UNIFORM EXAMINATIONS

Secondary Cycle Two

Information Document - June 2015 - August 2015 - January 2016

Science and Technology 555-410
Applied Science and Technology 557-410

Secondary IV

Québec

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TABLE OF CONTENTS

INTRODUCTION

This information document outlines the main components of the uniform examinations for the Secondary IV science programs, namely Science and Technology and Applied Science and Technology. Among other things, this document was designed to guide teachers in the preparatory work they must do throughout the year to ensure that their students can pass these examinations.

The Ministère de l'Éducation, du Loisir et du Sport (MELS) is responsible for producing uniform examinations for the *Theory* component of each program, which are to be administered in the June, August and January examination sessions. Each examination is based on the Framework for the Evaluation of Learning, the Progression of Learning and the Québec Education Program. Information gathered on examinations administered in previous years is also taken into account. In addition, MELS has encouraged the participation of the school system by inviting teachers and education consultants from different schools to contribute to the development and validation of these examinations.

Schools must administer each uniform examination at the appointed time in the official schedule established by the Minister.

The examinations for the *Practical* component are developed by educational institutions. However, these examinations must take into account the instructions in this document in order to ensure a measure of uniformity. It should be noted that during the 2013-2014 school year, MELS updated the prototype examinations for the experimental method and technological design process. These examinations are intended to assist teachers in familiarizing themselves with the evaluation process for the *Practical* component and are available on the password-protected site of the Direction de l'évaluation des apprentissages.

1. ELEMENTS TO BE EVALUATED

1.1 Evaluation Criteria

The evaluation criteria for each uniform examination are as follows:

- Proficiency in subject-specific knowledge targeted in the Progression of Learning
- Relevant use of scientific and technological knowledge
- Appropriate formulation of explanations or solutions

1.2 Additional Information on the Compulsory Concepts

The compulsory concepts in the Science and Technology and Applied Science and Technology programs are indicated in Appendices I and II by major area (The Living World, The Material World, The Earth and Space and The Technological World). Most of these concepts will be covered in the June 2015, August 2015 and January 2016 uniform examinations. Once again this year, educational institutions are responsible for evaluating the concepts printed in italics in these appendices. This temporary measure is designed to help teachers familiarize themselves with these programs and the related evaluation process. Furthermore, additional information on certain aspects of the programs is provided in Appendices III and IV.

MELS has decided not to include concepts related to The Living World in the June 2015, August 2015 and January 2016 certification examinations. As these concepts are more effectively evaluated locally than by means of certification examinations, educational institutions are entirely responsible for their evaluation.

An analysis of student answers on past examinations and teachers' comments have revealed that the variety of settings encountered in the different regions of Québec has an impact on student evaluation for certification purposes. For example, students living in urban, forest or rural areas experience their respective environments in specific ways, which may sometimes result in different interpretations of the realities presented in the examination questions related to The Living World.

However, because environmental issues are an integral part of the knowledge students develop in this subject, they will be incorporated into questions related to the other major areas. For example, a situation involving a human disturbance, such as a toxic spill, could be devised to measure students' comprehension of the concepts of catchment area and watershed divide. Other situations related to The Living World, and ecology in particular, will also be used in the certification examinations, as needed.

1.3 Proficiency in Knowledge and the Ability to Use It

Proficiency in knowledge means that the student is able to carry out a written task that shows that he or she knows and understands a concept (element, operation, relationship, model) related to science and technology. The ability to use knowledge means that the student is capable of applying a combination of concepts (elements, operations, relationships, models) related to science and technology. The questions relating to the student's proficiency in knowledge and ability to use it may be multiple-choice or constructed-response questions and involve one of the following:

– Identification or understanding of a concept
– Identification or formulation of examples pertaining to a concept
– Simple application of a formula or an idea related to a concept
– Understanding of a combination of concepts
– Application of a complex procedure
– Explanation or justification of one or more concepts that may require analysis

2. CONTENT OF THE UNIFORM EXAMINATIONS

2.1 Science and Technology (555-410)

The uniform examination for Science and Technology requires students to analyze situations and a technical object. Working alone, students must solve various problems using their knowledge of the compulsory concepts in three of the four areas of the program.

The examination, which consists of 25 questions worth 4 marks each, is divided into three parts:

- Part A consists of 15 multiple-choice questions worth 60% of the examination mark. These questions, which evaluate students' proficiency in or ability to use knowledge relating to the compulsory concepts, are presented in the Question Booklet.
- Part B consists of 5 constructed-response questions worth 20% of the examination mark. These questions are presented in the Student Booklet.
- Part C consists of 5 questions on the technological analysis of a technical object and is worth 20% of the examination mark. These questions are also presented in the Student Booklet.

The examination consists of:

- a Question Booklet
- a Student Booklet
- a scannable answer sheet (for the June examination)
- a visual aid (an animated demonstration of a technical object provided on DVD)
- a Marking Guide for teachers

Distribution and Weighting of the Questions Related to Each Area of the Science and Technology Program

	The Living World	The Earth and Space	The Material World	The Technological World	Number of Questions per Part
Part A	---	4 questions	9 questions	2 questions	15
Part B	---	1 question	3 questions	1 question	5
Part C	---	---	---	5 questions	5
Weighting	---	20%	48%	32%	100%

2.2 Applied Science and Technology (557-410)

The uniform examination for Applied Science and Technology requires students to analyze situations and a technical object. Working alone, students must solve various problems using their knowledge of the compulsory concepts in three of the four areas of the program.

The examination, which consists of 25 questions worth 4 marks each, is divided into three parts:

- Part A consists of 15 multiple-choice questions worth 60% of the examination mark. These questions, which evaluate students' proficiency in or ability to use knowledge relating to the compulsory concepts, are presented in the Question Booklet.
- Part B consists of 4 constructed-response questions worth 16% of the examination mark. These questions are presented in the Student Booklet.
- Part C consists of 6 questions on the technological analysis of a technical object and is worth 24% of the examination mark. These questions are also presented in the Student Booklet.

The examination consists of:

- a Question Booklet
- a Student Booklet
- a scannable answer sheet (for the June examination)
- a visual aid (an animated demonstration of a technical object provided on DVD)
- a Marking Guide for teachers

Distribution and Weighting of the Questions Related to Each Area of the Applied Science and Technology Program

	The Living World	The Earth and Space	The Material World	The Technological World	Number of Questions per Part
Part A	---	1 question	9 questions	5 questions	15
Part B	---	1 question	2 questions	1 question	4
Part C	---	---	---	6 questions	6
Weighting	---	8%	44%	48%	100%

3. CONDITIONS FOR ADMINISTERING THE UNIFORM EXAMINATIONS

3.1 Duration of the Examinations

The official schedule indicates that the duration of the examinations is 3 hours, which should be amply sufficient for all students to finish the examination and review their answers. However, an additional 15 minutes must be allotted, if needed, as provided for under section 4.3.7 of the *Administrative Guide for the Certification of Studies and Management of Ministerial Examinations*.

3.2 Procedure

Students must work alone, considering questions and analyzing problems that test their knowledge or their ability to use it. They must also analyze different aspects of a technical object. A video showing an animated demonstration of the technical object to be analyzed must play continuously during the examination.

Students must first read through the examination questions and reference materials presented in the Question Booklet and Student Booklet. Then they must answer the questions in the Student Booklet and on the scannable answer sheet (for the June examinations) by carrying out all the work according to the instructions provided.

The school must ensure that the equipment for projecting the animated demonstration of the technical object (DVD player and television or multimedia projector and computer) is available in the examination room.

While viewing the animated demonstration of the technical object, students are forbidden from communicating with one another or asking the invigilator questions about the technical object.

3.3 Permitted Materials

3.3.1 Science and Technology (555-410)

Only the following materials may be used during the examination:

– Ruler
– Calculator with or without a graphic display
– Periodic table of the elements provided in the Question Booklet (Appendix V)
– List of formulas and quantities provided in the Question Booklet (Appendix VI)

3.3.2 Applied Science and Technology (557-410)

Only the following materials may be used during the examination:

– Ruler
– Calculator with or without a graphic display
– List of formulas and quantities provided in the Question Booklet (Appendix VII)

3.3.3 Rules for using calculators or other materials

Calculators with or without a graphic display that are designed primarily to perform mathematical calculations may be used during ministerial examinations. Computers, tablet PCs, electronic organizers and calculators with an alphanumeric keyboard (QWERTY or AZERTY) are, however, prohibited.

Prior to the examination, students must be duly informed in writing of the rules regarding the use of calculators on a ministerial examination.

The data and programs stored in the calculator's memory must be erased before the examination. Before the day of the examination, students must have been given the opportunity to learn how to reset their calculator's memory. Using a calculator containing programs or data stored in the memory will be considered a form of cheating.

User guides, memory expansion features or any other calculator accessories are not permitted during the examination. Students may not share their calculator with another student. The use of a memory-aid sheet is also prohibited.

During the examination, students are strictly forbidden to have in their possession any electronic device (portable media player, smartphone, etc.) that can be used to surf the Internet, translate texts, create or save data, and send or receive information and messages. Any student who violates this rule must be expelled from the examination room and deemed to have cheated on the examination.

3.4 Measures Adapting the Conditions for Administering Ministerial Examinations

Measures that adapt the conditions for administering ministerial examinations may be taken to enable students with specific needs to demonstrate their learning. For further information on the implementation of these measures, please refer to the documents made available to schools by the Direction de la sanction des études.

4. MARKING THE UNIFORM EXAMINATIONS

4.1 Responsibility for Marking the Examinations

With respect to the June 2015 examinations, Part A will be marked by MELS and Parts B and C will be marked by educational institutions. Every part of the August 2015 and January 2016 examinations will be marked by educational institutions.

In grading the examination papers, teachers must refer to the instructions in the Marking Guide provided by MELS and should form a marking committee to ensure that they have a common understanding of these instructions. By analyzing some of the examination papers submitted, the committee will be better able to determine what is expected of students.

5. RESULTS ON THE UNIFORM EXAMINATIONS

The result obtained on either of the uniform examinations is expressed as a mark out of 100 and is the sum of the results for each of Parts A, B and C. This result counts for 50% of the *Theory* component.

5.1 June 2015 Examinations

All calculations for determining the final mark for the June 2015 examinations are carried out by MELS. The marks for Parts B and C must be submitted to MELS and indicated separately, out of their respective totals, and must not be converted into percentages.

5.2 August 2015 and January 2016 Examinations

All questions on the August 2015 and January 2016 examinations are marked by educational institutions. **Note that the marks must be submitted to MELS.**

6. EVALUATION OF THE *PRACTICAL* COMPONENT

With regard to the *Practical* component, teachers must evaluate student learning primarily by means of examinations in a laboratory or workshop. These examinations involve the experimental method and the technological design process. Educational institutions are entirely responsible for evaluating this component.

It is not advisable to use a single examination per year to evaluate the *Practical* component, as that would entail deriving 40% of the student's final mark from a single evaluation situation. To obtain valid results, it is recommended that students be evaluated on an individual basis each term.

The *Practical* component, administered and marked by educational institutions, is calculated out of 100 and counts for 40% of the student's subject mark.

Rubrics for evaluating students' work on practical examinations involving the experimental method and the technological design process are included in the prototype examinations available on the password-protected site of the Direction de l'évaluation des apprentissages. It is a good idea to use these rubrics throughout the year.

7. SUBJECT MARK AND MINIMUM PERFORMANCE STANDARD

The subject mark is based on the result for each component, weighted in accordance with the percentages established by the Minister and presented in the Framework for the Evaluation of Learning. Students earn credits for the program if they obtain a subject mark of at least 60%.

7.1 Weighting

The weighting for the two components is the same for both the Science and Technology program and the Applied Science and Technology program.

Practical component: 40% (school mark only)

Theory component: 60% (30% for the school mark and 30% for the uniform examination mark)

Compulsory Concepts That May Be Evaluated in Science and Technology

(version modified in 2014)

The scope of each concept is defined in the Progression of Learning.
Evaluation of the concepts shown in *italics* is the responsibility of educational institutions.

The Living World

Ecology
– Study of populations (density, distribution, biological cycles)

Dynamics of communities
– Biodiversity
– Disturbances

Dynamics of ecosystems
– Trophic relationships
– Primary productivity
– Material and energy flow
– Chemical recycling

The Earth and Space

Biogeochemical cycles
– Carbon cycle
– Nitrogen cycle

Climate zone
– Factors that influence the distribution of biomes
– Marine biomes
– Terrestrial biomes

Lithosphere
– Minerals
– Permafrost
– Energy resources
– Soil profile (horizons)

Hydrosphere
– Catchment area
– Ocean circulation
– Glacier and pack ice (ice floes)
– Salinity
– Energy resources

Atmosphere
– Greenhouse effect
– Atmospheric circulation
– Air mass
– Cyclone and anticyclone
– Energy resources

Space
– Solar energy flow
– Earth-Moon system (gravitational effect)

The Material World

Physical properties of solutions
– Concentration (g/L, %, ppm)
– Electrolytes
– pH scale
– Electrolytic dissociation
– Ions
– Electrical conductivity

Chemical changes
– Combustion
– Photosynthesis and respiration (carbon cycle)
– Acid-base neutralization reaction
– Balancing chemical equations
– Law of conservation of mass

Organization of matter
– Rutherford-Bohr atomic model
– Lewis notation
– Groups and periods in the periodic table

Electricity and electromagnetism
– Electrical charge
– Static electricity
– Ohm's law
– Electrical circuits
– Relationship between power and electrical energy

Electromagnetism
– Forces of attraction and repulsion
– Magnetic field of a live wire

Transformation of energy
– Law of conservation of energy
– Energy efficiency
– Distinction between heat and temperature

The Technological World

Mechanical engineering
– Characteristics of the linking of mechanical parts
– Guiding controls
– Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
– Speed changes
– Construction and characteristics of motion transformation systems (screw gear system, cams, connecting rods, cranks, slides, rotating slider crank mechanisms, rack-and-pinion drive)

Electrical engineering
– Power supply
– Conduction, insulation and protection
– Control
– Transformation of energy (electricity and light, heat, vibration, magnetism)

Materials
– Constraints
– Characteristics of mechanical properties
– Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - Composites
– Modification of properties (degradation, protection)

Compulsory Concepts That May Be Evaluated in Applied Science and Technology
(version modified in 2014)
The scope of each concept is defined in the Progression of Learning.
Evaluation of the concepts shown in *italics* is the responsibility of educational institutions.

The following are also evaluated: Techniques related to diagram drawing and graphic representation (see "Drawing diagrams" and "Constructing a graph using instruments" in the Techniques section of the Progression of Learning).

The Living World

Dynamics of ecosystems

– Disturbances
– Trophic relationships
– Primary productivity
– Material and energy flow
– Chemical recycling
– Factors that influence the distribution of biomes
– Ecosystems

The Earth and Space

Lithosphere
– Minerals
– Energy resources

Hydrosphere
– Catchment area
– Energy resources

Atmosphere
– Air mass
– Cyclone and anticyclone
– Energy resources

Space
– Solar energy flow
– Earth-Moon system (gravitational effect)

The Material World

Chemical changes
– Combustion
– Oxidation

Electricity
– Electrical charge
– Static electricity
– Ohm's law
– Electrical circuits
– Relationship between power and electrical energy

Electromagnetism
– Forces of attraction and repulsion
– Magnetic field of a live wire
– Magnetic field of a solenoid
– Electromagnetic induction

Transformation of energy
– Law of conservation of energy
– Energy efficiency
– Distinction between heat and temperature

Fluids
– Archimedes' principle
– Pascal's law
– Bernoulli's principle

Force and motion
– Force
– Types of forces
– Equilibrium of two forces
– Relationship between constant speed, distance and time
– Mass and weight

The Technological World

Graphical language
– Multiview orthogonal projection (general drawing)
– Functional dimensioning
– Developments (prism, cylinder, pyramid, cone)
– Standards and representations (diagrams, symbols)

Mechanical engineering
– Adhesion and friction of parts
– Linking of mechanical parts (degree of freedom of a part)
– Guiding controls
– Construction and characteristics of motion transmission systems (friction gears, pulleys and belt, gear assembly, sprocket wheels and chain, wheel and worm gear)
– Speed changes, *resisting torque, engine torque*
– Construction and characteristics of motion transformation systems (screw gear system, connecting rods, cranks, slides, cams, eccentrics and rotating slider crank mechanisms, rack-and-pinion drive)

Electrical engineering
– Power supply
– Conduction, insulation and protection (resistance and coding, *printed circuit*)
– Control (types: unipolar*, bipolar*, unidirectional, bidirectional)
– Transformation of energy (electricity and light, heat, vibration, magnetism)
– Other functions (condenser, diode, *transistor*, solid-state relay, *other semi-conductors*)

Materials
– Constraints
– Characteristics of mechanical properties
– Heat treatments
– Types and properties
  - Plastics (thermoplastics, thermosetting plastics)
  - Ceramics
  - *Composites*
– Modification of properties (degradation, protection)

Manufacturing
– Manufacturing (characteristics of drilling, tapping, threading and bending)
– Measurement and inspection
  – Direct measurement (vernier caliper)
  – Control, shape and position (plane, section, angle)

ADDITIONAL INFORMATION ON CERTAIN ASPECTS OF THE SCIENCE AND TECHNOLOGY PROGRAM

Note: Students are not required to take significant figures into account when gathering data or giving their answers.

The Living World

BIODIVERSITY

The biodiversity of a community can be defined as the relative abundance of the species living in that community. This necessarily implies that the species richness (the number of species) has already been taken into account.

The Material World

DIRECTION OF CURRENT

The direction of the current should be determined according to the polarity of the terminals, which is indicated on the source or ends of the wires.

NOBLE GASES

Group VIIIA (or group 18) consists of the elements that will be referred to as noble gases.

UNITS OF ENERGY

The watt-hour (W•h) and the kilowatt-hour (kW•h) are units of energy used in electricity.

The Technological World

CONSTRAINTS

External forces (shearing, compression, deflection, torsion and tension) exerted on materials and that have a tendency to deform them (this deformation is not necessarily apparent).

CHARACTERISTICS OF MECHANICAL PROPERTIES

Identification of properties (ductility, hardness, elasticity, fragility, malleability, resilience, stiffness, etc.) that indicate how a material behaves when subjected to one or more constraints.

Ductility and malleability are shaping properties generally associated with metals. These terms are not used to describe a component made out of metal.

Note that the mechanical property associated with a plastic plate subjected to deflection is elasticity and not malleability. This plastic plate is not considered malleable, since it was moulded or thermoformed rather than stretched out into a thin sheet by a rolling mill.

OTHER PROPERTIES

Corrosion resistance, electrical conductivity and thermal conductivity.

FLEXIBLE LINK

A link is flexible when there is a flexible linking component or flexible material. It ensures that the parts will return to their initial position if the object works properly.

PARTIAL LINK

A link is partial when the linked parts must move in relation to one another for the object to work properly.

GUIDING

Function of a component that controls the motion of a moving part so that it follows a specific trajectory.

EXPLODED VIEW

In the appendices of the Question Booklet, the components or sets of components that remain assembled (not separated) in an exploded view drawing are regarded as permanent links (fixed links: glued, soldered).

In the list of components included in the technical drawings, the abbreviation QTY will be used instead of Quantity.

REVERSIBILITY

A mechanism is reversible when a driven component can become a driver component and vice versa.

MATERIALS

The different materials will be examined with a view to associating them with some of their properties.

The use of materials will be studied, but not the way they are manufactured.

<table>
<tr><td>Metals and alloys</td><td colspan="2">Electrical conductivity
Hardness
Magnetism
Oxidation</td></tr>
<tr><td>Ceramics</td><td colspan="2">Hardness
Low electrical conductivity
Wear resistance
Heat resistance
Corrosion resistance</td></tr>
<tr><td>Composites</td><td colspan="2">Durability
Hardness
Elasticity
Lightness
Resilience
Stiffness
Corrosion resistance</td></tr>
<tr><td rowspan="2">Plastics</td><td>Thermoplastics</td><td>Chemical neutrality (unreactive)
Elasticity
Lightness
Resilience
Corrosion resistance</td></tr>
<tr><td>Thermosetting plastics</td><td>Hardness
Resilience
Heat resistance
Stiffness</td></tr>
</table>

ADDITIONAL INFORMATION ON CERTAIN ASPECTS OF THE APPLIED SCIENCE AND TECHNOLOGY PROGRAM

Note: Students are not required to take significant figures into account when gathering data or giving their answers.

The Material World

DIRECTION OF CURRENT

The direction of the current should be determined according to the polarity of the terminals, which is indicated on the source or ends of the wires.

UNITS OF ENERGY

The watt-hour (W•h) and the kilowatt-hour (kW•h) are units of energy used in electricity.

FORCE

A force produces 2 types of effects:

- a change in the state of motion of a body
- a deformation (distortion) of a body (elastic or plastic deformation, or a fracture)

The Technological World

According to the Progression of Learning, the graphical language associated with the various techniques is characterized by the increasing complexity of the objects to be represented. Students are required to know the drawing techniques used to represent a multiview orthogonal projection.

DIMENSIONING

Set of dimensions and tolerances that must be observed to manufacture an object and ensure that it works properly.

TOLERANCE

Precision (acceptable deviation) required in manufacturing the components of an object. If necessary, this tolerance is indicated as ± and is included in the title block.

FUNCTIONAL DIMENSIONING

Specific tolerance (acceptable deviation) that is associated with the dimensions (minimum and maximum) of a part of a component or of a component of an object and that is required for the object to work (e.g. $32.5^{+0.1}$ or $32.5_{-0.2}$ or $32.5\pm\ ^{0.3}_{0.1}$).

Play is the space allowed between two parts to ensure that they can move freely. Depending on the situation, there may or may not be any play between the parts.

CONSTRAINTS

External forces (shearing, compression, deflection, torsion and tension) exerted on materials and that have a tendency to deform them (this deformation is not necessarily apparent).

CHARACTERISTICS OF MECHANICAL PROPERTIES

Identification of properties (ductility, hardness, elasticity, fragility, malleability, resilience, stiffness, etc.) that indicate how a material behaves when subjected to one or more constraints.

Ductility and malleability are shaping properties generally associated with metals. These terms are not used to describe a component made out of metal.

Note that the mechanical property associated with a plastic plate subjected to deflection is elasticity and not malleability. This plastic plate is not considered malleable, since it was moulded or thermoformed rather than stretched out into a thin sheet by a rolling mill.

OTHER PROPERTIES

Corrosion resistance, electrical conductivity and thermal conductivity.

FLEXIBLE LINK

A link is flexible when there is a flexible linking component or flexible material. It ensures that the parts will return to their initial position if the object works properly.

PARTIAL LINK

A link is partial when the linked parts must move in relation to one another for the object to work properly.

GUIDING

Function of a component that controls the motion of a moving part so that it follows a specific trajectory.

EXPLODED VIEW

In the appendices of the Question Booklet, the components or sets of components that remain assembled (not separated) in an exploded view drawing are regarded as permanent links (fixed links: glued, soldered).

In the list of components included in the technical drawings, the abbreviation QTY will be used instead of Quantity.

REVERSIBILITY

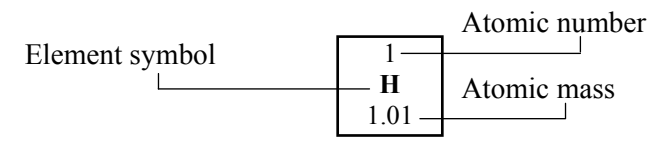
A mechanism is reversible when a driven component can become a driver component and vice versa.

MATERIALS

The different materials will be examined with a view to associating them with some of their properties. The use of materials will be studied, but not the way they are manufactured.

<table>
<tr><td>Metals and alloys</td><td colspan="2">Electrical conductivity
Hardness
Magnetism
Oxidation</td></tr>
<tr><td>Ceramics</td><td colspan="2">Hardness
Low electrical conductivity
Wear resistance
Heat resistance
Corrosion resistance</td></tr>
<tr><td>Composites</td><td colspan="2">Durability
Hardness
Elasticity
Lightness
Resilience
Stiffness
Corrosion resistance</td></tr>
<tr><td rowspan="2">Plastics</td><td>Thermoplastics</td><td>Chemical neutrality (unreactive)
Elasticity
Lightness
Resilience
Corrosion resistance</td></tr>
<tr><td>Thermosetting plastics</td><td>Hardness
Resilience
Heat resistance
Stiffness</td></tr>
</table>

PERIODIC TABLE OF THE ELEMENTS



	I A 1	II A 2	III B 3	IV B 4	V B 5	VI B 6	VII B 7	VIII B 8	VIII B 9	VIII B 10	I B 11	II B 12	III A 13	IV A 14	V A 15	VI A 16	VII A 17	VIII A 18
1	1 H hydrogen 1.01																	2 He helium 4.00
2	3 Li lithium 6.94	4 Be beryllium 9.01											5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
3	11 Na sodium 22.99	12 Mg magnesium 24.31											13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulphur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95
4	19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.90	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn manganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.71	29 Cu copper 63.55	30 Zn zinc 65.39	31 Ga gallium 69.72	32 Ge germanium 72.59	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.90	36 Kr krypton 83.80
5	37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium 98.91	44 Ru ruthenium 101.07	45 Rh rhodium 102.91	46 Pd palladium 106.40	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.75	52 Te tellurium 127.60	53 I iodine 126.90	54 Xe xenon 131.30
6	55 Cs caesium 132.91	56 Ba barium 137.33	57-71 lanthanoids	72 Hf hafnium 178.49	73 Ta tantalum 180.95	74 W tungsten 183.85	75 Re rhenium 186.21	76 Os osmium 190.20	77 Ir iridium 192.22	78 Pt platinum 195.09	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.37	82 Pb lead 207.20	83 Bi bismuth 208.98	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
7	87 Fr francium (223)	88 Ra radium (226)	89-103 actinoids	104 Rf rutherfordium (267)	105 Db dubnium (268)	106 Sg seaborgium (271)	107 Bh bohrium (272)	108 Hs hassium (270)	109 Mt meitnerium (276)	110 Ds darmstadtium (281)	111 Rg roentgenium (280)	112 Cn copernicium (285)	113 Uut ununtrium (284)	114 Fl flerovium (289)	115 Uup ununpentium (288)	116 Lv livermorium (293)	117 Uus ununseptium (292)	118 Uuo ununoctium (294)

6	57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium (145)	62 Sm samarium 150.36	63 Eu europium 151.96	64 Gd gadolinium 157.25	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05	71 Lu lutetium 174.97
7	89 Ac actinium (227)	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium (237)	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (262)

FORMULAS AND QUANTITIES
Science and Technology

FORMULAS

$C = \frac{m}{V}$

C : concentration
m : quantity of solute
V : quantity of solution

$P = V I$

P : electrical power
V : potential difference
I : electric current intensity

$V = R I$

V : potential difference
R : resistance
I : electric current intensity

$E = P \Delta t$

E : energy consumed
P : electrical power
Δt : time difference

$$\text{Energy efficiency} = \frac{\text{Amount of useful energy}}{\text{Amount of energy consumed}} \times 100$$

QUANTITIES

NAME	SYMBOL	VALUE
Density of water	ρ	1.0 g/mL or 1.0 kg/L or 1000 kg/m^3
Kilowatt-hour	kW•h	1 kW•h = 3 600 000 J

FORMULAS AND QUANTITIES

Applied Science and Technology

FORMULAS

$V = RI$

V : potential difference
R : resistance
I : electric current intensity

$F_g = mg$

F_g : gravitational force
m : mass
g : intensity of the gravitational field

$E = P\Delta t$

E : energy consumed
P : electrical power
Δt : time difference

$v = \frac{d}{\Delta t}$

v : average speed
d : distance
Δt : time difference

$P = VI$

P : electrical power
V : potential difference
I : electric current intensity

$$\text{Energy efficiency} = \frac{\text{Amount of useful energy}}{\text{Amount of energy consumed}} \times 100$$

QUANTITIES

NAME	SYMBOL	VALUE
Intensity of the gravitational field on Earth	g	9.8 N/kg
Kilowatt-hour	kW•h	1 kW•h = 3 600 000 J

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