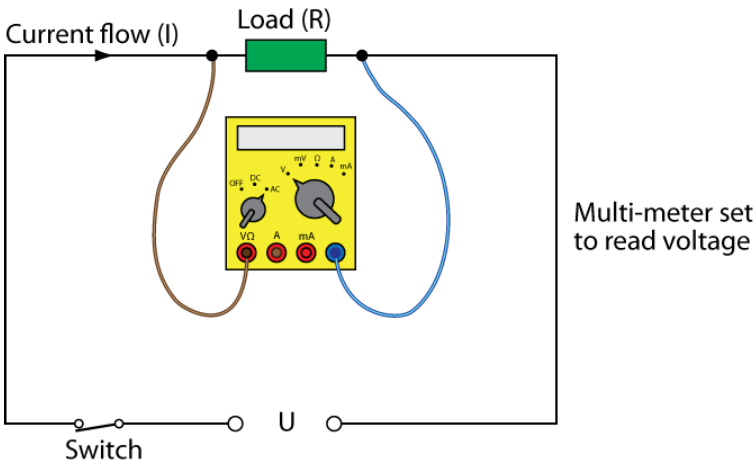
Figure 5 Ammeter connected in series

The reading shown on this instrument will depend upon the size of the load and the applied voltage. If the load is large, i.e. high resistance then the current (I), will be small, possibly in milliamps (mA), or even micro amps (μA).

There is an equation linking these together; $I = \frac{U}{R}$ this will be dealt with in more detail in another module, but suffice to say, the current flowing is dependent upon the size of supply and the size of the load.

Voltage

The electrician needs to be aware of what the supply voltage is applied to a circuit. If the voltage is too high, irreparable damage will be done, too low and the circuit will not function properly.
Testing for a voltage is also used when fault finding.
A good digital multimeter performs this function well enough for most situations.



The multimeter must be connected in **parallel** i.e. across the circuit as shown in Fig. 6.

Figure 6 Voltmeter connected across a circuit

The voltage reading is dependent upon the current flowing and the size of the load.
There is an equation linking these together; $U = I \times R$, this will be dealt with in more detail in another module.

Power

Technically, power is described as being the rate at which work is done or energy converted into another form. However, the electrician is more concerned with what is the power consumption, i.e. power used by a piece of equipment, so that he/she can work out how best to install it. There is a meter which can measure power directly and is called a wattmeter, but that is mainly used in the laboratory. It is really a combination of an ammeter and a voltmeter.

That being said, there are equations which can be used to determine the power consumption of a circuit, and which one is used is dependent upon what information is available.

If voltage and current are known; $P = U \times I$

If voltage and resistance are known; $P = \frac{U^2}{R}$

If current and resistance are known; $P = I^2 \times R$

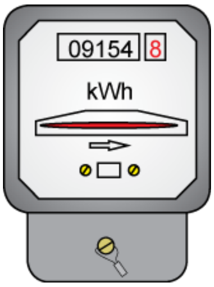
The unit of power is the watt.

Energy

Energy broadly means the capacity of something, a person, an animal or a physical system to do work and produce change.

The electricity companies charge all of us for the electrical energy we use. This can be for domestic, commercial or industrial usage. At the point of supply intake in all buildings there is an energy meter fixed and serviced by the local distributor. Electricians generally do not install the metering equipment; this is done by the local network operator.

A typical energy meter is shown in Fig. 7.



The cost of energy consumption can be calculated from;

$Cost = kW \times hours \times tariff$

The average tariff for electricity at the moment is 10.5p a unit, where one unit is 1 kW used for one hour.

Figure 7 Typical energy meter

Impedance

This is similar to resistance in that it is measured in ohms, but impedance specifically relates to circuits fed from an a.c. source. Resistance relates to circuits fed from a d.c. source. There is a mathematical reason for this which is beyond the scope of this course; but generally, any reference to impedance implies the circuit is a.c.

When carrying out electrical testing, the electrician is concerned with the impedance of circuits, as that is the factor which restricts the flow of current, just like resistance in a d.c. circuit.
If the impedance is too high only a small amount of current will flow and the protective device will not operate very quickly. This will be dealt with in more detail in a later module.

The instrument used to measure impedance in say a ring final circuit is an earth fault loop impedance tester such as the type here.

Figure 8 Impedance tester

The impedance of an a.c. circuit could also be found by calculation. This is done by connecting both an ammeter and a voltmeter into a circuit in the manner shown below.

Both instruments are set for a.c.

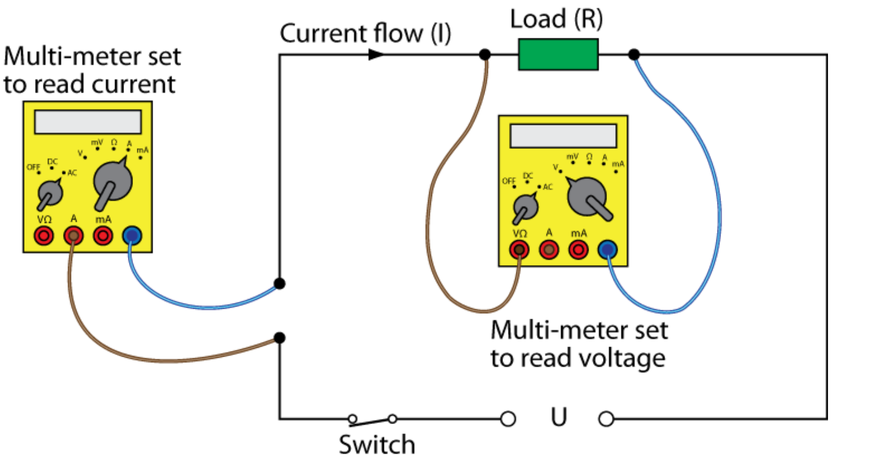


Figure 9 Instruments connected in a circuit to enable impedance be found

The impedance Z of the load can be found from; $Z = \dfrac{Voltmeter\ reading}{Ammeter\ reading} = \dfrac{U}{I}$

This will be dealt with in more detail in a later module.

Frequency

It is not often that an electrician is concerned with the supply frequency as it is usually very reliable and does not deviate beyond its allowed tolerance.

The measurement of frequency requires the use of a specialist instrument called an oscilloscope, which is generally found in college laboratories.

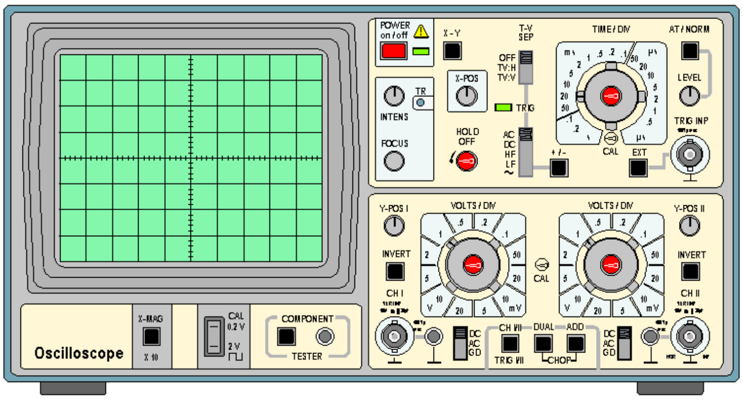


Figure 10 Oscilloscope

The advantage of using an oscilloscope is that it gives a picture of the supply waveform and can also be used to measure the voltage.

The frequency is the number of completes cycles per second. The equation linking these terms is;

$f = \frac{1}{t}$ where t is the time in seconds.

Exercise 3.

1) What instrument would be used to measure the resistance of a length of cable?

2) Draw a circuit diagram showing how you would measure both current and voltage.

3) If the readings on the instruments used in 2) above showed 2.5 mA and 50 V, what would be the;

   a) resistance

   b) power consumed by the circuit (use all three expressions given in the text)

4) What would be the cost if a 3 kW heater was left running for 5 hours and the tariff rate was 10p per kWh?

5) What would be the frequency of a supply if it took 10 ms to complete one cycle?

6) What is the time taken to complete one cycle if the supply frequency is 50 Hz?

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Engineering Learning Materials

Attempt all questions.

All marks are shown in the right-hand margin.

You should aim to pass with a 85 % minimum mark.

Anything less than this mark should lead you to re-read the text.

1). State the s.i. units for current; voltage; time; mass; length; resistance; magnetic flux and power. 8

2). A machine has an output of 200 kW and demands 250 kW of electrical energy. What is the overall efficiency? 2

3). What is the weekly cost of running the above machine for 5 hours a day Monday to Friday if electricity costs 10 p a unit? 6

4). If the efficiency of the machine could be improved to 95%, what would be the weekly saving in the cost of electricity? 10

5). How would the power of a circuit be determined if the only instrument an electrician had was a voltmeter, but the resistance was known? 4

Include a simple circuit diagram with your answer.

6). An electrician has a continuity tester available, how could the current drawn for a heating element be determined if only the supply voltage is known? 4

Include a simple circuit diagram with your answer.

7). Determine the periods for the following frequencies: 3

a) 7 Hz
b) 100 Hz
c) 470 kHz.

8). Determine the frequencies for the following periods: 3

a) 200 ms
b) 1.5 ms
c) 10 s.

Total 40