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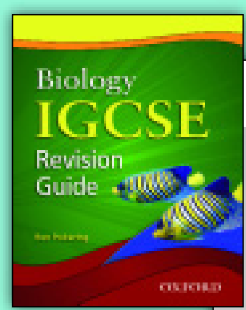

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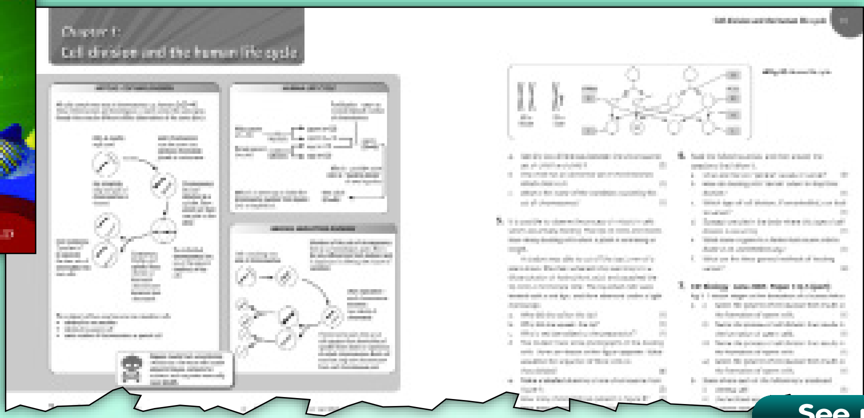

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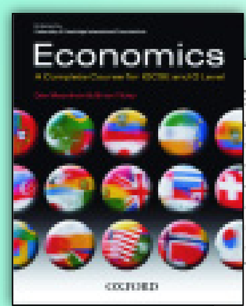

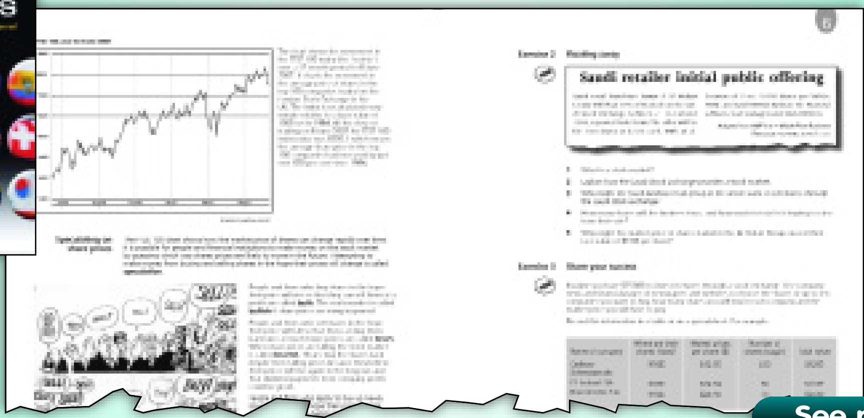

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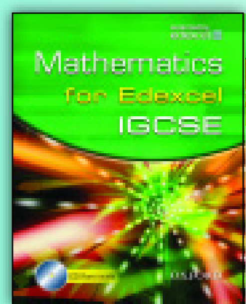

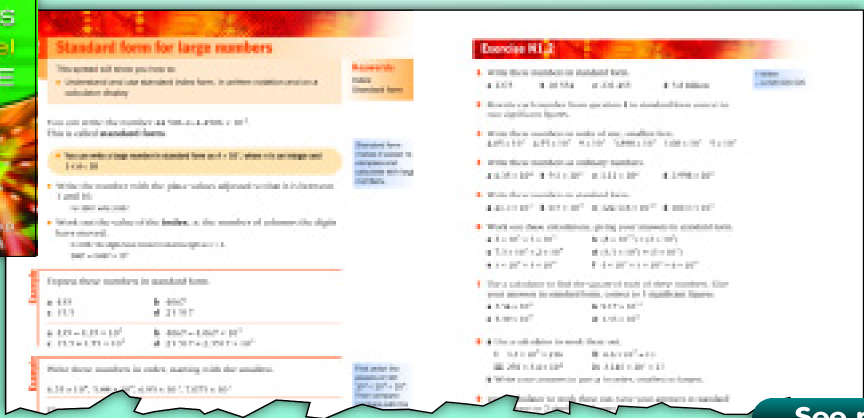

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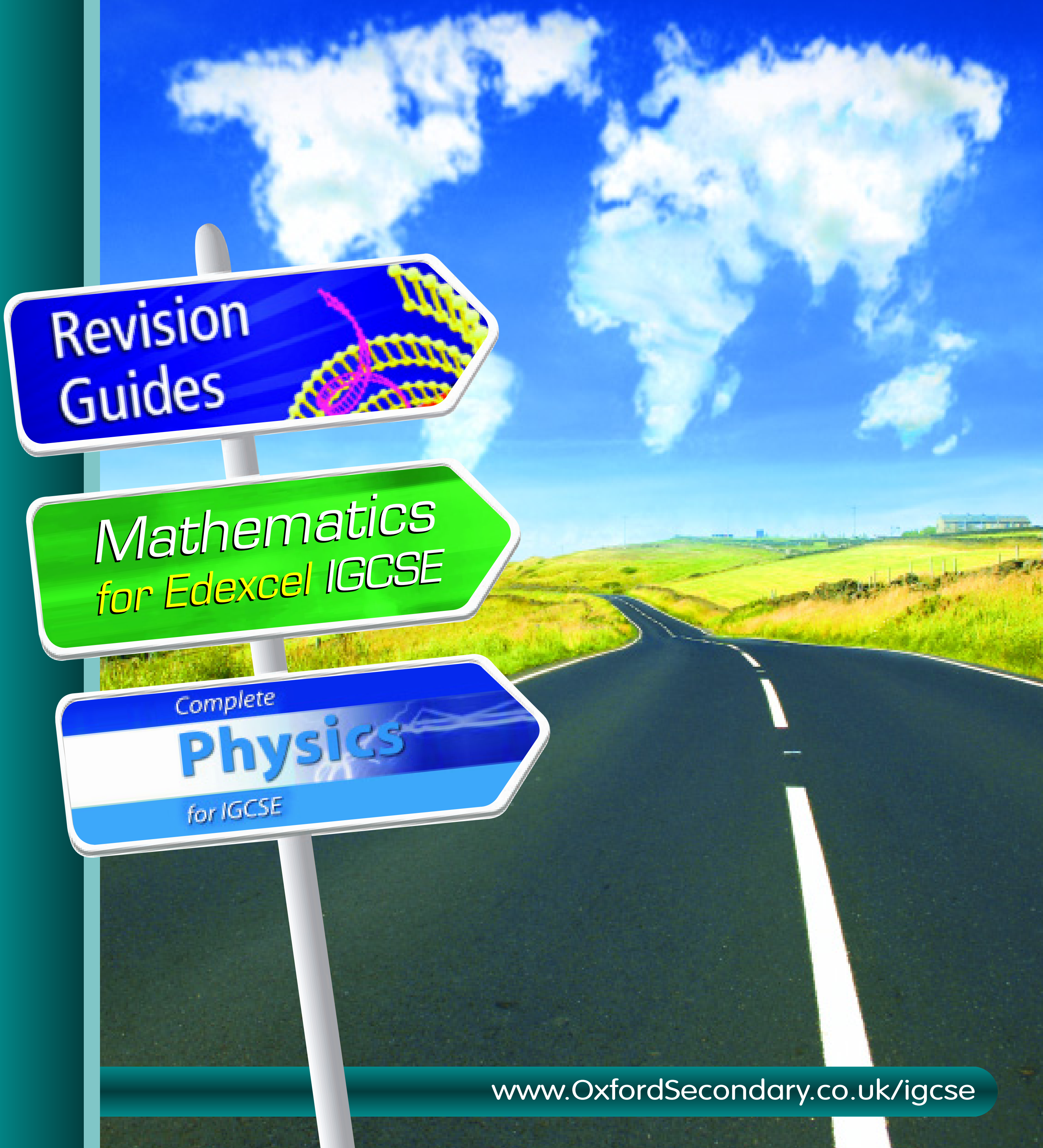

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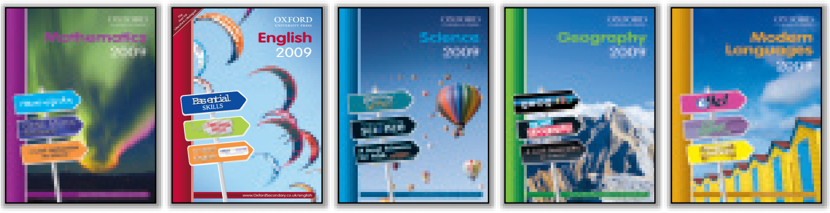

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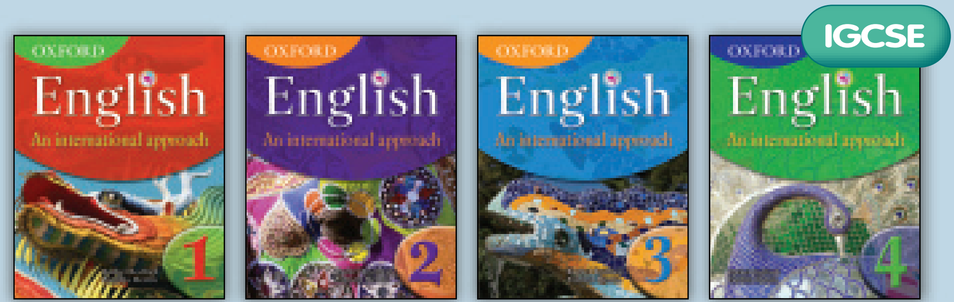

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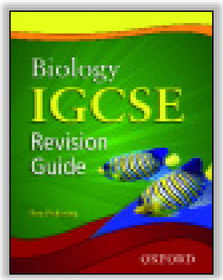

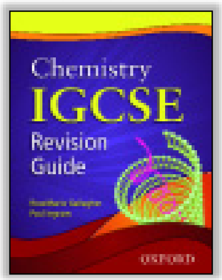

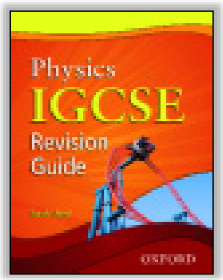

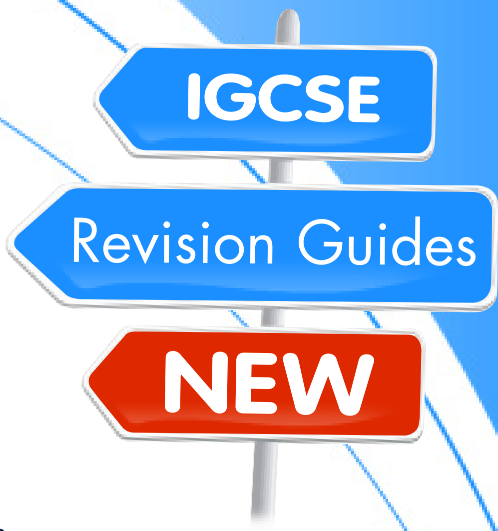

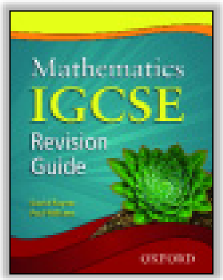

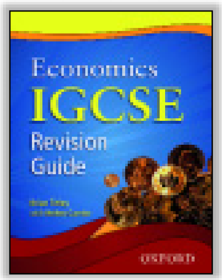

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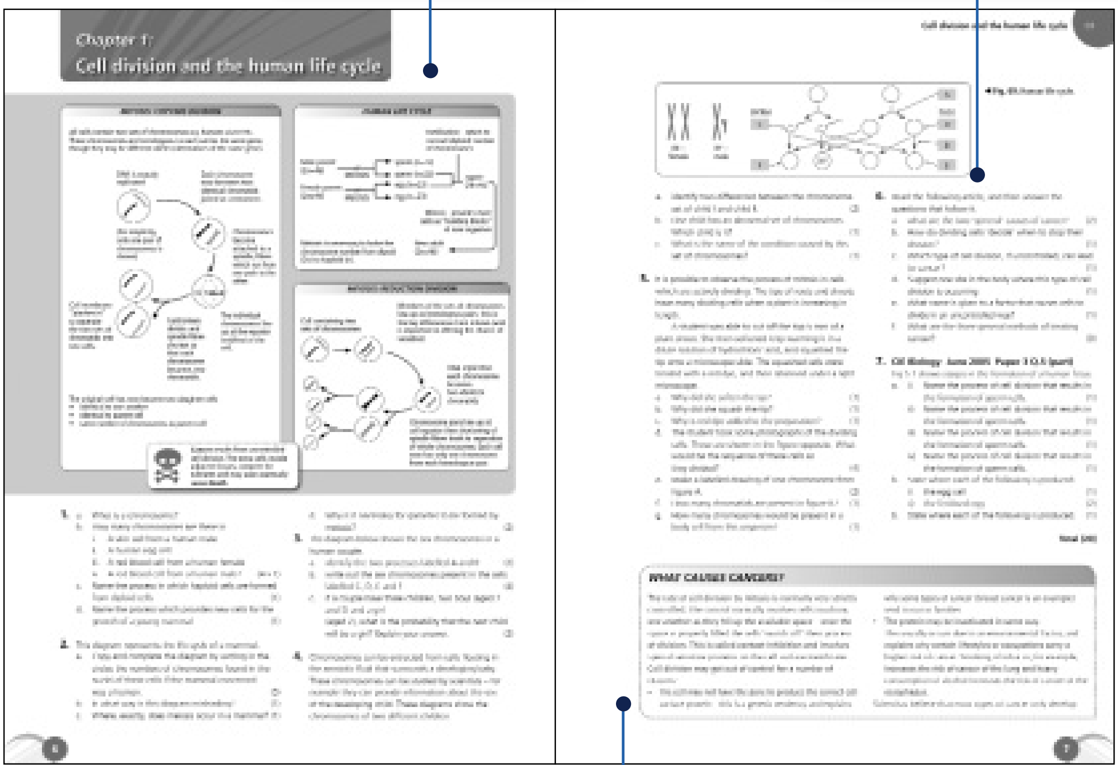

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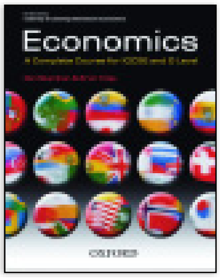

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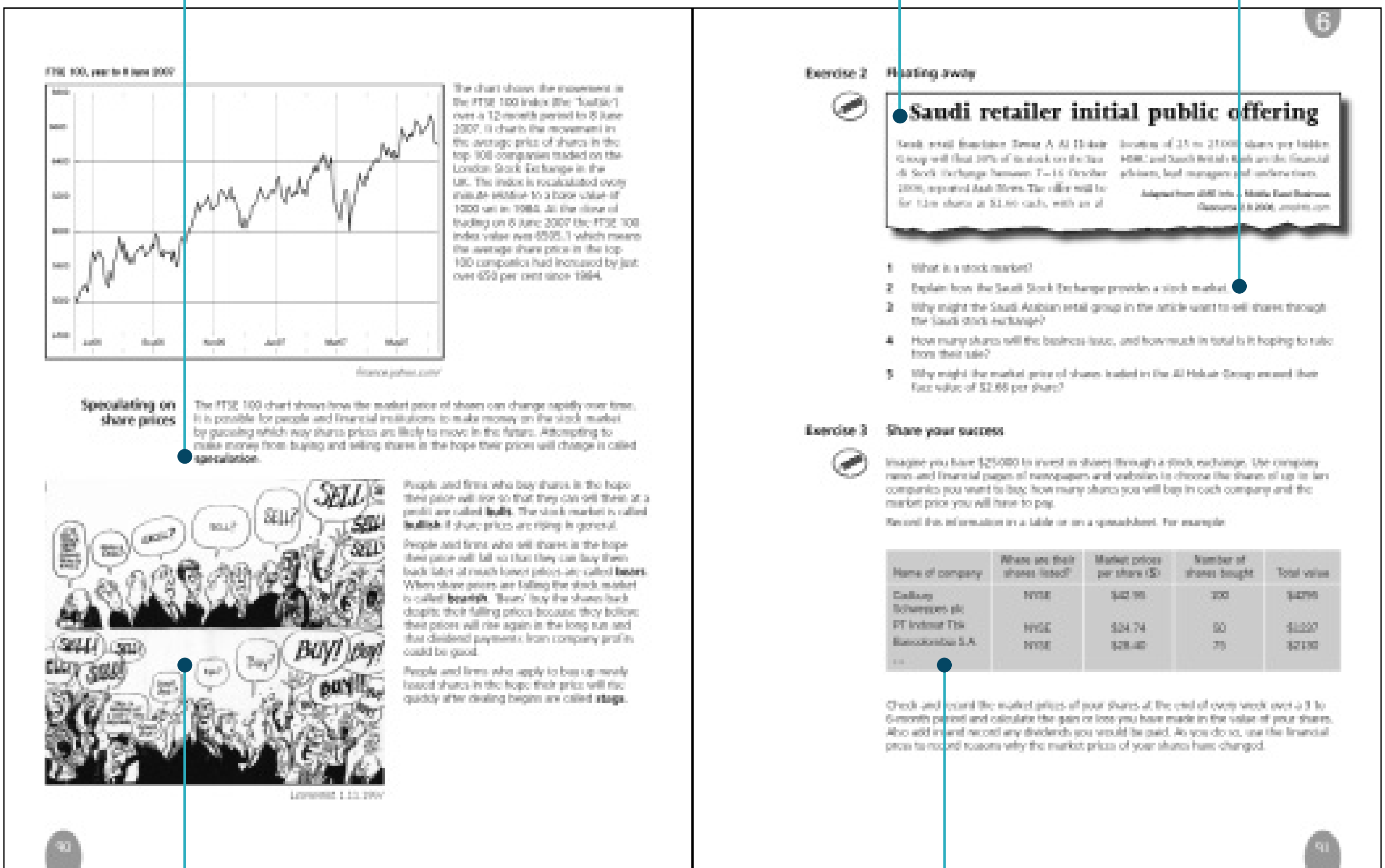

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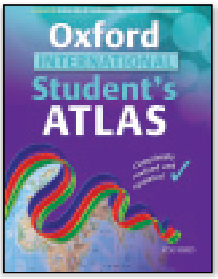

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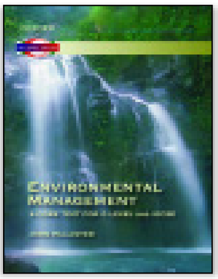

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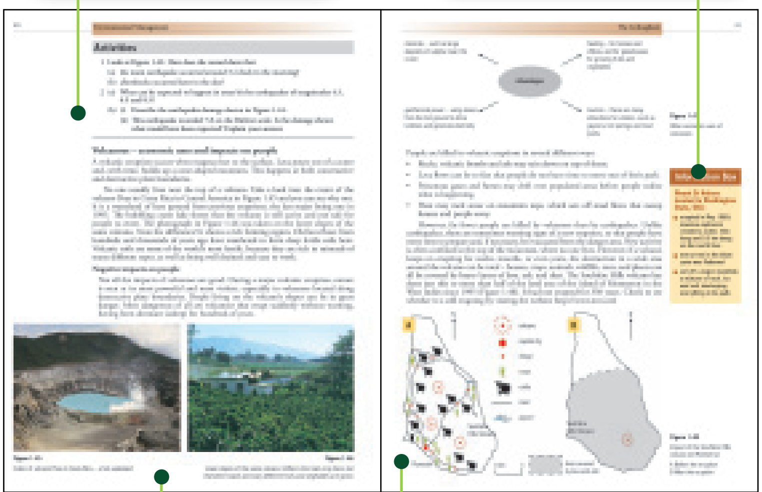

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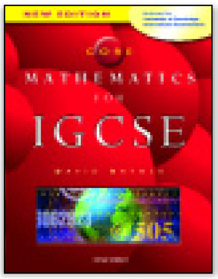

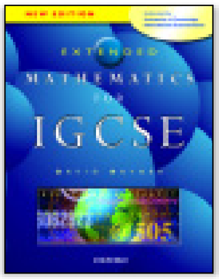

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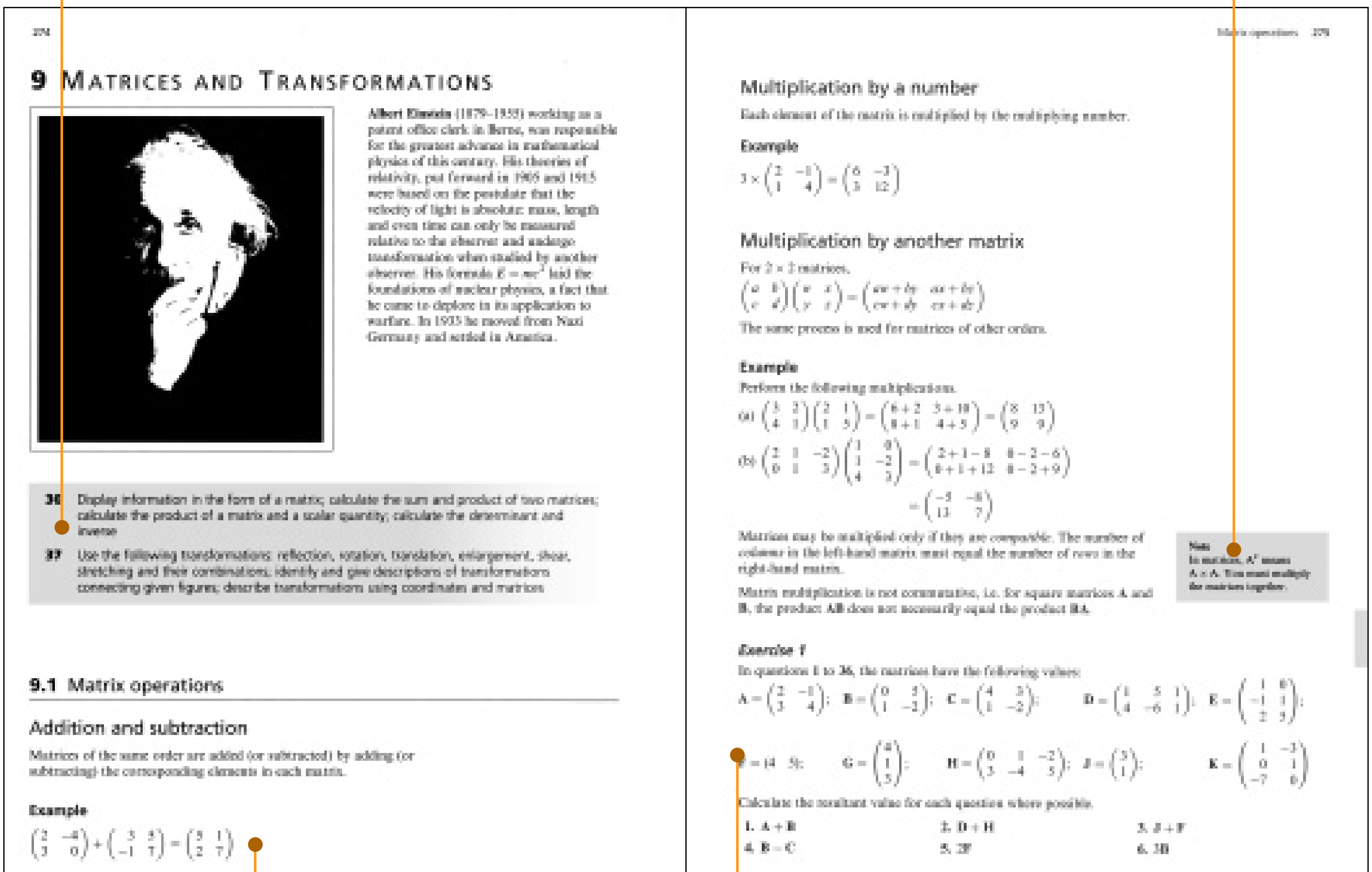
9 Matrices and Transformations

9.1 Matrix operations

Addition and subtraction

Example

Multiplication by a number

Example

Multiplication by another matrix

Example

Exercise 1

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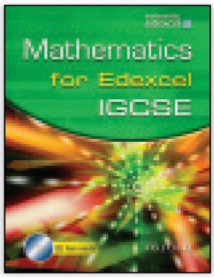

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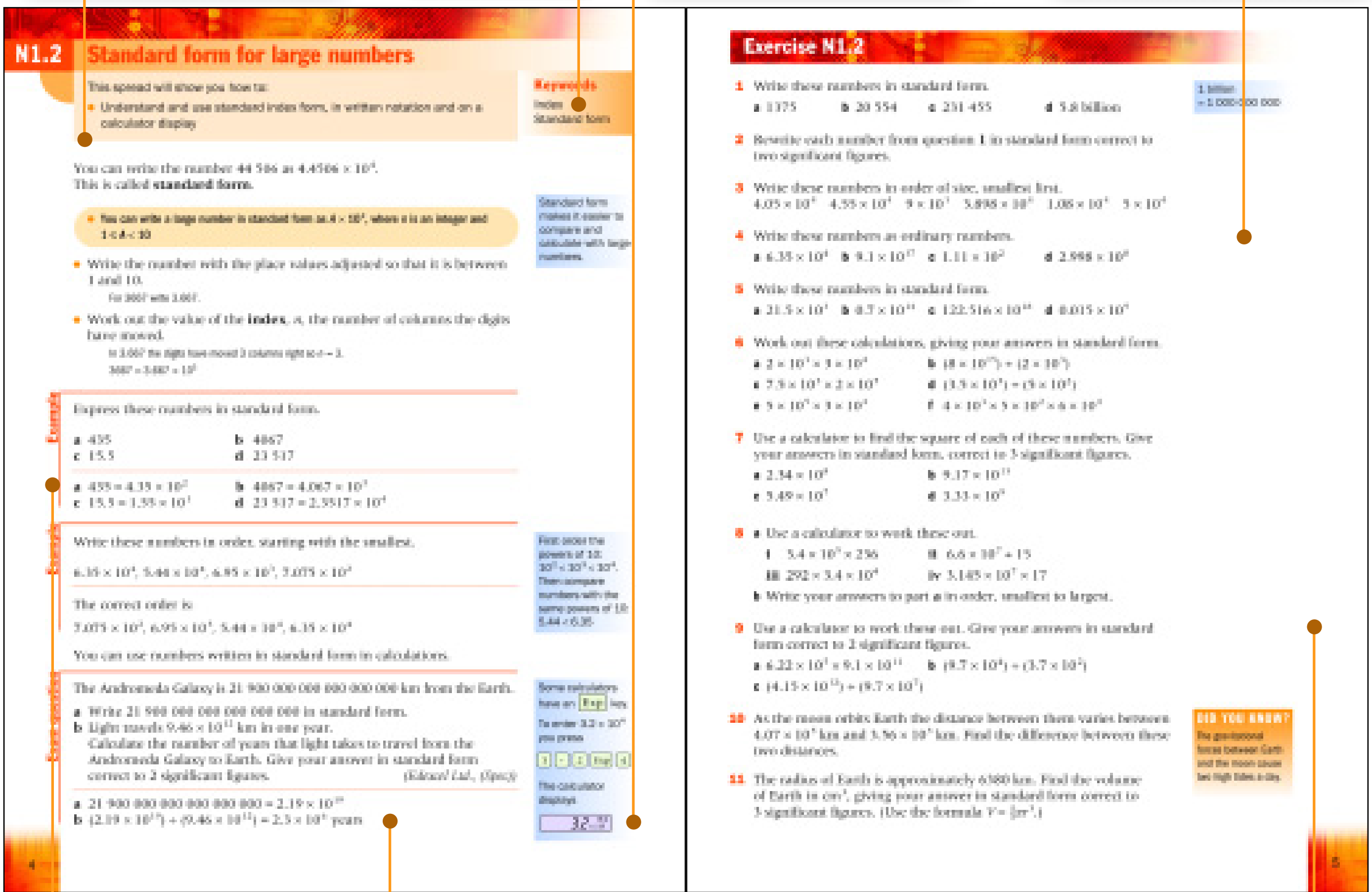

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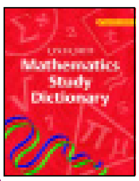

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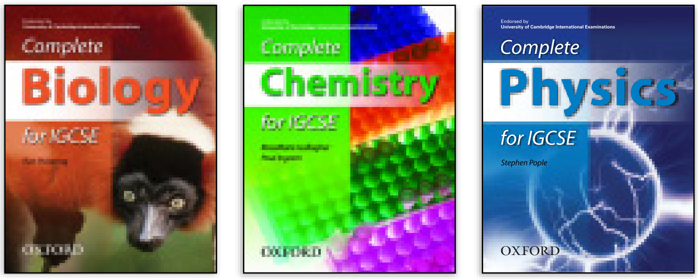

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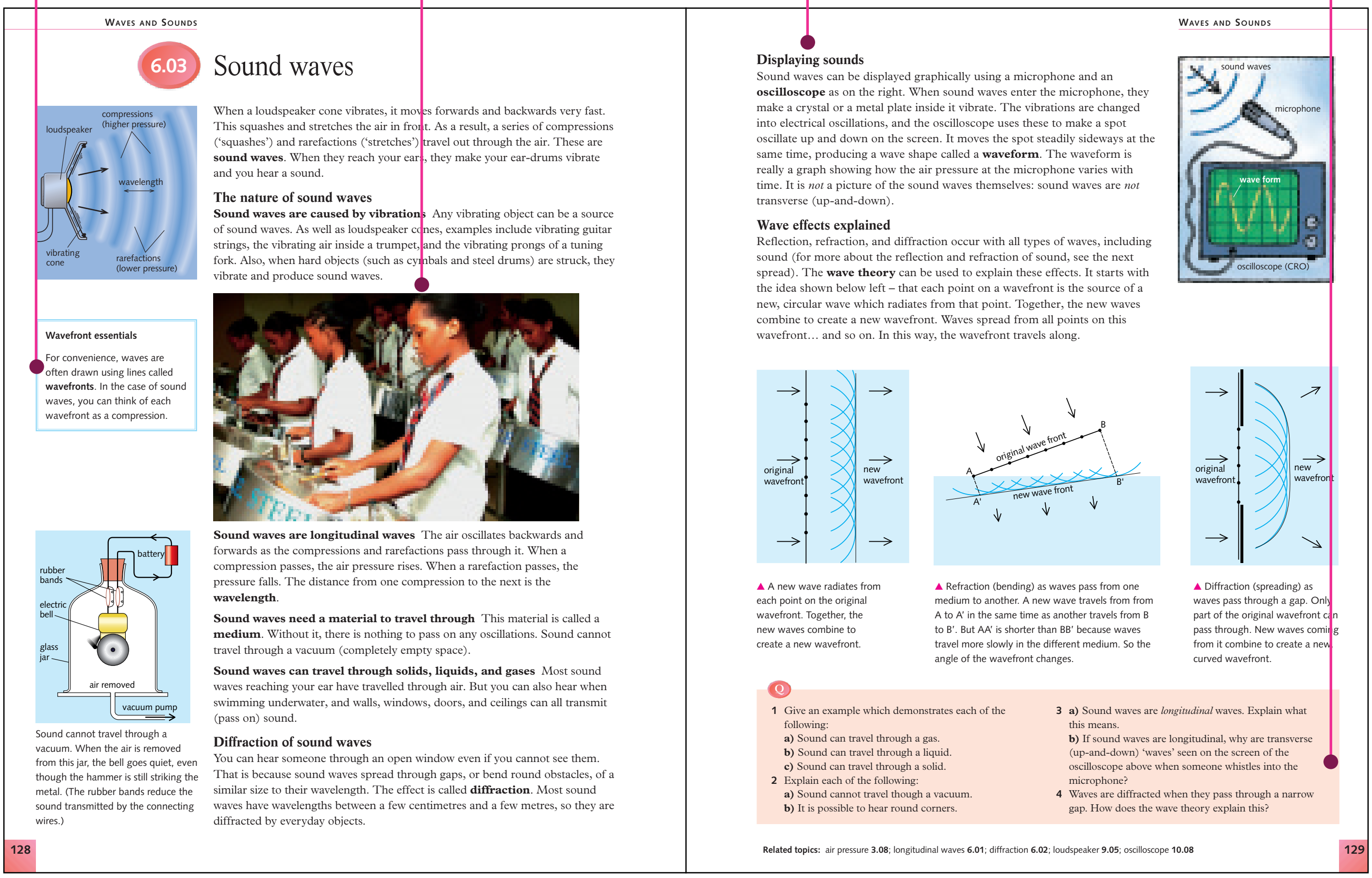

WAVES AND SOUNDS

6.03 Sound waves

When a loudspeaker cone vibrates, it moves forwards and backwards very fast. This squashes and stretches the air in front. As a result, a series of compressions ('squashes') and rarefactions ('stretches') travel out through the air. These are **sound waves**. When they reach your ears, they make your ear-drums vibrate and you hear a sound.

The nature of sound waves

Sound waves are caused by vibrations Any vibrating object can be a source of sound waves. As well as loudspeaker cones, examples include vibrating guitar strings, the vibrating air inside a trumpet, and the vibrating prongs of a tuning fork. Also, when hard objects (such as cymbals and steel drums) are struck, they vibrate and produce sound waves.

Wavefront essentials

For convenience, waves are often drawn using lines called **wavefronts**. In the case of sound waves, you can think of each wavefront as a compression.

Sound waves are longitudinal waves The air oscillates backwards and forwards as the compressions and rarefactions pass through it. When a compression passes, the air pressure rises. When a rarefaction passes, the pressure falls. The distance from one compression to the next is the **wavelength**.

Sound waves need a material to travel through This material is called a **medium**. Without it, there is nothing to pass on any oscillations. Sound cannot travel through a vacuum (completely empty space).

Sound waves can travel through solids, liquids, and gases Most sound waves reaching your ear have travelled through air. But you can also hear when swimming underwater, and walls, windows, doors, and ceilings can all transmit (pass on) sound.

Sound cannot travel through a vacuum. When the air is removed from this jar, the bell goes quiet, even though the hammer is still striking the metal. (The rubber bands reduce the sound transmitted by the connecting wires.)

Diffraction of sound waves

You can hear someone through an open window even if you cannot see them. That is because sound waves spread through gaps, or bend round obstacles, of a similar size to their wavelength. The effect is called **diffraction**. Most sound waves have wavelengths between a few centimetres and a few metres, so they are diffracted by everyday objects.

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WAVES AND SOUNDS

Displaying sounds

Sound waves can be displayed graphically using a microphone and an **oscilloscope** as on the right. When sound waves enter the microphone, they make a crystal or a metal plate inside it vibrate. The vibrations are changed into electrical oscillations, and the oscilloscope uses these to make a spot oscillate up and down on the screen. It moves the spot steadily sideways at the same time, producing a wave shape called a **waveform**. The waveform is really a graph showing how the air pressure at the microphone varies with time. It is *not* a picture of the sound waves themselves: sound waves are *not* transverse (up-and-down).

Wave effects explained

Reflection, refraction, and diffraction occur with all types of waves, including sound (for more about the reflection and refraction of sound, see the next spread). The **wave theory** can be used to explain these effects. It starts with the idea shown below left – that each point on a wavefront is the source of a new, circular wave which radiates from that point. Together, the new waves combine to create a new wavefront. Waves spread from all points on this wavefront… and so on. In this way, the wavefront travels along.

▲ A new wave radiates from each point on the original wavefront. Together, the new waves combine to create a new wavefront.

▲ Refraction (bending) as waves pass from one medium to another. A new wave travels from from A to A′ in the same time as another travels from B to B′. But AA′ is shorter than BB′ because waves travel more slowly in the different medium. So the angle of the wavefront changes.

▲ Diffraction (spreading) as waves pass through a gap. Only part of the original wavefront can pass through. New waves coming from it combine to create a new curved wavefront.

Q

1 Give an example which demonstrates each of the following:
   a) Sound can travel through a gas.
   b) Sound can travel through a liquid.
   c) Sound can travel through a solid.
2 Explain each of the following:
   a) Sound cannot travel though a vacuum.
   b) It is possible to hear round corners.
3 **a)** Sound waves are *longitudinal* waves. Explain what this means.
   b) If sound waves are longitudinal, why are transverse (up-and-down) 'waves' seen on the screen of the oscilloscope above when someone whistles into the microphone?
4 Waves are diffracted when they pass through a narrow gap. How does the wave theory explain this?

Related topics: air pressure **3.08**; longitudinal waves **6.01**; diffraction **6.02**; loudspeaker **9.05**; oscilloscope **10.08**

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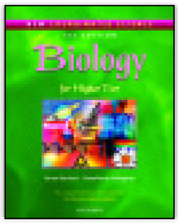

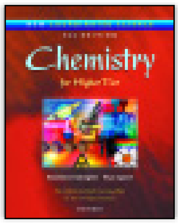

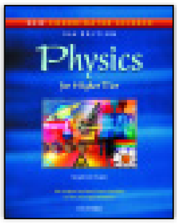

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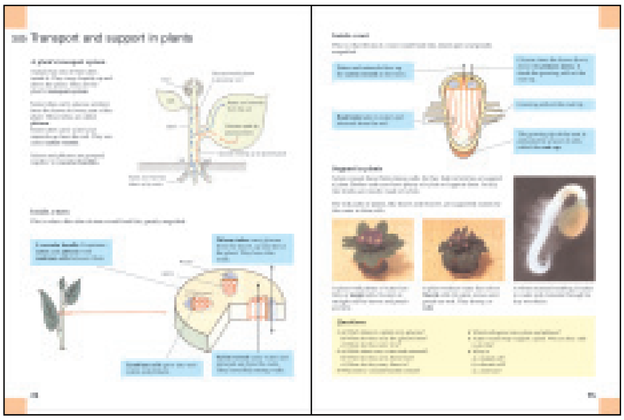

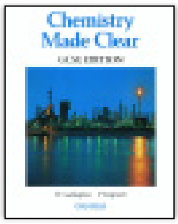

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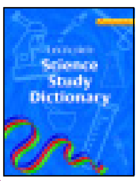

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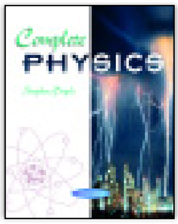

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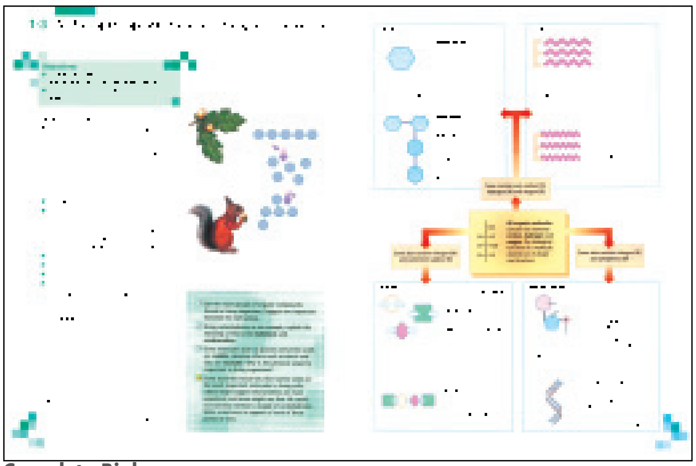

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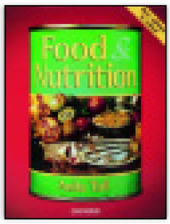

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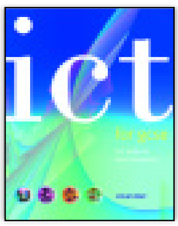

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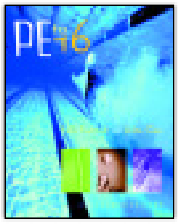

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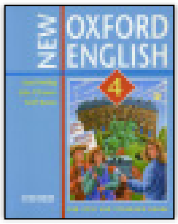

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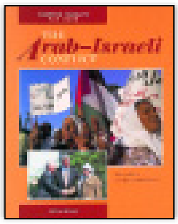

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