G.C.E. (A/L) ICT

Logic Gates

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01.

Consider the following scenario.

You are given the task of designing a "flame detection logic circuit" for a toxic waste incinerator. The intense "heat of the fire" is intended to neutralize the toxicity of the waste introduced into the incinerator. Thermal (detection of high temperature) flame detection system and ***three sensors*** are used. Each sensor comes equipped with a normally-open contact (open if no flame, closed if flame detected), which you will use to activate the ***inputs of a logic system***. Your task is to design the circuitry of the logic system to open the ***waste valve*** if and only if there is ***good flame*** proven by the sensors**.**

A strategy that would meet both needs would be a two out of three sensor logic, whereby the waste valve is opened if at least two out of the three sensors show good flame.

The following table assigns Boolean values for the above scenario.

Condition / functionality	***Boolean value***
Sensors show good flame	1
Sensors do not show good flame	0
Waste valve opened	1
Waste valve closed	0

(a) Construct a truth table for this system
(b) Write down the standard SOP Boolean expression from the truth table obtained in (***a***).
(c) Draw a combined gates to represent the truth table obtained in (***b***) (Use only AND, OR , and NOT gates).
(d) Simplify the Boolean expression obtained in (***c***) by using Karnaugh map or Boolean Laws.

02.

(a) Apply De Morgan's Law to the following expression and simplify the result. Show the stages of your working.

$F = \overline{\bar{A} + \overline{(B.A)}}$

(b) A line-following robot has three sensors. It moves along a black line on a white background whilst the following conditions are met:

- the sensor **U** does not detect any obstacle and.
- either, but not both, of the sensors **L** and **R** are on the black line only.

Sensor U returns 1 if it detects an obstacle and 0 if the path is clear. Sensors L and R each return 1 if they detect black and 0 if they detect white. A logic circuit will process the input from the sensors and produce an output M. M should be 1 if the robot is to move and 0 if the robot should stop.

(i) Write down the Boolean expression.
(ii) Construct a truth table for the Boolean expression obtained above in **(i)**.
(iii) What is the logic gate which is equivalent to the functionality of the Boolean expression obtained in **(i)** above?
(iv) Draw the logic circuit for the Boolean expression obtained in **(i)**.

03.

Chemical process gives out a warning signal (W = 1) when the process operates incorrectly. A logic circuit is used to monitor the process and to determine whether W = 1.

Input	Binary values	Process condition
A	***1***	Chemical rate = 20 litre / second
	0	Chemical rate < 20 litre / second
B	***1***	Temperature = 91^0C
	0	Temperature > 91^0C
C	***1***	Concentration > 5M
	0	Concentration = 5M

A warning signal (W = 1) will be generated if:
either Chemical rate < 20 litres /second
or Temperature > 91ºC and Concentration > 5M
or Chemical rate = 20 litres /second and Temperature > 91

(a) Write down the Boolean expression.
(b) Draw the logic circuit, using only AND, OR and NOT gates, for the Boolean expression obtained in **(a)**.
(c) Construct a truth table for the Boolean expression obtained above in **(a)**.
(d) Obtain the Boolean expression, without simplification, in sum of product (SOP) form using truth table or other method.

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