UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN ENGINEERING
SECOND SEMESTER EXAMINATIONS: 2016/2017

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 four (4) areas of application of linear circuits. [6 marks]
(b) The current at the terminal of a TV set is given as $I(t) = 15e^{-4t}$ and the voltage across the device is $V(t) = 20dI/dt$. Calculate the energy that is consumed by the TV in 20 seconds. [6 marks]
(c) A 20Ω resistor is connected in series with an unknown resistance R and the two are connected across a 220V supply. The power loss in the unknown resistance R is 50W. Draw the circuit diagram and find the value of R. [8 marks]

2. **(a)** State the Kirchhoff's law of voltage and current. With the support of a simple circuit diagram, show how the Kirchhoff's law can be used to divide source voltage among circuit elements. Use the case of only two elements. [6 marks]
(b) Explain the difference between *ideal independent* voltage source and *ideal dependent* current source. Give the circuit symbol representation of a voltage-controlled voltage source and voltage-controlled current source. Give one example of an independent voltage source and a dependent voltage source. [6 marks]
(c) A voltage regulator circuit in a stabilizer device has an input AC voltage of 110V and a Zener diode, which is rated 60V. The circuit has a series limiting resistor of 2 kΩ and a load resistor 6 kΩ. Sketch the circuit and find the following:
(i) open circuit voltage and indicate whether the diode is conducting. [2 marks]

(ii) load current and output voltage across the load. [2 marks]

(iii) voltage drop across the limiting resistor. [2 marks]

(iv) current through the Zener diode. [2 marks]

3. **(a)** State the following circuit theorems and illustrate each using simple diagram: *Superposition theorem, Thevenin's theorem,* and *Norton's theorem.* [6 marks]

(b) A 5V power source provides supply to a 4Ω resistor, which is connected to a parallel combination of 12Ω resistor and 5Ω resistor. The 5Ω resistor is also connected to a parallel combination of a 2Ω and 3Ω resistor. The 3Ω is supplied by a 10V voltage source. Sketch the circuit diagram and find the following:

(i) Thevenin voltage V_{TH} and resistance R_{TH} of the circuit. [6 marks]

(ii) current in the 2Ω load. [2 marks]

(iii) Norton equivalent current I_N and its equivalent circuit. [2 marks]

(iv) condition under which maximum power will be transferred to the 2Ω load and the value of the maximum power. [4 marks]

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

(b) Sketch the circuit diagram of a non-inverting Op-amp circuit and derive an expression for the output of the circuit. [4 marks]

(c) You have been tasked as an engineer working with the Coca-Cola plant to design an inverting amplifier circuit to amplify input signal of 10mV from a sensor circuit that monitors the bottling operation. The amplifier circuit is to drive a load (an alarm) of 2kΩ. To drive the load, the amplifier circuit must have a closed loop gain of 60 dB and an input resistance of 5kΩ. Draw the circuit diagram and find the design parameters of the circuit. Find the input current to the amplifier circuit, the output voltage required to drive the load, and the load current. [10 marks]

5. **(a)** Briefly explain the following linear circuit terms: *first order circuit, source-free circuit, time constant, natural response of a circuit, and forced response.* [5 marks]

(b) Suppose your laptop adaptor (modeled as series RL circuit) is connected to the power socket and is supplied by voltage Vs. Sketch the circuit diagram and derive the differential equation that describes this RL circuit under source free condition. Find the current through the inductor at a time $t > 0$. [6 marks]

(c) A 10V voltage source has a series source resistor of 3Ω that is connected to a switch. The other terminal of the switch is connected to parallel combination of a

9Ω resistor and 4Ω resistor. The 4Ω resistor is in turn connected to a 40mF capacitor. If the switch is closed for a long time ($t < 0$) and is then opened at $t = 0$, sketch the circuit diagram and find the following:

(i) voltage across the capacitor at time $t \geq 0$. [6 marks]

(ii) initial energy ($t = 0$) and final energy ($t > 0$) stored in the capacitor. [4 marks]

6. **(a)** What is resonance in electrical network? Briefly explain how resonant circuit is used in radio transmitters/receivers and in communication systems. [6 marks]

(b) A series RLC resonant circuit in a radio receiver system is supplied by a voltage source V = $10sin(\omega t)$. If $R = 5\Omega$, $L = 4$mH, and $C = 0.1\mu$F, sketch the circuit diagram and find the following:

(i) resonant frequency of the circuit in Hz. [2 marks]

(ii) maximum circuit current at resonance. [2 marks]

(iii) voltage across the inductor and capacitor. [4 marks]

(iv) power P dissipated at $\omega = \omega_0$ and the bandwidth BW. [4 marks]

(v) capacitor value required to tune in to radio Univers at 105.7 MHz. [2 marks]

7. **(a)** Design a first-order active low-pass filter with a cutoff frequency of 2 kHz and a gain of 40dB for implementation in a digital stethoscope. Sketch the circuit diagram and show all calculations for your design. [8 marks]

(b) A triangular input voltage V_{in} (t) with the following characteristics is applied to the input of a differentiator circuit which has resistor $R = 5$ kΩ and $C = 0.2\mu$F.

At $t = 0$, $V_{in}(t) = 0V$, at $t = 2ms$, $V_{in}(t) = 4V$, at $t = 4ms$, $V_{in}(t) = 0V$, at $t = 6$, $V_{in}(t) = 4V$, and at $t = 6ms$, $V_{in}(t) = 0V$.

(i) Sketch the circuit diagram and the input voltage waveform. [4 marks]

(ii) Find the output voltage from the differentiator circuit and sketch the output voltage waveform. [8 marks]

Useful Formulae

1. $\omega_1 = -(R/2L) + [(R/2L)^2 + (1/LC)]^{1/2}$ and $\omega_2 = (R/2L) + [(R/2L)^2 + (1/LC)]^{1/2}$

2. $BW = (\omega_2 - w_1) = (w_0 / Q)$ 3. $\omega_0 = [w_1 * w_2]^{1/2}$

4. $Q = (\omega_0 L / R) = (1/w_0 RC)$