ETH zürich

# Session 01
# Integer Arithmetic

**Informatik I**

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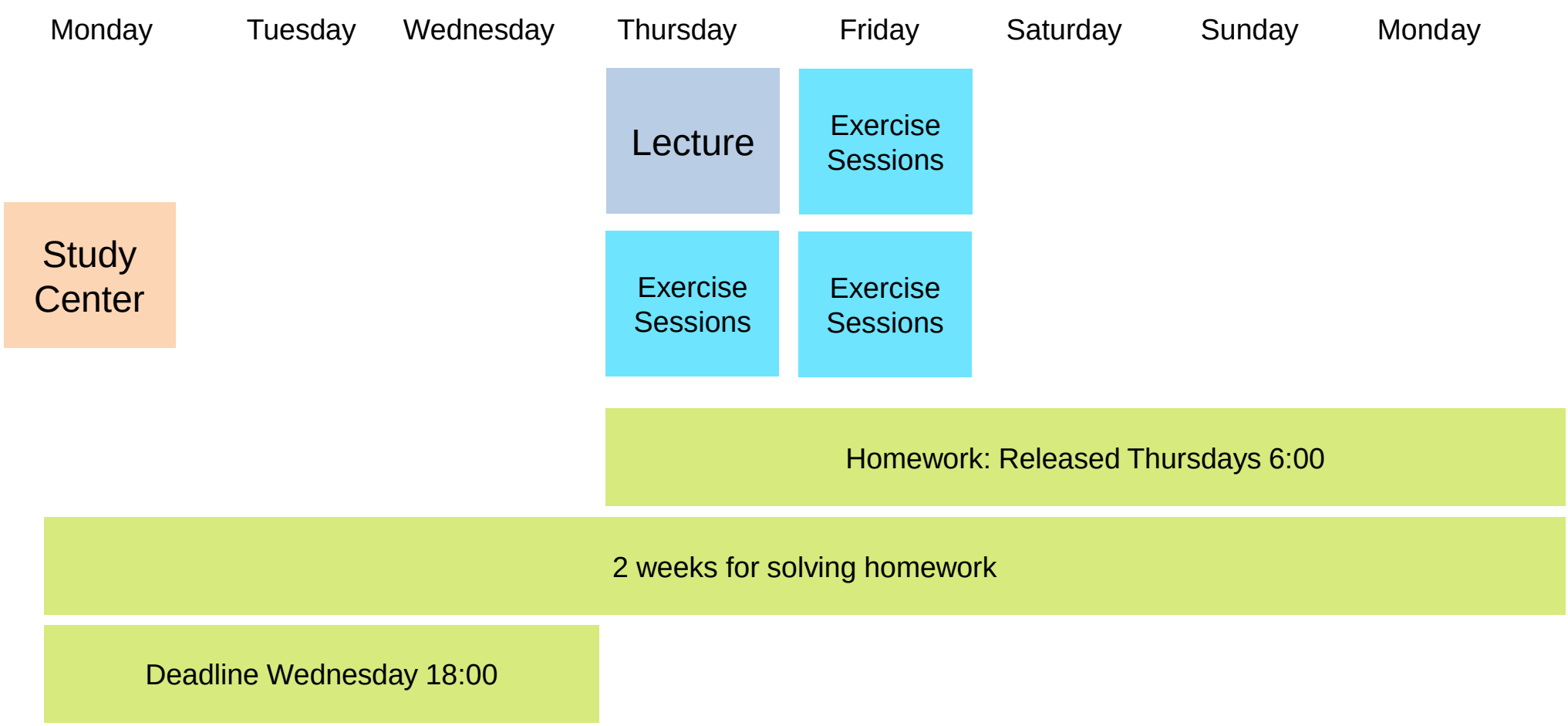
# Schedule

1. Course Organization
2. Main Topics
   - Division and Modulo Operators
   - Number Systems
   - Expressions
3. In-Class Code Example

# Weekly Schedule



# Weekly and Bonus exercises

- **Weekly exercises:**
  - Purpose: practice the new material
  - Released: Thursday at 6:00.
  - Deadline: A bit less than two weeks later (Wednesday at 18:00).
  - Allow earning experience points (XP)

- **Bonus exercises** (need around 2/3 experience points to unlock):
  - Purpose: combine knowledge from different topics
  - Allow earning max +0.25 towards the final grade (with 2/3 of bonus points)

# Weekly and Bonu

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Note:

- Only use constructs already introduced in the lecture and as specified in the task description
- Check the output of the autograder to view passed testcases and compiler warnings (0 pts if not corrected)

Study Center in GLC E29.2

- chance to ask for individual help regarding the course
- Time: Monday 12:15-14:00, starting in the second week of the semester

Exam

- 20~25p Theory Questions
- 5 Coding Examples with 10~15p each

# Integers

- Storage as binary numbers, bitsize dependent on OS: in C++ -> 32 bits
- Unsigned Integers $\mathbb{Z}$: [0,$2^{32}$-1] `-> 2^32 -1 = uint_max = -1, 2^32 = 0`
- Signed Integers $\mathbb{N}$: [-$2^{31}$,$2^{31}$-1] , 1 bit for sign
  - 2’s complement: 1. Convert the absolute value of x to binary. 2. Flip bits. 3. Add 1.

- Under-/Overflow when number exceeds min./max. value representable by data type
  - Overflow Detection of a+b: a < (int_max-b)

```
#include <limits>
```

`std::numeric_limits<T>::min()/max()`

# Division and Modulo Operators

- Integer division ignores digits behind the decimal point: (always rounds towards 0)

```
7 / 3 == 2
15 / 4 == 3
16 / 4 == 4
```

- Modulo division gets the remainder:

```
7 % 3 == 1
15 % 4 == 3
16 % 4 == 0
```

- The original number can be obtained like this:

```
(a/b)*b+(a%b)==a
```

**Note**: The modulo operator is not suitable for non-integer numbers!

# Division and Modulo Operators

- What question is answered by the output of the following code?

  Check divisibility: `a%b == 0 -> b|a`

```
int a;
std::cin >> a;
if (a % 2 == 0) {
    std::cout << "Yes" << std::endl;
} else {
    std::cout << "No" << std::endl;
}
```

Negative Modulo:

- takes sign of left term e.g. `(-7)%5= 2, 9%(-4)=1`
- add m

Rules:

- `(a+b)%m = ((a%m)+(b%m))%m`
- `(a*b)%m = ((a%m)*(b%m))%m`

# Number Systems

Method of expressing numbers

- decimal, binary 0b, hexadecimal 0x, octal 0

Base n system

- digits in [0, n-1]
- represented as powers of n

```
convert_base_from_decimal
  unsigned int result = 0;
  unsigned int basetenposition = 1;
  while (n != 0) {
    result += basetenposition * (n % b);
    n = n / b;
    basetenposition *= 10;
  }
```

# Expressions

Precedence and Associativity

- Higher precedence operators are evaluated first
- If same precedence, then evaluate according to associativity
- Order of operations:
  1. Unary arithmetic operators ( `++`, `--`, ... )
  2. Binary arithmetic operators ( `+`, `-`, ... )
  3. Relational operators (`<`, `>`, ... )
  4. Binary logical operators ( `&&`, ... )

L- and R-values

- semantic properties of expressions
- L-value: refers to an object, has an address in memory, can change its value.
- R-value: literals, cannot change its value. L-value can be used as R-value but not the other way around.

Attention: (a+b)*(a++), evaluation order depends on the compiler! Avoid!

# Evaluating Expressions

```
:: < a++ , a-- < ++a, -a,!a < *,/,% < +,- < <= ,<, > < ==, != < && < || < =,
assignment (+=,-=,*=,/=,%=) & unary (++a, -a,!a) operators left-associative
otherwise right-associative
```

1. Which of the following character sequences are not C++ expressions, and why not? Here, a and b are variables of type int.

| | |
|---|---|
| `(i) 1*(2*3)` | valid, rvalue, 6 |
| `(ii) (a=1)` | valid, lvalue, 1 |
| `(iii) (1` | invalid, no closing parenthesis |
| `(iv) (a*3)=(b*5)` | Invalid, left operand of the assignment operator must be an lvalue |

2. For all of the expressions that you have identified in 1, decide whether these are lvalues or rvalues, and explain your decisions.

3. Determine the values of the expressions and explain how these values are obtained. Which of these values are unspecified and can therefore not be determined uniquely?

# In-Class Code Example

Last 3 Digits: Write a C++ program which, for an integer $x \in Z \geq 1000$, outputs the last 3 digits

In general: For $n \in N$ and $x \in Z \geq 10^n$ , $(x\%10^n - x\%10^{n-1})/10^{n-1}$ corresponds to the nth digit of x

Question: How could we change the program from the previous task so that it outputs the last 3 bits?

Solution: Change all 10 into 2. (i.e. into the base of the system into which we are converting)

[code]expert basics:

- code snippets for auto-complete https://github.com/ajaxorg/ace/blob/master/src/snippets/c_cpp.snippets.js
- use pythontutor for interactive code execution https://pythontutor.com/cpp.html#mode=edit