# Trent: PHYS-COIS 2250H – Electronics

Final Examination : Tuesday April 14, 2015

Allowed: 3 hours. Calculator.
Answer <u>Question 1</u> and <u>two</u> out of the remaining <u>three</u> questions.
**Question 1 is worth 50% of the marks, and the others worth 25% each.**

1. (a) From the collector characteristics shown below, determine the approximate value of beta for this transistor. Further, given the resistor values in the circuit, determine the operating point (I_c, V_{ce}) of the transistor and roughly denote its location on a sketch of a graph of the transistor's collector characteristics.
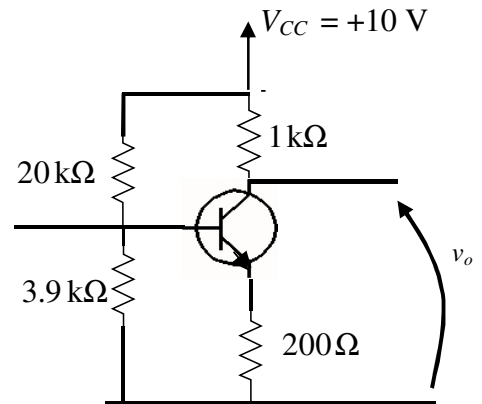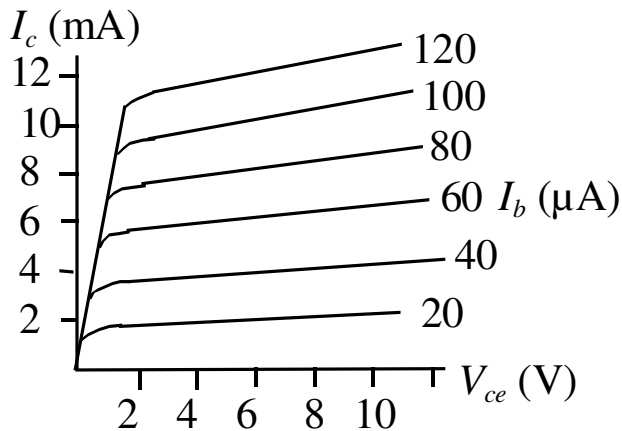

b) In the circuit to the right, if $v_1 = 10\sin \omega t$ volts, $R = 1\,k\Omega$ and $V = 4$ volts, sketch $v_1(t)$ and $v_2(t)$ on plots above/below each other, assuming an ideal diode.
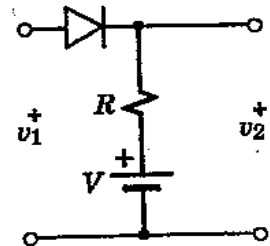

c) Derive and draw the Thevenin equivalent of the circuit below to the left of terminals a - b.
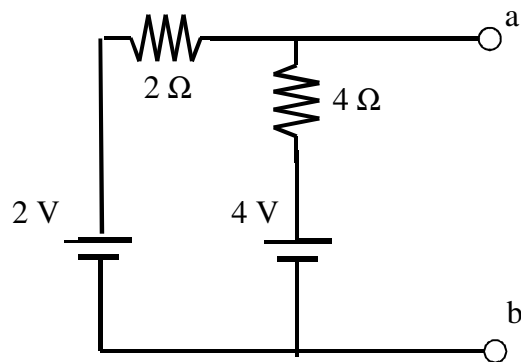
d) Derive using stated approximations the operation of the op-amp circuit shown below, assuming sinusoidal inputs of the same frequency but amplitudes of v_{10} and v_{20}, and **sketch** both these input signals and $v_o(t)$ on plots above/below each other.

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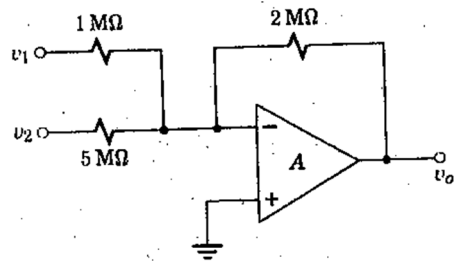
e) If the LR-combination below is connected to an AC voltage source of angular frequency ω, then a current $i(t) = I\cos(\omega t)$ flows.

$$i = I\cos\omega t$$
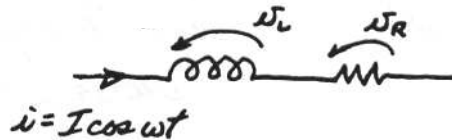
The total voltage $v(t)$ across both components can then be written as $v(t) = V_0\cos(\omega t + \phi)$. Derive an algebraic expression for V_0 and ϕ in terms of R, L and I, ω. If $L = 20\,\text{mH}$ and $R = 50\,\Omega$, determine ϕ for a frequency of $f = 1\,\text{kHz}$.

2. a) Complete the truth table for the circuit shown on the right and provide a Boolean expression for this circuit:
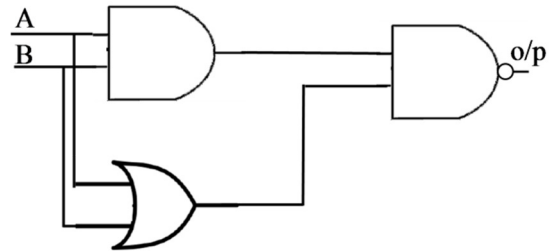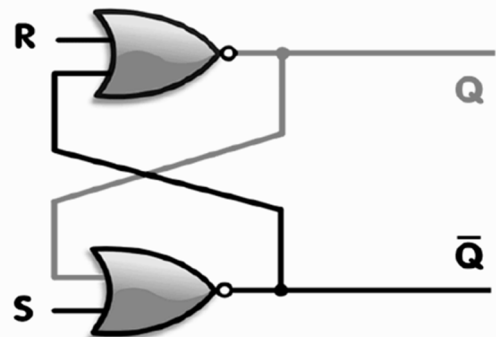

b) The QBASIC command OUT M,N sends the decimal number M to address N. The PC lab interface card contains a 12-bit DAC that produces a DC output voltage between 0 and 5 V, with the lowest 8 bits sent to address 548, and the upper four bits sent to address 549, which also starts the conversion.
i) What is the smallest voltage step which the DAC can output?
ii) What QBASIC commands are required to output a voltage of 2.6 V?

c) Complete the following table for the *RS flip-flop* shown on the right.

S	R	if at $t = 0^-$		$Q(t > 0)$	$\overline{Q}(t > 0)$
		Q	$\overline{Q}$		
0	0	0	1		
0	0	1	0		
1	0	0	1		
1	0	1	0		
0	1	0	1		
0	1	1	0		
1	1	0	1		
1	1	1	0		

2

3. a) A fixed voltage power supply uses one transformer, one diode, and a capacitor to produce a dc voltage, $V_c(t)$, with some remaining ripple. Sketch the configuration of this circuit and briefly describe the function and operation of each of the components.

b) Suppose the output from this power supply is $V_c(t) \approx 10$ V , and a 6 V Zener diode is used to provide a regulated dc voltage across a load in either configuration (i), or configuration (ii), as shown below.
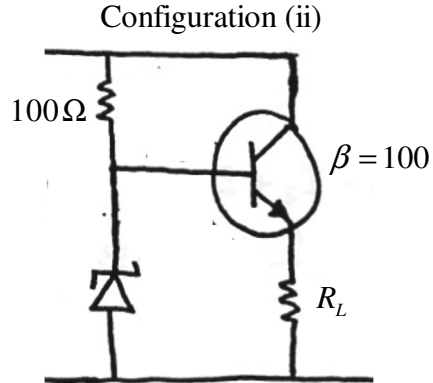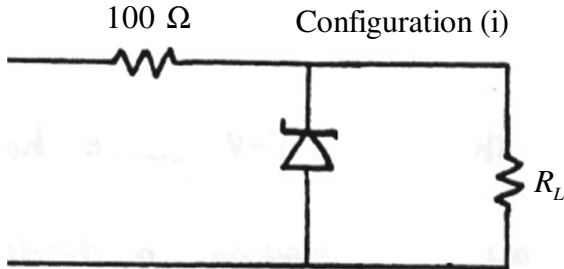
In each case, assuming a simple model for a Zener diode, what is the minimum value of the load resistance, $R_{L,\min}$, that can be satisfactorily powered from each supply, and what is the corresponding load current?

4. a) Draw the circuit for a *relaxation oscillator*, built from an operational amplifier, three resistors and one capacitor. Explain how such an oscillator works and provide plots above/below each other of the waveforms at the two op-amp inputs and also the output.

b) The diagram below shows a *phase-shift oscillator*, built from an operational amplifier, four resistors and three capacitors.
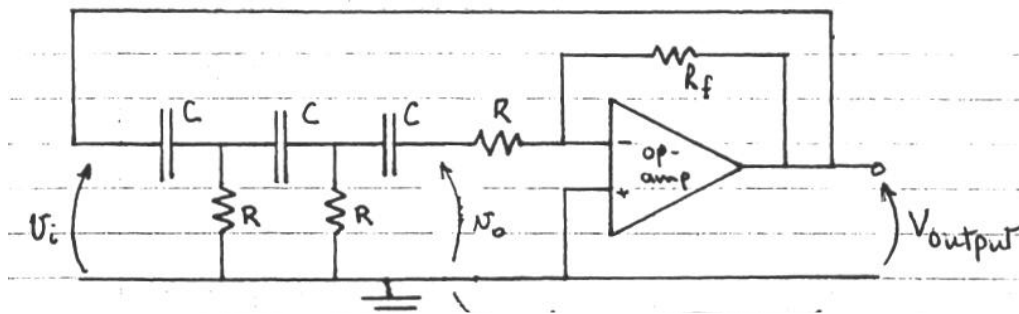
Explain how this oscillator works and, given that the three stage RC filter shown has the transfer ratio:

$$\frac{\tilde{v}_o}{\tilde{v}_i} = \frac{1}{1 - \dfrac{5}{(\omega RC)^2} + j\left[\dfrac{1}{(\omega RC)^3} - \dfrac{6}{\omega RC}\right]}$$

determine the algebraic expression for the frequency at which such an oscillator operates and sketch the form of the output. Find the numerical relationship between R_f and R that is required for this oscillator to operate optimally, and explain why this is so.