PHYS-COIS 2250H – Electronics

Final Examination : Sunday 16th December 2012.

Allowed: 3 hours. Calculator.
Answer <u>question 1</u> and <u>three</u> of the remaining four questions.
Question 1 is worth 40% of the marks, and the rest 20% each.

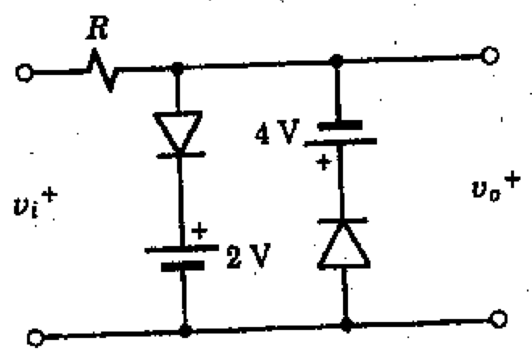
1.a) Sketch a two-port network that includes a Zener diode and a resistor R_S, that will act as a voltage regulator for some load, R_L. Briefly (in approximately two sentences) describe how it works, and what happens if R_S takes too small, and too large, a value.

b) Use a truth table to verify one of DeMorgan's theorems, given below:

$$\overline{A \bullet B} = \overline{A} + \overline{B}$$

Represent each side of this equation in terms of a circuit diagram containing logic gates.

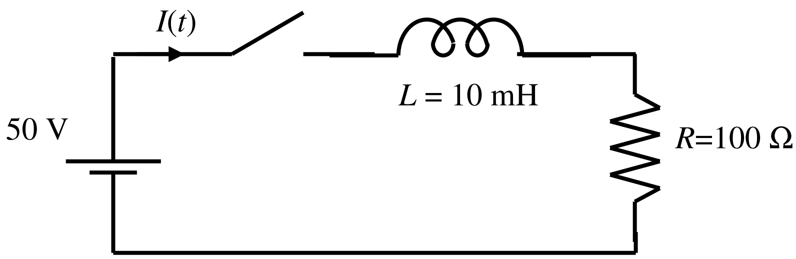
c) For the diode circuit shown with $v_i = 10\sin(\omega t)$, sketch $v_o(t)$ directly below a sketch of $v_i(t)$, and give your reasoning. Assume the diodes are ideal.



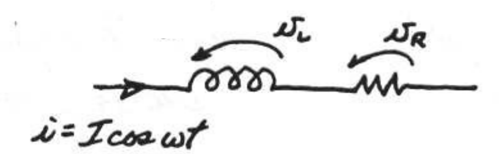
d) A lab interface card contains a 12-bit DAC that produces a voltage between 0 and 5 V. To output a voltage of 1.35 V what binary numbers (and equivalent decimal numbers) should represent i) the high byte, and ii) the low byte?

2) a) For the LR-combination shown below, connected to a DC voltage source and a switch, determine the current $I(t)$ in terms of V_s, L and R, assuming the switch is closed at $t=0$. Sketch this function and find at $t = 50\,\mu\text{s}$ what fraction of the maximum possible current exists.

[Note that a differential equation of the form $\frac{dy}{dx} + P(x)y = Q(x)$ can be solved by first multiplying each side by $e^{\int P(x)dx}$, and then the left hand side can be represented as a derivative of a single function].



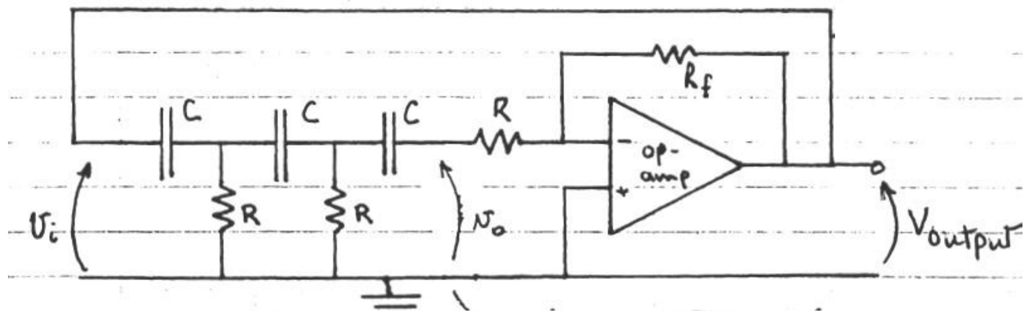
b) If this LR-combination is instead connected to an AC voltage source of angular frequency ω, then a current flows that can be represented by $i(t) = I\cos(\omega t)$.



The total voltage $v(t)$ can then be written as $v(t) = V_0\cos(\omega t + \phi)$. Derive using any reasonable method an algebraic expression for V_0 and ϕ in terms of I, R, L and ω. For the values of L and R given in part (a), determine ϕ for a frequency of $f = 100\,\text{Hz}$ and $f = 1\,\text{kHz}$.

3. a) Draw the circuit for a *relaxation oscillator*, built from an operational amplifier, three resistors and one capacitor. Explain, with diagrams showing the waveforms at the two op-amp inputs and also the output, how such an oscillator works.

b) The diagram below shows a *phase-shift oscillator*, built from an operational amplifier, four resistors and three capacitors.

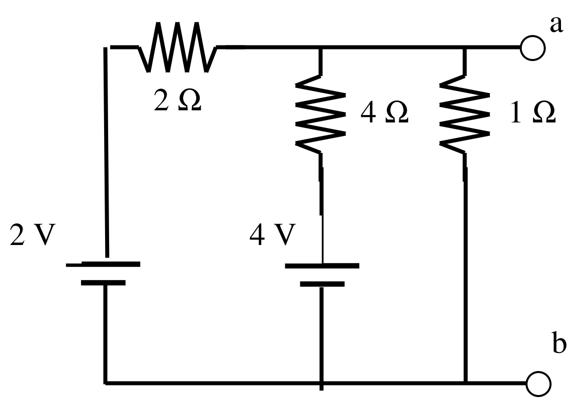


Explain how this oscillator works and, given that the three stage RC filter shown has the transfer ratio:

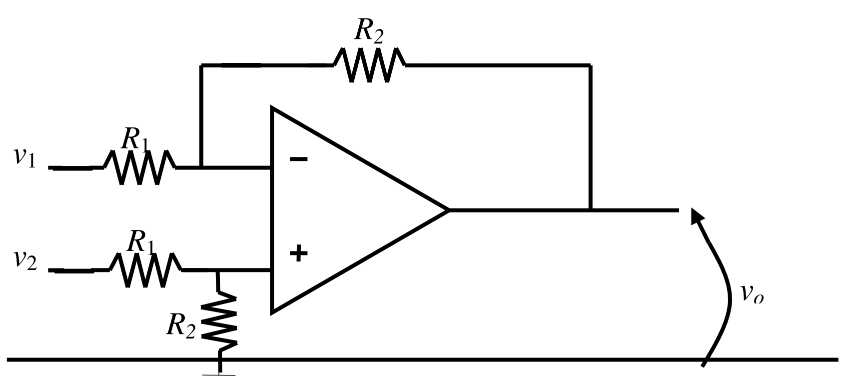
$$\frac{\tilde{v}_o}{\tilde{v}_i} = \frac{1}{1 - \frac{5}{(\omega RC)^2} + j\left[\frac{1}{(\omega RC)^3} - \frac{6}{\omega RC}\right]}$$

determine the frequency at which such an oscillator operates. Sketch the form of the output.

4. a) Derive and draw the Thevenin equivalent of the circuit below, across a-b



b) Find v_0 for the circuit below, stating any assumptions you use.



5. (a) From the collector characteristics shown below, determine beta of this transistor.

(b) Use these characteristics to choose reasonable values for all the resistors and the DC blocking capacitor shown for the emitter-biased amplifier shown, with a voltage gain of $v_o/v_i = -6$. The voltage gain for this amplifier is $-R_C/R_E$. Assume a minimum frequency of 50 Hz and a supply voltage $V_{cc} = 10$ V.