

IDENTIFYING DATA

Environmental technology

Subject	Environmental technology			
Code	V12G360V01703			
Study programme	Grado en Ingeniería en Tecnologías Industriales			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	4th	1st
Teaching language	#EnglishFriendly Spanish Galician			
Department				
Coordinator	Álvarez da Costa, Estrella			
Lecturers	Cameselle Fernández, Claudio			
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General description	Subject that belongs to the Block of Common Subjects of the Industrial Technologies. It is part of the curricula of all Degrees of Industrial Engineering.			

This subject provides an approach to Environmental Engineering, which is necessary to develop any engineering project. ~~In it we work areas of Chemistry and Process Engineering,~~ in order to study the pollutants behaviour and their effect on the environment and organisms, ~~to design physical-chemical processes to mitigate pollution,~~ as well as to evaluate the environmental impact of the industrial wastes.

~~The subject's objective~~ is to know, understand, and know how to apply the techniques used, on an industrial scale, in fields such as solid wastes treatment and management, wastewater treatment, soil remediation, treatment of polluting gas industrial emissions, and pollution prevention.

Subject of the "English Friendly" program.

International students may request the teacher Claudio Cameselle Fernandez:

- Materials and bibliographic references for the follow-up of the subject in English.
- Attend tutorials in English.
- Tests and evaluations in English.

Training and Learning Results

Code	
B7	CG7 Ability to analyze and assess the social and environmental impact of the technical solutions.
C16	CE16 Basic knowledge and application of environmental technologies and sustainability.
D1	CT1 Analysis and synthesis.
D2	CT2 Problems resolution.
D3	CT3 Oral and written proficiency.
D9	CT9 Apply knowledge.
D10	CT10 Self learning and work.
D12	CT12 Research skills.
D17	CT17 Working as a team.
D19	CT19

Expected results from this subject

Expected results from this subject	Training and Learning Results
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Basic knowledge and application of environmental technologies and sustainability	C16	D2 D3 D10 D19
Problem solving	C16	D2 D3 D10 D19
Oral and writing communication	C16	D2 D3 D10
Knowledge application to practical and real cases	C16	D2 D3 D10 D19
Analysis and synthesis	C16	D1 D2 D3 D9 D10 D12 D17 D19
Ability to analyze and determine the social and environmental impact of the technical solutions to environmental problems	B7	D1 D3 D9 D10 D17 D19

Contents

Topic	
Lesson 1: Introduction to the environmental technology.	1. Material cycle economy. 2. Introduction to the best available techniques (BAT).
Lesson 2: Management of waste and effluents.	1. Urban waste management. 2. Industrial waste management. Industrial waste treatment facilities. 3. Regulations.
Lesson 3: Treatment of urban and industrial wastes.	1. Valorization. 2. Physico-chemical treatment. 3. Biological treatment. 4. Thermal treatment. 5. Landfilling.
Lesson 4: Treatment of industrial and municipal wastewaters.	1. Characteristics of municipal and industrial wastewaters. 2. Wastewater treatment plant. 3. Sludge treatment. 4. Water treatment and reuse 5. Regulations
Lesson 5: Atmospheric pollution.	1. Types and origin of atmospheric pollutants. 2. Dispersion of pollutants in the atmosphere. 3. Effects of the atmospheric pollution. 4. Treatment of polluting gas emissions. 5. Regulations
Lesson 6: Sustainability and environmental impact assessment	1. Sustainable development 2. Life cycle analysis and economy. 3. Ecological footprint and carbon footprint. 4. Introduction to the environmental impact assessment
Practice 1: Codification of wastes	
Practice 2: Preparation of immobilized activated charcoal for use as an adsorbent.	
Practice 3: Contaminants removal by adsorption with immobilized activated charcoal.	
Practice 4: Coagulation-flocculation: Establishment of optimal working conditions.	
Practice 5: Simulation of certain stages of a EDAR	
Practice 6: Life Cycle Analysis of a product.	

Planning			
	Class hours	Hours outside the classroom	Total hours
Lecturing	26	52	78
Problem solving	11	22	33
Laboratory practical	12	12	24
Report of practices, practicum and external practices	0	6	6
Case studies	0	6	6
Essay questions exam	1.5	0	1.5
Essay questions exam	1.5	0	1.5

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies	
	Description
Lecturing	Teaching in the classroom of the key concepts and procedures for learning the syllabus contents.
Problem solving	Solving exercises with the teacher's help and independently.
Laboratory practical	Application of the knowledge acquired to the resolution of problems of environmental technology, using equipment and facilities available in the laboratory/computer room.

Personalized assistance	
Methodologies	Description
Laboratory practical	In tutorials, students can consult with their teacher any questions about laboratory practices or the report of practices to be done. The tutoring schedule of the teaching staff will be public and accessible to the students.
Lecturing	In tutorials, students can consult with their teacher any questions arising in the lectures and related to the contents seen in them. The schedule of tutorials of teachers will be public and accessible to students.
Problem solving	In tutorials, students can consult their teacher any questions about the resolution of problems raised in the classroom. The tutoring schedule of the teaching staff will be public and accessible to the students.

Assessment			
	Description	Qualification	Training and Learning Results
Report of practices, practicum and external practices	<p>Detailed report for each practices that includes an explanation of the experimental work, as well as the results obtained, their analysis and the conclusions drawn from them.</p> <p>The laboratory practices are in teams of 2 students, but the teacher may require the report to be submitted individually. A report submitted by a student who did not previously do the practical in the laboratory will not be evaluated under any circumstances.</p> <p>In the computer classroom practices, each student will work individually and, consequently, the reports will also be individual. Similarly, only the report handed by a student who has previously attended the corresponding practical session will be assessed.</p> <p>The competences: CG7, CE16, CT1, CT3, CT9 and CT10, are assessed based on the quality of the written report elaborated by each student on his/her own. The following points will be evaluated in the report: text style and correctness, structure and presentation, analysis and discussion of the results, and conclusions.</p> <p>Competences CT12 and CT17 will be assessed based on the laboratory work. Lab practices will be carried out in pairs, and it is expected the student develop research skills in the field of environmental technology.</p>	10	B7 C16 D1 D3 D9 D10 D12 D17

Case studies	All exercises, seminars, supervised work that may involve learning and service, practical cases and theoretical / practical tests that are made and delivered to the teacher throughout the course, related to the concepts and contents of the syllabus.	30	B7 C16	D2 D3 D10 D12
	Throughout a four-month time several tests are performed.			
	Competences CG7 and CE16 will be assessed considering the students' answers to the theoretical questions.			
	Competences CT2, CT10 and CT12 will be assessed considering the students answers to the exercises.			
	Competence CT3 will be assessed base on the two parts of the exam: theory and exercises; considering the precision and clarity of the answers.			
Essay questions exam	Test EC1: First theoretical-practical written test on the content of the first 3 topics of the subject syllabus.	30	B7 C16	D1 D2 D3 D9 D10 D19
	The theoretical part consists of a series of multiple-choice questions, while the practical part consists of a series of problems related to the topics of the subjects submitted for evaluation.			
	Both parts take place on the same day, in the middle of the semester and on the date set by the E.E.I. management for the "continuous assessment" tests.			
	CG7, CE16 and CT19 competences will be assessed in this test, based on student responses to the questions.			
	CT2, CT9 and CT19 competences will be assessed in this proof, based on the resolution of various exercises of environmental technology, which require the use of applied knowledge related to the contents of the subject.			
	CT1, CT3 and CT10 competences are also evaluated, since the test is written and requires students' analysis and synthesis skills.			
Essay questions exam	Test EC2: Second theoretical-practical written test on the content of the last 3 topics of the subject syllabus.	30	B7 C16	D1 D2 D3 D9 D10 D19
	The theoretical part consists of a series of multiple-choice questions, while the practical part consists of a series of problems related to the topics covered in the subjects submitted for evaluation.			
	Both parts take place on the same day, at the end of the lessons and on the date set by the E.E.I. management for the exams of the 2nd semester.			
	CG7, CE16 and CT19 competences will be assessed in this test, based on student responses to the questions.			
	CT2, CT9 and CT19 competences will be assessed in this proof, based on the resolution of various exercises of environmental technology, which require the use of applied knowledge related to the contents of the subject.			
	CT1, CT3 and CT10 competences are also evaluated, since the test is written and requires students' analysis and synthesis skills.			

Other comments on the Evaluation

Evaluation

A student who chooses continuous assessment, to pass the course, must achieve a **MINIMUM SCORE** of **4.0 points** (out of 10) **in all the evaluation tests detailed in this guide**, ie, "Essay questions exam" (Test EC1 and Test EC2), "Case studies" and "Report of practices". If a student reaches the minimum grade, to pass the subject must obtain a **FINAL GRADE** of ≥ 5.0 , that is, when the sum of grades of the "practice report", "Case study" and the "Essay questions exam" is ≥ 5.0 .

Students who **officially renounces continuous assessment**, will make a "GLOBAL EXAM" (Objective questions exam + Problem and/or exercise solving) that will be worth 90% of the final grade, and a "EXAM OF PRACTICES" that will be worth 10% of the final grade. In any case, to pass the course, ~~the student must achieve 50% of the maximum score in each of the constituent parts of the subject~~, ie, theory, problems and practices.

In addition, if a student misses more than 1 "laboratory practice", without a justified cause, in order to pass the course, he/she will have to do an exam of the practices that he/she did not do.

Second call:

In the second call the same criteria apply.

In relation to the July exam, the grade of "Case study" and "Practical report" will be kept, as soon as the student achieved the required minimum grade in the 1st call.

For the "Essay questions exam" if, at the 1st call, a student suspended one of the test (EC1 or EC2) and approves the other, on the July exam, you only need to repeat the suspended test.

Ethical commitment:

The student is expected to present an adequate ethical behavior. ~~If you detect unethical behavior~~ (copying, plagiarism, unauthorized use of electronic devices, etc.) shall be deemed that the student does not meet the requirements for passing the subject. In this case the final grade, in the current academic year, will FAIL (0.0 points).

~~The use of electronic devices during the assessment tests will be allowed.~~ The fact of introducing into the examination room an unauthorized electronic device, will be reason not pass the course in the current academic year, and the final grade will FAIL (0.0 points)

Sources of information

Basic Bibliography

Mihelcic, J.R. and Zimmermann, J. B., **Environmental Engineering: Fundamentals, sustainability, design**, Wiley, 2014
Davis, M.L. and Masten S.J., **Principles of Environmental Engineering and Science**, McGraw-Hill, 2014
Metcalf & Eddy, **Ingeniería de aguas residuales : tratamiento, vertido y reutilización**, McGraw-Hill, 1998
Acosta, J.A. et al., **Introducción a la contaminación de suelos**, Mundi-prensa, 2017

Complementary Bibliography

Tchobanoglous, G., **Gestión integral de residuos sólidos**, McGraw-Hill, 1996
Nemerow, N. L., **Tratamiento de vertidos industriales y peligrosos**, Diaz de Santos, 1998
Baird, C y Cann M., **Química Ambiental**, Reverté, 2014
Kiely, G., **Ingeniería Ambiental: fundamentos, entornos, tecnología y sistemas de gestión**, McGraw-Hill, 2001
Castells et al., **Reciclaje de residuos industriales: residuos sólidos urbanos y fangos de depuradora**, Díaz de Santos, 2009
Albergaria, J.M. and Nouws H.P.A., **Soil remediation**, Taylor and Francis, 2016
Sharma, H. D., and Reddy, K. R., **Geoenvironmental engineering: site remediation, waste containment, and emerging waste management technologies**, John Wiley & Sons, 2004
Wark and Warner, **Contaminación del aire: origen y control**, Limusa, 1996
Jonker, G. y Harmsen, J., **Ingeniería para la sostenibilidad**, Reverté, 2014
Azapagic, A. and Perdan S., **Sustainable development in practice: Case studies for engineers and scientists**, Wiley, 2011
Reddy, K.R., Cameselle, C. and Adams, J.A., **Sustainable Engineering: Drivers, Metrics, Tools, and Applications**, Wiley, 2019

Recommendations

Subjects that it is recommended to have taken before

Physics: Physics 1/V12G360V01102
Physics: Physics 2/V12G360V01202
Chemical technology/V12G360V01606
Chemistry: Chemistry/V12G380V01205

Other comments

Recommendations:

~~To enroll in this subject is necessary to have passed or be enrolled in all subjects of previous courses to the course that is located this subject.~~

A concise summary of the International System of Units, the **SI**

Metrology is the science of measurement, embracing all measurements, made at a known level of uncertainty, in any field of human activity.

The Bureau International des Poids et Mesures, the BIPM, was established by Article 1 of the Convention du Mètre, on 20 May 1875, and is charged with providing the basis for a single, coherent system of measurements to be used throughout the world. The decimal metric system, dating from the time of the French Revolution, was based on the metre and the kilogram. Under the terms of the 1875 Convention, new international prototypes of the metre and kilogram were made and formally adopted by the first Conférence Générale des Poids et Mesures (CGPM) in 1889. Over time this system developed, so that it now includes seven base units. In 1960 it was decided at the 11th CGPM that it should be called the *Système International d'Unités*, the SI (in English: the International System of Units). The SI is not static but evolves to match the world's increasingly demanding requirements for measurements at all levels of precision and in all areas of science, technology, and human endeavour. This document is a summary of the **SI Brochure**, a publication of the BIPM which is a statement of the current status of the SI.

The seven **base units** of the SI, listed in Table 1, provide the reference used to define all the measurement units of the International System. As science advances, and methods of measurement are refined, their definitions have to be revised. The more accurate the measurements, the greater the care required in the realization of the units of measurement.



The international prototype of the kilogram, \mathcal{K} , the only remaining artefact used to define a base unit of the SI.

Table 1 *The seven base units of the SI*

Quantity
Unit, symbol: definition of unit
length
metre, m: The metre is the length of the path travelled by light in vacuum during a time interval of $1/299\,792\,458$ of a second. <i>It follows that the speed of light in vacuum, c_0, is $299\,792\,458$ m/s exactly.</i>
mass
kilogram, kg: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram. <i>It follows that the mass of the international prototype of the kilogram, $m(\mathcal{K})$, is always 1 kg exactly.</i>
time
second, s: The second is the duration of $9\,192\,631\,770$ periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom. <i>It follows that the hyperfine splitting in the ground state of the caesium 133 atom, $\nu(\text{hfs Cs})$, is $9\,192\,631\,770$ Hz exactly.</i>
electric current
ampere, A: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length. <i>It follows that the magnetic constant, μ_0, also known as the permeability of free space is $4\pi \times 10^{-7}$ H/m exactly.</i>
thermodynamic temperature
kelvin, K: The kelvin, unit of thermodynamic temperature, is the fraction $1/273.16$ of the thermodynamic temperature of the triple point of water. <i>It follows that the thermodynamic temperature of the triple point of water, T_{tpw}, is 273.16 K exactly.</i>
amount of substance
mole, mol: <ol style="list-style-type: none"> The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles. <i>It follows that the molar mass of carbon 12, $M(^{12}\text{C})$, is 12 g/mol exactly.</i>
luminous intensity
candela, cd: The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of $1/683$ watt per steradian. <i>It follows that the spectral luminous efficacy, K, for monochromatic radiation of frequency 540×10^{12} Hz is 683 lm/W exactly.</i>

The seven **base quantities** corresponding to the seven **base units** are length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity. The **base quantities** and **base units** are listed, with their symbols, in Table 2.

Table 2 Base quantities and base units used in the SI

Base quantity	Symbol	Base unit	Symbol
length	l, h, r, x	metre	m
mass	m	kilogram	kg
time, duration	t	second	s
electric current	I, i	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
luminous intensity	I_v	candela	cd

All other quantities are described as **derived quantities**, and are measured using **derived units**, which are defined as products of powers of the **base units**. Examples of **derived quantities** and **units** are listed in Table 3.

Table 3 Examples of derived quantities and units

Derived quantity	Symbol	Derived unit	Symbol
area	A	square metre	m^2
volume	V	cubic metre	m^3
speed, velocity	v	metre per second	m/s
acceleration	a	metre per second squared	m/s^2
wavenumber	$\sigma, \tilde{\nu}$	reciprocal metre	m^{-1}
mass density	ρ	kilogram per cubic metre	kg/m^3
surface density	ρ_A	kilogram per square metre	kg/m^2
specific volume	v	cubic metre per kilogram	m^3/kg
current density	j	ampere per square metre	A/m^2
magnetic field strength	H	ampere per metre	A/m
concentration	c	mole per cubic metre	mol/m^3
mass concentration	ρ, γ	kilogram per cubic metre	kg/m^3
luminance	L_v	candela per square metre	cd/m^2
refractive index	n	one	1
relative permeability	μ_r	one	1

Note that refractive index and relative permeability are examples of dimensionless quantities, for which the SI unit is the number one, 1, although this unit is not written.

Some **derived units** are given a **special name**, these being simply a compact form for the expression of combinations of **base units** that are used frequently. Thus, for example, the

joule, symbol J, is by definition equal to $m^2 kg s^{-2}$. There are 22 special names for units approved for use in the SI at present, and these are listed in Table 4.

Table 4 Derived units with special names in the SI

Derived quantity	Name of derived unit	Symbol for unit	Expression in terms of other units
plane angle	radian	rad	$m/m = 1$
solid angle	steradian	sr	$m^2/m^2 = 1$
frequency	hertz	Hz	s^{-1}
force	newton	N	$m kg s^{-2}$
pressure, stress	pascal	Pa	$N/m^2 = m^{-1} kg s^{-2}$
energy, work, amount of heat	joule	J	$N m = m^2 kg s^{-2}$
power, radiant flux	watt	W	$J/s = m^2 kg s^{-3}$
electric charge, amount of electricity	coulomb	C	s A
electric potential difference	volt	V	$W/A = m^2 kg s^{-3} A^{-1}$
capacitance	farad	F	$C/V = m^{-2} kg^{-1} s^4 A^2$
electric resistance	ohm	Ω	$V/A = m^2 kg s^{-3} A^{-2}$
electric conductance	siemens	S	$A/V = m^{-2} kg^{-1} s^3 A^2$
magnetic flux	weber	Wb	$V s = m^2 kg s^{-2} A^{-1}$
magnetic flux density	tesla	T	$Wb/m^2 = kg s^{-2} A^{-1}$
inductance	henry	H	$Wb/A = m^2 kg s^{-2} A^{-2}$
Celsius temperature	degree Celsius	$^{\circ}C$	K
luminous flux	lumen	lm	$cd sr = cd$
illuminance	lux	lx	$lm/m^2 = m^{-2} cd$
activity referred to a radionuclide	becquerel	Bq	s^{-1}
absorbed dose, specific energy (imparted), kerma	gray	Gy	$J/kg = m^2 s^{-2}$
dose equivalent, ambient dose equivalent	sievert	Sv	$J/kg = m^2 s^{-2}$
catalytic activity	katal	kat	$s^{-1} mol$

Although the hertz and the becquerel are both equal to the reciprocal second, the hertz is only used for cyclic phenomena, and the becquerel for stochastic processes in radioactive decay.

The unit of Celsius temperature is the degree Celsius, $^{\circ}C$, which is equal in magnitude to the kelvin, K, the unit of thermodynamic temperature. The quantity Celsius temperature t is related to thermodynamic temperature T by the equation $t/^{\circ}C = T/K - 273.15$.

The sievert is also used for the quantities directional dose equivalent and personal dose equivalent.

The last four special names for units in Table 4 were adopted specifically to safeguard measurements related to human health.

For each quantity, there is only one SI unit (although it may often be expressed in different ways by using the special names). However the same SI unit may be used to express the values of several different quantities (for example, the SI unit J/K may be used to express the value of both heat capacity and entropy). It is therefore important not to use the unit alone to specify the quantity. This applies both to scientific texts and also to measuring instruments (i.e. an instrument read-out should indicate both the quantity concerned and the unit).

Dimensionless quantities, also called quantities of dimension one, are usually defined as the ratio of two quantities of the same kind (for example, refractive index is the ratio of two speeds, and relative permittivity is the ratio of the permittivity of a dielectric medium to that of free space). Thus the unit of a dimensionless quantity is the ratio of two identical SI units, and is therefore always equal to one. However in expressing the values of dimensionless quantities the unit one, 1, is not written.

Decimal multiples and sub-multiples of SI units

A set of prefixes have been adopted for use with the SI units, in order to express the values of quantities that are either much larger than or much smaller than the SI unit used without any prefix. The SI prefixes are listed in Table 5. They may be used with any of the **base units** and with any of the **derived units** with special names.

Table 5 The SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10 ¹	deca	da	10 ⁻¹	deci	d
10 ²	hecto	h	10 ⁻²	centi	c
10 ³	kilo	k	10 ⁻³	milli	m
10 ⁶	mega	M	10 ⁻⁶	micro	μ
10 ⁹	giga	G	10 ⁻⁹	nano	n
10 ¹²	tera	T	10 ⁻¹²	pico	p
10 ¹⁵	peta	P	10 ⁻¹⁵	femto	f
10 ¹⁸	exa	E	10 ⁻¹⁸	atto	a
10 ²¹	zetta	Z	10 ⁻²¹	zepto	z
10 ²⁴	yotta	Y	10 ⁻²⁴	yocto	y

When the prefixes are used, the prefix name and the unit name are combined to form a single word, and similarly the prefix symbol and the unit symbol are written without any space to form a single symbol, which may itself be raised to any power. For example, we may write: kilometre, km; microvolt, μV; femtosecond, fs; 50 V/cm = 50 V (10⁻² m)⁻¹ = 5000 V/m.

When the **base units** and **derived units** are used without any prefixes, the resulting set of units is described as being **coherent**.

The use of a coherent set of units has technical advantages (see the **SI Brochure**). However the use of the prefixes is convenient because it avoids the need to use factors of 10ⁿ to express the values of very large or very small quantities. For example, the length of a chemical bond is more conveniently given in nanometres, nm, than in metres, m, and the distance from London to Paris is more conveniently given in kilometres, km, than in metres, m.

The kilogram, kg, is an exception, because although it is a **base unit** the name already includes a prefix, for historical reasons. Multiples and sub-multiples of the kilogram are written by combining prefixes with the gram: thus we write milligram, mg, not microkilogram, μkg.

Units outside the SI

The SI is the only system of units that is universally recognized, so that it has a distinct advantage in establishing an international dialogue. Other units, i.e. non-SI units, are generally defined in terms of SI units. The use of the SI also simplifies the teaching of science. For all these reasons the use of SI units is recommended in all fields of science and technology.

Nonetheless some non-SI units are still widely used. A few, such as the minute, hour and day as units of time, will always be used because they are so deeply embedded in our culture. Others are used for historical reasons, to meet the needs of special interest groups, or because there is no convenient SI alternative. It will always remain the prerogative of a scientist to use the units that are considered to be best suited to the purpose. However when non-SI units are used, the conversion factor to the SI should always be quoted. A few non-SI units are listed in Table 6 below with their conversion factors to the SI. For a more complete list, see the **SI Brochure**, or the BIPM website.

Table 6 A few non-SI units

Quantity	Unit	Symbol	Relation to SI
time	minute	min	1 min = 60 s
	hour	h	1 h = 3600 s
	day	d	1 d = 86 400 s
volume	litre	L or l	1 L = 1 dm ³
mass	tonne	t	1 t = 1000 kg
energy	electronvolt	eV	1 eV ≈ 1.602 × 10 ⁻¹⁹ J
	pressure	bar	bar
length	millimetre of mercury	mmHg	1 mmHg ≈ 133.3 Pa
	ångström	Å	1 Å = 10 ⁻¹⁰ m
	nautical mile	M	1 M = 1852 m
force	dyne	dyn	1 dyn = 10 ⁻⁵ N
energy	erg	erg	1 erg = 10 ⁻⁷ J

Symbols for units begin with a capital letter when they are named after an individual (for example, ampere, A; kelvin, K; hertz, Hz; coulomb, C). Otherwise they always begin with a lower case letter (for example, metre, m; second, s; mole, mol). The symbol for the litre is an exception: either a lower case

letter or a capital L may be used, the capital being allowed in this case to avoid confusion between the lower case letter l and the number one, 1.

The symbol for a nautical mile is given here as M; however there is no general agreement on any symbol for a nautical mile.

The language of science: using the SI to express the values of quantities

The value of a quantity is written as the product of a number and a unit, and the number multiplying the unit is the numerical value of the quantity in that unit. One space is always left between the number and the unit. For dimensionless quantities, for which the unit is the number one, the unit is omitted. The numerical value depends on the choice of unit, so that the same value of a quantity may have different numerical values when expressed in different units, as in the examples below.

The speed of a bicycle is approximately

$$v = 5.0 \text{ m/s} = 18 \text{ km/h.}$$

The wavelength of one of the yellow sodium lines is

$$\lambda = 5.896 \times 10^{-7} \text{ m} = 589.6 \text{ nm.}$$

Quantity symbols are printed in an italic (slanting) type, and they are generally single letters of the Latin or Greek alphabet. Either capital or lower case letters may be used, and additional information on the quantity may be added as a subscript or as information in brackets.

There are recommended symbols for many quantities, given by authorities such as ISO (the International Organization for Standardization) and the various international scientific unions such as IUPAP and IUPAC. Examples are:

- T for temperature
- C_p for heat capacity at constant pressure
- x_i for the mole fraction (amount fraction) of species i
- μ_r for relative permeability
- $m(\mathcal{K})$ for the mass of the international prototype of the kilogram \mathcal{K} .

Unit symbols are printed in a roman (upright) type, regardless of the type used in the surrounding text. They are mathematical entities and not abbreviations; they are never followed by a stop (except at the end of a sentence) nor by an s for the plural. The use of the correct form for unit symbols is mandatory, and is illustrated by the examples in the **SI Brochure**. Unit symbols may sometimes be more than a single letter. They are written in lower case letters, except that the first letter is a capital when the unit is named after an individual. However when the name of a unit is spelled out, it should begin with a lower case letter (except at the beginning of a sentence), to distinguish the unit from the man.

In writing the value of a quantity as the product of a numerical value and a unit, both the number and the unit may be treated by the ordinary rules of algebra. For example, the equation $T = 293 \text{ K}$ may equally be written $T/\text{K} = 293$. This procedure is described as the use of quantity calculus, or the algebra of quantities. It is often useful to use the ratio of a quantity to its unit for heading the columns of tables, or labelling the axes of graphs, so that the entries in the table or the labels of the tick marks on the axes are all simply numbers. The example below

shows a table of vapour pressure as a function of temperature, and the logarithm of vapour pressure as a function of reciprocal temperature, with the columns labelled in this way.

T/K	$10^3 \text{ K}/T$	p/MPa	$\ln(p/\text{MPa})$
216.55	4.6179	0.5180	-0.6578
273.15	3.6610	3.4853	1.2486
304.19	3.2874	7.3815	1.9990

Algebraically equivalent forms may be used in place of $10^3 \text{ K}/T$, such as kK/T , or $10^3 (T/\text{K})^{-1}$.

In forming products or quotients of units the normal rules of algebra apply. In forming products of units, a space should be left between units (or alternatively a half high centred dot can be used as a multiplication symbol). Note the importance of the space, for example, m s denotes the product of a metre and a second, but ms denotes a millisecond. Also, when forming complicated products of units, use brackets or negative exponents to avoid ambiguities. For example, the molar gas constant R is given by:

$$\begin{aligned} pV_m/T &= R = 8.314 \text{ Pa m}^3 \text{ mol}^{-1} \text{ K}^{-1} \\ &= 8.314 \text{ Pa m}^3/(\text{mol K}). \end{aligned}$$

When formatting numbers the decimal marker may be either a point (i.e. a stop) or a comma, as appropriate to the circumstances. For documents in the English language a point is usual, but for many continental European languages and in some other countries a comma is usual.

When a number has many digits, it is customary to group the digits into threes about the decimal point for easy reading. This is not essential, but it is often done, and is generally helpful. When this is done, the groups of three digits should be separated only by a (thin) space; neither a point nor a comma should be used. The uncertainty in the numerical value of a quantity may often be conveniently shown by giving the uncertainty in the least significant digits in brackets after the number.

Example: The value of the elementary charge is given in the 2002 CODATA listing of fundamental constants as

$$e = 1.602\ 176\ 53\ (14) \times 10^{-19} \text{ C,}$$

where 14 is the standard uncertainty in the final digits quoted for the numerical value.

For further information see the BIPM website, or the **SI Brochure** 8th edition, which is available at



<http://www.bipm.org>

This summary has been prepared by the Comité Consultatif des Unités (CCU) of the Comité International des Poids et Mesures (CIPM), and is published by the BIPM.

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Recommended Literature

■ 1. Metcalf & Eddy – *Wastewater Engineering: Treatment and Resource Recovery*

Metcalf & Eddy, Inc.; George Tchobanoglous; H. David Stensel; Franklin L. Burton; Ryujiro Tsuchihashi. (2014). *Wastewater Engineering: Treatment and Resource Recovery* (5th ed.). McGraw-Hill Education.

ISBN: 978-0073401188

A comprehensive reference on wastewater treatment processes, including resource recovery and updated technologies.

■ 2. George Tchobanoglous & Frank Kreith – *Handbook of Solid Waste Management*

Tchobanoglous, G., & Kreith, F. (2002). *Handbook of Solid Waste Management* (2nd ed.). McGraw-Hill Professional.

ISBN: 978-0071356237

Focused on integrated strategies and techniques for municipal solid waste management.

■ 3. George Tchobanoglous, Hilary Theisen & Samuel A. Vigil – *Integrated Solid Waste Management: Engineering Principles and Management Issues*

Tchobanoglous, G., Theisen, H., & Vigil, S. A. (1993). *Integrated Solid Waste Management: Engineering Principles and Management Issues* (International ed.). McGraw-Hill.

ISBN: 978-0071128650 (also 978-9339205249 for 2019 reprint)

Covers engineering fundamentals, regulatory context, and management approaches for waste systems.

■ 4. Gerard Kiely – *Environmental Engineering*

Kiely, G. (2007). *Environmental Engineering*. McGraw-Hill Education.

ISBN: 978-0070634299

Presents environmental systems, air and water pollution control, and ecological modeling.

■ 5. K.R. Reddy, C. Cameselle & J.A. Adams – *Sustainable and Resilient Engineering: Drivers, Metrics, Tools, and Applications* (2nd ed.)

Reddy, K. R., Cameselle, C., & Adams, J. A. (2025). *Sustainable and Resilient Engineering: Drivers, Metrics, Tools, and Applications* (2nd ed.). John Wiley & Sons.

ISBN: 978-1394267682

Explores sustainability metrics, lifecycle tools, and engineering for resilience and climate adaptation.

6. Paul L. Bishop – *Pollution Prevention: Fundamentals and Practice*

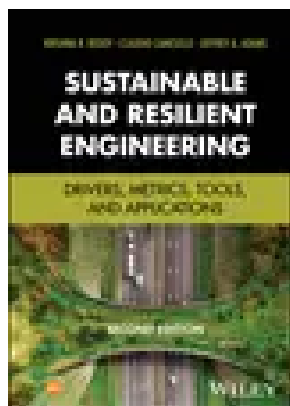
Bishop, P. L. (2000). *Pollution Prevention: Fundamentals and Practice*. McGraw-Hill / Waveland Press.

ISBN: 978-0071160582 (McGraw-Hill); 978-1577663485 (Waveland)

Focuses on pollution prevention strategies, waste minimization, and cleaner production techniques.

Comparative Summary (English)

Author / Title	Edition (English)	Year	ISBN	Main Focus
Metcalfe & Eddy et al. (<i>Wastewater Engineering</i>)	5th	2014	978-0073401188	Wastewater treatment and resource recovery
Tchobanoglous & Kreith (<i>Handbook of Solid Waste Management</i>)	2nd	2002	978-0071356237	Integrated solid waste management
Tchobanoglous, Theisen & Vigil (<i>Integrated Solid Waste Management</i>)	Intl. Ed.	1993 / repr. 2019	978-0071128650	Engineering principles and waste management issues
Kiely (<i>Environmental Engineering</i>)	Intl. Ed.	2007	978-0070634299	Environmental engineering systems and modeling
Reddy, Cameselle & Adams (<i>Sustainable and Resilient Engineering</i>)	2nd	2025	978-1394267682	Sustainable and resilient engineering practices
Bishop (<i>Pollution Prevention: Fundamentals and Practice</i>)	1st	2000	978-0071160582	Pollution prevention and cleaner production



Sustainable and Resilient Engineering: Drivers, Metrics, Tools, and Applications, 2nd Edition

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