CS 201 : Introductory Computational Physics

(Computational Science Program)

Tuesday, Thrusday, Friday

Lecture 1: Introduction

Course Instructor:
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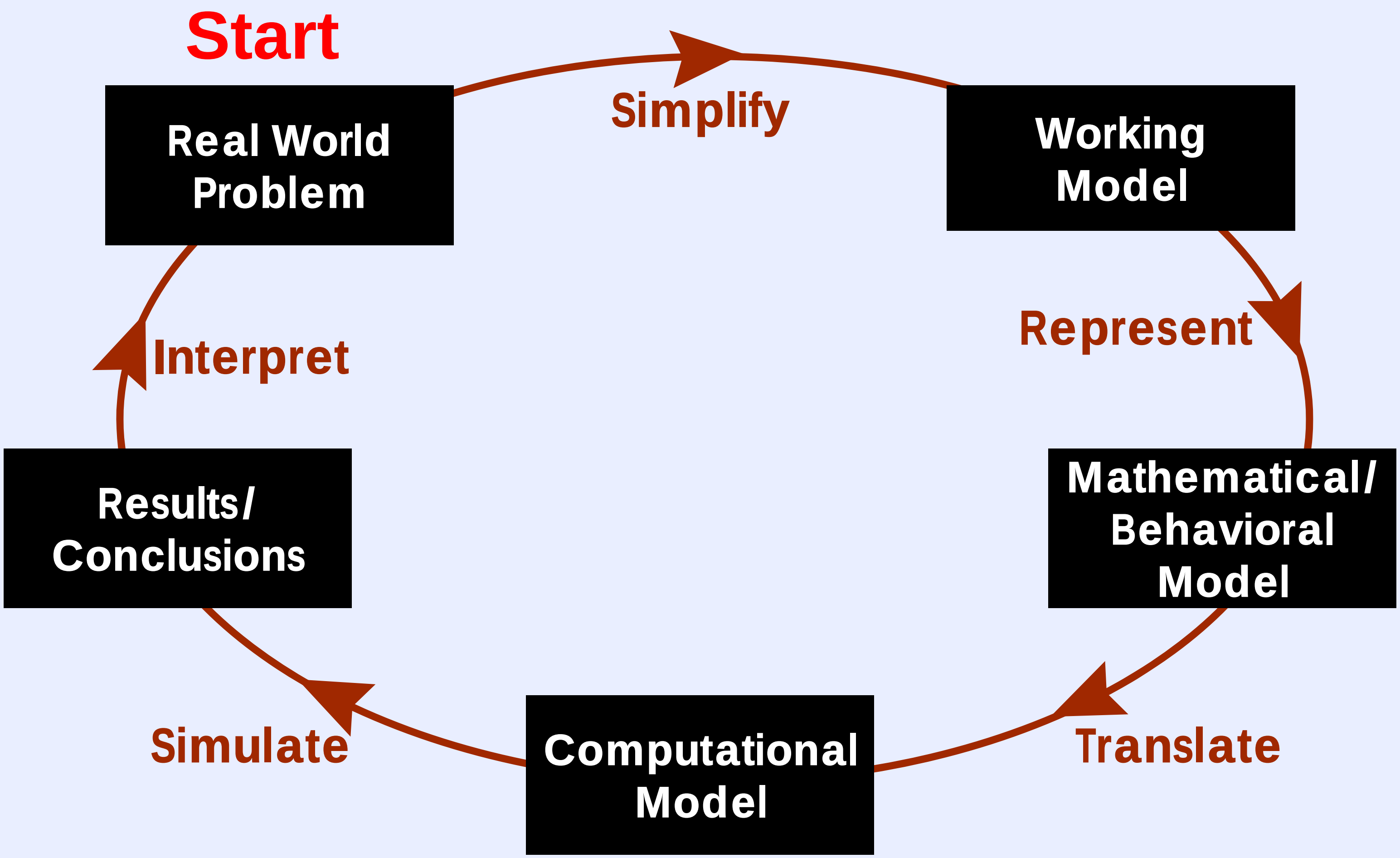
Lab session : 3 hours per week (lab 207).

Evaluation (theory + lab)

- First Term : 20%
- Second Term : 25%
- Third Term : 25%

- Lab Assignments+reports/attendance : 30%

Computational Physics (or CSci)



Approach we will follow

problem→theory→model→implementation → assessment

most important skills are:

- Problem (Engineering/scientific) solving,
- synthesizing information
- mathematical skills
- computing skills/ algorithm design
- analyze

CS201- topics

Focus→ Dynamics in space and time

Time and Length Scale ?

- Diameter of atom; Earth to Sun distance
- Heartbeat; Human life span

Powers of 10 & standard Greek Prefixes

TABLE 1–4
Metric (SI) Prefixes

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro†	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

† μ is the Greek letter "mu."

Rapid Estimation :Order of Magnitude

- Approximate value for a quantity. We are interested in obtaining rough or **order of magnitude estimates**.

- **Order of magnitude estimates**: Made by rounding off all numbers in a calculation to 1 sig fig, along with power of 10.
  - *Can be accurate to within a factor of 10 !!!*

Typical Lengths

TABLE 1–1 Some Typical Lengths or Distances (order of magnitude)

Length (or Distance)	Meters (approximate)
Neutron or proton (diameter)	10^{-15} m
Atom (diameter) →	10^{-10} m
Virus [see Fig. 1–5a]	10^{-7} m
Sheet of paper (thickness)	10^{-4} m
Finger width	10^{-2} m
Football field length	10^{2} m
Height of Mt. Everest [see Fig. 1–5b]	10^{4} m
Earth diameter	10^{7} m
Earth to Sun →	10^{11} m
Earth to nearest star	10^{16} m
Earth to nearest galaxy	10^{22} m
Earth to farthest galaxy visible	10^{26} m

Typical Times

TABLE 1–2 Some Typical Time Intervals

Time Interval	Seconds (approximate)
Lifetime of very unstable subatomic particle	10^{-23} s
Lifetime of radioactive elements	10^{-22} s to 10^{28} s
Lifetime of muon	10^{-6} s
Time between human heartbeats	10^{0} s (= 1 s)
One day	10^{5} s
One year	3×10^{7} s
Human life span	2×10^{9} s
Length of recorded history	10^{11} s
Humans on Earth	10^{14} s
Life on Earth	10^{17} s
Age of Universe	10^{18} s

Typical Masses

TABLE 1–3 Some Masses

Object	Kilograms (approximate)
Electron	10^{-30} kg
Proton, neutron	10^{-27} kg
DNA molecule	10^{-17} kg
Bacterium	10^{-15} kg
Mosquito	10^{-5} kg
Plum	10^{-1} kg
Human	10^{2} kg
Ship	10^{8} kg
Earth	6×10^{24} kg
Sun	2×10^{30} kg
Galaxy	10^{41} kg

Classical Mechanics

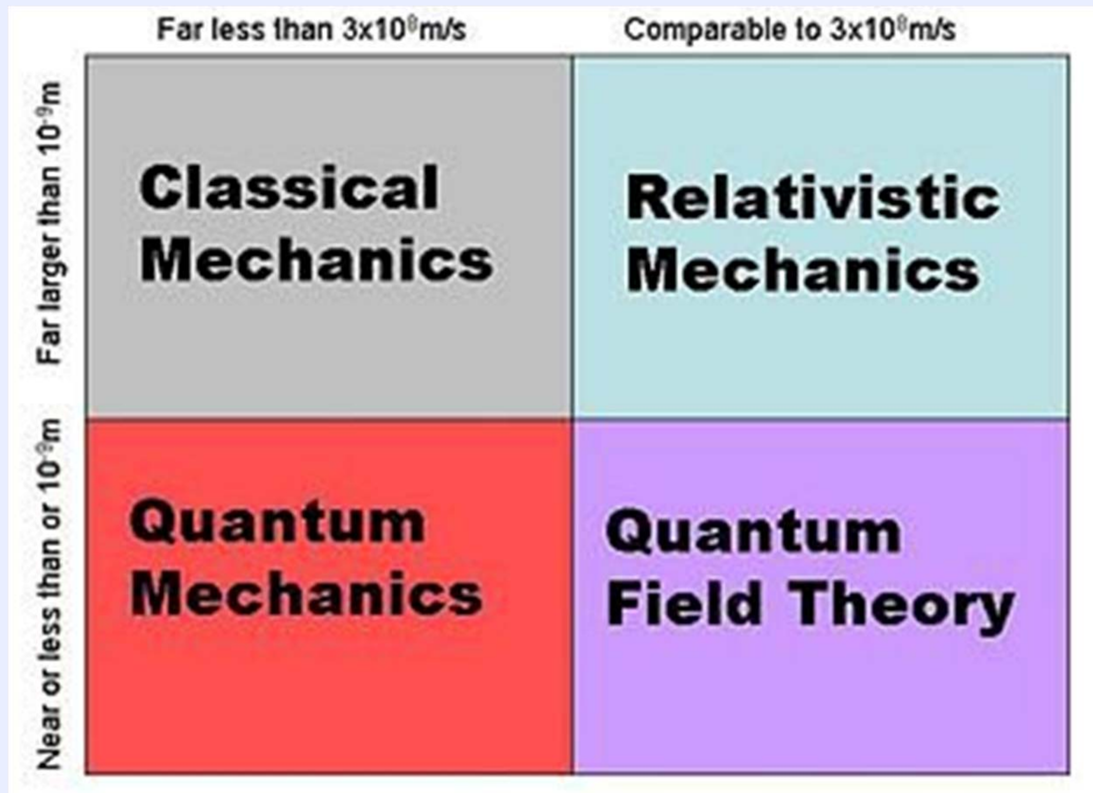
Limited to macroscopic objects moving at speeds "v" much, much smaller than the speed of light
$c = 3 \times 10^8$ m/s. As long as **$v \ll c$**, our discussion of CM will be valid.

Speed →

Our focus of this course *is "classical mechanics"*

What is the size of atom?

Size →



Newton's Laws + some other laws →
Describe most of macroscopic world!

So we will start with Newton's Law

So what is low speed, high speed, small size and large size in the structure of Physics?

What is Mechanics?

- Kinematics
- Dynamics

Mechanics

What is Mechanics?

- The science of ***HOW*** objects move (behave) under ***given forces***.
- Generally does not deal with the ***sources*** of forces.
- Focus is → “Given the forces, how do objects move”?

The study of objects in motion = Classical Mechanics

- How objects move → Kinematics
- Why objects move → Dynamics

Physics - Model, Theory, Law

Newton's **Laws** of motion !!!

- **Model:** An analogy of a physical phenomenon to something we are familiar with.
- **Theory:** Puts the model into mathematical language.
- **Law:** Concise & **general** statement about **how nature behaves**. Must be verified by many, many experiments! Only a few laws.

Brief Course content:

- **Review of important Mathematical Concepts (differential eqns., numerical solutions of ODEs)**
- **Elementary Mechanics (computational investigations)**
- **Oscillations and Motion (computational investigations)**

- Lagrangian and Hamiltonian Dynamics
- Rotational Motion and Rigid Bodies
- Some Other topics

Reference Book for theory part:

- **Classical Dynamics of Particles and Systems - By Thornton and Marion; Publisher:** Cengage.

- *Classical Mechanics*, By H. Goldstein, C. Poole, and J. Safko, Pearson India (optional).

Lab part (also for theory part):
Follow the Lectures and course materials.

Outcome

- Build computational models to investigate dynamical system and complex engineering problems.

- Ability to understand and analyze motion in real world surroundings using a small set of powerful fundamental principles.

Everything using MATLAB for this course

Computational Physics - objective?

- Bridge connecting **physics** with the **computation** and mathematics.
- Develop Computational tools to understand physics.

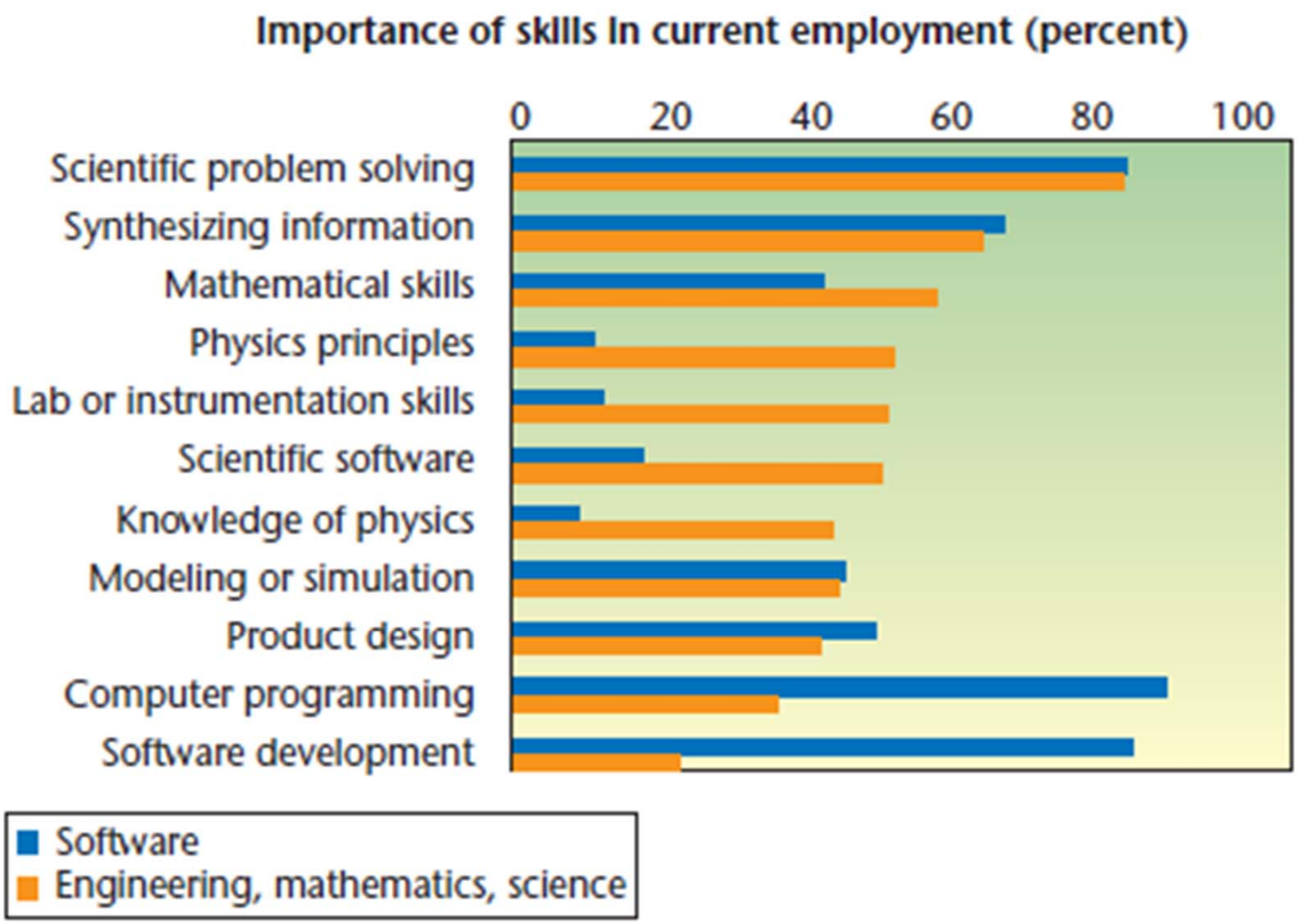
Need?

the average computer science/IT/ICT graduate does not have the strong mathematics and science background needed for technical employment,
and
that the average physics/ science graduate does not possess the requisite background in computation.

Some data, how CP is useful

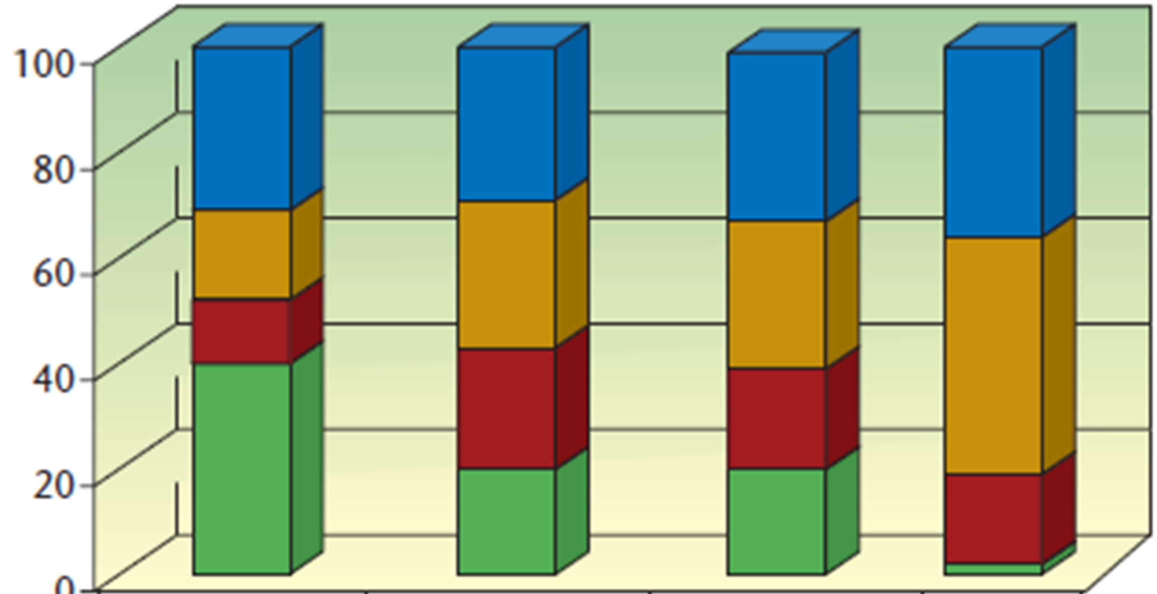
Computing in Science and Engineering Survey → Conducted primarily in USA reports its finding on Computational Physics education at undergraduate level.

Why Computational Physics



Different courses

Subject balance (percent in courses)



	Computational science	Computational science and engineering	Computational physics	Physics
Other	31	29	32	36
Application	17	28	28	45
Mathematics	12	23	19	17
Computing	40	20	20	2