

# 1999-2000 Physics Olympiad Preparation Program

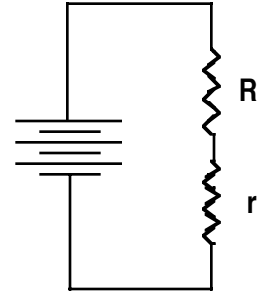
— University of Toronto —

## Problem Set 6: AC Circuits and Electronics

Due April 3, 2000

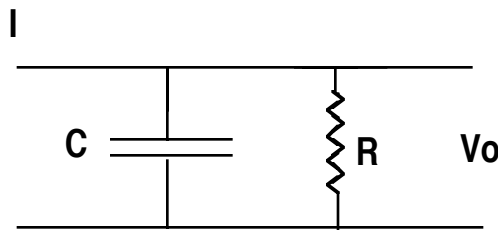
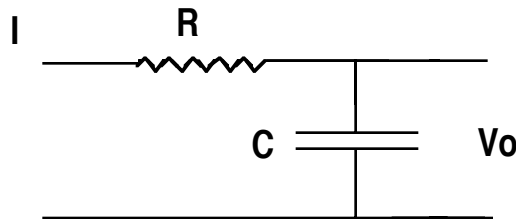
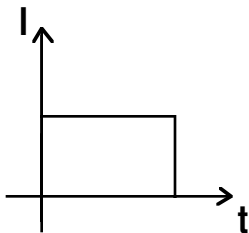
### 1) Ohm my!

You are given the circuit shown, which starts with a battery of voltage  $V$  and a resistor  $R$  across the battery. If I add another resistor  $r$  in series with  $R$ , what should be the value of  $r$  so that the power dissipated across it should be a minimum? Similarly, what should be the value if  $r$  is added in *parallel* with  $R$ ? [Robin]



### 2) A current affair

There are two circuits shown below, with the bottom part of the diagram held at ground. If the input is a current turned on, then off, as graphed, what is the output voltage vs. time?



[Yaser]

### 3) Pandora's box o' electronics

Consider a black box with 3 terminals (A, B, C). Only batteries & resistors are present inside. Given these measurements below (taken with a multimeter, between pairs of

Voltage:

	A	B	C
A		0 V	1.6 V
B			1.6 V
C			

Resistance:

	A	B	C
A		99 Ohms	nonsense (< 0)
B			nonsense (< 0)
C			

Current:

	A	B	C
A		0 A	0.015 A
B			0.031 A
C			

terminals), what is inside? Draw a circuit diagram, and specify the values of components.

[HINT: the above values, since they are experimental, have an error-bar in the last digit]

[HINT 2: measuring resistance across a battery will result in an error] [Peter]

#### 4) Only logical

Logic gates are used to electronically perform Boolean or Logical operations on input signals. The simplest is the NOT gate which is symbolised by the

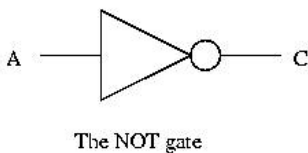
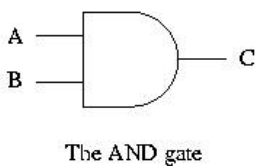


diagram at left. The response of the NOT gate can be summarized in the following truth table, at right. So if the input signal (A) is true or 1 the NOT gate response (C) is

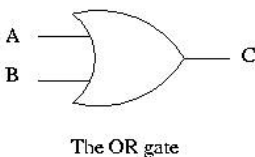
A	C
1	0
0	1

false or 0 (and *vice versa*).



Another type of logic gate is the AND gate with symbol shown at left and truth table at right. Thus the output C is true only when both A and B are true, otherwise C is false.

A	B	C
1	1	1
1	0	0
0	1	0
0	0	0



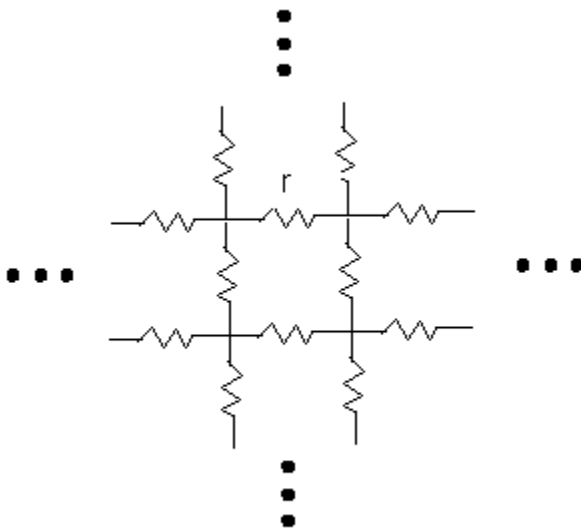
The OR gate has symbol shown at left.

- What do you suppose is the truth table for this gate?
- Build an OR gate using NOT and AND gates.
- Build an AND gate from NOT and OR gates.

#### BONUS

d) Build an EXCLUSIVE OR gate (where C is true if one of A or B is true but not both), using AND, OR and NOT gates. ... [Carrie]

5) Net worth



i) Consider an infinite square array of resistors  $r$ , sketched conceptually at left. Consider any 2 neighbouring points (separated by a resistance  $r$ ) — the equivalent resistance is  $r / 2$ . Show why.

ii) Consider now an array of equilateral triangles (arranged so that at any junction there are 6 resistors  $r$  coming off). What is the equivalent resistance across any arm?

iii) Consider an array of hexagons (arranged so that at any junction there are 3 resistors  $r$  coming off). Now what is the equivalent resistance across any arm?

iv) Consider a network of regular polygons in which, at any point,  $N$  resistors  $r$  are coming off. What is the equivalent resistance?

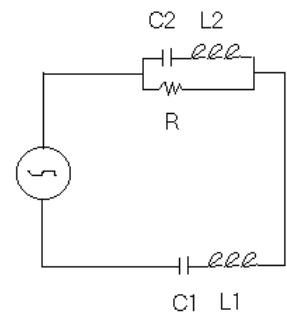
[BONUS: can you draw such a figure in 2 dimensions for  $N = 5$  ?] [Peter]

6) My current analysis...

Roughly sketch the impedance of this circuit, at right, as a function of the frequency  $\omega$  of the sinusoidal driving source (the circle with the squiggly bit). A qualitative description will do.

NOTE:  $\frac{1}{L_1 C_1} = \alpha^2 \neq \frac{1}{L_2 C_2} = \beta^2$

[BONUS: find the impedance as a function of frequency exactly] [Peter]



Remember to check the POPTOR web-page for hints and any necessary corrections!

[www.physics.utoronto.ca/~poptor](http://www.physics.utoronto.ca/~poptor)