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Full-Stack Software Development

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Lecture On: Bit Manipulation

Instructor: Arkoprovo Dey

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In Last Class, we covered....

- Analysis of Algorithms

Homework Discussion

1. Explain what is the Big-O Notation?
2. Explain the difference between time and space complexity.

Today’s Agenda

- Bit Manipulation

Binary Mathematics

Remember those kindergarten classes where we were taught to count?

We had learnt about the nine digits, and how we can use them to represent bigger numbers.

We had also learnt how to do various arithmetic operations like addition and subtraction upon these numbers!

Binary Mathematics

As we were kids, we did not exactly understand what was going on and learnt whatever we were taught.

Today, let's take a step back and understand a few things about the origin of the mathematical world as we know it today!

We'll go through a few questions to understand a few core pillars of the number system as we have it today.

Binary Mathematics

Why do we have 10 digits? Why not more? Why not lesser?

What is a ‘digit’? Why do we call it a ‘digit’?

Binary Mathematics

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What if we find intelligent life on some planet Zorg and they happen to have just 1 finger in each hand?

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How would the residents of Planet Zorg count?

They would probably end up with a system that had just 2 digits. Let’s call them ‘@’ and ‘&’. Now, let’s try to see how these beings would count.

Now, let’s consider the same thing, but instead of ‘@’ and ‘&’, let’s have the first 2 digits we have, ie. ‘0’ and ‘1’.

So how would that counting go?

This way of counting is essentially the bedrock of using Binary Mathematics!

We just have the two digits, ‘0’ and ‘1’, which we can use to perform all our mathematical operations. Binary is core ‘language’ of all the software we would be developing, and is the bread and butter of the Computer Science world.

Binary Mathematics

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But why complicate things? We are still on Planet Earth!

This is because at the lowest level, all our systems exchange information and run upon simple electrical connections (LOTs and LOTs of them), and the only information we can pass via them is via an electric current.

While we can choose to pass various voltages of current via these connections to help us pass more information, these systems would always be prone to external factors (like voltage surges) and wear and tear.

Binary Mathematics

But why complicate things? We are still on Planet Earth!

The simplest thing we can do over here is to only have 2 states; either pass current, or don’t pass current. This system would comparatively be much more robust, and that is the entire underlying justification of adopting a binary system in the computer science world.

The number ‘0’ represents the state of no current, and the number ‘1’ represents the state of a current!

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Let us now try to see how we can convert Binary numbers to human-readable Decimal numbers and vice versa.

Binary Mathematics

Decimal numbers

Let us see the underlying assumptions we make while representing a number in decimal format.

253 is nothing but -

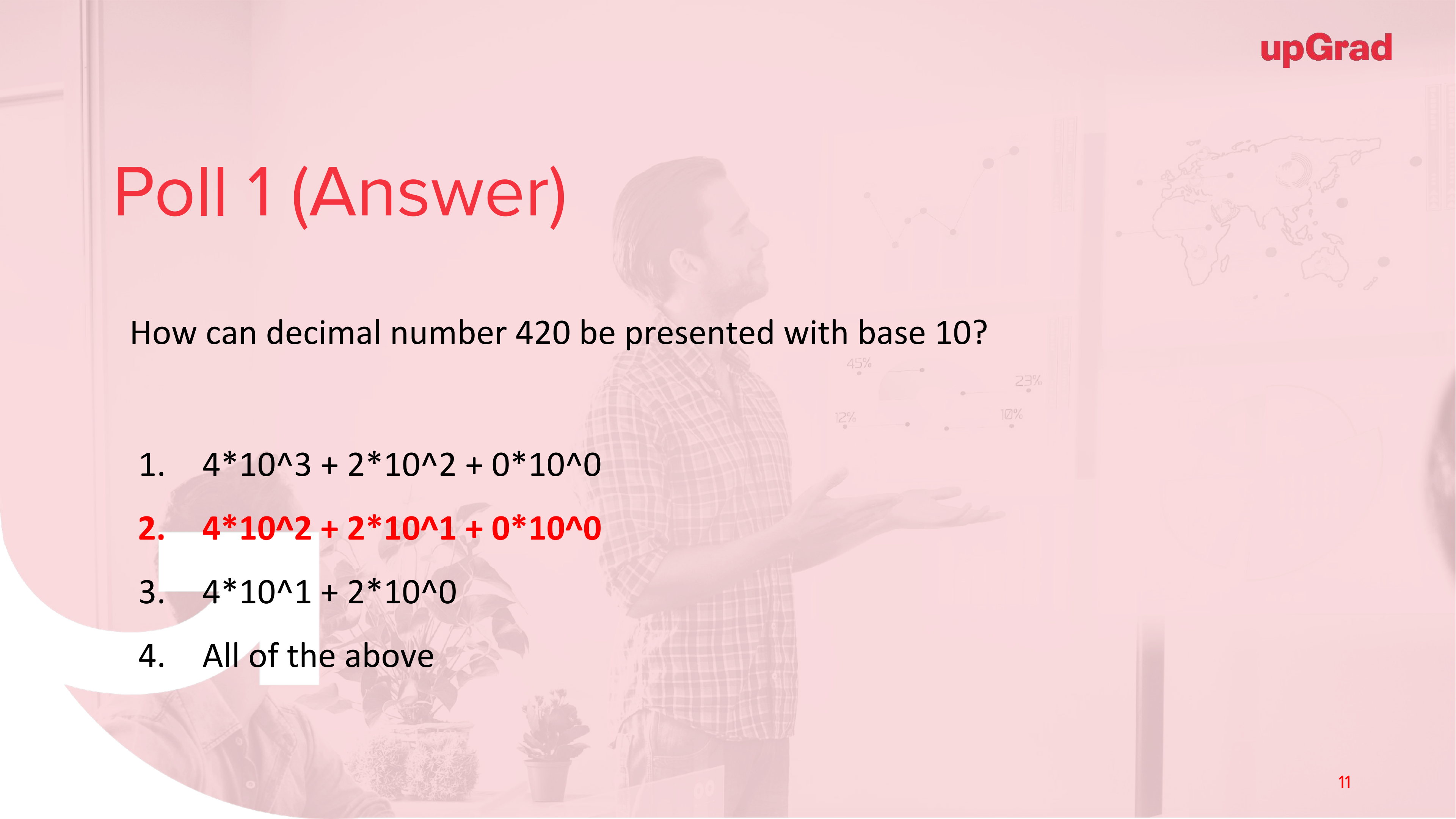
2 x 10^2 = 200 + 5 x 10^1 = 50 + 3 x 10^0 = 3

This is because we are writing these numbers in the decimal format, or what is known as base ‘10’.

Poll 1 (15 sec.)

How can decimal number 420 be presented with base 10?

1. 4*10^3 + 2*10^2 + 0*10^0
2. 4*10^2 + 2*10^1 + 0*10^0
3. 4*10^1 + 2*10^0
4. All of the above



Poll 1 (Answer)

How can decimal number 420 be presented with base 10?

1. 4*10^3 + 2*10^2 + 0*10^0
2. **4*10^2 + 2*10^1 + 0*10^0**
3. 4*10^1 + 2*10^0
4. All of the above

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Binary to Decimal number -

For a binary number like - 1001110, what do you think the break up would look like?

1 x 2^6 = 64 + 0 x 2^6 = 0 + 0 x 2^5 = 0 + 1 x 2^4 = 16 + 1 x 2^3 = 8 + 1 x 2^2 = 4 + 0 x 2^1 = 0

Which is nothing but 92!

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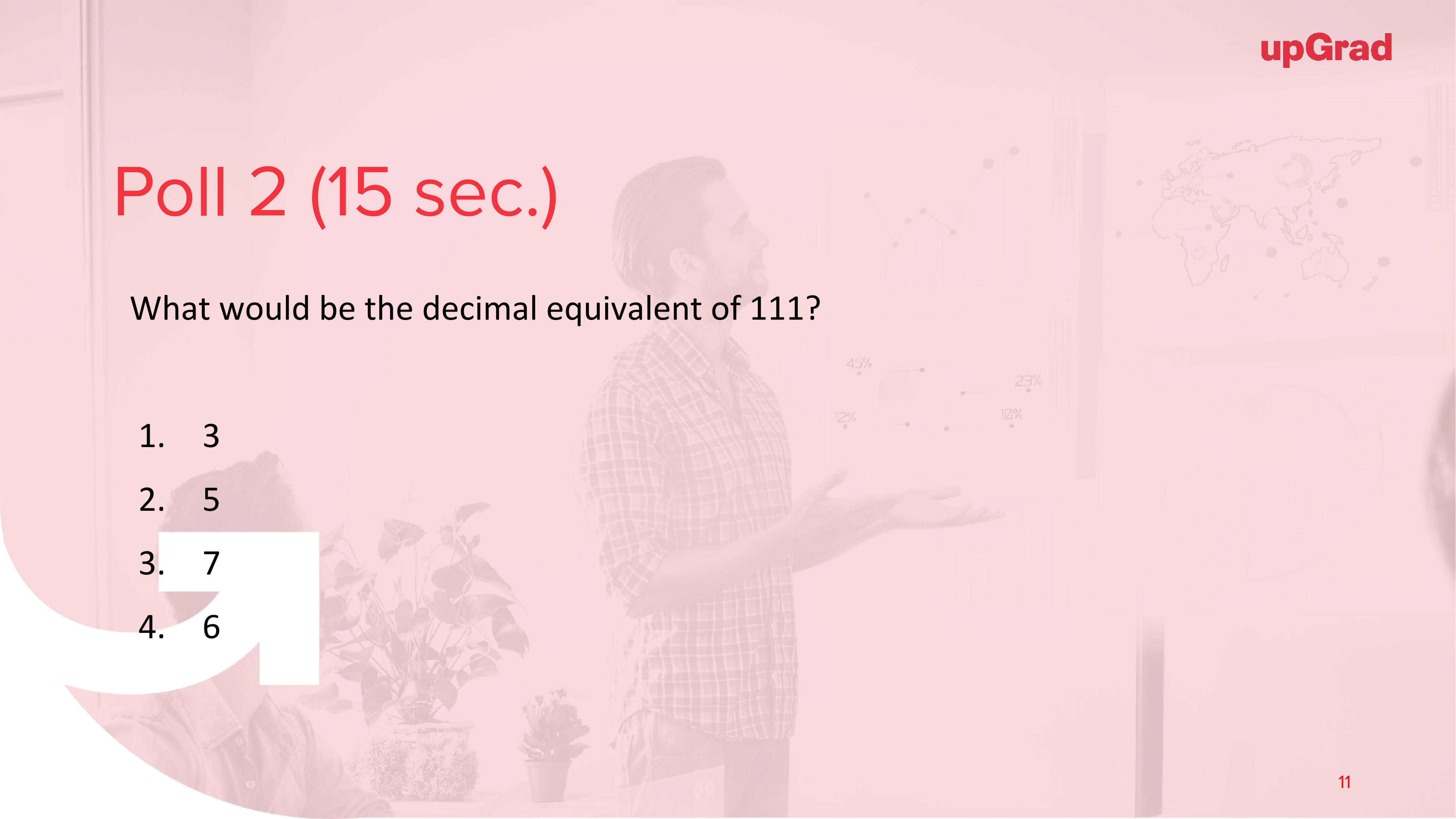

Poll 2 (15 sec.)

What would be the decimal equivalent of 111?

1. 3
2. 5
3. 7
4. 6

Poll 2 (Answer)

What would be the decimal equivalent of 111?

1. 3
2. 5
3. **7**
4. 6

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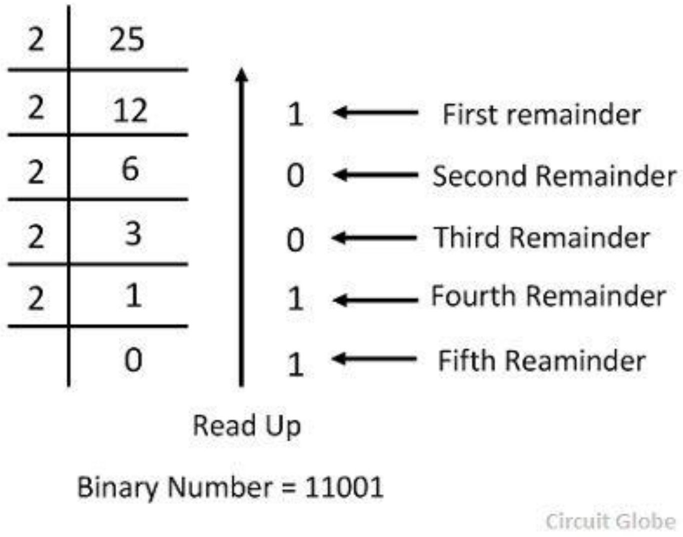
Converting Decimal to Binary numbers -

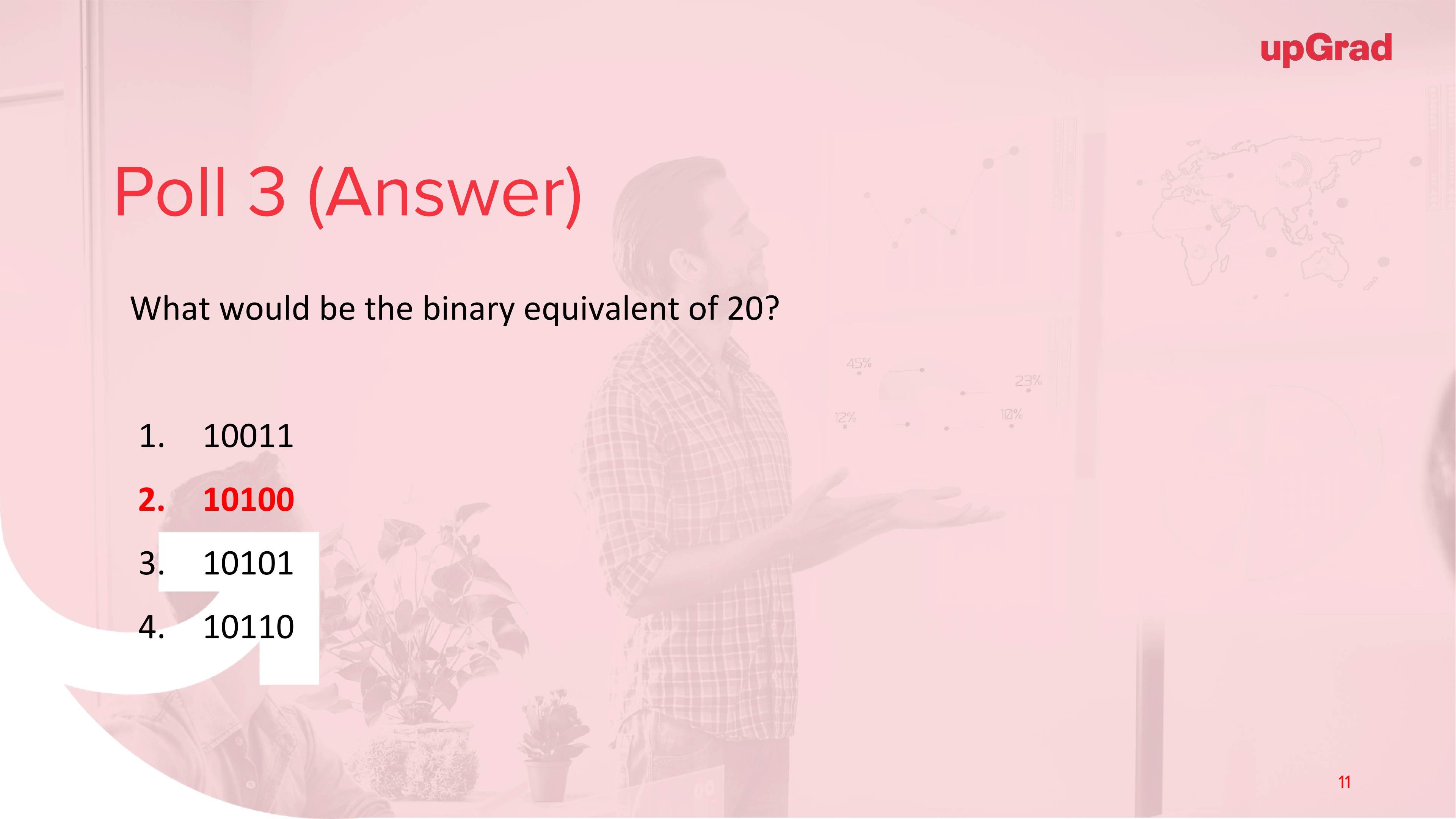
In order to convert Decimal to Binary numbers, we would just be doing the inverse of this!



Poll 3 (15 sec.)

What would be the binary equivalent of 20?

1. 10011
2. 10100
3. 10101
4. 10110



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Poll 3 (Answer)

What would be the binary equivalent of 20?

1. 10011
2. **10100**
3. 10101
4. 10110

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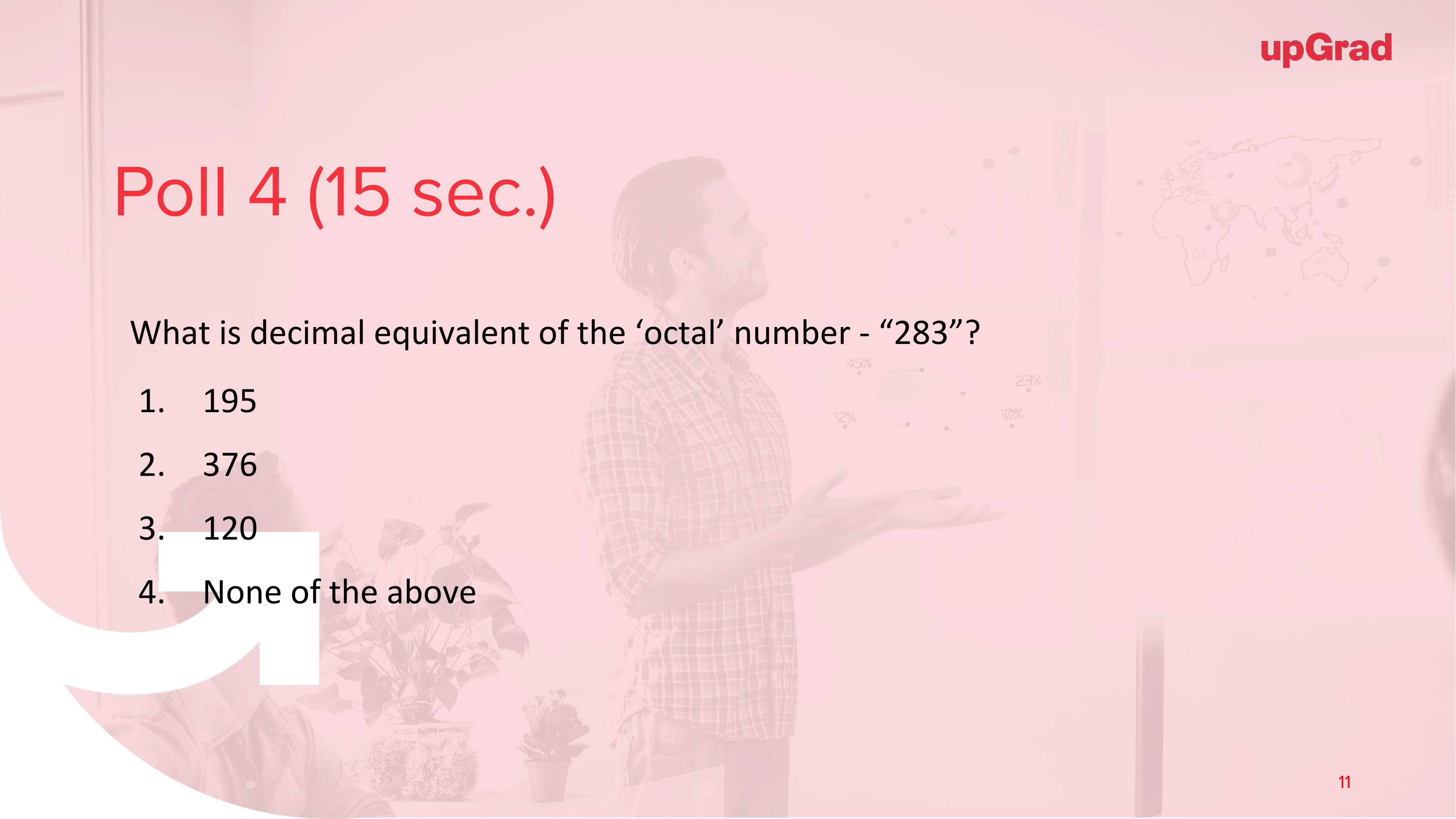
Food for thought!

How do you think this conversion would go if we were to try and convert a Decimal number to its ‘Octal’ (base 8) equivalent?

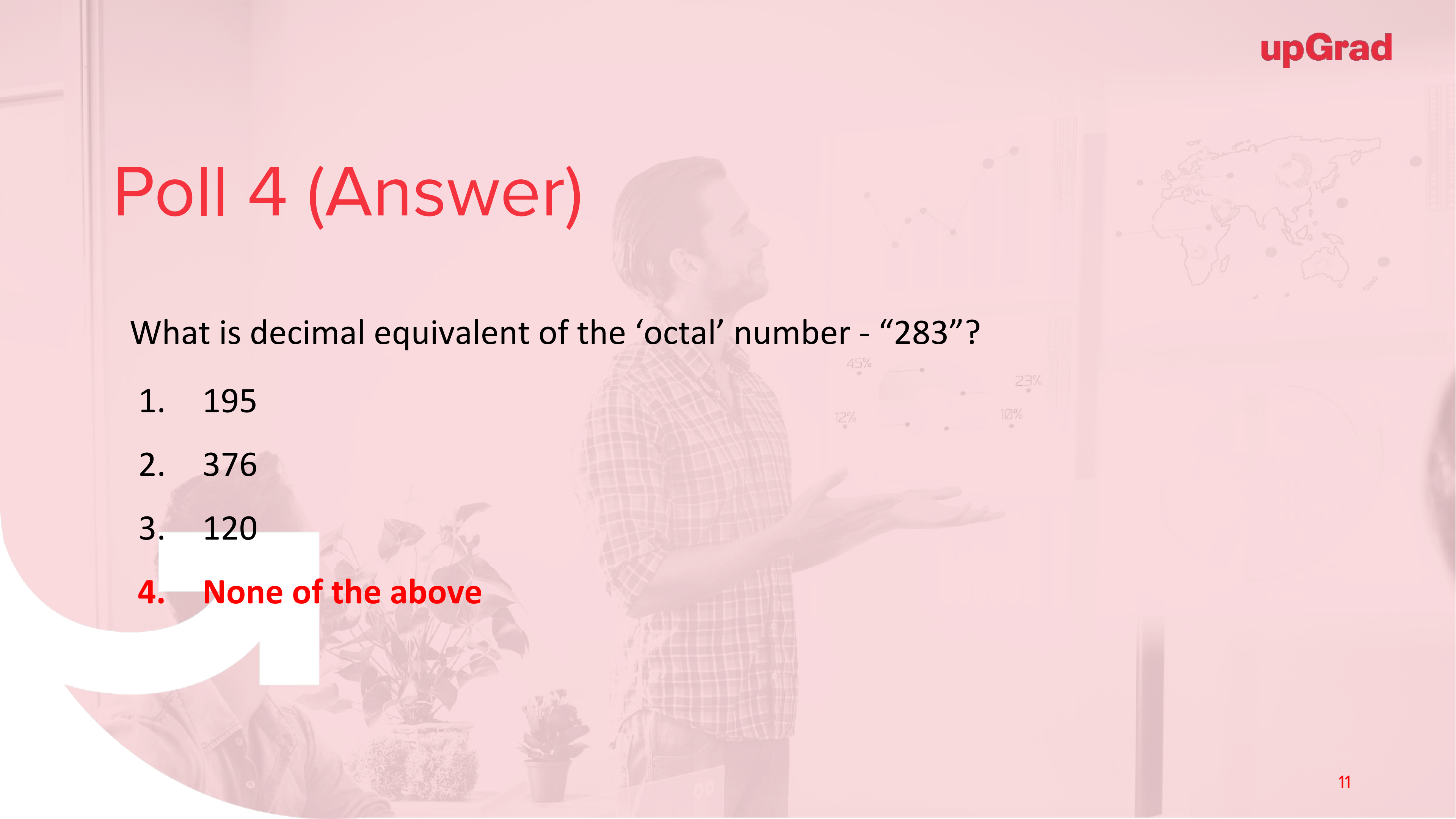
How would be go about with converting the same back to Decimal?



Poll 4 (15 sec.)

What is decimal equivalent of the ‘octal’ number - “283”?

1. 195
2. 376
3. 120
4. None of the above



Poll 4 (Answer)

What is decimal equivalent of the ‘octal’ number - “283”?

1. 195
2. 376
3. 120
4. **None of the above**

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Demystifying a couple of terms!

What is a ‘bit’?

Binary Mathematics

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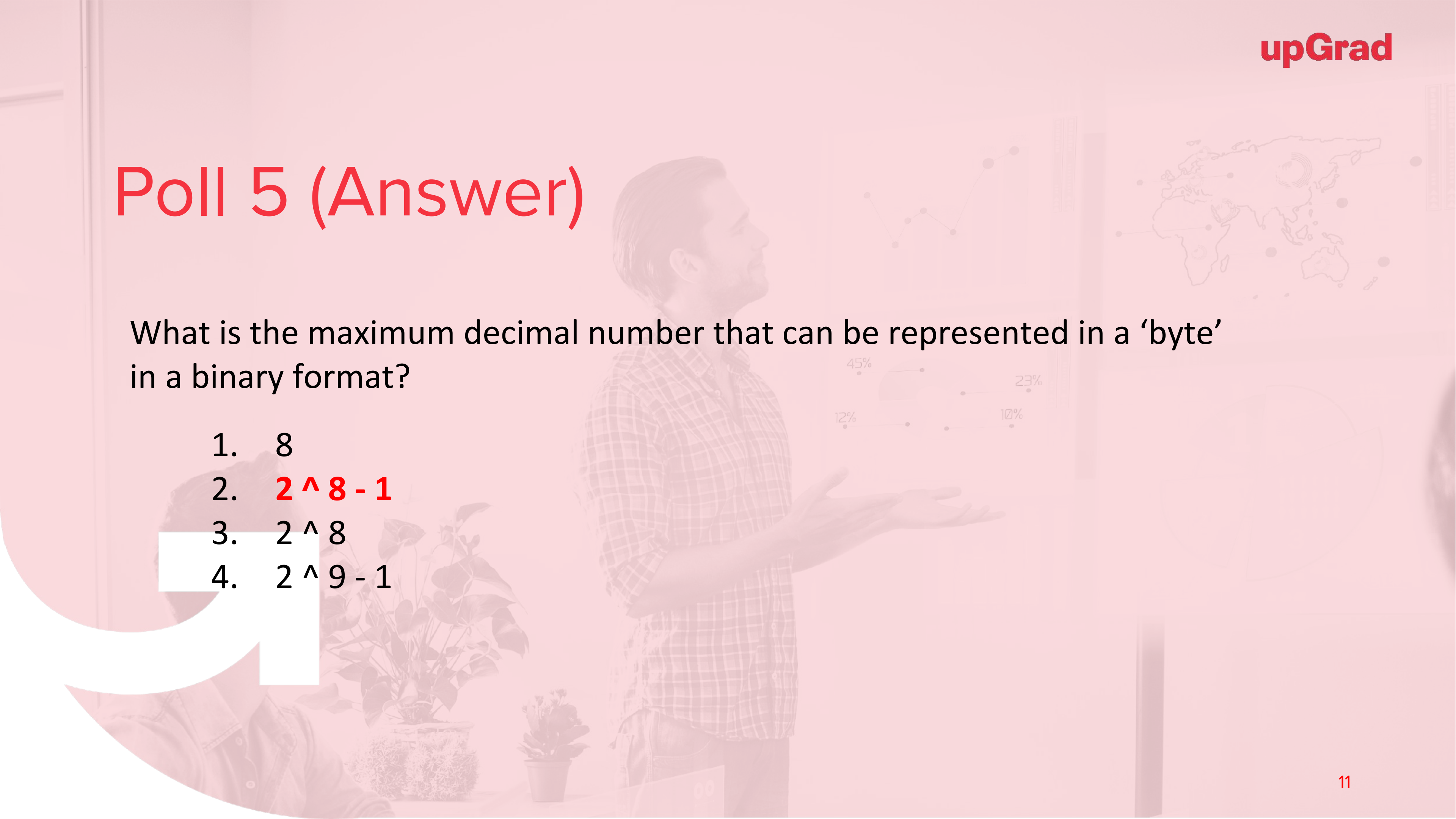
Demystifying a couple of terms!

What is a ‘byte’?

Poll 5 (15 sec.)

What is the maximum decimal number that can be represented in a ‘byte’ in a binary format?

1. 8
2. 2 ^ 8 - 1
3. 2 ^ 8
4. 2 ^ 9 - 1



Poll 5 (Answer)

What is the maximum decimal number that can be represented in a ‘byte’ in a binary format?

1. 8
2. **2 ^ 8 - 1**
3. 2 ^ 8
4. 2 ^ 9 - 1

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Demystifying a couple of terms!

What do you think a KB is then?

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Binary Operations

Let us now try to see how we can go about with adding 2 Binary numbers -

$$\begin{array}{cccccccc} & 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ + & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ \hline \end{array}$$

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Binary Operations

Along with basic arithmetic operations, we can have several other operators that work on a ‘binary’ or a ‘bit’ level. These help us execute several complex portions of logic, and design the underlying electronic circuits.

Let us look at a few of those.

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Binary Operations

The “AND” (&) operator -

A	B	A & B
0	0	0
0	1	0
1	0	0
1	1	1

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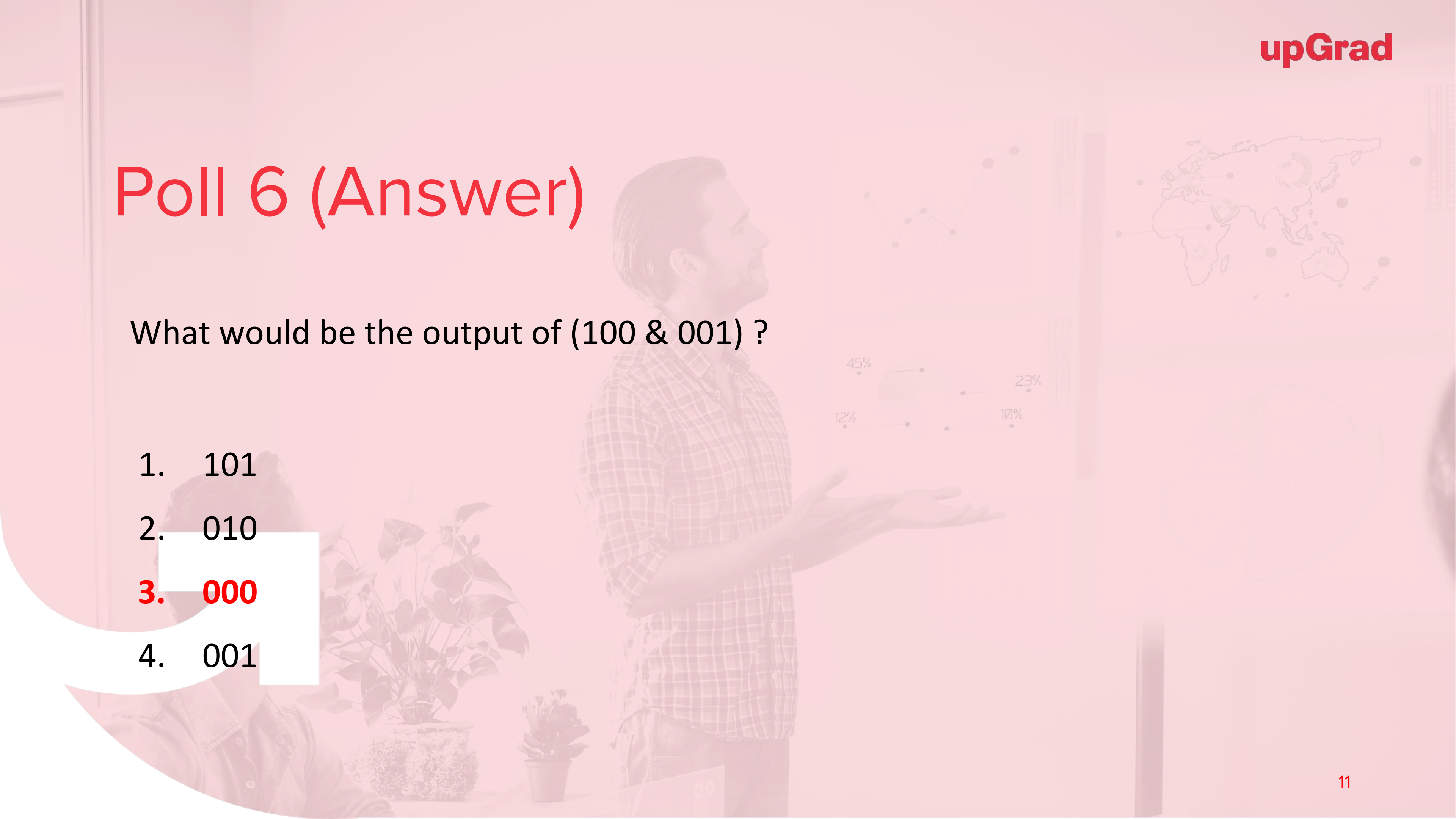
Poll 6 (15 sec.)

What would be the output of (100 & 001) ?

1. 101
2. 010
3. 000
4. 001



Poll 6 (Answer)

What would be the output of (100 & 001) ?

1. 101
2. 010
3. **000**
4. 001

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Binary Operations

The “OR” (|) operator -

A	B	A | B
0	0	0
0	1	1
1	0	1
1	1	1

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Poll 7 (15 sec.)

What would be the output of (100 | 001) ?

1. 101
2. 010
3. 000
4. 001

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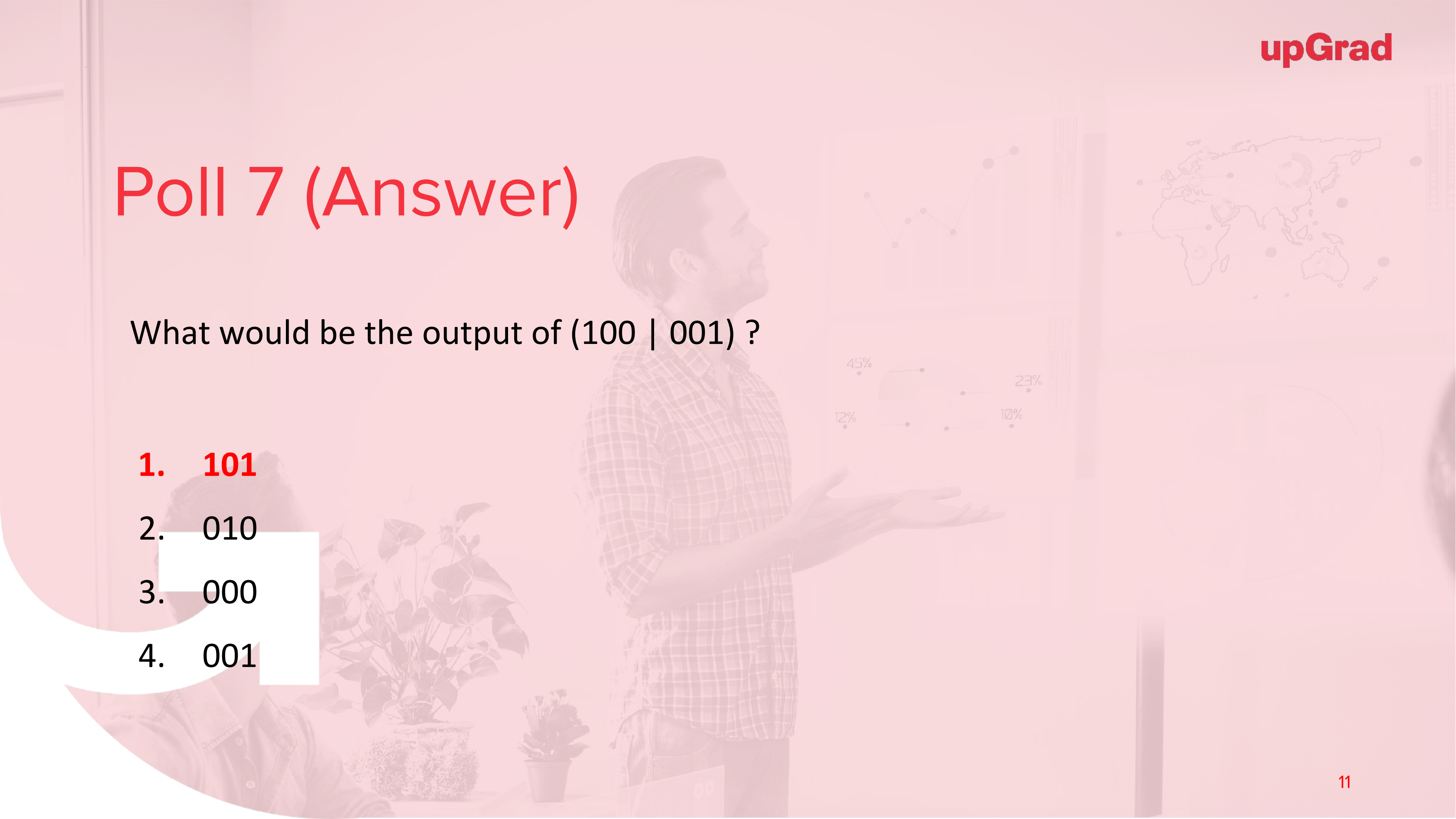
Poll 7 (Answer)

What would be the output of (100 | 001) ?

1. **101**
2. 010
3. 000
4. 001



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Binary Operations

The “NOT” (~) operator -

A	~ A
0	1
1	0

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Binary Operations

The “XOR” (^) operator -

A	B	A ^ B
0	0	0
0	1	1
1	0	1
1	1	0

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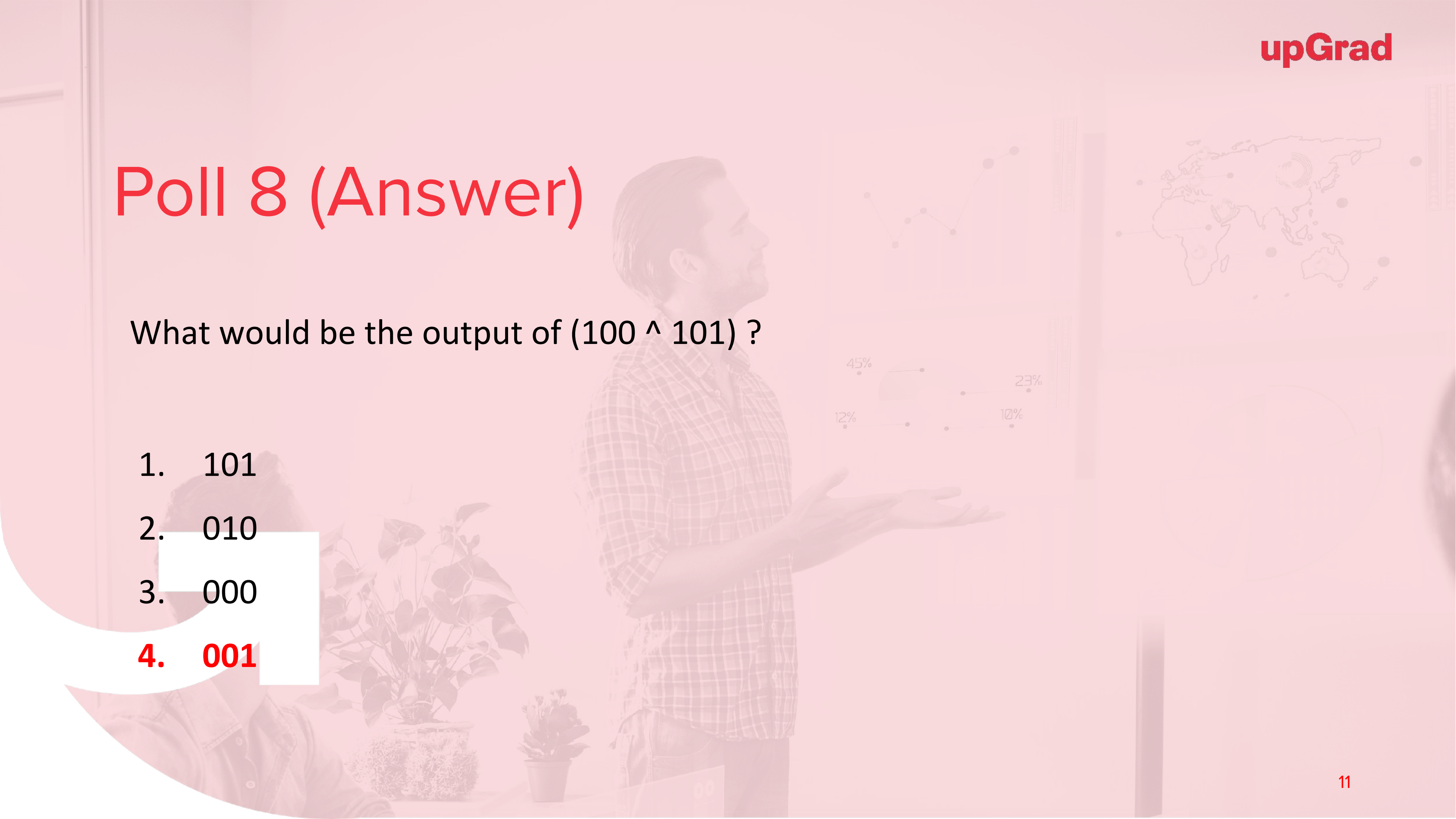
Poll 8 (15 sec.)

What would be the output of (100 ^ 101) ?

1. 101
2. 010
3. 000
4. 001



Poll 8 (Answer)

What would be the output of (100 ^ 101) ?

1. 101
2. 010
3. 000
4. **001**

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Binary Operations

The “XAND” operator -

A	B	A & B
0	0	1
0	1	0
1	0	0
1	1	1

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Binary Operations

The left-shift (<<) operator -

This operator shifts a binary number one place to the ‘left’.

Eg: 000100101 becomes 001001010

Can someone guess what is essentially happening over here?

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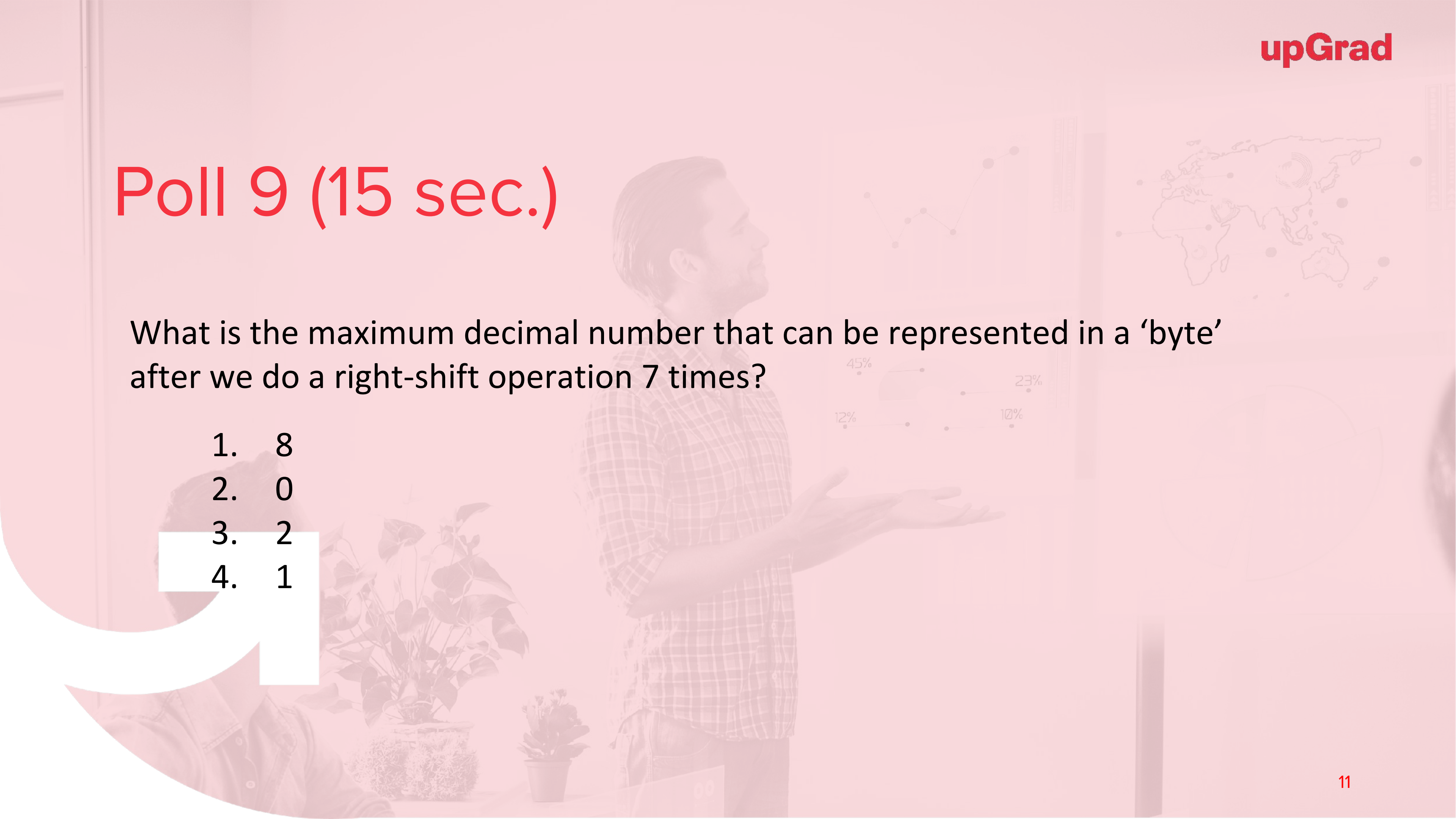
Binary Operations

The right-shift (>>) operator -

This operator shifts a binary number one place to the 'right'.

Eg: 000100101 becomes 000010010

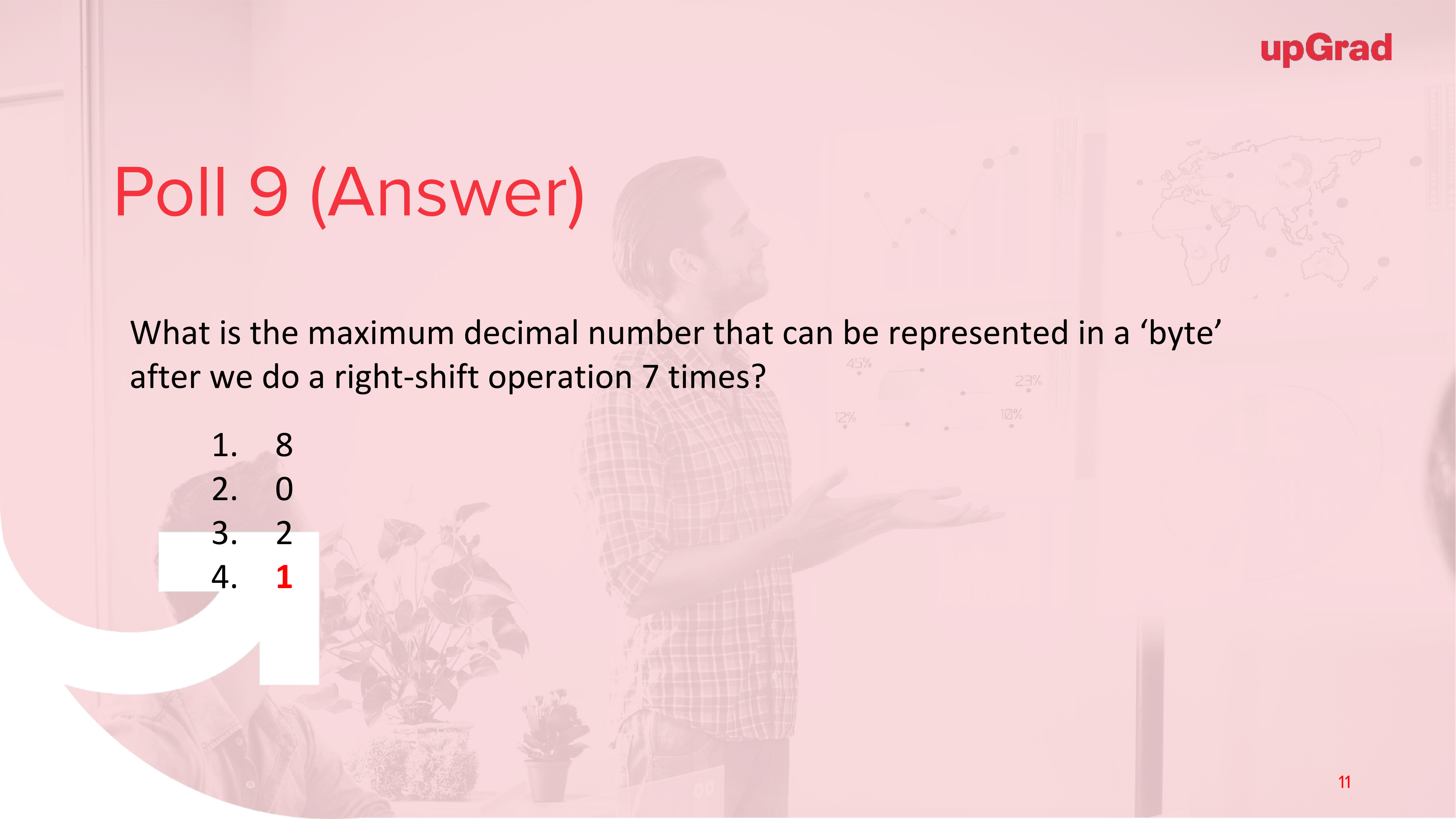
Can someone guess what is essentially happening over here?



Poll 9 (15 sec.)

What is the maximum decimal number that can be represented in a 'byte' after we do a right-shift operation 7 times?

1. 8
2. 0
3. 2
4. 1



Poll 9 (Answer)

What is the maximum decimal number that can be represented in a ‘byte’ after we do a right-shift operation 7 times?

1. 8
2. 0
3. 2
4. [✓ 1]

Hands-On Exercise 1

Write a function which takes a decimal number as an input and prints its binary equivalent.

Hands-On Exercise 2

Write a function which takes a binary number as an input and prints its decimal equivalent.

Hands-On Exercise 3

Take 2 decimal numbers as input, and add the two. However, you CANNOT use the ‘+’ or ‘++’ operator!

Hands-On Exercise 4

Take a decimal number ‘n’ as input, and print the ‘bit-reversed’ form of the number in ‘x’ bits.

Eg:

n = 25, x = 7

25 -> 0 0 1 1 0 0 1 -> on inversion -> 1 1 0 0 1 1 0 -> 102 (Answer!)

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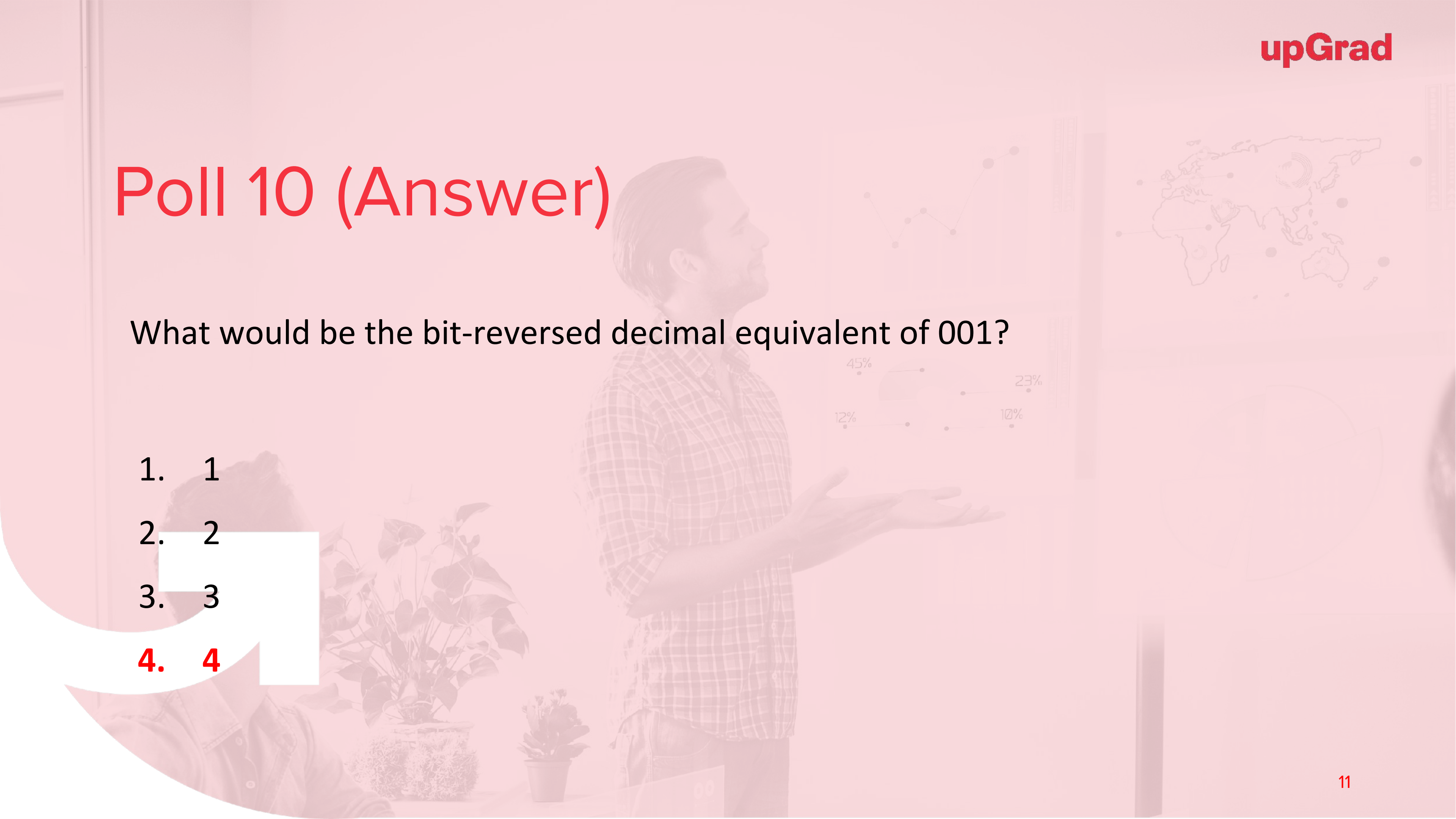
Poll 10 (15 sec.)

What would be the bit-reversed decimal equivalent of 001?

1. 1
2. 2
3. 3
4. 4



Poll 10 (Answer)

What would be the bit-reversed decimal equivalent of 001?

1. 1
2. 2
3. 3
4. **4**

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Homework

1. Write a function which takes a decimal number as an input and prints its octal equivalent.

2. Write a function which takes a octal number as an input and prints its decimal equivalent.

Tasks to complete after the session

Homework Questions
MCQs
Coding Questions

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In the next class...

- Mathematics

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Thank You!