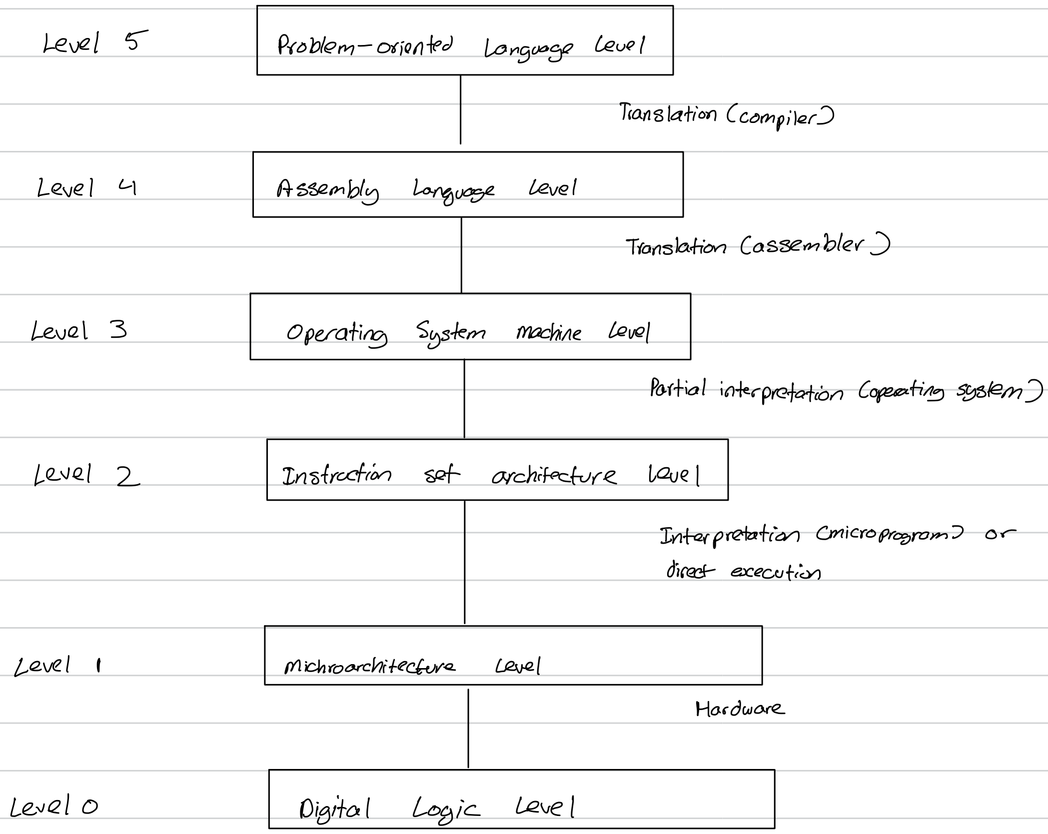
A Six Level Computer:



Excercise 1

1. 17 ⇒ binary

| | |
|---|---|
| | 17 |
| 1 | 8 |
| 0 | 4 |
| 0 | 2 |
| 0 | 1 |
| 1 | 0 |

10001

2 10010 ⇒ $2^1 + 2^4$ ⇒ 2 + 16 ⇒ 18

3 $2^7$ ⇒ 128

4.
$$\begin{array}{r} {}^{1\,1\,1}\;1010 \\ 0110 \\ \hline 10000 \end{array}$$

∴ 1010 ⇒ $2^1 + 2^3$ ⇒ 10
0110 ⇒ $2^1 + 2^2$ ⇒ 6 +
10000 ⇒ $2^4$ ⇒ 16

Excercise 2:

Question 1

1. 7 × 1ns = 7ns

2. $IPS = \frac{1}{10^9} = 10^8$ IPS

3 7ns + 19ns = 26ns

5 20 instructions in pipeline = 26ns

20 instructions without pipeline = 20 × 7 = 140ns

∴ $\frac{140}{26} = 5.38$

Hence 5.38 × 1000 MPS ⇒ 5380 MPS

Question 2:

20752 ⇒

| | |
|---|---|
| | 20752 |
| 0 | 10376 |
| 0 | 5188 |
| 0 | 2594 |
| 0 | 1297 |
| 1 | 648 |
| 0 | 324 |
| 0 | 162 |
| 0 | 81 |
| 1 | 40 |
| 0 | 20 |
| 0 | 10 |

| | |
|---|---|
| 0 | 5 |
| 1 | 2 |
| 0 | 1 |
| 1 | 0 |

101000100010000 → unsigned number

0101000100010000 → signed number

0 1 0 1 0 0 0 1 0 0 0 1 0 0 0 0

One complement → 0101000100010000

Twos complement → 0101000100010000
+ 1

0101000100010001

Question 3

1. $14356_{10}$

| | |
|---|---|
| | 14356 |
| 0 | 7178 |
| 0 | 3589 |
| 1 | 1794 |
| 0 | 897 |
| 1 | 448 |
| 0 | 224 |
| 0 | 112 |
| 0 | 56 |
| 0 | 28 |
| 0 | 14 |
| 0 | 7 |
| 1 | 3 |
| 1 | 1 |
| 1 | 0 |

11100000010100 → unsigned magnitude

0011100000010100 → Signed magnitude

0011100000010100 → one's complement

0011100000010100 → two's complement

2. Symmetric means that there equal number of negative and possitive numbers:

Symmetric : Sm , 1'C

Asymmetric : Excess $2^{n-1}$, 2'C

Symmetric addvantage : Straight forward

Symmetric disadvantage : We always have two zeros

Asymetric addvantage : Only one zero

" disadvantage : representing more negative numbers.

Excercise 03

Question 1 – Endianness :

1.

| | Big Endian | Little Endian |
|---|---|---|
| 0 | 0101 1100 | 1100 1111 |
| 1 | 1001 0110 | 0000 0011 |
| 2 | 0000 0011 | 1001 0110 |
| 3 | 1100 1111 | 0101 1100 |

2. " Welcome Class 2021" → little Endian

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $R_0$ | _ | e | m | o | c | l | e | W |
| $R_1$ | 0 | 2 | _ | s | s | a | l | C |
| $R_3$ | x | x | x | x | x | x | 1 | 2 |

→ Big Endian

Question 2

1. $2^{17}$ = possible words

2. a) 1001 0110 0001 1111

\# 1's = 9 ⇒ not Even parity

⇒ Error

(b) 1101 0011 1000 1000

\# 1's = 7 ⇒ not even parity

⇒ Error

(c) If there are more than two bit-flips

Question 3

1. Data ← [ 0101 → n bits

Check Bits x x x x → r bits

↓ CODE WORD

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| codeword | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | | 0 | | 1 | | 1 |
| 2 | | 1 | 0 | | | 0 | 1 |
| 4 | | | | 0 | 1 | 0 | 1 |
| | 0 | 1 | 0 | 0 | 1 | 0 | 1 |

(highlighted) = check bits

If there is a computer error and the parity bit changes due to computer error.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| codeword | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 → But wrong 0 | | 0 | | 1 | | 1 |
| 2 | | 1 | 0 | | | 0 | 1 |
| 4 | | | | 0 | 1 | 0 | 1 |
| | 0 | 1 | 0 | 0 | 1 | 0 | 1 |

(highlighted) = check bits

2. 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048

(a) 9 check bits

(b) 12 check bits

Question 5.

1. L1 — 3 cycles — 5% miss ratio

RAM — 180 cycles — ?

$0.95 \cdot 3$ cycles $+ 0.05 \cdot 180$ cycles

⇒ 2.85 cycles + 9.00 cycles

⇒ 11.85 cycles

2. L1 — 3 cycles — 5% miss ratio

RAM — 180 cycles — ?

L2 — 9 cycles — 20% miss ratio

L3 — 90 cycles — 30% miss ratio

| L1 access | | L1 miss + L2 access | | L1 miss, L2 miss, L3 access | | L1 miss, L2 miss, L3 miss, RAM |
|---|---|---|---|---|---|---|
| $\boxed{0.95 \cdot 3 \text{ cycles}}$ | + | $\boxed{0.05 \cdot 0.8 \cdot 9 \text{ cycles}}$ | + | $\boxed{0.05 \cdot 0.2 \cdot 0.7 \cdot 90 \text{ cycles}}$ | + | $\boxed{0.05 \cdot 0.2 \cdot 0.3 \cdot 180 \text{ cycles}}$ |

L1 access : 2.85 CPI

L2 access : 0.36 CPI

L3 access : 0.63 CPI

RAM : 0.54 CPI

4.38 CPI

3. L1 ⟶ 3 cycles ⟶ 10%

L2 ⟶ 9 cycles ⟶ 10%

L3 ⟶ 90 cycles ⟶ 15%

| L1 | | L2 | | L3 | | RAM |
|---|---|---|---|---|---|---|
| $\boxed{0.90 \cdot 3 \text{ cycles}}$ | + | $\boxed{0.10 \cdot 0.90 \cdot 9 \text{ cycles}}$ | + | $\boxed{0.10 \cdot 0.10 \cdot 0.85 \cdot 90 \text{ cycles}}$ | + | $\boxed{0.10 \cdot 0.10 \cdot 0.15 \cdot 180 \text{ cycles}}$ |

$L_1$ = 2.7 CPI

$L_2$ = 0.81 CPI

L3 = 0.765 CPI

RAM = 0.27 CPI

4.545 CPI

Excercise 4

Question 1 :

1. $14356_{10}$

| | |
|---|---|
| | 14356 |
| 0 | 7178 |
| 0 | 3589 |
| 1 | 1794 |
| 0 | 897 |
| 1 | 448 |
| 0 | 224 |
| 0 | 117 |
| 0 | 58 |
| 0 | 29 |
| 1 | 14 |
| 0 | 7 |
| 1 | 3 |
| 1 | 1 |
| 1 | 0 |

11101010010100 ⟶ Unsigned magnitud

0011101010010100 ⟶ Signed magnitude

0011101010010100 ⟶ One's complement

0011101010010100 ⟶ Two's compliment

  0011101010010100
+ 1000000000000000

1011101010010100 ⟶ excess $2^{m-1}$

2. Possitive number

| | Binary | Decimal |
|---|---|---|
| Signed magnitude : | 011111 | 31 |
| One's complement : | 011111 | 31 |
| two's compement : | 011111 | 31 |
| Excess $2^5$ : | 111111 | 31 |

3. Negative number

| | Binary | Decimal |
|---|---|---|
| Signed magnitude : | 111111 | -31 |
| One's complement : | 100000 | -31 |
| two's compement : | 100000 | -32 |
| Excess $2^5$ : | 00 0000 | -32 |

Question 2:

1. $-33_{10}$ =

| | 33 |
|---|---|
| 1 | 16 |
| 0 | 8 |
| 0 | 4 |
| 0 | 2 |
| 0 | 1 |
| 1 | 0 |

10100001 ⟶ unsigned magnitud

11010110 ⟶ signed magnitud

11011110
+ 00000001
11011111 ⟶ two's complement

| | 74 |
|---|---|
| 0 | 37 |
| 1 | 18 |
| 0 | 9 |
| 1 | 4 |
| 0 | 2 |
| 0 | 1 |
| 1 | 0 |

1001010 ⟶ unsigned magnitude

01001010 ⟶ Signed magnitude / one's / 2's complement

∴
  11011111
+ 01001010
  00101001

00101001 ⟶ $2^0 + 2^3 + 2^5$ ⟶ 1 + 8 + 32 ⟶ 41 (correct) & (no overflow)

Question 4.

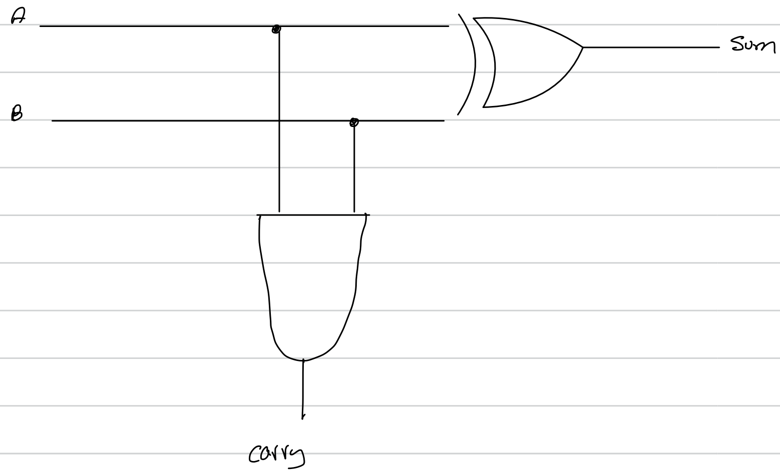
1. 0x03 7

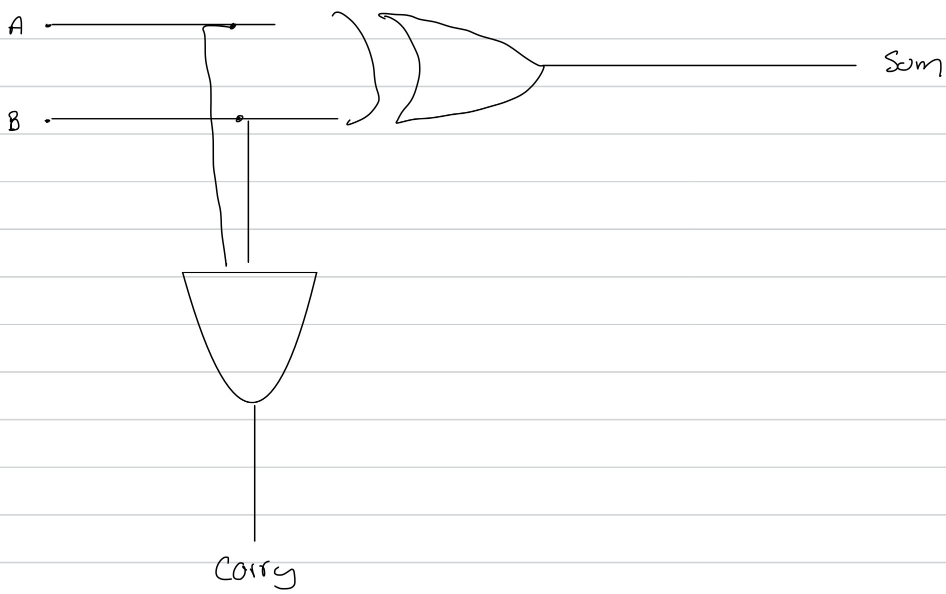
0x04 5

0x05 1

0x06 -

1-bit half adder



Exercise 6

Question 2:

1.

| a | b | c | p | q | r | e |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 |

∴

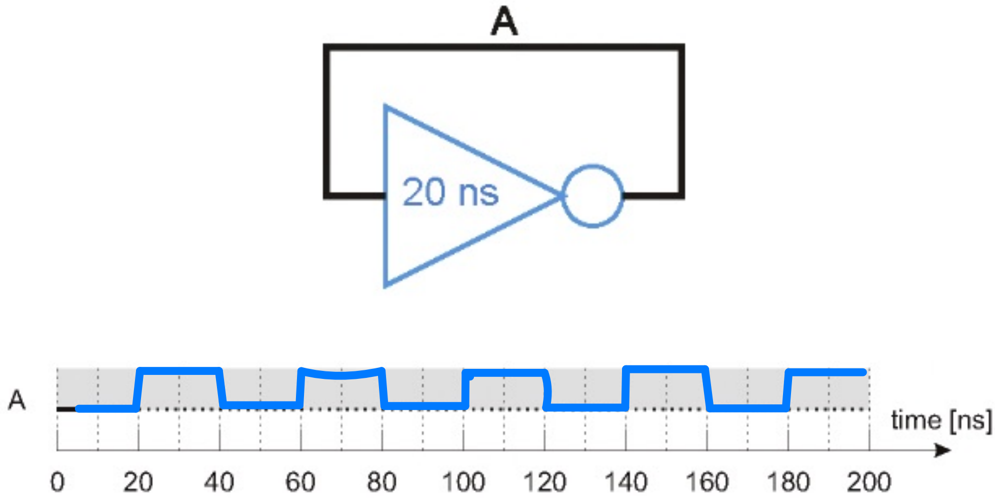
| | 00 | 01 (b) | 10 (b) | 11 |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 a | 0 | 1 | 1 (c) | 1 (c) |

$f(a,b,c) = ba + ca$

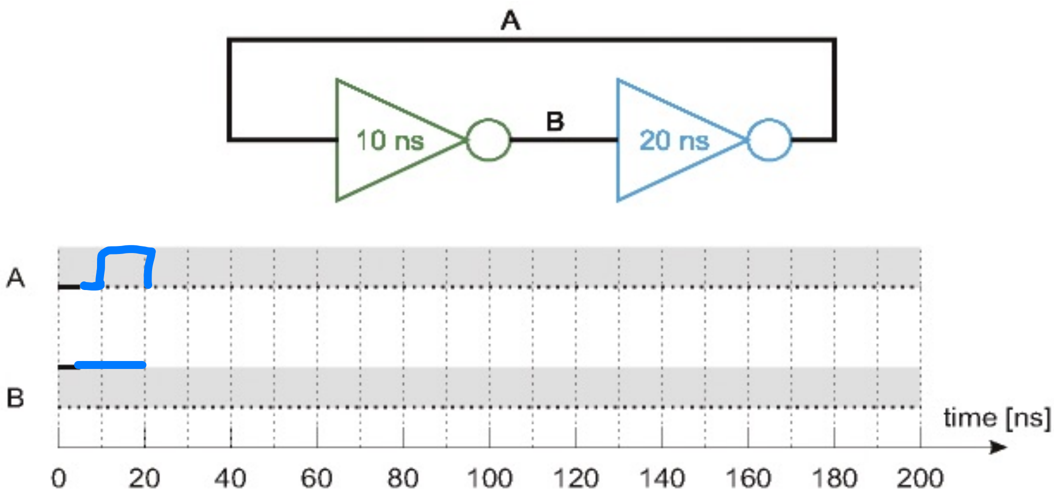
$= \bar{a} \cdot (\bar{b} + \bar{c})$

Exercise 5

1.




2.




Question 2 :

# Excercise 1

## Question 1.

**1.** 17 in binary

| | |
|---|---|
| 1 | 17 |
| 0 | 8 |
| 0 | 4 |
| 0 | 2 |
| 1 | 1 |
| | 0 |

$\therefore$ 10001

**2.** 10010 in unsigned decimal

$$\Rightarrow \begin{array}{ccccc} 1 & 0 & 0 & 1 & 0 \\ 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \end{array} = 2^4 + 2^1 = 16 + 2 = 18$$

**3.** 7 bits $\longrightarrow 2^7 - 1 = 128 - 1 = 127$

**4.** 1010 + 0110

$$\Rightarrow \begin{array}{r} 1010 \\ \underline{0110} \\ 10000 \end{array} = 16 \qquad \begin{array}{l} \longrightarrow 2^3 + 2^1 = 10 \\ \longrightarrow \underline{2^2 + 2^1 = 6} \\ \qquad\qquad\quad 16 \end{array}$$

# Excercise 2

## Question 1.

3. Program consisting of 20 instruction

$1^{st}$ instruction = 7 nanoseconds
rest 19 instructions = 19 nanoseconds

$\therefore$ 26 nano seconds

5. 20 instruction with Pipelining = 26 ns
20 instruction without pipelining = 20 × 7
= 140 ns

$$\text{Speed Up Ratio} = \frac{140}{26} = 5.38$$

we should clock non-pipelined data-path with frequency 5.38 × faster than the pipelined one.

## Question 2

1.

| | |
|---|---|
| 0 | 20752 |
| 0 | 10376 |
| 0 | 5188 |
| 0 | 2594 |
| 1 | 1297 |
| 0 | 648 |
| 0 | 324 |
| 0 | 162 |
| 1 | 81 |
| 0 | 40 |
| 0 | 20 |
| 0 | 10 |
| 1 | 5 |
| 0 | 2 |
| 1 | 1 |
| | 0 |

101000100010000 – unsigned
0101000100010000 – Signed 16-bit
0101000100010000 – One's complement
0101000100010000 – Two's complement

  0101000100010000
+ 1000000000000000
$\overline{\phantom{0}}$
1101000100010000 – Excess $-2^{16-1}$

# Question 3

1.

| | |
|---|---|
| | 14356 |
| 0 | 7178 |
| 0 | 3589 |
| 1 | 1794 |
| 0 | 897 |
| 1 | 448 |
| 0 | 224 |
| 0 | 112 |
| 0 | 56 |
| 0 | 28 |
| 0 | 14 |
| 0 | 7 |
| 1 | 3 |
| 1 | 1 |
| 1 | 0 |

111 0000001 0100 $\longrightarrow$ unsigned

00111 0000001 0100 $\longrightarrow$ signed

00111 0000001 0100 $\longrightarrow$ 1's complement

00111 0000001 0100 $\longrightarrow$ 2's complement

$$
\begin{array}{r}
0011100000010100 \\
+\ 1000000000000000 \\
\hline
1011100000010100
\end{array}
\longrightarrow \text{Excess } 2^{15}
$$

2. Largest + Number in 6 bits

<u>Signed Number:</u>

Decimal : $2^{5-1} = 32-1 = 31$

Binary : 011111

<u>One's Complement:</u>

Decimal : $2^{5-1} = 32-1 = 31$

Binary : 011111

<u>Two's Complement:</u>

Decimal : $2^{5-1} = 32-1 = 31$

Binary : 011111

<u>Excess $2^{m-1}$:</u>

Decimal : 31

Binary : 111111

3. Largest - number in 6 bits

<u>Signed Magnitude :</u>

Decimal : $2^5 - 1 = -31$

Binary : 111111

<u>One's complement :</u>

Decimal : -31

Binary : 100000

<u>Two's complement :</u>

Decimal : -32

Binary : 100000

<u>Excess $2^5$ :</u>

Decimal : -32

Binary : 000000

## Exercise 3

Question 1

1.

| | Big Endian | Little Endian |
|---|---|---|
| 0 | 01011100 | 11001111 |
| 1 | 10010110 | 00000011 |
| 2 | 00000011 | 10010110 |
| 3 | 11001111 | 01011100 |

2.

WELCOME CLASS 2021

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $R_0$ : | – | E | M | O | C | L | E | W |
| $R_1$ : | O | 2 | – | S | S | A | L | C |
| $R_2$ : | x | x | x | x | x | x | 2 | 1 |

# Floating Point

$$
\begin{array}{r}
0.0625 \\
16\overline{)100} \\
96 \\
\hline
0040 \\
32 \\
\hline
080 \\
80 \\
\hline
0
\end{array}
$$

1. $\underbrace{0}_{\text{Signed Bit}}\,\underbrace{10000010}_{\text{Exponent Bits}}\,\underbrace{10110\ldots\ldots0}_{\text{Fraction Bits}}$

I] $s = \underline{0}$ (Possitive Bit)

II] $(10000010)_2 = 2^1 + 2^7 = 2 + 128 = 130$

exp. bias $= 130 - 128 = \underline{\underline{2}} = e$

III] $m = 2^{-1} + 2^{-3} + 2^{-4}$

$= \frac{1}{2} + \frac{1}{8} + \frac{1}{16}$

$= 0.5 + 0.125 + 0.0625$

$= 0.6875$

$\therefore$ $1.6875 \times 10^{2}$

2. $\underbrace{0}_{\text{Signed Bit}}\,\underbrace{10001000}_{\text{Exponent Bit}}\,\underbrace{010011010010\cdots\cdots0}_{\text{Fraction Bit}}$

I] $e = 2^3 + 2^7 = 8 + 128 = 136$

exp.bias $= 136 - 128 = 8$

II] $2^{-2} + 2^{-5} + 2^{-6} + 2^{-8} + 2^{-11}$

$\Rightarrow \frac{1}{4} + \frac{1}{32} + \frac{1}{64} + \frac{1}{256} + \frac{1}{2048}$

$\Rightarrow \frac{2^9 + 2^6 + 2^5 + 2^3}{2048}$

$\Rightarrow \frac{512 + 64 + 32 + 8}{2048}$ 768 80

$\Rightarrow \frac{\cancel{616}}{\cancel{2048}}$ $\cancel{308}$ $\cancel{154}$ 77

$\cancel{1024}$ $\cancel{512}$ 256

$$
\begin{array}{r}
0.300 \\
256\overline{)\cancel{770}} \\
\cancel{768} \\
\hline
\cancel{00}\ 2000
\end{array}
$$