Pearson Edexcel

Your guide to Pearson Edexcel International Advanced Level (IAL) Science (Biology, Chemistry and Physics)

First teaching
September 2018

Welcome

Our International Advanced Level (IAL) qualifications have been developed in consultation with the international school community, including a large number of teachers and university lecturers, to be engaging for international learners and to give them the necessary skills to support progression to higher and further study.

Now available in 21 subjects, with the following subjects updated for first teaching in September 2018: Mathematics, Further Mathematics, Pure Mathematics, Biology, Chemistry, Physics, Business, Economics and **IT (NEW qualification from September 2018)**.

This guide provides an overview of our International Advanced Level (IAL) qualifications in Biology, Chemistry and Physics.

For further information, updates and support, visit **qualifications.pearson.com/ial**

"I gained a lot of knowledge and skills as well as the academic side in lectures. I gained great grades with my IALs and feel confident to move forward."

Wae Yee Hew, now studying Actuarial Science at Herriot Watt University, Malaysia

Illustration by Lauren Rolwing

Why choose Pearson Edexcel International Advanced Level (IAL)?

Pearson Edexcel International Advanced Level (IAL) qualifications are popular for many reasons including:

Flexible and modular structure

Pearson Edexcel IAL provides the flexibility to teach a modular A level qualification. This allows learners to take examinations at the right time for them. The modular structure includes a synoptic approach to assessment, which means learners are examined on their learning from each unit and are also able to demonstrate their knowledge and understanding across the whole subject.

The modular approach exam results provide formal feedback throughout the course. Learners are able to more quickly understand the standard required to reach the level of achievement they are aiming for. This understanding motivates them to improve, and builds a sense of ownership through bite-size, short-term goals.

Multiple examination opportunities

Examinations are available in January, June and October. As exams are spread throughout the course, revision is broken down into unit-sized chunks, and there are less 'all-or-nothing' exam periods, enabling learners to focus their revision appropriately.

Clear and straightforward question papers

Our question papers are clear and provide sufficient challenge and support for students of all ability ranges. Our mark schemes are straightforward so that the assessment requirements are clear.

AS results contribute to A level grade

International AS qualifications can be taken separately, as a stand alone qualification, or used as a stage on the way to completing an Advanced Level qualification. This provides international schools and learners with greater choice and flexibility to meet their needs and aspirations.

Recognised by universities worldwide

Our IALs are fully comparable to UK reformed GCE A levels and provide the same progression routes to university and employment. Crucially, Pearson Edexcel IALs are widely recognised by universities across the world for entry on to undergraduate degree level programmes. Global universities that recognise these qualifications include the UK Russell Group, the Australia Group of 8 (Go8) and top ranked universities in North America and Asia.

International focus

Pearson Edexcel IAL qualifications and accompanying published resources contain international content where possible, such as topic themes, examples, case studies, photos and currencies, making content more relevant and engaging for all learners. Language is also reviewed by a specialist to ensure materials are written with EAL learners in mind, in a clear and accessible style.

100% externally assessed

Learners can resit individual unit examinations.

Pearson Edexcel International Advanced Level (IAL) Biology, Chemistry and Physics from 2018

We have listened to feedback from all parts of the international school community, including a large number of teachers and universities, to ensure we develop our science qualifications to be engaging for international learners and to give them the necessary skills to support progression to to higher education or further study in biology, chemistry or physics.

Our IALs in Biology, Chemistry and Physics are designed to be studied over two years, with the option of a one-year AS level course. Results of the IAS qualification can contribute to the overall IAL grade.

The IAL Biology, Chemistry and Physics qualifications have several features which we know teachers and students love including:

- up-to-date, engaging content with an international focus to suit different schools around the world
- clear and straightforward question papers – our mark schemes are straightforward so that the assessment requirements are clear
- examinations are available 3 times a year in January, June and October to suit different delivery models
- students have the opportunity to re-sit individual units
- progression – IAS results will continue to contribute to IAL
- curriculum-matched textbooks and teacher supports have been developed to support teaching and learning from September 2018.

Biology

Your guide to assessment timelines

Specification	Level	Units	Jun 2018	Oct 2018	Jan 2019	Jun 2019	Oct 2019	Jan 2020	Jun 2020	Oct 2020	Jan 2021
BIOLOGY 2013 SPECIFICATION											
Biology 2013	AS	WBI01	✓	✓	✓	✓	✗	✗	✗	✗	✗
Biology 2013	AS	WBI02	✓	✓	✓	✓	✗	✗	✗	✗	✗
Biology 2013	AS	WBI03	✓	✓	✓	✓	✗	✗	✗	✗	✗
Biology 2013	A2	WBI04	✓	✓	✓	✓	✓	✗	✓	✗	✗
Biology 2013	A2	WBI05	✓	✓	✓	✓	✓	✗	✓	✗	✗
Biology 2013	A2	WBI06	✓	✓	✓	✓	✓	✗	✓	✗	✗
NEW BIOLOGY 2018 SPECIFICATION											
Biology 2018	AS	WBI11	✗	✗	✓	✓	✓	✓	✓	✓	✓
Biology 2018	AS	WBI12	✗	✗	✗	✓	✓	✓	✓	✓	✓
Biology 2018	AS	WBI13	✗	✗	✗	✓	✓	✓	✓	✓	✓
Biology 2018	A2	WBI14	✗	✗	✗	✗	✗	✓	✓	✓	✓
Biology 2018	A2	WBI15	✗	✗	✗	✗	✗	✗	✓	✓	✓
Biology 2018	A2	WBI16	✗	✗	✗	✗	✗	✗	✓	✓	✓

Helping students make the best progress they can

Covering biological laws, theories, models and their practical applications, our IAL Biology will extend learners' knowledge by broadening and deepening skills.

Students will:

- develop and use a range of mathematical skills that support their knowledge and understanding of biology
- gain experience in a variety of practical techniques and procedures, which will be assessed separately in Unit 3 (AS) and Unit 6 (A Level)
- widen their learning through a number of key transferable skills, which may be cognitive, intrapersonal or interpersonal (see Page 9 for more information on developing transferable skills)
- benefit from modular assessment, offered at different times of year to suit your delivery model
- be exposed to a range of question types in exams – testing breadth of knowledge, as well as allowing depth of understanding to be examined.

Chemistry

Your guide to assessment timelines

Specification	Level	Units	Jun 2018	Oct 2018	Jan 2019	Jun 2019	Oct 2019	Jan 2020	Jun 2020	Oct 2020	Jan 2021
CHEMISTRY 2013 SPECIFICATION											
Chemistry 2013	AS	WCH01	✓	✓	✓	✓	✗	✗	✗	✗	✗
Chemistry 2013	AS	WCH02	✓	✓	✓	✓	✗	✗	✗	✗	✗
Chemistry 2013	AS	WCH03	✓	✓	✓	✓	✗	✗	✗	✗	✗
Chemistry 2013	A2	WCH04	✓	✓	✓	✓	✓	✗	✓	✗	✗
Chemistry 2013	A2	WCH05	✓	✓	✓	✓	✓	✗	✓	✗	✗
Chemistry 2013	A2	WCH06	✓	✓	✓	✓	✓	✗	✓	✗	✗
NEW CHEMISTRY 2018 SPECIFICATION											
Chemistry 2018	AS	WCH11	✗	✗	✓	✓	✓	✓	✓	✓	✓
Chemistry 2018	AS	WCH12	✗	✗	✗	✓	✓	✓	✓	✓	✓
Chemistry 2018	AS	WCH13	✗	✗	✗	✓	✓	✓	✓	✓	✓
Chemistry 2018	A2	WCH14	✗	✗	✗	✗	✗	✓	✓	✓	✓
Chemistry 2018	A2	WCH15	✗	✗	✗	✗	✗	✗	✓	✓	✓
Chemistry 2018	A2	WCH16	✗	✗	✗	✗	✗	✗	✓	✓	✓

Helping students make the best progress they can

Covering the core chemical principles and laboratory skills, our IAL Chemistry will extend learners' knowledge by broadening and deepening skills.

Students will:

- develop and use a range of mathematical skills that support their knowledge and understanding of chemistry
- gain experience in a variety of practical techniques and procedures, which will be assessed separately in Unit 3 (AS) and Unit 6 (A Level)
- widen their learning through a number of key transferable skills, which may be cognitive, intrapersonal or interpersonal (see Page 9 for more information on developing transferable skills)
- benefit from modular assessment, offered at different times of year to suit your delivery model
- be exposed to a range of question types in exams – testing breadth of knowledge, as well as allowing depth of understanding to be examined.

Physics

Your guide to assessment timelines

Specification	Level	Units	Jun 2018	Oct 2018	Jan 2019	Jun 2019	Oct 2019	Jan 2020	Jun 2020	Oct 2020	Jan 2021
PHYSICS 2013 SPECIFICATION											
Physics 2013	AS	WPH01	✓	✓	✓	✓	✗	✗	✗	✗	✗
Physics 2013	AS	WPH02	✓	✓	✓	✓	✗	✗	✗	✗	✗
Physics 2013	AS	WPH03	✓	✓	✓	✓	✗	✗	✗	✗	✗
Physics 2013	A2	WPH04	✓	✓	✓	✓	✓	✗	✓	✗	✗
Physics 2013	A2	WPH05	✓	✓	✓	✓	✓	✗	✓	✗	✗
Physics 2013	A2	WPH05	✓	✓	✓	✓	✓	✗	✓	✗	✗
NEW PHYSICS 2018 SPECIFICATION											
Physics 2018	AS	WPH11	✗	✗	✓	✓	✓	✓	✓	✓	✓
Physics 2018	AS	WPH12	✗	✗	✗	✓	✓	✓	✓	✓	✓
Physics 2018	AS	WPH13	✗	✗	✗	✓	✓	✓	✓	✓	✓
Physics 2018	A2	WPH14	✗	✗	✗	✗	✗	✓	✓	✓	✓
Physics 2018	A2	WPH15	✗	✗	✗	✗	✗	✗	✓	✓	✓
Physics 2018	A2	WPH16	✗	✗	✗	✗	✗	✗	✓	✓	✓

Helping students make the best progress they can

Covering physical laws, theories, models and their practical applications, our IAL Physics will extend learners' knowledge by broadening and deepening skills.

Students will:

- develop and use a range of mathematical skills that support their knowledge and understanding of physics
- gain experience in a variety of practical techniques and procedures, which will be assessed separately in Unit 3 (AS) and Unit 6 (A Level)
- widen their learning through a number of key transferable skills, which may be cognitive, intrapersonal or interpersonal (see Page 9 for more information on developing transferable skills)
- benefit from modular assessment, offered at different times of year to suit your delivery model
- be exposed to a range of question types in exams – testing breadth of knowledge, as well as allowing depth of understanding to be examined.

Units studied at a glance

Edexcel International Advanced Level (IAL) Biology

- Unit 1: Molecules, Diet, Transport and Health
- Unit 2: Cells, Development, Biodiversity and Conservation
- Unit 3: Practical Skills in Biology I
- Unit 4: Energy, Environment, Microbiology and Immunity
- Unit 5: Respiration, Internal Environment, Coordination and Gene Technology
- Unit 6: Practical Skills in Biology II

Edexcel International Advanced Level (IAL) Chemistry

- Unit 1: Structure, Bonding and Introduction to Organic Chemistry
- Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols
- Unit 3: Practical Skills in Chemistry I
- Unit 4: Rates, Equilibria and Further Organic Chemistry
- Unit 5: Transition Metals and Organic Nitrogen Chemistry
- Unit 6: Practical Skills in Chemistry II

Edexcel International Advanced Level (IAL) Physics

- Unit 1: Mechanics and Materials
- Unit 2: Waves and Electricity
- Unit 3: Practical Skills in Physics I
- Unit 4: Further Mechanics, Fields and Particles
- Unit 5: Thermodynamics, Radiation, Oscillations and Cosmology
- Unit 6: Practical Skills in Physics II

Developing transferable skills valued by universities and employers

In recent years, universities and employers have highlighted the need for students and graduates to develop a range of transferable skills, often referred to as 'soft skills', to enable them to better meet the demands of undergraduate study and the world of work.

In fact, universities and employers consider transferable skills to be the largest skills gap overall.

1 in 6

employers have difficulty finding candidates with the skills they require[1]

54%

of companies say that skills shortages impact their ability to serve their customers[2]

1 in 3

skills in a job posting is a "soft skill"[1]

87%

of university professors do not think students have the research skills needed for degree-level study[3]

Pearson Edexcel International Advanced Levels (IALs) equip students with these embedded transferable skills sought after by universities and employers. They develop core competencies, such as problem-solving, critical thinking and verbal reasoning. Transferable skills are signposted in our IAL qualifications and learning materials to support student development of them.

[1] *Employability - Personal & Social Capability Framework report from Pearson, 2016.*
[2] *Employability report from PSB for Pearson, 2016.*
[3] *Bridging the Gap: Understanding the Differing Research Expectations of First-Year Students and Professors, Meg Raven, Mount Saint Vincent University, 2016.*

Supporting you at every stage

We provide an unparalleled level of support services, tools, resources and training alongside our qualifications, making teachers and students lives easier at every stage.

FREE resources and support	Planning, teaching & learning	Exam preparation and assessment	Results support
Getting started guide	✓		
Training events (face-to-face and online)	✓		
Subject advisor support	✓	✓	✓
Community forums	✓	✓	✓
Schemes of work	✓		
Sample assessment materials	✓	✓	
Examiner reports		✓	✓
Exemplar marked responses		✓	
Past papers		✓	
examWizard		✓	
Mark schemes		✓	
ResultsPlus mock exam analysis		✓	
ResultsPlus		✓	✓
Access to Scripts service (ATS)			✓
Additional paid for resources			
Printed and digital courseware (such as textbooks)	✓	✓	

Your free subject support

- **Our subject advisors provide** fast, reliable, expert help and aim to answer all emailed questions within 48 hours and resolve 90% of issues phoned in on the first call. Email **TeachingScience@pearson.com** or call **+ 44 (0)20 7010 2190**
- **Connect with other educators** around the world, share ideas and resources and stay up to date with the latest subject developments by joining our international schools community at **community.pearsoninternationalschools.com**.

Offering more advanced support services and tools

Our technology capability also allows us to provide the following unique services and tools to teachers and students:

ResultsPlus provides detailed information on exam performance and a platform to view and compare student results – as individuals or as groups – across the world. It helps with planning improvements in teaching and learning. ResultsPlus Direct is a free online service that gives students a detailed breakdown and comparison of their performance in Pearson Edexcel exams, globally, to help them identify areas of improvement.

examWizard is our free exam preparation tool containing a bank of past Pearson Edexcel exam questions, mark schemes and examiners' reports for a range of subjects. It saves you time by enabling you to create your own mock exams, topic tests, homework or revision activities in minutes and links directly to associated examiner reports and mark schemes!

Access to Scripts Service (ATS) is an online service which allows access to view electronically marked exam papers, free of charge, providing enhanced transparency and support for teachers to evaluate a student's performance on particular questions in relation to what they have been taught.

Awarding reliability. We use ePEN, our unique, image-based marking system ensuring real time monitoring, quality control and reporting to ensure the highest quality marking and provision of data for tools such as ResultsPlus. Pearson Edexcel exam marking processes have been proven to produce the most reliable results. This demonstrates that our qualifications maintain the highest standards and can be relied upon to deliver to expectation.

> **Because of ResultsPlus, students can learn about their mistakes and rectify.**

Kanagambigai, Chief Counsellor, Chemistry Lecturer, A levels Department, HELP Academy, Malaysia commenting on the ResultsPlus mocks service.

Published resources

Developed for the 2018 International Advanced Level (IAL) specification, these new resources are specifically designed for international students, with a strong focus on progression, recognition and transferable skills, allowing learning in a local context to a global standard.

Matched to the new 2018 specifications

These new resources are written specifically to offer a complete match to the content, structure and modular approach of the new 2018 specifications. Offering support to a qualification that is fully comparable to the reformed UK GCE A levels, and recognised as equal to the GCE by universities worldwide.

Internationally appropriate content

Appropriate international content puts learning in a real-world context and includes a range of different contexts, photos, examples and currencies – making it engaging and relevant for all learners. Language is reviewed by a specialist to ensure materials are written in a clear and accessible style.

Lots of exam practice

Exam practice provides opportunities to assess understanding at key points, so students can make the best progress they can.

Signposted transferable skills

Transferable skills, needed for progression into higher education and employment, are embedded throughout the Student Books. They are explicitly signposted so students understand what skills they are developing and therefore go on to use these skills more effectively in the future.

Supporting learning beyond the classroom

Each Student Book provides access to an ActiveBook, which is a digital version of the Student Book, and can be accessed online, anytime, anywhere.

Better support for you

The online teacher resources provide a range of planning, teaching and assessment resources, saving you valuable time.

**Pearson highly recommends, but does not mandate, the use of our resources for teaching and learning the International Advanced Level (IAL).*

Chapter introductions help students think about the concepts they will be introduced to.

A checklist details maths knowledge required per chapter. The **Maths Skills** reference at the back of the book provides a starting point for revision and further practice.

TOPIC 4 PLANT STRUCTURE AND FUNCTION, BIODIVERSITY AND CONSERVATION

CHAPTER 4B CLASSIFICATION

In 2012, scientists working in Papua New Guinea found the smallest known vertebrate to date – a tiny frog measuring 7.7 mm in length. *Paedophryne amanuensis* feeds on tiny mites in the leaf litter of its rainforest home – and it can jump up to 30 times its own body length. DNA analysis shows that tiny frogs have evolved 11 times in different areas of the world, all filling a similar niche. In 2014, a new species of dead-leaf toad (*Rhinella yunga*) was discovered in the Peruvian Andes. In shape, colour and patterning, it resembles a dead leaf and, with the poison it exudes from glands on the back of its head, the toad looks similar to other toads of the same genus. It was only when scientists noticed that these toads lack eardrums that they realised they had discovered a new species. Finding new species is always exciting, but it becomes even more special when that new species is already endangered, such as the new species of orang-utan identified in November 2017.

Scientists used two different methods of identifying these new species – traditional observation of physical characteristics such as eardrums, and DNA analysis of the genome. In this chapter, you will find out more about how we classify the organisms in the world around us – and why it is important that we do so.

You will learn the main taxonomic groups of the living world including domains, kingdoms and species, and will begin to classify different organisms. You will consider the problems of defining a species in a way that is useful for all types of organism and evaluate the different ones in use. The use of DNA technology is having a major impact on our ability to identify organisms and work out how they are related to other species. There has been a long-running debate about the numbers of domains and kingdoms which should be used in classification – decide who you think is right!

MATHS SKILLS FOR THIS CHAPTER

- **Recognise and use expressions in decimal and standard form** (e.g. *when considering the number of base pairs in DNA and the proportion of those base pairs that may differ between species*)
- **Use scales for measuring** (e.g. *size and parts of different organisms for comparisons when classifying*)
- **ntages** (e.g. *regarding the proportion of base pairs shared in genes from different*

What prior knowledge do I need?

- Classification
- The importance of biodiversity
- The impact of developments in biology on classification systems

Chapters 2C and 3B

- Gene mutations and genetic variation caused by meiosis and sexual reproduction

Chapter 3C

- That there is extensive genetic variation within a species

What will I study in this chapter?

- The reasons for classification
- The hierarchy of classification: domain, kingdom, phylum, class, order, family, genus and species
- The common definition of a species as a group of organisms with similar characteristics that normally interbreed to produce fertile offspring – and the many limitations of this definition
- Other ways in which a species can be defined
- Why there are problems in assigning organisms to a species, identifying new species, and how these problems are being addressed
- The increasing value of DNA sequencing in distinguishing between species and in helping to determine the relationships between species
- The evidence for the three-domain model of classification as an alternative to the five-kingdom model

What will I study later?

Topic 4C

- Biodiversity
- How to measure biodiversity
- How species are well adapted to their habitat
- That variation within a species is important
- How new species arise as a result of natural selection
- How reproductive isolation can cause the formation of new species
- The concept of a gene pool and how the proportion of alleles can change within a population
- The need to conserve endangered species.

Topic 5B (Book 2: iAL)

- The need to be able to classify organisms for practical investigations of populations in the field
- Understand the concepts of niche and succession

Assumed knowledge and key concepts are outlined. References to previous and future student book chapters are provided.

Sample pages from Edexcel International AS/A Level Biology Student Book 1

1C 1 COMPARING MASSES OF SUBSTANCES

SPECIFICATION REFERENCE 1.1 1.2 1.4

LEARNING OBJECTIVES

- Understand the terms: relative atomic mass, based on the ^{12}C scale; relative molecular mass; relative formula mass; molar mass, as the mass per mole of a substance in g mol^{-1}.
- Understand how to calculate relative molecular mass and relative formula mass from relative atomic masses.
- Perform calculations using the Avogadro constant L (6.02×10^{23} mol^{-1}).

RELATIVE ATOMIC MASS (A_r)

As chemists discovered more and more elements in the nineteenth century, they began to realise that the masses of the elements were different. They could not weigh individual atoms, but they were able to use numbers to compare the masses of atoms of different elements. For this reason, they began to use the term 'relative atomic mass'.

The chemists soon realised that the element whose atoms had the smallest mass was hydrogen, so the relative atomic mass of hydrogen was fixed as 1. Atoms of silicon had double the mass of nitrogen atoms, and nitrogen atoms were 14 times heavier than hydrogen atoms. This meant that the relative atomic mass of nitrogen was 14, and that of silicon was 28. At first, mostly whole numbers were used, but eventually it was possible to find the mass of an atom to several decimal places. The Periodic Table in the Data Booklet uses 1 decimal place for lighter elements and whole numbers for heavier ones.

After the discovery of isotopes, the ^{12}C isotope of carbon was used in the definition of relative atomic mass.

A suitable definition of relative atomic mass is:

the weighted mean (average) mass of an atom compared to $\frac{1}{12}$ of the mass of an atom of ^{12}C

It is often useful to remember this expression:

$$A_r = \frac{\text{mean mass of an atom of an element}}{\frac{1}{12} \text{ of the mass of an atom of } ^{12}C}$$

RELATIVE MOLECULAR MASS (M_r)

Relative atomic masses are used for atoms of elements. Relative molecular masses are used for molecules of both elements and compounds. They are easily calculated by adding relative atomic masses.

Table A shows values for some common elements taken from the Data Booklet.

ELEMENT	RELATIVE ATOMIC MASS
hydrogen	1.0
carbon	12.0
oxygen	16.0
sulfur	32.1
copper	63.5

table A

Note that A_r and M_r do not have units.
Here are some examples of calculations.

WORKED EXAMPLE 1

What is the relative molecular mass of carbon dioxide, CO_2?

$M_r = 12.0 + (2 \times 16.0) = 44.0$

WORKED EXAMPLE 2

What is the relative molecular mass of sulfuric acid, H_2SO_4?

$M_r = (2 \times 1.0) + 32.1 + (4 \times 16.0) = 98.1$

EXAM HINT

Make sure you use the relative atomic masses shown on the Periodic Table in the Data Booklet.

RELATIVE FORMULA MASS (M_r)

This term has the same symbol as relative molecular mass, but the 'formula' part means that it includes both molecules and ions. Worked example 3 below is slightly more complicated because of the water of crystallisation, but there is also another problem. Hydrated copper(II) sulfate is an ionic compound, so it is not a good idea to refer to its relative *molecular* mass. That is why it is called relative *formula* mass.

WORKED EXAMPLE 3

What is the relative formula mass of hydrated copper(II) sulfate, $CuSO_4.5H_2O$?

$M_r = 63.5 + 32.1 + (4 \times 16.0) + 5\{(2 \times 1.0) + 16.0\} = 249.6$

The term 'relative formula mass' should also be used for compounds with giant structures, such as sodium chloride and silicon dioxide.

MOLAR MASS (M)

Another way around the problem in Worked example 3 is to use the term **molar mass**, which is the mass per mole of any substance (molecular or ionic). the units g mol^{-1} (grams per mo mole) which will be fully explair can think of one mole (1 mol) o quantity as the relative formula units of grams.

Our curriculum-matched Edexcel IAL Science Student Books include clearly signposted features such as:

- Learning Objectives
- Specification references
- Learning Tips, Exam Hints, and Worked Examples
- Did you Know? boxes
- Subject vocabulary at the end of each section, and also in the glossary at the back of the book
- Checkpoint questions test **understanding of the key learning points in each chapter.**

So, this is the expression you can use:

$$\text{amount in mol} = \frac{\text{mass of substance in g}}{\text{molar mass in g mol}^{-1}} \text{ or } n = \frac{m}{M}$$

Table B shows examples of working out the amounts in moles of some substances using this expression.

SUBSTANCE	O_2	CH_4	H_2O	NH_4NO_3
mass in g	5.26	4.0	100	14.7
molar mass, M in g mol^{-1}	32.0	16.0	18.0	80.0
amount in mol	0.164	0.25	5.56	0.184

table B

THE AVOGADRO CONSTANT

Amedeo Avogadro (1776–1856) was an Italian chemist whose name is used in naming the **Avogadro constant**. We are introducing him here because the scaling-up factor from atoms, molecules and ions to grams is named after him.

▲ **fig A** The Italian chemist, Amedeo Avogadro

The value of the Avogadro constant is approximately 602 000 000 000 000 000 000 000 mol^{-1}. It is easier to write this number using standard form: 6.02×10^{23} mol^{-1}.

You do not need to know a definition of the Avogadro constant, and it is best to think of it as the number of particles (atoms, molecules or ions) in one mole of any substance. For example, there are:

6.02×10^{23} helium atoms in 4.0 g of He
6.02×10^{23} carbon dioxide molecules in 44.0 g of CO_2
6.02×10^{23} nitrate ions in 62.0 g of NO_3^-

CALCULATIONS USING THE AVOGADRO CONSTANT

You will need to use the value of L in the types of calculation shown here.

1 Calculate the number of particles in a given mass of a substance. Start by using the expression:

$$\text{amount in mol} = \frac{\text{mass of substance in g}}{\text{molar mass in g mol}^{-1}} \text{ or } n = \frac{m}{M}$$

then multiply the amount in mol by the Avogadro constant.

WORKED EXAMPLE 4

How many H_2O molecules are there in 1.25 g of water?

$n = \frac{1.25}{18.0} = 0.0694$ mol

number of molecules = $6.02 \times 10^{23} \times 0.0694 = 4.18 \times 10^{22}$

2 Calculate the mass of a given number of particles of a substance: start by dividing the number of particles by the Avogadro constant, then multiply the result by the molar mass.

WORKED EXAMPLE 5

What is the mass of 100 million atoms of gold?

$n = \frac{100 \times 10^6}{6.02 \times 10^{23}} = 1.66 \times 10^{-16}$ mol

$m = 1.66 \times 10^{-16} \times 197.0 = 3.27 \times 10^{-14}$ g

(There are lots of atoms, but only a tiny mass.)

CHECKPOINT

1. Malachite is an important mineral with the formula $Cu_2CO_3(OH)_2$. Calculate its relative formula mass.
2. How many molecules of sugar ($C_{12}H_{22}O_{11}$) are there in a teaspoon measure (4.20 g)?

DID YOU KNOW?

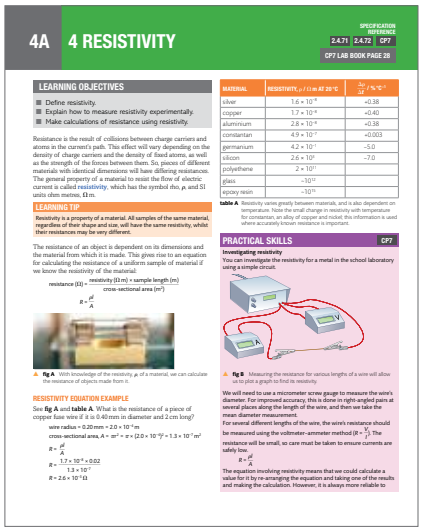
The symbol L is used for the Avogadro constant (using A would be confusing because of the use of A_r for relative atomic mass). L comes from the surname of Johann Josef Loschmidt (1821–1895), an Austrian chemist who was a contemporary of Avogadro. He made many contributions to our understanding of the same area of knowledge.

SUBJECT VOCABULARY

molar mass the mass per mole of a substance; it has the symbol M and the units g mol^{-1}

Avogadro constant (L) 6.02×10^{23} mol^{-1}, the number of particles in one mole of a substance

Sample pages from Edexcel International AS/A Level Chemistry Student Book 1



4A 4 RESISTIVITY

SPECIFICATION REFERENCE 2.4.71 2.4.72 CP7

CP7 LAB BOOK PAGE 28

LEARNING OBJECTIVES

- Define resistivity.
- Explain how to measure resistivity experimentally.
- Make calculations of resistance using resistivity.

Resistance is the result of collisions between charge carriers and atoms in the current's path. This effect will vary depending on the density of charge carriers and the density of fixed atoms, as well as the strength of the forces between them. So, pieces of different materials with identical dimensions will have differing resistances. The general property of a material to resist the flow of electric current is called resistivity, which has the symbol ρ, and SI units ohm metres, Ω m.

LEARNING TIP

Resistivity is a property of a material. All samples of the same material, regardless of their shape and size, will have the same resistivity, whilst their resistances may be very different.

The resistance of an object is dependent on its dimensions and the material from which it is made. This gives rise to an equation for calculating the resistance of a uniform sample of material if we know the resistivity of the material:

resistance (Ω) = $\frac{\text{resistivity } (\Omega \text{ m}) \times \text{sample length (m)}}{\text{cross-sectional area (m}^2\text{)}}$

$R = \frac{\rho l}{A}$

fig A With knowledge of the resistivity, ρ, of a material, we can calculate the resistance of objects made from it.

RESISTIVITY EQUATION EXAMPLE

See **fig A** and **table A**. What is the resistance of a piece of copper fuse wire if it is 0.40 mm in diameter and 2.0 cm long?

wire radius = 0.20 mm = 2.0×10^{-4} m

cross-sectional area, $A = \pi r^2 = \pi \times (2.0 \times 10^{-4})^2 = 1.3 \times 10^{-7}$ m^2

$R = \frac{\rho l}{A}$

$R = \frac{1.7 \times 10^{-8} \times 0.02}{1.3 \times 10^{-7}}$

$R = 2.6 \times 10^{-2}\ \Omega$

MATERIAL	RESISTIVITY, ρ / Ω m AT 20 °C	$\frac{\Delta\rho}{\Delta T}$ / % °C^{-1}
silver	1.6×10^{-8}	+0.38
copper	1.7×10^{-8}	+0.40
aluminium	2.8×10^{-8}	+0.38
constantan	4.9×10^{-7}	+0.003
germanium	4.2×10^{-1}	−5.0
silicon	2.6×10^{3}	−7.0
polyethene	2×10^{21}	
glass	$\sim 10^{12}$	
epoxy resin	$\sim 10^{15}$	

table A Resistivity varies greatly between materials, and is also dependent on temperature. Note the small change in resistivity with temperature for constantan, an alloy of copper and nickel; this information is used where accurately known resistance is important.

PRACTICAL SKILLS CP7

Investigating resistivity

You can investigate the resistivity for a metal in the school laboratory using a simple circuit.

fig B Measuring the resistance for various lengths of a wire will allow us to plot a graph to find its resistivity.

We will need to use a micrometer screw gauge to measure the wire's diameter. For improved accuracy, this is done in right-angled pairs at several places along the length of the wire, and then we take the mean diameter measurement.

For several different lengths of the wire, the wire's resistance should be measured using the voltmeter–ammeter method ($R = \frac{V}{I}$). The resistance will be small, so care must be taken to ensure currents are safely low.

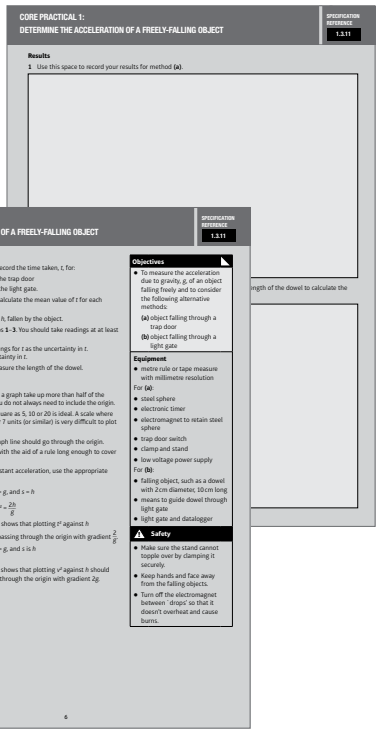
$R = \frac{\rho l}{A}$

The equation involving resistivity means that we could calculate a value for it by re-arranging the equation and taking one of the results and making the calculation. However, it is always more reliable to

In the Student Book, the Core Practical specification and Lab Book references are supplied in the relevant sections.

Practical skills boxes explain techniques used in the Core Practicals, and also detail useful skills and knowledge gained in other related investigations.

This Student Book is accompanied by a **Lab Book**, which includes instructions and writing frames for the Core Practicals, as well as practical skills practice questions and answers.



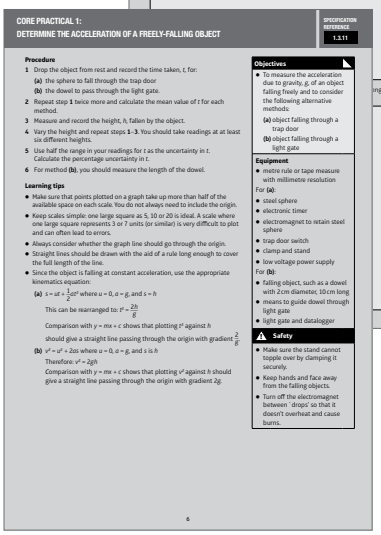
CORE PRACTICAL 1:
DETERMINE THE ACCELERATION OF A FREELY-FALLING OBJECT

SPECIFICATION REFERENCE 1.3.11

Results

1 Use this space to record your results for method **(a)**.

length of the dowel to calculate the



CORE PRACTICAL 1:
DETERMINE THE ACCELERATION OF A FREELY-FALLING OBJECT

SPECIFICATION REFERENCE 1.3.11

Procedure

1 Drop the object from rest and record the time taken, t, for:
   (a) the sphere to fall through the trap door
   (b) the dowel to pass through the light gate.
2 Repeat step **1** twice more and calculate the mean value of t for each method.
3 Measure and record the height, h, fallen by the object.
4 Vary the height and repeat steps **1**–**3**. You should take readings at at least six different heights.
5 Use half the range in your readings for t as the uncertainty in t. Calculate the percentage uncertainty in t.
6 For method **(b)**, you should measure the length of the dowel.

Learning tips

- Make sure that points plotted on a graph take up more than half of the available space on each scale. You do not always need to include the origin.
- Keep scales simple: one large square as 5, 10 or 20 is ideal. A scale where one large square represents 3 or 7 units (or similar) is very difficult to plot and can often lead to errors.
- Always consider whether the graph line should go through the origin.
- Straight lines should be drawn with the aid of a rule long enough to cover the full length of the line.
- Since the object is falling at constant acceleration, use the appropriate kinematics equation:

(a) $s = ut + \frac{1}{2}at^2$ where $u = 0$, $a = g$, and $s = h$

This can be rearranged to: $t^2 = \frac{2h}{g}$

Comparison with $y = mx + c$ shows that plotting t^2 against h should give a straight line passing through the origin with gradient $\frac{2}{g}$

(b) $v^2 = u^2 + 2as$ where $u = 0$, $a = g$, and s is h

Therefore: $v^2 = 2gh$

Comparison with $y = mx + c$ shows that plotting v^2 against h should give a straight line passing through the origin with gradient $2g$.

Objectives

- To measure the acceleration due to gravity, g, of an object falling freely and to consider the following alternative methods:
  - **(a)** object falling through a trap door
  - **(b)** object falling through a light gate

Equipment

- metre rule or tape measure with millimetre resolution

For **(a)**

- steel sphere
- electronic timer
- electromagnet to retain steel sphere
- trap door switch
- clamp and stand
- low voltage power supply

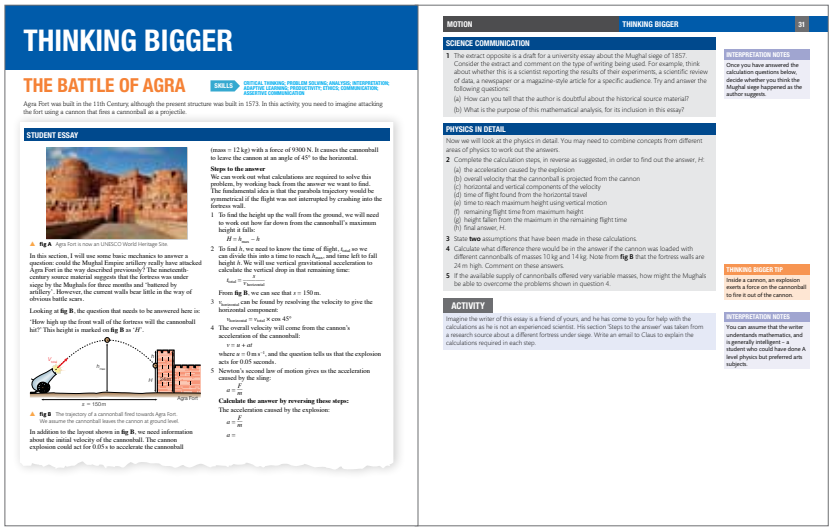
For **(b)**

- falling object, such as a dowel with 2 cm diameter, 10 cm long
- means to guide dowel through light gate
- light gate and datalogger

Safety

- Make sure the stand cannot topple over by clamping it securely.
- Keep hands and face away from the falling objects.
- Turn off the electromagnet between 'drops' so that it doesn't overheat and cause burns.

6



THINKING BIGGER

THE BATTLE OF AGRA

SKILLS CRITICAL THINKING, PROBLEM SOLVING, ANALYSIS, INTERPRETATION, CREATIVE THINKING, OPPORTUNITY, ETHICS, COMMUNICATION, ASSERTIVE COMMUNICATION

Agra Fort was built in the 11th Century although the present structure was built in 1573. In this activity you need to imagine attacking the fort using a cannon that fires a cannonball as a projectile.

STUDENT ESSAY

fig A Agra Fort is now an UNESCO World Heritage Site.

In this section, I will use some basic mechanics to answer a question: could the Mughal Empire artillery really have attacked Agra Fort in the way described previously? The nineteenth-century source material suggests that the fortress was under siege by the Mughals for three months and 'battered by artillery'. However, the current walls bear little in the way of obvious battle scars.

Looking at **fig B**, the question that needs to be answered here is:

'How high up the front wall of the fortress will the cannonball hit?' This height is marked on **fig B** as 'H'.

fig B The trajectory of a cannonball fired towards Agra Fort. We assume the cannonball leaves the cannon at ground level.

In addition to the layout shown in **fig B**, we need information about the initial velocity of the cannonball. The cannon explosion could act for 0.05 s to accelerate the cannonball (mass = 12 kg) with a force of 9300 N. It causes the cannonball to leave the cannon at an angle of 45° to the horizontal.

Steps to the answer

We can work out what calculations are required to solve this problem, by working back from the answer we want to find. The fundamental idea is that the parabola trajectory would be symmetrical if the flight was not interrupted by crashing into the fortress wall.

1 To find the height up the wall from the ground, we will need to work out how far down from the cannonball's maximum height it falls:
$H = h_{max} - h$

2 To find h, we need to know the time of flight, t_{total} so we can divide this into a time to reach h_{max} and time left to fall height h. We will use vertical gravitational acceleration to calculate the vertical drop in that remaining time:
$t_{total} = \frac{h}{v_{horizontal}}$
From **fig B**, we can see that $x = 150$ m.

3 $v_{horizontal}$ can be found by resolving the velocity to give the horizontal component:
$v_{horizontal} = v_{max} \times \cos 45°$

4 The overall velocity will come from the cannon's acceleration of the cannonball:
$v = u + at$
where $u = 0$ m s^{-1}, and the question tells us that the explosion acts for 0.05 seconds.

5 Newton's second law of motion gives us the acceleration caused by the sling:
$a = \frac{F}{m}$
Calculate the answer by reversing these steps:
The acceleration caused by the explosion:
$a = \frac{F}{m}$
$a =$

MOTION THINKING BIGGER 31

SCIENCE COMMUNICATION

1 The extract opposite is a draft for a university essay about the Mughal siege of 1857. Consider the extract and comment on the type of writing being used. For example, think about whether this is a scientist reporting the results of their experiments, a scientific review of data, a newspaper or a magazine-style article for a specific audience. Try and answer the following questions:
   (a) How can you tell that the author is doubtful about the historical source material?
   (b) What is the purpose of this mathematical analysis, for its inclusion in this essay?

INTERPRETATION NOTES

Once you have answered the calculation questions below, decide whether you think the Mughal siege happened as the author suggests.

PHYSICS IN DETAIL

Now we will look at the physics in detail. You may need to combine concepts from different areas of physics to work out the answers.

2 Complete the calculation steps, in reverse as suggested, in order to find out the answer, H:
   (a) the acceleration caused by the explosion
   (b) overall velocity that the cannonball is projected from the cannon
   (c) horizontal and vertical components of the velocity
   (d) time of flight found from the horizontal travel
   (e) time to reach maximum height using vertical motion
   (f) remaining flight time from maximum height
   (g) height fallen from the maximum in the remaining flight time
   (h) final answer, H.

3 State **two** assumptions that have been made in these calculations.

4 Calculate what difference there would be in the answer if the cannon was loaded with different cannonballs of masses 10 kg and 14 kg. Note from **fig B** that the fortress walls are 24 m high. Comment on these answers.

5 If the available supply of cannonballs offered very variable masses, how might the Mughals be able to overcome the problems shown in question 4.

THINKING BIGGER TIP

Inside a cannon, an explosion exerts a force on the cannonball to fire it out of the cannon.

ACTIVITY

Imagine the writer of this essay is a friend of yours, and he has come to you for help with the calculations as he is not an experienced scientist. His section 'Steps to the answer' was taken from a research source about a different fortress under siege. Write an email to Claus to explain the calculations required in each step.

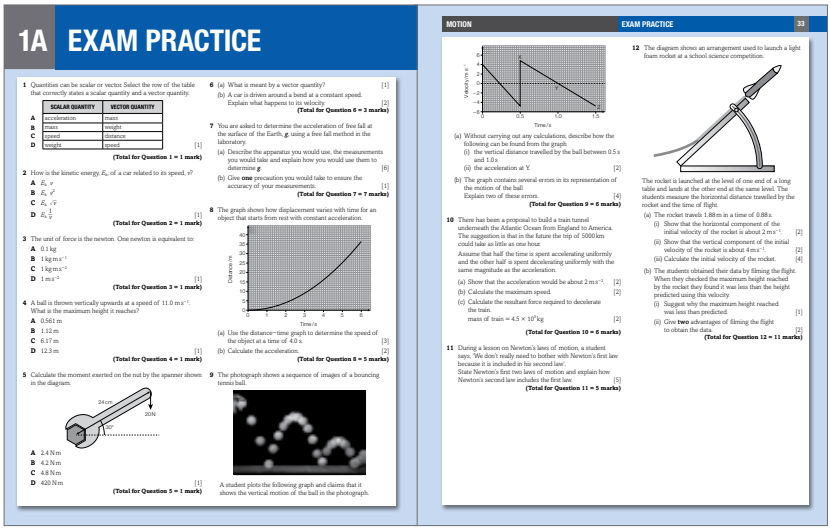
INTERPRETATION NOTES

You can assume that the writer understands mathematics, and is generally intelligent – a student who could have done A level physics but preferred arts subjects.

At the end of most chapters there is an opportunity to read and work with real-life research and writing about science.

The activities help you to read real-life material that's relevant to your course, analyse how scientists write, think critically and consider how different aspects of your learning piece together.

Transferable skills are practised both here and in the checkpoint questions.



1A EXAM PRACTICE

1 Quantities can be scalar or vector. Select the row of the table that correctly states a scalar quantity and a vector quantity.

	SCALAR QUANTITY	VECTOR QUANTITY
A	acceleration	mass
B	mass	weight
C	speed	distance
D	weight	speed

[1]
(Total for Question 1 = 1 mark)

2 How is the kinetic energy, E_k, of a car related to its speed, v?
A $E_k \propto v$
B $E_k \propto v^2$
C $E_k \propto \sqrt{v}$
D $E_k \propto \frac{1}{v}$
[1]
(Total for Question 2 = 1 mark)

3 The unit of force is the newton. One newton is equivalent to
A 0.1 kg
B 1 kg m s^{-2}
C 1 kg m s^{-1}
D 1 m s^{-2}
[1]
(Total for Question 3 = 1 mark)

4 A ball is thrown vertically upwards at a speed of 11.0 m s^{-1}. What is the maximum height it reaches?
A 0.561 m
B 1.12 m
C 6.17 m
D 12.3 m
[1]
(Total for Question 4 = 1 mark)

5 Calculate the moment exerted on the nut by the spanner shown in the diagram.

A 2.4 Nm
B 4.2 Nm
C 4.8 Nm
D 420 Nm
[1]
(Total for Question 5 = 1 mark)

6 (a) What is meant by a vector quantity? [1]
(b) A car is driven around a bend at a constant speed. Explain what happens to its velocity. [2]
(Total for Question 6 = 3 marks)

7 You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory.
(a) Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine g. [6]
(b) Give **one** precaution you would take to ensure the accuracy of your measurements. [1]
(Total for Question 7 = 7 marks)

8 The graph shows how displacement varies with time for an object that starts from rest with constant acceleration.

(a) Use the distance–time graph to determine the speed of the object at a time of 4.0 s. [3]
(b) Calculate the acceleration. [2]
(Total for Question 8 = 5 marks)

9 The photograph shows a sequence of images of a bouncing tennis ball.

A student plots the following graph and claims that it shows the vertical motion of the ball in the photograph.

MOTION EXAM PRACTICE 33

(a) Without carrying out any calculations, describe how the following can be found from the graph
   (i) the vertical distance travelled by the ball between 0.5 s and 1.0 s
   (ii) the acceleration at Y [2]
(b) The graph contains several errors in its representation of the motion of the ball
Explain two of these errors. [4]
(Total for Question 9 = 6 marks)

10 There has been a proposal to build a train tunnel underneath the Atlantic Ocean from England to America. The suggestion is that in the future the trip of 5000 km could take as little as one hour.
Assume that half the time is spent accelerating uniformly and the other half is spent decelerating uniformly with the same magnitude as the acceleration.
(a) Show that the acceleration would be about 2 m s^{-2}. [2]
(b) Calculate the maximum speed. [2]
(c) Calculate the resultant force required to decelerate the train.
mass of train = 4.5×10^7 kg [2]
(Total for Question 10 = 6 marks)

11 During a lesson on Newton's laws of motion, a student says, 'We don't really need to bother with Newton's first law because it is included in his second law'.
State Newton's first two laws of motion and explain how Newton's second law includes the first law. [5]
(Total for Question 11 = 5 marks)

12 The diagram shows an arrangement used to launch a light foam rocket at a school science competition.

The rocket is launched at the level of one end of a long table and lands at the other end at the same level. The students measure the horizontal distance travelled by the rocket and the time of flight.
(a) The rocket travels 1.88 m in a time of 0.88 s.
   (i) Show that the horizontal component of the initial velocity of the rocket is about 2 m s^{-1}. [2]
   (ii) Show that the vertical component of the initial velocity of the rocket is about 4 m s^{-1}. [2]
   (iii) Calculate the initial velocity of the rocket. [4]
(b) The students obtained their data by filming the flight. When they checked the maximum height reached by the rocket they found it was less than the height predicted using this velocity.
   (i) Suggest why the maximum height reached was less than predicted. [1]
   (ii) Give **two** advantages of filming the flight to obtain the data. [2]
(Total for Question 12 = 11 marks)

Exam-style questions at the end of each chapter are tailored to the specification to allow for practice and development of exam writing technique. They also allow for practice responding to the **command words** used in the exams.

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> **I like the modular nature of it, the fact that I can choose whichever core units I want to do, whichever applied units I want to do. It's very comprehensive. It opens up many doors to many universities, international.**

Wang, Pearson Edexcel International Advanced Level student from Sri Lanka, studying Chemistry, Biology, Physics, and Mathematics.

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