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Cambridge International AS and A Level
Physics
Coursebook

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Example answers and all other end-of-chapter questions were written by the authors.

Contents

Introduction

This book covers the entire syllabus of Cambridge International Examinations AS and A Level Physics. It is designed to work with the syllabus that will be examined from 2016. It is in three parts:

- Chapters 1–16 and P1: the AS level content, covered in the first year of the course, including a chapter (P1) dedicated to the development of your practical skills
- Chapters 17–32 and P2: the remaining A level content, including a chapter (P2) dedicated to developing your ability to plan, analyse and evaluate practical investigations
- Appendices of useful formulae, a Glossary and an Index.

The main tasks of a textbook like this are to explain the various concepts of physics that you need to understand and to provide you with questions that will help you to test your understanding and prepare for your examinations. You will find a visual guide to the structure of each chapter and the features of this book on the next two pages.

When tackling questions, it is a good idea to make a first attempt without referring to the explanations in this Coursebook or to your notes. This will help to reveal any gaps in your understanding. By working out which concepts you find most challenging, and by spending more time to understand these concepts at an early stage, you will progress faster as the course continues.

The CD-ROM that accompanies this Coursebook includes answers with workings for all the questions in the book, as well as suggestions for revising and preparing for any examinations you take. There are also lists of recommended further reading, which in many cases will take you beyond the requirements of the syllabus, but which will help you deepen your knowledge and explain more of the background to the physics concepts covered in this Coursebook.

In your studies, you will find that certain key concepts come up again and again, and that these concepts form ‘themes’ that link the different areas of physics together. It will help you to progress and gain confidence in tackling problems if you take note of these themes. For this Coursebook, these key concepts include:

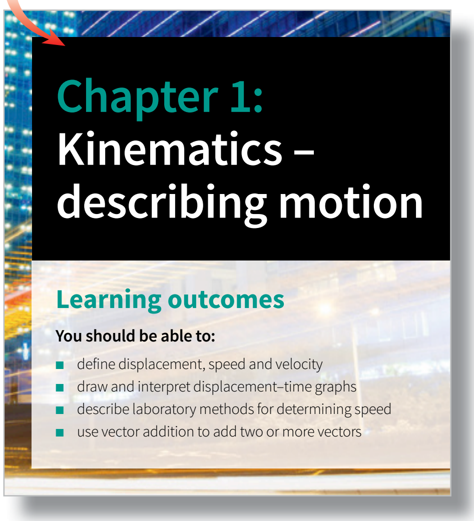
- Models of physical systems
- Testing predictions against evidence
- Mathematics as a language and problem-solving tool
- Matter, energy and waves
- Forces and fields

In this Coursebook, the mathematics has been kept to the minimum required by the Cambridge International Examinations AS and A Level Physics syllabus. If you are also studying mathematics, you may find that more advanced techniques such as calculus will help you with many aspects of physics.

Studying physics can be a stimulating and worthwhile experience. It is an international subject; no single country has a monopoly on the development of the ideas. It can be a rewarding exercise to discover how men and women from many countries have contributed to our knowledge and well-being, through their research into and application of the concepts of physics. We hope not only that this book will help you to succeed in your future studies and career, but also that it will stimulate your curiosity and fire your imagination. Today’s students become the next generation of physicists and engineers, and we hope that you will learn from the past to take physics to ever-greater heights.

How to use this book

Each chapter begins with a short list of the facts and concepts that are explained in it.



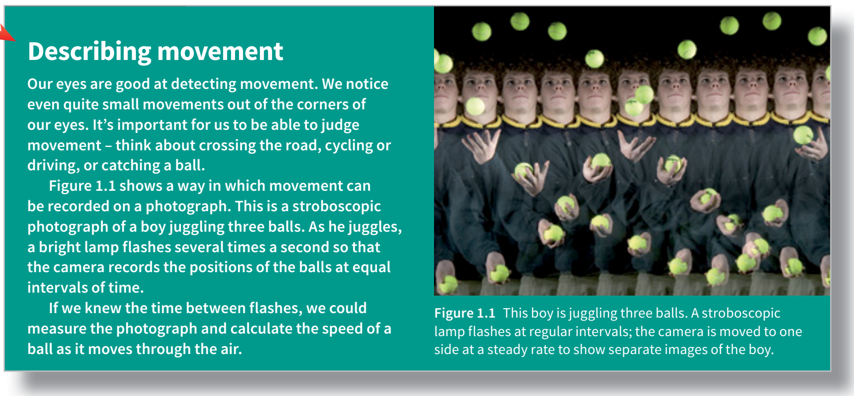
Chapter 1:
Kinematics – describing motion

Learning outcomes

You should be able to:

- define displacement, speed and velocity
- draw and interpret displacement–time graphs
- describe laboratory methods for determining speed
- use vector addition to add two or more vectors

There is a short context at the beginning of each chapter, containing an example of how the material covered in the chapter relates to the 'real world'.



Describing movement

Our eyes are good at detecting movement. We notice even quite small movements out of the corners of our eyes. It's important for us to be able to judge movement – think about crossing the road, cycling or driving, or catching a ball.

Figure 1.1 shows a way in which movement can be recorded on a photograph. This is a stroboscopic photograph of a boy juggling three balls. As he juggles, a bright lamp flashes several times a second so that the camera records the positions of the balls at equal intervals of time.

If we knew the time between flashes, we could measure the photograph and calculate the speed of a ball as it moves through the air.

Figure 1.1 This boy is juggling three balls. A stroboscopic lamp flashes at regular intervals; the camera is moved to one side at a steady rate to show separate images of the boy.

The text and illustrations describe and explain all of the facts and concepts that you need to know. The chapters, and often the content within them as well, are arranged in a similar sequence to your syllabus, but with AS and A Level content clearly separated into the two halves of the book.

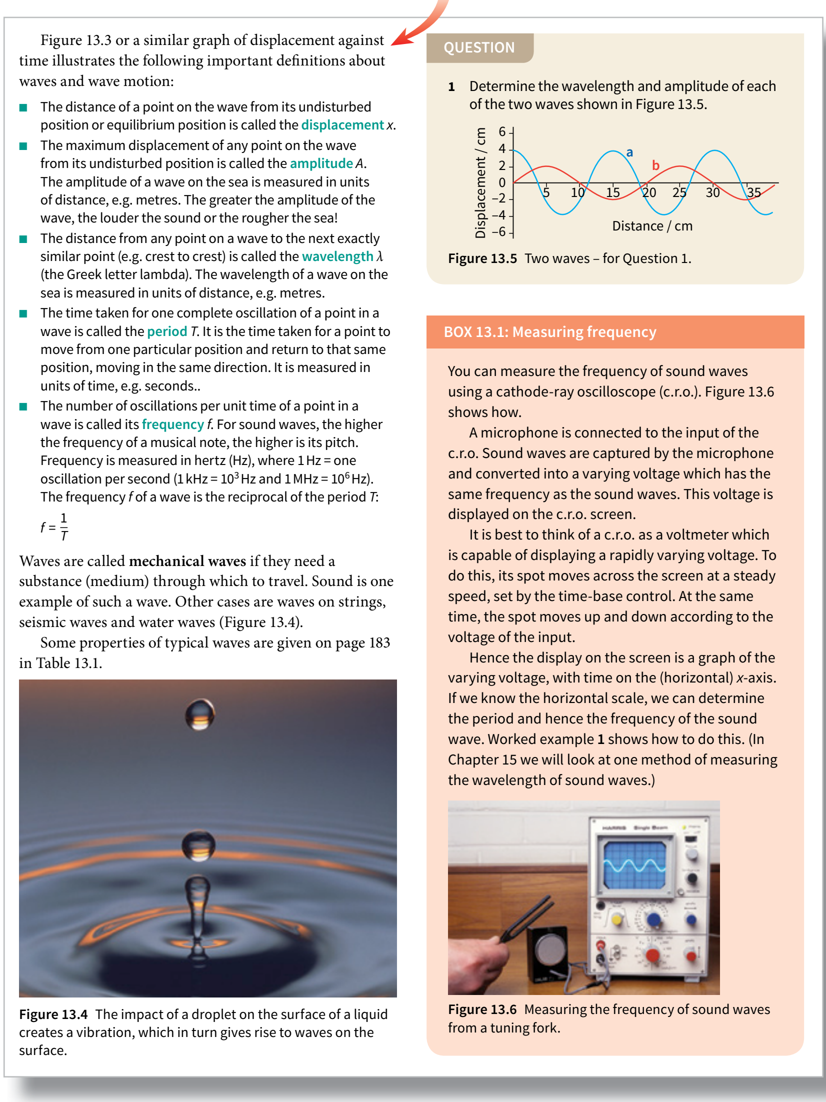


Figure 13.3 or a similar graph of displacement against time illustrates the following important definitions about waves and wave motion:

- The distance of a point on the wave from its undisturbed position or equilibrium position is called the **displacement** *x*.
- The maximum displacement of any point on the wave from its undisturbed position is called the **amplitude** *A*. The amplitude of a wave on the sea is measured in units of distance, e.g. metres. The greater the amplitude of the wave, the louder the sound or the rougher the sea!
- The distance from any point on a wave to the next exactly similar point (e.g. crest to crest) is called the **wavelength** λ (the Greek letter lambda). The wavelength of a wave on the sea is measured in units of distance, e.g. metres.
- The time taken for one complete oscillation of a point in a wave is called the **period** *T*. It is the time taken for a point to move from one particular position and return to that same position, moving in the same direction. It is measured in units of time, e.g. seconds..
- The number of oscillations per unit time of a point in a wave is called its **frequency** *f*. For sound waves, the higher the frequency of a musical note, the higher is its pitch. Frequency is measured in hertz (Hz), where 1 Hz = one oscillation per second ($1\,\text{kHz} = 10^3\,\text{Hz}$ and $1\,\text{MHz} = 10^6\,\text{Hz}$). The frequency *f* of a wave is the reciprocal of the period *T*:

  $$f = \frac{1}{T}$$

Waves are called **mechanical waves** if they need a substance (medium) through which to travel. Sound is one example of such a wave. Other cases are waves on strings, seismic waves and water waves (Figure 13.4).

Some properties of typical waves are given on page 183 in Table 13.1.

Figure 13.4 The impact of a droplet on the surface of a liquid creates a vibration, which in turn gives rise to waves on the surface.

QUESTION

1 Determine the wavelength and amplitude of each of the two waves shown in Figure 13.5.

Figure 13.5 Two waves – for Question 1.

BOX 13.1: Measuring frequency

You can measure the frequency of sound waves using a cathode-ray oscilloscope (c.r.o.). Figure 13.6 shows how.

A microphone is connected to the input of the c.r.o. Sound waves are captured by the microphone and converted into a varying voltage which has the same frequency as the sound waves. This voltage is displayed on the c.r.o. screen.

It is best to think of a c.r.o. as a voltmeter which is capable of displaying a rapidly varying voltage. To do this, its spot moves across the screen at a steady speed, set by the time-base control. At the same time, the spot moves up and down according to the voltage of the input.

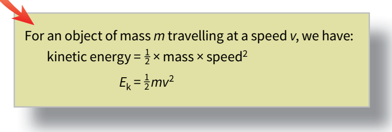
Hence the display on the screen is a graph of the varying voltage, with time on the (horizontal) *x*-axis. If we know the horizontal scale, we can determine the period and hence the frequency of the sound wave. Worked example **1** shows how to do this. (In Chapter 15 we will look at one method of measuring the wavelength of sound waves.)

Figure 13.6 Measuring the frequency of sound waves from a tuning fork.

Questions throughout the text give you a chance to check that you have understood the topic you have just read about. You can find the answers to these questions on the CD-ROM.

This book does not contain detailed instructions for doing particular experiments, but you will find background information about the practical work you need to do in these Boxes. There are also two chapters, P1 and P2, which provide detailed information about the practical skills you need to develop during your course.

Important equations and other facts are shown in highlight boxes.



For an object of mass *m* travelling at a speed *v*, we have:

kinetic energy = $\frac{1}{2}$ × mass × speed^2

$$E_\text{k} = \tfrac{1}{2}mv^2$$

Wherever you need to know how to use a formula to carry out a calculation, there are worked example boxes to show you how to do this.

WORKED EXAMPLE

1 In Figure 6.5, trolley A of mass 0.80 kg travelling at a velocity of 3.0 m s^{-1} collides head-on with a stationary trolley B. Trolley B has twice the mass of trolley A. The trolleys stick together and have a common velocity of 1.0 m s^{-1} after the collision. Show that momentum is conserved in this collision.

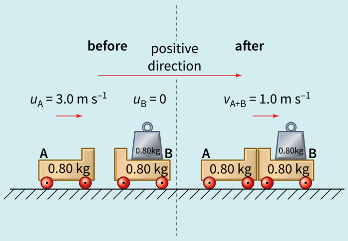


Figure 6.5 The state of trolleys A and B, before and after the collision.

Step 1 Make a sketch using the information given in the question. Notice that we need two diagrams to show the situations, one before and one after the collision. Similarly, we need two calculations – one for the momentum of the trolleys before the collision and one for their momentum after the collision.

Step 2 Calculate the momentum before the collision:

momentum of trolleys before collision

$$= m_A \times u_A + m_B \times u_B$$
$$= (0.80 \times 3.0) + 0$$
$$= 2.4\,\text{kg m s}^{-1}$$

Trolley B has no momentum before the collision, because it is not moving.

Step 3 Calculate the momentum after the collision:

momentum of trolleys after collision

$$= (m_A + m_B) \times v_{A+B}$$
$$= (0.80 + 1.60) \times 1.0$$
$$= 2.4\,\text{kg m s}^{-1}$$

So, both before and after the collision, the trolleys have a combined momentum of 2.4 kg m s^{-1}. Momentum has been conserved.

Key words are highlighted in the text when they are first introduced.

The metre, kilogram and second are three of the seven SI base units. These are defined with great precision so that every standards laboratory can reproduce them correctly.

You will also find definitions of these words in the Glossary.

base units Defined units of the SI system from which all other units are derived.

There is a summary of key points at the end of each chapter. You might find this helpful when you are revising.

Summary

- Forces are vector quantities that can be added by means of a vector triangle. Their resultant can be determined using trigonometry or by scale drawing.
- Vectors such as forces can be resolved into components. Components at right angles to one another can be treated independently of one another. For a force F at an angle θ to the x-direction, the components are:

  x-direction: $F\cos\theta$

  y-direction: $F\sin\theta$
- The moment of a force = force × perpendicular distance of the pivot from the line of action of the force.
- The principle of moments states that, for any object that is in equilibrium, the sum of the clockwise moments about any point provided by the forces acting on the object equals the sum of the anticlockwise moments about that same point.
- A couple is a pair of equal, parallel but opposite forces whose effect is to produce a turning effect on a body without giving it linear acceleration.

  torque of a couple = one of the forces × perpendicular distance between the forces
- For an object to be in equilibrium, the resultant force acting on the object must be zero and the resultant moment must be zero.

Questions at the end of each chapter begin with shorter answer questions, then move on to more demanding exam-style questions, some of which may require use of knowledge from previous chapters. Answers to these questions can be found on the CD–ROM.

1 Figure 15.19 shows a stationary wave on a string.

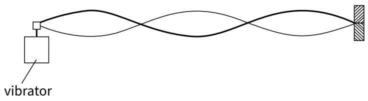


Figure 15.19 For End-of-chapter Question 1.

a On a copy of Figure 15.19, label one **node** (N) and one **antinode** (A). [1]

b Mark on your diagram the wavelength of the standing wave and label it λ. [1]

c The frequency of the vibrator is doubled. Describe the changes in the standing wave pattern. [1]

2 A tuning fork which produces a note of 256 Hz is placed above a tube which is nearly filled with water. The water level is lowered until resonance is first heard.

a Explain what is meant by the term **resonance**. [1]

b The length of the column of air above the water when resonance is first heard is 31.2 cm. Calculate the speed of the sound wave. [2]