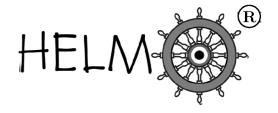


Student's Guide



HELM: Helping Engineers Learn Mathematics

http://helm.lboro.ac.uk

About the HELM Project

HELM (Helping Engineers Learn Mathematics) materials were the outcome of a three-year curriculum development project undertaken by a consortium of five English universities led by Loughborough University, funded by the Higher Education Funding Council for England under the Fund for the Development of Teaching and Learning for the period October 2002 – September 2005, with additional transferability funding October 2005 – September 2006.

HELM aims to enhance the mathematical education of engineering undergraduates through flexible learning resources, mainly these Workbooks.

HELM learning resources were produced primarily by teams of writers at six universities: Hull, Loughborough, Manchester, Newcastle, Reading, Sunderland.

HELM gratefully acknowledges the valuable support of colleagues at the following universities and colleges involved in the critical reading, trialling, enhancement and revision of the learning materials:

Aston, Bournemouth & Poole College, Cambridge, City, Glamorgan, Glasgow, Glasgow Caledonian, Glenrothes Institute of Applied Technology, Harper Adams, Hertfordshire, Leicester, Liverpool, London Metropolitan, Moray College, Northumbria, Nottingham, Nottingham Trent, Oxford Brookes, Plymouth, Portsmouth, Queens Belfast, Robert Gordon, Royal Forest of Dean College, Salford, Sligo Institute of Technology, Southampton, Southampton Institute, Surrey, Teesside, Ulster, University of Wales Institute Cardiff, West Kingsway College (London), West Notts College.

HELM Contacts:

Post: HELM, Mathematics Education Centre, Loughborough University, Loughborough, LE11 3TU.

Email: helm@lboro.ac.uk Web: http://helm.lboro.ac.uk

HELM Workbooks List

1	Basic Algebra	26	Functions of a Complex Variable
2	Basic Functions	27	Multiple Integration
3	Equations, Inequalities & Partial Fractions	28	Differential Vector Calculus
4	Trigonometry	29	Integral Vector Calculus
5	Functions and Modelling	30	Introduction to Numerical Methods
6	Exponential and Logarithmic Functions	31	Numerical Methods of Approximation
7	Matrices	32	Numerical Initial Value Problems
8	Matrix Solution of Equations	33	Numerical Boundary Value Problems
9	Vectors	34	Modelling Motion
10	Complex Numbers	35	Sets and Probability
11	Differentiation	36	Descriptive Statistics
12	Applications of Differentiation	37	Discrete Probability Distributions
13	Integration	38	Continuous Probability Distributions
14	Applications of Integration 1	39	The Normal Distribution
15	Applications of Integration 2	40	Sampling Distributions and Estimation
16	Sequences and Series	41	Hypothesis Testing
17	Conics and Polar Coordinates	42	Goodness of Fit and Contingency Tables
18	Functions of Several Variables	43	Regression and Correlation
19	Differential Equations	44	Analysis of Variance
20	Laplace Transforms	45	Non-parametric Statistics
21	z-Transforms	46	Reliability and Quality Control
22	Eigenvalues and Eigenvectors	47	Mathematics and Physics Miscellany
23	Fourier Series	48	Engineering Case Study
24	Fourier Transforms	49	Student's Guide
25	Partial Differential Equations	50	Tutor's Guide

© Copyright Loughborough University, 2015



Contents

49

Student's Guide

49.1	Introduction to HELM	1
49.2	HELM Workbooks	4
49.3	General Advice to Students Studying Mathematics	10
49 4	Index of Engineering Contexts in Workhooks 1 to 48	22



Introduction

The HELM project (Helping Engineers Learn Mathematics) was supported by a £250,000 HEFCE FDTL4 grant for the period Oct 2002-Sept 2005. A HEFCE - funded Transferability Study was undertaken October 2005-September 2006 encouraging the wider uptake of the use of the HELM materials.

1. The HELM project

The HELM team comprised staff at Loughborough University and four consortium partners in other English universities: Hull, Manchester, Reading and Sunderland. The project's aims were to considerably enhance, extend and thoroughly test Loughborough's original Open Learning materials. These were to be achieved mainly by the writing of additional Workbooks and incorporating engineering examples and case studies closely related to the mathematics presented, enhancing the question databanks, upgrading the Interactive Learning segments and adding some more for basic mathematics topics, and promoting widespread trialling.

The HELM project's output consisted of Workbooks, Interactive Learning segments, a Computer Aided Assessment regime which is used to help 'drive the student learning' and a report on possible modes of usage of this flexible material.

The Workbooks may be integrated into existing engineering degree programmes either by selecting isolated stand-alone units to complement other materials or by creating a complete scheme of work for a semester or year or two years by selecting from the large set of Workbooks available. These may be used to support lectures or for independent learning.

HELM's emphasis is on flexibility - the work can be undertaken as private study, distance learning or can be teacher-led, or a combination, according to the learning style and competence of the student and the approach of the particular lecturer.

Section 49.1: Introduction

2. HELM project Workbooks

50 Workbooks are available which comprise:

- 46 Student Workbooks (listed in 50.4) written specifically with the typical engineering student in mind containing mathematical and statistical topics, worked examples, tasks and related engineering examples.
- A Workbook containing an introduction to dimensional analysis, supplementary mathematical topics and physics case studies.
- A Workbook containing Engineering Case Studies ranging over many engineering disciplines.
- A Students' Guide
- A Tutor's Guide (this document)

The main project materials are the Workbooks which are subdivided into manageable Sections. As far as possible, each Section is designed to be a self-contained piece of work that can be attempted by the student in a few hours. In general, a whole Workbook typically represents 2 to 3 weeks' work. Each Workbook Section begins with statements of pre-requisites and the desired learning outcomes.

The Workbooks include (a) worked examples, (b) tasks for students to undertake with space for students to attempt the questions, and, often, intermediate results provided to guide them through problems in stages, and (c) exercises where normally only the answer is given.

It is often possible for the lecturer to select certain Sections from a Workbook and omit other Sections, possibly reducing the reproduction costs and, more importantly, better tailoring the materials to the needs of a specific group.

With funding from **sigma** the workbooks were updated during 2014 and republished Spring 2015, and are now available to all Higher Education Institutes worldwide.

3. HELM project Interactive Learning Segments

These are now outdated and unavailable.



4. HELM project Assessment Regime

In formal educational environments assessment is normally an integral part of learning, and this was recognised by the HELM project. Students need encouragement and confirmation that progress is being made. The HELM assessment strategy was based on using Computer-Aided Assessment (CAA) to encourage self-assessment, which many students neglect, to verify that the appropriate skills have been learned. The project's philosophy was that assessment should be at the heart of any learning and teaching strategy and Loughborough University's own implementation of HELM makes extensive use of CAA to drive the students' learning.

In the past HELM provided an integrated web-delivered CAA regime based on Questionmark Perception for both self-testing and formal assessment, with around 5000 questions; most having a page of specific feedback. These are now largely superseded and so no longer available to other institutions.

HELM Workbooks

1. List of Workbooks

No.	Title	Pages
1	Basic Algebra	89
2	Basic Functions	75
3	Equations, Inequalities & Partial Fractions	71
4	Trigonometry	77
5	Functions and Modelling	49
6	Exponential and Logarithmic Functions	73
7	Matrices	50
8	Matrix Solution of Equations	32
9	Vectors	66
10	Complex Numbers	34
11	Differentiation	58
12	Applications of Differentiation	63
13	Integration	62
14	Applications of Integration 1	34
15	Applications of Integration 2	31
16	Sequences and Series	51
17	Conics and Polar Coordinates	43
18	Functions of Several Variables	40
19	Differential Equations	70
20	Laplace Transforms	72
21	z-Transforms	96
22	Eigenvalues and Eigenvectors	53
23	Fourier Series	73
24	Fourier Transforms	37
25	Partial Differential Equations	42
26	Functions of a Complex Variable	58
27	Multiple Integration	83
28	Differential Vector Calculus	53
29	Integral Vector Calculus	80
30	Introduction to Numerical Methods	64
31	Numerical Methods of Approximation	86
32	Numerical Initial Value Problems	80
33	Numerical Boundary Value Problems	36
34	Modelling Motion	63
35	Sets and Probability	53
36	Descriptive Statistics	51



No.	Title	Pages
37	Discrete Probability Distributions	60
38	Continuous Probability Distributions	27
39	The Normal Distribution	40
40	Sampling Distributions and Estimation	22
41	Hypothesis Testing	42
42	Goodness of Fit and Contingency Tables	24
43	Regression and Correlation	32
44	Analysis of Variance	57
45	Non-parametric Statistics	36
46	Reliability and Quality Control	38
47	Mathematics and Physics Miscellany	69
48	Engineering Case Studies	97
49	Student's Guide	31
50	Tutor's Guide	75

2. Nomenclature used for problems

- **Examples** are problems with fully worked solutions.
- **Engineering Examples** (found in most Mathematics Workbooks but not the Statistics Workbooks) are problems with an engineering context having fully worked solutions.
- Tasks are problems with spaces for the student's working, followed by fully worked solutions. Many Tasks are often broken up into stages with the answer to a stage given before the next stage is reached. [Note: Some tutors may provide workbooks without these worked solutions.]
- Exercises are problems for the student to do without spaces provided for the student's working. In general they do not have fully worked solutions, merely answers, but exceptions are: Numerical Workbooks 30-33 and Statistics Workbooks 35-46 which do have fully worked solutions.

3. Notation used

In general HELM uses italic serif font letters (e.g. f(x)) to represent functions, variables and constants. However, as exceptions HELM Workbooks use the following non-italic sans-serif letters:

Mathematics

e for the exponential constant and for the exponential function (primarily use in introductory Workbook 6, elsewhere e is often used)

i where $i^2 = -1$

In for natural logarithm

Statistics

E for Expectation

P for Probability

V for Variance

M for Median

Complex numbers

HELM uses i rather than j to represent $\sqrt{(-1)}$ so $i^2 = -1$, although there are one or two exceptions to this (in Workbook 48: Engineering Case Studies).

Vectors

HELM uses underlining of vectors rather than using bold e.g. \underline{a}

HELM uses $\underline{\hat{n}}$ for the unit normal vector but does not put the $\hat{\ }$ on the basic unit vectors in the x,y and z directions which have the standard symbols $\underline{i},j,\underline{k}$.

Identities

Although HELM introduces and uses the identity symbol ' \equiv ' extensively in Workbook 1: Basic Algebra and in Workbook 4: Trigonometry it is not normally used elsewhere and the more normal ' \equiv ' is used except where emphasis seems advisable. (HELM is therefore not consistent.)

4. Description of HELM Workbook layout

On the following three pages are explanatory pages concerning Workbook Layout.



Description of HELM Workbook layout

Complex Arithmetic



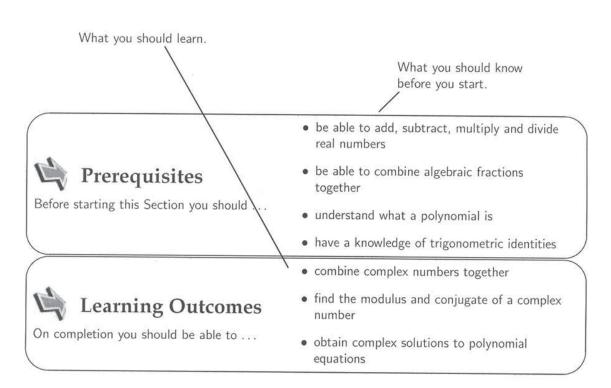


Introduction

Complex numbers are used in many areas of engineering and science. In this Section we define what a complex number is and explore how two such numbers may be combined together by adding, subtracting, multiplying and dividing. We also show how to find 'complex roots' of polynomial equations.

A complex number is a generalisation of an ordinary real number. In fact, as we shall see, a complex number is a pair of real numbers ordered in a particular way. Fundamental to the study of complex numbers is the symbol i with the strange looking property $i^2 = -1$. Apart from this property complex numbers follow the usual rules of number algebra.

Workbook introduction.



Key Points.

Take especial note of these.



Key Point 1

The symbol i is such that

$$i^2 = -1$$

Using the normal rules of algebra it follows that

$$i^3 = i^2 \times i = -i$$
 $i^4 = i^2 \times i^2 = (-1) \times (-1) = 1$

and so on.

Task for you to try with space for your working. Answer presented after solution box.



If $z=-2+\mathrm{i}$ and $w=3+2\mathrm{i}$ find expressions for

(a)
$$z+2w$$
, (b) $|z-w|$ and (c) zw

Your solution

(a)

Answer

$$z + 2w = 4 + 5i$$

Your solution

(b) Hint: you should find that $z-w=-5-\mathrm{i}$

Answer

$$|z-w| = \sqrt{(-5)^2 + (-1)^2} = \sqrt{26}$$

Your solution

(c)

Answer

$$zw = -6 + 3i - 4i + 2i^2 = -8 - i$$



Worked example.

Solution with explanation follows in box.



Example 2 Find
$$\frac{z}{w}$$
 if $z = 2 - 3i$ and $w = 2 + i$.

Solution

$$\begin{split} \frac{z}{w} &= \frac{2-3\mathrm{i}}{2+\mathrm{i}} &= \frac{(2-3\mathrm{i})\times(2-\mathrm{i})}{(2+\mathrm{i})\times(2-\mathrm{i})} & \text{rationalising} \\ &= \frac{4-3+\mathrm{i}(-6-2)}{4+1} & \text{multiplying out} \\ &= \frac{1}{5} - \frac{8}{5}\mathrm{i} & \text{dividing through} \end{split}$$

Exercise for you to do.

Answers follow in box (usually no detailed solution).



Exercises

- 1. Find the roots of the equation $x^2 + 2x + 2 = 0$.
- 2. If i is one root of the cubic equation $x^3 + 2x^2 + x + 2 = 0$ find the two other roots.
- 3. Find the complex number z if $2z + z^* + 3i + 2 = 0$.
- 4. If $z = \cos \theta + \mathrm{i} \sin \theta$ show that $\frac{z}{z^*} = \cos 2\theta + \mathrm{i} \sin 2\theta$.

Answers 1. $x = -1 \pm i$ 2. -i, -2 3. $-\frac{2}{3} - 3i$

General Advice to Students Studying Mathematics

49.3

1. Communication with the lecturer or tutor

When your lecturer or tutor writes something that you cannot understand, says something which you don't hear clearly, or provides notes which seem unintelligible or wrong, don't be reluctant to query it! Almost certainly you won't be the only one with this problem. Help yourself and the rest of the class. You will also be doing the lecturer or tutor a favour. Furthermore, ask the question as soon as you reasonably can. Waiting until the end of class can be very frustrating for all concerned!

2. Reading instructions

It seems human nature not to want to read instructions properly (if at all) when faced with a practical task. This even applies to mathematics problem sheets, to coursework and to examination papers. Careful reading of instructions is especially important in mathematics, otherwise you can finish up giving the right answer to the wrong problem and so gaining little or no credit when credit is really due. Miscopying the question is easily done in mathematics and can have dire consequences. It is easy to turn a simple problem into a fiendishly difficult one by doing that - and not only losing credit for that question but also wasting a lot of time (which may well indirectly lead to further loss of credit).

3. Handwriting

If your handwriting is not clear your tutor will have difficulty reading your work when trying to help you, and when marking your work may misread what you intended or get frustrated and lose patience and so not award the mark that the work merits. It has even been known for students to find it hard to read their own writing a few days later!

What are your particular idiosyncrasies in handwriting, which lead to misreading? Be aware and avoid them when it really matters!

Here are some possibilities for confusion (but there many others!)



- \bullet + and t
- 0 and o and O (zero and lower and upper case letter 'oh')
- 1 and I and / and I and i ('one'; letter 'ell'; 'slash' or 'solidus'; letters "I" and "i")
- 2 and z
- j and y and g
- \times and \times (times sign and letter ' x')

Clarifying what you mean by use of brackets is discussed later, but here is an example where you either must write very clearly or resort to brackets to avoid ambiguity:

What do you mean by $\sqrt{3}/2$? Is it $(\sqrt{3})/2$ or $\sqrt{(3/2)}$? You can express whichever you mean more clearly by writing it as either $\frac{\sqrt{3}}{2}$ or $\sqrt{\frac{3}{2}}$, or by using brackets.

4. Calculators

Although calculators are much better at doing calculations than students they do not always give the right answer.

One of the commonest error with calculators is **forgetting to switch between degrees and radians**. Radians are invariably used in calculus and it is sensible to keep your calculator in this mode. (It is only if x is in radians that the derivative of $\sin(x)$ is $\cos(x)$, for example.)

Another error arises when using graphics facilities. Some graphic calculators only display the right half of the graph $y=x^{1/2}$ if the general root key $(\sqrt[x]{y})$ is used but will give both halves if there is a special cube root button $(\sqrt[3]{y})$ which is used.

(The explanation lies in the fact that the general root key $(\sqrt[x]{y})$ uses logarithms during the computational process and, since the log of a negative number is not defined, the negative part is "lost".)

5. Brackets (aka parentheses)

Omitting pairs of brackets can lead to faulty algebraic manipulations and incorrect numerical computations.

Expanding $-2 \times (p-q)$ should lead to -2p+2q but if (through laziness) it is expressed as $-2 \times p-q$ then the outcome is likely to be -2p-q or maybe -2p-2q.

HELM (2015): 11

Expressing $-3(x+1)^2$ as $-3 \times x^2 + 2x + 1$ is a recipe for disaster leading to $-3x^2 + 2x + 1$ instead of $-3x^2 - 6x - 3$.

(Incidentally, a more subtle error is the belief that a **minus sign means a negative number**. This is not true if x is a negative number, of course.)

Writing fractions can be a problem. For instance, if you write "2/7y" do you mean "(2/7)y" or "2/(7y)"? To be safe you can insert brackets in such an expression or write it clearly as either $\frac{2}{7}y$ or $\frac{2}{7y}$ as appropriate.

In integration, too, problems can easily arise:

$$2\int (4x^3 + 4x - 3)dx = 2 \times x^4 + 2x^2 - 3x + \text{constant} = 2x^4 + 2x^2 - 3x + C$$
 WRONG!

It should be

$$2\int (4x^3 + 4x - 3)dx = 2(x^4 + 2x^2 - 3x) + C = 2x^4 + 4x^2 - 6x + C$$
 RIGHT!

In general, if in any doubt put in brackets. This nearly always works.

6. BODMAS to the rescue!

Order of operations

Common mathematical practice is to perform particular mathematical operations in certain orders. Such conventions reduce the number of brackets needed. For example, it is understood that "4x+3" means "(4x+3)", and never "4(x+3)" In general multiplication is performed **before** (has precedence over) addition. This priority can be reversed by inserting brackets if necessary. It is essential to use the correct order (precedence) of these operations in arithmetic and algebra.

What is -4^2 ? It is tempting to think that the expression means $(-4)^2$ which is +16 but the mathematical convention is to perform the exponentiation operation before applying the negation operation (represented by the minus sign), and so -4^2 is actually $-(4^2)$, which is -16.

These conventions are encapsulated in the BODMAS rule for deciding the order in which to do mathematical operations. (This is introduced in HELM Workbook 1.)

12



BODMAS: (Brackets, 'Of', Division, Multiplication, Addition, Subtraction):

- 1. Brackets take highest priority deal with items inside a pair of brackets first.
- 2. Of is a form of multiplication (e.g. 'half of 10' means $1/2 \times 10$) and comes next.
- 3. Division and Multiplication come next and left-to-right order is required (e.g. $4 \div 7x \times k$ is evaluated as $(4 \div 7) \times k$ and not as $4 \div (7x \times k)$).
- 4. Addition and Subtraction come last (in either order will do but left-to-right is normal).

When faced with several operations at the same level of precedence the left-to-right order is normally used, but it is not essential.

Beware of calculators

Not all calculators follow these conventions in all circumstances, and ambiguities can arise, so you should check what you get for operations such as $4 \div 7 \times 7, 2-3^2$ and 3^{2+1} . Inserting brackets will sort out these problems if you are unsure what your calculator will do, or if you want to force it to do something it won't do otherwise.

7. Equality and Identity

The equals sign (=) is often wrongly used as a shorthand symbol for "gives" or "leads to" or like phrases. For instance, when finding the third derivative of $x^3 + 2x - 3$, some students will write

$$\frac{d^3}{dx^3}(x^3 + 2x - 3) = 3x^2 + 2 = 6x = 6$$

These four expressions are not equal of course.

This practice is more annoying to the tutor than harmful to the student!

The use of = is commonplace throughout mathematics and hides the distinction between expressions which are true for particular values (e.g. 2x = 2) and those, which are ALWAYS true (e.g. 2x = x + x). The special identity symbol (\equiv) is (or rather can be) used for these: e.g. $2x \equiv x + x$. This symbol has been used sometimes in the HELM Workbooks where emphasis is important (especially in Workbook 1: Basic Algebra and in Workbook 4: Trigonometry) but we *have not done so consistently* - it just isn't the way mathematicians and engineers work! In practice it is nearly always obvious from the context, which is meant.

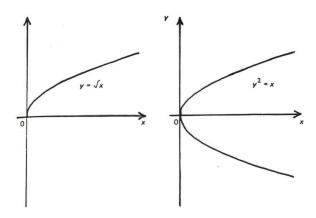
HELM (2015): 13

8. Notational problems

Square root symbol

Every positive number has two real square roots. The expression \sqrt{n} actually means "the **nonnegative** square root of n," but many think it can represent either of the square roots of n - i.e., it represents two numbers. This error is actually encouraged by the common practice of referring to \sqrt{n} as "the square root of " instead of the more carefully worded "the **positive** square root of ". In fact even that phrase isn't quite correct in all circumstances since it could be zero!

The graphs of $y = \sqrt{x}$ and $y^2 = x$ below illustrate the point:



If you want to refer to both roots then you must use $\pm \sqrt{\ }$, as in the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

What about $x^{\frac{1}{2}}$? Usually this is taken to mean \sqrt{x} but, particularly in complex number work, it can mean **any** value of the root. So $y=x^{\frac{1}{2}}$ could mean either of the graphs shown above!

Another common error is to replace $\sqrt{1-\sin^2\theta}$ by $\cos\theta$ (because $1-\sin^2\theta\equiv\cos^2\theta$). This is wrong because $\cos\theta$ can be negative whereas $\sqrt{}$ is never negative, so the result should be expressed as $|\cos\theta|$.

Trigonometric inverses

The expression $\sin^k x$ is interpreted in different ways, depending on the value of k.

$$\sin^3 x \equiv (\sin x)^3$$
 and similarly for cos, tan, sec, cosec and cot

but

 $\sin^{-1} x$ means the inverse sine function, sometimes written as $\arcsin(x)$, and similarly for \cos , \tan , \sec , \csc and \cot .



Note that $\arcsin(x) \neq (\sin x)^{-1}$ but $\csc(x) \equiv (\sin x)^{-1}$ because ...

 \sin^{-1} is the **inverse function** to \sin^{-1}

 $1/\sin$ is the **reciprocal function** of sin, which is called cosec.

9. Checking your work

Human nature seems to lead to most of us being overconfident in our ability to be accurate. In day-to-day life (and indeed in engineering) some imprecision is often acceptable (such as when driving a car, unless in a Formula One race perhaps). But this is not so in mathematics where **absolute** accuracy is demanded. It is vitally important to check your work. (Of course in a timed examination the benefit and disadvantage of checking have to be weighed against each other and will depend upon the circumstances and personal traits.) Ideally you should check by using some alternative method but whether you use the same method or a different one is less important than the act of checking itself.

When solving an algebraic equation (or differential equation), normally an easy way to check the answer is to substitute the result back into original equation, and see if it satisfies the equation. This leads us onto the next more specific situation where checking is very important.

10. Irreversible steps in solving equations

If you apply the same operations to both sides of an equation, the result must be another equation (i.e. the equality must be preserved). The new equation must have all the solutions that the original equation has. **BUT it might also have some new solutions**. This may not seem logical or even possible but unfortunately it is the case when you apply certain operations (which are not reversible).

Reversible operations

- 1. Multiplying both sides of an equation (except by zero) is reversible: e.g. "multiply both sides by 3": the set of values of x which satisfy $2x^2=11x-5$ is exactly the same as the set of values of x that satisfy $6x^2=33x-15$ [i.e x=5 and $x=\frac{1}{2}$]. (We can simply reverse the operation here by multiplying both sides by $\frac{1}{3}$.)
- 2. Cubing both sides of an equation is reversible: e.g. the set of values of x which satisfy x+1=-3 is exactly the same as the set of values of x that satisfy $(x+1)^3=-27$ [i.e. x=-3 only]. (We can simply reverse the operation here by cube rooting both sides.)
- 3. Subtraction is reversible: e.g. "subtract 8 from both sides". The set of values of x which satisfy $2x^2=8$ is exactly the same as the set of values of x that satisfy $2x^2-8=0$. [i.e. x=2 and x=-2] (We can simply reverse the operation here by adding 8 to both sides.)

HELM (2015): 15

Irreversible operations

Some operations are not reversible, and using them can introduce new solutions (called extraneous solutions) not valid for the original equation.

- 1. Square rooting is irreversible: e.g. x=-9 has only one solution, which is x=-9 of course, but after squaring both sides we get $x^2=81$, which has two solutions, x=9 and x=-9.
- 2. Multiplication of an equation in variable x by x is irreversible: this always introduces a solution x=0: e.g. $2x^2=8$ has two roots 2 and -2 but $2x^3=8x$ has three roots 2 and -2 and 0.
- 3. More generally, multiplication of an equation in variable x by x-c is irreversible: the resulting equation will have the additional new solution x=c. [The reason is that multiplying any equation by zero preserves the equality and the factor x-c is zero when x=c.]

When any steps taken involve an irreversible operation, then it is essential to check for extraneous roots at the end.

The most common irreversible operation used in solving equations is squaring.

11. Additivity of operations

Many students confuse operations which are additive and those which are not. The normal (wrong) assumption is that the operation will be additive.

An operation f is **additive** if it satisfies f(x+y) = f(x) + f(y) for all x and y. E.g. 2(x+y) = 2x + 2y.

This is **true for some operations**. Examples are:

- 1. Algebra: k(p+q) = kp + kq
- 2. Differentiation: d(u+v)/dx = du/dx + dv/dx
- 3. Integration: $\int (u+v)dx = \int u \ dx + \int v dx$
- 4. Laplace transformation: $\mathcal{L}(f+g) = \mathcal{L}(f) + \mathcal{L}(g)$
- 5. Matrix (transposition): $(A+B)^T = A^T + B^T$

It is **not true for most** operations. Examples are:

- 1. Trigonometric identities: e.g. $\sin(x+y) \neq \sin(x) + \sin(y)$
- 2. Raising to a power: e.g. $(x+y)^2 \neq x^2 + y^2$



17

- 3. Taking square root: e.g. $\sqrt{x^2+y^2} \neq \sqrt{x^2} + \sqrt{y^2}$
- 4. Exponentiation: $\exp(x+y) \neq \exp(x) + \exp(y)$
- 5. Taking logarithm: $\log(x+y) \neq \log(x) + \log(y)$
- 6. Matrices (inversion): $(A + B)^{-1} \neq A^{-1} + B^{-1}$

This is a common mistake made by first year undergraduates who have not studied mathematics for some time.

12. Commutativity of operations

Two operations f and g **commute** if you get the same result when you perform them in either order: i.e. f(g(x)) = g(f(x)). E.g. if f means "doubling" and g means "trebling" then f(g(5)) = f(15) = 30 and g(f(5)) = g(10) = 30 so f(g(5)) = g(f(5)).

This is true for some combinations of operations. Examples are:

- 1. Powers and roots of positive numbers: $(\sqrt{x})^3 = \sqrt{(x^3)}$
- 2. Multiplication by a constant and integration: $2 \int u \, dx = \int 2u \, dx$

It is **not true for most** combinations of operations. Examples are:

- 1. "Doubling" and "Adding 1" \neq "Adding 1" and "Doubling"
- 2. Powers and addition: $(x+1)^3 \neq x^3 + 1^3$
- 3. Taking cosine and squaring: $\cos(x^2) \neq \{\cos(x)\}^2$
- 4. Multiplication and differentiation: $(u \times v)' \neq u' \times v'$
- 5. Division and integration: $\int (u/v) dx \neq \int u dx / \int v dx$

13. Dimensions and scaling

Dimensional analysis is an important topic for engineers and is treated in Workbook 47. It doesn't tell you if you have the right formula or answer, but it can indicate that something must be wrong. Here are some simple examples:

1. If you're asked to find a length, and your answer is some number of square cms, then you must have made an error somewhere.

HELM (2015):

- 2. If you're asked to find an area and your answer is a negative number, then you know you've made an error somewhere UNLESS it is a calculus problem (where an area below the axis may be represented as a negative quantity).
- 3. The formula for the area, S, of a triangle with sides a,b,c must have dimensions of area so it cannot possibly be either of the following:

$$S = a \times b \times c$$
 or $S = a + b + c$

It might in theory be

$$S = (a+b+c)^2$$

which has the right dimensions for area, though that isn't actually correct of course!

There is in fact a complicated formula involving only a, b, c for S, called Heron's formula:

$$S = \sqrt{\{(a+b+c)(b+c-a)(c+a-b)(a+b-c)/16\}}.$$

You can check that this is dimensionally correct.

Unit Conversion

A related problem is converting from one unit to another. Just because 1~m=100~cm does not mean that $1~m^3=100~cm^3$. Obvious, perhaps, but an easy mistake to make when not concentrating. In fact, of course, there are three dimensions here so the scale factor is 100^3 and $1~m^3=1\,000\,000~cm^3$.

Scaling error

If the question is a real-world problem, you should ask: "Is my answer sensible?" For instance, if you are given a list of the main components used in the manufacture of a truck and are asked to estimate its unladen weight, and you come up with an answer of 1000 tonnes, then you must have made a mistake either in the calculations or in the units.

14. Some further traps

It is important to remember the following:

(a) Cancelling in fractions

Don't fall into the trap of partial cancelling.

This is correct:

$$\frac{(x-1)(x+2)}{(x+3)(x+2)} = \frac{(x-1)}{(x+3)}$$
 (provided $x \neq -2$)



but this is NOT correct:

$$\frac{(x-1)+(x+2)}{(x+3)(x+2)} = \frac{(x-1)+1}{(x+3)}$$

You only cancel once when the factors in the numerator are multiplied but you must cancel each time when the factors in the numerator are added (or subtracted).

(b) Inequalities

 $x \le 2$ and $x \ge -1$ can be combined to give $-1 \le x \ge 2$

BUT $x \ge 2$ and $x \le -1$ cannot be combined to give $2 \ge x \le -1$, which makes no sense. It is not possible to express these as a single equality (because it would imply $2 \le -1$!).

(c) Solving equations

$$(x-1)(x-2) = 0 \Rightarrow x-1 = 0 \text{ or } x-2 = 0$$
 TRUE!

BUT

$$(x-1)(x-2) = 2 \Rightarrow x-1 = 2 \text{ or } x-2 = 2$$
 FALSE!

It is only with zero right-hand side that such factorisation is valid.

(d) Differentiation

The term $\frac{dy}{dx}$ indicates differentiation of the expression y with respect to the variable x. The operation of differentiation itself can be expressed as $\frac{d}{dx}$. It is not strictly correct to separate out the dy and the dx as in $\frac{dy}{dx}=x^2\Rightarrow dt=x^2dx$ but this does work (in solving differential equations), however mathematicians don't like it!

(e) Integration

$$\int \frac{1}{x} dx = \ln(x) + c \qquad \text{NOT CORRECT!}$$

$$\int \frac{1}{x} dx = \ln|x| + c \qquad \text{CORRECT!}$$

15. Stationary Points and Points of Inflection

Most students (and some teachers!) have an imperfect understanding of the definitions of local maximum, local minimum and point of inflection. Simple graphs can be used to illustrate these features.

HELM (2015): 19

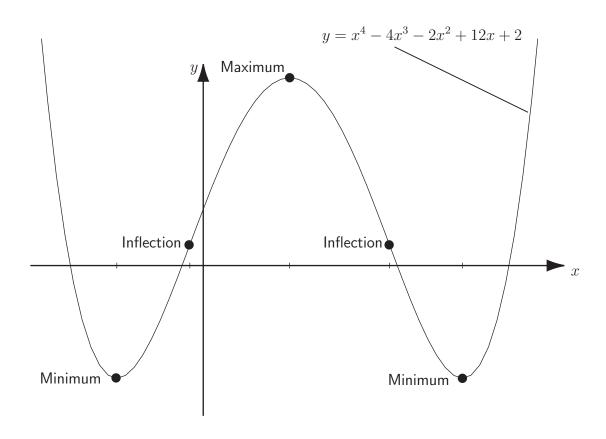
Of the following three statements only the first two are known with any certainty by most students:

Given a twice differentiable function f for which f'(a) = 0

- (1) If f''(a) > 0, then f(x) has a minimum when x = a,
- (2) If f''(a) < 0, then f(x) has a maximum when x = a,
- (3) If f''(a) = 0, then f(x) has minimum or a maximum or a point of inflection when x = a.

Many students think (3) always leads to a point of inflection but the graph of $f(x) = x^4$ clearly shows this to be untrue when x = 0.

Another misconception is that a point of inflection **requires** f'(a)=0. This is not true as can easily be seen, for example, on the sine curve. This raises another point - for any continuous function there is always a point of inflection between every local minimum and local maximum. The graph below highlights these features.



Maxima and Minima without Calculus

Students all too readily turn to the calculus when needing to find maxima and minima. There are, however, cases when alternative approaches are simpler, quicker or more informative:

20



Example 1

Find the minimum value of $f(x) \equiv x^2 + 2x + 3$.

Completing the square gives $f(x) = (x+1)^2 + 2$.

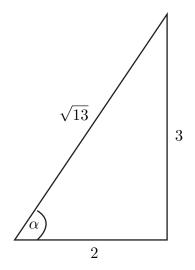
This clearly is a minimum when x=-1 and there f(x) has value 2.

Example 2

Find the maximum value of $f(x) \equiv 2\sin(x) + 3\cos(x)$.

Using the trigonometric identity $\sin(A+B) \equiv \sin A \cos B + \cos A \sin B$ and utilising the triangle in the diagram we have

$$f(x) = \sqrt{13} \left[\frac{2}{\sqrt{13}} \sin x + \frac{3}{\sqrt{13}} \cos x \right]$$
$$= \sqrt{13} [\cos \alpha \sin x + \sin \alpha \cos x]$$
$$= \sqrt{13} \sin(x + \alpha)$$



This clearly has a maximum value of $\sqrt{13}$ at $x=\frac{\pi}{2}-\alpha$ (for example), which is where $\sin(x+\alpha)=\sin\left(\frac{\pi}{2}\right)=1.$

Index of Engineering Contexts in Workbooks 1 to 48

49.4

Engineering Topic	Workbook	Page Number
Acceleration in polar coordinates	Wbk 47	67
Admittance of an electronic circuit	Wbk 3	69
Aerofoil	Wbk 26	14, 19
Aircraft	Wbk 9	13
Aircraft wings	Wbk 42	4
Aircraft wings	Wbk 45	26
Airline booking	Wbk 39	29
Alloy impurities	Wbk 41	18
Alloy spacers	Wbk 44	4, 16
Alloy stretching	Wbk 45	27
Alloy-twisting resistance	Wbk 45	26
Aluminium alloy tensile strength	Wbk 44	45
Aluminium sheet faults	Wbk 42	4
Amplifier	Wbk 10	26
Amplitude	Wbk 3	67, 74
Amplitude modulation	Wbk 4	47
Amusement rides	Wbk 34	6, 43-50
An LC circuit with sinusoidal input	Wbk 19	48
An RC circuit with single frequency input	Wbk 19	26
Angular velocity of Earth	Wbk 34	40
Anti-lock brakes	Wbk 45	11
Arrhenius' law	Wbk 6	32
Assembly machines	Wbk 44	33
Asteroid	Wbk 17	22
Atomic theory	Wbk 47	13, 14
Ball bearing diameters	Wbk 40	19
Banked tracks	Wbk 34	49
Basketball	Wbk 34	26
Battery lifetime	Wbk 41	15
Beam	Wbk 19	65, 67
Beam	Wbk 20	52
Beam deflection	Wbk 48	20
Beam deformation	Wbk 48	15
Beats	Wbk 19	64
Bending moment for a multiple structure	Wbk 48	35
Bending moment of beam	Wbk 19	65



Bicycle	Bending moment of beam	Wbk 43	18
Black body radiation			
Bolt hole diameters			
Bottle design			
Brake Wbk 4 14 Buckling of a strut Wkb 12 44 Buckling of columns Wbk 48 26 Buffer Wbk 20 39 Cable Wbk 15 21 Cable Wbk 43 7, 12 Cable breaking strength Wbk 45 31 Cable suspended Wbk 48 40 Calculator battery life Wbk 41 15 Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CCD player output Wbk 42 7 Centre of mass Wbk 27 55-65 Centre of pressure Wbk 27 15 Chain alloy Wbk 45 27 Charge Wbk 9 40 Charge on a capacitor Wbk 20 49 Chemical process Wbk 44 49 Chemical reaction Wbk 6 32 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 35 Coomunication network Wbk 36 27 Component lifetime Wbk 37 Compressive strength Wbk 38 24, 25 Compressive strength of blocks Wbk 44 43 Concrete compressive strength Wbk 34 28 Control charts Wbk 44 43 Concrent wbk 45 27 Crank mechanism Wbk 46 24-38 Corrent wbk 47 Corrent model Wbk 37 Corrent wbk 38 21 Conservation of energy Wbk 34 28 Corrent ws 45 4 12 Current associated with magnetic field Wbk 28 28			
Buckling of a strut Buckling of columns Wbk 48 Buffer Wbk 20 Buffer Wbk 20 Cable Wbk 15 Cable Wbk 43 Cable Wbk 43 Cable Wbk 45 S1 Cable wbk 45 S1 Cable wbk 48 Cable wbk 48 Cable breaking strength Wbk 45 Cable wbk 48 Calculator battery life Wbk 41 Capacitor Wbk 20 Car accessories Wbk 35 Cartons for powder Wbk 41 Castings Wbk 41 Castings Wbk 41 Catlysts Wbk 44 Calculator buttery Wbk 42 Car accessories Wbk 41 Castings Wbk 41 Castings Wbk 42 Catlysts Wbk 44 Cable Catlysts Wbk 44 Caplayer output Wbk 42 Contre of mass Wbk 27 Centre of mass Wbk 27 Chain alloy Wbk 45 Charge Wbk 9 Charge Wbk 9 Charge Wbk 9 Charge on a capacitor Wbk 20 Chemical process Wbk 44 Chemical process Wbk 44 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Circular motion Wbk 34 Scoonut shy Wbk 34 Coomunication network Wbk 1 Communication network Wbk 1 Communication network Wbk 39 Communication network Wbk 39 Component lifetime Wbk 38 Component variation Wbk 38 Component variation Wbk 38 Component variation Wbk 38 Component variation Wbk 38 Concrete compressive strength of blocks Wbk 44 Concrete compressive strength Wbk 45 Conservation of energy Wbk 34 Contrete compressive strength Wbk 46 Carank used to drive a piston Wbk 12 Current Wbk 11 Current associated with magnetic field Wbk 28			
Buckling of columns Buffer Wbk 20 39 Cable Cable Wbk 43 7, 12 Cable breaking strength Cable suspended Calculator battery life Capacitor Car accessories Wbk 41 Cartons for powder Catalysts Catlysts Centre of mass Chain alloy Charge Charge Charge Wbk 42 Charge Charge Wbk 43 Concrete compressive strength Wbk 44 Concrete compressive strength Wbk 45 Corrank wechanism Wob 46 Caraccessories Wbk 47 Wbk 49 Caraccessories Wbk 41 Wbk 42 Corrant wibh 42 Concrete of mass Wbk 47 Centre of mass Wbk 27 Charge Wbk 9 Charge Wbk 9 Charge Wbk 9 Charge Wbk 44 Component lifetime Wbk 48 Concrete compressive strength Wbk 48 Concreting of vehicle Wbk 49 Corrant webs 40 Corrant work Corrant work Concrete compressive strength Wbk 44 Corrant work Corrant work Corrant work Corrant work Corrant work Concrete compressive strength Wbk 44 Corrant wesd to drive a piston Wbk 12 Current Wbk 13 Current Wbk 14 Current associated with magnetic field Wbk 28 Ze Current Wbk 12 Current Wbk 12 Ze Current			
Buffer Wbk 20 39 Cable Wbk 15 21 Cable Wbk 43 7, 12 Cable breaking strength Wbk 45 31 Cable suspended Wbk 48 40 Calculator battery life Wbk 41 15 Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CD player output Wbk 42 7 Centre of mass Wbk 27 55-65 Centre of pressure Wbk 27 15 Chain alloy Wbk 45 27 Charge Wbk 49 Charge Wbk 40 Charge on a capacitor Wbk 40 Chemical process Wbk 44 49 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 25 Coonut shy Wbk 34 25 Communication network Wbk 15 Communication network Wbk 16 Communication network Wbk 17 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 34 25 Conservation of energy Wbk 34 28 Crank used to drive a piston Wbk 12 33 Current Wbk 12 33 Current Wbk 12 21 Current associated with magnetic field Wbk 28 28			
Cable Wbk 43 7, 12 Cable breaking strength Wbk 45 31 Cable suspended Wbk 48 40 Calculator battery life Wbk 41 15 Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CD player output Wbk 27 7 Centre of mass Wbk 27 55-65 Centre of pressure Wbk 27 15 Chain alloy Wbk 45 27 Charge Wbk 49 Chemical process Wbk 40 Chemical reaction Wbk 40 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 Coomunication network Wbk 1 52 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength Of concrete Wbk 44 Concrete compressive strength Wbk 34 28 Concreting modeled Wbk 34 Concrete compressive strength Wbk 34 Concrete compressive			
Cable Wbk 43 7, 12 Cable breaking strength Wbk 45 31 Cable suspended Wbk 48 40 Calculator battery life Wbk 41 15 Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CD player output Wbk 42 7 Centre of mass Wbk 27 55-65 Centre of pressure Wbk 9 40 Charge Wbk 9 40 Charge Wbk 9 40 Charge on a capacitor Wbk 20 49 Chemical process Wbk 44 49 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 35 Coconut shy Wbk 48 26 Communication network Wbk 15 27 Component lifetime Wbk 16 32 Component variation Wbk 17 52 Component lifetime Wbk 17 52 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 44 43 Concrete compressive strength Wbk 34 28 Control charts Wbk 46 Control charts Wbk 47 Corank used to drive a piston Wbk 12 33 Current Wbk 12 33 Current Wbk 12 33 Current Wbk 12 121 Current associated with magnetic field Wbk 28 28			
Cable breaking strength Cable suspended Wbk 48 40 Calculator battery life Wbk 41 15 Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CD player output Wbk 42 7 Centre of mass Wbk 27 55-65 Centre of pressure Wbk 45 27 Charge Wbk 40 Charge on a capacitor Wbk 40 Chemical process Wbk 44 49 Chemical reaction Wbk 6 32 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 35 Coconut shy Coomunication network Wbk 15 27 Communication network Wbk 16 32 Communication network Wbk 17 10 Circular motion Wbk 34 25 Communication network Wbk 17 27 Component lifetime Wbk 38 24, 25 Component variation Wbk 49 Compressive strength of blocks Wbk 44 Conductor coating Wbk 38 Conservation of energy Wbk 34 Conductor coating Wbk 45 Control charts Wbk 46 Crank used to drive a piston Wbk 12 33 Current Wbk 12 12 Current associated with magnetic field Wbk 28 28			
Cable suspended Calculator battery life Capacitor Wbk 41 Car accessories Wbk 35 Cartons for powder Wbk 41 Castings Wbk 41 Catalysts Wbk 44 Wbk 42 CD player output Wbk 42 Centre of mass Wbk 27 Chain alloy Wbk 45 Charge Wbk 49 Charge on a capacitor Wbk 49 Chemical process Wbk 44 Wbk 49 Circle cutting machine Wbk 47 Coonut shy Coonut shy Coonut shy Coomunication network Communication network Compressive strength of concrete Wbk 43 Concrete compressive strength Concreting of vehicle Wbk 44 Corrent wbk 43 Corrent wbk 44 Corrent of pressure Wbk 44 Corrent of pressure Wbk 45 Coomunication of wbk 66 Wbk 17 Coomunication Wbk 34 Coomunication Wbk 35 Coconut shy Wbk 48 Communication network Wbk 7 Component lifetime Wbk 38 Component variation Wbk 39 Concrete compressive strength Wbk 44 Concrete compressive strength Wbk 45 Control charts Wbk 46 Carank used to drive a piston Wbk 11 Current associated with magnetic field Wbk 28 Carrent Current associated with magnetic field Wbk 28 Carrent Current associated			·
Calculator battery life Capacitor Wbk 20 49 Car accessories Wbk 35 18 Cartons for powder Wbk 41 13 Castings Wbk 41 9 Catalysts Wbk 44 49 CD player output Wbk 27 55-65 Centre of mass Wbk 27 15 Chain alloy Wbk 45 27 Charge Wbk 9 40 Charge on a capacitor Wbk 20 49 Chemical process Wbk 44 49 Chemical reaction Wbk 6 32 Circle cutting machine Wbk 34 35 Coconut shy Wbk 34 25 Columns buckling Wbk 38 24 Communication network Wbk 7 27 Component lifetime Component variation Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 44 43 Concrete compressive strength Wbk 34 28 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 46 22 Crank used to drive a piston Wbk 12 33 Current Wbk 11 21 Current associated with magnetic field Wbk 28 28			
Capacitor Car accessories Wbk 35 Cartons for powder Wbk 41 Castings Wbk 41 Catalysts Wbk 44 Wbk 42 CD player output Wbk 27 Centre of mass Wbk 27 Centre of pressure Wbk 27 Chain alloy Wbk 45 Charge Wbk 9 Charge on a capacitor Chemical process Wbk 44 Circle cutting machine Wbk 34 Circle cutting machine Wbk 34 Coonut shy Communication network Communication network Component lifetime Wbk 38 Component variation Wbk 39 Concrete compressive strength of blocks Conductor coating Corak used to drive a piston Wbk 12 Wbk 13 Wbk 44 Wbk 14 Wbk 15 Wbk 34 Wbk 36 Wbk 38 Wbk 38 Wbk 48 Concrent of pressure Wbk 49 Wbk 40 Wbk 40 Wbk 40 Wbk 40 Wbk 40 Wbk 40 Wbk 41 Wbk 41 Wbk 42 Wbk 42 Wbk 42 Wbk 45 Wbk 45 Wbk 45 Wbk 45 Wbk 45 Wbk 46 Wbk 46 Carank used to drive a piston Wbk 11 Current associated with magnetic field Wbk 28 Wbk 28			
Car accessories Cartons for powder Castings Wbk 41 Castings Wbk 41 Catalysts Wbk 44 Wbk 42 CD player output Centre of mass Wbk 27 Centre of pressure Wbk 27 Chain alloy Wbk 45 Charge Wbk 9 Charge on a capacitor Chemical process Wbk 44 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Coroular motion Wbk 34 Coconut shy Columns buckling Communication network Communication network Component lifetime Wbk 38 Component variation Wbk 39 Compressive strength of blocks Conductor coating Cornet mechanism Cornet work Cornering of vehicle Crank used to drive a piston Wbk 12 Wbk 28 Wbk 48 Courrent Wbk 11 Current associated with magnetic field Wbk 28 Ze Wbk 41 Volume 49 Coround 49 Volume 49 Coround 49 Volume 49 Coround 49 Volume 49 Coround 49 Coround 49 Volume 49 Coround 49 Coround 49 Volume 49 Coround 49			
Cartons for powder Castings Wbk 41 Castings Wbk 41 Wbk 44 Wbk 44 CD player output Centre of mass Wbk 27 Centre of pressure Wbk 27 Chain alloy Wbk 45 Chain alloy Wbk 45 Charge on a capacitor Chemical process Wbk 44 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Corount shy Columns buckling Communication network Component lifetime Component lifetime Compressive strength of blocks Conductor coating Wbk 34 Concrete compressive strength Conservation of energy Wbk 44 Wbk 46 Carank used to drive a piston Wbk 12 Current Wbk 14 Wbk 14 Wbk 15 Wbk 36 Wbk 47 Wbk 37 Wbk 37 Wbk 38 Wbk 48 Concrete compressive strength Wbk 44 Wbk 45 Concrete compressive strength Wbk 46 Wbk 47 Concrete compressive strength Wbk 48 Concrete compressive strength Wbk 49 Concrete compressive strength Wbk 40 Wbk 41 Concrete compressive strength Wbk 41 Concrete compressive strength Wbk 42 Concrete compressive strength Wbk 46 Cank used to drive a piston Wbk 12 Wbk 12 Wbk 12 Wbk 12 Current Wbk 12 Current associated with magnetic field Wbk 28 Wbk 28	•		
Castings Catalysts Wbk 44 Wbk 44 CD player output Wbk 42 Centre of mass Wbk 27 Centre of pressure Wbk 27 Chain alloy Wbk 45 Chain alloy Wbk 45 Charge Wbk 9 Charge on a capacitor Wbk 20 Chemical process Wbk 44 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Coroular motion Wbk 34 Coonut shy Columns buckling Communication network Component lifetime Wbk 38 Component variation Compressive strength of blocks Conductor coating Wbk 34 Conservation of energy Wbk 34 Corank used to drive a piston Wbk 12 Current Wbk 13 Current Wbk 34 Courrent associated with magnetic field Wbk 28 Current Wbk 12 Correct Wbk 14 Correct cutting machine Wbk 38 Wbk 48 Component Variation Wbk 39 Wbk 49 Component Variation Wbk 49 Wbk 44 Wbk 44 Wbk 45 Concrete compressive strength Wbk 46 Wbk 46 Carank used to drive a piston Wbk 28 Wbk 48 Current Wbk 28 Wbk 28			
Catalysts CD player output Centre of mass Centre of pressure Chain alloy Charge Charge on a capacitor Chemical process Circle cutting machine Circular motion Coconut shy Columns buckling Communication network Component lifetime Component variation Compressive strength of concrete Concrete compressive strength Conductor coating Conservation of energy Wbk 34 28 Control charts Cornering of vehicle Wbk 44 Crank mechanism Wbk 46 Crank used to drive a piston Wbk 28 Current Wbk 28 Ze	-	-	
CD player output Centre of mass Wbk 27 Centre of pressure Chain alloy Charge Charge Charge on a capacitor Chemical process Circle cutting machine Circular motion Coconut shy Columns buckling Communication network Component lifetime Component variation Compressive strength of concrete Conservation of energy Control charts Coral mechanism Coral wbk 44 Coral mechanism Concrete compressive apiston Coral wbk 45 Communication of energy Coral wbk 46 Corank used to drive a piston Wbk 27 Wbk 48 Correct of mass Wbk 49 Wbk 49 Wbk 49 Wbk 49 Wbk 41 Wbk 38 Wbk 45 Wbk 46 Wbk 38 Corrent Corrent Wbk 46 Wbk 46 Corank used to drive a piston Wbk 11 Current Wbk 12 Wbk 28 Wbk 28			
Centre of mass Centre of pressure Chain alloy Charge Charge Charge on a capacitor Chemical process Circle cutting machine Circular motion Circular motion Coconut shy Communication network Component lifetime Component variation Concrete compressive strength Conductor coating Control charts Conrect control charts Corank used to drive a piston Webk 27 Webk 27 Combub 49 Chemical reaction Whok 40 Whok 40 Whok 41 Whok 41 Whok 32 Whok 34 Zoncontel in the work Component lifetime Whok 38 Whok 39 Whok 39 Whok 39 Whok 44 Whok 45 Whok 45 Whok 45 Whok 45 Whok 46 Whok 48 Concrete compressive strength Whok 48 Conductor coating Whok 38 Control charts Whok 46 Whok 46 Crank used to drive a piston Whok 11 Current Whok 12 Whok 28 Whok 28 Whok 28 Whok 28 Whok 28 Whok 31 Current Whok 11 Current associated with magnetic field Whok 28 Whok 28			
Centre of pressure Chain alloy Charge Wbk 45 Charge Wbk 9 Charge on a capacitor Chemical process Wbk 44 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Circular motion Wbk 34 Coconut shy Wbk 48 Communication network Communication network Component lifetime Wbk 38 Component variation Compressive strength of concrete Wbk 44 Conductor coating Control charts Corank used to drive a piston Wbk 12 Vwbk 12 Vwbk 13 Vwbk 38 Vwbk 39 Vwbk 39 Vwbk 39 Vwbk 39 Vwbk 40 Control charts Vwbk 40 Corank used to drive a piston Wwbk 11 Current Wwbk 12 Vwbk 28 Vwbk 28			
Chain alloy Charge Wbk 9 Charge Charge on a capacitor Wbk 20 Chemical process Wbk 44 Wbk 6 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Circular motion Wbk 34 Wbk 1 S2 Communication network Wbk 7 Component lifetime Wbk 38 Wbk 38 Wbk 39 Wbk 39 Wbk 39 Wbk 39 Wbk 45 Wbk 45 Wbk 45 Wbk 44 Wbk 44 Wbk 43 Compressive strength of concrete Wbk 44 Wbk 44 Wbk 43 Concrete compressive strength Wbk 34 Wbk 45 Concrete compressive strength Wbk 44 Wbk 44 Wbk 45 Conductor coating Wbk 38 Conductor coating Wbk 34 Wbk 45 Control charts Wbk 46 Wbk 34 Wbk 46 Canak used to drive a piston Wbk 12 Wbk 11 Current Wbk 11 Wbk 28			
Charge on a capacitor Wbk 20 49 Chemical process Wbk 44 49 Chemical reaction Wbk 6 32 Circle cutting machine Wbk 17 10 Circular motion Wbk 34 35 Coconut shy Wbk 34 25 Columns buckling Wbk 48 26 Communication network Wbk 1 52 Communication network Wbk 7 27 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 45 4, 14 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 38 21 Conservation of energy Wbk 34 28 Control charts Wbk 46 24-38 Cornering of vehicle Wbk 4 62 Crank used to drive a piston Wbk 12 33 Current Wbk 12 28 Current Subbase Subba			
Charge on a capacitor Chemical process Wbk 44 Wbk 6 Chemical reaction Wbk 6 Circle cutting machine Wbk 17 Circular motion Wbk 34 Communication network Wbk 1 Communication network Wbk 7 Wbk 7 Wbk 38 Wbk 38 Wbk 38 Wbk 39 Wbk 45 Wbk 45 Wbk 45 Wbk 45 Wbk 45 Wbk 46 Wbk 48 Concrete compressive strength Wbk 38 Wbk 48 Conductor coating Wbk 38 Wbk 48 Conductor coating Wbk 38 Wbk 46 Wbk 36 Wbk 46 Wbk 46 Wbk 46 Crank used to drive a piston Wbk 11 Wbk 11 Wbk 28 Wbk 28			
Chemical process Chemical reaction Chemical reaction Wbk 6 32 Circle cutting machine Wbk 17 Circular motion Wbk 34 35 Coconut shy Wbk 34 25 Columns buckling Wbk 48 Communication network Wbk 1 Component lifetime Wbk 38 Component variation Wbk 39 Component variation Wbk 45 Component variation Wbk 48 Component variation Wbk 49 Component variation Wbk 40 Component variation Wbk 40 Component variation Wbk 41 Component variation Wbk 43 Component variation Wbk 44 Wbk 45 Component variation Wbk 45 Wbk 45 Wbk 46 Wbk 48			49
Chemical reaction Circle cutting machine Circular motion Coconut shy Columns buckling Communication network Component lifetime Compressive strength of blocks Concrete compressive strength Conductor coating Conservation of energy Control charts Crank mechanism Circular motion Wbk 17 Wbk 34 25 Wbk 48 26 Communication network Wbk 7 27 Component lifetime Wbk 38 24, 25 Wbk 45 4, 14 Compressive strength of blocks Wbk 45 Wbk 44 43 Concrete compressive strength Wbk 34 Conservation of energy Wbk 34 Control charts Wbk 46 Crank mechanism Wbk 4 Current Wbk 11 Current associated with magnetic field Wbk 28 Ze			
Circle cutting machine Circular motion Coconut shy Wbk 34 Columns buckling Communication network Component lifetime Component variation Compressive strength of blocks Concrete compressive strength Conductor coating Conservation of energy Control charts Crank mechanism Current Circular motion Wbk 34 35 Wbk 34 25 Wbk 48 26 Wbk 47 27 Communication network Wbk 7 27 Wbk 38 24, 25 Wbk 39 17, 18-20 Wbk 39 17, 18-20 Wbk 45 4, 14 Compressive strength of concrete Wbk 44 Wbk 44 43 Concrete compressive strength Wbk 38 Conservation of energy Wbk 34 Wbk 46 24-38 Cornering of vehicle Wbk 34 Crank mechanism Wbk 4 Crank used to drive a piston Wbk 11 Current associated with magnetic field Wbk 28 Z8		Wbk 6	32
Circular motion Coconut shy Columns buckling Communication network Communication network Component lifetime Component variation Compressive strength of blocks Concrete compressive strength Conductor coating Conservation of energy Control charts Cornering of vehicle Crank mechanism Current Coconum Wbk 34 25 Wbk 48 26 Wbk 7 27 Component Wbk 38 24, 25 Wbk 39 17, 18-20 Wbk 45 4, 14 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 38 21 Conservation of energy Wbk 34 28 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 46 Crank used to drive a piston Wbk 11 Current Wbk 12 Sa Current Wbk 28 Ze		Wbk 17	10
Columns buckling Communication network Wbk 1 52 Communication network Wbk 7 27 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 45 4, 14 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 38 21 Conservation of energy Wbk 38 21 Conservation of energy Wbk 34 28 Control charts Wbk 46 24-38 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 4 62 Crank used to drive a piston Wbk 11 21 Current associated with magnetic field Wbk 28 28			35
Columns buckling Communication network Communication network Wbk 7 27 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 45 4, 14 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 38 21 Conservation of energy Wbk 38 21 Conservation of energy Wbk 34 28 Control charts Wbk 46 24-38 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 4 62 Crank used to drive a piston Wbk 11 21 Current associated with magnetic field Wbk 28 28	Coconut shy	Wbk 34	25
Communication network Communication network Wbk 7 27 Component lifetime Wbk 38 24, 25 Component variation Wbk 39 17, 18-20 Compressive strength of blocks Wbk 45 4, 14 Compressive strength of concrete Wbk 44 43 Concrete compressive strength Wbk 38 21 Conductor coating Wbk 38 21 Conservation of energy Wbk 34 28 Control charts Wbk 46 24-38 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 4 62 Crank used to drive a piston Wbk 11 21 Current associated with magnetic field Wbk 28 28		Wbk 48	26
Component lifetime Component variation Compressive strength of blocks Compressive strength of concrete Wbk 45 Concrete compressive strength Conductor coating Conservation of energy Control charts Cornering of vehicle Crank mechanism Crank used to drive a piston Current Wbk 38 24, 25 Wbk 45 4, 14 Wbk 44 43 Concrete compressive strength Wbk 44 Wbk 43 21 Conservation of energy Wbk 34 Wbk 46 24-38 Cornering of vehicle Wbk 46 Wbk 46 Crank used to drive a piston Wbk 12 Wbk 11 Current associated with magnetic field Wbk 28 Z8		Wbk 1	52
Component variation Compressive strength of blocks Wbk 45 4, 14 Compressive strength of concrete Wbk 44 Concrete compressive strength Conductor coating Wbk 38 Conservation of energy Wbk 34 Control charts Wbk 46 Cornering of vehicle Wbk 34 Crank mechanism Wbk 46 Crank used to drive a piston Wbk 11 Current associated with magnetic field Wbk 28 Wbk 28	Communication network	Wbk 7	27
Compressive strength of blocks Compressive strength of concrete Wbk 44 Concrete compressive strength Conductor coating Conservation of energy Wbk 34 Control charts Cornering of vehicle Crank mechanism Crank used to drive a piston Current Current associated with magnetic field Wbk 45 4, 14 43 Wbk 44 43 Current Wbk 44 43 Current Wbk 38 21 Wbk 34 28 Conservation of energy Wbk 46 24-38 Conservation of vehicle Wbk 34 62 Crank mechanism Wbk 46 Wbk 12 33 Current Wbk 11 Z1 Current associated with magnetic field Wbk 28 Z8	Component lifetime	Wbk 38	24, 25
Compressive strength of concrete Concrete compressive strength Conductor coating Conservation of energy Control charts Cornering of vehicle Crank mechanism Crank used to drive a piston Current Current associated with magnetic field Wbk 44 43 Wbk 44 43 Wbk 48 21 Wbk 34 28 C4-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 11 21 Current Wbk 12 28	Component variation	Wbk 39	17, 18-20
Compressive strength of concrete Concrete compressive strength Conductor coating Conservation of energy Control charts Cornering of vehicle Crank mechanism Crank used to drive a piston Current Current associated with magnetic field Wbk 44 43 Wbk 44 43 Wbk 48 21 Wbk 34 28 C4-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 46 24-38 Wbk 11 21 Current Wbk 12 28	Compressive strength of blocks	Wbk 45	4, 14
Conductor coating Conservation of energy Wbk 34 Wbk 46 Wbk 46 Wbk 46 Wbk 46 Cornering of vehicle Wbk 34 Wbk 46 Wbk 34 Wbk 46 Wbk 46 Crank mechanism Wbk 4 Crank used to drive a piston Wbk 12 Wbk 11 Current associated with magnetic field Wbk 28 Wbk 28		Wbk 44	43
Conductor coating Conservation of energy Wbk 34 Wbk 46 Wbk 46 Wbk 46 Wbk 46 Cornering of vehicle Wbk 34 Wbk 46 Wbk 34 Wbk 46 Wbk 46 Crank mechanism Wbk 4 Crank used to drive a piston Wbk 12 Wbk 11 Current associated with magnetic field Wbk 28 Wbk 28		Wbk 44	43
Conservation of energy Control charts Wbk 46 24-38 Cornering of vehicle Wbk 34 36-39, 51 Crank mechanism Wbk 4 62 Crank used to drive a piston Wbk 12 Wbk 12 Current Wbk 11 Current associated with magnetic field Wbk 28 Wbk 28		Wbk 38	21
Control charts Cornering of vehicle Crank mechanism Crank used to drive a piston Current Current associated with magnetic field Wbk 46 24-38 Wbk 34 36-39, 51 Wbk 4 62 Wbk 12 33 Wbk 11 21 Current associated with magnetic field Wbk 28 28		Wbk 34	28
Crank mechanism Crank used to drive a piston Current Current associated with magnetic field Wbk 4 62 Wbk 12 33 Wbk 11 21 Wbk 28 28		Wbk 46	24-38
Crank used to drive a piston Wbk 12 33 Current Wbk 11 21 Current associated with magnetic field Wbk 28 28	Cornering of vehicle	Wbk 34	36-39, 51
Current Wbk 11 21 Current associated with magnetic field Wbk 28 28	Crank mechanism	Wbk 4	62
Current Wbk 11 21 Current associated with magnetic field Wbk 28 28	Crank used to drive a piston	Wbk 12	33
Ŭ .		Wbk 11	21
	Current associated with magnetic field	Wbk 28	28
Current in line Wbk 29 26, 67	Current in line	Wbk 29	26, 67

Currents in a ladder network Wbk 8 30 Currents in three loops Wbk 8 30 Currents in two loops Wbk 8 16 Cutting steel quality Wbk 45 9 Dam Wbk 27 3, 15, 36 Defective components Wbk 35 48 Defects (in components and products) Wbk 37 8, 19, 20, 23, 24, 40, 42, 54-58 Deflection of a beam Wbk 48 20 Deflection of a uniformly loaded beam Wbk 49 67 Deflection of a uniformly loaded beam Wbk 40 52 Demodulation Wbk 4 40 Detecting a train on a track Wbk 30 62 Diffraction Wbk 4 6 Diffraction Wbk 47 2-23 Diode Wbk 31 20 Divergence of a magnetic field Wbk 28 43 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Wbk 13 19 Electric circuit Wbk 13 19	Current in loop	Wbk 29	27
Currents in three loops Wbk 8 30 Currents in two loops Wbk 45 9 Dam Wbk 27 3, 15, 36 Defective components Wbk 35 48 Defects (in components and products) Wbk 37 8, 19, 20, 23, 24, 40, 42, 54-58 Deflection of a beam Wbk 48 20 Deflection of a uniformly loaded beam Wbk 19 67 Deflection of a uniformly loaded beam Wbk 20 52 Demodulation Wbk 4 40 Detecting a train on a track Wbk 30 62 Diffraction Wbk 4 6 Diffusion equation Wbk 25 8, 14 Dimensional analysis Wbk 47 2-23 Diode Wbk 31 20 Divergence of a magnetic field Wbk 28 43 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Wbk 48 8 Electric circuit Wbk 13 19 Electric circuit Wbk 29 46	<u> </u>		
Currents in two loops Cutting steel quality Dam Wbk 27 Nbk 27 Nbk 35 Defective components Wbk 35 Defects (in components and products) Deflection of a beam Wbk 48 Deflection of a uniformly loaded beam Wbk 48 Deflection of a uniformly loaded beam Wbk 49 Demodulation Wbk 40 Detecting a train on a track Wbk 30 Deffection equation Wbk 46 Diffusion equation Wbk 47 Diwergence of a magnetic field Wbk 31 Drag Wbk 34 Drag Wbk 34 Drag Wbk 34 Drag Wbk 47 Dynamometer Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 20 Electric current Wbk 20 Sa Sa Sa Sa Sa Sa Sa Sa Sa S		_	
Cutting steel quality Dam Wbk 27 Dam Wbk 27 Defective components Wbk 35 Defective components Wbk 35 Defects (in components and products) Wbk 37 Deflection of a beam Wbk 48 Deflection of a uniformly loaded beam Wbk 19 Deflection of a uniformly loaded beam Wbk 49 Deflection of a uniformly loaded beam Wbk 40 Detecting a train on a track Wbk 30 Deffection of wbk 4 Detecting a train on a track Wbk 30 Diffraction Wbk 4 Diffraction Wbk 4 Diffusion equation Wbk 25 Diode Wbk 31 Diode Wbk 31 Diode Wbk 31 Diode Wbk 34 Drag Wbk 47 Dynamometer Wbk 18 Elastic behaviour Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 29 Electric current Wbk 38 Electric current Wbk 39 Electric current Wbk 30 Electric current Wbk 31 Electric current Wbk 32 Electric field Wbk 33 Electric field Wbk 31 Electric field Wbk 32 Electric field Wbk 33 Electric field Wbk 33 Electric field Wbk 33 Electric field Wbk 31 Electric field Wbk 33 Electric field Wbk 31 Electric field Wbk 33 Electric field Wbk 33 Electric field Wbk 31 Electric field Wbk 33 Electric field Wbk 33 Electric field Wbk 34 Electric field Wbk 35 Electric field Wbk 36 Electric field Wbk 37 Electric field Wbk 37 Electric field Wbk 38 Electric field Wbk 39 Electric field Wbk 39 Electric field Wbk 30 Electric field Wbk 31 Electric field Wbk 31 Electric field Wbk 31 Electric field Wbk 32 Electric field Wbk 33 Electric field Wbk 34 Ele	<u> </u>		
Dam			
Defective components		-	
Defects (in components and products) Deflection of a beam Deflection of a uniformly loaded beam Demodulation Demodulation Wbk 4 Detecting a train on a track Wbk 30 Detecting a train on a track Wbk 30 Diffraction Wbk 4 Diffusion equation Wbk 25 Diffusion equation Wbk 47 Dimensional analysis Wbk 47 Divergence of a magnetic field Wbk 28 Drag Wbk 31 Drag Wbk 47 Dynamometer Wbk 14 Diffusion Wbk 48 Elastic behaviour Earth horizon Wbk 48 Elastic behaviour Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 13 Electric circuit Wbk 13 Electric current Wbk 20 Electric current Wbk 35 Electric current Wbk 38 Electric current Wbk 38 Electric current Wbk 38 Electric field Wbk 41 Electric field Wbk 42 Electric field Wbk 43 Electric field Wbk 44 Electric field Wbk 45 Electric field Wbk 46 Electric field Wbk 47 Electric field Wbk 48 Electric field Wbk 49 Electric field Wbk 49 Electric field Wbk 40 Electric field Wbk 40 Electric field Wbk 41 Electric field Wbk 43 Electric field Wbk 44 Electric field Wbk 45 Electric field Wbk 46 Electric meters Wbk 47 Electric motor Wbk 48 Electric motor Wbk 49 Electric motor Wbk 49 Electric wire Electric wire Electric wire Electromagnetic power Wbk 41 Electromagnetic power Wbk 45 Electromotive force Wbk 47 Electromotive force			
Deflection of a beam			_
Deflection of a beam Deflection of a uniformly loaded beam Deflection of a uniformly loaded beam Deflection of a uniformly loaded beam Wbk 20 Demodulation Wbk 4 Detecting a train on a track Diffraction Wbk 4 Diffraction Wbk 4 Diffusion equation Wbk 25 Diode Wbk 31 Diode Wbk 31 Diode Wbk 31 Drag Wbk 47 Drag Wbk 48 Drag Wbk 48 Drag Wbk 47 Drag Wbk 48 Drag Wbk 48 Drag Wbk 48 Drag Wbk 48 Drag Wbk 49 Drag Wbk 40 Drag Wbk 40 Drag Wbk 41 Drag Wbk 41 Drag Wbk 41 Drag Wbk 42 Drag Wbk 43 Drag Wbk 43 Drag Wbk 44 Drag Drag Wbk 45 Drag Wbk 47 Drag Wbk 48 Drag Drag Wbk 48 Drag Drag Wbk 40 Drag Drag Wbk 41 Drag Drag Wbk 41 Drag Drag Wbk 41 Drag Drag Wbk 41 Drag Drag Drag Wbk 41 Drag Drag Drag Drag Drag Wbk 41 Drag Drag Drag Drag Drag Drag Drag Drag	Defects (iii components and products)	VVDK 31	
Deflection of a uniformly loaded beam Deflection of a uniformly loaded beam Deflection of a uniformly loaded beam Demodulation Wbk 4 Wbk 30 Detecting a train on a track Wbk 30 Diffraction Wbk 4 Diffusion equation Wbk 25 Diode Wbk 31 Diode Wbk 31 Diode Wbk 31 Diode Wbk 34 Divergence of a magnetic field Wbk 28 Drag Wbk 47 Drag Wbk 48 Drag Wbk 47 Drag Wbk 14 Divergence of a magnetic field Wbk 18 Drag Wbk 14 Drag Wbk 15 Drag Wbk 14 Drag Wbk 15 Drag Wbk 16 Drag Wbk 17 Drag Wbk 18 Drag Drag Drag Wbk 18 Drag Drag Drag Wbk 18 Drag Drag Drag Drag Drag Drag Drag Drag	Deflection of a heam	\/\bl. 49	
Deflection of a uniformy loaded beam Wbk 20 52 Demodulation Wbk 4 40 Detecting a train on a track Wbk 30 62 Diffraction Wbk 4 6 Diffruction Wbk 4 6 Diffusion equation Wbk 25 8, 14 Dimensional analysis Wbk 47 2-23 Diode Wbk 31 20 Divergence of a magnetic field Wbk 28 43 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Wbk 14 16 Earth horizon Wbk 13 19 Electric circuit Wbk 13 19 Electric circuit Wbk 18 38 Electric circuit Wbk 18 38 Electric circuit Wbk 20 36. 44. 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 25 Electric field Wbk 9 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 28 50 Electric wire Wbk 33 10 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electromotive force Wbk 11 21 Electromotive force Wbk 11 21		-	-
Demodulation Detecting a train on a track Diffraction Diffraction Diffusion equation Diffusion equation Dimensional analysis Diode Divergence of a magnetic field Drag Drag Dynamometer Earth horizon Electric circuit Electric circuit Electric current Ubk 29 Electric current Ubk 35 Electric current Ubk 36 Electric field Wbk 37 Electric field Wbk 38 Drag Dynamometer Wbk 10 Electric circuit Ubk 11 Electric circuit Ubk 12 Electric current Ubk 29 Electric current Ubk 35 Electric current Ubk 38 Electric current Ubk 38 Electric field Ubk 41 Electric field Ubk 43 Electric meters Ubk 43 Electric meters Ubk 43 Electric motor Ubk 29 Electric potential Ubk 28 Electric potential Ubk 28 Electric wire Ubk 31 Ubk 41 Electromagnetic power Ubk 6 Electromotive force Ubk 47 Electromotive force Ubk 47			
Detecting a train on a track Diffraction Diffusion equation Diffusion equation Dimensional analysis Diode Divergence of a magnetic field Drag Drag Wbk 34 Drag Drag Wbk 47 Drag Drag Wbk 47 Drag Wbk 48 Earth horizon Earth horizon Wbk 13 Drag Wbk 14 Earth horizon Wbk 13 Electric circuit Wbk 12 Electric circuit Wbk 12 Electric circuit Wbk 20 Electric circuit Wbk 29 Helectric current Wbk 35 Electric current Wbk 35 Electric current Wbk 38 Drag Electric current to screen Wbk 41 Electric fan Electric field Wbk 9 Electric field Wbk 11 Electric field Wbk 13 I1 Electric field Wbk 13 I1 Electric field Wbk 13 I1 Electric field Wbk 29 Drag Wbk 39 Electric field Wbk 30 Electric field Wbk 30 Electric field Wbk 30 Electric field Wbk 30 Electric field Wbk 31 Electric field Wbk 31 Electric field Wbk 33 Drag Electric meters Wbk 39 Electric motor Wbk 29 Transported Wbk 29 Transported Wbk 30 Electric motor Wbk 30 Electric motor Wbk 30 Electric motor Wbk 30 Electric motor Wbk 41 Electric motor Wbk 41 Electric motor Wbk 45 Electric motor Wbk 46 Electric motor Wbk 47 Electric motor Wbk			
Diffraction Diffusion equation Diffusion equation Wbk 25 8, 14 Dimensional analysis Wbk 47 2-23 Diode Wbk 31 20 Divergence of a magnetic field Wbk 28 43 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Earth horizon Earth horizon Wbk 13 19 Electric circuit Wbk 12 26 Electric circuit Wbk 18 38 Electric circuit Wbk 20 36. 44. 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric field Electric field Wbk 9 39-44 Electric field Wbk 13 11 Electric field Wbk 13 11 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric owneres Wbk 41 16 Electric owneres Wbk 33 10 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electromotive force Wbk 11 21 Electromotive force Wbk 47 9		-	
Diffusion equation Dimensional analysis Diode Divergence of a magnetic field Drag Drag Wbk 34 Drag Wbk 47 Drag Wbk 48 Elastic behaviour Wbk 13 Electric circuit Wbk 12 Electric circuit Wbk 18 Electric circuit Wbk 20 Electric circuit Wbk 29 Electric current Wbk 35 Electric current Wbk 35 Electric current Wbk 38 Electric current Wbk 38 Electric current Wbk 38 Electric fan Wbk 38 Electric field Wbk 41 Electric field Wbk 41 Electric field Wbk 41 Electric field Wbk 41 Electric field Wbk 43 Electric field Wbk 43 Electric field Wbk 41 Electric field Wbk 43 Electric field Wbk 44 Electric field Wbk 45 Electric meters Wbk 49 Electric motor Wbk 29 Electric potential Wbk 28 Electric potential Wbk 28 Electric wire Wbk 33 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 11 Electromotive force Wbk 47 Electron			
Dimensional analysis Diode Divergence of a magnetic field Drag Drag Dynamometer Wbk 47 Earth horizon Elastic behaviour Electric circuit Electric circuit Electric circuit Electric circuit Electric current Electric current Wbk 38 Electric current Wbk 39 Electric current Wbk 38 Electric current Wbk 38 Electric current Wbk 38 Electric field Electric field Electric field Electric field Electric motor Wbk 29 Electric meters Wbk 39 Electric motor Wbk 39 Electric motor Wbk 39 Electric motor Wbk 38 Electric motor Wbk 39 Electric motor Wbk 39 Electric motor Wbk 39 Electric motor Wbk 38 Electric motor Wbk 39 Electric motor Wbk 39 Electric motor Wbk 39 Electric motor Wbk 38 Electric motor Wbk 38 Electric motor Wbk 41 Electric potential Wbk 28 Electric wire Wbk 33 10 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 17 Electromotive force Wbk 47 Wbk 47		_	
Diode Divergence of a magnetic field Drag Drag Wbk 34 Drag Wbk 47 Drag Wbk 48 Earth horizon Wbk 13 Earth horizon Wbk 13 Electric circuit Wbk 12 Electric circuit Wbk 18 Electric circuit Wbk 20 Blectric circuit Wbk 29 Blectric current Wbk 35 Blectric current Wbk 38 Electric current Wbk 38 Electric current Wbk 38 Electric fan Wbk 38 Electric field Wbk 41 Electric field Wbk 9 Blectric field Wbk 13 Electric field Wbk 13 Electric field Wbk 13 Electric field Wbk 29 Electric field Wbk 29 Electric field Wbk 29 Electric meters Wbk 39 Electric meters Wbk 39 Electric motor Wbk 29 Electric potential Wbk 28 Electric potential Wbk 28 Electric wire Wbk 33 Electric wire Wbk 33 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 47 Electromotive force Wbk 47			·
Divergence of a magnetic field Drag Wbk 34 56 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Elastic behaviour Electric circuit Wbk 12 26 Electric circuit Wbk 18 38 Electric circuit Wbk 20 36. 44. 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric current wbk 38 20 Electric feld Electric field Wbk 19 39-44 Electric field Wbk 10 16 Electric field Wbk 10 24, 28, 35 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric overent Wbk 38 10 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electromotive force Wbk 11 21 Electromotive force Wbk 47 9	_		
Drag Wbk 34 56 Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Wbk 13 19 Electric circuit Wbk 12 26 Electric circuit Wbk 18 38 Electric circuit Wbk 20 36, 44, 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric fan Wbk 38 25 Electric fan Wbk 39 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 14 16 Electromagnetic power Wbk 6 50 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21			
Drag Wbk 47 15, 23 Dynamometer Wbk 14 16 Earth horizon Wbk 13 19 Electric circuit Wbk 12 26 Electric circuit Wbk 20 36, 44, 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric fan Wbk 38 25 Electric fan Wbk 39 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 28 50 Electric wire Wbk 33 10 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electromotive force Wbk 17 9			
Dynamometer Wbk 14 16 Earth horizon Elastic behaviour Electric circuit Electric circuit Electric circuit Electric current Wbk 20 36. 44. 49 Electric current Wbk 35 33, 39, 40 Electric current Wbk 38 20 Electric current Wbk 38 20 Electric fan Electric fan Electric field Wbk 9 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Electric wire Wbk 38 10 Electric wire Wbk 38 10 Electrodynamic meters Wbk 6 50 Electromotive force Wbk 47 9			
Earth horizon Elastic behaviour Electric circuit Electric circuit Electric circuit Electric circuit Electric current Electric fan Electric fan Electric field Electric meters Wbk 39 Electric meters Wbk 39 Electric motor Wbk 29 Electric potential Electric wire Wbk 33 Electric wire Wbk 33 Electric wire Wbk 41 Electrodynamic meters Wbk 6 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 47 Electromotive force Wbk 47			
Elastic behaviour Electric circuit Electric circuit Electric circuit Electric circuit Electric circuit Electric circuit Electric current Electric fan Electric field Electric meters Electric motor Electric motor Electric potential Electric wire Wbk 28 Electric wire Wbk 33 Electric wire Wbk 34 Electrodynamic meters Wbk 45 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 17 Electromotive force Electromotive force Electromotive force Electromotive force Wbk 47 Electromotive force	Dynamometer	Wbk 14	16
Elastic behaviour Electric circuit Electric circuit Electric circuit Electric circuit Electric circuit Electric circuit Electric current Electric fan Electric fan Electric field Electric meters Electric motor Electric motor Electric potential Electric wire Wbk 28 Electric wire Wbk 33 Electric wire Wbk 34 Electrodynamic meters Wbk 45 Electromagnetic power Wbk 6 Electromotive force Wbk 11 Electromotive force Wbk 17 Electromotive force Electromotive force Wbk 47		\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	
Electric circuit Electric circuit Electric circuit Electric circuit Electric circuit Electric current Electric fan Electric fan Electric field Electric meters Electric motor Electric motor Electric potential Electric wire Electrodynamic meters Wbk 14 Electromagnetic power Electromotive force Electron Wbk 47 Electron Wbk 47 Electron		-	_
Electric circuit Electric circuit Electric circuit Electric current to screen Electric fan Electric field Electric meters Electric meters Electric motor Electric potential Electric wire Electrodynamic meters Wbk 14 Electromagnetic power Electromotive force Wbk 47 Electromagnetic power Electron Wbk 47 Electromagnetic power Electron Wbk 47			
Electric circuit Electric current Electric current to screen Electric fan Electric field Electric meters Wbk 39 Electric meters Wbk 39 Electric motor Electric potential Electric wire Wbk 33 Electrodynamic meters Wbk 41 Electromagnetic power Wbk 6 Electromotive force Wbk 47 Electron Wbk 47			
Electric current Electric current Electric current Wbk 35 Wbk 38 Wbk 38 Electric current to screen Electric fan Electric fan Electric field Electric field Electric field Electric field Wbk 11 Electric field Wbk 13 Electric field Wbk 13 Electric field Wbk 13 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 Electric motor Wbk 29 Electric potential Electric potential Wbk 28 Electric wire Wbk 33 Electric wire Wbk 33 Electrodynamic meters Wbk 41 Electromagnetic power Wbk 6 Electromotive force Wbk 47 Electron Wbk 47			
Electric current Electric current Wbk 38 20 Electric current to screen Electric fan Electric field Electric meters Electric meters Electric motor Electric potential Electric wire Electric wire Electrodynamic meters Electromagnetic power Electromotive force Wbk 37 9			
Electric current to screen Wbk 41 24, 28, 35 Electric fan Wbk 38 25 Electric field Wbk 9 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 47 9			
Electric current to screen Electric fan Wbk 38 Electric field Wbk 9 39-44 Electric field Wbk 11 Electric field Wbk 13 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 29 Electric motor Wbk 29 Electric potential Wbk 28 Electric wire Wbk 33 Electric wire Wbk 33 Electric wire Wbk 34 Electrodynamic meters Wbk 45 Electromagnetic power Wbk 6 Electromotive force Wbk 47 Electron Wbk 47			
Electric fan Wbk 38 25 Electric field Wbk 9 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 3 10 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9			
Electric field Wbk 9 39-44 Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9			
Electric field Wbk 11 16 Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9			
Electric field Wbk 13 11 Electric field Wbk 29 19, 63, 67, 68 Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9			
Electric field Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Electromotive force Wbk 11 21 Electron Wbk 47 9			
Electric meters Wbk 39 28 Electric motor Wbk 29 27 Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9			11
Electric motor Electric potential Wbk 29 27 Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9	Electric field	Wbk 29	19, 63, 67, 68
Electric potential Wbk 28 50 Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9	Electric meters	Wbk 39	28
Electric wire Wbk 33 10 Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9	Electric motor	Wbk 29	27
Electrodynamic meters Wbk 14 16 Electromagnetic power Wbk 6 50 Electromotive force Wbk 11 21 Electron Wbk 47 9	Electric potential	Wbk 28	50
Electromagnetic powerWbk 650Electromotive forceWbk 1121ElectronWbk 479	Electric wire	Wbk 33	10
Electromotive force Wbk 11 21 Electron Wbk 47 9	Electrodynamic meters	Wbk 14	16
Electron Wbk 47 9		Wbk 6	50
	Electromotive force	Wbk 11	21
Electronic circuits Wbk 3 69	Electron	Wbk 47	9
	Electronic circuits	Wbk 3	69



Electronic component failure Wbk 42 19	
Electronic component lifetime Wbk 46 6	
Electronic filters Wbk 12 2, 60	1
Electronic monitoring components Wbk 42 5, 6	
Electrostatic charge Wbk 13 11	
Electrostatic potential Wbk 11 16	
Electrostatics Wbk 9 39-44	1
Electrostatics Wbk 47 13	т
Energy Wbk 14 13	
Energy Wbk 34 10, 2	ΙQ
Energy Wbk 47 18	.0
9 1	
'	
Exponential decay of sound intensity Wbk 6 46	
Extension of spring Wbk 43 21	
Facility of a small of the same of the sam	
Feedback applied to an amplifier Wbk 10 26	
Feedback convolution Wbk 21 75	
Field due to point charges Wbk 9 40	
Field strength around a charged line Wbk 29 67	
Field strength on a cylinder Wbk 29 68	
Flight overbooking Wbk 39 29	_
Fluid flow Wbk 26 36-3	
	6, 91
Fluid power transmission Wbk 12 31	
Fluid theory Wbk 47 14, 2	:0
Force on a loop from an electric field Wbk 29 27	
Fraunhofer diffraction Wbk 47 56, 6	0
Fuel injection system efficiency Wbk 45 18	
Fuel injection systems Wbk 44 10	
Fun ride - rollercoaster Wbk 34 44	
Fun ride - 'Rotor' Wbk 34 46	
Fun ride - 'Yankee Flyer' Wbk 34 47	
Gain Wbk 10 26	
Gauss' law Wbk 29 63, 6	5
Harmonic oscillator Wbk 23 69	
Heat conduction Wbk 48 76	
Heat conduction equation Wbk 25 8, 14	
Heat conduction equation Wbk 32 48	
Heat conduction through a furnace wall Wbk 25 32	
Heat flow in an insulated metal plate Wbk 1 85	
Height of building Wbk 18 34	
Helmholtz's equation Wbk 25 18	

High frequency line equation Wbk Hooke's law Wbk Wbk		21
	. 47	
11 . 1		6
Horizon distance Wbk	4	8
Hydraulic brakes Wbk	: 12	31
Hypertension and noise Wbk	43	8
Ideal gas equation Wbk	47	18
Ideal gas law Wbk	18	13, 18
Ideal gas law and Redlich-Kwong equation Wbk	18	18
Impedance Wbk	12	60-63
Instant coffee production Wbk	46	30, 32, 35
Insulating blocks Wbk	45	4, 14, 29
Interference field Wbk	47	51
Interference fringes Wbk	47	64
Interference fringes Wbk	: 4	31
Inverse square law decay of electromagnetic power Wbk	6	50
Joukowski transformation Wbk	26	19
Kepler's laws Wbk	47	12
Kinetic energy Wbk	: 1	79
Kinetic energy Wbk	6	32
Kinetic energy Wbk	34	10, 28
Kirchhoff's law Wbk	3	10
Kirchhoff's law Wbk	8	28-30
Kirchhoff's law Wbk	20	49
Ladder network Wbk		60
Laplace's equation Wbk		7, 17, 25, 36
Laplace's equation Wbk	26	11
Laplace's equation Wbk	33	19, 27, 30, 34
Lifetime Wbk	38	11, 13, 24, 25
Lift Wbk	47	15
Light bulb lifetime Wbk	46	5
Light bulbs Wbk	38	11
Light ray propagation Wbk	47	53
Light rays Wbk	12	29
Light rays Wbk		16
Light waves Wbk		31
Light waves Wbk		48
Light waves Wbk		13
Lightning strike Wbk		46
Lorentz force Wbk	29	27



Mach number	Wbk 47	16
Magnetic field	Wbk 11	21
Magnetic field	Wbk 28	28, 43, 45
Magnetic field from a current line	Wbk 29	29
Magnetic flux	Wbk 13	51
Magnetic flux	Wbk 29	43
Magnets	Wbk 39	28
Manufacturing components	Wbk 35	48
Masses on spring	Wbk 20	47
Maximum height of projectile	Wbk 34	12
Maximum range of projectile	Wbk 34	14
Measuring the height of a building	Wbk 18	34
Metal bar temperature	Wbk 32	53-57, 60-64
Microphones	Wbk 48	10
Mixture - pressure in	Wbk 31	79-81
Modelling vibrating systems	Wbk 23	68
Models - beetles	Wbk 5	18
Models - carton	Wbk 5	33
Models - falling rock	Wbk 5	6-10, 26-30
Models - ferry	Wbk 5	18
Models - profit	Wbk 5	18, 30
Models - rain	Wbk 5	12
Models - rain level	Wbk 5	15
Models - road level	Wbk 5	14
Models - rocket	Wbk 5	10
Models - satellite	Wbk 5	10
Models - snowfall	Wbk 5	17
Models - sound	Wbk 5	46
Models - supply and demand	Wbk 5	21
Models - tide level	Wbk 5	39-44
Modulation	Wbk 4	40
Network	Wbk 1	52
Network	Wbk 7	4, 25-28
Newton's law of cooling	Wbk 32	3
Newton's laws of motion	Wbk 47	13
Newton's second law	Wbk 9	13
Newton's second law	Wbk 15	3
Newton's second law	Wbk 28	6
Newton's second law	Wbk 34	60
Noise	Wbk 43	8
Noise barriers	Wbk 4	6
Noise reduction by sound barriers	Wbk 4	6
	1	1

Ohm's law Optical interference fringes due to glass plate Orbit Ovbk 47 Output signal Paint weathering Parabolic mirror Parachute Parachute Parachute Parachute Parachute Parallel design of components Pendulum Pendulum Pipe Pipe Wbk 47 Pipe Pipe Wbk 47 Piston ring diameter Planetary motion Plastic bottle design Poiston's equation Poisson's equation Poisson's equation Pressure Pressure Pressure Pressure Pressure Pressure Pressure Production line data Wbk 48 31 Vwbk 47 20 Wbk 47 20 Wbk 47 7, 10-11 Vwbk 48 50, 51 Vwbk 39 17 Planetary motion Wbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 48 Vwbk 47 Vwbk 48 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 48 Vwbk 47 Vwbk 46 Vwbk 47 Vwbk 48 Vwbk 46 Vwbk 46 Vwbk 46 Vwbk 46 Vwbk 46 Vwbk 46 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 48 Vwbk 48 Vwbk 47 Vwbk 47 Vwbk 48 Vwbk 48 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk 47 Vwbk
Orbit
Orbit
Output signal Paint weathering Parabolic mirror Wbk 44 29 Parachute Parachute Wbk 6 48 Parachute Parachute Wbk 34 58 Parallel design of components Wbk 46 7-9 Pareto charts Pendulum Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 34 7 Point - scratch resistance Wbk 35 20 Poisson's equation Wbk 36 20 Poisson's equation Wbk 37 20 Pressure Wbk 38 20 Pressure Wbk 39 4 Pressure Wbk 31 52 Wbk 35 20 Point - shock resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 37 3 19, 28, 31 Population dynamic models Wbk 37 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas
Output signal Paint weathering Parabolic mirror Wbk 44 29 Parachute Parachute Wbk 6 48 Parachute Parachute Wbk 34 58 Parallel design of components Wbk 46 7-9 Pareto charts Pendulum Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 34 7 Point - scratch resistance Wbk 35 20 Poisson's equation Wbk 36 20 Poisson's equation Wbk 37 20 Pressure Wbk 38 20 Pressure Wbk 39 4 Pressure Wbk 31 52 Wbk 35 20 Point - shock resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 37 3 19, 28, 31 Population dynamic models Wbk 37 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas
Paint weathering Parabolic mirror Wbk 47 27, 28, 29 Parachute Parachute Wbk 6 48 Parachute Wbk 34 58 Parallel design of components Wbk 46 7-9 Pareto charts Wbk 46 35 Pendulum Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 13 79 Pressure of gas
Parabolic mirror Parachute Wbk 34 58 Pendulum Wbk 46 7-9 Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 25 18 Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas
Parabolic mirror Parachute Parachute Parachute Parachute Parallel design of components Wbk 46 Pareto charts Pendulum Pendulum Pipe Wbk 47 Pipe Pipe Wbk 47 Piston ring diameter Planetary motion Plastic bottle design Plastic tube tensile strength Point - scratch resistance Poisson's equation Poisson's equation Possure Pressure Pressure Pressure Pressure Wbk 31 Powk 47 Powk 48 Powk 47 Powk 47 Powk 47 Powk 47 Powk 47 Powk 48 Powk 47 Powk 47 Powk 47 Powk 48 Powk 47 Powk 47 Powk 48 Powk 47 Powk 49 Powk 49 Powk 49 Powk 47 Powk 48 Powk 47 Powk 48 Powk 48 Powk 48 Powk 47 Powk 48 Powk 48 Powk 48 Powk 47 Powk 48 Powk 49 P
Parachute Parallel design of components Wbk 34 58 Parellel design of components Wbk 46 7-9 Pareto charts Wbk 46 35 Pendulum Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 25 18 Poisson's equation Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Parallel design of components Pareto charts Wbk 46 35 Pendulum Wbk 47 7, 10-11 Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Piston ring diameter Wbk 39 17 Planetary motion Plastic bottle design Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Point - shock resistance Wbk 35 20 Poisson's equation Poisson's equation Wbk 32 8-11 Pressure Wbk 35 79 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 31 79 Wbk 32 8-11 Pressure of gas
Pareto charts Pendulum Wbk 47 Pendulum Wbk 48 Fo, 51 Pipe Wbk 47 Pipe Wbk 47 Pipe Wbk 39 Piston ring diameter Wbk 39 Plastic bottle design Wbk 31 Point - scratch resistance Wbk 35 Poisson's equation Wbk 36 Poisson's equation Wbk 37 Poulation dynamic models Pressure Wbk 37 Wbk 38 Wbk 39 Wbk 31 Wbk 31 Wbk 31 Wbk 34 Wbk 35 Wbk 35 Wbk 35 Wbk 35 Wbk 35 Wbk 36 Wbk 36 Wbk 37 Wb
Pendulum Pendulum Wbk 48 50, 51 Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Plastic bottle design Wbk 41 12 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Poisson's equation Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Pressure Wbk 27 3, 15, 36 Pressure Wbk 31 79 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas
Pendulum Pipe Wbk 47 20 Pipe mass Wbk 3 27 Piston ring diameter Planetary motion Wbk 47 12 Plastic bottle design Plastic tube tensile strength Wbk 34 52 Point - scratch resistance Point - shock resistance Wbk 35 20 Poisson's equation Wbk 35 20 Poisson's equation Wbk 36 20 Poisson's equation Wbk 37 20 Poisson's equation Wbk 38 20 Poisson's equation Wbk 39 4 Pressure Wbk 30 8-11 Pressure Wbk 30 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pipe mass Wbk 3 27 Piston ring diameter Wbk 39 17 Planetary motion Wbk 47 12 Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 25 18 Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pipe mass Piston ring diameter Wbk 39 Planetary motion Wbk 47 Planetary motion Wbk 31 Plastic bottle design Wbk 31 Plastic tube tensile strength Wbk 44 Point - scratch resistance Wbk 35 Poisson's equation Wbk 35 Poisson's equation Wbk 33 Population dynamic models Wbk 32 Pressure Wbk 34 Pressure Wbk 37 Wbk 38 Wbk 39 Wbk 31 Wbk 31 Wbk 32 Wbk 32 Wbk 32 Wbk 32 Wbk 32 Wbk 32 Wbk 34 Wbk 37
Piston ring diameter Planetary motion Plastic bottle design Plastic tube tensile strength Point - scratch resistance Poisson's equation Poisson's equation Population dynamic models Pressure Pressure Pressure Piston ring diameter Wbk 39 Wbk 47 12 Wbk 31 52 Wbk 44 47 Point - scratch resistance Wbk 35 20 Poisson's equation Wbk 25 Wbk 33 Population dynamic models Wbk 32 Pressure Wbk 9 Wbk 27 A Pressure Wbk 47 Pressure Wbk 47 Wbk 47 Pressure in an ideal multicomponent mixture Wbk 31 Pressure of gas Wbk 18 Wbk 18
Planetary motion Wbk 47 12 Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 25 18 Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Planetary motion Plastic bottle design Wbk 31 52 Plastic tube tensile strength Wbk 44 47 Point - scratch resistance Wbk 35 20 Point - shock resistance Wbk 35 20 Poisson's equation Wbk 25 18 Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Plastic tube tensile strength Point - scratch resistance Point - shock resistance Poisson's equation Poisson's equation Population dynamic models Pressure P
Plastic tube tensile strength Point - scratch resistance Point - shock resistance Poisson's equation Poisson's equation Population dynamic models Pressure P
Point - scratch resistance Point - shock resistance Poisson's equation Poisson's equation Population dynamic models Pressure Wbk 32 Wbk 32 8-11 Pressure Wbk 9 Pressure Wbk 27 Wbk 27 Wbk 27 Wbk 47 Pressure Wbk 47 Pressure in an ideal multicomponent mixture Wbk 31 Wbk 35 Wbk 25 Wbk 32 Wbk 32 Wbk 32 Wbk 47 Wbk 27 Wbk 47 Wbk 47 Wbk 31
Poisson's equation Wbk 25 18 Poisson's equation Wbk 33 19, 28, 31 Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Poisson's equation Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Poisson's equation Population dynamic models Wbk 32 8-11 Pressure Wbk 9 4 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Population dynamic models Pressure Wbk 9 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pressure Wbk 9 4 Pressure Wbk 27 3, 15, 36 Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pressure Wbk 47 16 Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pressure in an ideal multicomponent mixture Wbk 31 79 Pressure of gas Wbk 18 13
Pressure of gas Wbk 18 13
Production line data Wbk 46 27, 30, 32, 35.
1
Projectile Wbk 4 47
Projectile - angled launch Wbk 34 12
Projectile - energy Wbk 34 10, 28
Projectile - height Wbk 34 12
Projectile - horizontal launch Wbk 34 9
Projectile - inclined plane Wbk 34 30
Projectile - range Wbk 34 14
Projectile - without air drag Wbk 34 9
Propagation time difference Wbk 47 53
Propellant Wbk 45 6, 7, 16
Pulley belt tension Wbk 14 8
Pumping engine bearing lifetime Wbk 46 12-13



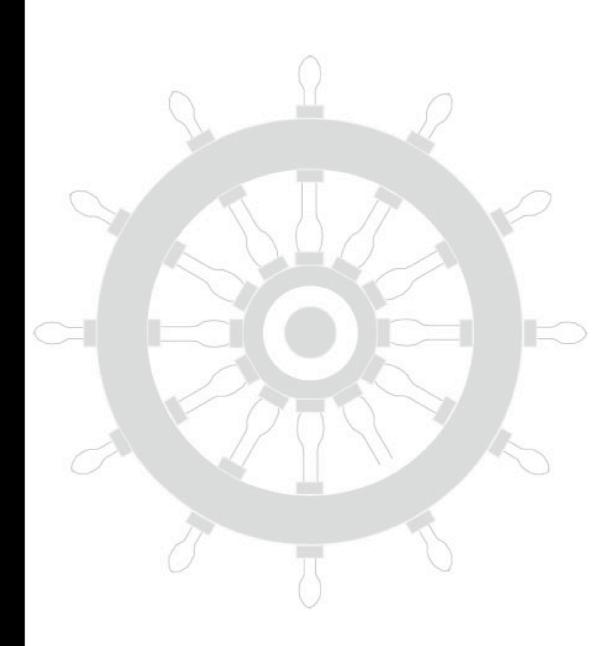
Quadratic resistance	Wbk 34	57, 59, 62
Quality control	Wbk 37	8
	Wbk 46	
Quality control	VVDK 40	21-38
Radiation	Wbk 47	20 41 42 46
		38, 41, 43, 46
Radiation emitted by microwave oven	Wbk 42	
Radioactive decay	Wbk 27	58
Railway signals location	Wbk 48	72
Range of projectile	Wbk 34	12
Redlich-Kwong equation	Wbk 18	18
Refraction	Wbk 12	29
Refraction	Wbk 48	13
Relays	Wbk 41	10
Reliability in a communication network	Wbk 1	52
Reservoir	Wbk 27	42, 54
Resistance - linear	Wbk 34	56
Resistance - quadratic	Wbk 34	57, 59, 62
Resisted motion	Wbk 34	56-63
Reverberation	Wbk 6	46
Roadholding of car	Wbk 44	31
Rocket	Wbk 8	31
Rocket fuel shear strength	Wbk 45	6, 7, 16
Rollercoaster ride	Wbk 34	44
Roundabout	Wbk 34	36
Route network	Wbk 7	27
Notice network	VVDICT	
Sampling	Wbk 21	3, 85-95
Satellite motion	Wbk 48	60, 63
Schrödinger's equation	Wbk 15	18
Series design of components	Wbk 46	7, 9
Shear force and bending moment of a beam	Wbk 19	65
Shear strength	Wbk 43	18
	Wbk 13	19
Shear stress and strain		
Shot putting	Wbk 34	22
Signal sampling	Wbk 21	85-95
Simple harmonic motion	Wbk 4	68
Simple harmonic motion	Wbk 25	6
Skateboarding	Wbk 34	31
Skiing	Wbk 34	15
Snowflake falling	Wbk 48	56
Solenoid	Wbk 13	51
Solid rocket fuel	Wbk 45	6, 7, 16
Sonic boom	Wbk 14	12
Sound intensity	Wbk 5	46
Sound intensity	Wbk 6	46
Sound waves	Wbk 4	6
Sound waves	Wbk 48	2, 7, 10
	1	<u> </u>

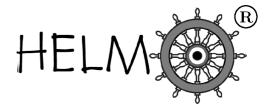
Spring Wbk 43 21 Spring Wbk 20 39 Springs Wbk 20 39 Steel alloy corrosion Wbk 44 21 Steel bar Wbk 13 19 Steel cables Wbk 41 25, 29, 37 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stresss Wbk 8 10 Stress Wbk 8 10 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 41 10	Spot welds	Wbk 43	18
Spring Wbk 47 6 Springs - damped Wbk 20 39 Springs Wbk 20 47 Steel alloy corrosion Wbk 44 21 Steel cables Wbk 13 19 Steel cables Wbk 13 18 Striffness Wbk 13 18 Strain Wbk 8 10 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 8 10 Stress Wbk 8 10 Stress Wbk 13 19 Stress Wbk 8 10 Stress Wbk 13 19 Stress Wbk 13 19 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Subrace tension Wbk 47 14, 17 Surface tension Wbk 47 14, 17	•		
Springs Wbk 20 39 Springs Wbk 40 47 Steel alloy corrosion Wbk 44 21 Steel cables Wbk 13 19 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain Wbk 8 10 Strain Wbk 39 18-20 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stressen Wbk 31 19 18 Stresses wbk 13 19 19 Stresses wbk 43 10 10 Stresses and strains on a section of material wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 47 14, 17 Suspended cable Wbk 47 14, 17 Suspended cable Wbk 48 40 System reliability Wbk 46 7-9 System reliability Wbk 26 71 Tank - ellipsoidal Wbk 27 79 Tank - ellipsoidal			
Springs Wbk 20 47 Steel alloy corrosion Wbk 44 21 Steel cables Wbk 41 25, 29, 37 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain Wbk 39 18-20 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 47 5, 7 Submarine equation Wbk 47 5, 7 Submarine equation Wbk 47 14, 17 Suspended cable Wbk 41 10 System reliability			•
Steel alloy corrosion Wbk 44 21 Steel bar Wkb 13 19 Steel cables Wbk 41 25, 29, 37 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 8 10 Stresses and strains on a section of material Wbk 8 10 Stresses and strains on a section of material Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 37 Telegraph equation Wbk 25 16 Tensile strength Wbk 44 45, 47 Tension in spring Wbk 44 45, 47 <td></td> <td></td> <td></td>			
Steel bar Wkb 13 19 Steel cables Wbk 41 25, 29, 37 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 48 40 System reliability Wbk 48 40 System response Wbk 27 79 Tank - ellipsoidal Wbk 27 79 Tank - ellipsoidal Wbk 27 79 Telegraph equation Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47		-	
Steel cables Wbk 41 25, 29, 37 Stiffness Wbk 13 18 Strain Wbk 8 10 Strain Gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 27 79 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 33 10 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tension in spring Wbk 47 6 Tension in spring Wbk 47 6			
Stiffness Wbk 13 18 Strain Wbk 8 10 Strain Wbk 13 19 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 8 10 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 47 5, 7 Submarine equation Wbk 47 14, 17 Suspended cable Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 27 79 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Tempial strength Wbk 41 21 Tension Wbk 44 45, 47 Tension			
Strain Wbk 8 13 19 Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 10 Stress Wbk 13 19 19 Stresses and strains on a section of material Wbk 8 10 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 37 Telegraph equation Wbk 33 10 Tensile strength Wbk 31 12 Tensile strength Wbk 41 21 Tension in spring Wbk 44 45, 47 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 Thermal insulation Wbk 18 8 Tolerance limits Wbk 30 19		_	
Strain gauge resistance Wbk 39 18-20 Streamlines Wbk 26 14 Stress Wbk 8 10 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 27 79 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 33 10 Tengeraph equation Wbk 33 10 Tensile strength Wbk 33 10 Tensile strength Wbk 41 21 Tension in spring Wbk 44 45, 47 Tension in string Wbk 47 6 Tension in string Wbk 47 7			
Strain gauge resistance Wbk 39 18-20 Stress Wbk 8 10 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tension in spring Wbk 44 45, 47 Tension in spring Wbk 47 6 Tension in string Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49			_
Streamlines Wbk 26 14 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 15 21 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tension in spring Wbk 44 45, 47 Tension in spring Wbk 47 6 Tension in string Wbk 47 6 Tension in string Wbk 47 13 The web-flange Wbk 17 13 <			
Stress Wbk 8 10 Stress Wbk 13 19 Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 15 21 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Tiddly-winks Wbk 49 52 Torque Wbk 48 19 Torgion Wbk 18 19 Torgion Wbk 18 19 Torgion Wbk 18 19 Torgion Wbk 19 19			
Stress		-	
Stresses and strains on a section of material Wbk 8 10 String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 15 21 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 28 6 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 17 13			
String Wbk 47 5, 7 Submarine equation Wbk 25 16 Surface tension Wbk 47 14, 17 Suspended cable Wbk 15 21 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension in spring Wbk 47 6 Tension in string Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19			
Submarine equation Surface tension Wbk 47 Suspended cable Suspended cable Wbk 48 Wbk 48 Wbk 41 Switches Wbk 41 System reliability Wbk 46 System response Wbk 20 Tank - ellipsoidal Telegraph equation Tensile strength Wbk 41 Tension Wbk 44 Tension in spring Wbk 47 Terminal velocity The current continuity equation Wbk 29 The web-flange Wbk 30 Tolerance limits Wok 41 Torque Wbk 32 Torque Wbk 33 Tororion Wbk 47 Tension Wbk 47 Tension in spring Wbk 47 Tension in string Wbk 47 Tension in string Wbk 47 Terminal velocity Wbk 6 Wbk 19 Tolerance limits Wbk 46 Torque Wbk 31 Torque Wbk 13 Torrorion Wbk 13 Torrorion Wbk 13 Torrorion Wbk 13 Torsion Wbk 13 Torrorion			
Surface tension Wbk 47 14, 17 Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Torque Wbk 9 52 Torque Wbk 28 6			
Suspended cable Suspended cable Wbk 48 40 Switches Wbk 41 10 System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 25 16 Tensine strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 17 13 Torque Wbk 9 52 Torque Wbk 9 52 Torque Wbk 13 19 Torsion Wbk 13 19	-		_
Suspended cable Switches Switches System reliability Wbk 46 7-9 System response Wbk 20 Tank - ellipsoidal Tank - elliptic Wbk 27 Telegraph equation Tensile strength Wbk 41 Tensile strength Wbk 44 Tension Wbk 47 Tension in spring Wbk 47 Terminal velocity Wbk 6 The current continuity equation Wbk 17 Thermal diffusivity Wbk 32 Tolerance limits Wbk 43 Wbk 44 Wbk 45 Wbk 47 Wbk 47 Wbk 48 Wbk 47 Wbk 47 Wbk 47 Wbk 47 Wbk 47 Wbk 48 Wbk 47 Terminal velocity Wbk 6 Wbk 47 Terminal velocity Wbk 6 Wbk 17 Terminal diffusivity Wbk 32 Wbk 32 Wbk 34 Wbk 34 Wbk 34 Wbk 34 Wbk 36 Tolerance limits Wbk 46 Torque Wbk 28 Torque Wbk 28 Torque Wbk 28 Torsion Wbk 13			-
Switches System reliability Wbk 46 7-9 System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 25 16 Tengeraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 12 46 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wbk 48 6 Torque Wbk 9 52 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion			
System reliability System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 25 16 Tensierature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 12 46 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 47 Torque Wbk 48 Torque Wbk 49 Torque Wbk 30 Wbk 40 Wbk 41 Wbk 42 Wbk 43 Wbk 45 Wbk 46 Wbk 47 Wbk 46 Wbk 47 Torque Wbk 46 Wbk 46 Wbk 46 Wbk 47 Torque Wbk 46 Wbk 46 Wbk 46 Wbk 47 Torque Wbk 46 Wbk 48 Torque Wbk 48 Torque Wbk 48 Torque Wbk 47 Torque Wbk 48			
System response Wbk 20 71 Tank - ellipsoidal Wbk 27 79 Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 17 13			
Tank - ellipsoidal Tank - elliptic Wbk 27 37 Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 29 46 Torque Wbk 9 52 Torque Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion			
Tank - elliptic Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wobk 46 24 Torque Wbk 28 6 Torque Wbk 28 6 Torsion Wbk 17 13	устан такретта		. –
Tank - elliptic Telegraph equation Wbk 25 16 Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wobk 46 24 Torque Wbk 28 6 Torque Wbk 28 6 Torsion Wbk 17 13	Tank - ellipsoidal	Wbk 27	79
Telegraph equation Temperature of wire Wbk 33 10 Tensile strength Wbk 41 21 Tensile strength Wbk 44 45, 47 Tension Wbk 47 6 Tension in spring Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wbk 9 52 Torque Wbk 13 19 Torque Wbk 13 19 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion	_		
Temperature of wire Tensile strength Tensile strength Wbk 41 Tension Wbk 44 Wbk 45, 47 Tension Wbk 47 Tension in spring Wbk 47 Tension in string Wbk 47 Terminal velocity Wbk 6 The current continuity equation Wbk 29 The web-flange Wbk 17 Thermal diffusivity Wbk 32 Wbk 32 Wbk 34 Thermal insulation Wbk 34 Tolerance limits Wbk 46 Torque Wbk 9 Torque Wbk 13 Torque Wbk 28 Torque Wbk 13 Wbk 13 Wbk 14 Wbk 15 Wbk 15 Wbk 16 Wbk 17 Wbk 17 Wbk 16 Wbk 17 Wbk 17 Wbk 17 Wbk 18 Wbk 18 Wbk 19 Wbk 18	·		
Tensile strength Tensile strength Wbk 44 45, 47 Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 13 19 Torsion	<u> </u>		
Tensile strength Tension Wbk 44 45, 47 Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 9 52 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	·	Wbk 41	21
Tension Wbk 14 8 Tension in spring Wbk 47 6 Tension in string Wbk 47 7 Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13			45, 47
Tension in string Terminal velocity Wbk 6 49 The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13		Wbk 14	8
Tension in string Terminal velocity The current continuity equation The web-flange Thermal diffusivity Why 32 46 Thermal insulation Why 34 19 Tolerance limits Torque Why 35 2 Torque Why 36 24 Torque Why 36 24 Torque Why 37 3 Why 38 3 Why 39 52 Torque Why 30 52 Torque Why 30 52 Torque Why 31 19 Torque Why 32 6 Torsion Why 31 19 Torsion Why 31 19 Torsion Why 31 19 Torsion	Tension in spring	Wbk 47	6
Terminal velocity The current continuity equation Wbk 29 46 The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13		Wbk 47	7
The current continuity equation The web-flange Wbk 17 13 Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 17 13	_	Wbk 6	49
The web-flange Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	The current continuity equation	Wbk 29	46
Thermal diffusivity Wbk 32 46 Thermal insulation Wbk 1 85 Tiddly-winks Wbk 34 19 Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	The web-flange	Wbk 17	13
Thermal insulationWbk 185Tiddly-winksWbk 3419Tolerance limitsWbk 4624TorqueWbk 952TorqueWbk 1319TorqueWbk 286TorsionWbk 1319TorsionWbk 1713	_	Wbk 32	46
Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	Thermal insulation	Wbk 1	85
Tolerance limits Wbk 46 24 Torque Wbk 9 52 Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	Tiddly-winks	Wbk 34	19
Torque Wbk 13 19 Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13		Wbk 46	24
Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	Torque	Wbk 9	52
Torque Wbk 28 6 Torsion Wbk 13 19 Torsion Wbk 17 13	Torque	Wbk 13	19
Torsion Wbk 13 19 Torsion Wbk 17 13		Wbk 28	6
		Wbk 13	19
Torsion of mild-steel bar Whk 13 10	Torsion	Wbk 17	13
TOTSION OF THING SECONDAI	Torsion of mild-steel bar	Wbk 13	19



Total energy	Wbk 34	28
Traffic flow	Wbk 37	11, 46
Train on a track	Wbk 30	62
	Wbk 25	16
Transmission line equation		
Transverse vibrations equation	Wbk 25	18
Turbochargers	Wbk 41	17
Turbulence	Wbk 47	16
Two dimensional fluid flow	Wbk 26	36
Tyre mileage	Wbk 38	13
) A // L 0	
Undersea cable fault location	Wbk 3	25
van der Waals' equation	Wbk 47	18, 19, 23
Velocity of a rocket	Wbk 8	31
Velocity on a bend	Wbk 34	51
Vibrating system	Wbk 20	47
Vibration	Wbk 23	69
Vibration of string	Wbk 47	5
Vintage car brake pedal mechanism	Wbk 4	14
Viscosity	Wbk 47	14, 15, 16
Volume of liquid in an ellipsoidal tank	Wbk 27	79
Volume of liquid in an elliptic tank	Wbk 27	37
Washing machine faults	Wbk 42	20
Water flow	Wbk 47	20
Water height in an open channel	Wbk 48	45
Water wheel efficiency	Wbk 12	28
Waterflow	Wbk 28	12, 13, 25, 30
Wave equation	Wbk 32	70
Waves	Wbk 4	40-42
Waves	Wbk 47	17
Waves	Wbk 48	3, 7, 10
Wear on rollers	Wbk 40	11
Weathering of paint	Wbk 44	29
Woodscrew size variation	Wbk 40	6
Work done moving a charge in an electric field	Wbk 29	19
22.1.2 2.1 2.2 2.1. 2.1. 2.		
Young's modulus	Wbk 8	10
Young's modulus	Wbk 20	52
	1121120	_ _

NOTES





HELM: Helping Engineers Learn Mathematics

http://helm.lboro.ac.uk