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Student Handout.

750 Demonstrate knowledge of electrical test instruments and take measurements LV 2 Credits 2

Resources:

References
Electricity Regulations 1997;
Health and Safety in Employment Act 1992;

AS/NZS 3000:2000, *Electrical installations (the Australian/New Zealand Wiring Rules)*;
AS/NZS 4836:2001, *Safe working on low-voltage electrical installations;*

Electrical Workers Registration Board, *Manual for Safety Training in the Electrical Industry*, (2000) Wellington; and all subsequent amendments and replacements.

Definitions
a.c – alternating current;
d.c – direct current.

The *prove-test-prove* method refers to proving the instrument before and after a test to ensure that it works properly, and is particularly important when confirming electrical isolation. Some instruments have fused leads and may give false indication of isolation if the fuse is open circuit or blows during the test. Proving is done by applying the instrument to a circuit that is known to be energised and observing the measured voltage, testing the circuit to be isolated to ensure it is in fact isolated, then proving the instrument again on a circuit that is known to be energised.

Element 1. Demonstrate knowledge of electrical test instruments.

1.1 Moving Coil Meters. This meter consists of a powerful 'horseshoe' permanent magnet with soft iron pole pieces providing a circular shaped air gap. Mounted in the middle of this air gap is a cylindrical soft iron core on a central axel. Which lowers the reluctance of the air gap, increasing the magnetic fields intensity. A coil of many turns of fine wire is wound on a former in a rectangular pattern about the soft iron core. This coil is mounted so it is free to move about the central axel in the circular air gap of the assembly.

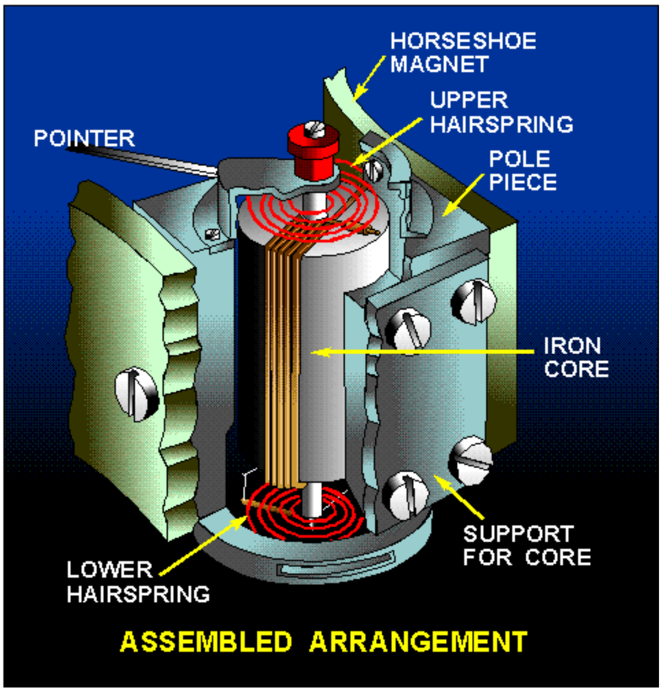
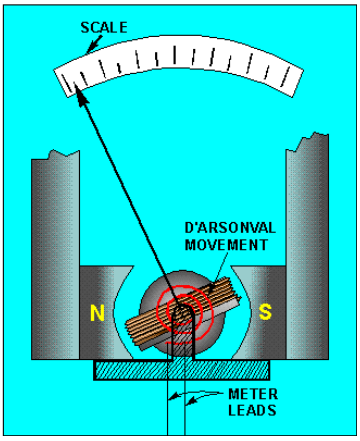


Figure 1. This permanent-magnet moving-coil meter movement is the basic movement in most measuring instruments. It is commonly called the d'Arsonval movement because it was first employed by the Frenchman d'Arsonval in making electrical measurements. Figure 1-10 is a view of the d'Arsonval meter movement used in a meter.



The current to be measured (or part of it) passes through the moving coil using the two light hairsprings as conductors. These springs are in opposition to each other and the strength of the induced magnetic field causes the coil to be displaced in the field of the permanent magnets. This causes a pointer attached to the centre point of the coil to move uniformly over a graduated calibrated in the units the instrument is designed to measure (**Figure 2**).

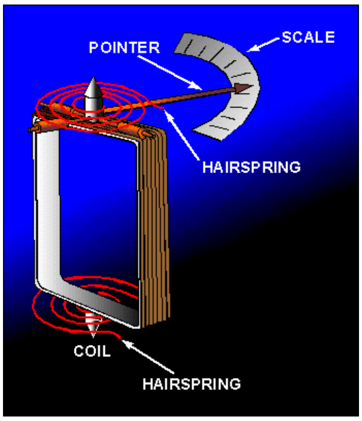


Figure 3. With the use of hairsprings, the coil will return to its initial position when there is no current. The springs will also tend to resist the movement of the coil when there is current through the coil. When the attraction between the magnetic fields (from the permanent magnet and the coil) is exactly equal to the force of the hairsprings, the coil will stop moving toward the magnet.

Moving Iron Meters. There are two distinct types that differ by using attraction or repulsion to deflect a pointer of a calibrated scale.

The moving-vane meter movement (sometimes called the moving-iron movement) is the most commonly used movement for ac meters.

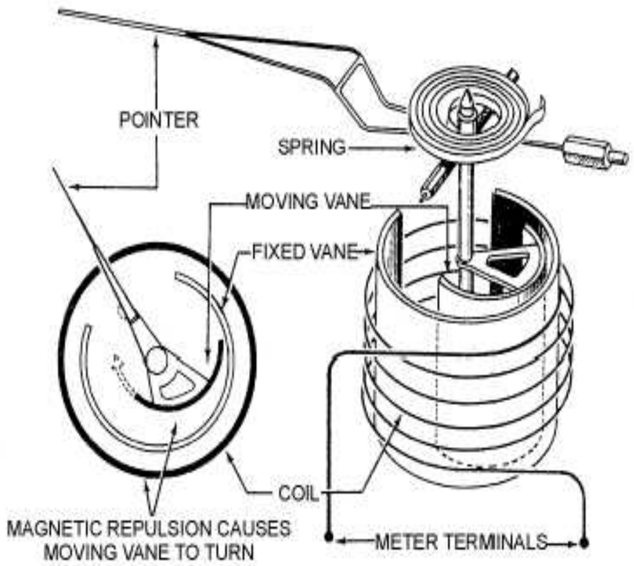


Figure 4. The moving-vane meter operates on the principle of magnetic repulsion between like poles.

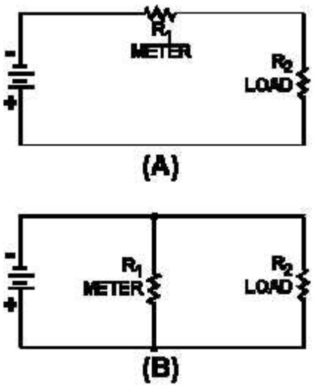
The current to be measured flows through a coil, producing a magnetic field, which is proportional to the strength of the current. Suspended in this field are two iron vanes. One is in a fixed position, the other, attached to the meter pointer, is movable.

The magnetic field magnetizes these iron vanes with the same polarity regardless of the direction of current flow in the coil. Since like poles repel, the movable vane pulls away from the fixed vane, moving the meter pointer.

This motion exerts a turning force against the spring. The distance the vane will move against the force of the spring depends on the strength of the magnetic field, which in turn depends on the coil current.

The moving iron instrument is more robust and cheaper to produce but less accurate than the moving coil instrument. This instrument also has the advantage of not being polarised (not concerned with which direction the current flows.) so it can be used to measure AC and DC.

1.2 Analogue instruments are described in terms of their principles of operation and their applications.



AMMETERS

An ammeter is a device that measures current. Since all meter movements have resistance, a resistor will be used to represent a meter in the following explanations. Direct current circuits will be used for simplicity of explanation.

If R1 represents an ammeter, the only way in which total circuit current will flow through the meter (and thus be measured) is to have the meter (R1) in series with the circuit load (R2), as shown in **Figure 5(A).**

In complex electrical circuits, you are not always concerned with total circuit current. You may be interested in the current through a particular component or group of components. In any case, an ammeter is always connected in series with the circuit you wish to test. **Figure 6** shows various circuit arrangements with the ammeter(s) properly connected for measuring current in various portions of the circuit.

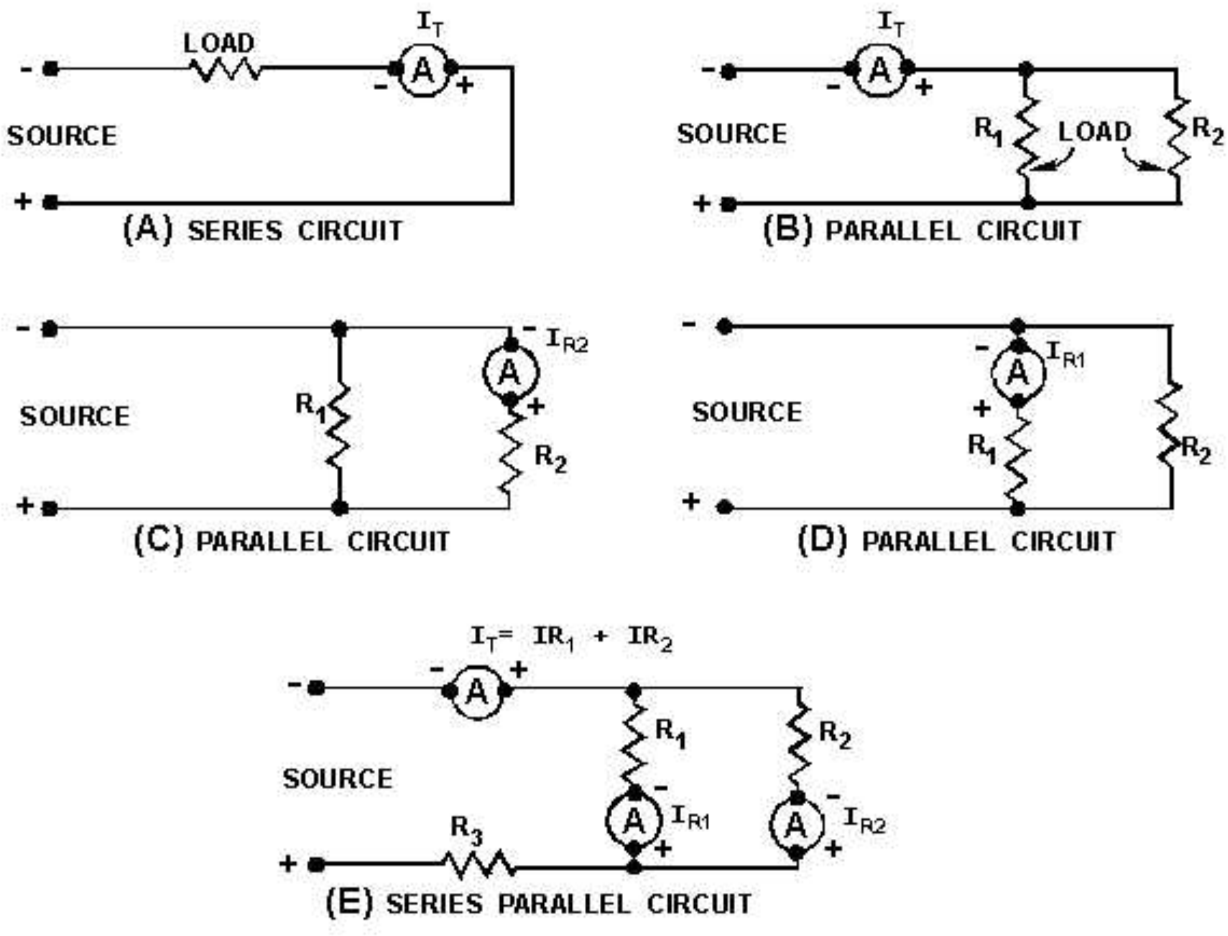


Figure 6.

Connecting an ammeter in parallel would give you not only an incorrect measurement, it would also damage the ammeter, because too much current would pass through the meter.

AMMETER SENSITIVITY

Ammeter sensitivity is the amount of current necessary to cause full-scale deflection (maximum reading) of the ammeter.

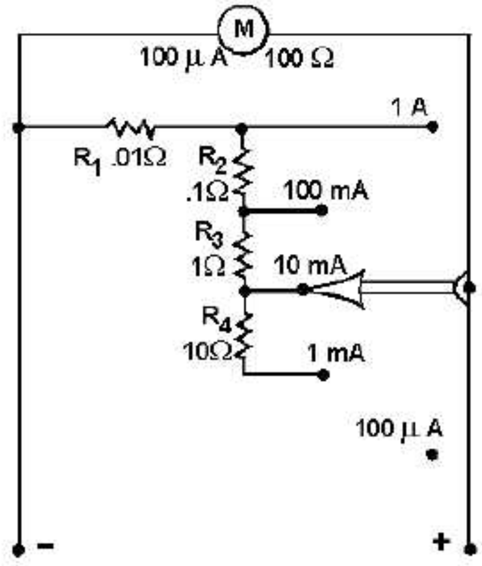
The smaller the amount of current, the more "sensitive" the ammeter. For example, an ammeter with a maximum current reading of 1 milliampere would have a sensitivity of 1 milliampere, and be more sensitive than an ammeter with a maximum reading of 1 ampere and a sensitivity of 1 ampere.

Sensitivity can be given for a meter movement, but the term "ammeter sensitivity" usually refers to the entire ammeter and not just the meter movement. An ammeter consists of more than just the meter movement.

AMMETER RANGES

If you have a meter movement with a sensitivity of 1 milliampere, you can connect it in series with a circuit and measure currents up to 1 milliampere. But what do you do to measure currents over 1 milliampere?

By adding several shunt resistors in the meter case, with a switch to select the desired resistor, the ammeter will be capable of measuring several different maximum current readings or ranges.



Most meter movements in use today have sensitivities of from 5 microamperes to 1 milliampere. **Figure 7** shows the circuit of meter switching to different ranges.

This ammeter has five ranges (100 microamperes; 1, 10, and 100 milliampere; 1 ampere) selected by a switch.

By adding several shunt resistors in the meter case, with a switch to select the desired resistor, the ammeter will be capable of measuring several different maximum current readings or ranges.

With the switch in the 100 microampere position, all the current being measured will go through the meter movement. None of the current will go through any of the shunt resistors. If the ammeter is switched to the 1 milliampere position, the current being measured will have parallel paths of the meter movement and all the shunt resistors (R1, R2, R3, and R4).

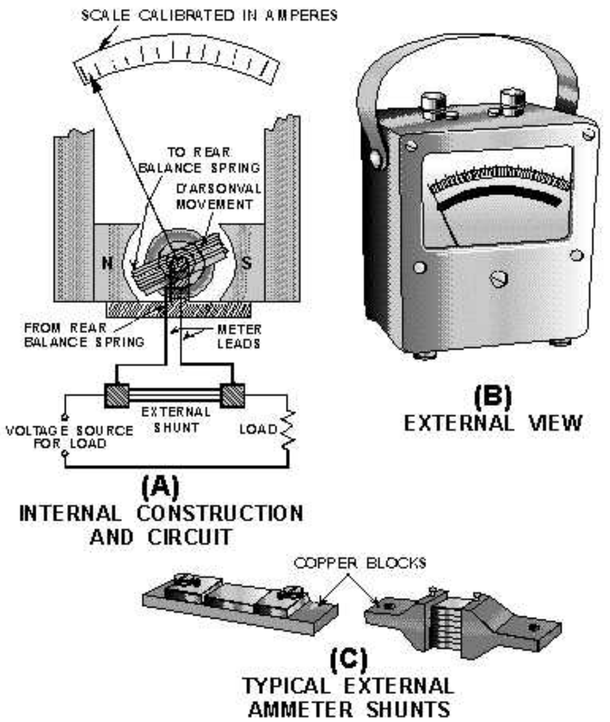
Now, only a portion of the current will go through the meter movement and the rest of the current will go through the shunt resistors. When the meter is switched to the 10-milliampere position (as shown in fig. 1-22), only resistors R1, R2, and R3 shunt the meter.

Since the resistance of the shunting resistance is less than with R4 in the circuit (as was the case in the 1-milliampere position), more current will go through the shunt resistors and less current will go through the meter movement. As the resistance decreases and more current goes through the shunt resistors.

As long as the current to be measured does not exceed the range selected, the meter movement will never have more than 100 microamperes of current through it.

Shunt resistors are made with close tolerances. That means if a shunt resistor is selected with a resistance of .01 ohms (as R1 in **Figure 7**.), the actual resistance of that shunt resistor will not vary from that value by more than 1 percent.

Since a shunt resistor is used to protect a meter movement and to allow accurate measurement, it is important that the resistance of the shunt resistor is known very accurately.



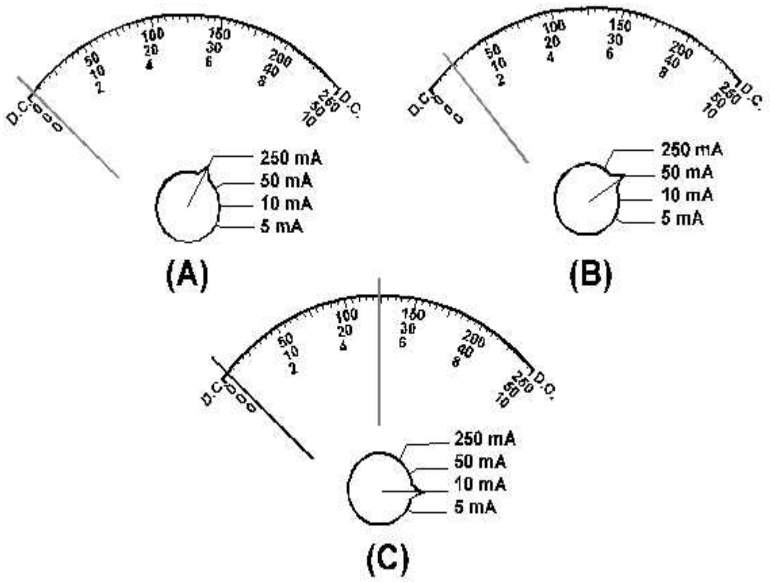
For higher current ranges (above 50 amperes) ammeters that use external shunts are used. The external shunt resistor serves the same purpose as the internal shunt resistor.

The external shunt is connected in series with the circuit to be measured and in parallel with the ammeter. This shunts (bypasses) the ammeter so only a portion of the current goes through the meter.

Each external shunt will be marked with the maximum current value that the ammeter will measure when that shunt is used. **Figure 8** shows an ammeter that is designed to use external shunts and a d'Arsonval meter movement.

A shunt resistor is nothing more than a resistor in parallel with the meter movement. To measure high currents, very small resistance shunts are used so the majority of the current will go through the shunt. Since the total resistance of a parallel circuit (the meter movement and shunt resistor) is always less than the resistance of the smallest resistor, as an ammeter's range is increased, its resistance decreases.

This is important because the load resistance of high-current circuits is smaller than the load resistance of low-current circuits. To obtain accurate measurements, it is necessary that the ammeter resistance be much less than the load resistance, since the ammeter is connected in series with the load



Range Selection Part of the correct use of an ammeter is the proper use of the range selection switch.

If the current to be measured is larger than the scale of the meter selected, the meter movement will have excessive current and will be damaged.

Therefore, it is important to always start with the highest range when you use an ammeter. If the current can be measured on several ranges, use the range that results in a reading near the middle of the scale. **Figure 9** illustrates these points.

Reading an ammeter at various ranges. The (A) shows the highest range (250 milliampere) has been selected and the pointer deflection is very small. It would be difficult to properly interpret this reading with any degree of accuracy. The (B) shows the second reading, with the next largest range (50 milliampere). The meter deflection is a little greater. It is possible to interpret this reading as 5 milliampere. Since this approximation of the current is less than the next range, the meter is switched as shown in (C).

The range of the meter is now 10 milliampere and it is possible to read the meter indication of 5 milliampere with the greatest degree of accuracy. Since the current indicated is equal to (or greater than) the next range of the ammeter (5 milliampere), the meter should NOT be switched to the next range.

AMMETER SAFETY PRECAUTIONS

The following list contains the **MINIMUM** precautions to observe when using an ammeter. ·

- Ammeters must always be connected in series with the circuit under test.
- Always start with the highest range of an ammeter.
- De-energize and discharge the circuit completely before you connect or disconnect the ammeter.
- In dc ammeters, observe the proper circuit polarity to prevent the meter from being damaged.
- Never use a dc ammeter to measure ac.

- Observe the general safety precautions of electrical and electronic devices.

VOLTMETERS

All the meter movements discussed so far react to current, and you have been shown how ammeters are constructed from those meter movements. It is often necessary to measure circuit properties other than current.

Voltage measurement, for example, is accomplished with a VOLTMETER.

VOLTMETERS ARE CONNECTED IN PARALLEL While ammeters are always connected in series, voltmeters are always connected in parallel.

This time, you do not need to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible. In other words, a voltmeter should have a very HIGH resistance.

Which measurement technique do you think will be the more useful? In fact, voltage measurements are used much more often than current measurements.

The processing of electronic signals is usually thought of in voltage terms. It is an added advantage that a voltage measurement is easier to make. The orginal circuit does not need to be changed. Often, the meter probes are connected simply by touching them to the points of interest.

The same rule applies about starting on the highest scale, but again we have to be careful to choose AC or DC scales appropiatly. If in doubt choose the highest AC voltage scale first, as this has the best protection for the instrument. There are always possibility of electric shock when using test instruments.

Before attempting to make a voltage measurement, think about the anticipated result. Is this a DC or AC voltage? How much voltage will be present? If things are not working correctly what is the highest voltage that I might find?

A voltage is ALWAYS measured between TWO points. Is one of those points GROUND? If not, can you make a different measurement such that one of the measurement points IS GROUND? If your measurements are all referenced to GROUND (the usual case), you can connect the black lead to GROUND with a clip (see below), and probe the other point with the red lead.

Set the selector switch on the meter to the range that is higher than the maximum anticipated voltage of the appropriate type (DC or AC). If the maximum anticipated voltage is not known, set the meter to the highest range available.

Wherever possible connect the meter into the circuit when the circuit is OFF, then power up the circuit without touching anything. Read the meter, then turn the circuit OFF. If the reading is lower than the next available lower range on the meter you may set the meter to a lower range while the circuit is on.

When doing this touch ONLY the meter with ONE hand, and be careful to only lower the meter one range, allow the readings to stabilize (2 or 3 seconds) before proceeding lower. Accidentally setting the meter to a current of resistance range can damage the meter, and the circuit it is connected to. If the circuit has sufficient power the meter can explode or burst into flames. I know from experience that this will happen if you try to measure the resistance of the wall outlet. Most modern meters are "fuse and diode protected" this is to prevent fireworks, but will not usually save the meter from an overload of this magnitude.

Measuring DC voltage

Measuring voltage is the exact opposite to measuring current: the meter is placed in PARALLEL with the circuit or component being measured and you measure the potential difference (voltage) between the two points. Once again, the test leads must be in the right meter sockets, polarity must be observed, and you should start with the highest range and work down.

Measuring AC voltage

This is the same as measuring DC voltages, just follow the same steps and remember that the meter must be placed in PARALLEL with the circuit or component being measured. A word of explanation about what the meter actually reads... During one cycle an AC wave starts at zero, rises to a peak, falls back to zero, and then does the same thing in the other direction.

The majority of meters indicate what is called the 'RMS' value of the voltage. This value (which stands for Root Mean Square) is a special kind of average, taking into account the fact that the voltage is always changing. The 'RMS' voltage has exactly the same 'work value' as a DC voltage of the same magnitude. In other words, if you supplied an electric heater with 240 volts RMS, and then 240 volts DC, in both cases the heater would give out the same heat. Multimeters fall into two classes when it comes to measuring AC voltage. Most meters can only indicate the correct 'RMS' voltage when the AC signal is a sine wave. More expensive meters can indicate the 'RMS' value for a variety of wave shapes; these meters are called 'true RMS' meters. Fortunately, the majority of AC voltages that you will want to measure are in the form of a sine wave, so your meter will indicate the correct value.

Points to remember

1. Meter in Series for Current
2. Meter in Parallel for Voltage
3. Start on the highest range and work down for Voltage and Current
4. Isolate component when measuring resistance
5. Take care of your meter

Range: instruments – d.c ammeter, d.c voltmeter, ohmmeter, multimeter;
Applications – use of series and parallel shunts, battery, potentiometer, diode, selector switch.

1.3 Digital instruments are described in terms of their principles of operation and their applications.

Range: instruments – multimeter, clip-on ammeter, insulation tester;
Applications – a.c and d.c voltage and current, resistance, insulation, continuity, diode testing; other specialised functions.

1.4 Instruments are identified from physical or pictorial displays, and a sketch provided showing how each would be connected to perform a measurement.

Range: voltmeter, ammeter, ohmmeter, multimeter, clip-on ammeter, insulation tester. Instruments may be analogue or digital.

1.5 Consequences of incorrect use of test instruments are stated.

Range: incorrect uses include – polarity reversed, use of wrong instrument, incorrect connection to the circuit, incorrect range or function selection, open circuit fuse in fused lead, broken test lead, open circuit test lead.

Element 2. *Take electrical measurements.*

2.1 Instrument is selected to match the type of measurement in terms of range and class of instrument.

2.2 Instrument is visually inspected for safety prior to testing according to industry practice.

2.3 The prove-test-prove method is demonstrated according to industry practice.

2.4 Measurements are taken following industry practice and safety procedures.

2.5 The approximate tolerance for each measurement is stated, according to industry practice.

Student Assessment.

Note: This part of the assessment is open book and 100% is the required result.

Name: ___________________________________

Course: ___________________________________

Date: ____________________________________

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