State

1. Fill out the timing diagram for the circuit below:

   +---+ +---+ +---+
   | IN-| D Q| -s0-| D Q| -s1-| D Q| --Out
   +---+ +---+ +---+
   | | | | |
   CLK-------------------------

   clk __________
   in __________
   s0 ________
   s1 ________
   out ________

2. Fill out the timing diagram for the circuit below:

   +---+ +---+
   | A--| D Q| -R1-| D Q| -R2--
   +---+ +---+
   | | |
   CLK---------| o--+

   clk __________
   !clk __________
   A ________
   R1 ________
   R2 ________

Logic Gates

1. Label the following logic gates:

   ![Logic Gates Diagram]

   Solution: not, and, or, xor, nand, nor, xnor

2. Convert the following to boolean expressions:

   (a) NAND
Solution: \( \bar{A} \bar{B} + \bar{A}B + AB \)

(b) XOR

Solution: \( \bar{A}B + AB \)

(c) XNOR

Solution: \( \bar{A} \bar{B} + AB \)
3. Create an AND gate using only NAND gates.

**Solution:**

![Diagram of two NAND gates connected to form an AND gate]

4. How many different two-input logic gates can there be? How many n-input logic gates?

**Solution:** A truth table with $n$ inputs has $2^n$ rows. Each logic gate has a 0 or a 1 at each of these rows. Imagining a function as a $2^n$-bit number, we count $2^{2^n}$ total functions, or 16 in the case of $n = 2$.

### Boolean Logic

$1 + A = 1$  \hspace{1cm} A + \bar{A} = 1$  \hspace{1cm} A + AB = A$  \hspace{1cm} (A + B)(A + C) = A + BC$

$0B = 0$  \hspace{1cm} BB = 0$  \hspace{1cm} A + \bar{AB} = A + B$

DeMorgan’s Law:  \hspace{1cm} \bar{AB} = A + \bar{B}$  \hspace{1cm} \bar{A} + \bar{B} = \bar{AB}$

1. Minimize the following boolean expressions:

   (a) Standard: $(A + B)(A + \bar{B})C$

   **Solution:**

   $$ (AA + A\bar{B} + AB + B\bar{B})C = (A + A(\bar{B} + B))C = AC $$ (1)

   (b) Grouping & Extra Terms: $\bar{A}\bar{B}C + \bar{A}BC + ABC + AB\bar{C} + ABC + ABC$

   **Solution:**

   $$ \bar{A}C(\bar{B} + B) + AC(B + \bar{B}) + AC(B + \bar{B}) = \bar{A}C + AC $$ (2)

   $$ = \bar{A}C + AC $$ (3)

   $$ = (\bar{A} + A)C + AC $$ (4)

   $$ = A + C $$ (5)

   (c) DeMorgan’s: $A(BC + BC)$

   **Solution:**

   $$ A(BC + BC) = \bar{A} + BC + \bar{BC} $$ (6)

   $$ = \bar{A} + B\bar{C}BC $$ (7)

   $$ = \bar{A} + (B + C)(\bar{B} + \bar{C}) $$ (8)

   $$ = \bar{A} + B\bar{C} + BC $$ (9)