Physics I: Measurements, Motion and Newton's Law

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Course Overview

This course introduces the essential foundations of physics, focusing on measurement, uncertainty, and the study of simple motion. Students will build problem-solving skills and understand how physical laws describe everyday phenomena.

Syllabus Highlights

- **Measurements and Units**
  - Physical quantities and SI units
  - Accuracy vs. precision
  - Significant figures and rounding
  - Uncertainty and error propagation
  - Types of experimental errors
  - Reporting scientific results
- **Motion Along a Straight Line**
  - Position, displacement
  - Elapsed time and time intervals
  - Average vs. instantaneous velocity/acceleration
  - Motion with constant acceleration
  - Graphical analysis: $\mathbf{x} - t$, $\mathbf{v} - t$, $\mathbf{a} - t$ plots
  - Free fall and vertical motion
  - Integrating velocity to get position
  - Using motion equations for problem solving
  - Real-world applications: projectiles, falling objects
  - Integration method
- **Newton's Three Laws of Motion**
  - Newton's Three Laws of Motion
  - Free-body diagrams and force analysis
  - Common types of forces (gravity, friction, etc.)
  - Applications of Newton's laws in everyday situations
  - Limitations of Newtonian mechanics
- **Circular & Simple Harmonic Motion (SHM)**
  - Uniform Circular motion
  - Centripetal acceleration & force
  - Applications of circular motion
  - SHM and the restoring force concept
  - Mathematical description of SHM
  - Energy in SHM: potential and kinetic energy
  - Relationship between circular motion and SHM
- **Basic Python Skills for Physics**
  - Python syntax and Jupyter notebooks
  - Variables, loops, and simple plotting
  - Implementing the trapezoid rule for integration
  - Round-off errors and numerical accuracy
  - Writing small programs to solve physics problems

Key Equations

- **Instantaneous Velocity:** $v = \frac{dx}{dt}$
- **Instantaneous Acceleration:** $a = \frac{dv}{dt}$
- **Kinematic Equation 1:** $v = v_0 + at$
- **Kinematic Equation 2:** $x = x_0 + v_0 t + \frac{1}{2}at^2$
- **Kinematic Equation 3:** $v^2 = v_0^2 + 2a(x - x_0)$
- **Free Fall:** $y = y_0 + v_0 t - \frac{1}{2}gt^2$
- **Newton's Second Law:** $\mathbf{F} = m\mathbf{a}$
- **Friction (kinetic):** $f_k = \mu_k N$
- **Friction (static, maximum):** $f_s \leq \mu_s N$
- **Angular velocity:** $\omega = \frac{2\pi}{T} = 2\pi f$
- **Centripetal acceleration:** $a_c = \frac{v^2}{r} = \omega^2 r$
- **Centripetal force:** $F_c = \frac{mv^2}{r} = m\omega^2 r$
- **Period–velocity relation:** $v = \frac{2\pi r}{T}$
- **SHM Displacement:** $x(t) = A\cos(\omega t + \phi)$
- **SHM Velocity:** $v(t) = -A\omega\sin(\omega t + \phi)$
- **SHM Acceleration:** $a(t) = -\omega^2 x(t)$
- **SHM Restoring force:** $F = -kx$
- **Angular frequency (spring):** $\omega = \sqrt{\frac{k}{m}}$
- **Angular frequency (pendulum):** $\omega = \sqrt{\frac{g}{L}}$
- **Period of SHM:** $T = \frac{2\pi}{\omega}$
- **Total energy:** $E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

References

- Young, H. D., Freedman, R. A., — *University Physics with Modern Physics, Fifth Ed.*, Pearson, 2019
- Matthes, Eric. — *Python crash course: A hands-on, project-based introduction to programming.* no starch press, 2023.

Enrollment Information

Course Fee: $80 per lecture (2.5 hours) Duration: 8 Weeks/Lectures In-person class in Naperville.
For inquiries and enrollment, visit our website at https://nexus-stem.org/