Welcome
Web URL:

General Information
Lectures: SK

Text: University Physics  Young & Freedman
Study Guide: Introductory Classical Mechanics
MIT 8.01 Study Guide
Busza, Cartwright, Guth

Lectures: MWF 10-11
11-12
Recitations: MW 26 Sections 2/wk
TR

Homework/Quizzes
Switching Sections
  • New Instructor’s Permission
  • Notify UPhys Office
Homework:
- Average 1 assignment/wk [≈ 3 prob/wk]
- On weeb. Wednesday previous week.
- Due Thursdays 4:30 pm
- Solutions on Web.
- Grade ≈ 3/week; random problems.
- Read assignments as soon as you have them. Think about problems and ask questions in recitations. Don’t wait for last day. Cooperation is encouraged; independent write-ups only!

Cyber Tutor:
- Web-based homework and grading
- On weeb.
- Due: Tuesdays 11 pm
- Approx 4 prob/wk

Tutoring:
Class Quizzes:

Q1: Sep 29 M
Q2: Oct 24 F
Q3: Nov 21 F

Makeup: Oct 7 T
        Nov 4 T
        Dec 2 T

Final Exam: Dec 3 hrs

No valid excuse ⇒ zero

Grading

Quizzes   36%
Final     36%
Homework  9
Recitation 10
Mastering Phy. 9

Laboratory

- No formal laboratory
- Lecture demonstrations
There are approximately 700 students taking 8.01 with a broad spectrum of skills and experience.

Physics: There are students who have seen essentially no physics previously. There are others who are just shy of Advanced Placement in 8.01.

Math/Calculus: Calculus is an essential tool for teaching physics - we will start slowly but increase its use rapidly. Many here have advanced placed 18.01. I will not take advantage of that in fairness to others but will try and pace what you are learning in 18.01

- Algebra
- Trigonometry
  - Must have the facility at your fingertips
- Vectors
  - Can't wait for 18.01/18.02
  - Introductory lecture in 8.01

Options:
8.012: More challenging option/Calculus, Vectors
Delay 8.01 to 2nd Term / Issue of Major Choice
Commitment

This will not be a course for memorizing a lot of formulas, etc. I will try to teach you about concepts, ideas and the laws of mechanics — as well as some of the important principles of physics. You will be required to apply these to problems.

- 3 Hrs lectures
- 2 Hrs Recitation
- 7 Hrs Homework (\(\approx\text{Average}\))
- 12 Hrs/Wk.

If you make this level-of-commitment you will learn a lot of physics and have no trouble passing.

Recitations will help you in doing the problems and explaining some physics not completely covered in lecture. They are important!!

Tutors will also be available. Schedule will be announced later.

If you decide to switch recitations:
  - Must have permission of new instructor
  - Must notify UP Office.
Physics

As you proceed with your study of physics for the next two terms you will learn about the achievements of such scientific giants as Galileo, Copernicus, Newton, Maxwell and Einstein whose work among others forms the foundation of our present understanding of the physical world.

We begin in 8.01 our study of physics with the subject of mechanics — the study of motion and its causes. A natural starting point since everyday experience offers many examples of mechanical principles — more so than any other area of physics.

We will introduce the language of physics:
- measurement units / standards
- calculational techniques / calculus
- vector algebra

We start by developing a language for describing motion:
- an ideal particle moving along a straight line
- motion in a plane,
  - parabolic motion / ballistics
  - circular path motion
The big step will be to consider the relationship between motion and the forces that are always associated with it. Whenever a particle speeds up, slows down or changes the direction of its motion—there is always an associated force. The relationship between force and motion is contained in Newton's three laws of motion.

Physics is an experimental science. We will see the interplay between theory and experiment. Every physical theory must ultimately be grounded in experimental observations of phenomena in the physical world.

I will try to teach you, along with my colleagues, how to apply these laws to solving practical problems. I will develop systematic problem solving procedures that help to set up problems and carry out solutions efficiently and accurately.

You will see some of the beauty and symmetry of physics when you see how these essential relationships of mechanics are all described in a neat and compact package called "Newton's laws of Motion."
Classical Mechanics

In the study of mechanics we shall concern ourselves with the motion of a particle. This motion is described by giving its position as a function of time.

specific position + time $\Rightarrow$ event
position $\Rightarrow$ velocity $\Rightarrow$ acceleration

Ideal Particle
- classical physics concept
- point-like object/no size
- mass

Measurements of position, time and mass completely describe this ideal classical particle.
- Elementary particles have charge, spin—Ignore!

Position:
If a particle moves along $\omega$:
- curve $\Rightarrow$ 1-coordinate
- surface $\Rightarrow$ 2-coordinates
- volume $\Rightarrow$ 3-coordinates

General description requires a coordinate system with an origin.
- fixed reference point, origin
- a set of axes or directions
- instructions on labelling as point relative to origin—axes
Rectangular Coordinates

- simplest system
- easiest to visualize
Spherical Coordinates

- Still need 3 numbers to specify completely
- Nice system for motions on a spherical surface

\( r \rightarrow \) distance from origin to point \( P(x, \theta, \phi) \)

\( \phi \rightarrow \) angle between line through poles (z-axis) and line \( \overline{OP} \). (latitude = \( \frac{\pi}{2} - \phi \))

\( \theta \rightarrow \) angle in xy-plane measured from x-axis related to longitude.

\[ x = r \sin \phi \cos \theta \]
\[ y = r \sin \phi \sin \theta \]
\[ z = r \cos \phi \]

\[ r^2 = x^2 + y^2 + z^2 \]
\[ \tan \phi = \sqrt{x^2 + y^2} / z \]
\[ \tan \theta = y / x \]
Cylindrical Coordinates

- $r$ → distance from cylindrical axis to point $P$
- $z$ → height above the horizontal plane
- $\theta$ → angle in $xy$-plane measured from $x$-axis

$x = r \cos \theta$

$y = r \sin \theta$

$z = z$

$r^2 = x^2 + y^2$

$tan \theta = \frac{y}{x}$

$z = z$
Space:
3-dimensional Euclidean
• sum of angles in plane $\Delta = 180^\circ$

Time:
Time is absolute!!
• the rate at which time elapses is independent of position and independent of velocity.

Euclidean Geometry
+ Absolute Time

Classical or Newtonian Physics

Isaac Newton: (1642 - 1727)
• Principia Mathematica (1687)
  • For nearly 200 yrs these laws stood unchallenged as a basis for scientifically explaining the physical world.
  • Today these laws are still the essential ingredients of engineering/physics.

- Laws of Motion
- Universal Gravitation
Shortcomings:

We know that the postulates of Space-Time are not exactly true.

- Light rays passing by the sun are deflected. Sum of angles in a $\Delta \neq 180^\circ$.

- Clocks moving at high velocity ($v \sim c$) or which are in a gravitational field keep time at a different rate compared with clocks at rest. $\rightarrow$ Time Dilation

- Neutron Stars: $\alpha = 10^{11}$ qees
- Black Holes: Even light is trapped.

New Theory: Special Relativity $\cup$ A. Einstein
General Relativity $\cup$ (space/time $\rightarrow$ curved)

- Effects are very small for $v \ll c$
- Play an undetectable role in the basic mechanics we will study.

- Elementary Particles: Short distances, times, $v \ll c$ $\rightarrow$ Quantum Mechanics.
Units of Measurement

Length: meter
Time: second
Mass: kilogram

International System of Units (SI) (1971) 7-base units

Length: foot
Time: second

British

Weight: pound
Mass: slug

(derived unit)

Length: [10^-6 Pole \rightarrow Equator distance] (1792)
Original Standard - Platinum-inidium bar (1m) long at the Int. Bureau of Weights and Measures (Paris)

Number of wavelengths of krypton laser light

(1960: 1,650,763.73 X's Kr-86 atomic standard)

(1983) length of path travelled by light in a vacuum in a time interval of 1/299,792,458 seconds.

\[ d = \frac{c \cdot t}{c} \]

Distance \[ \uparrow \]
Time \[ \uparrow \]
Speed of light

\[ c = 2.99792458 \times 10^8 \text{ m/s} \] [Exactly defined]

Einstein's Theory: \[ c = \text{constant} \] makes sense to fix its value
Length \[ \Rightarrow \] depends on unit of time.
Lengths
Farthest observed quasar (1987)
Wavelength of visible light
Radius of a proton

Time
Life time of a proton (est.)
Age of universe
Lifetime of most unstable particle
Planck time

Mass
Known universal
Elephant
Electron
Time:

Originally = \frac{1}{60 \times 60 \times 24} \text{ of a mean solar day.}

- not very precise since there is a variation due to earth's rotation, etc.
  (winds, tides, air, glaciers)

Presently = Atomic Standard

1 \text{ second} = 9,192,631,770 \text{ vibrations of a cesium atom}
  \text{Cs-133} \Rightarrow \text{cesium atomic clock} \quad 1 \approx \frac{1}{\text{30,000}} \text{ yrs.}

Accuracy \approx \frac{1}{10^{13}} \Rightarrow 1 \text{ s in 300,000 yrs.}

Mass:

Standard: A cylinder of platinum-inidium alloy
  at \text{BqGMN (Paris)}
  \equiv 1 \text{ kg, exactly by definition}

Atomic Standard

- None yet
- Possibly in future.

\text{e.g.} \ Hydrogen or Krypton atoms

- Some very large number would represent 1-kg.
Relative Mass Measurements

- Nuclear reactions

\[ ^{12}\text{C (atom)} = 12\, \text{u} \] \hspace{1cm} \text{(Atomic Mass Units)}

- Other masses can be measured relative to carbon very precisely.

\[ 1\, \text{u} \sim 1.66054 \times 10^{-27}\, \text{kg}. \]

Derived Units

Volume \[ = \, L^3 \quad \text{(m}^3) \]

Density \[ \rho = \frac{M}{V} = \frac{\text{Mass}}{\text{Volume}} = ML^{-3} \quad \text{(kg/m}^3) \]

Velocity \[ = \frac{\text{Length}}{\text{Time}} = LT^{-1} \quad \text{(m/s)} \]
Changing Units

- Essential skill required for solving physics probs.
- "chain-hink-conversion"

\[ S = 80 \text{ km/hr} \]
\[ = \ ? \text{ m/s} \]

Know:
\[ 1\text{ hr} = 3600 \text{ s} \]
\[ \therefore 1 = \frac{1\text{ hr}}{3600 \text{ s}} \]

Also
\[ 1000\text{ m} = 1 \text{ km} \]
\[ \therefore 1 = \frac{1\text{ km}}{1000 \text{ m}} \]

\[ S = \frac{80\text{ km}}{\frac{\text{hr}}{3600 \text{ s}}} \times \frac{1\text{ hr}}{3600 \text{ s}} \times \frac{1}{\frac{1\text{ km}}{1000 \text{ m}}} \]
\[ = 80 \times \frac{1000}{3600} \text{ m/s} = 22 \text{ m/s} \]

*units obey same rules as algebraic variables and numbers!!*

Powers of Ten: (10 min)
Dimensional Analysis

- Dimensions refer to type of units [m, L, T] required to describe a physical process.
- For beginners it is particularly useful to treat dimensions just like all other variables (quantities) in the calculation.

\[ S = \sqrt{L/T} \]

\[ [L] = [\sqrt{L/T}] = [L] \]

- Scheme for working out relationships and basic dependences in physics.

Rules:
- In an equation we can only add or subtract quantities which have the same dimension.
- The quantities on each side of an equality must have the same dimension.
Example

Is this eq. correct:

\[ v_f = v_i + \frac{1}{2} a t^2 \]

\[ \uparrow \quad \uparrow \quad \text{acceleration} \]

Final Initial

\[ \left[ \frac{L}{T} \right] = \left[ \frac{L}{T} \right] + \frac{1}{2} \left[ \frac{L}{T^2} \right] \times t^2 \]

N.G.

- Dimensions cannot check for constants such as \( \frac{1}{2}, \ \pi, \ etc. \)
Example: Simple Pendulum

What does period $T$ depend on?
- mass $m$
- length $l$
- gravity $g$
- deflection $\theta$

Assume $T = C \cdot l^\omega \cdot m^x \cdot g^y \cdot \theta^z$

$\uparrow$ dimensionless constant

Write out units:
$[T] = [L]^1 [M]^x [T]^y$

$\theta \Rightarrow$ No dimensions, does not appear

$[T] = [L]^1 [M]^x [T]^{-2z}$

$1 = -2z$
$0 = \omega + z$
$0 = x$

Equate dimensions both sides

Solve: $z = -\frac{1}{2}$
$\omega = \frac{1}{2}$
$x = 0$

$\therefore T = C \sqrt{\frac{l}{g}} \cdot f(\theta)$

$\uparrow \sqrt{g}$ $\uparrow$ cannot determine now

$2\pi \ (\text{see later})$