NAME: ______________________________________________

(Print) Last Name, First Name

STUDENT NUMBER: ____________________________

UBC Okanagan

The Irving K. Barber School of Arts and Sciences

Physics 231— Winter 2013/2014 – Term 1

FINAL EXAMINATION

Instructor: Jake Bobowski

Saturday, December 5, 2013 Time: 18:00 - 21:00

Location: ART 386

This Examination was prepared by Jake Bobowski

Not including this coversheet, the exam consists of 15 numbered pages.

- **Attempt all of problems 1 through 4.**
- **Attempt any three of problems 5 through 8.**

If necessary, you may use the backs of pages for calculations.

**<u>You must clearly show your work to receive full credit.</u>**

**<u>Writing down only the correct final answer will not earn full credit.</u>**

**Include units** with the final answer whenever appropriate.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | total |
|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 15 | 10 | 10 | 10 | 10 | 10 | 75 |
| | | | | | | | | |

PHYSICS 231 Final Examination Name: ____________________
2013/14 Term 1 Student Number: ______________

**Free Response**: Write out complete answers to the following questions. Show your work.

(10pts) **1.** You have three resistors with specified resistances and uncertainties: $R_1 \pm \delta R_1$, $R_2 \pm \delta R_2$, and $R_3 \pm \delta R_3$.

(a) If the three resistors are connected in series, what is the equivalent resistance $R_{\mathrm{s}} \pm \delta R_{\mathrm{s}}$? Find expressions for $R_{\mathrm{s}}$ and $\delta R_{\mathrm{s}}$ in terms of $R_1$, $R_2$, $R_3$ and their uncertainties.

(b) If the three resistors are connected in parallel, what is the equivalent resistance $R_{\mathrm{p}} \pm \delta R_{\mathrm{p}}$? Find expressions for $R_{\mathrm{p}}$ and $\delta R_{\mathrm{p}}$ in terms of $R_1$, $R_2$, $R_3$ and their uncertainties.

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| 10 pts |

(c) Suppose you want to make a 300 Ω resistor. Given the limited equipment that you have in the lab, your options are to combine three 100 $\Omega \pm 5\%$ resistors in series or to combine three 900 $\Omega \pm 5\%$ resistors in parallel. Compare the resulting numerical values of $\delta R_{\rm s}$ and $\delta R_{\rm p}$.

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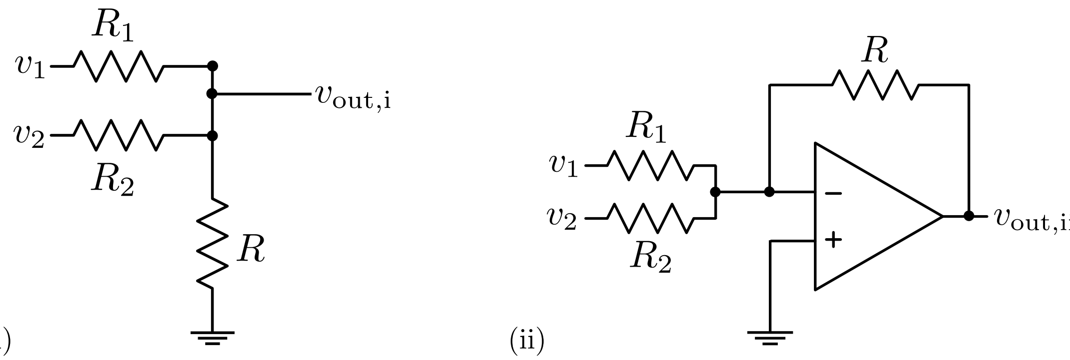
| 0 pts |

(10pts) **2.** Consider the following two circuits:




(i) (ii)

(a) For circuit (i), find and expression for $v_{\text{out,i}}$ in terms of $v_1$, $v_2$, $R_1$, $R_2$, and $R$.

10 pts

(b) For circuit (ii), find and expression for $v_{\mathrm{out,ii}}$ in terms of $v_1$, $v_2$, $R_1$, $R_2$, and $R$.

(c) Finally, in your expressions for $v_{\mathrm{out,i}}$ and $v_{\mathrm{out,ii}}$ from parts (a) and (b) set $R_1 = R$ and $R_2 = R$. Simplify your answers as much as possible and write down the resulting $v_{\mathrm{out,i}}$ and $v_{\mathrm{out,ii}}$ expressions.

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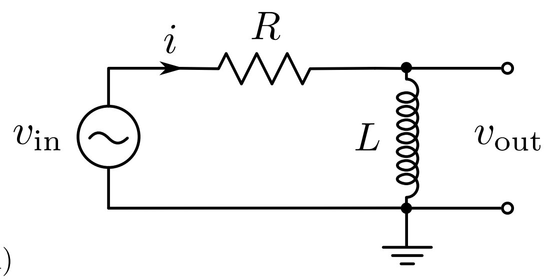
| 0 pts |

(15pts) **3.** Consider the $LR$-series circuit shown below:




(i)

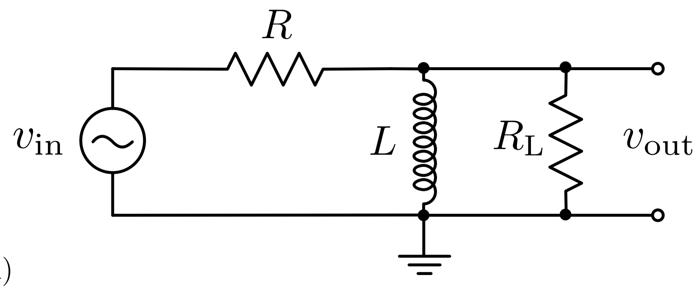
(a) If the input voltage is given by $v_{\text{in}} = V_0 \sin \omega t$, what are the amplitude $I_0$ and phase $\phi$ of the current $i$?

15 pts

(b) For circuit (i) on the previous page, find an expression for $\left|\frac{v_{\text{out}}}{v_{\text{in}}}\right|$ in terms of $\omega$, $R$, and $L$. Sketch $\left|\frac{v_{\text{out}}}{v_{\text{in}}}\right|$ as a function of $\omega$. What kind of filter is this circuit?

0 pts

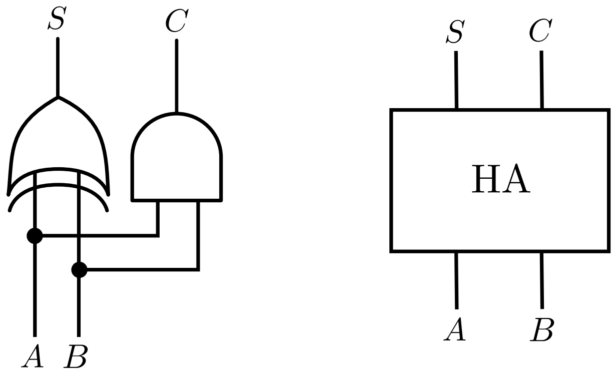
(c) If an oscilloscope is connected across the inductor, the input resistance $R_{\mathrm{L}}$ of the oscilloscope is placed in parallel with the inductor as shown below in circuit (ii):




(ii)

For this modified circuit, what is the new expression for $\left|\frac{v_{\mathrm{out}}}{v_{\mathrm{in}}}\right|$? It is not necessary to do complicated calculations to find the appropriate expression. Instead, try coming up with an equivalent replacement that turns this back into a series circuit similar to the one shown in figure (i).

(10pts) **4.** Recall the half-adder circuit used to add to single-bit binary numbers which has two inputs $A$ and $B$ and two outputs $S$ and $C$:




(a) Write down the truth table for the half-adder circuit.

(b) Fill in the missing data on the truth table given on the next page. What kind of operation is this circuit performing on the pair of 2-bit binary inputs $(A_1, A_0)$ and $(B_1, B_0)$?

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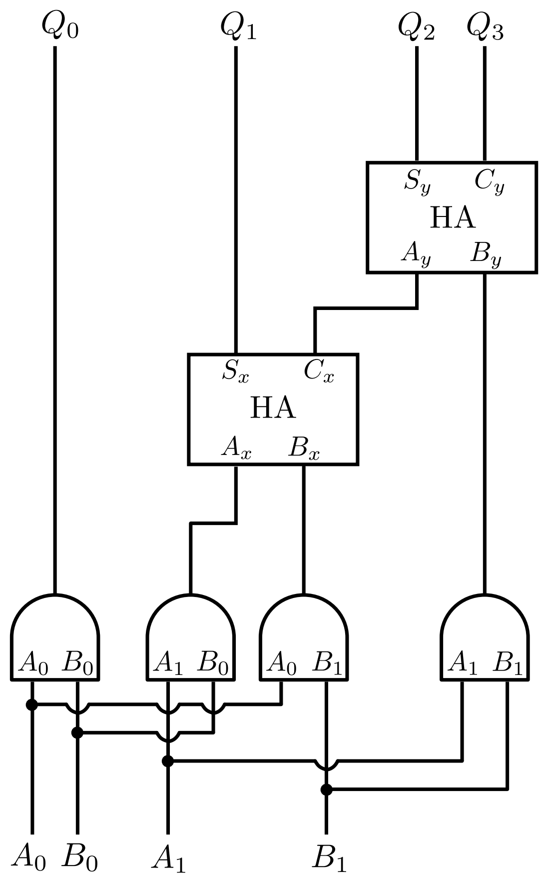
| 10 pts |




| $A_1$ | $A_0$ | $B_1$ | $B_0$ | $A_x$ | $B_x$ | $S_x$ | $C_x$ | $A_y$ | $B_y$ | $S_y$ | $C_y$ | $Q_3$ | $Q_2$ | $Q_1$ | $Q_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | | | | | | | | | | | |
| 0 | 0 | 0 | 1 | | | | | | | | | | | | |
| 0 | 0 | 1 | 1 | | | | | | | | | | | | |
| 1 | 0 | 0 | 0 | | | | | | | | | | | | |
| 0 | 1 | 0 | 1 | | | | | | | | | | | | |
| 1 | 0 | 1 | 0 | | | | | | | | | | | | |
| 1 | 1 | 1 | 0 | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | | | | | | | | | | | | |

0 pts

Complete any of the **three** remaining problems (5, 6, 7, 8).

Clearly indicate which three problems you which to be graded by entering three numbers into the table below.

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(10pts) **5.** Use Euler's equation $\left(e^{\pm j\phi} = \cos\phi \pm j\sin\phi\right)$ to derive the following two trigonometric identities:

$$\cos^2\phi = \frac{1+\cos 2\phi}{2}$$
$$\sin^2\phi = \frac{1-\cos 2\phi}{2}$$

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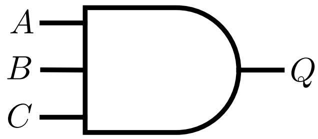
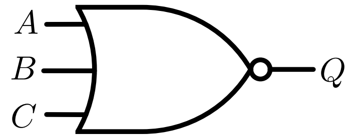
| 10 pts |

(10[pts]) **6.** In class we only talked about logic gates with two inputs, however, it is possible to make some logic gates with any number of inputs. A 3-input gate AND and a 3-input NOR gate are shown below:




The truth for the 3-input AND gate is:

| $A$ | $B$ | $C$ | $Q$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

(a) Write down the truth table for the 3-input NOR gate.

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| 10 pts |

(b) Design a 3-input NOR gate using only transistors and resistors. *Hint*: One common design uses three transistors.

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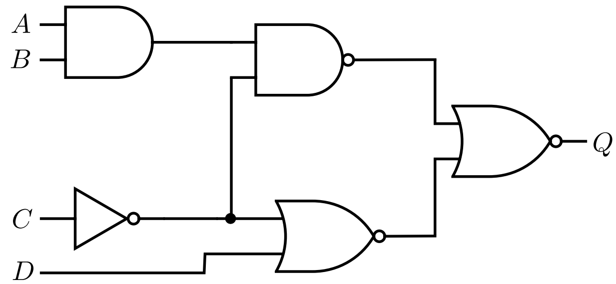
(10pts) **7.** Consider the digital circuit shown below:




(a) Write down the logic expression for the output $Q$. (For example, recall that the logic expression for the $X$ AND $Y$ operation is $X \cdot Y$.)

(b) Simplify the expression for $Q$ obtained in part (a) as much as possible. For part of your solution, you may find De Morgan's theorems helpful: $\overline{A \cdot B} = \overline{A} + \overline{B}$ and $\overline{A + B} = \overline{A} \cdot \overline{B}$. Draw the simplified digital circuit. Are any of the inputs irrelevant to the state of the output $Q$?

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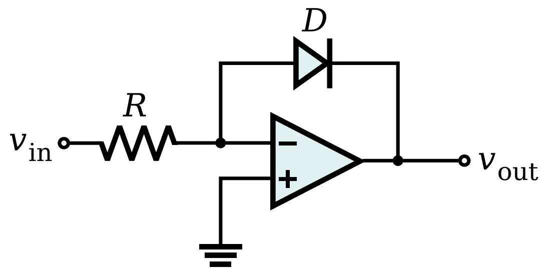
| 10 pts |

(10[pts]) **8.** Consider the so-called "log amplifier" shown below:




Recall that the current in a diode is given by $I_{\text{D}} = I_0 \left(e^{eV_{\text{D}}/k_{\text{B}}T} - 1\right)$ where $I_0$ is a constant and $V_{\text{D}}$ is the voltage across the diode. Assuming that $v_{\text{in}}$ and $R$ are chosen such that $I_{\text{D}} \gg I_0$, show that:

$$v_{\text{out}} = G \ln\left(\frac{v_{\text{in}}}{RI_0}\right)$$

Find an expression for the proportionality constant $G$.

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| 10 pts |