

Name: .....

Student Number:.....

**Instructions – please read****Time = 120 minutes****Total = 80 marks****Attempt all questions. All questions are worth equal marks and you should spend approximately 15 minutes on each question.****You can bring one A4 sized sheet with your own notes on both sides with you into the test.**

Write and/or sketch your answers in the open spaces provided on this test sheet. Show the details of your workings where appropriate – do not just show the final answer. A blank sheet is provide at the back if you should need more space. Ensure that all answer sheets are handed in.

The values of some selected constants are provided on page 2 and the test starts on page 3.

Question	Marks	Obtained
1	10	
2	10	
3	10	
4	10	
5	10	
6	10	
7	10	
8	10	
Maximum marks	80	

### Selected physical constants

Electron charge	q	$1.9 \times 10^{-19} \text{ C}$
Atomic mass unit	amu	$1.66 \times 10^{-27} \text{ kg}$
Avogadro's number	$N_A$	$6.02 \times 10^{23} \text{ mol}^{-1}$
Boltzmann constant	k or $k_B$	$1.38 \times 10^{-23} \text{ J.K}^{-1} = 8.62 \times 10^{-5} \text{ eV.K}^{-1}$
Electron charge	e	$1.6 \times 10^{-19} \text{ C}$
Permeability of vacuum	$\mu_0$	$4\pi \times 10^{-7} \text{ H.m}^{-1}$
Permittivity of vacuum	$\epsilon_0$	$8.85 \times 10^{-12} \text{ F.m}^{-1}$
Plank's constant	h	$6.626 \times 10^{-34} \text{ J.s} = 4.136 \times 10^{-15} \text{ eV.s}$
Speed of light	c	$2.99 \times 10^8 \text{ m.s}^{-1}$

**Question 1.**

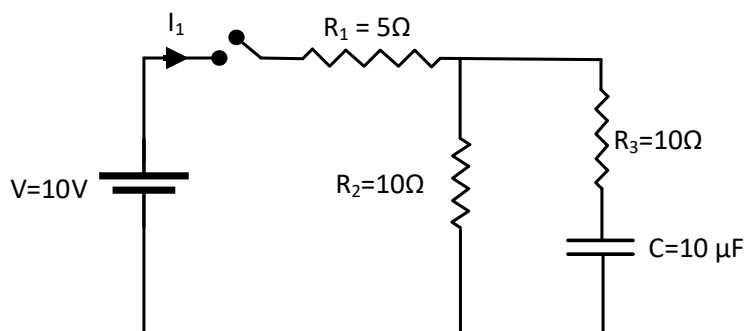
**[10]**

Select the answer that best matches each statement or question by placing an X in the appropriate :

**(a)** The electrical resistance in a conductor is:

- Directly proportional to the conductivity of the material
- Directly proportional to the length of the conductor
- Directly proportional to the cross-sectional area of the conductor
- Constant with temperature

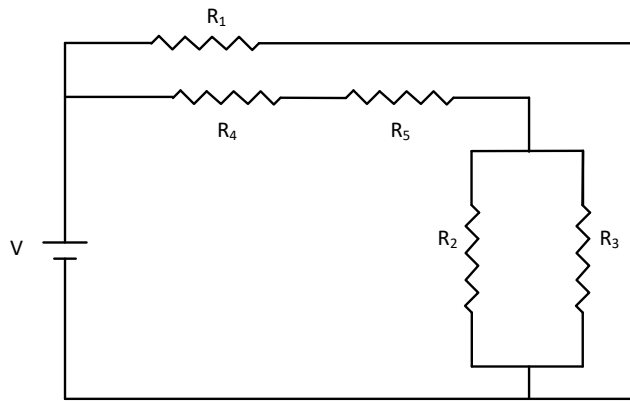
**(b)** In the circuit below the capacitor is initially discharged before the switch closes.



The current  $I_1$  at time  $t=0$  (immediately after the switch closes) is:

- Infinitely high
- 0 A
- 1 A
- 0.67 A

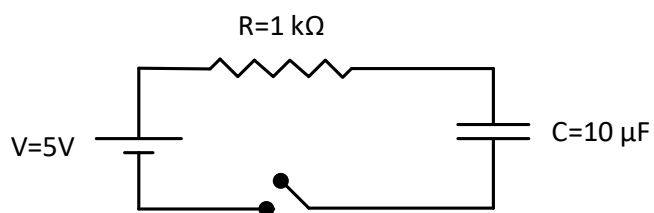
(c) Consider the circuit below, where  $R_1 < R_2 < R_3 < R_4 < R_5$ :



The total resistance of the circuit,  $R_T$ , will be:

- $R_T < R_1$
- $R_T > R_5$
- $R_2 < R_T < R_3$
- Impossible to say without actual resistor values.

(d) For the circuit below, what would be the approximate time between the closure of the switch and when the capacitor can be considered fully charged.

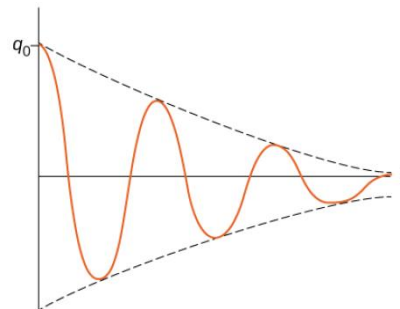
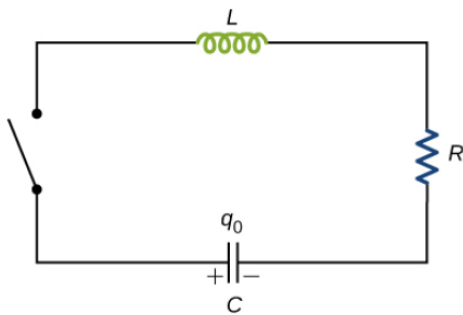


- 10 ms
- 30 ms
- 50 ms
- 100 ms

(e) An AC voltmeter measures across the terminals of an AC generator that outputs a frequency of 45 Hz and measures a voltage of 7.07 V. The expression that describes the output of the generator is:

- $v(t) = 7.07\sin(45t)$
- $v(t) = 10\sin(45t)$
- $v(t) = 7.07\sin(283t)$
- $v(t) = 10\sin(283t)$

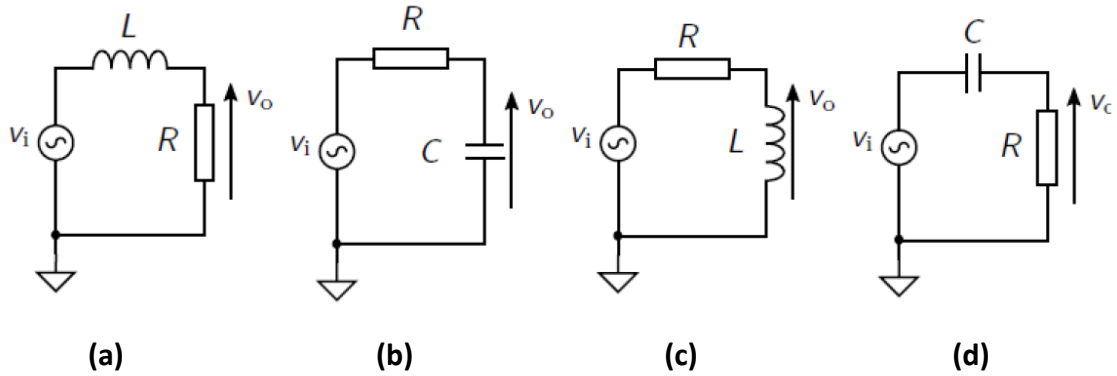
(f) In the RCL circuit below the capacitor is charged before the switch is closed. The charge over the capacitor is then observed with time and the plot shown below is obtained.



From this behaviour of charge over the capacitor, what would be the approximate relationship between R, L and C

- $R = 0$  with no influence from L and C
- $R \ll 2\sqrt{L/C}$
- $R = 2\sqrt{L/C}$
- $R \gg 2\sqrt{L/C}$

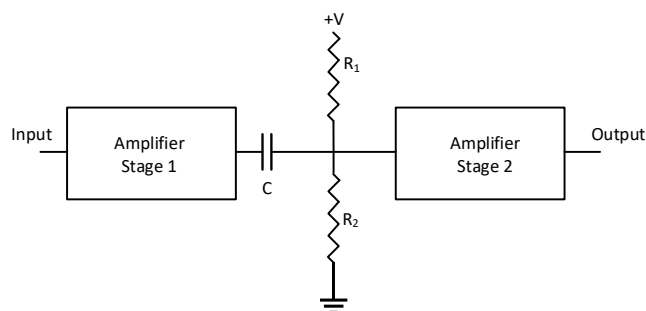
(g) The circuits for four first order filters are shown below, with  $v_o$  indicating in each instance where the output signal is measured.



Which of the above circuits act as a high pass filter ?

- (a) and (b)
- (a) and (c)
- (b) and (c)
- (c) and (d)

(h) Consider the capacitor in the circuit below.



The main function of this capacitor is:

- To block AC and pass only DC to the next amplifier stage
- To block DC and pass only AC to the next amplifier stage
- To delay any signal between the two amplifier stages by one time constant
- To totally electrically disconnect the two circuits.

**Question 2:**

**[10]**

**(a)** Consider a length of electrically conducting wire with a cross sectional area  $A$ . The conductor contains a density of charge carriers  $n$  (carriers/unit volume) and these charge carriers move with an average drift velocity  $v_D$  when an electric field is applied.

Use the definition of electric current to derive an equation relating the electric current to the density of charge carriers, the cross-sectional area and the average drift velocity.

(5)

**(b)** A cylindrical electrical conducting wire has a length of 15 cm and a diameter of 2 mm. It is given that the conducting material has a resistivity of  $8 \times 10^{-8} \Omega \cdot \text{m}$ .

(i) Calculate the resistance of this wire. (2)

(ii) Calculate the amount of charge that will flow through the wire in 10 seconds if a voltage of 1 V is applied over the ends of the wire. (3)



**Question 3**

**[10]**

(a) (i) Calculate the capacitance of two rectangular conducting plates, each with dimensions 10 x 10 cm and with a separation distance of 5 mm between the plates. (2)

(ii) A piece a 5 mm thick Teflon with a dielectric constant of 2.1 is inserted between the plates in (i). Calculate the new value of the capacitance. (1)

(iii) Explain with the aid of a sketch why the observed value of the capacitance will change when a dielectric is inserted between the plates. (2)

**(b) (i)** Calculate the inductance of a helical air-filled coil with a length of 20 cm, a cross sectional area of  $30 \text{ mm}^2$  and consisting of 400 turns of wire. (3)

(ii) What would be the energy stored in this coil if a current of 5 A is passing through it ? (2)

**Question 4**

**[10]**

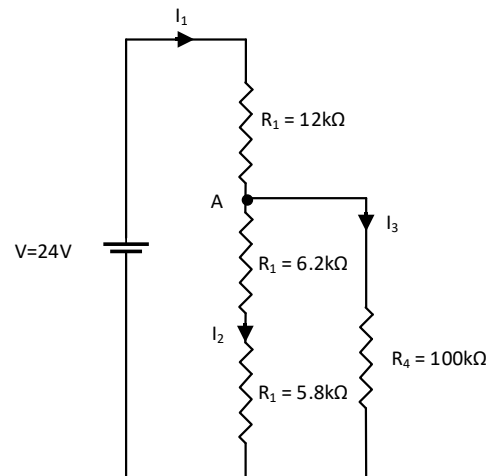
For the circuit on right calculate:

(i) The total resistance (2)

(ii) The currents  $I_1$ ,  $I_2$  and  $I_3$  (3)

(iii) The voltage at point A (2)

(iv) When constructing the circuit, a resistor with value  $100\ \Omega$  is accidentally used for  $R_4$ . Explain qualitatively what will be the result on the circuit performance, particularly with reference to the previously calculated values of  $V_A$  and  $I_3$ . (3)





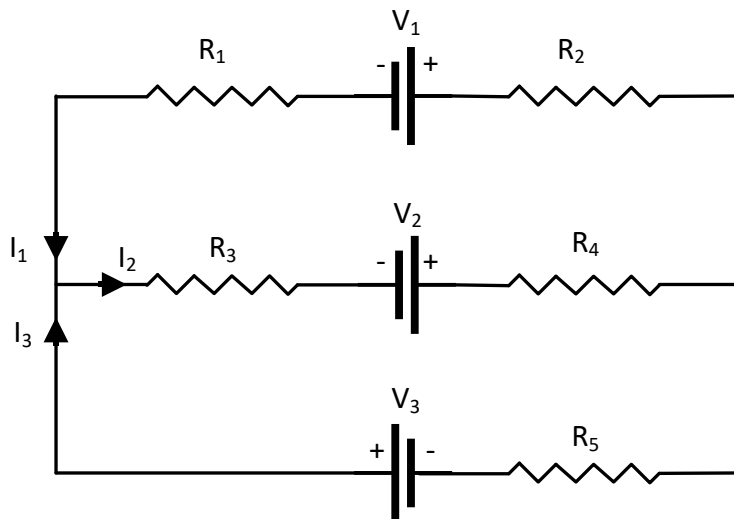
**Question 5**

**[10]**

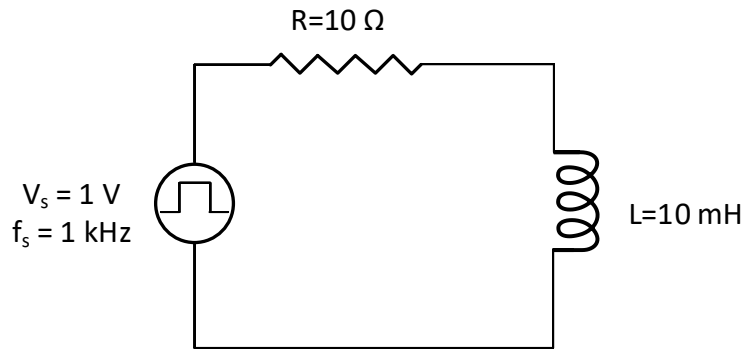
(a) (i) State Kirchoff's two rules in words.

(2)

(ii) Use these rules to write a set of equations for the circuit below that can be used to calculate the magnitudes and directions of the resultant currents. (3)



**(b)** In the circuit below, the signal generator outputs a square wave  $V_s$  of 0 to 1 V with a frequency of 1 kHz.



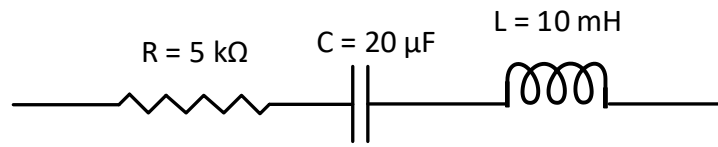
- (i) Sketch a graph of the input waveform  $V_s$  with time for one complete cycle. (1)
- (ii) What is the time constant of the circuit? (1)
- (iii) Sketch a graph of the current in the circuit with time for one complete input cycle. (2)
- (iv) Calculate the maximum value of the current in the circuit. (1)

**Question 6**

**[10]**

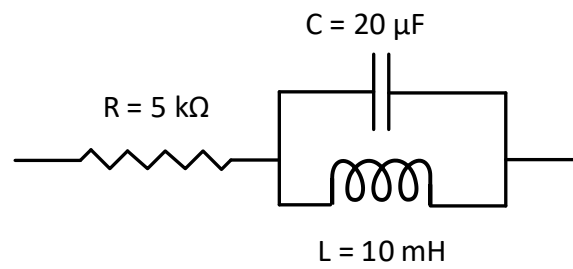
Calculate the impedance at 5 kHz for each of the circuits below. Show your result in both rectangular and polar form and plot the resultant impedance value on the complex plane.

(i)



(5)

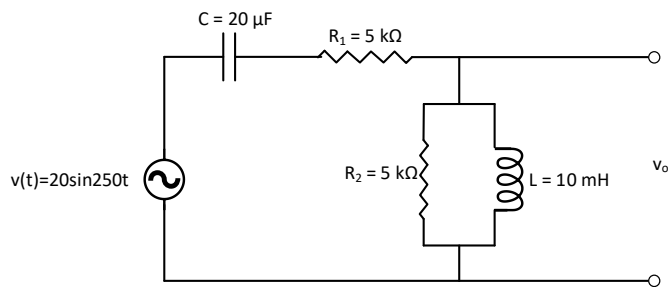
(ii)



(5)

### Question 7

In the circuit below, calculate the output voltage  $v_o$  if  $C = 20\mu\text{F}$ ,  $R_1 = 5\text{k}\Omega$ ,  $L = 10\text{ mH}$ ,  $R_2 = 5\text{k}\Omega$  and the input voltage  $v(t) = 20\sin(250t)$ . (10)



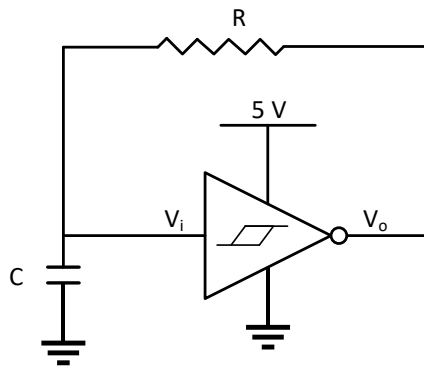


**Question 8**

**[10]**

**(a)** Design a first order high pass filter that has a corner frequency of 10 kHz. Base your design on a resistor of 1 k $\Omega$  and determine the appropriate value(s) for the other component(s). Sketch your circuit and clearly show the input and output of your filter. (5)

**(b)** The circuit below shows a Schmitt trigger inverter connected to an external resistor and capacitor.



- (i) What do we call this type of circuit and what would be a typical application? (2)
- (ii) Sketch both the expected voltage at the input ( $V_i$ ) and the voltage at the output ( $V_o$ ) with time. Clearly show the timing relationship between these two signals. (3)

\*\*\*\*\*End of Test\*\*\*\*\*



