PHY101: Introduction to Physics I

Monsoon Semester 2024
Lecture 1

Department of Physics, School of Natural Sciences,
Shiv Nadar Institution of Eminence, Delhi NCR

Instructors:
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Dr. Binson Babu (*binson.babu@snu.edu.in*)

Do you know?

- Enrollment (then only your name will be reflected on ERP). Any issue: Contact rahul.ishwar@snu.edu.in , D block, ground floor, academic office.
- Blackboard (then only you will be able to access materials and notifications about this course). Any issue: Contact rahul.ishwar@snu.edu.in, D block, ground floor, academic office.
- SAMS (Student Attendance Management System) (Check your attendance preferably the next day after each class and see if it is marked, if not email to the instructor before 7 days are over). Any issue: Contact your instructor *via* email
- Biometry (works within five minutes after the Instructor operate it), Any issue: Contact IT team, ithelpdesk@snu.edu.in
- Learning and Academic Support Centre (You will receive emails for LASC support, get it for clearing doubts). For more information: Contact ashraf.saeed@snu.edu.in

Aims of this course

- To bridge the gap between 10, +2 and standard undergraduate levels.

- To develop an understanding of the basic Physics laws and skills to apply various physical concepts to science and engineering through problem solving.

Course outline and syllabus

Mechanics:

- ❑ Reference frames and coordinate systems
- ❑ Newton's laws of motion in vector notation
- ❑ Conservation of energy
- ❑ Application of Newton's laws of motion
- ❑ Dynamical stability of systems: Potential energy diagram
- ❑ Collisions: Impulse, conservation of energy and linear momentum
- ❑ Conservation of angular momentum and rotation of rigid bodies in plane

Thermal Physics:

- ❑ Averages, probability and probability distributions

- ❑ Thermal equilibrium and macroscopic variables:

  Pressure of an ideal gas from Newton's laws

  - the kinetic theory of gases. Maxwell's velocity distribution

- ❑ Laws of Thermodynamics and the statistical origin of the second law of thermodynamics

- ❑ Application of thermodynamics: Efficiency of heat engines and air-conditioners, Thermodynamics of batteries and rubber bands

At the end of the course you should be able to:

Understand the laws of Newtonian mechanics and apply these laws to study dynamics of many body and rigid body systems.

Demonstrate the understanding of kinetic theory of gases, laws of Thermodynamics, concept of entropy etc., and apply this understanding to various physical systems.

Course Materials

Text/Reference books:

1. An Introduction to Mechanics, by Kleppner and Kolenkow
2. Physics for Scientists and Engineers with Modern Physics, by J. W. Jewett, R. A. Serway
3. Fundamentals of Physics, by Resnick, Halliday and Walker
4. Feynman Lecture Series, Vol. 1
5. Books by M. R Spiegel (Schaum series)

Other relevant materials

Lecture slides from instructor, Videos, animations, web sources

Additional Details:

Attendance requirements:

As per SNIoE policy (75%). Will be strictly followed. Failure to meet attendance criteria will invite F* grade for the student.

Course prerequisite:

This is a calculus-based introductory physics course and the students should have taken elementary calculus course prior to this course.

Reasonably good mathematical background (Calculus, Differential equation, Algebra, Geometry, Graphical analysis, Coordinate system, Transformation of coordinate system, vectors)

Weekly Homework:

Tutorials:

- Tutorial sheets will be provided with one week time to solve. Solutions will be discussed in the tutorial sessions.

Tutorials will start from **19th August, 2024**

Evaluation scheme:

- Quiz 1 : 15 % (each having 20 marks): MCQ type
- Quiz 2 : 15 % (each having 20 marks): Tutorial based
- Mid-semester exam: 35%
- End-semester examination: 35%

Note: Any unfair means during the examination will invite “F” grade.

Grading Scheme

- Less than 35 % - F grade
- 80 % above - A grade

Meeting hours with the instructor (Group L)

A student may contact his/her respective instructor for any academic issues during the following contact hours without prior notification:

Instructor: Prof. Susanta Sinha Roy
Meeting hours: Monday (2 pm – 4 pm)
Office: A021B

Meeting hours with the instructor (Group L)

A student may contact his/her respective instructor for any academic issues during the following contact hours without prior notification:

Instructor: Dr. Rana Nandi
Meeting hours: Friday (2 pm – 4 pm)
Office: A021C

Meeting hours with the instructor (Group L)

A student may contact his/her respective instructor for any academic issues during the following contact hours without prior notification:

Instructor: Dr. Sucheta Mondal
Meeting hours: Thursday (10 am – 12 pm)
Office: R004E (Research block)

Meeting hours with the instructor (Group L)

A student may contact his/her respective instructor for any academic issues during the following contact hours without prior notification:

Instructor: Dr. Binson Babu
Meeting hours: Thursday (3 pm – 5 pm)
Office: R004D (Research block)

Syllabus for the examinations

- **Quiz 1:** Topics covered till the last week's lecture.

(Tentative exam date –5th September, 2024)

- **Mid Sem.:** Syllabus will be informed before the exam (starting from the 1st day of the course).

(During mid-sem exam period – 27th Sept. to 4th October, 2024)

- **Quiz 2:** Topics covered till the last week's lecture.

(Tentative exam date – 7th November, 2024)

- **End Sem.:** Topics covered up to mid-sem. exam: 30%-40%

  and topics covered from mid sem. to the end sem. exam: 70%-60%

(During end-sem exam period – 2nd December to 10th December, 2024)

Note: This is a tentative plan. Any alteration will be communicated a week in advance.

NB: ***Tutorial questions can be expected in the Exam.***

What is Physics?

Physics, the most fundamental physical science, is concerned with the fundamental principles of the Universe.

It is the foundation upon which the other sciences— astronomy, biology, chemistry, and geology—are based.

The beauty of physics lies in the simplicity of its fundamental principles and in the manner in which just a small number of concepts and models can alter and expand our view of the world around us.

Identify the limited number of fundamental laws

Predict the results of the future!
Mathematical relation between **quantities**

Classifications in Physics?

The study of physics can be divided into six main areas:

Classical mechanics: Concerning the motion of objects that are large relative to atoms and move at speeds much slower than the speed of light

Relativity: A theory describing objects moving at any speed, even speeds approaching the speed of light

Thermodynamics: Dealing with heat, work, temperature, and the statistical behavior of systems with large numbers of particles.

Electromagnetism: Concerned with electricity, magnetism, and electromagnetic fields.

Optics: The study of the behavior of light and its interaction with materials.

Quantum mechanics: a collection of theories connecting the behavior of matter at the submicroscopic level to macroscopic observations.

Physics and Measurement

Quantities

Physics is based on experimental observations and quantitative measurements and it is developed by learning how to measure the **quantities** involved

What is a Physical quantity?

It is used to refer anything that can be measured such as length, time, temperature, pressure, etc.

Physical quantities

Basic Physical quantities

- Length
- Mass
- Time
- Electric current
- Temperature
- Amount of substance
- Luminous intensity

Derived Physical quantities

- velocity = length/ time
- Acceleration = length /$(time)^2$
- Force = Mass * Acceleration
- etc..

Physics and Measurement

Units

- Each quantity is measured with its own **unit**, by comparison with a standard

- **Unit** is a universal name assigned for measuring a quantity

Modern scientific and engineering quantifications are based on the Système International d'Unités (International System of Units, commonly abbreviated as SI) that was adopted in 1960

BASIC SI UNITS

Unit of	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Physics and Measurement

Length

1 Meter = The distance traveled by light in vacuum during a time of 1/299 792 458 second

Approximate Values of Some Measured Lengths

	Length (m)
Distance from the Earth to the most remote known quasar	1.4×10^{26}
Distance from the Earth to the most remote normal galaxies	9×10^{25}
Distance from the Earth to the nearest large galaxy (Andromeda)	2×10^{22}
Distance from the Sun to the nearest star (Proxima Centauri)	4×10^{16}
One light-year	9.46×10^{15}
Mean orbit radius of the Earth about the Sun	1.50×10^{11}
Mean distance from the Earth to the Moon	3.84×10^{8}
Distance from the equator to the North Pole	1.00×10^{7}
Mean radius of the Earth	6.37×10^{6}
Typical altitude (above the surface) of a satellite orbiting the Earth	2×10^{5}
Length of a football field	9.1×10^{1}
Length of a housefly	5×10^{-3}
Size of smallest dust particles	$\sim 10^{-4}$
Size of cells of most living organisms	$\sim 10^{-5}$
Diameter of a hydrogen atom	$\sim 10^{-10}$
Diameter of an atomic nucleus	$\sim 10^{-14}$
Diameter of a proton	$\sim 10^{-15}$

Mass

Physics and Measurement

Courtesy of National Institute of Standards and Technology, U.S. Department of Commerce

Kilogram (kg), is defined as the mass of a specific platinum–iridium alloy cylinder (90% platinum and 10% iridium) kept at the International Bureau of Weights and Measures at Sèvres, France.

"Le Grand K"

https://phys.org/news/2019-05-adieu-le-grand-kilogram-redefined.html

MAY 20, 2019

Adieu, Le Grand K: The kilogram to be redefined for the first time in 130 years

by Deborah Netburn, Los Angeles Times

Credit: CC0 Public Domain

Latest Definition. (November 2018 **)**

Kilogram (kg), is defined by taking the fixed numerical value of the Planck constant **h** to be **6.626 070 15 x 10^{-34}** when expressed in the unit **J s**, which is equal to **kg m^2 s^{-1}**, where the metre and the second are defined in terms of ***c*** and $\Delta\nu_{Cs}$.

$$1\ \text{kg} = \frac{h}{6.626\,070\,15 \times 10^{-34}}\ \text{m}^{-2}\ \text{s}$$

$\Delta\nu_{Cs}$ **=** hyperfine transition frequency of the caesium 133 atom

***c* =** speed of light in vacuum

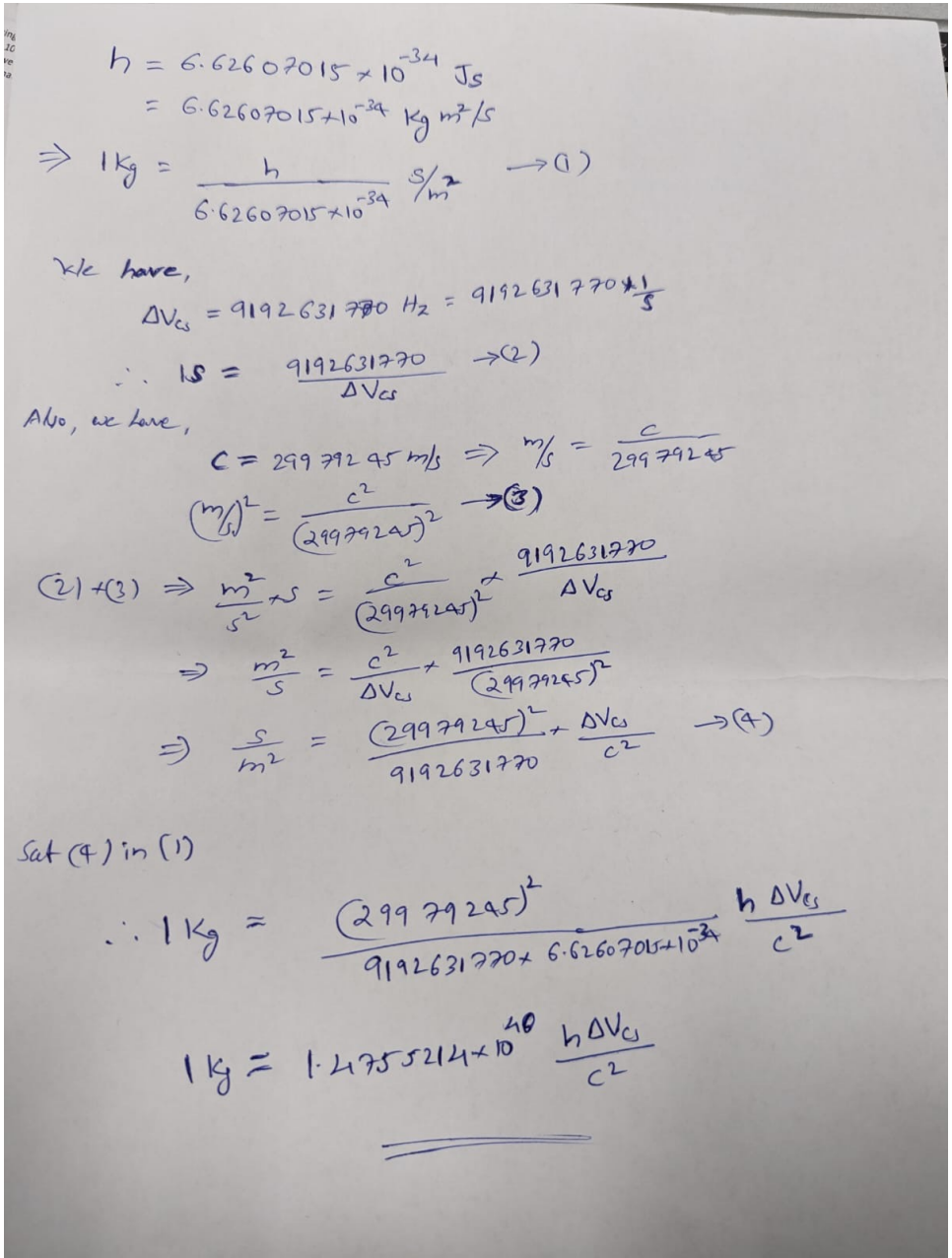
$$1\ \text{kg} = \frac{299\,792\,458^2}{9\,192\,631\,770 \times 6.626\,070\,15 \times 10^{-34}} \frac{h\,\Delta\nu_{Cs}}{c^2}$$

$$\approx 1.475\,5214 \times 10^{40}\ \frac{h\,\Delta\nu_{Cs}}{c^2}$$

https://www.bipm.org/en/si-base units/kilogram

Mass

Physics and Measurement
Solution



$$h = 6.62607015 \times 10^{-34}\ Js$$
$$= 6.62607015 \times 10^{-34}\ kg\ m^2/s$$

$$\Rightarrow 1\ kg = \frac{h}{6.62607015 \times 10^{-34}}\ s/m^2 \quad \rightarrow (1)$$

We have,

$$\Delta V_{Cs} = 9192631770\ Hz = 9192631770 \times \frac{1}{s}$$

$$\therefore 1s = \frac{9192631770}{\Delta V_{Cs}} \quad \rightarrow (2)$$

Also, we have,

$$c = 299792458\ m/s \Rightarrow m/s = \frac{c}{299792458}$$

$$(m/s)^2 = \frac{c^2}{(299792458)^2} \quad \rightarrow (3)$$

$$(2) \times (3) \Rightarrow \frac{m^2}{s^2} \times s = \frac{c^2}{(299792458)^2} \times \frac{9192631770}{\Delta V_{Cs}}$$

$$\Rightarrow \frac{m^2}{s} = \frac{c^2}{\Delta V_{Cs}} \times \frac{9192631770}{(299792458)^2}$$

$$\Rightarrow \frac{s}{m^2} = \frac{(299792458)^2}{9192631770} \times \frac{\Delta V_{Cs}}{c^2} \quad \rightarrow (4)$$

Sub (4) in (1)

$$\therefore 1\ kg = \frac{(299792458)^2}{9192631770 \times 6.62607015 \times 10^{-34}} \frac{h\,\Delta V_{Cs}}{c^2}$$

$$1\ kg = 1.47552214 \times 10^{40}\ \frac{h\,\Delta V_{Cs}}{c^2}$$

Physics and Measurement

Mass

Approximate Masses of Various Objects

	Mass (kg)
Observable Universe	$\sim 10^{52}$
Milky Way galaxy	$\sim 10^{42}$
Sun	1.99×10^{30}
Earth	5.98×10^{24}
Moon	7.36×10^{22}
Shark	$\sim 10^{3}$
Human	$\sim 10^{2}$
Frog	$\sim 10^{-1}$
Mosquito	$\sim 10^{-5}$
Bacterium	$\sim 1 \times 10^{-15}$
Hydrogen atom	1.67×10^{-27}
Electron	9.11×10^{-31}

Physics and Measurement

Time

One second is defined as **9 192 631 770 times** the period of vibration of radiation from the **cesium-133 atom**.

The primary time standard in the United States is a cesium fountain atomic clock developed at the National Institute of Standards and Technology laboratories in Boulder, Colorado. The clock will neither gain nor lose a second in 20 million years.

Physics and Measurement

Time

Approximate Values of Some Time Intervals	
	Time Interval (s)
Age of the Universe	5×10^{17}
Age of the Earth	1.3×10^{17}
Average age of a college student	6.3×10^{8}
One year	3.2×10^{7}
One day	8.6×10^{4}
One class period	3.0×10^{3}
Time interval between normal heartbeats	8×10^{-1}
Period of audible sound waves	$\sim 10^{-3}$
Period of typical radio waves	$\sim 10^{-6}$
Period of vibration of an atom in a solid	$\sim 10^{-13}$
Period of visible light waves	$\sim 10^{-15}$
Duration of a nuclear collision	$\sim 10^{-22}$
Time interval for light to cross a proton	$\sim 10^{-24}$

Physics and Measurement

Dimensional of a Physical Quantities

Dimension of a quantity signifies its relation to the assumed set of fundamental quantities. It denotes the physical nature of a quantity

Length [L]
Mass [M]
Time [T]
Temperature [K]
Electric Current [A]
Amount of Substance [mole]
Luminous Interest [cd]

Derived Quantities

Physics and Measurement

Dimensional of a Physical Quantities

Derived Quantities

Area of a plane, $[A] = [L]^2 \rightarrow$ 2 Dimension
Volume, $[V] = [L]^3 \rightarrow$ 3 Dimension

- What would be the dimension of density which is mass/volume?

$$[ML^{-3}]$$

- What's about acceleration?

$$[LT^{-2}]$$

Physics and Measurement

Dimensional Analysis

The time period *T* of small oscillations in a simple pendulum of length *l* is given by (g is the acceleration due to gravity)

(a) $T = 2\pi\sqrt{\frac{g}{l}}$,

(b) T= $2\pi\sqrt{lg}$,

(c) T = $2\pi\sqrt{\frac{l}{g}}$

Physics and Measurement

Dimensional Analysis

=> Quantities can be added or subtracted if they have same dimension

=> The terms on both sides of an equation must have the same dimension

Physics and Measurement

Dimensional Analysis

Q1 Suppose the acceleration a of a particle moving with uniform speed **v** in a circle of radius **r** is proportional to some power of **r**, say $\mathbf{r}^{n}$, and some power of **v**, say $\mathbf{v}^{m}$. Determine the values of **n** and **m** and write the simplest form of an equation for the acceleration.

$$a \propto r^n v^m$$

$$a = k\, r^n v^m$$

$$[a] = [k\, r^n v^m]$$

$$[L/T^2] = [L^n]\,[L/T]^m = L^{n+m}/T^m$$

n + m = 1 **m = 2** **n = -1**

$$a = k\, r^{-1} v^2 = k\, v^2/r$$

Physics and Measurement

Q2 Theory of relativity reveals that the mass can be converted into energy. Einstein found that the energy E is proportional to certain power of mass (**m**) and speed of light (**c**). Find out a simple relation among **E, m** and **c** using dimensional analysis.

Suppose $E = m^a c^b$

Writing the dimension formula on both sides

$[ML^2T^{-2}] = [M]^a\,[LT^{-1}]^b$

$[ML^2T^{-2}] = [M^aL^bT^{-b}]$

Equating the dimensions of both sides, we have

$a = 1,\ b = 2$

Thus $E = mc^2$