EOES syllabus

"Experiment is the sole source of truth. It alone can teach us something new; it alone can give us certainty".

Henri Poincaré - La Science et l'Hypothèse (1901)

Two of the aims of the Olympiad are:
• to give students the opportunity to experience what it means to be a researcher; and
• to measure their scientific skills against those of the other participants.

In university or high school labs the are asked to investigate certain phenomena in an **interdisciplinary** way through various experiments. These phenomena are not necessarily part of secondary education curricula. They often link up with ongoing scientific research.

This syllabus provides the organizers of the Olympiad with an overview of the techniques that can be used and have been used in the different disciplines, but also gives teachers and students an idea of the skills the participants can be asked to master. The document is a tool which helps everybody to prepare for the olympiad.

◊ THE TASKS

It is good practice to present each of the two tasks of the competition with its own theme. Within this theme, the organizers develop a storyline/scenario within which various investigative acts take place. Through observation, experiments, measurements, processing data, making connections, and reasoning, participants are expected to formulate correct answers to various aspects of the phenomenon under investigation.

What does this syllabus mean for the competitors?

All this implies that students should be able to

- work together as a team,
- read appropriate texts and related features (i.e. graphs) to obtain scientific information,
- evaluate the information gathered from texts and other sources,
- create models to explain and/or predict scientific phenomena, processes, or relationships,
- design investigations that will produce data that can be used to answer scientific questions. This includes determining the goal of the investigation, developing predictions, and designing procedures,
- use a wide range of practical apparatus and techniques correctly,
- conduct investigations to gather data from measurements using appropriate tools and methods and choose and use appropriate (SI)units,
- present observations and data in an appropriate format,
- analyze and interpret qualitative and quantitative experimental results,
- use appropriate mathematical and digital skills for analysis of quantitative data such as
    - using significant figures in an appropriate way
    - plotting and interpreting suitable graphs from experimental results, including selection and labelling of axes with appropriate scales, quantities and units and measurement of gradients and intercepts,
- follow safety rules and foresee and circumvent any unnecessary risks.
- apply knowledge from the disciplines chemistry, biology, and physics in different contexts and situations.

What does this mean for the organisers?

- Additional topics may be investigated in the tasks, provided sufficient information to work on them is given in the tasks themselves. This may include additional science topics as well as the use of sophisticated apparatus.

- The tasks should enable the competitors to exhibit not only their knowledge and skills but also their ability to think creatively and to work together as a team.

- The tasks have to include suitable safety regulations and should be constructed in such a way that no extra verbal instruction or explanation about the testing procedure is necessary.

- Answers should not be language dependent. Responses should be alphabetic, numerical, graphical, illustrative, formulas or a box tick.

- The test design should avoid negative marking.

- Each task must be designed so that the team can achieve a number of milestones or stage results. A laboratory assistant may judge and mark achievements during the tests according to agreed procedures.

- No experiments should be carried out which cause deterioration of the living conditions of vertebrates. No handling of species protected by EU law is permitted.

What does it mean for the mentors?

The mentors:
- can use the document to design experiments meant for regional and national experimental olympiads within their country.
- can use the document to prepare their students on the international olympiad.

◊ TECHNIQUES AND SKILLS

Since there are many techniques that can be used as well in biology as in chemistry and/or physics, we have grouped them in a joint table for the three disciplines.

However, we have made a distinction between techniques and skills that can be considered ‘basic’ (they are considered to be known by the students and do not need further explanation during the EOES competition) and others that are not so obvious, but which can be used with proper accompanying explanations within the tasks.

Since some techniques or skills can be considered basic for one science but advanced for another, we have made this distinction in the table by putting the letter **A** in the table where we think the technique or skill is **advanced** for that science.

Given the importance of mathematical skills and data processing, we have discussed them in a separate document.

Topic	Instrument(s) / material	Techniques / skills	B	C	P	Examples
Basic Skills						
Dimensions (physical)	(Folding) ruler, meter stick, Vernier caliper, Palmer caliper (micrometer)	Using the right instrument for the measurement of different sizes.	•	•	•	• Measuring a mussel shell (LxWxH) with a Vernier calipers (B) • Measuring the Rf-value (C) • Measuring the thickness of metal foil with a micrometer (P)
Scientific drawings and schemes	Pencil(s), paper, eraser, ruler.	Mastering the different techniques to produce a scientific drawing, scheme or diagram.	•	•	•	• Drawing a cross-section section of a plant stem (B) • Drawing the set-up for a chemical practical (C) • Drawing an electrical circuit (P)
Temperature measurements	Analog or digital thermometer	Use of appropriate instrument / apparatus to measure / record measurements of temperature.	•	•	•	• Registering ambient temperature during ecological work (B) • Controlling reaction temperatures (C) • Determination of boiling point of a liquid (P)

Basic / Advanced Skills	Instrument(s) / material	Techniques / skills	B	C	P	Examples
Agar plates (pouring of -)	(Nutrient) Agar, hotplate, conical flask, cotton plug, Petri dishes	Using aseptic techniques to produce cultures of micro-organisms.	•			Using aseptic techniques to investigate the effect of antimicrobial substances on microbial growth (B)
Amount (moles) determination	Balance, measuring cylinder, ruler …	Use of appropriate instrument / apparatus to measure or record measurements of mass and volume. Stoichiometry	•	•	A	• Stoichiometry of biochemical reactions (B) • Stoichiometry of chemical reactions (C) • Ideal gas law (P)
Buffer solution	Solute, pipettes, volumetric flasks, micropipette, pipette bulb,	Buffer preparation, principles Buffer principles (only conceptually, no theory) and buffer usage		A		

Calorimetry/enthalpy determination	Calorimeter	Measuring the amount of heat involved in a chemical or physical process	A	A	•	• Comparing the heat released by the same amount of carbohydrate, lipid and protein (B) • To investigate the reaction heat of a chemical reaction (C) • Study of heat transfer associated with changes of its states (P)
Chromatography (paper, thin layer and column -)	Chromatography paper, TLC-sheets or chromatography column.	Separation of different components from a solution mixture. Principles.	•	A		• Separation of leaf pigments (B) • Separation of diesel components (C) - qualitative analysis; Rf factor (C)
Colorimetry and Spectrophotometry	Colorimeter or spectrophotometer + accessories	Determining the presence and/or concentration of a coloured substance in a solution.	A	A		• Following the progress of a starch-amylase catalysed reaction with a colorimeter (B) • Determination of $KMnO_4$ concentration in a solution via spectrophotometric analysis and Beer's law (C)
Crystallization Recrystallization	Conical flasks, stemless funnel, Büchner funnel, (fluted) filter paper, hot plate	Removing impurities by recrystallisation after crystallisation.		A		• Purification of solids, crystalline products (C)
Density determination	Hydrometer pycnometer + balance	Measuring density or specific gravity of a liquid (hydrometer) or the density / specific gravity of substances in the gaseous, liquid, and solid states (pycnometer).	A	A		Determination of the density of solid, liquid or gases (B) (C) (P)
Determination of biological samples	Determination key, photographs, microscope, binocular, samples	Use of a dichotomous determination key	•			• Identification of cork producing trees (B)
Distillation Fractional Distillation	Distillation flask, head, condenser, take-off adapter	Distillation is used to separate the components of a liquid mixture by vaporising the liquids, condensing the vapours and collecting the condensate.	A	A	•	• Extraction of ethanol after fermentation (B) • Production of distilled water (C) • Separation of liquids according to their boiling points (C)
Electricity generation	Dynamo, generator, solar cell				A	Determination of the amount of incident light through the amount of electricity produced (P)

Electricity measurements	Digital multimeter analog voltmeter analog ammeter	Measuring different electrical stimuli, such as voltage, current and resistance		A	•	• Registering the conversion of chemical energy in electrical energy (C) • Experimental study of Kirchhoff's laws (P)
Electrochemical cell	Electrodes, voltmeter, salt bridge	Setting up of electrochemical cells and measuring voltages.	A	A	A	• Lemon battery using zinc and copper electrodes (B) • Redox reactions generating electric current (C) • Different kind of batteries (P)
Electrolysis	Electrodes, voltmeter, DC power source	Separation of elements from a solution by using a direct electric current, driving a non-spontaneous chemical reaction.	A	A	A	• Electrolysis of water (B) • Separation of copper and nickel from an aqueous solution by their difference in equilibrium potential (C) • EMF and electrolysis (P)
Filtration	Conical (Büchner) flask, (Büchner) funnel, (fluted) filter paper	Solid particles in a liquid or gaseous fluid are removed by the use of a filter medium that permits the fluid to pass.	•	•		• Filtration of water samples before qualitative analysis (B) • Vacuum filtration with Büchner funnel to collect recrystallized compounds (C)
Gel electrophoresis	Agarose gel, gel tank, running buffer, loading dye, ladders to compare, stain for visualising bands	Using an electric field, charged molecules (like DNA and proteins) can be made to move through a gel and are separated according to their seize	A			Whodunit where students have to identify the perpetrator of a painting theft from a found DNA sample, by comparing the sample to that of different suspects (B)
General principles of precipitation method	Tubes, glass, dropper	Practical skills; use of chemical equipment	•	•		
Identification of biological molecules with qualitative reagents	Biuret reagent, Fehling's solution (A + B), Benedict's reagent Sudan III reagent	Demonstrating the presence of: reducing sugars (Fehling's or Benedict's reagent) / lipids (Sudan III reagent) / proteins (Biuret reagent).	•	A		Demonstrating the presence of: • glucose in fruit juice (B) (C) • lipids and proteins in whole milk (B) (C)
Laser light	Laser pen	Setting up experiments where a unidirectional monochromatic light beam is required.			A	Identify a substance by determining its specific rotation angle (P)
Lenses	Lenses: biconvex, biconcave, plano-convex, plano-concave, equi- and convexoconcave	Predicting the optical properties of diffe-rent lens types, given their forms and dimensions.	•		•	• Eye lens and nearsightedness or farsightedness (B) • Lens properties and focal distance (P)

Liquid-liquid extraction	Separatory funnel, erlenmeyers, beakers…	This technique uses two immiscible solvents; the desired compound in solution or suspension in one solvent is extracted into the other solvent.	A	A		• Separation of anthocyanic and non-anthocyanic flavonoids (B) • Separation of a carboxylic acid from a hydrocarbon (C)
Microscope slide (preparation of -)	Microscope slide, cover slip, staining solution(s),	Mastering preparation techniques such as dry mount, wet mount, squash, staining.	•			Preparation of microscope slides of • plant and animal cells, fungi, bacteria … (B) • plant and animal tissues (B)
Microscopy	Light microscope / stereoscopic microscope	Use of a light microscope at high and low power; use of a graticule. Use of a stereomicroscope for 3 D observation of small organisms.	•			• Stereoscopic observation of shrimp anatomy (B) • Microscopic observation of plasmolysis of plant cell (B) • Microscopic observation of different stages of mitosis (B)
Mirrors	Flat, convex and concave mirrors	Predicting imaging by different types of mirrors.			•	• Understanding the principle of a solar oven (P) • Use of parabolic reflectors in telescopes (P)
pH measurement	pH indicator (paper) + corresponding charts or electronic pH-meter	Measuring pH using pH paper or universal pH indicator and pH charts. Measuring pH with pH meter or pH probe on data logger.	•	•		• Studying the effect of pH on enzyme kinetics (B) • Monitoring pH during chemical reactions requiring constant pH (C)
Photoresistor (Light dependent resistor - LDR)	Different kind of photoresistors	Using light detection to activate or stop the flow of current in an electrical circuit.			A	• Explaining the use of photoresistors in street lights (P)
Prisms (optical)	Different kind of prisms	Predicting the light path through a prism.			•	• The use of prisms in binocular microscopes (P)
Preparation of solution	Pipettes, conical flasks, volumetric flasks, micropipette, pipette bulb, balance	Dilution, dissolution		•		
pH measurement	pH indicator (paper) + corresponding charts or electronic pH-meter	Measuring pH using pH paper or universal pH indicator and pH charts. Measuring pH with pH meter or pH probe on data logger.		•		

Qualitative analysis of inorganic ions	Test tubes, centrifuge, indicator paper, bunsen…	Reading flow charts with reaction sequences; making and recording qualitative observations.	A	A		• Determination of presence of sodium-ions in urine (B) • Determination of presence of carbonates in water (B)(C) determination and qualitative analysis of metal cations (C)
Qualitative analysis of organic substances	Polarimetry	Polarimeter		A		Identify sugars and sweeteners in beverages (C)
Rate of reaction (continuous monitoring method)	Stopwatch, titration set or gas collecting apparatus.	Measuring the amount of product formed in a certain period of time. This is done by continuous monitoring.	•	A		• Effect of temperature on oxygen production during photosynthesis (B) • Production of distilled water (C)
Serial dilution and production of a calibration curve	Solute, pipettes, conical flasks, volumetric flasks, micropipette, pipette bulb	Mastering the techniques to produce a serial dilution in order to produce a correct calibration curve.	•	•		• Serial dilution of glucose solution (1 mol/L) to determine via a calibration curve the unknown water potential of a potato (B) • Serial dilution of $CuSO_4$-solute to determine via a calibration curve and spectroscopy the unknown concentration of a $CuSO_4^{2-}$ solution (C)
Spectrophotometry	Spectrophotometer, cuvette	Beer-Lamber law; quantitative analysis, calibration curve		A		*see Colorimetry*
Stain Test	Chemicals, samples	Sudan red test Gram staining	•			• Identification of cell types (B) • Gram staining of bacteria (B)
Titrations (acid-base -, redox -, precipitation -, complexometric -)	Burette, pipette, conical flask (erlenmeyer), micropipette, pipette bulb	Measurement of the volume of a liquid; use of a volumetric flask, pipette, burette; making up a standard solution; use of a appropriate indicator…	•	•		• Determination of ascorbic acid concentration in orange juice (B) • Determination of acetic acid concentration in vinegar (C)
Video Analysis	Video camera, video analysis software	Analysis of various forms of motion in physics and biology, study of light distribution, measuring light intensity	A	A	A	• Study the motion of an oscillator (P) • Study the motion of a living organism (B) • Finding the wavelength of laser light in Young's double slit experiment (P) • Measuring the speed of a chemical reaction (C)
Viscosity of liquids	Viscosimeter	Measuring/comparing the viscosity of different liquids.			A	Diluting a liquid to obtain a desired viscosity (P)
Volumetric change of gas mixture	Eudiometer	Measuring the change in volume of a gas mixture following a physical, chemical or biochemical change.	A	A	A	Measuring the amount of biogas production during a simulated digestion (B) (C) (P)
Water uptake by plants	Potometer		A			Study the magnitude of evapotranspiration of leaves (B)

Mathematics

Graphing			•	•	•	Title, labels, units, linear scale, >50% page
Uncertainty in slope and intercept					A	e.g. box method
Error propagation					A	
Exponents/logarithms					•	
Trigonometric functions					•	e.g. sin(wt)