# Computers and programming languages introduction

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Lecture 01

# Class goals and structure

Primary purpose

- learn to to specify a problem
- break it up into algorithmic pieces
- implement a program to execute these pieces
    - learn Matlab

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Weekly schedule

- Monday, Wednesday: normal lecture hours
- Friday: short lecture, lab, hands on

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- Final project: 25%

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Assignments and lecture notes will be posted on my homepage

- http://physics.wm.edu/∼evmik/

# Homeworks and midterm project deadlines

- **due date**: corresponding Monday at 1:00pm for email submission
- report to be submitted via email as well as a carbon copy to be collected at the beginning of the Monday class

If there is no listings and no algorithms/data files, you will get zero points.

**Late submission penalties**

For each consequent day after the due date there will be a penalty (10% out of maximum possible score). Even if submission happens 1 minute after the due date, it holds 1 day penalty.

**Projects homework preparation recommendation**

Do not wait till the last day to finish your exercise. Programs almost never work at the first try and require quite a lot of time to debug.

# Collaboration and grading scale

- Collaborations are not permitted for homeworks.
- Projects to be done in group of 2 or 3 persons. This is the time to actively discuss and cooperate. Only one report per such group is needed.
  - But everyone is expected to have a full understanding of the project.
  - Be ready to answer questions related to the project without your group support.

Grading scale

| **Grade** | **percentage** | **Grade** | **percentage** | **Grade** | **percentage** |
|---|---|---|---|---|---|
| | | A | 94-100 | A- | 90-94 |
| B+ | 87-90 | B | 84-87 | B- | 80-84 |
| C+ | 77-80 | C | 74-77 | C- | 70-74 |
| D+ | 67-70 | D | 64-67 | D- | 60-64 |
| F | $<60$ | | | | |

# Recommended reading

Everything required for this class will be provided during lecture times.
Two **optional** books for your own references.
A short Matlab reference book: "Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers" bu Rudra Pratap

- ISBN-10: 0199731241
- ISBN-13: 978-0199731244

A more extended treatment of numerical algorithm with Matlab: "Numerical Methods in Engineering with MATLAB" by Jaan Kiusalaas

- ISBN-10: 0521191335
- ISBN-13: 978-0521191333

# Early history of computing

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- abacus
- sliding ruler
- pre-calculated tables of function (logarithm, trigonometry . . . )
- mechanical calculators

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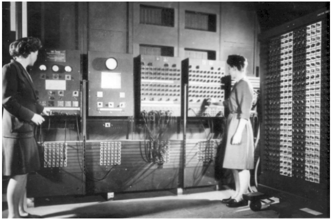
Modern computers appear at 1946 -ENIAC (Electronic Numerical Integrator And Computer)



- weight: 30 tons
- cost: $500,000 ($6,000,000 adjusted)
- power consumption: 150 kW

# ENIAC vs modern PC

Speed measured in operations per second

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- 5000 additions
- 357 multiplications
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Athlon 3000+ (2GHz)

- 70,000,000 additions
- 70,000,000 multiplications
- 50,000,000 divisions
- 15,000,000 sin operations

# Common features of modern computer

- Central Processing Unit (CPU)
- memory
  - holds data and executable code
- data input and output
- same hardware can do different calculation sequences
- usually use binary system
- programmable for any general task

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Different computer architectures (AMD, Mac, Intel, ARM . . . ) have different proportionality coefficient.

My 2 GHz AMD PC can do about 50 MegaFLOPS

# Computers . . .

*Computers are incredibly fast,*

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Thus

Computer is not a substitute for a brain

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  - Fortran, LISP, C, C++, Forth
- higher-level languages
  - Tcl, Java, JavaScript, PHP, Perl, Python
- Unfortunately none of them serves all needs.

# Programming languages implementations

**Compiled**

- generate computers binary code
  - it takes time
- faster execution time
- a bit harder to debug
- if you find and fixed an error (bug) you need to recompile
- Examples: Assembler, C, C++, Fortran

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**Interpreted**

- No compilation
- interpretation to machine code per instruction
- slow (since you have to interpret same instruction over and over)
- cross-platform code
- Examples: Perl, JavaScript, Lua, Php, Tcl, Shells, Matlab

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**just-in-time compilation**

- middle ground
- compile once to bytecode
- cross-platform
- Examples: Java, Python

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# Matlab as a language of choice

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- interpreted
  - easy to use and debug
- quite fast if done right, since main functions are compiled
- large selection of scientific related functions
- built in graphics/plotting
- Turing complete (you can do with it everything which computer is capable)
- designed to do numerical calculations

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**Contra**

- interpreted
  - could be slow if programmed inefficiently
- Not free to modify internals
- quite fast since for main functions it calls a compiled code
- rudimentary symbolic calculations

# Matlab: where to get

- Free for W&M students
- available for Mac and Windows
- visit `http://www.wm.edu/offices/it/a-z/software/`
- go to ‘Licensed software”
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# Discretization - The main weakness of computers

- coming from resources limitation

For example:

$$1/6 = 0.1666666666666666\cdots$$

But computer has limited amount of memory. Thus it cannot hold infinite amount of digits and has to truncate somewhere.
Let's say it can hold only 4 significant digits.

$$1/6 = 0.1667_c$$

This called round off error due to truncation/rounding. Then for computer

$$1/6 = 1/5.999$$

or

$$\mathbf{0.1667}123 = \mathbf{0.1667}321 = \mathbf{0.1667}222 = \mathbf{0.1667}111$$

or even more interesting

$$20 \times (1/6) - 20/6 = 20 \times 0.1667 - 3.333 = 3.334 - 3.333 = 10^{-4}$$

# Binary representation - why PHYS 256

Modern general purpose computers use binary representation

- bit is a smallest unit of information
- bit value is either 0 or 1

Bit is too small so we use byte

- byte = 8 bits stitched together
- byte can represent values in the range $-128 \cdots 0 \cdots 127$
- the major (the left most) bit usually holds the sign ($s$) of the number
  - 0: means positive
  - 1: means negative
- $01001010_2$
- decimal representation $01001010_2$ = $(-1)^0 \times (0 \times 2^0 + 1 \times 2^1 + 0 \times 2^2 + 1 \times 2^3 + 0 \times 2^4 + 0 \times 2^5 + 1 \times 2^6)$ = $2 + 8 + 64$ =74

# Binary representation (cont.)

Byte is clearly to small to be used for real life computation.
Matlab uses 8 bytes or 64 bits for number representation

- available range $-2,147,483,648 \cdots 0 \cdots 2,147,483,647$
- you can find this range by executing `intmin` and `intmax`
- notice that you cannot use numbers outside of this range
  - $2,147,483,647 + 10 = 2,147,483,647$
  - this is called overflow error

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- resulting number should have a form $(-1)^s \times c \times b^q$
  - where $s$ is a sign bit (1 in our case)
  - c is mantissa or coefficient (1.237)
  - b is the base (10)
  - q is the exponent (14)

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Computers internally use binary base

- $b = 2$
- 64 bits for full representation
  - 52+1 bits for mantissa (about 17 decimal digits)
  - 11 bits for exponent ($\pm$307)

# Limits of the float representation

- maximum $\pm 1.797693134862316 \times 10^{308}$ (use `realmax` in Matlab)
  - $(1.797693134862316 \times 10^{308}) \times 10 =$ `Inf`
  - overflow error
- minimum $\pm 2.225073858507201 \times 10^{-308}$ (use `realmin` in Matlab)
  - $(2.225073858507201 \times 10^{-308})/10 = 0$
  - underflow problem
- truncation error
  - $1.797693134862316 + 20 = 21.797693134862318$
  - $1.797693134862316 + 100 = 101.797693134862\_\_$
- how to mitigate
  - try to use numbers of the similar magnitude
  - do not rely on the least significant digits