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A Learner's Guide to SI Units and their Conversion

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Workbook for students

Edexcel
A Learner's Guide to SI Units and their Conversion

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Introduction

One of the important areas where Science and Technology students need support is in the conversion of units. This booklet is designed to be useful for students in all Science, Technology and Engineering subjects.

This booklet has been produced to:

- introduce students to SI base and derived units and
- help students with the conversion of multiple and sub-multiple units to SI base and derived units.

This booklet can be used:

- by the student for individual study and self assessment or
- as an aid to teaching.

The units used in this booklet are based on the seven base units of the "International System of Units" (SI system).

What are units?

1 You have probably used units without thinking about them. For example, when using a ruler, you may have used centimetres or millimetres for the unit of length.

A unit is a **quantity** or an **amount used** as a standard of measurement.

List some other units have you used:

_____

_____

_____

2 Symbols are used to represent units. For example the letter m represents the metre.

Write down the symbols for the units that you listed above:

_____

_____

_____

3 The unit of length, the metre, is not built from other units. Units that are not built from other units are called base units.

4 Some units are built up from other units. For example, the unit of area is built from the unit of length.

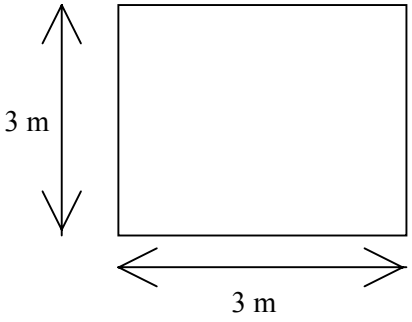
Area = length x length

Square metre = metre x metre

$m^2 = m^1 \times m^1$

Derived unit *Base unit*

Example 1



Area = 3 m x 3 m = **9 m^2**

Units that are built up from other units are known as **derived** units.

The square metre is a derived unit.

5 Different units may be used to make up a derived unit eg m s^{-1}.

The different units are separated by a space.

State whether each of the following units is a base unit or a derived unit:

m s^{-2} _____

kg _____

m^3 _____

s _____

6 Sometimes one symbol represents two or more different base units.

Example: The unit for force is the newton. Its symbol is N. The newton is derived from the base units kilogram, metre and second:

N = kg m s^{-2}

Base units

Name	Symbol	Topic Area
metre	m	Length
second	s	Time
kelvin	K	Temperature
kilogram	kg	Mass
ampere	A	Electric current
mole	mol	Amount of substance
candela	cd	Luminous intensity

Derived units

Name	Symbol	Topic Area
newton	N	Force
joule	J	Energy
hertz	Hz	Frequency
ohm	Ω	Electric resistance
volt	V	Potential difference
watt	W	Power
pascal	Pa	Pressure

When a unit is named after a person, the name begins with a small letter (newton) but the symbol starts with a capital (N).

7 When a unit is used which has a power of 1, the power is excluded for convenience, eg

$m^1 = m$

$s^1 = s$

8 Many of the topic areas are abbreviated using the Greek alphabet, eg

Name	Symbol	Topic Area
Theta	θ	Temperature
Lambda	λ	Wavelength
Mu	μ	Friction Coefficient
Rho	ρ	Density
Sigma	Σ	Stefan's Constant
Omega	Ω	Electrical Resistance

Operations with units

When operations are carried out using units, the units from the same topic area must be the same, eg

- millimetres cannot be added to metres (without converting the millimetres to metres first)
- metres can be added to metres.

Addition and subtraction

Measurements can only be added or subtracted if they have the same units.

Example 1:

Two lengths are added together and both are in metres:

✓ 2 m + 3 m = 5 m

The sum is also in metres.

Example 2:

One length is subtracted from another and both are in metres:

✓ 6 m – 2 m = 4 m

The difference is also in metres.

Example 3:

Lengths measured in different units cannot be added:

X 10 m + 5 cm = ?

Exercise 1

Carry out the following operations and check your answers

1	2 m + 3 m + 4 m	=	**3**	N + 3 N + 2 N	=
2	5 s + 6 s – 4 s	=	**4**	4 J – J + 2 J	=

Multiplication

When multiplying the same topic area units the indices (power numbers) are added together.

Example 1:

$\mathbf{m^1 \times m^1 = m^2}$	ie: $m \times m = m^2$	eg $2\ m \times 2\ m = 4\ m^2$

When multiplying two different units the indices should not be changed.

Example 2:

$\mathbf{m \times s^2 = m\ s^2}$	eg $6\ m \times 2\ s^2 = 12\ m\ s^2$

Exercise 2

Carry out the following operations and check your answers

5	$4\ m \times 2\ m$	=	**7**	$5\ N \times 8\ m$	=
6	$2\ m \times 3\ s^2$	=	**8**	$6\ m^2 \times m$	=

Division

When the same units with the same power are divided they cancel each other and in some cases the result is a ratio.

Example 1

$\frac{\mathbf{m}}{\mathbf{m}} = \mathbf{ratio\,(no\,units)}$	eg	$\frac{\mathbf{6\,m}}{\mathbf{2\,m}} = \mathbf{3}$

When different topic area units are divided, the denominator (bottom of the fraction) unit changes its power sign from positive to negative or vice versa.

Example 2

$\frac{\mathbf{m}}{\mathbf{s}} = \mathbf{m\,s^{-1}}$	eg	$\frac{\mathbf{8\,m}}{\mathbf{2\,s}} = \mathbf{4\,m\,s^{-1}}$

Exercise 3

Carry out the following operations and check your answers:

9	$\frac{4\,K}{4\,K}$	=	**11**	$\frac{12\,m}{3\,s^2}$	=
10	$\frac{3\,m \times 5\,s}{s}$	=	**12**	$\frac{10\,N}{5\,m^2}$	=

Submultiple and multiple units

Submultiple unit

When using a 30 cm ruler to measure objects, most people take the measurement in centimetres or millimetres since it is easier to write 5 mm than 0.005 m.

Base units that are too big for some measurements, for example, the metre can be split into smaller units, e.g. the millimetre.

Base units can be split into smaller units called submultiple units.

The millimetre is an example of a submultiple unit and it is a smaller quantity than the metre.

A submultiple unit is a smaller quantity unit than a base unit.

Multiple unit

Sometimes the base unit can be too small. For example, large distances are often measured in kilometres instead of metres.

The kilometre is a larger quantity than the metre.

A multiple unit is a larger quantity than the base unit.

Common prefixes used for multiple and submultiple units are shown in the table below:

Prefix	Symbol	Number in words	Number in figures	Powers of ten
Mega	M	Million	1 000 000	10^6
Kilo	k	Thousand	1 000	10^3
Centi	c	Hundredth	$\frac{1}{100}$	10^{-2}
Milli	m	Thousandth	$\frac{1}{1\,000}$	10^{-3}
Micro	u	Millionth	$\frac{1}{1\,000\,000}$	10^{-6}

Multiple and submultiple units **must** be converted into SI units when used in formulae for problem solving.

Conversion of units

Conversion is an operation of changing submultiple or multiple units into SI base units.

The Conversion Factor is the figure, which relates the multiple, or submultiple unit to the SI unit.

Rules for conversion

Rule 1

When converting a multiple unit (larger quantity) into the SI base unit (smaller quantity), multiply the **multiple unit** by the conversion factor.

Larger Quantity -------> Smaller Quantity = Multiply by a factor

Example

The kilometre is a multiple unit of the SI base unit of length, the metre. A kilometre is one thousand times larger than the metre.

Multiple	Conversion Factor	Conversion	SI units
1 kilometre (km)	1 000	1 x 1 000	1 000 m

Relationship 1 kilometre = 1 000m = 1 x 10^3 m

Rule 2

When converting a submultiple unit (smaller quantity) into the SI base unit (larger quantity) **divide** the submultiple unit by the conversion factor.

Smaller Quantity --------> Larger Quantity = Divide by a factor

Example

The millimetre is a submultiple unit (smaller quantity) of the SI base unit of length, the metre. A millimetre is one thousand times smaller than the metre.

Submultiple	Conversion Factor	Conversion	SI units
1 millimetre (mm)	1 000	1/1 000	0.001 m

Relationship 1 millimetre = 0.001 m = 1 x 10^{-3} m

Conversion examples and exercises

Length

SI base unit metre (m)

Multiple or Submultiple	Conversion Factor	Relationship
Multiple – kilometre km	1 000	1 km = 1 000 m
Submultiple – centimetre cm	100	100 cm = 1 m
Submultiple – millimetre mm	1 000	1 000 mm = 1 m

Examples

Convert the following into metres:

1 5 kilometres

5 km = 5 x 1 000 = 5 000 m = 5×10^3 m

2 25 centimetres

25 cm = $\frac{25}{100}$ = 0.25 m = 2.5 x $10\ m^{-1}$

3 236 millimetres

236 mm = $\frac{236}{1\ 000}$ = 0.236 m = 2.36 x 10^{-1} m

Exercise 4

Convert the following into metres:

13	12 km	**16**	220 cm
14	6.32 km	**17**	212 mm
15	12 cm	**18**	1234 mm

Area

Derived unit square metre (m2)

Multiple or submultiple	Conversion factor	Relationship
Multiple – hectare	10 000	1 hectare = 10 000 m^2
Submultiple – square millimetre mm^2	1 000 000	1 000 000 mm^2 = 1 m^2
Submultiple – square centimetre cm^2	10 000	10 000 cm^2 = 1 m^2

The hectare is a multiple unit used for measuring large areas.

Examples

Convert the following into square metres:

1 **6.2 hectares**

6.2 hectares = 6.2 x 10 000 = 62 000 m^2 = 6.2 x 10^4 m^2

2 **200 square centimetres**

$200cm^2 = \frac{200}{10\ 000} = 0.02\ m^2 = 2 \times 10^{-2}\ m^2$

3 **5210 square millimetres**

$5210\ mm^2 = \frac{5\ 210}{1\ 000\ 000} = 0.00521\ m^2 = 5.210 \times 10^{-3}\ m^2$

Exercise 5

Convert the following into square metres:

19	2 500 cm^2	**22**	21 510 mm^2
20	22.2 cm^2	**23**	0.21 hectares
21	600 mm^2	**24**	23 hectares

Volume

Derived unit cubic metre (m^3)

Multiple or Submultiple	Conversion Factor	Relationship
Submultiple – cubic millimetre mm^3	1 000 000 000	1 000 000 000 mm^3 = 1 m^3
Submultiple – cubic centimetre cm^3	1 000 000	1 000 000 cm^3 = 1 m^3
Submultiple – cubic decimetre dm^3 (or litre l)	1 000	1 000 dm^3 = l m^3 (or litres)

Examples

Convert the following into cubic metres:

1 102 dm^3 or litres

102 litres = $\frac{102}{1\,000}$ = 0.102 m^3 = 1.02 x 10^{-1} m^3

2 235 cubic centimetres

253 cm^3 = $\frac{235}{1\,000\,000}$ = 0.000235 m^3 = 2.35 x 10^{-4} m^3

3 10290 cubic millimetres

10290 mm^3 = $\frac{10\,290}{1\,000\,000\,000}$ = 0.00001029 m^3 = 1.029 x 10^{-5} m^3

Exercise 6

Convert the following into square metres:

25	5 200 mm^3	**28**	25 000 litres
26	112 345 mm^3	**29**	10.2 litres
27	55 cm^3		

Mass

SI unit kilogram (kg)

Multiple or submultiple	conversion factor	Relationship
Submultiple – gram g	1 000	1 000 g = 1 kg
Multiple – tonne t	1 000	1 tonne = 1 000 kg

Examples

Convert the following into kilograms:

1 200 grams

200 g = $\frac{200}{1\,000}$ = 0.2 kg = 2×10^{-1} kg

2 3.3 tonne

3.3 tonne = 3.3 x 1 000 = 3 300 kg = 3.3×10^{3} kg

Exercise 7

Convert the following into kilograms:

30	2 520 g	**32**	0.56 tonne
31	22 g	**33**	21 tonne

Time

SI unit second (s)

Multiple or submultiple	Conversion factor	Relationship
Multiple – minute min	60	1 min = 60 s
Multiple – hour h	3 600	1 h = 3 600 s

Examples

Convert the following into seconds:

1	**5 minutes**			
	5 minutes	= 5 x 60	= 300 s	= 3.0×10^2 s
2	**2 hours**			
	2 hours	= 2 x 3 600	= 7 200 s	= 7.2×10^3 s

Exercise 8

Convert the following into seconds

34	12 min	**36**	6 h
35	21 min	**37**	3 h 25 min

Temperature

SI unit kelvin (K)

This is purely a mathematical relationship between temperature scales, there are no multiples or submultiples. Degree celsius can be converted into kelvin.

Other scale	Conversion factor	Relationship
Degree Celsius °C	Add 273	0 °C = 273 K

Examples

Convert the following into kelvin:

1	**25 Degree celsius**			
	25°C	=	25 + 273	= 298 K
2	**120 Degree celsius**			
	120°C	=	120 + 273	= 393 K

Convert the following into degrees celsius

3	**523 Kelvins**			
	523 K	=	523 – 273	= 250°C

Exercise 9

Convert the following into kelvin (or degrees Celsius):

38	10°C	**40**	400°C
39	–5°C	**41**	659 K

Density

Derived unit kilogram per cubic metre kg m^{-3}

Multiple or submultiple	Conversion factor	Relationship
Multiple-gram per cubic centimetre	1 000	1 g cm^{-3} = 1 000 kg m^{-3}

Examples

Convert the following into kilograms per cubic metre:

1	**0.8 gram per cubic centimetre** 0.8 g cm^{-3} = 0.8 x 1000 = 800 kg m^{-3} = 8.0 x 10^2 kg m^{-3}
2	**5.6 gram per cubic centimetre** 5.6 g cm^{-3} = 5.6 x 1000 = 5 600 kg m^{-3} = 5.6 x 10^3 kg m^{-3}

Exercise 10

Convert the following into kilogram per cubic metre:

42	1.2 g cm^{-3}	**44**	7.3 g cm^{-3}
43	4.1 g cm^{-3}		

Force

Derived unit newton (N)

Multiple or submultiple	Conversion factor	Relationship
Multiple kilonewton kN	1 000	1 kN = 1 000 N

Examples

Convert the following into newtons:

1	**5 kilonewtons** 5 kN = 5 x 1 000 = 5 000 N = 5.0×10^3 N
2	**8.26 kilonewtons** 8.26 x 1 000 = 8 260 N = 8.26×10^3 N

Exercise 11

Convert the following into newtons:

45	12 kN	**47**	2.12 kN
46	41 kN	**48**	25 kN

Stress and pressure

SI unit Newton per square metre ($N\ m^{-2}$) or Pascal (Pa)

Multiple or submultiple	Conversion factor	Relationship
Multiple – Newton per square millimetre $N\ mm^{-2}$	1 000 000	$1\ N\ mm^{-2} = 1\ 000\ 000\ N\ m^{-2}$

Examples

Convert the following into newton per square metres:

1 **0.5 newtons per square millimetre**

$0.5\ N\ mm^{-2} = 0.5 \times 1\ 000\ 000 = 500\ 000\ N\ m^{-2} = 5 \times 10^{5}\ N\ m^{-2}$

2 **0.0025 newtons per square millimetre**

$0.0025\ N\ mm^{-2} = 0.0025 \times 1\ 000\ 000 = 2\ 500\ N\ m^{-2} = 2.5 \times 10^{3}\ N\ m^{-2}$

Exercise 12

Convert the following into newtons per square metre:

49	$0.0001\ N\ mm^{-2}$	**50**	$0.00002\ N\ mm^{-2}$

Answers to exercises

Exercise 1

1 9 m

2 7 s

3 6 N

4 5 J

Exercise 2

3 8 m^2

4 6 m s^2

7 40 N m

8 6 m^3

Exercise 3

9 2

10 15 m

11 4 m s^{-2}

12 2 N m^{-2}

Exercise 4

13 12 000 m = 1.2 x 10^4 m

14 6 320 m = 6.32 x 10^3 m

15 0.12 m = 1.2 x 10^{-1} m

16 2.2 m

17 0.212 m = 2.12 x 10^{-1} m

18 1.234 m

Exercise 5

19 0.25 m^2 = 2.5 x 10^{-1} m^2

20 0.00222 m^2 = 2.22 x 10^{-3} m^2

21 0.0006 m^2 = 6 x 10^{-4} m^2

22 0.02151 m^2 = 2.151 x 10^{-2} m^2

23 2 100 m^2 = 2.1 x 10^3 m^2

24 230 000 m^2 = 2.3 x 10^5 m^2

Exercise 6

25 0.0000052 m^3 = 5.2 x 106 m^3

26 0.000112345 m^3 = 1.12345 x 10^{-4} m^2

27 0.000055 m^3 = 5.5 x 10^{-5} m^3

28 25 m^3 = 2.5 x 10 m^3

29 0.0102 m^3 = 1.02 x 10^{-2} m^3

Exercise 7

30 2.52 kg

31 0.022 kg = 2.2 x 10^{-2} kg

32 560 kg = 5.6 x 10^2 kg

33 21 000 kg = 2.1 x 10^4 kg

Exercise 8

34 720 s $= 7.2 \text{ X } 10^2$ s

35 1 260 s $= 1.26 \text{ x } 10^3$ s

36 21 600 s $= 2.16 \text{ x } 10^4$ s

37 12 300 s $= 1.23 \text{ x } 10^4$ s

Exercise 9

38 283 K

39 268 K

40 673 K

41 386°C

Exercise 10

42 1 200 kg m^{-3} $= 1.2 \text{ x } 10^3$ kg m^{-3}

43 4 100 kg m^{-3} $= 4.1 \text{ x } 10^3$ kg m^{-3}

44 7 300 kg m^{-3} $= 7.3 \text{ x } 10^3$ kg m^{-3}

Exercise 11

45 12 000 N $= 1.2 \text{ x } 10^4$ N

46 41 000 N $= 4.1 \text{ x } 10^4$ N

47 2 120 N $= 2.12 \text{ x } 10^3$ N

48 25 000 N $= 2.5 \text{ x } 10^4$ N

Exercise 12

49 100 N m^{-2} $= 1.0 \text{ x } 10^2$ N m^{-2}

50 20 N m^{-2} $= 2.0 \text{ x } 10^1$ N m^{-2}

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