

Bit Manipulation

0, 1 → Binary numbers

0/1
bit

2 + 3

8 bits ⇒ 1 byte

int ⇒ 4 bytes ⇒ $4 \times 8 \Rightarrow 32$ bits

decimal
↓
binary → operate
↑
binary

$\begin{array}{r} 2^1 \\ \hline 2 | 10 \\ 2 | 5 \\ 2 | 2 \\ 2 | 1 \\ \hline 0 \end{array}$

⇒

$1 \ 0 \ 1 \ 0 \ 1$
 $\begin{array}{l} \xrightarrow{2^0 \times 1} \\ \xrightarrow{2^1 \times 0} \\ \xrightarrow{2^2 \times 1} \\ \xrightarrow{2^3 \times 0} \\ \xrightarrow{2^4 \times 1} \end{array}$
 $\begin{array}{r} 1 \\ 0 \\ 4 \\ 0 \\ 0 \\ 16 \\ \hline 21 \end{array}$

Bitwise Operators

& | ^ ~ << >> >>>

① And (&)

a & b → are bits	
0	0
0	1
1	0
1	1

$a \& 0 \Rightarrow 0$
 $a \& 1 \Rightarrow a$

OR (|)

a b	
0	0
0	1
1	0
1	1

$$\begin{array}{l} a | 1 \Rightarrow 1 \\ a | 0 \Rightarrow a \end{array}$$

$$\begin{array}{r} 101 \\ \times 101 \\ \hline 01 \end{array}$$

$$\begin{array}{r} 1011 \\ \times 0110 \\ \hline \underline{\underline{01111}} \end{array}$$

② XOR (^)

$a \wedge b$

a ^ b	
0	0
0	1
1	0
1	1

$a \wedge 0 \Rightarrow a$
 $a \wedge 1 \Rightarrow \sim a$
 $0 \wedge 1 \Rightarrow 1$
 $1 \wedge 1 \Rightarrow 0$

$$\begin{array}{r} 00000101 \\ 00000111 \\ \hline \end{array}$$

$$\begin{array}{r} 000000010 \\ \hline \end{array} \Rightarrow 2$$

$$a \wedge a \Rightarrow 0$$

④ \sim 's Compliment

$\sim a$

$\sim 0 \Rightarrow 1$

$\sim 1 \Rightarrow 0$

~ 2

000000010

111111101

⑤ Left Shift ($<<$)

$a = \underbrace{101110}_{110100\text{---}} \underbrace{100}_{00}$

$a << 2$

0100 00 00

$a << 4$

1 000001

2 000010

4 000100

8 001000

$1 << x \Rightarrow 2^x$

101 << 1

$x << 1 \Rightarrow 2^x$

1010

$x \rightarrow$ decimal number

⑥ Right shift >>

a = 0 1 0 0 0 1 1

a>>2

0 0 0 1 0 0 0 1

b = 1 0 1 1 0 1 1 0

b>>2

1 1 1 0 1 1 0 1

⑦ Triple right shift >>>

new bits are always 0

Only 0 is added on left

a = 0 1 0 0 0 1 1

a>>>2

0 0 0 1 0 0 0 1

b = 1 0 1 1 0 1 1 0

b>>>2

0 0 1 0 1 1 0 1

Ques Turn the i th bit on

$$\begin{array}{l} n, i \Rightarrow 5 \\ n \Rightarrow 105 \\ \begin{array}{r} & 8 & 7 & 6 & 5 & 4 & 3 & 2 & 1 \\ & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ \hline & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \end{array} \xrightarrow{\quad\quad\quad} \text{mask} \end{array}$$

Ques Turn the i th bit off

$$\begin{array}{l} n, i \Rightarrow 6 \\ n \Rightarrow 8 \\ \begin{array}{r} & 8 & 7 & 6 & 5 & 4 & 3 & 2 & 1 \\ & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ \hline & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \end{array} \quad 00100000 \end{array}$$

Ques Toggle the i th bit

$$\begin{array}{l} n, i \Rightarrow 5 \\ n \Rightarrow 8 \\ \begin{array}{r} & 8 & 7 & 6 & 5 & 4 & 3 & 2 & 1 \\ & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{array} \end{array}$$

Ques Check ith bit is on ?

i=4

8 7 6 5 4 3 2 1
0 1 1 0 1 0 0 1
8 0 0 0 0 1 0 0 0

op

op == 0 \Rightarrow bit was off

else bit was on

Ques Count the on bits (bits which are 1)

(n)

8 7 6 5 4 3 2 1
0 1 1 0 1 0 0 1

① while(n != 0) {
 if(n & 1 > 0) count++;
 n = n >> 1;

}

② Left shift 1 \geq 32 times
check every bit

Ques First set bit from left \Rightarrow 2
01110101

Ques First set bit from right \Rightarrow 1

Ques Swap 2 numbers

$$a = 5$$
$$b = 3$$

$$a = a \wedge b;$$

$$b = a \wedge b;$$

$$a = a \wedge b;$$

$$a = 3$$
$$b = 5$$

Ques $1(2(1(5(5/2(3)4)4)4)$ 4

n

Ques Reverse the bits

10 9 8 7 6 5 4 3 2 1
0 1 1 0 1 0 0 0 1 0

i New = $s_{32 - cur + 1}$
Cur New
+1

1 10 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

2 9

3 8

4 7 bit = $n \gg (cur - 1) \ \& \ 1$

5 6

bit << ($n - 1$)

6 5

7 4

```
8      3      public int reverseBits(int n) {  
9      2      int ans = 0;  
10     1      for(int cur = 1; cur <= 32; cur++) {  
              int bit = (n >> (cur - 1)) & 1;  
              int newPos = 32 - cur + 1;  
              int mask = bit << (newPos - 1);  
              ans = ans | mask;  
              }  
              return ans;
```

10 10

↑
c

0 1 0 1

Ques Single number 2

Every no is present thrice except one number which is present only once. Find that

① Brute force

$$TC \Rightarrow O(n^2)$$

0	1	1	0	1	1	0	1	1	99
---	---	---	---	---	---	---	---	---	----

② Sort the array

$$TC \Rightarrow O(n \log_2 n)$$

0	1	0	1	1	1	1	1	99
---	---	---	---	---	---	---	---	----

③ Hashmap

0	3
1	3
99	1

$$TC \Rightarrow O(n)$$

$$SC \Rightarrow O(n)$$

3, 3, 3, 6

④ Bitwise

$$TC \Rightarrow O(32n)$$

$$\Rightarrow O(n)$$

$$SC \Rightarrow O(1)$$

0 0 1 1

0 0 1 1

0 0 1 1

0 1 1 0

0 1 1 0

③ Bitwise sol

Ones $\Rightarrow 3n+1 \Rightarrow 1, 4, 7, 10, 13, \dots$

twos $\Rightarrow 3n+2 \quad 2, 5, 8, 11, 14, \dots$

3, 6, 3, 3



0 0 1 1

1 1 1 0

0 \Rightarrow 0 1 1 0
t \Rightarrow 0 0 0 0

① update twos

② update ones

③ remove factor
of 3 from
ones and twos