Do only six of the seven questions. Cross out the one you do not want to do.

1. How many address lines are needed for a memory having 32768 locations? Show your work. (4)

   **Answer**
   
   \[ 32768 = 2^{15} \]
   
   so 15 address lines are needed.
2. Derive the truth table for the circuit below

\[
\begin{array}{ccc}
 x & y & z \\
0 & 0 & 0 \\
0 & 0 & 1 \\
0 & 1 & 0 \\
0 & 1 & 1 \\
1 & 0 & 0 \\
1 & 0 & 1 \\
1 & 1 & 0 \\
1 & 1 & 1 \\
\end{array}
\]

\textit{Answer}
3. Circle all the parts of the datapath, including the connection lines where the data traverse, that are responsible for performing the instruction.
Answer
4. What two elements are required in order for the interrupt-driven I/O mechanism to work? Briefly describe how these two elements work.

**Answer**
1) A signal from the I/O device indicating that it is ready.
2) A test by the processor during each instruction cycle to see if such a signal is present.

5. a) What problem could occur if a program does not check the *Ready* bit of the KBSR before reading the KBDR?
b) What problem could occur if the keyboard hardware does not check the KBSR before writing to the KBDR?
c) Which of the above two problems is more likely to occur? Give your reason.

**Answer**
1) The program can read the same character several times.
2) The keyboard can overwrite a character that the program has not yet read.
3) Problem a) is more likely to occur because the program is executing instructions much faster than a typist can type in new characters.
6. Write a LC-2 program to copy 50 words starting from memory location x4000 to x4500. Include comments to make the program easier to understand. (4)

Answer

```plaintext
.ORIG x3000
LD R5, from
LD R6, to
LD R0, fz

next LDR R1, R5, #0
STR R1, R6, #0
ADD R5, R5, #1
ADD R6, R6, #1
ADD R0, R0, #-1
BRP next
HALT

fz .FILL #50
from .FILL x4000
to .FILL x4500
.END
```

7. Assume that memory location x4000 contains a pointer (address) to the first of three consecutive locations in memory containing integers. Write a LC-2 program to add these three integers and store the total in location x4500. Include comments to make the program easier to understand. (4)

Answer

```plaintext
.ORIG x3000
LD R5, data
LDR R1, R5, #0
LDR R2, R5, #1
LDR R3, R5, #2
AND R0, R0, #0
ADD R0, R0, R1
ADD R0, R0, R2
ADD R0, R0, R3
LD R5, total
STR R0, R5, #0
HALT

data .FILL x4000
total .FILL x4500
.END
```