PW SKILLS

C++
Bitwise Operations

Lecture- 37

Sanket Singh

COLLEGE WALLAH

Converting a decimal number to binary and vice versa

lsb → least significant bit

msb → most significant bit

Binary 2 decimal →

1 0 1

1 1 0 1

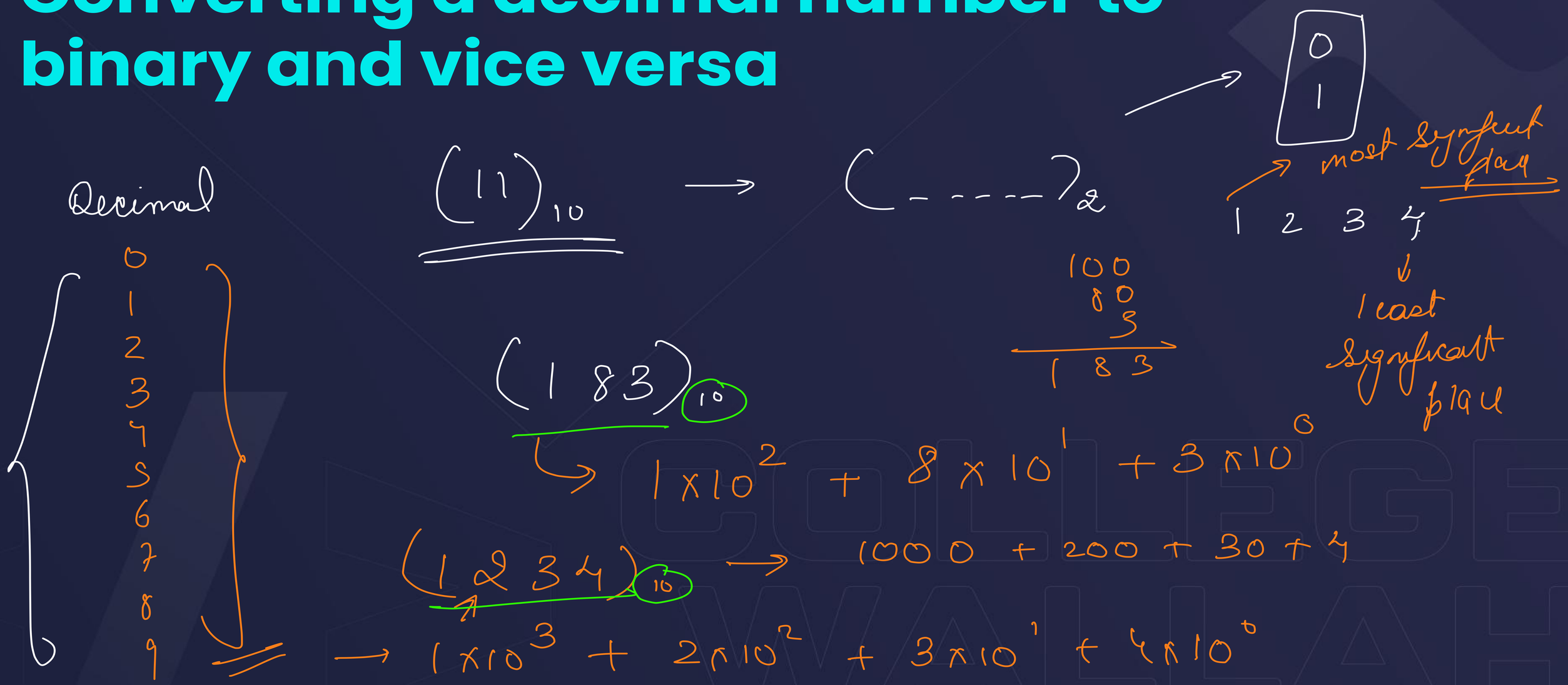
msb

lsb

0 0 1 1 0 1 0 1

COLLEGE WALLAH

Converting a decimal number to binary and vice versa



6 → 1 1 0

0 1 0

7 ← 1 1 1

0 1 0 → 2

2

(0 0 1 1 0 1)$_2$ =

$0\times2^5 + 0\times2^4 + 1\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0$

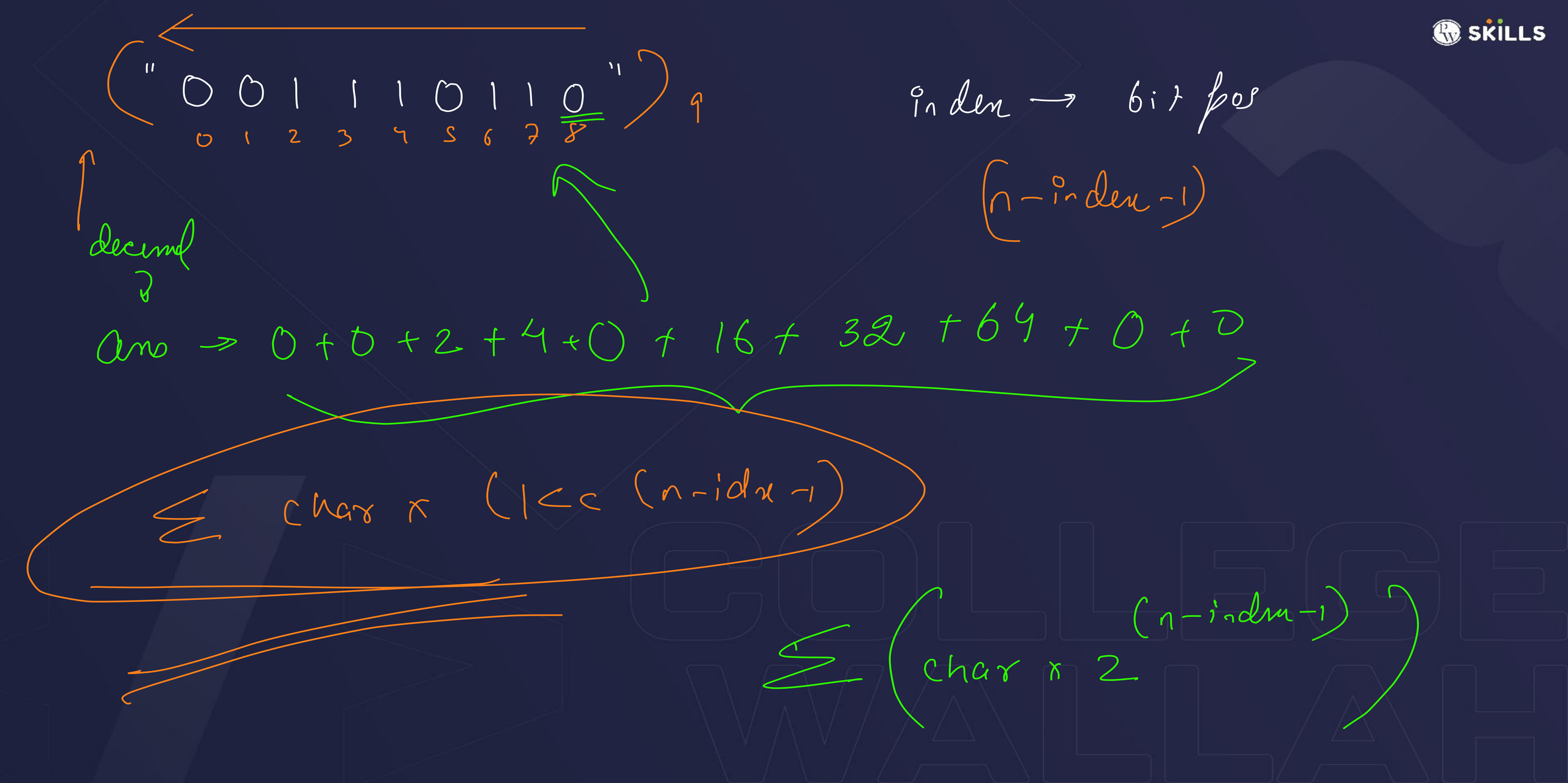
$1\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0$

8 + 4 + 0 + 1

8 + 4 + 1 ⇒ 13

1 0 1 1 → $1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0$

8 + 0 + 2 + 1 → 11


"0 0 1 1 1 0 1 1 0"
0 1 2 3 4 5 6 7 8
n
index → bit pos
(n-index-1)
decimal
ans → 0+0+2+4+0+16+32+64+0+0
Σ char × (1<<(n-idx-1))
Σ (char × 2^(n-index-1))

SKILLS

$2^0 \rightarrow 1 \longrightarrow 1$

$2^1 \rightarrow 2 \longrightarrow 10$

$2^2 \rightarrow 4 \longrightarrow 100$

$2^3 \rightarrow 8 \longrightarrow 1000$

$2^4 \rightarrow 16 \longrightarrow 10000$

$2^5 \rightarrow 32 \longrightarrow 100000$

$2^x \rightarrow 100000\ldots$ (x times)

$7 \rightarrow 00000111$

$7 << 3$

00111000

$<< \rightarrow$ bit shift

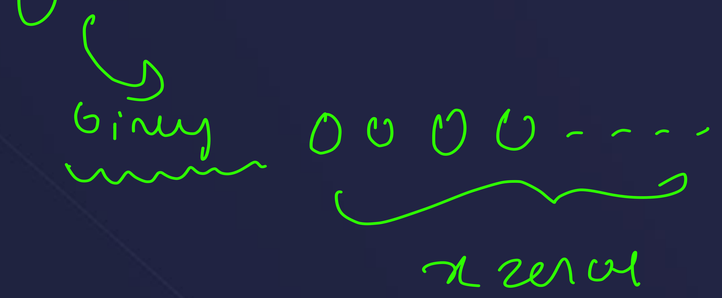
$5 << 2$

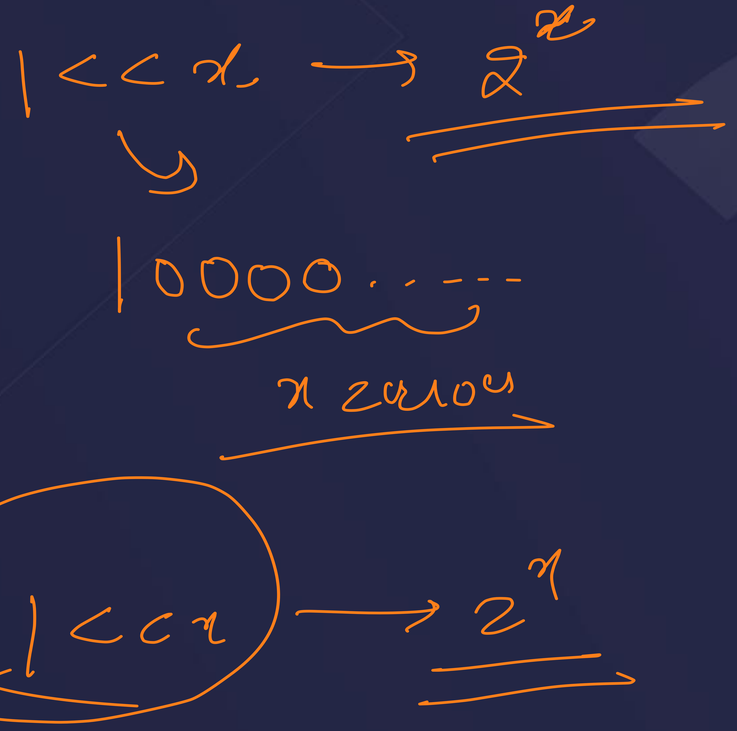
101

00010100

one

none or some zeroes





SKILLS
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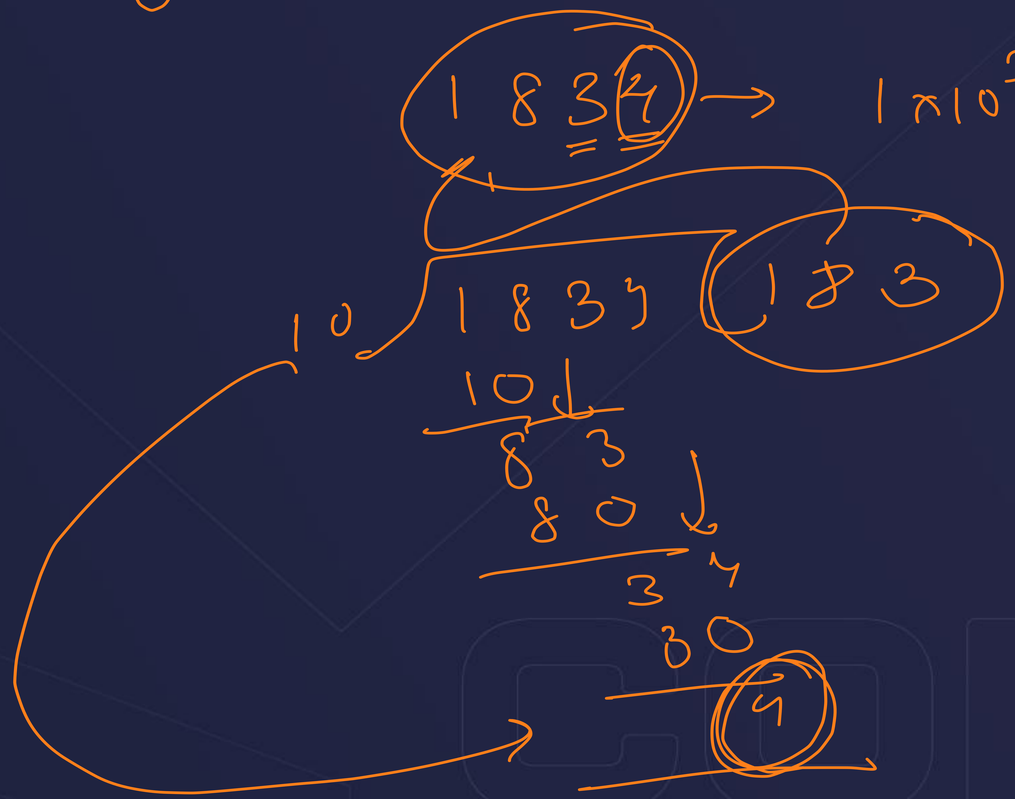
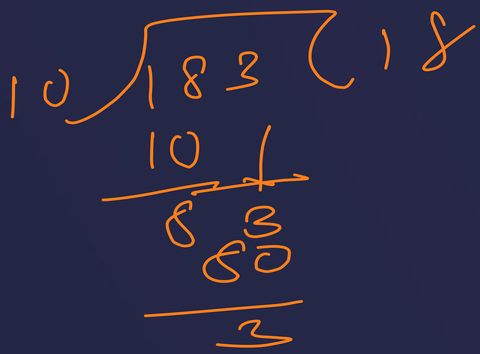
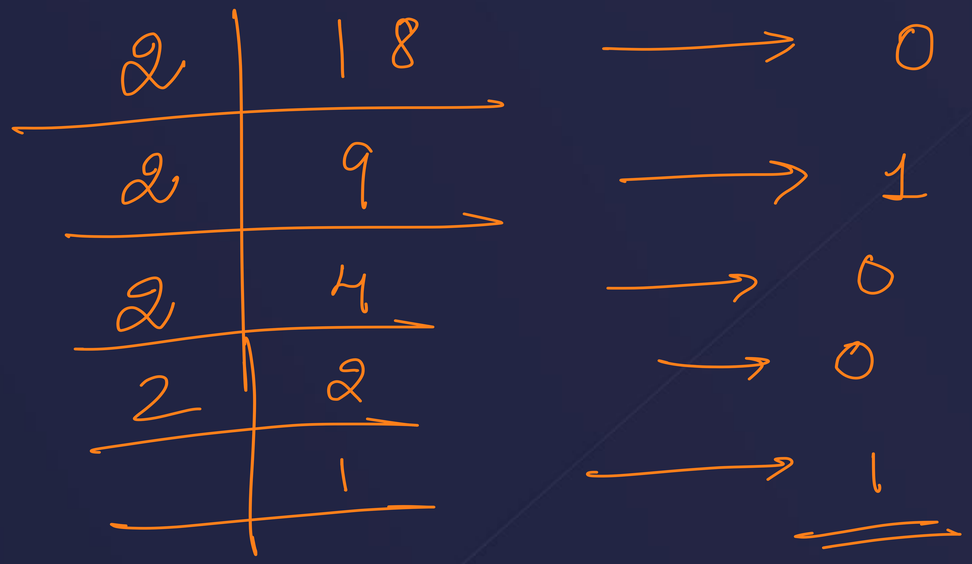
Decimal Binary ⟶ 18 → $1 \times 10^1 + 8 \times 10^0$







$10010 \rightarrow 18$

COLLEGE WALLAH

0 → 0000 ✓
1 → 0001 ✓
2 → 0010 ✓
3 → 0011 ✓
4 → 0100 ✓
5 → 0101 ✓
6 → 0110 ✓
7 → 0111 ✓
8 → 1000 ✓

4

even → lsb → 0

odd → lsb → 1

18 → 9 (18 % 2 == 0)

0 1 0

(9 % 2 == 0) ?

X

s → 0 1 0 X

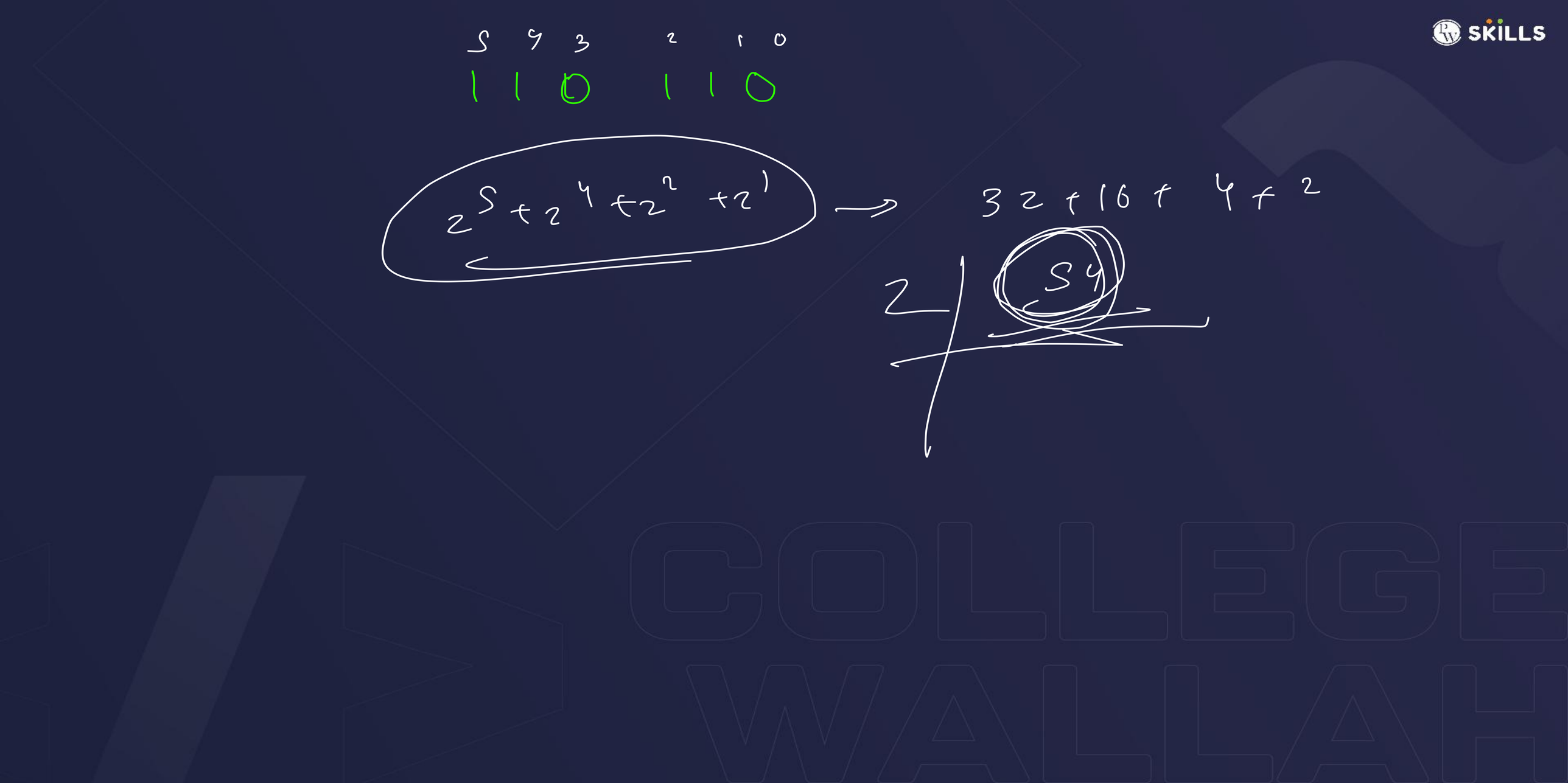
s >> 1

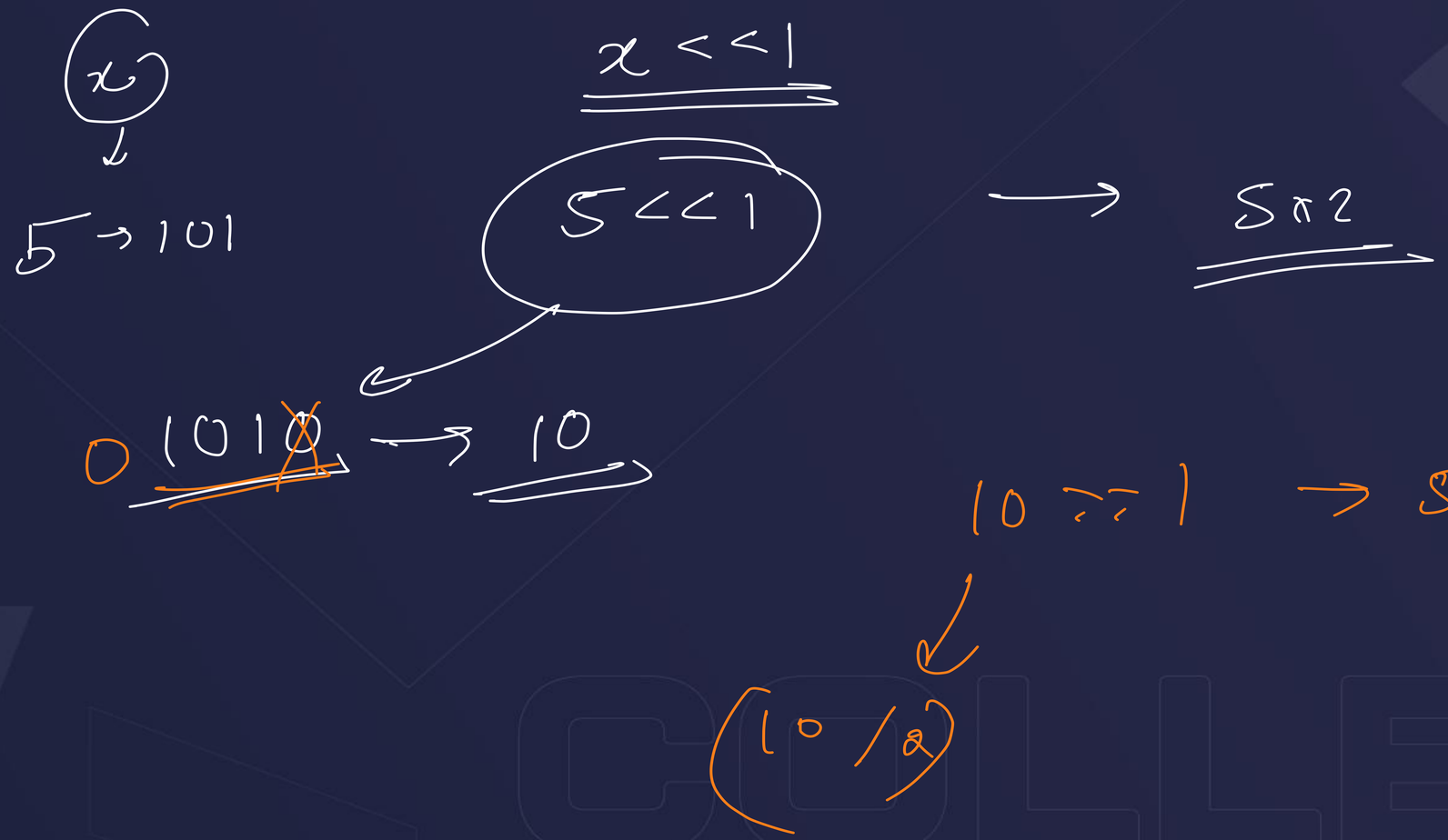
right shift

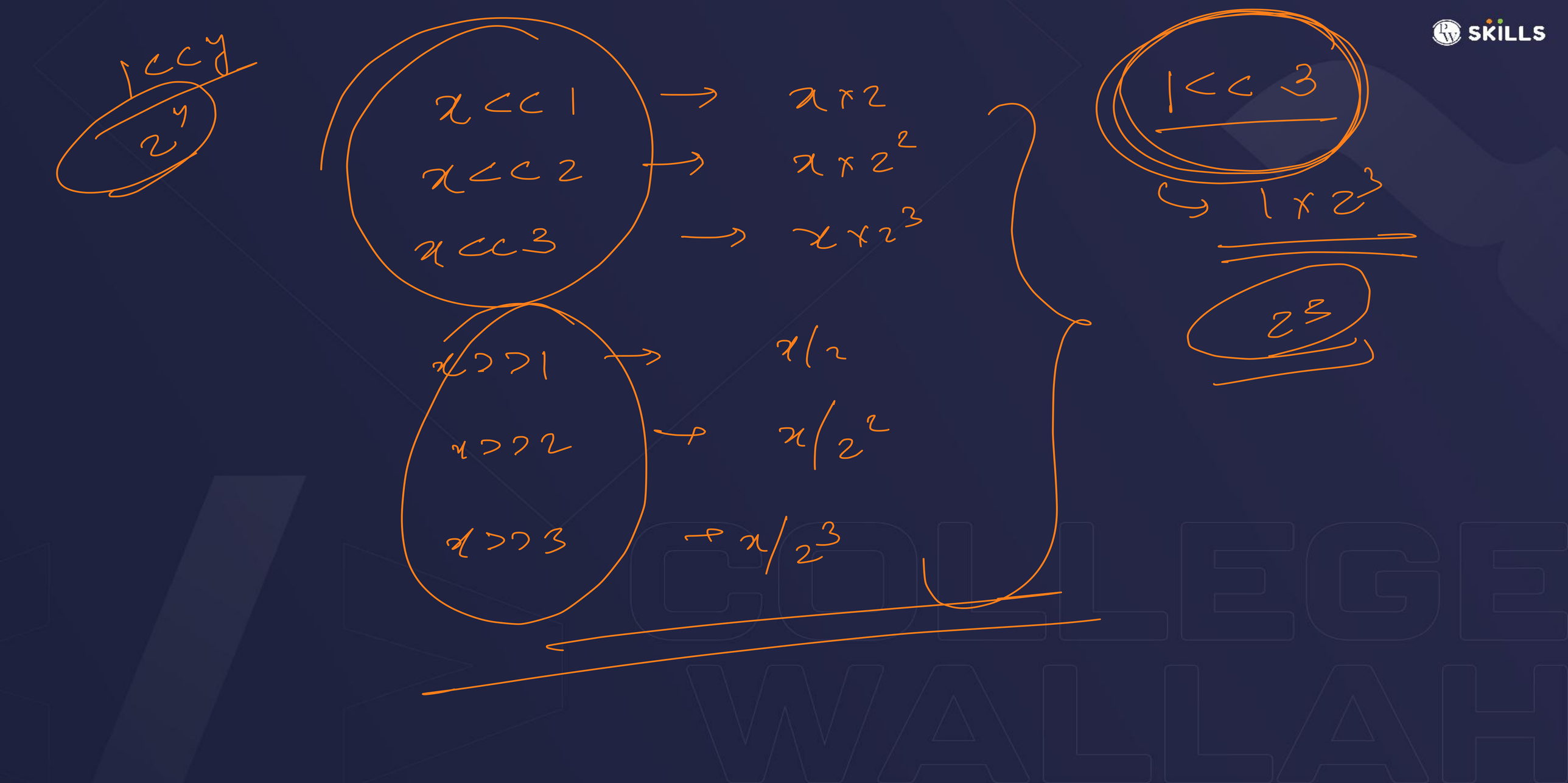
0 1 0 X

→ 2

s / 2 | 1 → 9


5 4 3 2 1 0
1 1 0 1 1 0
$2^5 + 2^4 + 2^2 + 2^1$
32 + 16 + 4 + 2
2
54

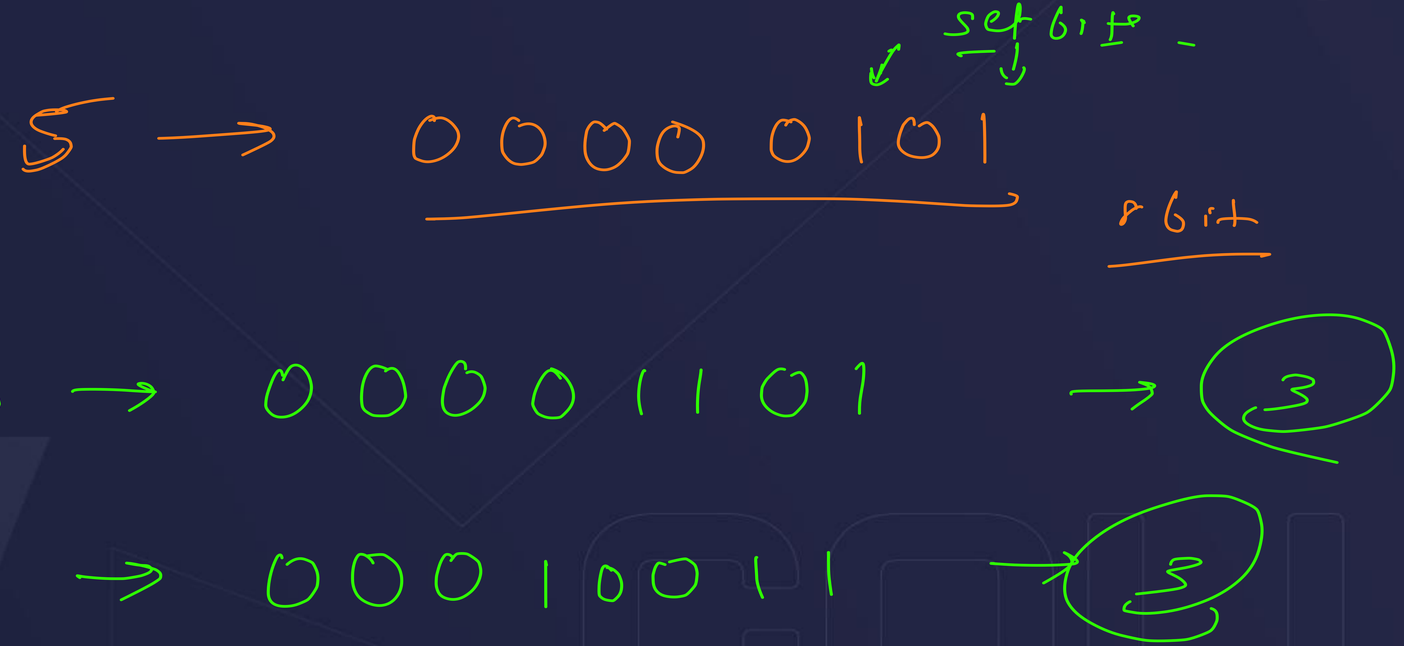

x
5 → 101
x << 1
5 << 1
5 * 2
0 1010 → 10
10 :: 1 → 5
(10)2


1<<y
2^y
x<<1
x<<2
x<<3
x*2
x*2^2
x*2^3
x>>1
x>>2
x>>3
x/2
x/2^2
x/2^3
1<<3
1*2^3
2^3

Practice

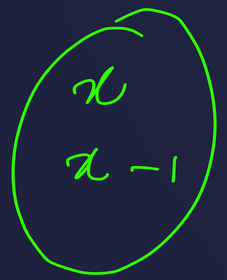
__builtin_popcount(n) →

Find the number of set bits for any integer n.



13 → 1101
12 → 1100

16 → 10000
15 → 01111



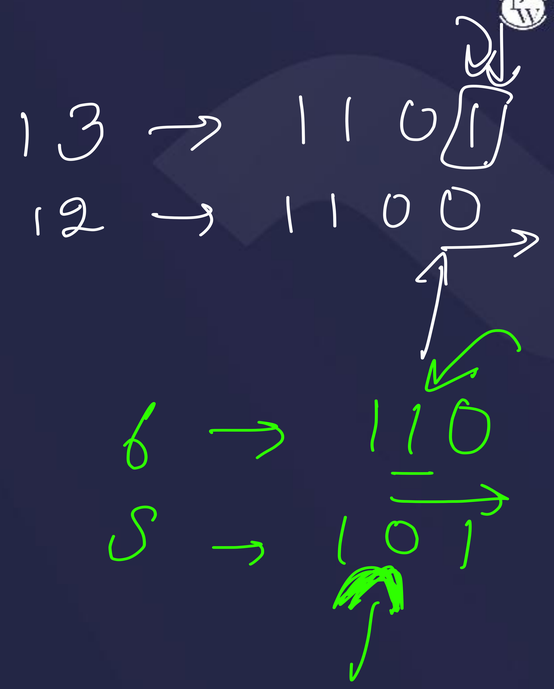
10 → 1010
9 → 1001

3 → 011
2 → 010

6 → 110
5 → 101

23 → 10111
22 → 10110

22 → 10110
21 → 10101



x

22 → 1 0 1 1 0

21 → 1 0 1 0 1

23 → 1 0 1 1 1

22 → 1 0 1 1 0

16 → 1 0 0 0 0

15 → 0 1 1 1 1

9 → 1 0 0 1

8 → 1 0 0 0

7 6 5 4 3 2 1 0

204 1 1 0 0 1 1 0 0

128 + 64 + 8 + 4

192 → 200 → 204

203 1 1 0 0 1 0 1 1

128 + 64 + 8 + 2 + 1

192 → 200 → 203

Same flipped

22 & 21

$x \rightarrow$ 10110

$x-1 \rightarrow$ 10101

10100

$x \,\&\, x-1$

bitwise and

22 & 21

22 → 22 & 21 → 10110 & 10101

20 → 10100

20 & 19 → 10100 & 10011

16 → 10000

16 & 15 → 10000 & 01111

→ 0

Brian Kernighan's

$x = x \,\&\, x-1$

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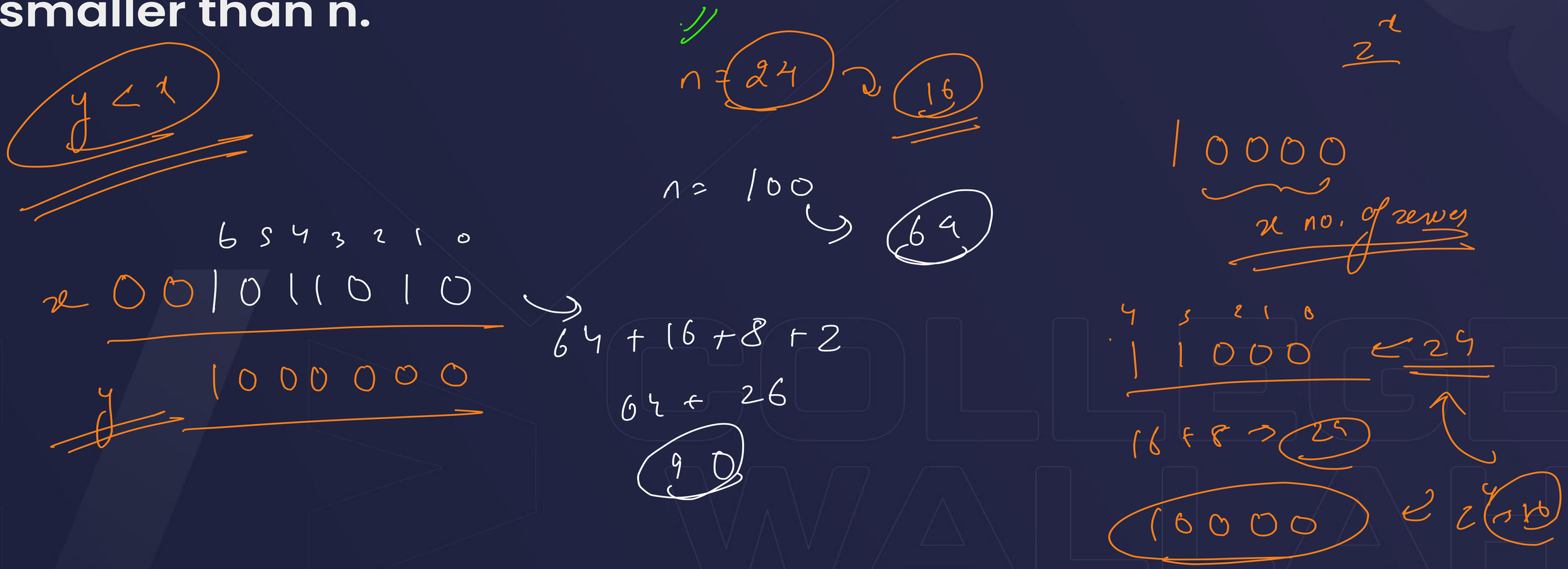
SKILLS
COLLEGE WALLAH

Practice

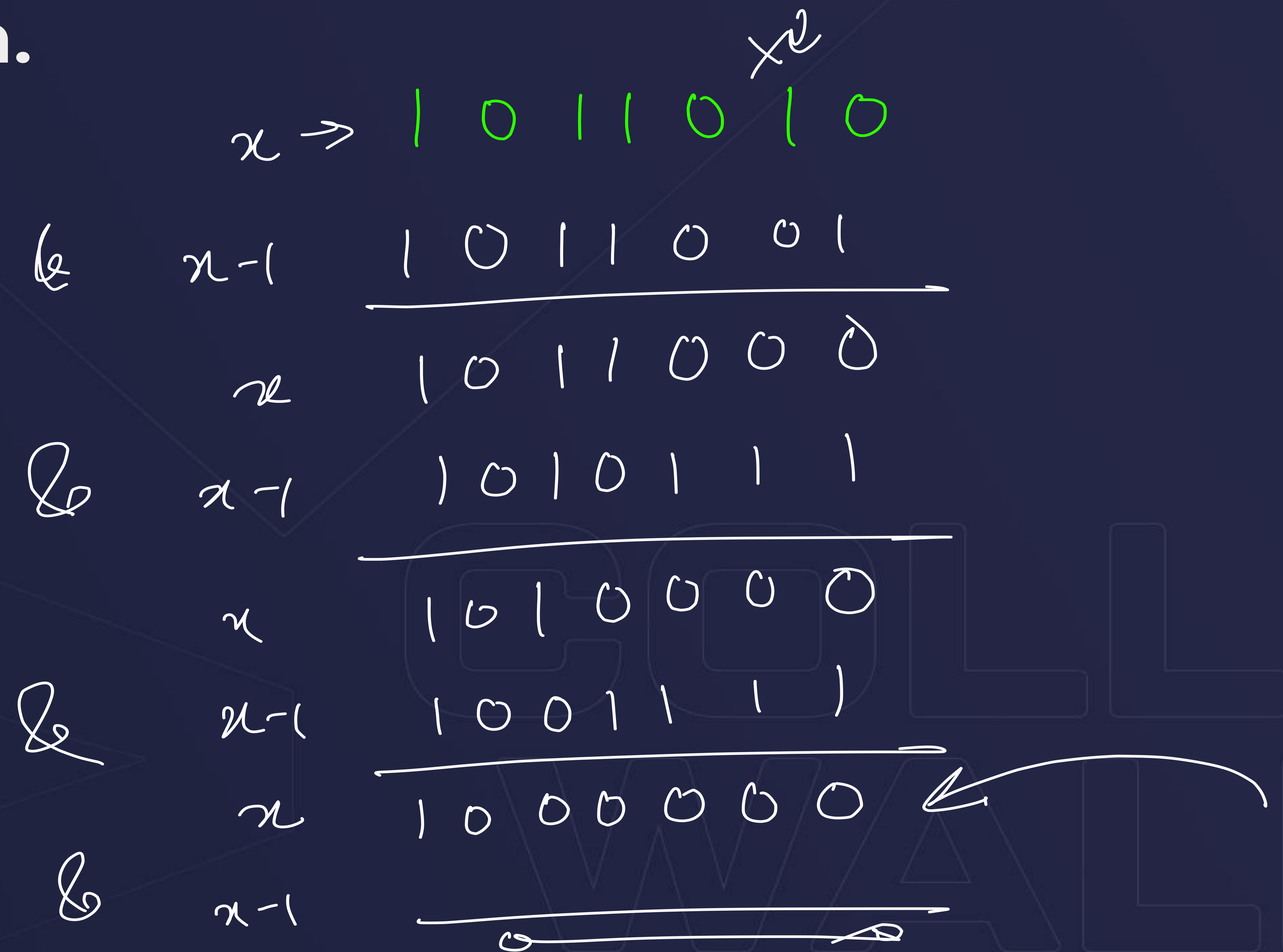
Given an integer n, find the maximum power of two that is smaller than n.



Practice

Hey

Given an integer n, find the maximum power of two that is smaller than n.



Practice

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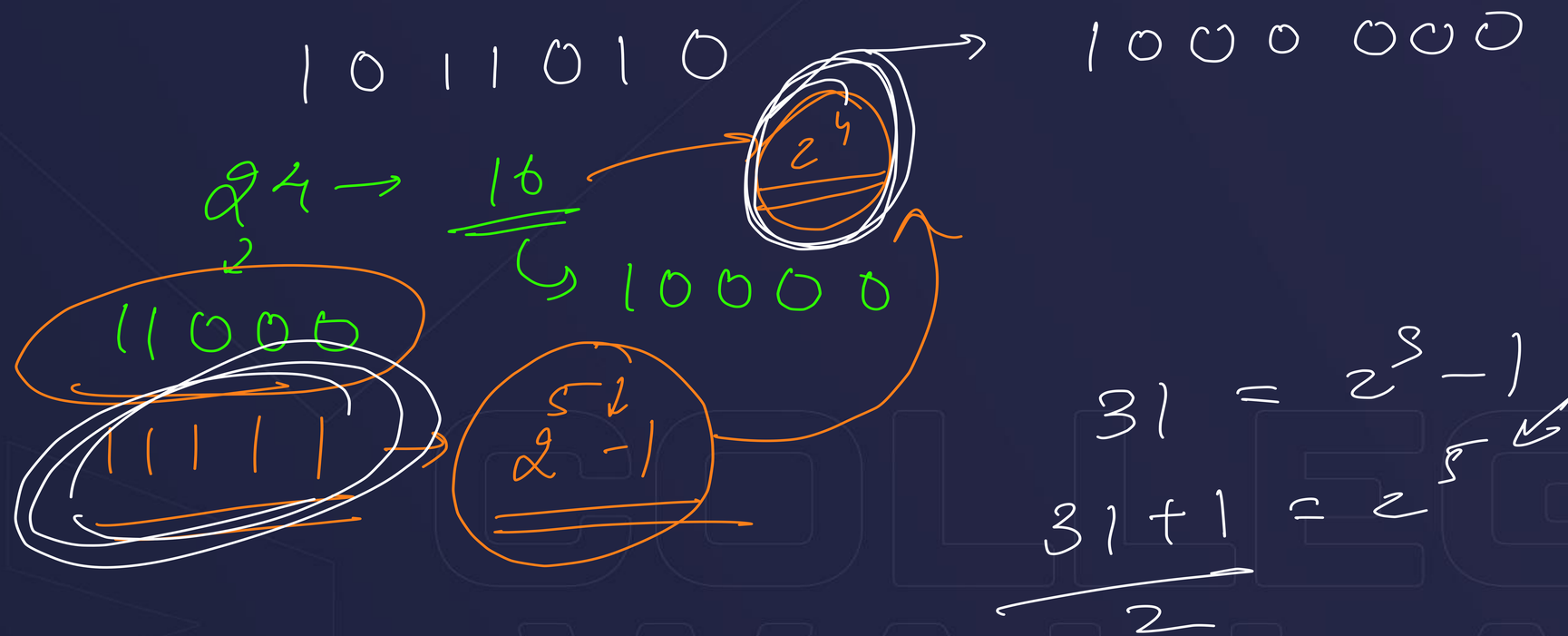

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N (10000000)

N = N | (N >> 1) → N = 11000000

N = N | N >> 2 N 00111000

N = N | N >> 4 11110000

00001111

N = N | N >> 8 1111111100000000

$N = 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0$

2^7

$N = N \mid N >> 1$

$N = N \mid N >> 2$

$N = N \mid N >> 4$

$N = N \mid N >> 8$

$N = N \mid N >> 16$

$1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \mid 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0$ (7)

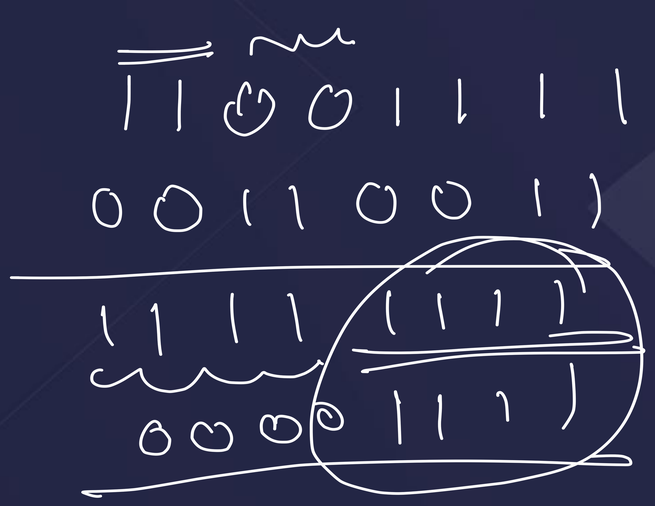
$1\ 1\ 0\ 0\ 0\ 0\ 0\ 0$

$0\ 0\ 1\ 1\ 0\ 0\ 0\ 0$

$1\ 1\ 1\ 1\ 0\ 0\ 0\ 0$

$0\ 0\ 0\ 0\ 1\ 1\ 1\ 1$

$1\ 1\ 1\ 1\ 1\ 1\ 1\ 1$



$N = N | N >> 1$

$N = N | N >> 2$

$N = N | N >> 4$

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Practice

Given an integer n, flip all its bits i.e. if the given bit is 1, change it to 0 and vice versa.

Practice

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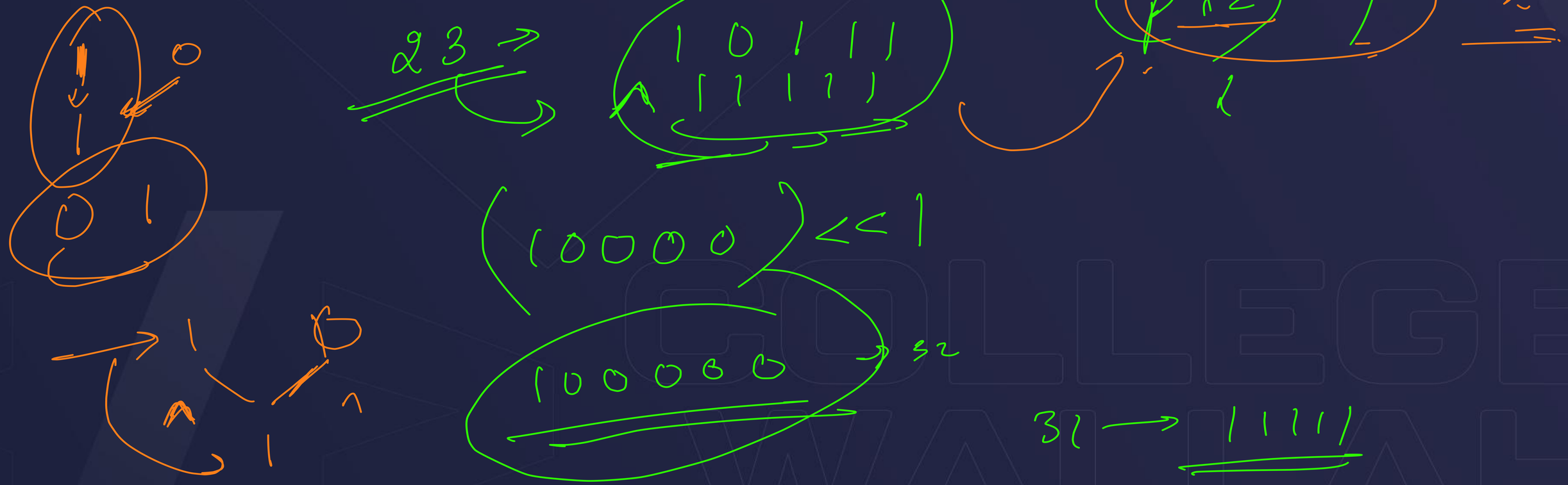


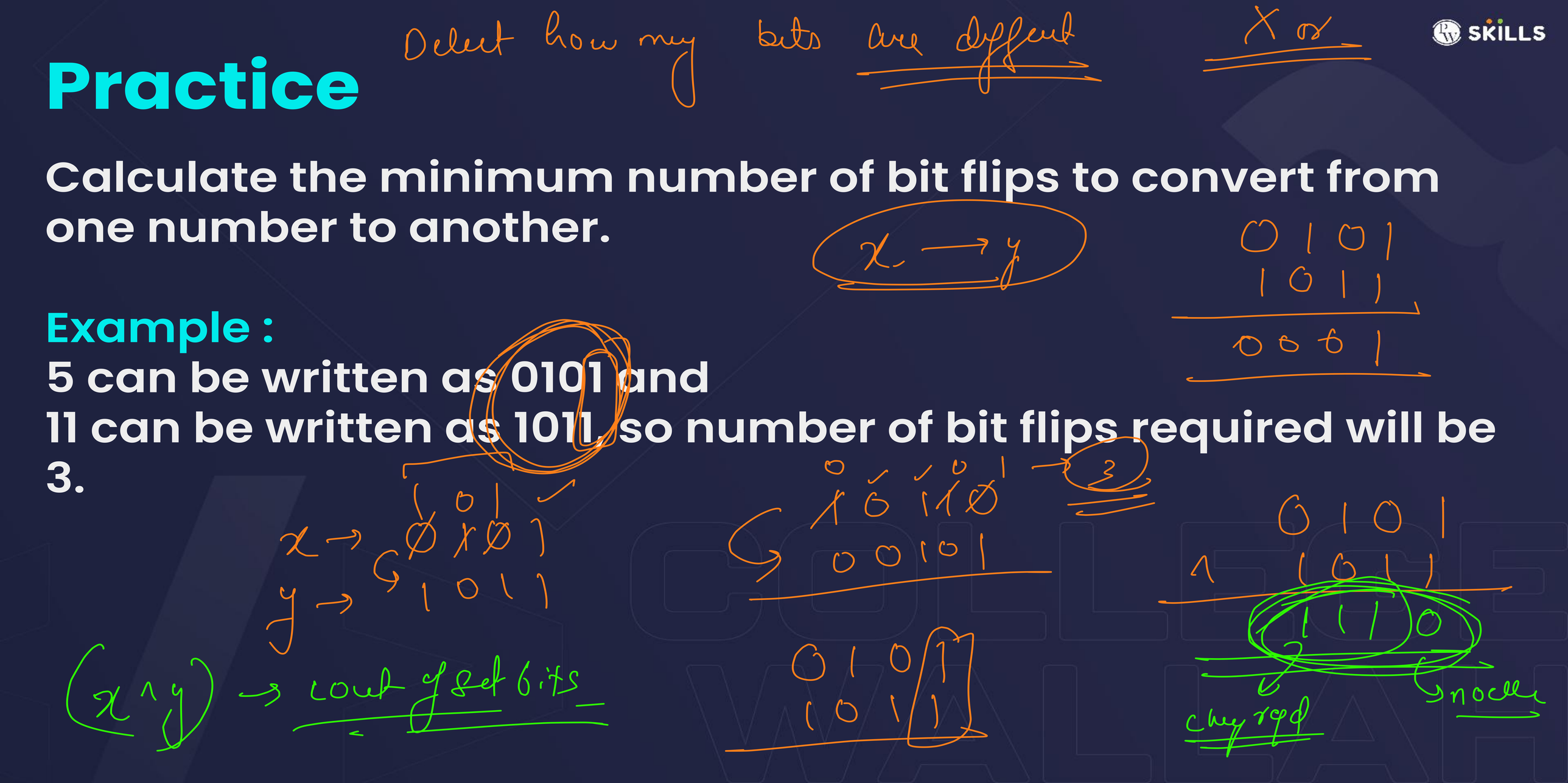
Practice

Calculate the minimum number of bit flips to convert from one number to another.

Example :

5 can be written as 0101 and

11 can be written as 1011, so number of bit flips required will be 3.



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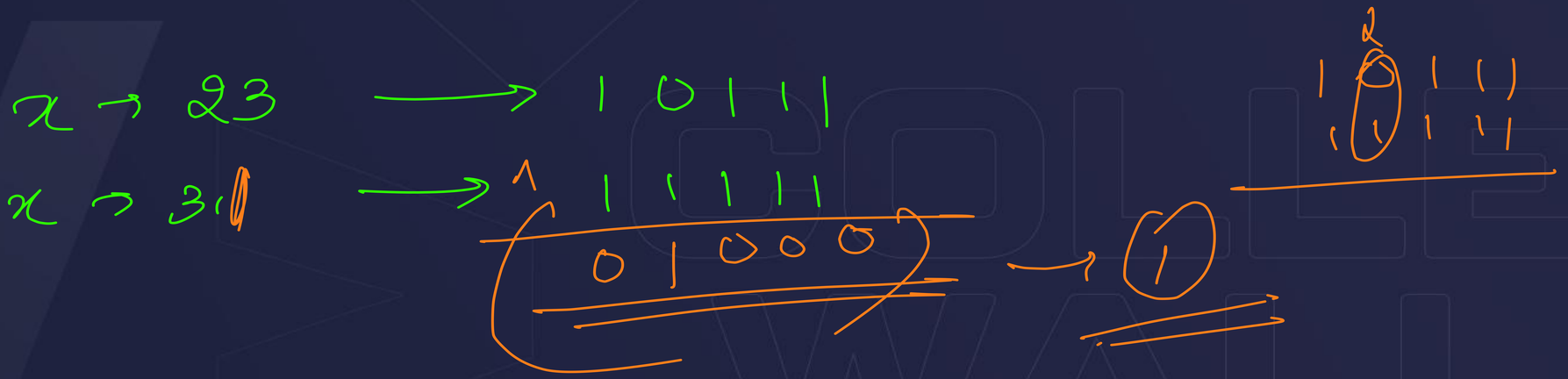
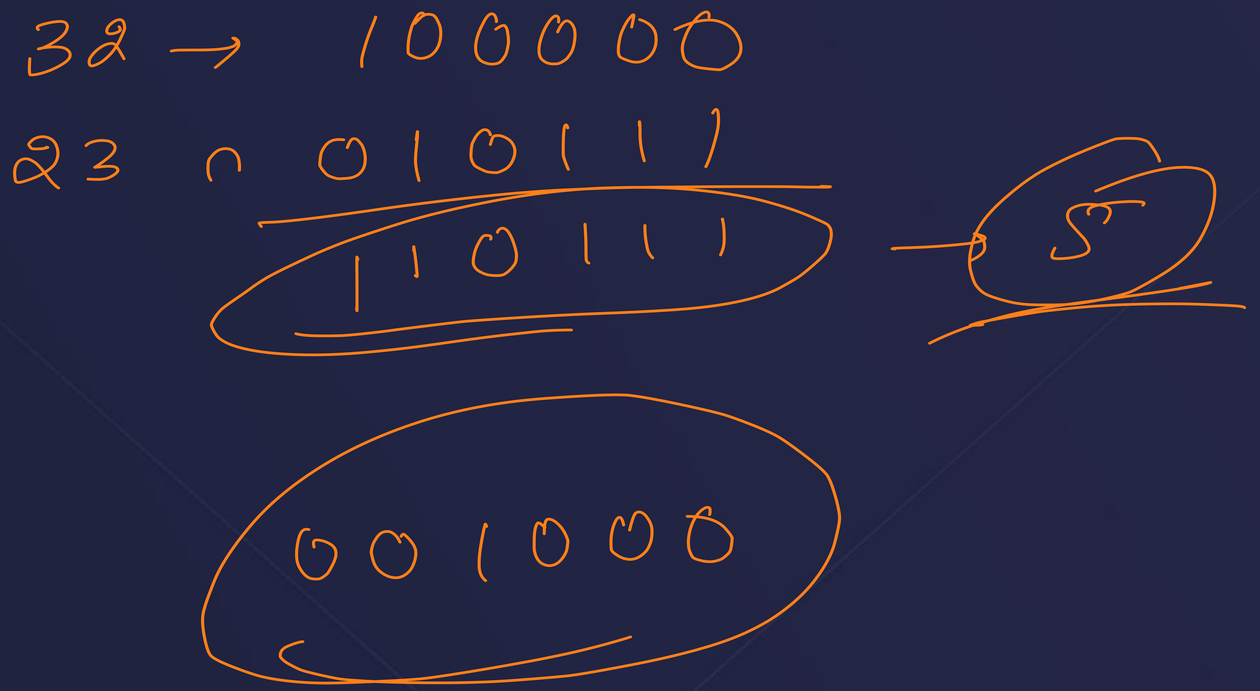


COLLEGE WALLAH



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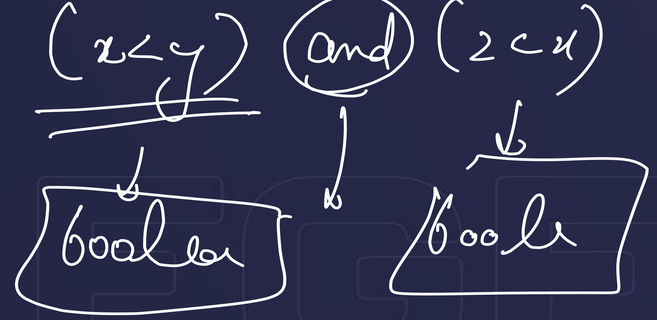
Basic bitwise operations

- AND
- OR
- NOT
- XOR

↳ these are applied on the corresponding bits of the data.

logical
- and &&
- or ||
- not !

Boolean input



Basic bitwise operations

- AND → &
- OR → |
- NOT → ~
- XOR → ^

~

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And

X	Y	Result
0	0	0
0	1	0
1	0	0
1	1	1

OR

X	Y	Result
0	0	0
0	1	1
1	0	1
1	1	1

XOR

X	Y	Result
0	0	0
0	1	1
1	0	1
1	1	0

NOT

X	Result
0	1
1	0

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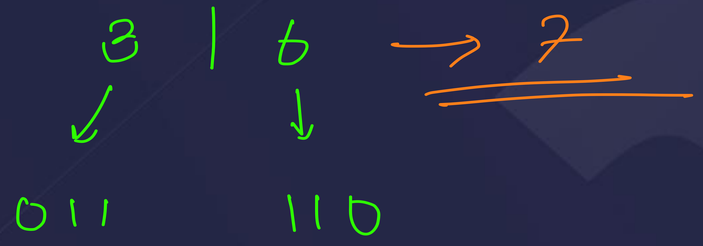
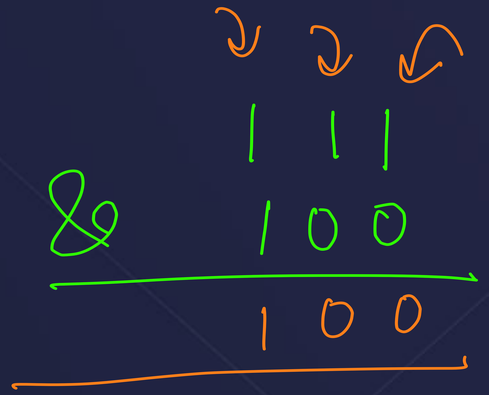
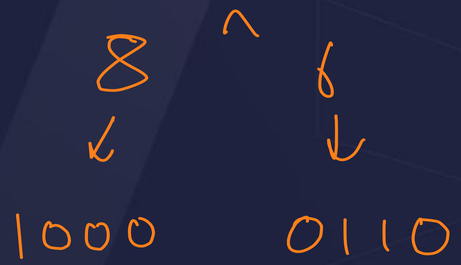
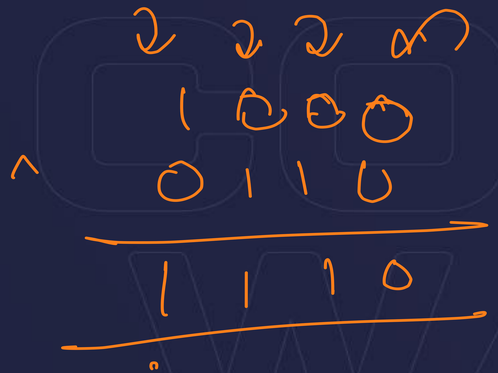
7 & 4 → 4
111
100


3 | 6 → 7
011
110


111
& 100
100

011
110
111


8 ^ 6
1000
0110


1000
^ 0110
1110
14

AND vs OR

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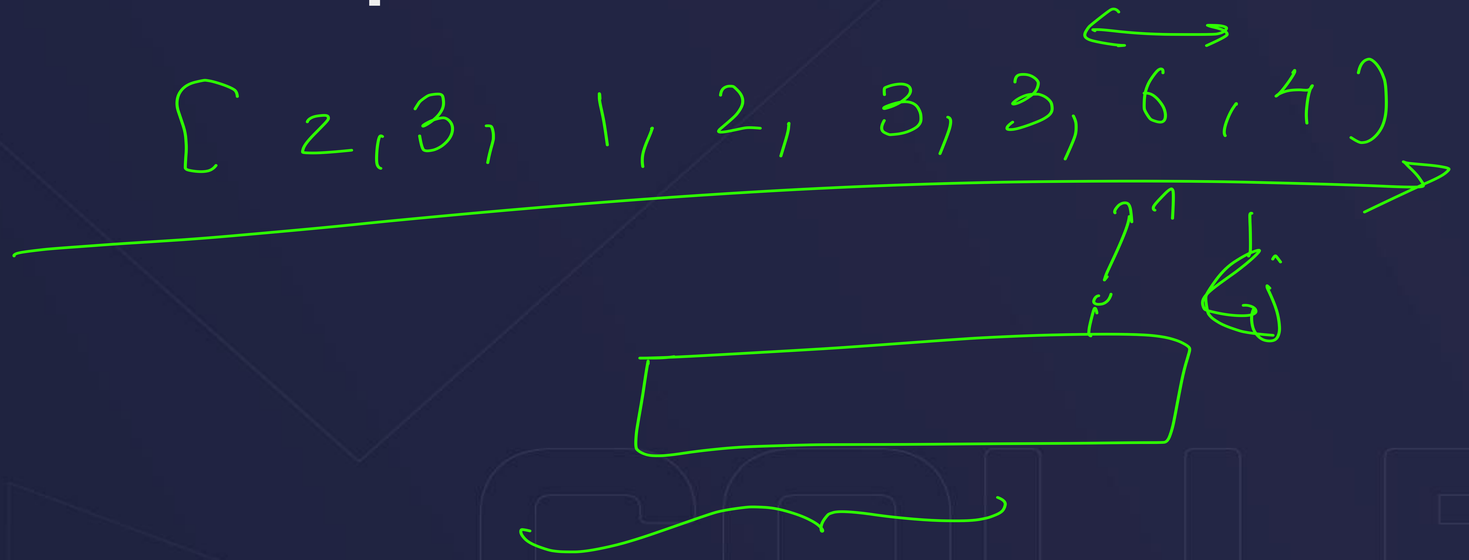
Practice

Given an integer array. Find the length of longest subarray which has maximum possible bitwise AND value.



Practice

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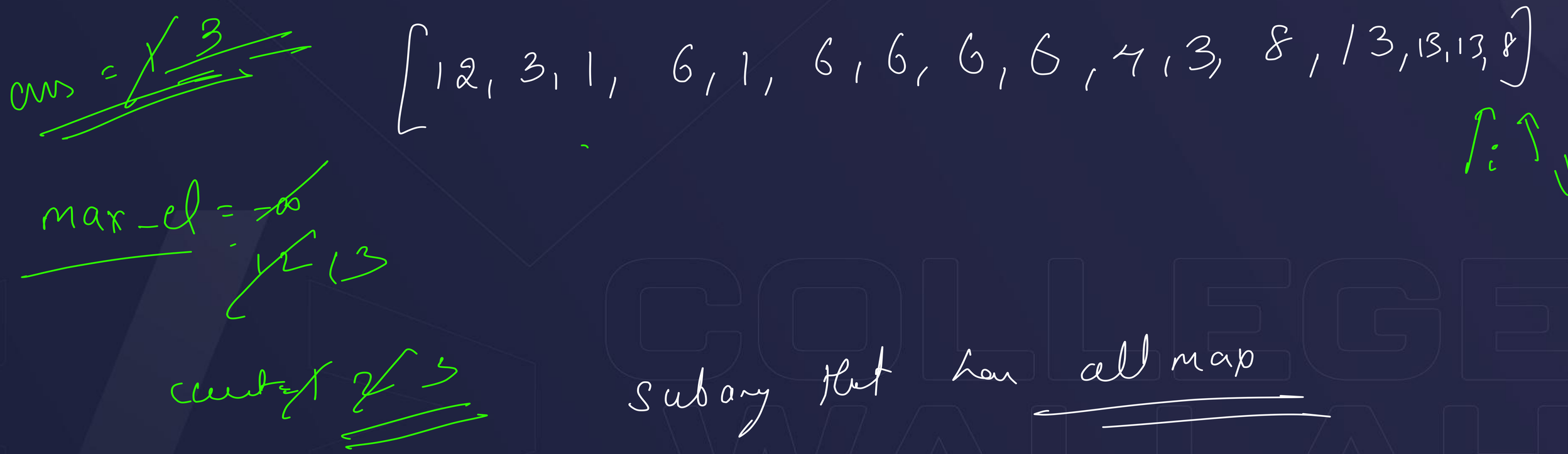

Basic Properties of XOR

- A ^ 0 = A
- A ^ A = 0
- If A ^ B = C, then A ^ C = B

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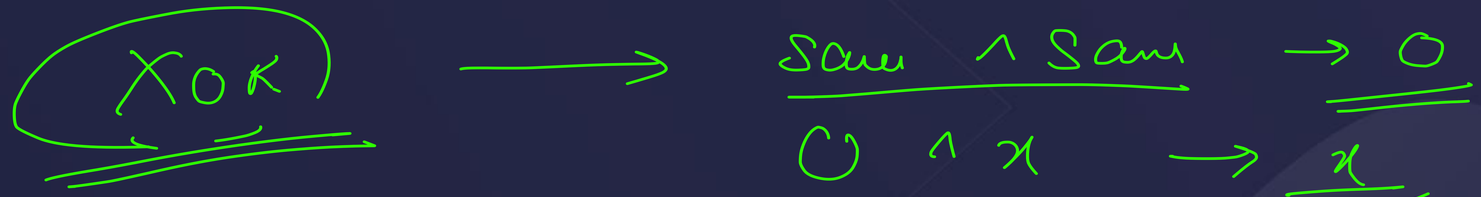
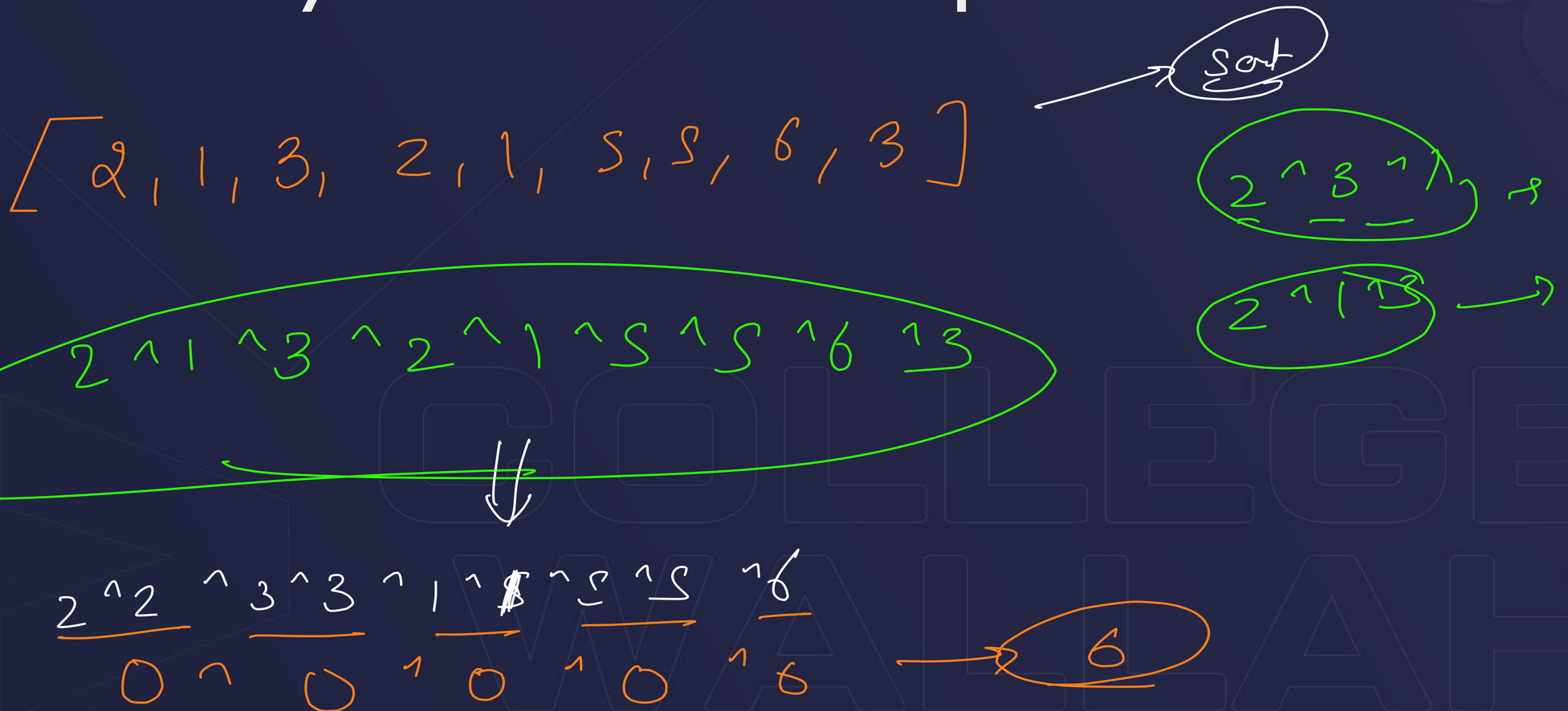
Practice

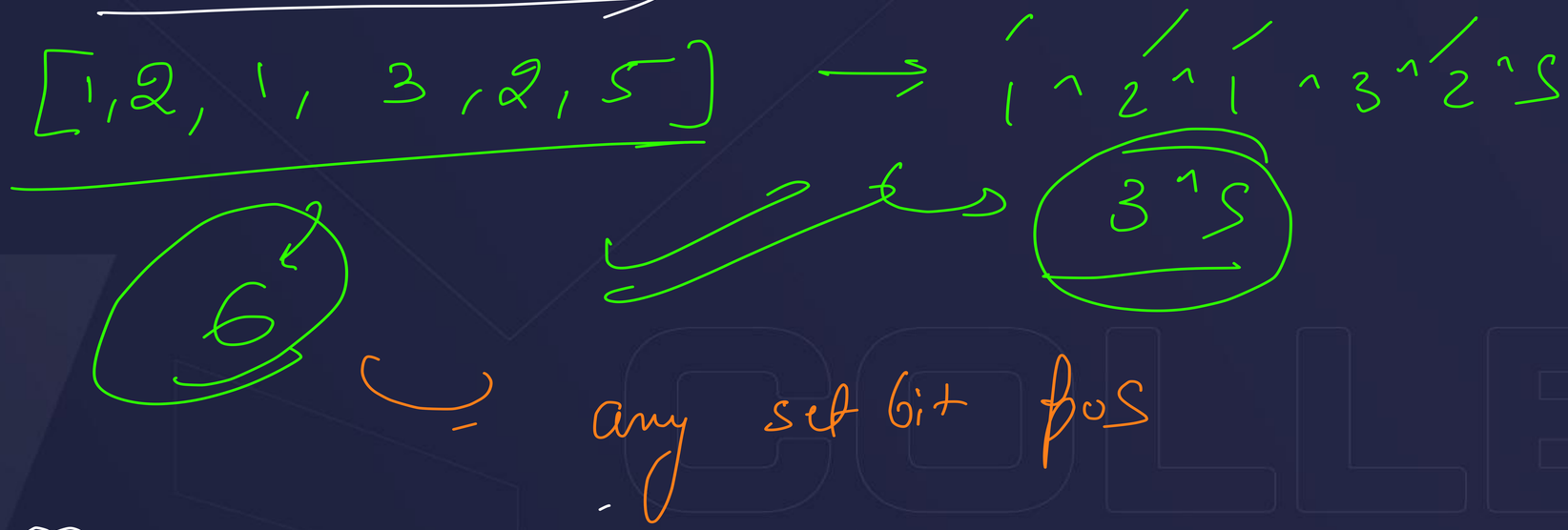


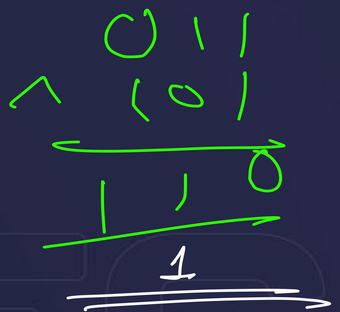
Given an integer array where every element occurs twice except one occurs only once. Find that unique element.

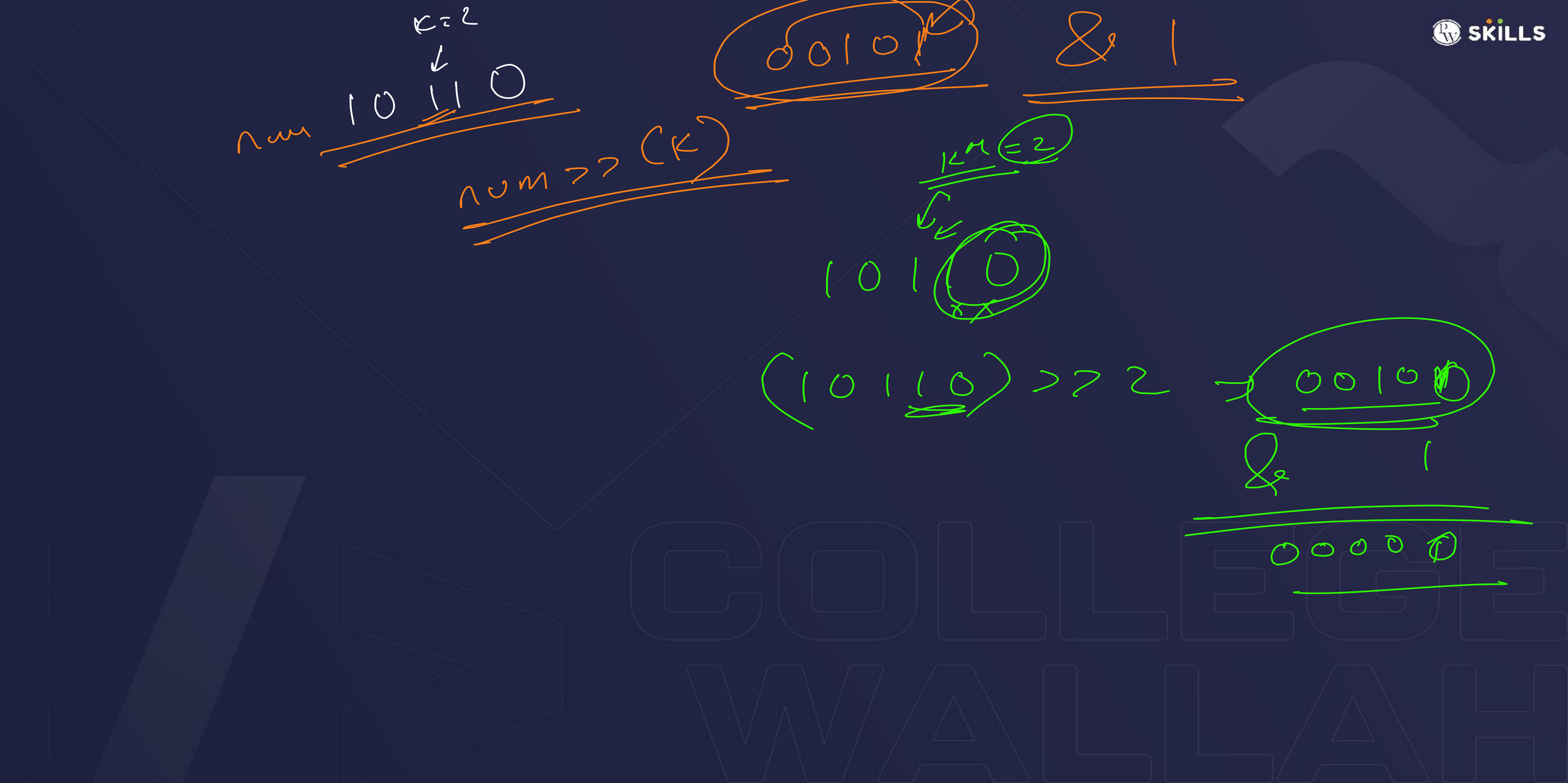


Practice

Given an integer array nums, in which exactly two elements appear only once and all the other elements appear exactly twice. Find the two elements that appear only once






K=2
num 10110
num >> (K)
00101 & 1
K=2
1011 0
(10110) >> 2
00101
&
1
00001

Modulo operator (%)

% remainder

print ans modulo 10^9+7

% remainder

$13 \% 4 = 1$

$$4\overline{)13}\,(3$$
$$12$$
$$1$$

int → 32bit

$(10^8 \times 10^8) \% 5$

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$C = (x \times y)$

cos

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$(10^8 \times 10^8)$ % 5

$\downarrow$

10^{16}

$\log_{a+b}$

$(a+b) \log c \Rightarrow (a \log c + b \log c) \log c$

$\downarrow \qquad \downarrow$

$([0, c-1] + [0, c-1]) \log c$

$\hookrightarrow [0, c-1]$

$(a \times b) \log c \Rightarrow (a \log_a c \times b \log_a c) \log_a c$

$(a-b)\,q_0\,c \rightarrow (aq_0c - bq_0c)\,q_0\,c$

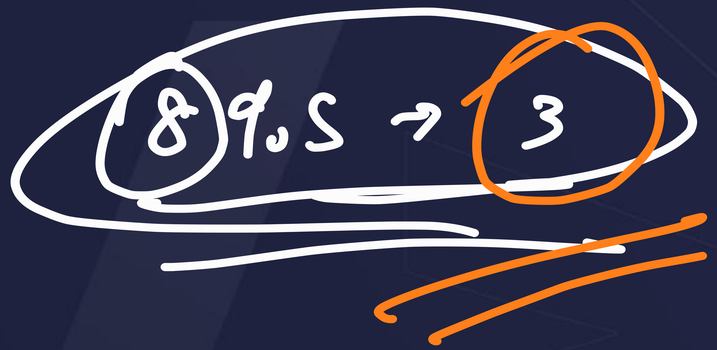
$\downarrow$

$(22-14)\,q_0\,s \rightarrow (22q_0s - 14q_0s)\,q_0\,s$

$\downarrow$

$(2 - 7)\,q_0\,s$

$(-2)\,q_0\,s$



$$(a-b)\,q_0 c = (a\,q_0 c - b\,q_0 c + c)\,q_0 c$$

$$(22-(4)\,q_0 s = (22\,q_0 s - 14\,q_0 s + s)\,q_0 s$$

$$(z - 4 + s)\,q_0 s$$

$$3\,q_0 s \to 3$$

$A \equiv B \bmod C$

- represents $A \% C = B \% C$

Basic operations in modulo arithmetic

(+ , - , *)

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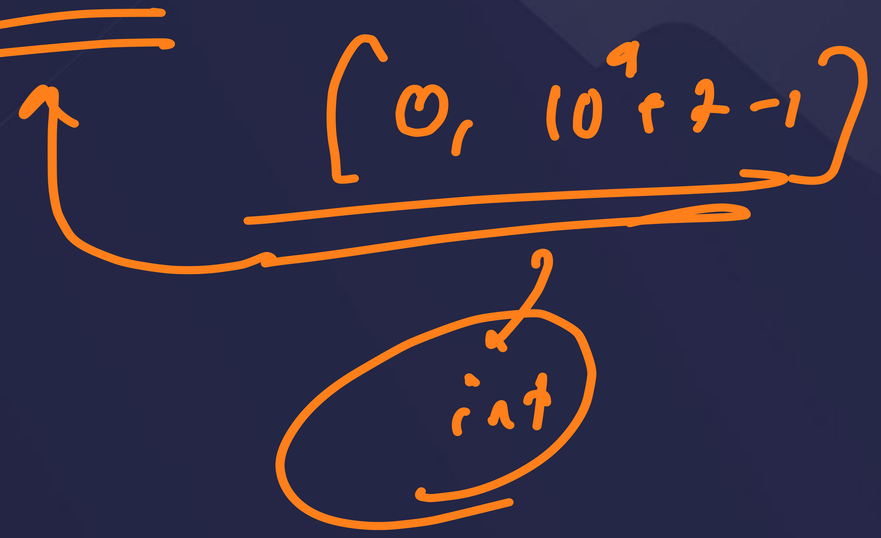
Modulo the result by 10^9+7

Why do we use $10^9 + 7$?



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Practice

7! = 7 x 6!

8! = 8 x 7!

Print factorial of first 25 natural numbers and modulo the result by 10^9+7.

0! = 1

1! = 1

x! = (x) x (x-1) x (x-2) ------ x 3 x 2 x 1

0!

fact[i] = i x fact[i-1]

Practice

Print factorial of first 25 natural numbers and modulo the result by 10^9+7.

$$(a \times b) \% c = (a \% c \times b \% c) \% c$$

$$fact[i] = (i \% c \times fact[i-1] \% c) \% c$$

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Calculation of Inverse Modulo

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Practice

Calculate the inverse modulo of first 10 natural numbers and modulo the result by $10^9 + 7$.

Thank you!

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