UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physics I - T1

2627-1-E3005Q004-T1

Aims

1. Knowledge and Understanding
By the end of the course, students will acquire:
• In-depth knowledge of the fundamental concepts of classical mechanics (particles, systems of particles, rigid bodies), classical thermodynamics, gravitation, fluid dynamics, mechanical waves, and special relativity.
• An understanding of physical laws and conservation principles underlying observable phenomena.
• Familiarity with mathematical and geometric tools for describing motion, with the use of vector formalism and reference frame transformations.
2. Applied Knowledge and Understanding
Students will develop the ability to:
• Set up and solve physics problems in mechanics and thermodynamics using appropriate mathematical tools, identifying the relevant physics laws.
• Develop simplified models to describe complex physical phenomena, assessing the validity of the approximations used.
• Tackle elementary relativity problems (application of Lorentz transformations, particle collisions, space-time diagrams).
3. Independent Judgment
Students will be able to:
• Correctly interpret theoretical predictions and evaluate numerical results obtained when solving problems.
4. Communication Skills
Students will be able to:
• Clearly and accurately explain the concepts covered in the course, using proper scientific and mathematical language.
• Present and discuss the solutions to exercises in a clear, organized, and rigorous manner, both in written and oral form.
5. Learning Skills
The course will provide:
• Methodological skills to approach the study of subjects in subsequent years.
• The ability to consult specialized texts in order to independently deepen their understanding of the concepts

presented during lectures.

Contents

Kinematics and dynamics of the massive particle, work of a force, energy.

Kinematics and dynamics of systems of massive particles and of a rigid body.

Kepler's laws for the motion of the planets and Newton's law of gravitation.

Ideal gas, first and second principle of thermodynamics, entropy.

Lorentz transformations for time and space. Mass and energy in relativity.

Detailed program

The experimental method and the operational definition of measurable quantities. Systems of units, fundamental units, lengths, times, masses.

Vectors:

Properties of a vector space, the vector displacement, sum, difference and multiplication of vectors, scalar product and vector product among vectors. Components of a vector.

Equations of components for a basis change.

Kinematics of a particle:

Vector position, and displacement. Definition of instantaneous velocity and acceleration. One-dimensional case: uniform motion, motion with constant acceleration.

Uniform motion and motion with constant acceleration in three dimensions with the example of the parabolic motion of a projectile.

Derivative of a vector, intrinsic representation of velocity and acceleration, tangential and normal components of the acceleration.

Polar coordinates.

Circular motion, velocity and angular acceleration, centripetal and tangential acceleration in circular motion. Uniform and uniformly accelerated circular motion.

Harmonic motion, characteristics of motion for x, v, a. Differential equation of harmonic motion.

Relative motions (only translation of origin), transformations of Galileo for r, v, a between O and O '. Galileo's principle of relativity.

The vector angular velocity and description of the motion of a particle through the angular velocity.

Velocity ??and acceleration in a moving reference frames (rf) (with rotations and translations), Coriolis acceleration.

Dynamics of the material point:

Newton's law, inertial reference frames (irf).

Concept of interaction, static operational definition of force, experimental observations on forces and accelerations that lead to Newton's II law.

Fundamental forces and empirical forces. Weight, normal force (as a constraint on the motion).

III Newton's law.

Static and dynamic friction forces, motion on an inclined plane.

Frictional force in fluids: F = -kv, equation of motion.

Tension of an ideal string, example with the Atwood machine.

Description of the motion of a pendulum.

Elastic force and ideal spring.

Work, definition with integral curvilinear.

Relationship between work and kinetic energy.

Conservative forces, potential energy, mechanical energy.

Examples for a constant force, weight strength, elastic force.

F = - grad U, equilibrium (stable or unstable).

Description of the dynamics in non-inertial rf: fictitious (inertial) forces.

Definition of momentum, average force.

Systems of particles:

Definition of center of mass (CM) for a system of particles and for a body, momentum of a system and relationship with Forces.

Angular momentum of a system, torque of a forces, relationship between angular momentum and torque.

Angular momentum in the CM reference frame. Koenig's theorem for angular momentum.

Kinetic energy of a system. Koenig's theorem for kinetic energy.

Work of in a system of particles (external and internal). Potential energy in a system.

Description of the motion of a two-body system in the absence of external forces and reduced mass.

Impulsive forces in collisions. Elastic and anelastic collisions. Elastic collisions in the CM rf, discussion for 1D collisions, in the CM rf and in the laboratory rf.

Dynamics for rigid bodies:

Definition of a rigid body and degrees of freedom of a rigid body.

Motion of translation, motion of rotation around a fixed axis (RFA) or combined.

Moment of inertia. Kinetic energy and angular momentum (along the axis of rotation) for RFA. Examples with L not parallel to the rotation axis. Dynamic equations for a rigid body , work in a RFA.

Huigens-Steiner's theorem.

Physical pendulum.

Static of a rigid body, levers.

Effect of an impulse on a rigid body free or bound to RFA.

Examples of collisions between rigid bodies.

Rolling without slipping motion, example on an inclined plane.

Variable mass systems: example of the rocket.

Harmonic oscillator:

Equation for a free harmonic oscillator. Dumped harmonic oscillator: equation, complex solutions, large dumping and small dumping.

Forced and dumped oscillator equation and solution, transferred power and resonance.

Gravitation:

Kepler's laws, derivation of Newton's law of gravitation.

Newton's law of gravitation, two-body problem.

Gravitational potential energy, potential energy and trajectories,

Potential, kinetic and mechanical energy for circular orbits.

Gravitational force potential energy of an extended body.

Gravitational force for a homogeneous sphere.

Example with determination of the tidal force for the earth (moon and sun) system.

Derivation of the equations of planets starting from Newton's law.

Waves:

Concept of wave, progressive and regressive wave, D'Albert's equation.

Sinusoidal waves. Wave on a string. Waves on a solid bar. Energy carried by the waves. Average power for sinusoidal waves. Reflection of waves in a string. Impedance of a medium.

Reflection and transmission to the interface of two media with different Zs.

Pressure waves in gases. Acoustic waves (decibels).

Coupled pendulums, normal modes, energy in normal modes.

Overlap of waves: stationary waves, example with a string, interference, beats.

3D waves (hints), planar and spherical waves.

Doppler effect and Mach cone.

Thermodynamics:

System and environment, thermodynamic variables, equilibrium states, thermodynamic transformations, principle 0, thermometric quantities and temperature, thermometers. Pressure.

Work of a gas. Internal energy and the first principle of thermodynamics. Historical definition of heat. Calorimetry, thermal capacity and specific heat. Phase transitions.

Boyle's law, Gay-Lussac's law, equation of state of an ideal gas. Work (W) of a gas for isocore, isobar and isothermal transformations (reversible). Internal energy of an ideal gas. Relationship $Cp = Cv + R$. Equation of a reversible adiabatic transformation.

Gas transformations: Q, ?U, W for isochor, isobar, isotherm and adiabatic transformations.

Cyclic transformations, efficiency for thermal cycles, coefficient of performance and heat pumps.

Second principle of thermodynamics (Kelvin-Planck and Clausius), Carnot's theorem, thermodynamic temperature. Clausius theorem. Definition of entropy.

Examples of entropy variation: gas transformations, temperature variations of solids or liquids, phase transformations.

Clayperion equation.

Transformations in the T-S plane.

Heat propagation mechanisms: convection, conduction, irradiation.

Kinetic theory of gases, relationship between T and average quadratic velocity and average kinetic energy for monoatomic gases,

Interpretation of internal energy and CV. Average kinetic energy and T for diatomic and polyatomic / solid gases, mentioning quantum effects.

Maxwell-Boltzmann distribution for gas velocity.

Hints on statistical interpretation of entropy.

The following topics concern only the students of the Physic degree.

Fluids:

Definition of fluid, normal stresses and shear stresses, volume forces.

Stevino's law, Pascal's law. Link between pressure and volume forces.

Case of conservative forces. Changes in a non-inertial frame (example rotating fluid).

Archimede's law. Thrust center. Example in non-inertial frame.

Ideal fluid in motion: Bernoulli equation.

Real fluids, viscosity, hydraulic impedance, Poiseuille law, Reynolds criterion.

Special relativity:

Newton's laws and invariance for Galileo's transformations, Galileo's principle of relativity.

Maxwell equations and incompatibility with of Galileo's transformations, ether theory, Michelson-Morley measure. Principles of relativity (constancy of c), deduction of Lorentz transformations, proper time and time dilatation, length contraction, Doppler effect for electromagnetic waves.

Principle of conservation of relativistic momentum, mass and energy. Conservation of E and p in relativistic collisions. Space-time diagrams, space type and time type separations. Relativistic invariants. Hints of quadrivector and Minkowski metric formalism.

Prerequisites

Basic knowledge of mathematic (capability to solve equations and sistems of equations).

A basic knowledge of calculus (differential and integral) is recommended.

Teaching form

Instructional teaching with lectures and exercise sessions.

Textbook and teaching resource

- Mazzoldi, Nigro, Voci, Fisica 1, EdiSES (Meccanica e termodinamica). (avalaible only in Italian)
- Halliday, Resnick, Krane, Fisica 1, Ambrosiana. (also in the original version in English)
- For the relativity topic: R.Resnik, Introduzione alla relatività ristretta. (also in the original version in English)

Semester

October - November: mechanics and dynamics of a massive particle (4 CFU).

December - January: mechanics and dynamics of systems of massive particle and rigid bodies (4 CFU).

March - April: Mechanical waves and thermodynamics (4 CFU).

May - June: Fluid Mechanics and Special Relativity (4 CFU).

Assessment method

A written test and an oral test (after passing the written test) are required.

The grade is determined by the oral test: the outcome of the written test or of the ongoing tests is used to guide the oral test, but the final result is not a weighted average of the results of the oral and written tests.

The written tests consist of solving exercises, while during the oral test the theoretical knowledge of the topics covered in the course and the ability to interpret and apply concepts learned are assessed. The property of language, clarity, completeness and readiness in exposition are also evaluated.

The written test can be replaced by four tests on specific topics during the course, two per semester. The students of the Degree Course in Mathematics following only the first 12 credits, must take only the first three partial tests.

The written test is considered passed if a not-insufficient results is obtained in 3/4 of the tests [or 2/3 of the tests for those who follow only 12 credits]. Absence counts as an insufficient test.

After passing the written test, it is possible to take the oral exam in any exam session, within the academic year. The passing of the written test remains valid even after failing the oral test.

The oral tests are carried out starting from the calendar day for the session and in the following days. Normally, after the closing date to subscribe a given session, a detailed calendar of the oral exams dates will be announced via e-learning.

The final result is not a weighted average of the results of the written and oral tests, but is determined by a global assessment, based on:

- precision and correctness in solving the exercises (written test);
- knowledge of the physics subjects, ability to discuss practical cases, precision of language, clarity, completeness and readiness in the exposition (oral test).

Office hours

Usually the teacher is always available for reception, however the presence is guaranteed only if previously arranged, either in classroom or by e-mail.

Sustainable Development Goals

QUALITY EDUCATION | DECENT WORK AND ECONOMIC GROWTH | INDUSTRY, INNOVATION AND INFRASTRUCTURE