CSE 29
Lecture 4 Summary

January 15, 2026

📣 Logistical Q&A

- Have we learned everything we need to know to complete PSET 1 and PA 1?
  - Not yet. The first assignment is weird because we haven't covered enough fundamentals yet. We are learning as we go. The next assignments will be different, because we will already learn everything we need to know for the assignment before it is released.

🧠 Review Questions

1. What is the signed + unsigned interpretation of 10000001?
2. How many code points are encoded by the UTF-8 sequence?

   11010101 10111111 11101011 10110110 10000001

3. `char s[] = { 0b01100001, 98, 'c', '\0'};`

   `printf("%s", s);` //What does this print?

Try these questions out yourself before looking at the answers!
Answers in speaker notes of this slide 👇

The annotated handout also has the solutions as gone over in lecture

Questions

Q: Would C put a null terminator `'\0'` in `s` in Review Question 3 if we did not explicitly do so?

A: No. C only implicitly adds a null terminator in string literals.

Ex:

```
char s1[] = "abc"; // will have null terminator

char s2[] = {'a', 'b', 'c'}; // will not have null terminator
```

Bitwise Operators

Why bitwise?

It can make certain tasks easier, where using algebra would be difficult

Useful particularly for tasks like assignment 1 where by definition code points use specific bit patterns.

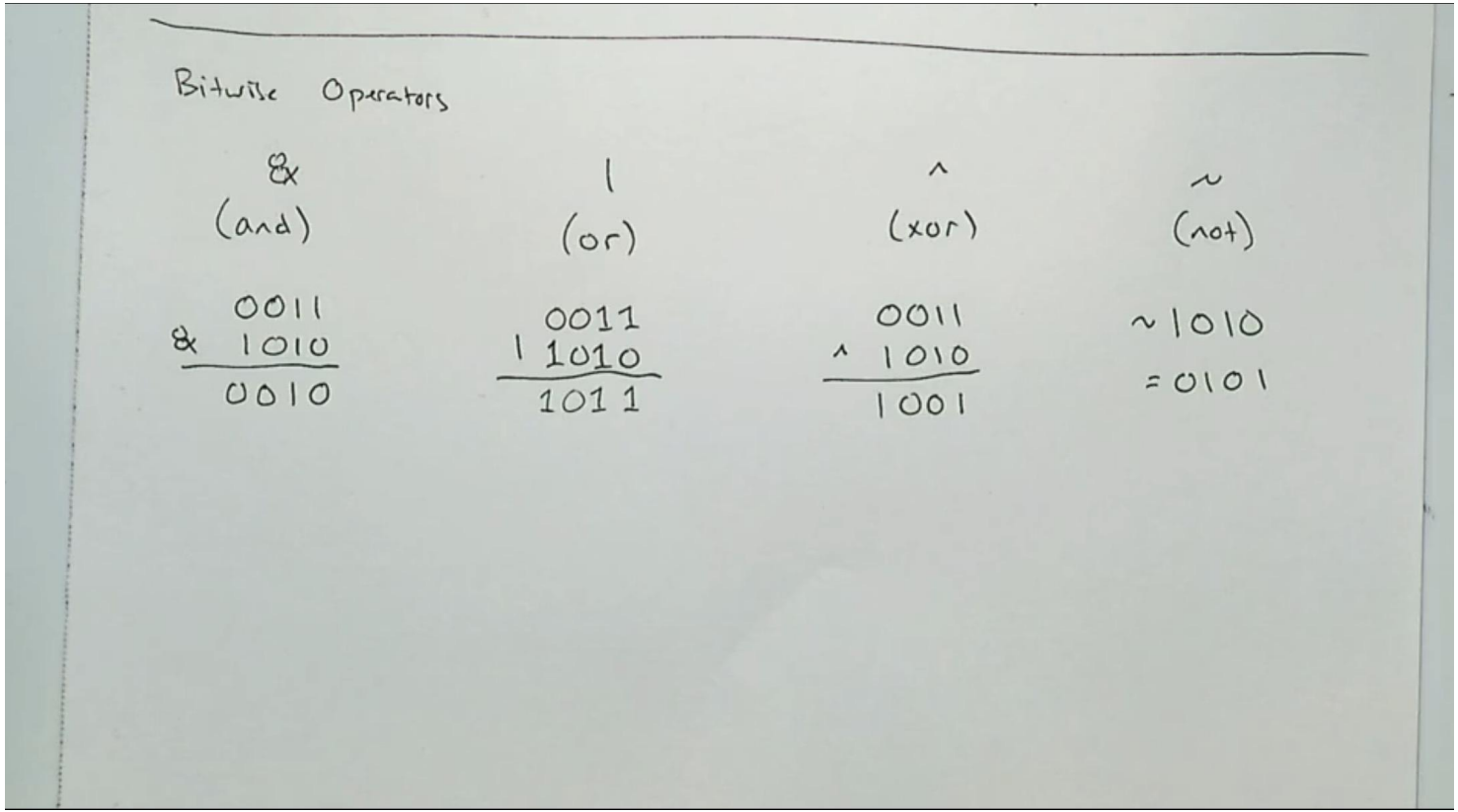
Allows us to check the values of specific bits

Allows us to set bits

Bitwise Operators

Examples and definitions given on 4-bit values, but they extend to any number of bits

- & (and)
- | (or)
- ^ (xor)
- ~ (not)



Bitwise Operator Truth Table

Bitwise Operator Truth Table

X	Y	X&Y	X|Y	X^Y	~(X)
0	0	0	0	0	1
0	1	0	1	1	1
1	0	0	1	1	0
1	1	1	1	0	0

Bitwise Operators Example

```
char c1 = 0b01100001;

char c2 = 0b11001110;

char c3 = 0b11100001;

char c4 = 0b11110111;

char mask = 0b11110000;
```

Try to fill in the blanks, answers in speaker notes!

```
c1 & mask = ________;

c2 & mask = ________;

c3 & mask = ________;

c4 & mask = ________;
```

Implementing the `is_3byte_utf8` function

Function description: Given a byte, return 1 if it is a starting byte for 3-byte UTF-8 characters. Otherwise, return 0.

Function Header:

```
int is_3byte_utf8(char c) {}
```

Try it out using bitwise operators and masks!
Solution on the next slide

Implementing the `is_3byte_utf8` function

Solution: Use a mask to only get the 4 left bits of the char and see if it matches up with the prefix for the starting byte of a 3-byte utf-8 character (1110)

```
int8_t is_3byte_utf8(char c) {
    return (c & mask) == 0b11100000;
}
```

`mask` was previously defined as `0b11110000`

Bitwise Operator Q&A

- Why does this function have an int8_t (or int) return type?
  - There is not a boolean data type in C. In 0, it is interpreted as false. If it's non-zero, it is interpreted as true. Commonly, 1 is true. int8_t is the smallest available size since it is 8 bits, but it will function the same for our purposes as an int(4 bytes) or int8_t (1 byte)
- What does (c & mask) == 0b11100000 evaluate to?
  - It's a number (0 or 1) that can be interpreted as false or true (0 and anything not 0, respectively)
- What does the == evaluate to?
  - False evaluates to 0, and true evaluates to not 0, commonly 1
- Could we use division or less than/greater than a value to do this?
  - Yes, but using bitwise operators matches the specs and is more computationally efficient
- Could less than 8 bits be used to store a boolean (or anything else)?
  - There is no data type in C that does this, but you could create your own encoding/decoding scheme.

Bitwise Q&A continued

- Does the mask look the same for different functions
  - This mask is useful for the 3-byte UTF-8 character case because the prefix of the start byte is 4 bits (1110). Masks can look different based on what bits you need to mask out
- Is there a reason C really likes 32 bit things?
  - Historically, the most efficient layout of hardware called SRAM cells was 32 side by side. This got us the 32 bit int which holds about 4 billion different values which was very good. Then 32 was programmed in many places so it's still prevalent. It was good engineering awhile ago and now it's historical.

Shifting Operators (covered in 12:30 lecture)

- << (left shift)
  - Move all the bits over to the left by a certain number, then pad with 0's on the empty right slots
- >> (right shift)
  - Move all the bits over to the right by a certain number
  - Padding the empty slots on the left side depends on the data type (see next slide)

```
0b00110001 << 2 = 0b11000100

0b00110001 << 3 = 0b10001000

0b00110001 >> 2 = 0b00001100
```

These red bits are "lost"

Blue bits is the empty slots we filled in

Right Shifts are special

We are using an **Arithmetic Right Shift**, where the left is padded with the most significant (leftmost) bit

In **C**, right shift behavior depends on the **type of value** being shifted.

If the value is **signed** (data type is `int` or `int32_t`	If the value is **unsigned** (data type is `unsigned int` or `uint32_t`)
0b10001100 >> 2 → 0b11100011	0b10001100 >> 2 → 0b00100011
Here, the leftmost bit is a 1, so the left will be padded with 1s	Here, the leftmost bit is a 0, and the left is padded with 0s

Shifting Operator Q&A

- How do you know when to use a data type that specifies the number of bits
  - Different compilers interpret `int`s as different amounts of bits, which could mess a up a program if you code expecting 32 bits and compile it with a compiler that has a default `int` size of 16 bits. An `int32_t` will always be interpreted as 32 bits. It's good practice to be specific in the number of bits you are expecting.
- Is the default `int` on most systems signed 32-bit?
  - Yes

Hexadecimal

Hexadecimal

- Hexadecimal came about because programmers realized it was much easier to convert binary (base 2) to base 16 than to decimal (base 10), especially as numbers get increasingly bigger
- It is *significantly* easier to write a binary sequence in hexadecimal than binary (and you're much less likely to make a mistake)
- You can write `0x<hex_num>` in C, and it will have the same value as the decimal and binary equivalent, just like how you can write `0b<bin_num>`

Bin	Dec	Hex	Bin	Dec	Hex
0000	0	0	1000	8	8
0001	1	1	1001	9	9
0010	2	2	1010	10	A
0011	3	3	1011	11	B
0100	4	4	1100	12	C
0101	5	5	1101	13	D
0110	6	6	1110	14	E
0111	7	7	1111	15	F

0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

16's 1's

0x A7

A * 16 + 7 * 1

160 + 7

167

0xA7

0b 1010 0111

$A * 16^1 + 7 * 16^0$

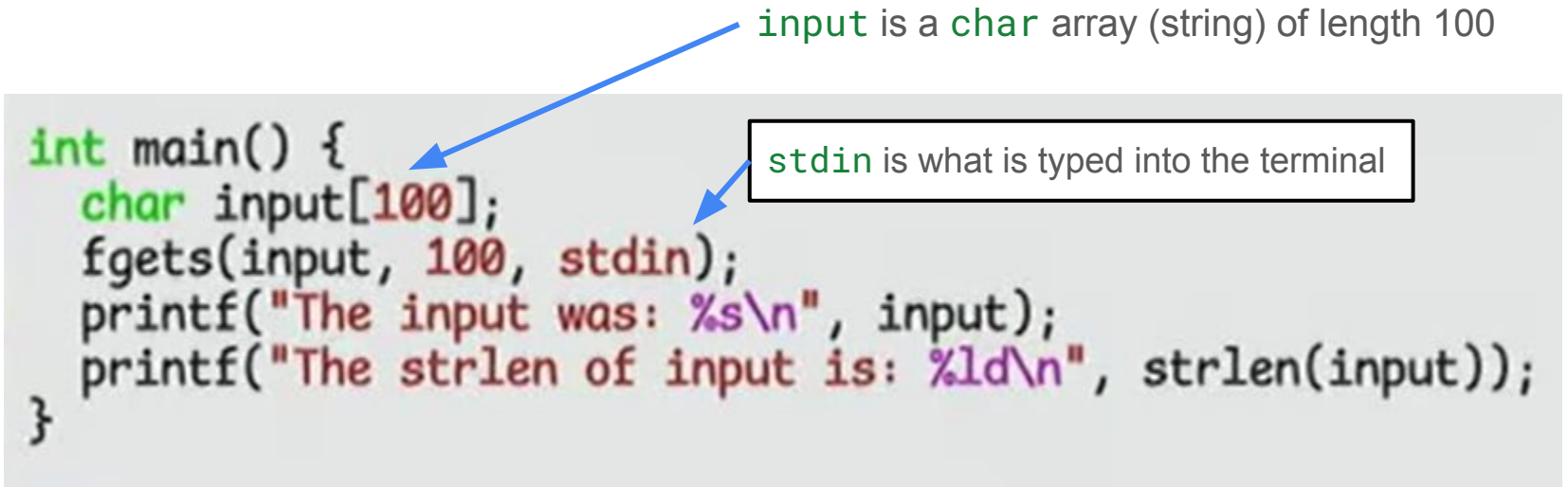
$= 10 * 16^1 + 7 * 16^0$

$= 167$

Implementing Functions from PSET1

Creating `main` function

This is similar to the main functions in your starter code for PSETs!



`fgets` stores what's typed in `stdin` into `input`

Side Note: How do I Compile my Code?

The command to compile your code is

What comes after “gcc” can occur in any order EXCEPT that whatever comes immediately after “-o” is the new executable name. Example below

```
gcc my_code.c -o my_executable_name
```

without `-o`, we wouldn’t be able to choose the name for our executable program file. The default executable name `a.out` would be the name if we didn’t choose it

For this PA, we are going to compile using `gcc utf8analyzer.c -o utf8analyzer` and run the executable by using `./utf8analyzer`

Exercise: Implementing Functions from PSET

Try to implement the three functions below before looking at the answers in the following slides! These are also functions that are part of PSET 1.

- `int8_t is_ascii (char s[])`
- `int8_t width_from_start_byte (char c)`
- `int32_t utf8_len (char s[])`

Function descriptions are in the following slides!

Implementing `is_ascii` function

Function Description: Given a string (`char s[]`), determine if all of the characters are ASCII characters. If yes, return `1`, if not return `0`.

Function Header: `int8_t is_ascii (char s[])`

Implementing `is_ascii` function

Function Description: Given a string (`char s[]`), determine if all of the characters are ASCII characters. If yes, return `1`, if not return `0`.

```
int8_t is_ascii(char s[]) {
  for(int i = 0; s[i] != '\0'; i += 1) {
    if((s[i] & 0b10000000) == 0b10000000) {
      return 0; // This 0 means "false"
    }
  }
  return 1;
}
```

Implementing `width_from_start_byte`

Function Description: Given a `char c` (a byte) that represents a start byte, determine how many bytes the character has and return that number. If it is not a valid start byte, return `-1`.

Function Header: `int8_t width_from_start_byte (char c)`

Implementing `width_from_start_byte`

Function Description: Given a `char c` (a byte) that represents a start byte, determine how many bytes the character has and return that number. If it is not a valid start byte, return `-1`.

```
int8_t width_from_start_byte(char c) {
  if((c & 0b10000000) == 0b00000000) { return 1; } // ASCII = 1 byte
  if((c & 0b11100000) == 0b11000000) { return 2; } // 2 byte case
  if((c & 0b11110000) == 0b11100000) { return 3; } // 3 byte case
  if((c & 0b11111000) == 0b11110000) { return 4; } // 3 byte case
  // if((c & 0xF8) == 0xF0)   thanks robot
  return -1;
}
```

Implementing `utf8_len`

Function Description: Given a string `char s[]` with UTF-8 characters, count the number of code points in the string.

Function Header: `int32_t utf8_len (char s[])`

Hint: Think about how you can use `width_from_start_byte` here

Implementing `utf8_len`

Function Description: Given a string `char s[]` with UTF-8 characters, count the number of code points in the string.

Hint: Think about how you can use `width_from_start_byte` here

```
// Count the number of _code points_ in the string
int32_t utf8_len(char s[]) {
  int byte_index = 0, cp_count = 0;
  while(s[byte_index] != '\0') {
    int width = width_from_start_byte(s[byte_index]);
    cp_count += 1;
    byte_index += width;
  }
  return cp_count;
}
```

Result from testing all 3 functions

```
34
35 int main() {
36   char input[100];
37   fgets(input, 100, stdin);
38   printf("The input was: %s\n", input);
39   printf("The strlen  of input is: %ld\n", strlen(input));
40   printf("The utf8len of input is: %d\n", utf8_len(input));
41   printf("Is ASCII? %d\n", is_ascii(input));
42   printf("Width based on byte 0: %d\n", width_from_start_byte(input[0]));
43 }
```

```
$ ./utf8analyzer
🦀 ate 🍌
The input was: 🦀 ate 🍌

The strlen  of input is: 14
The utf8len of input is: 8
Is ASCII? 0
Width based on byte 0: 4
$
```

strlen is wrong because it counts the bytes up to the null terminator, but non-ASCII characters have more than 1 byte

utf8len is one off because when we type in the terminal, we press Enter, which is a newline character (\n). This is NOT counting the null terminator.

"🦀 ate 🍌\n" ← invisible newline character

Joe's Notes (11am)