

## Week8 monday

**Theorem:**  $A_{TM}$  is not Turing-decidable.

**Proof:** Suppose **towards a contradiction** that there is a Turing machine that decides  $A_{TM}$ . We call this presumed machine  $M_{ATM}$ .

By assumption, for every Turing machine  $M$  and every string  $w$

- If  $w \in L(M)$ , then the computation of  $M_{ATM}$  on  $\langle M, w \rangle$  \_\_\_\_\_
- If  $w \notin L(M)$ , then the computation of  $M_{ATM}$  on  $\langle M, w \rangle$  \_\_\_\_\_

Define a **new** Turing machine using the high-level description:

$D =$  “ On input  $\langle M \rangle$ , where  $M$  is a Turing machine:

1. Run  $M_{ATM}$  on  $\langle M, \langle M \rangle \rangle$ .
2. If  $M_{ATM}$  accepts, reject; if  $M_{ATM}$  rejects, accept.”

Is  $D$  a Turing machine?

Is  $D$  a decider?

What is the result of the computation of  $D$  on  $\langle D \rangle$ ?

**Theorem** (Sipser Theorem 4.22): A language is Turing-decidable if and only if both it and its complement are Turing-recognizable.

**Proof, first direction:** Suppose language  $L$  is Turing-decidable. WTS that both it and its complement are Turing-recognizable.

**Proof, second direction:** Suppose language  $L$  is Turing-recognizable, and so is its complement. WTS that  $L$  is Turing-decidable.

Give an example of a **decidable** set:

Give an example of a **recognizable undecidable** set:

Give an example of an **unrecognizable** set:

**True or False:** The class of Turing-decidable languages is closed under complementation?

Definition: A language  $L$  over an alphabet  $\Sigma$  is called **co-recognizable** if its complement, defined as  $\Sigma^* \setminus L = \{x \in \Sigma^* \mid x \notin L\}$ , is Turing-recognizable.

Notation: The complement of a set  $X$  is denoted with a superscript  $c$ ,  $X^c$ , or an overline,  $\overline{X}$ .