DC ELECTRICAL FUNDAMENTALS TRIAL MID-SEMESTER TEST

- This test is **closed** book, calculator permitted.
- Time permitted 1½ hours.
- Answer questions in the spaces provided.
- **60 MARKS TOTAL (70% pass)**
- Clearly label all currents, resistors and voltage drops in the circuits and state any assumptions in order to obtain a full mark
- When calculating values, show clearly all steps, starting with the formula, then substituting with numbers and finally show the measuring units of the obtained result. Otherwise **NO MARKS** are given

Q1) What does the ohmmeter measure? **[1 mark]**

Ans: Resistance

Q2) What does the voltmeter measure? **[1 mark]**

Ans: E.m.f (or voltage)

Q3) What does the ammeter measure? **[1 mark]**

Ans: Electrical current

Q4) Define the term 'resistor'. **[1 mark]**

Ans: The resistor is an electronic device, which is deliberately built to oppose the electrical current with a predefined amount of electrical resistance.

Q5) Define the term 'battery'. **[1 mark]**

Ans: The battery is an electronic component, which produces an e.m.f. as a result of an internal chemical reaction.

Q6) How a voltmeter always should be connected? (circle the correct answer) **[1 marks]**

a. **in parallel**
b. in series
c. doesn't matter

Q7) How an ammeter always should be connected? (circle the correct answer) **[1 mark]**

a. in parallel
b. **in series**
c. doesn't matter

Q8) How can twenty million Ohms be expressed in MΩ? **[1 mark]**

Ans: 20 MΩ

Q9) How many μA is 0.0000123 A? **[1 mark]**

Ans: 12.3 μA

Q10) What is 'electrical current'? **[1 mark]**

Ans: It is the rate of flow of electrons through a certain point.

Q11) What is 'voltage'? **[2 marks]**

Ans: It is the potential difference between two points.

Q12) What does the abbreviation 'e.m.f'. mean? What is the difference between 'e.m.f.' and 'voltage'?

[2 marks]

Ans: E.m.f. stands for electro-motive force and it is the engineering term for voltage. E.m.f is the voltage across a battery without a load. E.m.f. is the voltage provided by an ideal battery (i.e. if the internal resistance of the battery is zero)

Q13) Define the process of 'measurement'. **[1 mark]**

Ans: Measurement is the process of comparison between two quantities – one of which has a predefined value and the other is unknown.

Q14) What does 'a base unit of measurement' mean? **[1 mark]**

Ans: In order to measure anything, certain physical parameters with pre-defined quantities have to be accepted as **base units.** The international system SI specifies seven base units.

Q15) List the base units in the system SI. **[3 marks]**

Ans:
1. Meter [m] for length
2. Kilogram [kg] for mass
3. Second [s] for time
4. Ampere [A] for electric current
5. Kelvin [K] for temperature
6. Candela [cd] for luminous intensity
7. Mole [mol] for amount of substance

Q16) What does a 'derivative unit of measurement' mean? **[1 mark]**

Ans: These are units of measurements that are obtained from the base units. For example km/h is obtained from meter and second, which are both base units.

Q17) What are the main advantages of the system SI? **[2 marks]**

Ans: 1. All measurement units are decimal (i.e. based on the number 10 and not on 12)
2. There is a very quick conversion for very large or very small quantities using a convenient system of Greek prefixes.
3. Simplicity.
4. It is based on seven base units only

Q18) What does 'scientific notation' mean? **[1 mark]**

Ans: In scientific notation, a quantity is expressed as a product of a number between 1 and 9 and power of ten.

Q19) What does 'engineering notation' mean? **[1 mark]**

Ans: In engineering notation, a quantity is expressed as a product of a number between 1 and 999 and power of ten, with an exponent that is multiple of 3 (or zero).

Q20) Why are scientific and engineering notations being used? **[1 mark]**

Ans: They are useful to represent either very large or very small numbers.

Q21) Which of the two notations is more useful in electro technology? **[1 mark]**

Ans: Probably the engineering notation, as it offers a quick conversion to the relevant Greek prefixes (mili, micro etc).

Q22) Express these numbers in a scientific notation **[4 marks]**

200 $= 2 \times 10^2$
5000 $= 5 \times 10^3$
0.000063 $= 6.3 \times 10^{-5}$
0.00000015 $= 1.5 \times 10^{-7}$

Q23) Express these numbers in an engineering notation **[4 marks]**

300 $= 300$
7000 $= 7 \times 10^3$
0.000047 $= 47 \times 10^{-6}$
0.00000058 $= 580 \times 10^{-9}$

Q24) Perform the following operations, using powers of ten **[4 marks]**

$(2 \times 10^2) + (5 \times 10^3) = (0.2 \times 10^3) + (5 \times 10^3) = 5.2 \times 10^3$
$(10 \times 10^{-2}) - (3 \times 10^{-3}) = (100 \times 10^{-3}) - (3 \times 10^{-3}) = 97 \times 10^{-3}$
$(5 \times 10^5) \times (4 \times 10^7) = 20 \times 10^{12}$
$(25 \times 10^4) \div (5 \times 10^{-3}) = 5 \times 10^7$

Q25) Express each quantity using a metric prefix **[4 marks]**

50 000 V = 50 kV
25 000 000 Ω = 25 M Ω
0.000036 A = 36 μA
0.000000000047 F = 47 pF

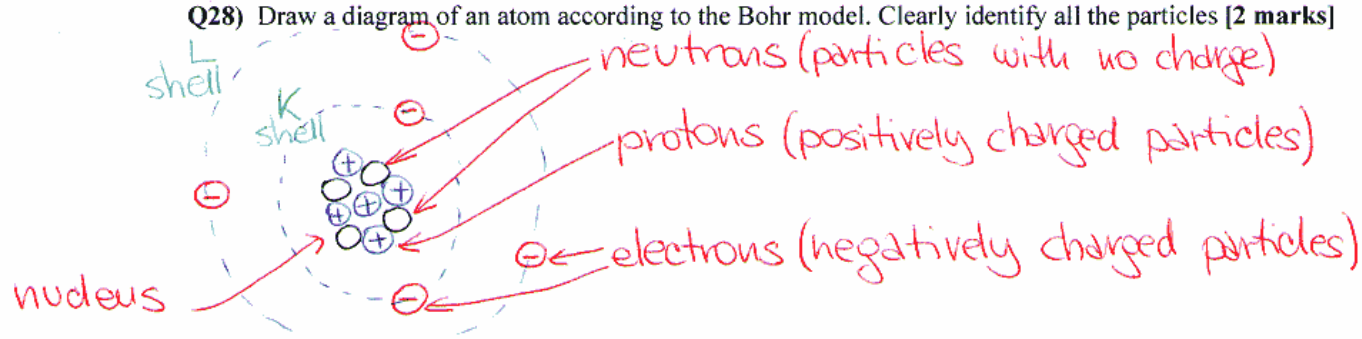
Q26) Add these quantities **[4 marks]**

200 Ω + 2 k Ω = 200 Ω + 2000 Ω = 2200 Ω = 2.2 k Ω
50 kV + 5 MV = 50 kV + 5000 kV = 5050 kV = 5.05 MV
630 μA + 10 mA = 0.63 mA + 10 mA = 10.63 mA
1500 pF + 120 nF = 1.5 nF + 120 nF = 121.5 nF

Q27) What is an atom? **[1 mark]**

Ans: An atom is the smallest particle of an element, which retains the characteristics of that element.

Q28) Draw a diagram of an atom according to the Bohr model. Clearly identify all the particles **[2 marks]**



Q29) What does the term 'atomic number' mean? **[1 mark]**

Ans: The atomic number equals the numbers of the protons in the nucleus.

Q30) What is an 'electron shell'? **[1 mark]**

Ans: Electrons orbit the nucleus at precisely defined energy bands, called shells.

Q31) Is it true that electrons at the L shell posses more energy than the ones in the K shell? **[1 mark]**

Ans: It is true, because the further away electrons are from the nucleus, the more energy they possess.

Q32) What are 'valence electrons'? **[1 mark]**

Ans: The outermost shell in an atom is known as a valence shell and the electrons occupying it are called valence electrons.

Q33) Define 'conductors'. **[1 marks]**

Ans: These are materials that readily allow the flow of electrical current. Their valence number is 1, 2 or 3.

Q34) Define 'insulators'. **[1 marks]**

Ans: These are materials that greatly oppose the flow of electrical current. Their valence number is 5 or more.

Q35) Define 'semiconductors'. **[1 marks]**

Ans: These are materials, which electrical properties are in the middle between those of conductors and insulators. Their valence number is always 4. Typically silicon, silicon oxide and germanium are used.

Q36) How many Coulombs does the number 123.1×10^{17} represent? **[2 marks]**

Ans: $Q = \frac{\text{number of electrons}}{6.25 \times 10^{18} \text{ electrons/C}} =$

$= \frac{123.1 \times 10^{17}}{6.25 \times 10^{18}} = 19.696 \times 10^{-1} C = 1.9696 C \approx 2C$

Q37) The voltage in a circuit is 10 V. The el. charge is 500 mC. What is the energy? **[2 marks]**

Ans: $V = \frac{W}{Q}$

$W = V \times Q = 10 \times 0.5 = 5 J$

Q38) What two *general* types of batteries do you know? **[1 marks]**

Ans: Primary cells – cannot be recharged and secondary cells, which can be recharged.

Q39) What types of primary cells do you know? **[1 marks]**

Ans: carbon-zinc, alkaline, mercury.

Q40) What types of secondary cells do you know? **[1 marks]**

Ans: Lead-acid, nickel-cadmium, nickel-metal-hydride and lithium-ion batteries.

Q41) What are the advantages of the lead-acid batteries? **[1 marks]**

Ans: They can deliver very large amounts of current at the initial moment.

Q42) What are the advantages of the lithium-ion batteries? **[1 marks]**

Ans: They are the most powerful secondary cell batteries and do not suffer from memory effect.

Q43) How long time it takes to transfer 2 C of el. charge with an el. current of 200 μA? **[2 marks]**

Ans: $I = \frac{Q}{t}$

$t = \frac{Q}{I} = \frac{2}{200 \times 10^{-6}} = \frac{2}{2 \times 10^{-4}} = 1 \times 10^{4}\,s = 10,000\,s = 166.66\,min =$
$= 2.77\,h = 2h\,46.66\,min = 2h\,46'\,40''$

Q44) What is 'memory effect'? **[1 marks]**

Ans: When a battery is cyclically charged and recharged only to a portion of its full capacity, it will "forget" its full capacity rating. Subsequently, it will begin to operate on a lower capacity threshold, determined by the latest few charges and discharges only.

Q45) What is the difference between a potentiometer and a rheostat? **[1 marks]**

Ans: A potentiometer is a three terminal variable resistor. It is mainly used as a voltage divider. A rheostat is a two terminal variable resistor. It is mostly used as a current limiting device.

Q46) What is the resistance value and the tolerance of a resistor marked with red, violet, orange, gold? **[1 marks]**

Ans: 2 7 x 10^3 Ω +/- 5 % = 27 k Ω +/- 5%

Q47) Calculate the upper and the lower limit for the resistor value given above **[3 marks]**

1. 5% of 27,000 Ω is $\frac{5 \times 27\,000}{100} = 1.35\,k\Omega$
2. Upper limit = 27 kΩ + 1.35 kΩ = 28.35 kΩ
3. Lower limit = 27 kΩ − 1.35 kΩ = 25.65 kΩ

Q48) What are the main advantages of electronic switches as opposed to mechanical? **[1 marks]**

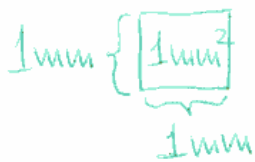
Ans: The output can be automated and the achieved frequency of switching can be extremely high.

Q49) What is the difference between a fuse and a circuit breaker? **[1 marks]**

Ans: A fuse is a disposable component. After it "blows", it has to be replaced, whereas the circuit breaker can be reset and used many times. The disadvantages of the circuit breaker are its size, complexity and cost.

Q50) Find the resistance of a 100 m copper wire, with a cross-sectional area of 1 mm^2. The resistivity of copper is ρ (Cu) = 1.75×10^{-8} Ωm. **[3 marks]**

First, convert the cross-sectional area from mm^2 to m^2. Look at the drawing:



$1\,mm = 1 \times 10^{-3}\,m$ ∴

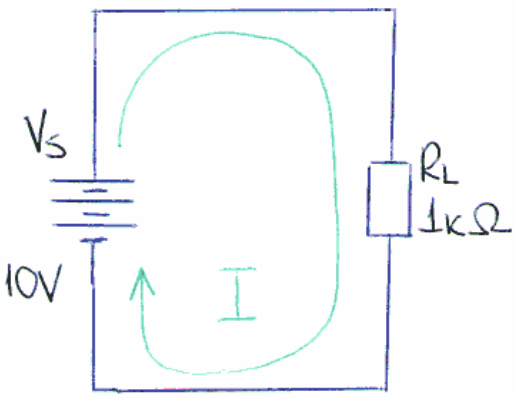
$A = 1\,mm \times 1\,mm = 1 \times 10^{-3} \times 1 \times 10^{-3} =$

$= 1 \times 10^{-6}\,m^2$ →

$$R = \rho \frac{l}{A} = 1.75 \times 10^{-8} \frac{100}{1 \times 10^{-6}} = 1.75 \times 10^{2} =$$

$= 1.75\,\Omega$ →

Q51) In the circuit below calculate the value of the current. **[3 marks]**



Note: Clearly label all circuit components and currents, before commencing calculations!

$$I = \frac{V_S}{R_L} = \frac{10}{1 \times 10^3} = 10 \times 10^{-3}\,A = 10\,mA$$ →

Q52) For the circuit in the previous question Q12 what resistor power values you would use? **[3 marks]**

$$P_{RL} = \frac{V_S^2}{R_L} = \frac{10^2}{1000} = \frac{100}{1000} = 0.1\,W \quad [1/4\,W]$$

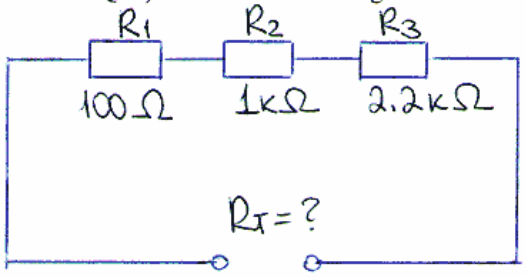
$P_{RL} = I^2 R = (0.01)^2 \times 1000 = 0.1\,W$ [1/4 W] } double checking

$P_{RL} = I \times V = (0.01) \times 10 = 0.1\,W$ [1/4 W] }

Q53) What is the cost of the consumed electrical energy, if a heater with a power rating of 2500 W is switched on for 10 hours? Use the domestic supply tariff for Western Australia, which in July 2012 was 24.8866 cents/kWh. Disregard the daily supply charges.

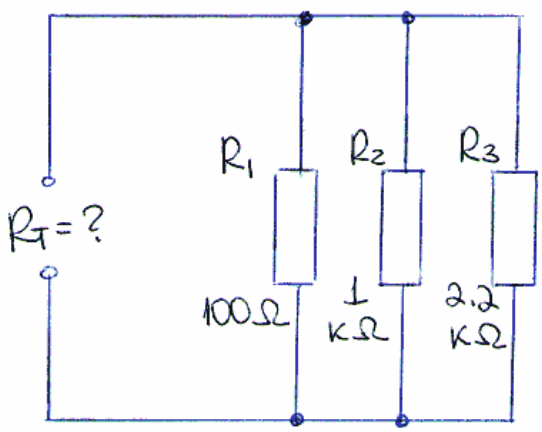
Ans: Power consumption = power rating x time = 2.5 kW x 10 h = 25 kWh
Cost = power consumption x price = 25 kWh x \$0.248866 = AU \$ 6.22

Q54) Given the following circuit calculate the total resistance. **[3 marks]**



$R_T = R_1 + R_2 + R_3 =$
$= 100 + 1000 + 2200 =$
$= 3300\ \Omega = 3.3\ k\Omega$

Q55) Given the following circuit calculate the total resistance. **[3 marks]**



$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} =$
$= \frac{1}{100} + \frac{1}{1000} + \frac{1}{2200}$

$R_T = 87.3\ \Omega$

Q56) Calculate the power rating of the resistors from Q55 above assuming a power supply of 10V. **[3 marks]**

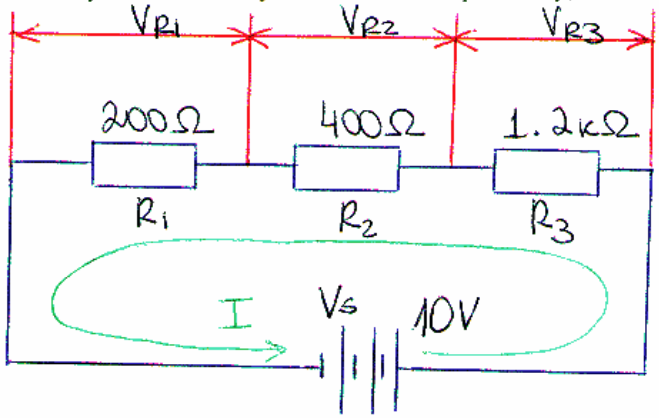
$P_{R1} = \frac{V_S^2}{R_1} = \frac{10^2}{100} = \frac{100}{100} = 1W$ [1W]

$P_{R2} = \frac{V_S^2}{R_2} = \frac{10^2}{1000} = \frac{100}{1000} = 0.1W$ [1/4W]

$P_{R3} = \frac{V_S^2}{R_3} = \frac{10^2}{2200} = \frac{100}{2200} = 0.045W$ [1/8W]

resistors nominal power ratings

Q57) Calculate the following circuit using three different methods of calculation. By achieving the same result three times you can be certain in its correctness. Also, in such a way you demonstrate that you can correct your mistakes independently, without the need of a tutor. **[6 marks]**



Method 1:

$R_T = R_1 + R_2 + R_3 =$
$= 200 + 400 + 1200 =$
$= 1800 = 1.8\,k\Omega$

$I = \frac{V_S}{R_T} = \frac{10}{1800} = 5.55\,mA$

$V_{R1} = I \times R_1 = 5.55 \times 10^{-3} \times 200 =$
$= 1.11V$

$V_{R2} = I \times R_2 = 5.55 \times 10^{-3} \times 400 =$
$= 2.22V$

$V_{R3} = I \times R_3 = 5.55 \times 10^{-3} \times 1200 =$
$= 6.66V$

Method 2:

$V_S = V_{R1} + V_{R2} + V_{R3} =$
$= 1.11 + 2.22 + 6.66 =$
$= 9.99V$

The sum of the three voltage drops should equal V_S.

Method 3:

Solving a system of three equations with three variables (V_{R1}, V_{R2} and V_{R3})

$V_{R2} = 2V_{R1}$
$V_{R3} = 6V_{R1}$
$V_{R1} + V_{R2} + V_{R3} = 10$

The "ratios" method
The ratios of the voltage drops is exactly the same as the ratios of the corresponding resistors.

$V_{R1} + 2V_{R1} + 6V_{R1} = 10$
$9V_{R1} = 10$
$V_{R1} = \frac{10}{9} = 1.11V$
$V_{R2} = 2V_{R1} = 2 \times 1.11 = 2.22V$
$V_{R3} = 6V_{R1} = 6 \times 1.11 = 6.66V$

Q58) The input power of a machine is 150 W. The efficiency of the machine is 75 %. What is the output power? **[2 marks]**

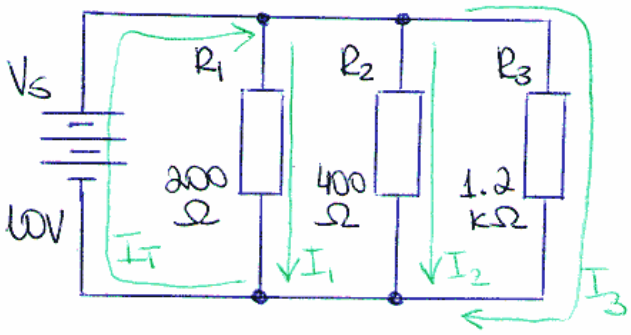
Efficiency is often labelled with the Greek letter "eta" η.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\ [\%]$$

$$P_{out} = \frac{P_{in} \times \eta}{100} = \frac{150 \times 75}{100} = 112.5W$$

The output power is always less than the input power, because of the losses.

Q59) Calculate the following circuit using three different methods of calculation. By achieving the same result three times you can be certain in its correctness. Also in such a way you demonstrate that you can correct your mistakes independently, without the need of a tutor. **[6 marks]**



Method 1:

$I_1 = \frac{V_S}{R_1} = \frac{10}{200} = 0.05A = 50mA$

$I_2 = \frac{V_S}{R_2} = \frac{10}{400} = 0.025A = 25mA$

$I_3 = \frac{V_S}{R_3} = \frac{10}{1200} = 0.00833A = 8.33mA$

$I_T = I_1 + I_2 + I_3 =$

$= 50 + 25 + 8.33 = 83.33mA$

Method 2:

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} =$

$= \frac{1}{200} + \frac{1}{400} + \frac{1}{1200}$

$R_T = 120\Omega$

$I_T = \frac{V_S}{R_T} = \frac{10}{120} = 83.33mA$

By finding the total resistance and applying Ohm's law, we obtain the same result for the total current, as with the first method.

Method 3:

System with three equations and three variables (I_1, I_2, I_3)

$I_2 = \frac{I_1}{2}$

$I_3 = \frac{I_1}{6}$

$I_1 + I_2 + I_3 = 83.33$

The sum of the three branch currents must equal this number, because we already checked this twice with Method 1 and 2.

The total current here is given in mA, which means that the final answers for I_1, I_2 and I_3 will be also obtained in mA

$I_1 + \frac{I_1}{2} + \frac{I_1}{6} = 83.33$

$6I_1 + 3I_1 + I_1 = 6 \times 83.33$

$10I_1 = 500$

$I_1 = \frac{500}{10} = 50mA$

$I_2 = I_1 \div 2 = 50/2 = 25mA$

$I_3 = I_1 \div 6 = 50/6 = 8.33mA$

Note: Only 1/3 of the questions solved here will be given to you on the actual test!

END OF TEST
(Check your work!)

The ratios of branch currents is inversley proportional to the ratios of the corresponding resistors.