UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN ENGINEERING
SECOND SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF COMPUTER ENGINEERING
CPEN 206: LINEAR CIRCUITS (3 Credits)

INSTRUCTION: *Answer any five (5) Questions of your choice.*

TIME ALLOWED: *THREE (3) HOURS*

1. **(a)** What do you understand by the term "linear circuit"? Give two (2) reasons why it is important to study linear circuit and four (4) areas of application of linear circuits. [7 marks]

   (b) The current flowing through the positive terminal of a TV set is given as $I(t) = 15e^{-4t}$ and the voltage across the device is $V(t) = 20dI/dt$. Find the power absorbed by the TV and calculate the energy consumed by the TV in 20 seconds. [9 marks]

   (c) Find the resistance of a 1m length of copper wire with rectangular cross section area of 2.5cm by 0.05cm. Assume that $\rho = 1.724 \times 10^{-8}$ ohm-meter. [4 marks]

2. **(a)** Explain the difference between an *ideal independent* voltage source and an *ideal dependent* voltage source. Give one example each of an independent current source and an independent voltage source. [4 marks]

   (b) A 12V source supplies a 3Ω resistor that is connected to a parallel combination of 8Ω resistor and 4Ω resistor. The 4Ω resistor is in turn connected to a parallel combination of a 7Ω resistor and a 5Ω resistor. The 5Ω resistor is connected to a 9V power supply. Sketch the circuit diagram and find the branch currents in the circuit using node analysis method. [9 marks]

   (c) The characteristics of a voltage signal in a telephone wire is given as follows: $v(t) = 0$ at $t = 0$, $v(t) = 20\mu V$ at $t = 20ms$, $v(t) = 0$ at $t = 30ms$, $v(t) = -20\mu V$ at $t = 40ms$, and $v(t) = 0$ at $t = 50ms$. Sketch the voltage signal and derive an expression

for the voltage signal in the wire. [7 marks]

3. **(a)** Explain the difference between *Thevenin theorem* and *Norton theorem*. Use simple circuit diagrams to support your answer. [4 marks]

(b) A 2V source supplies a 2Ω resistor that is connected to a parallel combination of 12Ω resistor and 1Ω resistor. The 1Ω resistor is in turn connected to the parallel combination of a 5Ω resistor and a 3Ω resistor. The 3Ω resistor is supplied by a 4V voltage supply.

(i) Sketch the circuit diagram and find the Thevenin equivalent voltage V_{TH} and Thevenin equivalent resistance R_{TH} of the circuit. [10 marks]

(ii) Find the current in the 5Ω resistor. [2 marks]

(iii) What is the condition under which maximum power will be transferred to the 5Ω resistor? What is the value of this maximum power? [4 marks]

4. **(a)** Sketch a diagram of the 8-pin operational amplifier and indicate the function of each pin. State four (4) application areas of an operational amplifier. [6 marks]

(b) Sketch the circuit diagram of the differentiator circuit and derive an expression for the output of the circuit at time t = 0. Assume the input voltage to the circuit is $V_{in} = 2\cos 3000\pi t$, R = 100kΩ, and C = 0.02μF. [7 marks]

(c) A triangular input voltage $v(t)$ with the following characteristics is applied to the differentiator circuit in 4 (b) above: $v(t) = 0$ at $t = 0$V, $v(t) = 4$V at $t = 2$ms, $v(t) = 0$V at $t = 4$ms, $v(t) = -4$V at $t = 6$ms, and $v(t) = 0$V at $t = 8$ms. Sketch the input voltage and derive an expression for the input voltage signal. Find the output signal voltage signal from the differentiator and sketch the signal. [7 marks]

5. **(a)** Design an inverting operational amplifier circuit that could be used for the amplification of signals received from a sensor. Your circuit must have an input resistance of 20 kΩ and a gain of 40dB. [7 marks]

(b) A passive filter circuit has a series arrangement of an L, C and R elements. The input voltage to the circuit **Vs** = $20sin(\omega t)$, R = 2 Ω, L = 1mH, and C = 0.4pF. Find resonance frequency in Hz and magnitude of the current at resonance. [6 marks]

(c) A 4-bit DAC circuit has a feedback resistor R_f = 10 kΩ and input resistors R_1 = 10 kΩ, R_2 = 20 kΩ, R_3 = 30 kΩ and R_4 = 40 kΩ. The binary input voltage is [V_1, V_2, V_3, V_4] with V_1 as the MSB and V_4 as the LSB. Sketch the circuit diagram of the DAC and find the analog output for the binary input [0101]. [7 marks]

6. **(a)** Briefly explain the following linear circuit terms: *source-free circuit*, *time constant*, and *natural response of a circuit*. [6 marks]

(b) A 20V source has a series resistor of 3Ω that is in turn connected to a parallel combination of a 20mF capacitor and a 1Ω resistor. The 1Ω resistor is connected to a 20Ω resistive load. If the capacitor voltage at time $t = 0$ is 20V, sketch the circuit diagram and find the voltage across the capacitor and the load at time $t > 0$. Find initial energy ($t = 0$) and final energy ($t > 0$) stored in the capacitor. [9 marks]

(c) With the support of a simple circuit diagram, briefly describe how a first order RC circuit can be applied in camera application. [5 marks]