Halesowen College

Be College Ready

ENGINEERING LEVEL 3

INTRODUCTION TO OCR CAMBRIDGE TECHNICAL ENGINEERING.

The College offers the the OCR Cambridge Technical in Engineering (L3) as either the Extended Certificate (6 units over two years, equivalent to one A level) and the Diploma (12 units over two years, equivalent to two A levels). Both contain four compulsory examined units (Mathematics for Engineers, Science for Engineers, Principles of Mechanical Engineering and Principles of Electrical and Electronic Engineering). The remaining units are made up of centre assessed (coursework) units on materials and sustainability. The Certificate will have three exams at the end of the first year and one at the end of the second, whilst for the Diploma all four exams will be taken at the end of the first year.

Unit 1 - Mathematics for engineering *Examined unit*	**Unit 2 - Science for engineering** *Examined unit*	**Unit 3 - Principles of mechanical engineering** *Examined unit*	**Unit 4 - Principles of electrical & electronic engineering** *Examined unit*
Algebra Quadratic & cubic equations Trigonometry & geometry Curve sketching Calculus Statistics & probability	Practical work and errors Motion and energy Electricity Materials Fluid flow & pressure Thermal properties	Forces and equilibrium Motion and energy Stress, strain & shear Areas, volumes and centroids Turning moments, levers and pulleys	Circuit theory Alternating current circuits Motors and generators Mains supplies Analogue electronics Digital electronics

For the examined units, each week classes will consist of the study of the theory related to a topic area supported by handouts, demonstrations, practical work and IT resources. In addition to this, all students are expected to spend time each week on independent study for this subject which may include:

- Completion of homeworks consisting application/analysis questions (taken from past papers), either on paper or using online quizzes
- Completion of a practical write-up
- Completing set reading
- Time to review/revise the work completed to date and complete revision notes based around the topic checklists in your preferred format (flash cards, posters, etc) and prepare for topic tests/ mock exams

Revision sessions and mocks will be held prior to examinations, plus topic tests will be set throughout the year to give practice at examination technique and answering questions within set time limits.

For a full copy of the specification please see ***www.ocr.org.uk,*** following the links to Cambridge Technicals in Engineering.

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PREPARATION FOR SEPTEMBER

BUILDING ON YOUR CURRENT KNOWLEDGE

In any Level 3 course there is little or no 'spare' time, and it is important to get off to the best start possible. As such, it will be assumed you will be fully familiar with the scientific and mathematical work you have completed to date. In particular, you should review the following topics over the summer vacation in preparation for your Engineering course.

PHYSICS/SCIENCE	MATHEMATICS
Motion and forces Energy Heat and temperature Properties of matter Electricity and circuits Waves, light and the EM spectrum The structure of the atom Nuclear power Practical techniques, practical write-up	Calculator working (including large & small numbers, powers and roots, trigonometric functions, etc.) BODMAS Standard form Decimal places and significant figures Graph plotting & analysis Re-arranging equations Use of brackets (factorisation, expansion) Trigonometry & Pythagoras

SKILLS DEVELOPMENT

Complete the following activities from the Engineering skills pack in the Appendix:

1. Read through Appendix A (How to rearrange equations) and complete the practice questions in it; bring your work to the the first Engineering class in September. This is to develop your mathematical skills

2. Produce a poster on an aspect of Engineering which particularly interests you - see Appendix B. This is to develop your research, communication and presentation skills

3. Correct use of units is vital in Engineering; a practical result without its unit is useless, and in calculations if the quantities used are not in the correct units the answer will be incorrect. Read through Appendix C (Units and the S.I. System) so that you are familiar with the use of units in Engineering. In particular, note the section on how units are made bigger and smaller (multiples and sub-multiples). This is to develop your skills for tackling Engineering questions and practicals. There will be short test on units in the first week of the course

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APPENDIX A - HOW TO REARRANGE EQUATIONS.

In Engineering questions, it is usually the case that the quantity we need to calculate is not the subject of the equation as it is given on the formula sheet (the subject of an equation is the quantity by itself, in the numerator position, on one side of the equal sign). The equation needs to be rearranged to make this quantity the subject, and this can be a several stage process.

You should be familiar with the order in which a numerical calculations are evaluated - brackets first, then any functions such a square roots, then multiplication and division, then addition and subtraction (BODMAS). When rearranging, this order is reversed, i.e.:

1. If there are any terms that are added or subtracted, move these first (note that only free terms can be moved; any inside brackets will have to wait until later).

   Add or subtract the term to both sides to move it, e.g.
   $a + b - c = d \Rightarrow a = d - b + c$
   An addition on one side becomes a subtraction on the other, and vice versa

2. If there are any terms that are multiplied or divided, move these next (note that only free terms can be moved; any inside brackets will have to wait until later).

   Multiply or divide the term on both sides to move it, e.g.
   $\frac{a \times b}{c} = d \Rightarrow a = \frac{d \times c}{b}$
   Note $a = \frac{b}{c} \Rightarrow \frac{a}{b} = \frac{1}{c}$, not c
   A term moves from the numerator position on one side to the denominator on the other, and vice versa

3. If there are any functions such as square roots or logs, deal with these next (again, anything in brackets will have to wait).

   Apply the opposite function on both sides, e.g.
   $\sqrt{a} = b \Rightarrow a = b^2$

4. If there are any brackets present, expand them now to free the terms inside them, or convert more than one occurrence of the quantity into just one occurrence by factorisation.

   Expanding brackets:
   $a(b + c) = a \times b + a \times c$

   Factorising:
   $a \times b + a \times c = a(b + c)$

5. It could be by this stage the quantity you wish to be the subject isn't in that position yet - in this case, go back to stage (1) and repeat the sequence. Keep cycling around the sequence until the rearrangement is done.

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Example: Make L the subject of $C = \frac{k}{(L + e)^2}$

(C is the count rate of a radioactive source a distance L from the end of a detector tube; e is the distance the radiation travels into the tube before it is detected and k is a constant for the experiment).

Answer: There are no free + or - terms, so progress to step (2)

L is currently in the denominator position, so needs to be moved across the equal sign to the numerator (note all of $(L + e)^2$ needs to be moved, as we are not at step (4) yet):

$(L + e)^2 \times C = k$

C needs to be moved away from L (still at step (2)):

$(L + e)^2 = {}^{k}/_{C}$

The square needs to be removed, so square-root both sides (step (3)):

$(L + e) = \sqrt{({}^{k}/_{C})}$ (Note all of ${}^{k}/_{C}$ is square-rooted).

There is no longer any requirement for the bracket, so expand it (step (4)):

$L + e = \sqrt{({}^{k}/_{C})}$

L is not yet the subject, so go back to step (1); there is now a + or - term to move, the + e:

$L = \sqrt{({}^{k}/_{C})} - e$

It could be that the quantity you wish to make the subject appears twice (or more) in the equation. In this case, get all the terms containing this quantity onto one side of the equation and factorise it out (step (4)

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Example: A hot object (a) and a cool object (b) are put into contact such that heat energy can flow between them until they reach a common temperature. The equation for this is:

$$C_a(T_1 - T_2) = C_b(T_2 - T_3)$$

Where C_a and C_b are the heat capacities of the two objects, T_1 and T_3 are their starting temperatures, and T_2 is the common temperature. Make T_2 the subject of the equation.

Answer: There are no free + or - terms to move, so go to step (2)

It would not help greatly to move C_a or C_b at this stage, so go to step (3)

There are no functions to deal with, so go to step (4)

The brackets can now be expanded:

$$C_aT_1 - C_aT_2 = C_bT_2 - C_bT_3$$

Back to step (1) - bring all the terms with T_2 in them to one side, and put all the other terms on the other side:

$$C_aT_1 + C_bT_3 = C_bT_2 + C_aT_2$$

Nothing to do at steps (2) and (3), so move to step (4), in this case factorising out T_2 :

$$C_aT_1 + C_bT_3 = T_2(C_b + C_a)$$

Back to step (1); there are no useful + or - movements, so use step (2) to move the $(C_b + C_a)$ term across the equation:

$$\frac{C_aT_1 + C_bT_3}{(C_b + C_a)} = T_2$$ (note $(C_b + C_a)$ divides into all of the left-hand side)

Equations can be read right-to-left as well as left-to-right, so:

$$T_2 = \frac{C_aT_1 + C_bT_3}{(C_b + C_a)}$$

There is one general rule to follow: whenever change is made to one side of the equation (e.g. squaring), exactly the same change must be made to the other. E.g. if $a = b + c$ and we wanted a^2, then:

$$a^2 = (b + c)^2 \neq b^2 + c^2$$

The symbol $\neq$ means not equal to. This can be quickly confirmed by just trying the equation with some numbers, e.g. $b = 2$ and $c = 3$. Then $a = 5$, and $a^2 = 25$, but $b^2 + c^2 = 13$, clearly incorrect.

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EXERCISE:

Rearrange the following equations (answers at the bottom of the page).

(a) $R = \frac{V}{I}$ for I = ...

(b) $v = u + at$ for u = ...

(c) $v = u + at$ for a = ...

(d) $hf = E_K + \Phi$ for f = ...

(e) $s = ut + \frac{1}{2}at^2$ for u = ...

(f) $v^2 = u^2 + 2as$ for u = ...

(g) $F = \frac{GMm}{r^2}$ for r = ...

(h) $n_1\sin(\Theta_1) = n_2\sin(\Theta_2)$ for Θ_2 = ...

(i) $E = I(R + r)$ for r = ...

(j) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ for m_1 = ...

Answers:

(a) $I = \frac{V}{R}$ (b) $u = v - at$ (c) $a = \frac{(v - u)}{t}$ (d) $f = \frac{(E_K + \Phi)}{h}$

(e) $u = \frac{(s - \frac{1}{2}at^2)}{t}$ (f) $u = \sqrt{(v^2 - 2as)}$ (g) $r = \sqrt{(GMm/F)}$

(h) $\Theta_2 = \sin^{-1}\left(\frac{n_1\sin(\Theta_1)}{n_2}\right)$ (i) $r = \frac{(E - IR)}{I}$ (j) $m_1 = \frac{(m_2v_2 - m_2u_2)}{(u_1 - v_1)}$

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APPENDIX B - POSTER

Produce a poster on an aspect of Engineering which particularly interests you. It should:

- Be A3 size (or two A4 sheets joined together).
- Briefly outline the Engineering principles applied
- Contain at least one appropriate scientific image and one appropriate graph
- Have a section listing the sources you used (if this is a textbook give the title, author and date of publication, if a journal or magazine article give the article name, journal/magazine title, issue number and date, and if a website the full web address and the date you accessed it)

Bring the poster into the first Engineering session in September; in small groups you will have the opportunity to explain your poster to other students and then it will be displayed within the lab. This is to develop your research, communication and presentation skills. .

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APPENDIX C - UNITS AND THE SI SYSTEM.

INTRODUCTION

In Engineering we are concerned with measuring the amounts of various quantities such as mass, velocity, electrical current, etc, and then using these quantities in calculations to find other results. Any measured (or calculated) quantity is made up of two parts: its magnitude, which is simply how big that quantity is, and its unit, which tells you how the quantity was measured.

For example, consider a measurement of the speed of a car. You might find that the car was travelling at 30 miles per hour. So to split this quantity up into its two parts, its magnitude is 30, and its units are miles per hour (implying that the way in which the speed was measured was by finding how many miles the car travelled in one hour). However, you could have measured the car's speed in a different way - one possibility is to measure the number of metres the car travelled in one second. In doing this, you would have found that the magnitude of the car's speed would be different to that measured in miles per hour, because one metre is shorter than one mile and one second is shorter than one hour.

It is vitally important that for all measurements and calculated results you give both the magnitude and the units of the quantity. Again using the car example, if you gave its speed just as 30, with no units, this would be meaningless, as nobody else would know whether you meant 30 miles per hour, 30 metres per second, 30 kilometres per hour, etc. So it is necessary for you to have a knowledge of the standard scientific units, and be able to use them.

THE SI SYSTEM

A standard international system of units has been agreed - the SI System (Systeme International d'Unites), which is built upon the metric system. In this system, there are seven **FUNDAMENTAL QUANTITIES** (which are length, mass, time, electrical current, temperature, amount of a substance and luminous intensity), and the units of any other quantity can be made up by combining the units of these seven fundamental quantities. Each quantity has a name, a symbol (which is simply a 'short-hand' way of writing the name of the quantity), and a unit, with the unit having an abbreviation (which is again just a short-hand way of writing the unit's name.)

THE FUNDAMENTAL QUANTITIES

The seven fundamental quantities and their units are:

Quantity	Symbol	Unit	Unit abbreviation
Length	l or L	metre	m
Mass	M or m	kilogramme	kg
Time	t	second	s
Electrical current	I	ampere	A
Temperature	T	kelvin	K
Amount of a substance	n	mole	mol
Luminous intensity	L	candela	cd

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DERIVED QUANTITIES

These are quantities whose units may be made up from the seven fundamental units, although to simplify their use, many are given their own individual units. The thing to remember is that the units of these quantities are in no way basic or fundamental, but are simply made up from combinations of the true seven fundamental units given above; a selection of these is given below.

Quantity	Symbol	Unit	Unit abbreviation
Area	A	square metre	m^2
Volume	V	cubic metre	m^3
Density	ρ	kilogramme per cubic metre	$kg\ m^{-3}$
Velocity	v	metre per second	$m\ s^{-1}$
Acceleration	a	metre per second per second	$m\ s^{-2}$
Angle	θ	radian	rad
Frequency	f	hertz	Hz
Period	T	second	s
Refractive index	n	No unit	No unit
Charge	Q or q	coulomb	C
Potential difference	PD	volt	V
Resistance	R	ohm	Ω
Resistivity	ρ	ohm metre	Ω m
Force	F	newton	N
Weight	W	newton	N
Moment of a force	M	newton metre	N m
Moment of a couple	T	newton metre	N m
Youngs modulus	E	newton per metre per metre	$N\ m^{-2}$
Work done	W or W.D.	joule	J
Energy	E	joule	J
Potential energy	E_P	joule	J
Kinetic energy	E_K	joule	J
Power	P	watt	W
Atomic number	Z	No unit	No unit
Mass number	A	No unit	No unit
Heat	Q	joule	J
Specific heat capacity	c	joule per kilogramme per kelvin	$J\ kg^{-1}\ K^{-1}$
Latent heat	L	joule	J
Specific latent heat	l	joule per kilogramme	$J\ kg^{-1}$
Pressure	p or P	newton per metre^2 or pascal	$N\ m^{-2}$ or Pa
Momentum	p	kilogramme metre per second	$kg\ m\ s^{-1}$
Electric field strength	E	newton per coulomb or volt per metre	$N\ C^{-1}$ or $V\ m^{-1}$
Capacitance	C	farad	F
Magnetic flux density	B	tesla	T
Magnetic flux	Φ	weber	Wb
Angular velocity	ω	radian per second	$rad\ s^{-1}$
Gravitational constant	G	newton metre^2 per kilogramme^2	$N\ m^2\ kg^{-2}$
Molar gas constant	R	joule per mole per kelvin	$J\ mol^{-1}\ K^{-1}$
Boltzmann constant	k	joule per kelvin	$J\ K^{-1}$

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PREFIXES TO UNITS

Prefixes may be added to units to change their size. There are two types: **multiple**, which increase the size of the unit, and **sub-multiple**, which decrease the size of the unit. In the SI system, all prefixes have a name, a symbol, and a value, which must be multiplied with the unit to give the new (prefixed) unit's size.

Table of SI sub-multiples of units.

Prefix	Symbol	Value (to multiply unit by)	
deci	d	10^{-1}	(0·1)
centi	c	10^{-2}	(0·01)
milli	m	10^{-3}	(0·001)
micro	μ	10^{-6}	(0·000001)
nano	n	10^{-9}	(0·000000001)
pico	p	10^{-12}	(0·000000000001)
femto	f	10^{-15}	(0·000000000000001)
atto	a	10^{-18}	(0·000000000000000001)

Table of SI multiples of units.

Prefix	Symbol	Value (to multiply unit by)	
deka	da	10^{1}	(10)
hecto	h	10^{2}	(100)
kilo	k	10^{3}	(1000)
mega	M	10^{6}	(1000000)
giga	G	10^{9}	(1000000000)
tera	T	10^{12}	(1000000000000)

An example of using a sub-multiple is the conversion of metres (m for short) to millimetres (mm for short). The table above shows that the multiplying value for this is 10-3 (0.001), i.e. 1 mm is one thousandth of a metre, and, alternately, there are 1000 mm in a metre. To convert a length given in mm to m, you must divide that length by 1000; to convert a length given in m to mm, you must multiply that length by 1000.

Example: What is the length 2.8 m in mm?

Answer: Length given in mm = length given in m x 1000

length in mm = 2.8 x 1000 = 2800 mm

An example of using a multiple is the conversion of metres to kilometres (km for short). The table above shows that the multiplying value for this is 103(1000), i.e. 1 m is one thousandth of a kilometre, and, alternately, there are 1000 m in a kilometre. To convert a length given in m to km, you must divide that length by 1000; to convert a length given in km to m, you must multiply that length by 1000.

Example: What is the length 2.8 m in km?

Answer: Length given in km = length given in m + 1000

length in km = 2.8 + 1000 = 0.0028 km

One 'rule of thumb' to remember - when converting a quantity's units, the actual size of the quantity is not changing; hence if the unit is getting smaller the magnitude must get bigger (as in the first example above), and if the unit is getting bigger the magnitude must get smaller (as in the second example above).