**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:

```
  __________
  __________
```

```
  __________
  __________
```

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

2. Convert the following to boolean expressions:

(a) NAND
(b) XOR

Solution: $\overline{A}B + \overline{A}B + AB$

(c) XNOR

Solution: $\overline{A}B + AB$
3. Create an AND gate using only NAND gates.

![NAND gate diagram]

Solution:

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

\[ 1 + A = 1 \quad A + \bar{A} = 1 \quad A + AB = A \quad (A + B)(A + C) = A + BC \]
\[ 0B = 0 \quad BB = 0 \quad A + AB = A + B \]
DeMorgan’s Law: \( \overline{AB} = A + B \quad \overline{A + B} = \overline{A} \overline{B} \)

1. Minimize the following boolean expressions:

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

Solution:
\[
(\overline{AC}(\overline{B} + B) + AC(B + \bar{B}) + AC(B + \bar{B}))C = (\overline{A} + A(\overline{\bar{B}} + B))C = AC
\]  

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

Solution:
\[
\overline{A\bar{C}(\bar{B} + B) + AC(B + \bar{B}) + AC(B + \bar{B})} = \overline{A\bar{C} + A\bar{C} + AC} = \overline{A\bar{C} + A\bar{C} + AC} + AC = (\overline{A + A})\bar{C} + (\bar{C} + C) = A + \bar{C}
\]

(c) DeMorgan’s: \( A(\overline{BC} + BC) \)

Solution:
\[
\overline{A(BC + BC)} = \overline{A + BC + BC} = A + BC BC = \overline{A + B\bar{C}BC} = A + (B + C)(\bar{B} + \bar{C}) = \overline{A + B\bar{C} + BC}
\]