

CEnT-S syllabus

Mathematics

Numbers

In order to answer questions related to this nucleus, it is necessary to work with numbers, using different representations of the numbers themselves and choosing those that are more useful depending on the situation and goals. The ability to make estimates, besides being useful in itself, allows one to quickly assess the plausibility of the result of calculations and thus provides a useful control tool.

- Elementary operations and ordering between integer, rational, real numbers
- division with remainder between natural numbers. Factorisation, divisors and multiples of a natural number
- power with integer exponent, root of a positive number, power with rational exponent of a positive number
- percentage of a number, percentage change
- calculation and transformation of expressions.

Algebra

In order to answer questions related to this nucleus, it is necessary to work with literal expressions and transform them appropriately according to the goals. Given equations must also be transformed in such a way as to obtain equivalent equations that can be solved more easily or from which the relevant information on solutions can be obtained. The same consideration applies to inequalities and systems.

- Manipulation and evaluation of literal expressions, equalities and inequalities
- factorisation and roots of a polynomial
- concept of solution and 'set of solutions' of an equation, an inequality, a system
- algebraic equations and inequalities of first and second degree or related to them
- manipulation and resolution of linear or other simple systems.

Geometry

In order to answer questions related to this nucleus, it is necessary to understand and use descriptions and representations of elementary geometric figures and their simple combinations. To analyse the properties of a certain geometric configuration, it is often useful to use different representations and both synthetic and analytical points of view.

- Classification and properties of the most common plane and space figures: straight lines, planes, angles, triangles, quadrilaterals, regular polygons, circumferences, prisms, pyramids, cylinders, cones, spheres
- calculation of perimeters, areas and volumes
- concept of similarity and relations between similar figures
- cartesian coordinates. Distance between two points in the Cartesian plane
- equation of a straight line in the Cartesian plane, slope of a straight line, intersection of straight lines
- equation of a circumference. Representation of subsets of the plane using equations, inequalities and systems.

Functions

In order to answer questions related to this nucleus, it is necessary to correlate the information obtained from different representations of the same function; for example, thanks to the information that can be read on the graph of a function f , to determine the solutions of an inequality of the type $f(x) > 0$. It is necessary to be aware of how the behaviour varies and how the graph of functions in a certain family changes as the defining parameters vary. It is also very useful to quickly visualise the graph of the functions $x \mapsto af(x)$, $x \mapsto f(ax)$, $x \mapsto f(x) + a$, $x \mapsto f(x + a)$ from the graph of the function $x \mapsto f(x)$.

- Concept of function. Composition of functions, invertible functions and inverse function. Main properties and characteristics of functions
- interpretation and transformations of the graph of a function. Graphic resolution of equations and inequalities expressed by functions
- characteristic properties and graph of elementary functions: power functions and root functions, polynomial functions of first and second degree, functions of the type $f(x)=1/(ax+b)$, absolute value function, exponential functions and logarithmic functions in different bases.

Exponential and logarithms

In order to answer questions related to this nucleus, it is necessary to transform logarithms into powers and vice versa, applying the definition of logarithm, and to manipulate expressions using the properties of power elevation and the corresponding properties of logarithms. It is also useful to be able to estimate and compare the values of logarithms and of powers with any real exponent.

- Definition of logarithm and elementary algebraic properties of the exponential and logarithm functions
- elementary exponential and logarithmic equations and inequalities.

Combinatorics and probability

In order to count the elements of a set, it is necessary to represent them in some suitable way and to have suitable systematic listing and counting strategies. The calculation of the probability of an event is only required in the

case of random phenomena for which the possible events are finite in number. In such a situation, it is necessary to find an appropriate representation of the set of events.

- Representation and counting of finite sets. Dispositions, combinations, permutations
- probability of events as ratio between favourable outcomes and possible outcomes
- probability of the union event of disjoint events, probability of the intersection event of independent events.

Basic Statistics

In order to answer questions related to this nucleus, it is necessary to be able, in simple situations, to read, interpret and compare different representations of a set of data, which refer to characteristics of a given population, identifying some essential features. To do so, it is fundamental to know the concepts of data, variables and observations, as well as recognise and understand the use of different scales of measurement (nominal, ordinal, interval, ratio).

- Representation and interpretation of data using tables and graphs (histograms, pie charts, etc.)
- concept of absolute and relative frequency
- measures of central tendency (mean, median, and mode).

Reasoning on texts and data

Logic and deductive reasoning

Questions in this nucleus require the ability to:

- understand common language words that function as logical connectives (negation, conjunction, disjunction, implication) and the expressions 'every', 'all', 'each', 'none', 'at least'
- establish in which cases a given proposition is verified or not and recognize compatibility, incompatibility or equivalence between propositions
- deduce logical consequences from one or more propositions or the falseness of a proposition, using different representations, including sets and their fundamental operations (union, intersection, difference, complement)
- negate a given proposition or identify a counterexample to a given proposition
- understand and use the concepts of necessary condition, sufficient condition, necessary and sufficient condition
- use different representations to deduce logical consequences.

Interpretation and manipulation of data

Questions in this nucleus require the ability to:

- understand texts that use different types of languages and representations, move from one type of representation to another
- extract numerical information from texts, tables and graphs (e.g. histograms, pie charts, line charts)
- draw conclusions from a certain data set or determine whether a certain statement is supported by the data
- understand and use different criteria for sorting data
- recognise the process required to obtain a certain piece of information from a data set.

Problem solving and basic mathematical language

Questions in this nucleus require the ability to:

- understand the information of a given text that may include figures, tables, diagrams
- represent the information of a given problem using schemas, tables, sets, diagrams
- calculate or estimate the result of simple operations, sort and compare numbers
- understand and use the concepts of percentage, ratio, proportionality, arithmetic mean
- translate a relationship expressed in words into an equation (algebraic modelling) or extract information from a given equation or formula
- assess the validity of a mathematical result as a solution to a real problem.

Biology

Biological molecules

The nucleus addresses the chemical composition of living matter, with particular reference to the biological significance of water and main classes of biomolecules. Candidates must be able to recognise different levels of macromolecular organisation (monomers and polymers, primary, secondary, tertiary and quaternary structures), understand chemical interactions involved and associate the characteristics of biomolecules with their function and localisation in the cell.

Questions are based on the following topics:

- biological properties of water, hydrophilic and hydrophobic molecules
- carbohydrates
- lipids
- proteins
- nucleic acids.

Cell biology

This nucleus covers the fundamental aspects of cell structure and functioning, with respect to prokaryotic and eukaryotic cells, in plant and animal systems. In particular, candidates must be able to identify the differences between different

cell types and associate the structure of organelles and cellular constituents with their functions, with reference to:

- differences between prokaryotic and eukaryotic cells
- structural and functional characteristics of eukaryotic cells, including specifics on cellular components: plasma membrane, nucleus, ribosomes, the endomembrane system (i.e. the endoplasmic reticulum, Golgi apparatus and lysosomes), mitochondria and cytoskeleton
- structural and functional characteristics of essential plant cell components, with particular emphasis on their peculiarities and differences from animal cells: cell wall, chloroplasts and other plastids, vacuoles.

Cell cycle, cell division, inheritance

This nucleus focuses on the structure of genetic material in prokaryotes and eukaryotes, and the molecular basis of gene expression; candidates are also requested to understand the basis of gene flow, the principles of inheritance and apply Mendel's laws. The nucleus also includes the characteristics of cell cycle and the mechanisms of cell division.

Questions are based on the following topics:

- genome characteristics in prokaryotes and eukaryotes
- coding of genetic information in DNA and RNA; general characteristics of replication, transcription and translation
- cell cycle
- cell division in prokaryotes and eukaryotes. Mitosis and meiosis.
- Mendelian inheritance.

Elements of plant biology and ecology

The nucleus includes principles of plant anatomy and fundamentals of their life processes, necessary to understand the central role of plants in ecosystems. Candidates must also recognize essential characteristics of ecosystems and be able to solve problems about energy flows in ecosystems and relationships/ interdependencies among living organisms in ecosystems.

Questions are based on:

- structural and functional characteristics of plants: root, stem, leaf, flower, fruit, seed
- photosynthesis, energy flows
- ecosystems and food chains
- biotic interactions: competition, predation, parasitism, mutualism and commensalism.

Elements of animal anatomy and physiology

This nucleus covers the hierarchical levels of multicellular organisation in

mammals. A basic understanding of structural and functional characteristics of tissues, organs and systems is required. Candidates are expected to correctly associate structure and function across multiple levels of organisation, including:

- epithelial, connective, muscular, and nervous tissues
- the musculoskeletal apparatus and the digestive, respiratory, circulatory, excretory, and nervous systems.

Chemistry

Macroscopic Properties of Matter

To address this nucleus, it is necessary to understand the different states of matter and the quantities that describe them, as well as to recognize the physical and chemical transformations between these states and the fundamental laws that govern them.

- Particle model of matter. States of matter and physical changes. Chemical transformations
- macroscopic properties of gases, liquids, and solids
- homogeneous and heterogeneous mixtures. Methods for separation of mixtures
- fundamental laws of chemistry (Lavoisier, Proust, Gay-Lussac, Avogadro).

Microscopic Properties of Matter and Composition of Substances

To address this nucleus, it is necessary to understand the structure of atoms and their components, to write electronic configurations and determine valence electrons; to identify the types of bonds between atoms and distinguish ionic substances from covalent compounds; and to become familiar with bonding theories and intermolecular forces.

- Atomic structure
- Lewis structures (electron dot model)
- chemical formulas. Compounds and ions. Atomic mass and relative atomic mass (A_r), relative molecular mass (M_r)
- types of chemical bonds: ionic, covalent, metallic; bond polarity
- intermolecular forces and hydrogen bonding
- molecular geometry (VSEPR theory) and hybridisation.

Periodic Trends and Atomic Structure

To address this nucleus, it is necessary to understand the structure of the periodic table and how to relate an element's electronic configuration to its position within it; to describe periodic trends and use them to predict atomic properties and reactivity.

- The periodic table of elements: periods and groups
- atomic models and quantum numbers
- isotopes

- periodic trends (e.g., electronegativity, atomic radius, ionisation energy)
- electron configurations: Aufbau principle, Pauli exclusion principle.

Chemical Reactions and Stoichiometry

To address this nucleus, it is necessary to be able to read, write, and correctly balance chemical reactions; to understand and work with the units of measurement needed to determine the quantities of substances involved in a process or chemical transformation; and to know the formulation of the fundamental laws of chemistry and be able to apply them.

- Balancing chemical equations
- definition of the concept of mole and Avogadro's constant
- mass-to-mole conversions
- concepts of limiting reactant and theoretical yield. Relationship between the number of moles (chemical quantity) and mass in reaction schemes
- units of concentration (mol dm^{-3} , g dm^{-3} , percentage composition) and related calculations.

Thermodynamics and Kinetics

To address this nucleus, it is necessary to distinguish between reactions that absorb or release energy; to know the properties of gases and the relationship between molecular speed and operating conditions; to understand the concept of equilibrium and to be able to work with the quantities that describe it; to distinguish between the concepts of spontaneity and reaction rate; and to understand the concepts of activation energy and the role of catalysis.

- Ideal gas laws. Partial pressures
- fundamental concepts of thermodynamics (internal energy, enthalpy, entropy, Gibbs free energy)
- endothermic and exothermic reactions
- dynamic chemical equilibrium (equilibrium constant and reaction quotient)
- activation energy, catalysis, reaction rate, and its dependence on temperature and pressure.

Compounds and Solutions

To address this nucleus, it is necessary to have acquired the correct terminology and to know how to assign both IUPAC and traditional nomenclature to compounds and ions; to understand the properties of compounds and their behaviour in aqueous solutions; and to know the properties of solutions and be able to work with the necessary units of measurement.

- Formulas, nomenclature (IUPAC and traditional) and main properties of inorganic compounds
- electrolytes, non-electrolytes, and solubility
- solution properties (e.g., conductivity, colligative properties)

- chemical properties of metals.

Acids and Bases

To address this nucleus, it is necessary to be able to identify acidic and basic substances, understand their properties, write and manage the related equilibria in solution, and calculate the pH value; as well as to be familiar with acid-base theories and the use of indicators.

- Definitions of acids and bases; acid-base reactions
- strength of acids and bases, pH calculation, pH indicators
- neutralisation reactions and salt formation
- pH of salt solutions (acidic/basic hydrolysis), buffer solutions.

Oxidation and Reduction (Redox)

To address this nucleus, it is necessary to know how to calculate the oxidation state of an atom within a chemical compound, recognize a redox reaction, and balance it by identifying the species that gain and lose electrons (oxidizing and reducing agents).

- Redox reactions and theoretical models
- identification of oxidants and reductants (redox potential scale). Oxidation numbers and atomic valence
- balancing simple redox reactions.

Organic Chemistry

To address this nucleus, it is necessary to know and distinguish the different classes of hydrocarbons and the main organic compounds by identifying the functional groups that characterise them and assigning the correct nomenclature.

- Hybridisation of carbon. Structure and characteristics of the simplest carbon compounds
- combustion reactions
- isomerism and relationship between structure and properties
- nomenclature and main properties of alkanes, alkenes, alkynes, cycloalkanes, benzene and aromatic compounds, alcohols, aldehydes, ketones, ethers, esters and carboxylic acids.

Applied Chemistry

To address this nucleus, it is necessary to understand the main chemical transformations related to everyday life and environmental and sustainability issues; to be able to read and interpret labels; and to know the main safety rules for handling chemical products in everyday use.

- Measurements, units, and uncertainties in experimental data
- chemical transformations in daily life

- correct reading of commercial product labels (beverages, food, chemicals)
- key environmental issues (acid rain, greenhouse effect, smog)
- chemical safety regulations.

Physics

Physical quantities and measurement

To successfully address the questions related to this nucleus, it is necessary to be able to: work with the values of physical quantities; perform vector calculus limited to composition and decomposition of vectors and the scalar and vector product (including the manipulation of expressions containing sine, cosine and tangent, defined as ratios between the sides of a right-angled triangle); use the SI units of measurement appropriately; use scientific notation, also to make estimates of orders of magnitude. It is also important to be able to recognise the graphical representations of the main functional models commonly used to express relationships between physical quantities.

- Main physical quantities (distinguished between fundamental and derived), units of measurement in the SI and their conversion from units of measurement used in everyday life
- prefixes used for multiples and submultiples, and their expression as powers of 10 in scientific notation
- graphical representations and basic functional models: direct and inverse proportionality, linear dependence, quadratic and inverse-square law, sinusoidal periodic dependence, exponential and logarithmic dependencies
- vector sum, difference, scalar and vector products in 3D.

Point particle kinematics

To successfully answer the questions related to this nucleus, familiarity with the main concepts useful to describe motion (position, displacement, trajectory, velocity, acceleration, frequency, period) is required. Candidates must also be able to apply this knowledge in order to: calculate the velocity and acceleration of a body from information on position and time; determine or estimate the kinematic parameters of the most common types of motion (linear and circular), also based on their graphical representations.

- Description of motion: position, trajectory, displacement, time instant and time interval. Velocity and acceleration of a body with their corresponding units of measurement
- uniform linear motion and uniformly accelerated linear motion, also described using the graphs of position, velocity and acceleration as a function of time
- free-falling motion of a body
- uniform circular motion (period, frequency, linear and angular velocity, centripetal acceleration and algebraic relations among them)
- galilean transformation between inertial reference frames.

Point particle dynamics, energy and work

To successfully answer the questions related to this nucleus, knowledge of the main concepts inherent to the variation of a body's state of motion (force and mass) is required. It is essential to have a solid understanding of the concepts of work and energy, which are closely linked to that of force. Candidates must also be able to apply this knowledge in order to: apply the relationship between force and acceleration to determine one of them, given the other, and vice versa; using the units of measurement appropriately; be able to use the principle of conservation of mechanical energy.

- Principle of inertia
- concept of force and Second Law of motion (normal forces, gravitational force, tension of an ideal string)
- concept of work of a force, power, kinetic energy, and work–energy principle
- potential energy (gravitational) and the mechanical energy conservation principle.

Fluid mechanics and thermodynamics

To successfully address the questions related to this nucleus, it is necessary: to be familiar with the knowledge of the statics and dynamics of ideal fluids; to be able to quantitatively describe the state of the ideal gas through the correct use of state variables (P , V , T); to understand the concept of heat and its transmission, temperature and its scales. Special familiarity is required with the concepts of density and pressure and the appropriate use of their units in ideal fluids and gases, also with reference to commonly used units not included in the SI (e.g. litre, atmosphere, calorie).

- Quantities for describing fluids at rest: density, pressure (including the value of atmospheric pressure)
- laws governing hydrostatics and related phenomena: Pascal's Law, Stevin's Law, Archimedes' principle
- quantities, concepts, and laws for fluids dynamics: flow in a pipeline, continuity law for ideal fluids, Bernoulli's principle
- concept of an ideal gas and quantities used to define its state: pressure, volume, temperature
- kelvin and Celsius thermometric scales
- ideal gas Law (equation of state)
- heat as a form of energy exchange, thermodynamic definition of work, the first law of thermodynamics
- qualitative aspects of the second law of thermodynamics, with reference to the limitations of conversion between mechanical and thermal energy.

Electromagnetism principles

Questions in this nucleus require the ability to: determine, in simple situations, the forces acting on point-like electric charges; understand and use the concept of electric field as a property of space that accounts for the interaction at a

distance between charges; know and apply Ohm's law in order to determine the current intensity in a conductor, given the potential difference at its ends, and vice versa; understand and be able to describe the behaviour of a permanent magnet, to be familiar with the graphical representation of the effect of a magnet on the surrounding space in terms of field lines; recognise wavelength and period of a wave as expressions of its dual periodicity in space and time; understand and be able to use the algebraic relationship between wavelength, frequency and propagation velocity of a wave.

- Phenomenology of electrostatic interactions between point charges and Coulomb's Law
- concept of electric field and simple examples: electric field of one or many point charges and uniform electric field
- electrical behaviour of materials: insulators and conductors
- electric current as charges in motion; electric current intensity, electrical resistance and Ohm's first law
- phenomenology of interactions between permanent magnets
- magnetic field concept and graphical representation of the magnetic field
- different types of waves (light and sound) and algebraic relationships among their characteristic quantities: amplitude, frequency, wavelength, propagation velocity
- electromagnetic spectrum.