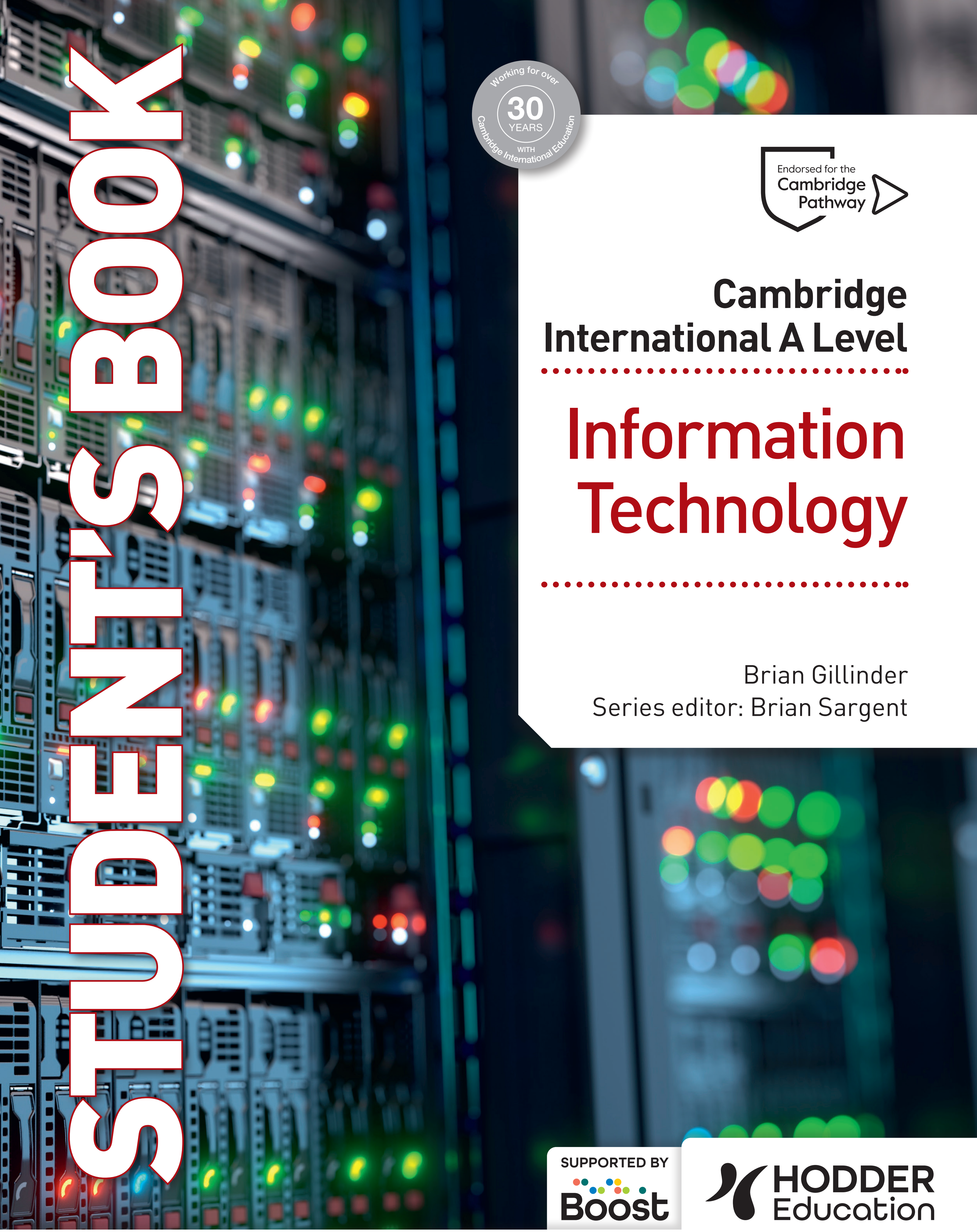

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Contents

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Introduction

This textbook has been written to provide the knowledge, understanding and practical skills required by those studying the A Level content (Topics 12–21) of the Cambridge International AS & A Level Information Technology 9626 syllabus for examination from 2025. Students studying A Level will need to be familiar with the AS Level content (Topics 1–11) covered in Hodder Education's *Cambridge International AS Level Information Technology*.

How to use this book

This textbook, endorsed by Cambridge International Education, has been designed to make your study of Information Technology as successful and rewarding as possible.

Organisation

The book comprises 10 chapters, the titles of which correspond exactly with the topics in the syllabus. Each chapter is broken down into sections. While these sections largely reflect the subtopics in the syllabus, the order of the subtopics in a few chapters has been changed from that in the syllabus to make for a more logical approach to the content.

Features

Each chapter contains a number of features designed to help you effectively navigate the syllabus content.

At the start of each chapter, there is a blue box that provides a summary of the content to be covered in that topic.

In this chapter you will learn:

- ★ the types of new and emerging technologies
- ★ the impacts of the new and emerging technologies.

There is also a box that lists the knowledge you should have before beginning to study the chapter.

Before starting this chapter, you should:

- ★ be familiar with the terms: project, collaborative working, scheduling and review.

Each chapter includes Activities to allow you to check your understanding of the concepts covered and practise the skills demonstrated in the text.

Activity 12b

1 Describe a distributed ledger database.
2 Describe the contents of a blockchain created during a digital currency transaction.

The practical chapters also contain Tasks. The text demonstrates the techniques used to carry out the tasks. It provides easy-to-follow step-by-step instructions, so that practical skills are developed alongside knowledge and understanding.

Task 18j

The selection of recipients for an invitation to a conference could be made on the basis of where the recipient lives. Create a spreadsheet with the names of ten different recipients, five of whom live in one country, two in a different country, two in another different country and one in another. Create a master document of an invitation with mail-merge fields that selects the recipient depending on their country.

Finally, each chapter ends with Practice questions. These questions and their answers have been written by the author and the answers can be found at: www.hoddereducation.co.uk/cambridgeextras.

Practice questions

1 Layers are used when creating a computer graphic.
   a Explain why layers are used. [4]
   b Explain why layers are usually merged in the final image. [3]

2 a Describe how rulers, grids and guidelines can assist in the placing of objects when creating digital images. [6]
   b Describe the differences between the effects on an image of crop and cut out. [4]

3 Colour wheels are used in graphic image creation as an aid to choosing colours.
   a What is a colour wheel? [2]
   b Describe two limitations of using colour wheels. [2]

4 Why are colour-management systems (CMS) needed? [6]

Text colours

Some words or phrases within the text are printed in **red**. Definitions of these terms can be found in the glossary at the back of the book. In the practical section, words that appear in **blue** indicate an action or location found within the software package, for example 'Select the **Home** tab.' Words that appear in **green** indicate spreadsheet functions or formulas, for instance 'Pivot charts are created from the **Insert**, **Pivot chart** menu options.'

Problem-solving

When there are practical tasks that require problems to be solved, it is important to use your knowledge, logic and imagination. Firstly, it is necessary to understand the task so the problem can be identified. At A Level, you are expected to use your knowledge and practical skills, find the most efficient techniques and methods and then complete the practical tasks. The process of problem-solving in this context involves identifying and understanding the problem, gathering knowledge and using skills so the solution can be created, choosing the best method of creating the solution, and finally testing and reviewing the solution. By carefully following the instructions in the tasks and applying your knowledge and skills, you should be able to produce the required solution to the given problem and complete the tasks.

Assessment

The information in this section is taken from the Cambridge International Education syllabus. You should always refer to the appropriate syllabus document for the year of your examination to confirm the details and for more information. The syllabus document is available on the Cambridge International Education website at www.cambridgeinternational.org.

For the A Level part of the course, you will take two examination papers:

Paper 3 Advanced Theory (1 hour 45 minutes)

Paper 4 Advanced Practical (2 hours 30 minutes)

The Advanced Practical examination is based on Topics 17–21 of the subject content but may include practical tasks from AS Level Topics 8–10. Tasks are set in a problem-solving context. Students are expected to use the skills gained from studying the AS Level Topics 8–10 and apply them when solving the A Level practical tasks.

Command words

The table below, taken from the syllabus, includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context. Make sure you are familiar with these.

Command word	What it means
Analyse	Examine in detail to show meaning, identify elements and the relationship between them
Assess	Make an informed judgement
Compare	Identify/comment on similarities and/or differences
Contrast	Identify/comment on differences
Define	Give precise meaning
Describe	State the points of a topic/give characteristics and main features
Discuss	Write about issue(s) or topic(s) in depth in a structured way
Evaluate	Judge or calculate the quality, importance, amount or value of something
Explain	Set out purposes or reasons/make the relationships between things clear/say why and/or how and support with relevant evidence
Identify	Name/select/recognise
Justify	Support a case with evidence/argument
State	Express in clear terms
Suggest	Apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals/put forward considerations

Notes for teachers

Key concepts

These are the essential ideas that help students to develop a deep understanding of the subject and to make links between the different topics. Although teachers are likely to have these in mind at all times when they are teaching the syllabus, the following icons are included in the textbook at points where the key concepts relate to the text.

Hardware and software

Hardware and software interact with each other in an IT system. It is important to understand how these work and how they work together with each other, and with us in our environment.

Networks

Computer systems can be connected together to form networks allowing them to share data and resources. The central role networks play in the internet, mobile and wireless applications and cloud computing has rapidly increased the demand for network capacity and performance.

The internet

The internet is a global communications network. It uses standardised communications protocols to allow computers worldwide to connect and share information in many different forms. The impact of the internet on our lives is profound. While the services the internet supports can provide huge benefits to society, they have also introduced issues, for example security of data.

System life cycle

Information systems are developed within a planned cycle of stages. They cover the initial development of the system through to its scheduled updating or redevelopment.

New technologies

As the information industry changes so rapidly, it is important to keep track of new and emerging technologies and consider how they might affect everyday life.

13 New and emerging technologies

In this chapter you will learn:

★ the types of new and emerging technologies
★ the impacts of the new and emerging technologies.

Before starting this chapter, you should:

★ be familiar with the terms: radio transmission, smartphone, compression, recycling.

13.1 Types of new and emerging technologies

13.1.1 Artificial intelligence

Artificial intelligence (AI) or **machine intelligence** is defined as the ability of computer systems, or computer-based machines, to carry out tasks that would normally only be possible by humans. AI mimics or copies human thinking processes, for example problem-solving and learning from experience, and is the ability of computing devices or software to interact with the environment in a manner similar to that of humans. AI involves being aware of the environment (through using sensors) and carrying out actions depending on what is sensed. AI would, like a human, examine and analyse its environment and then use algorithms to take actions. The actions taken by AI are designed to increase the chances of achieving a set target or goal.

Early AI algorithms had a step-by-step approach with precise sets of instructions and choices for problem-solving, but humans do not simply follow a set of pre-defined instructions to achieve a goal. While some problems can be solved in this way, most humans learn by experience and apply their knowledge to new situations. Artificial intelligence definitions now take this into account and, to be deemed AI, a system must be able analyse its surroundings or external data, carry out actions, learn from any new data gathered as a result of the actions and carry out further actions to achieve a goal. The concept of learning is important because it ensures that AI can deal with new, unexpected or changing situations without human intervention. AI can make decisions on its own.

Humans also solve problems and make decisions quickly by intuitive means or just by guesses. Humans make assumptions based on their knowledge of the world around them, use what is known as common sense and take into account abstract feelings or thoughts when making decisions. The challenge of developing artificial intelligence is to recreate all of these in machines. Developments in computing technology, such as supercomputers, advances in

▲ **Figure 13.1** A supercomputer built for artificial intelligence

computational sciences, game theory and machine learning involving the study of algorithms and statistics, contribute to the advances in AI.

Impacts of artificial intelligence

Almost any task that requires thoughts and decisions can be carried out by artificial intelligence systems. Rules-based expert systems, using if–then rules to go through large bodies of knowledge, make use of AI to solve complex problems by reasoning. This is used in air-traffic control, speech recognition, diagnoses of illness and disease, diagnosing faults in machinery and engines, identifying organic materials, and many other sectors.

Self-driving cars and trucks use AI to analyse and control the movement of the vehicle. Self-driving vehicles must be able to cope and navigate safely in unknown or high-risk environmental conditions, such as in areas not in their pre-installed maps or in poor weather. They must be able to make instant, difficult decisions in unexpected or potentially dangerous situations. However, moral and ethical issues are a challenge to AI systems.

Online trading of stocks and shares makes use of AI to analyse financial markets and make decisions to trade or not to trade. Forecasts and predictions can be made on future trading prices by data mining to discern trends in the large amounts of data. AI can operate without breaks and can react to changes in financial markets much faster than humans, resulting in greater profits. It can also combat fraud by analysing patterns and spotting unusual financial activity. Financial records can also be kept by AI.

AI has an impact on health care. It is enhancing the care that is given to patients, and is helping around the world with the diagnosis of illnesses and diseases and reducing the number of trained professionals required. AI is used in data mining and in expert systems based on the analysis of large numbers of incidences of diseases and their symptoms. Doctors can use these systems to access the knowledge of experts and increase the speed of diagnosis of an individual. AI and expert systems may also be used by individuals to self-diagnose and seek treatment sooner.

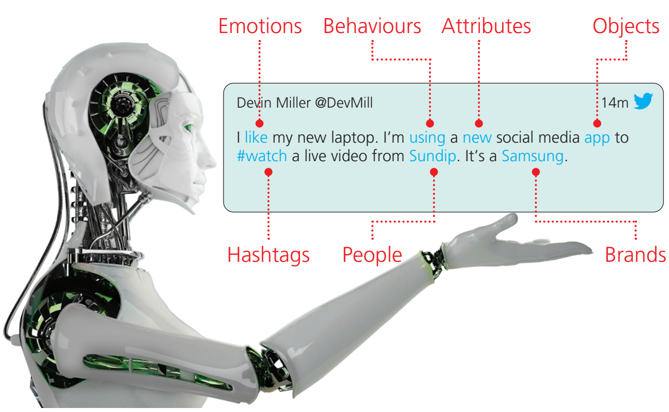
AI has assisted in the creation of prescription drugs to combat disease by reducing the costs and time taken to develop new drugs. AI identifies diseases and conditions that could be successfully targeted by new drugs, or by existing drugs that could be used in new treatments. AI and data mining can be used to predict the effects of existing and new drugs against diseases. The time taken for clinical trials of drugs has been reduced by using AI to identify suitable patients for the trials, to analyse the data from the trials and to raise alerts if the trials do not produce useful or helpful results. Artificial intelligence systems can also reduce the amount of manual work required by technicians by automating testing, classifying and statistical analysis of the tests and results, helping to allocate specific drugs depending upon patients' likely response to the treatment. Patients are more likely to receive drugs that will improve their condition and speed up their recovery rate.

▲ **Figure 13.2** An AI-controlled surgical robot

In the care of patients, AI is used in chatbots that provide patients with access to advice on their health, in wearable devices, for instance **fitness trackers**, that record, monitor and alert the user to health issues, and in analysing the health of a patient. Virtual nursing assistants use AI to monitor patients and answer questions more promptly. Personalised genetic analysis by AI can reveal genetic conditions and provide suggestions for possible courses of treatment. Lifestyle and disease management can be researched and suggested by AI systems. The use of AI has increased survival rates from diseases and improved patient care.

Virtual assistants using AI are found in computer operating systems that power desktop computers, laptops and smartphones to provide smart assistants and enhance the user experience. Voice control of devices, controlling smartphone camera effects and monitoring battery levels all make use of artificial intelligence. Devices in the home linked to online AI systems that analyse and interpret the spoken commands and behaviour of users can control heating, air conditioning, lighting or other household systems, or they can be used to answer questions, play music as smart speakers or order goods online. While these devices can make life easier and more pleasant for the users, there are serious concerns about the privacy and security of the large amounts of data that need to be collected so that the AI can learn and make sensible decisions that reflect the individual user's needs.

Notifications and customised advertising in social-media feeds rely upon AI to provide data to the user when they log in to their social-media applications depending on their usage patterns. Smart email apps can use AI to scan emails, reject spam emails and categorise emails for easier access by the user. Smart reply systems suggest replies in contexts decided by artificial intelligence.



▲ **Figure 13.3** AI analysing a social-media post

In business, chatbots can be used to interact with users online. Chatbots, or chatter robots, provide a chat interface that allows a human user to interact with a computer program using AI. The AI uses natural language processing, video and audio analysis to provide customer care by answering questions and enquiries at any time of the day or night. Customer service can be provided 24 hours a day without the need for staff. Costs can be reduced as chatbots can replace many employees. Customers receive instant responses to their queries. Online retailers and travel services selling flights and hotels can use chatbots with AI to provide customer services. The AI uses data mining to analyse massive amounts of data to provide customers with answers customised to their specific enquiry.

Computer games are another area where AI enhances the user experience. Gamers can play against AI-generated opponents called bots. The game bots can take the part of other cars in racing games or opponents in action games. AI-powered opponents can learn from the actions of the player and adjust and evolve their play accordingly.

Military uses of artificial intelligence are mostly concerned with the fast analysis of data in combat scenarios, training simulations and decision-making. The aim is to decrease the reaction time and make more informed decisions. AI-controlled military drones and weapons present ethical concerns about who or what makes decisions that might involve the use of force. The removal of humans from the decision-making process into a monitoring role has been opposed by many people because they say that AI cannot be trusted to distinguish properly between friend and foe or to decide on a proportional response to a military threat.

Artificial intelligence requires high-powered computing to run, which means more electricity has to be generated; depending on how the electricity is produced, this can be damaging to the environment. These systems consume large quantities of rare metals, plastics and other materials when manufactured. The extraction and production of the raw materials causes damage to the environment through mining and the disposal of the waste products. Pollution of waterways with waste water and excess heat from the extraction and refining processes may become a problem.

13.1.2 Augmented reality

Augmented reality (AR) is the enhancement of a real-world experience by overlaying computer-generated objects onto real objects. The computer-generated objects can be obvious overlays giving information or directions, or can be made to appear to the user's visual, auditory and other senses in much the same way as the real objects in a scene.

Augmented reality changes the user's perception of the real world, whereas virtual reality (VR) completely replaces the real world with a simulation. In contrast to virtual reality, augmented reality scenarios are real, for example a doctor cannot perform a real operation using VR but can use augmented reality to assist in a live surgical procedure.

Augmented reality systems use similar technology to virtual reality. While the hardware is similar, however, there are a number of important differences. AR is in real time so AR headsets must include a camera to capture live scenes, there must be microphones to

▲ **Figure 13.4** AR being used in a medical procedure capture any external sounds, and there must be processors that can integrate these in real time with exterior scenes. Output devices such as headsets or eyeglasses must be able to overlay the images onto the scene that the viewer sees around them. Cameras can be built into eyeglasses and the images can be displayed on screens that replace the glass or can be projected into the eye of the viewer. Sometimes, people with reduced visual capabilities have been shown to be able to make out objects better in this way. Attempts have been made to create AR-capable contact lenses using microprocessors, LEDs and wireless antennae, but these have not appeared commercially. A head-up display (HUD), where the AR images are shown on a clear display in front of the viewer's line of vision, can also be used.

Impacts of augmented reality

Emergency services can use AR to help train first responders and doctors. First responders wearing AR equipment can be alerted to danger areas and assisted in finding victims needing rescue. First responders can also be helped by the overlay of information and of geographical and navigational guidance on a real scene. Safe routes, dangerous objects and local information can be added to the real surroundings seen by the viewer.

Computer games make use of AR to immerse players in the game, placing computer game characters and features into real-life situations. Gamers can search for and interact with characters and objects placed in geographical locations using GPS on their smartphones to run the game software app.

The impact of augmented reality on businesses has been to increase product awareness and sales. Customers have an enhanced experience of buying because they can interact with a product before buying it, can visualise objects better and make more informed decisions. The fashion industry and real estate businesses use AR to help sell their products to customers anywhere in the world and at any time. However, it does depend upon the potential purchaser having access to a smartphone or mobile device and to the internet. Tourism has benefitted from the use of AR; places, buildings and objects can have their information displayed to visitors without the need for printed posters or expensive displays. Museums can overlay details and videos of artefacts as visitors move around the displays.

The benefits of using augmented reality in education include students being more motivated and engaged in learning. This increases their participation in lessons and lectures and enhances their learning of topics. Individuals can access relevant information in real time as it applies to their immediate situation. This allows better and more accurate navigation, more informed decisions about what to buy and greater awareness of their surroundings. Individuals with reduced cognitive or intellectual abilities can be helped in their activities.

The use of augmented reality in medicine means that diseases can be diagnosed more accurately and surgeons can perform more accurate procedures. This increases the chances of safe recovery for patients.

Augmented reality raises some issues about the privacy of users and others. People using AR can deliberately or inadvertently invade other people's privacy. A group of people may be taking part in an AR experience and be quite content and in agreement with the sharing of their experiences and actions with others. However, bystanders and property owners may not be happy to have their actions and property appear in AR situations as they have not given permission and have no control of the use and storage of the information.

Further drawbacks include expensive hardware and software to implement augmented reality, which may be too costly for many educational and business organisations. An individual using augmented reality experiences has less contact with reality, potentially increasing the chance of social isolation. As with other computer-based activities, there may be some adverse effects on eyesight as well as other health issues resulting from prolonged use.

13.1.3 Virtual reality

Virtual reality (VR) is a simulation of the real world using computing technology. Sensors and actuators are used to provide the inputs and outputs to give the necessary sensory feedback for the simulations. Virtual reality headsets are used to provide video and audio to the user so as to immerse them in the simulation and exclude the real world. Forces, vibrations and other sensory feedback can be given to the user by 3D touch systems, also called haptic technology, or by kinaesthetic communication devices, such as joysticks, 3D mouses, gaming steering wheels and game controllers. These are connected wirelessly and are used to move objects within the virtual reality world and to provide movement, positional and touch feedback to the user.

▲ **Figure 13.5** VR headset in use

Impacts of virtual reality

Users of virtual reality can experience scenarios such as trekking in the mountains, touring an archaeological site, exploring a museum or art gallery, or become immersed in a computer game without leaving home. More serious uses include meditation and health therapies, occupational health, physical rehabilitation and professional training scenarios. Data about the environment can be captured and combined with video, still imagery and audio to create 3D virtual environments. These can be especially useful for teaching in schools, for viewing houses virtually to rent or buy, or for providing low-risk virtual scenarios for people in potentially high-risk professions, such as doctors, aircraft pilots or firefighters. Procedures like surgeries can be virtually practised, refined and shared with other surgeons before carrying them out in reality. VR can even be used to assist people to overcome fears and anxieties such as fear of spiders or of flying. Exposing people to virtual situations where there is no risk of being hurt or injured can treat anxieties, phobias and psychoses. This is called virtual reality exposure therapy (VRET). It has been shown to be highly effective in treating some fears.

Computer video games are currently the main application for VR, where gamers can reach out and touch or turn their heads to see objects around them to enhance the gaming experience. Often a complex controller is not required and the situation closely simulates real life. In entertainment, VR can be used to stream live theatrical and concert performances in real time, allowing very large numbers of viewers to experience the event. Drawbacks of using VR include the high cost of the equipment and software and the limited number of scenarios available, say in education settings. It has also been suggested that excessive use of VR may create an over-reliance on the virtual world and impede communication between people in the real world.

13.1.4 Robotics

The study and science of robotics includes the branches of engineering and computer and other sciences that deal with the design and creation of machines that replace or copy human actions. Robotic machines or robots all have features in common: a computer system, a mechanical structure or frame, and a power supply.

A computer system is always included. Computer programs control the robot and determine what tasks are carried out and when the tasks are done. The programs may have user input of commands or may have a degree of independence. A robot designed to paint cars on an assembly line will be controlled by user inputs of command instructions, while a robot designed to explore new or dangerous areas will be equipped with artificial intelligence to make its own decisions. The robots use sensors to react to their environment and actuators carry out appropriate tasks.

The mechanical structure is customised to the purpose of the robotic device. A robot designed for cleaning floors has a structure to support the cleaning tools, power supply, navigation devices and the computing hardware. Night-vision cameras would be found on security robots but not on robotic vacuum cleaners.

The machinery needs a power supply to provide an electrical supply to the components. This is often a portable supply such as a battery or solar energy supply.

Activity 13a

1. Explain why the mechanical structure of a robotic device that freely moves around cleaning floors is different from the structure of a robot that cleans windows by hanging from wires down the side of a building.
2. Describe the information that artificial intelligence needs to determine from the data it receives from sensors fitted to a floor-cleaning robot.

The computer programming of a robotic device depends on its function. Robotic devices can enhance the movements, the accuracy of movement and the strength of humans. Humans have complete control over this type of robot by programming them to do specific, often repetitive, tasks or by remote control over wireless telecommunications systems.

Some robotic devices require human operators to command their tasks, and the robot will 'work out' how to complete the task. The human operator supervises the robotic device in carrying out the tasks. Sometimes, the human operator has to approve or specify any changes of operations, such as a change in actuator during a task.

Fully autonomous robots carry out tasks without human interaction. Tasks range from very complex explorations of areas, where the robot has to interact with the environment and make decisions itself, to relatively simple, repetitive tasks such as fitting parts to cars on factory assembly lines. The use of artificial intelligence to control robots allows the robot to learn from its actions and apply the learning to similar situations. This enables robots to have some autonomy in their actions where human interaction is limited or not feasible. A robotic explorer on a distant planet cannot, with the limitations and delays in direct communications, easily be controlled by a human operator so it must have the ability to make some operational decisions itself.

Activity 13b

Some scientists think that humanoid robots are not necessary.

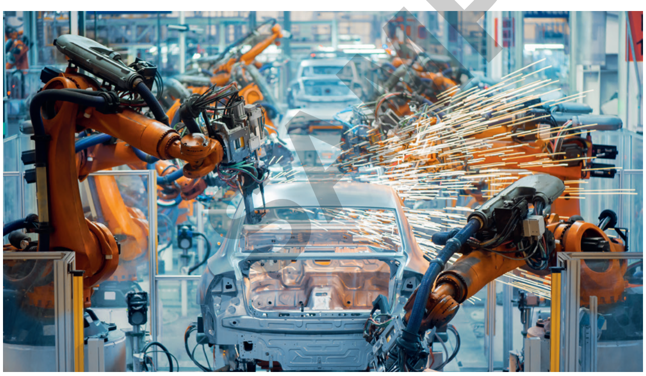
1. Explain why a robot that looks human in shape would not be suitable for assembling the doors of a car.
2. Explain why humanoid robots are not popular with the public when used for greeting and serving guests in hotels.

Impacts of robotics

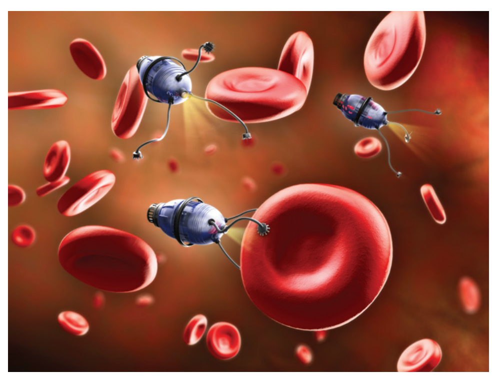
Robots can be built to operate effectively in places that are too dangerous or where it is impossible for humans to go. In space exploration, autonomous or semi-autonomous robotic machines can be sent to explore space or other planets without expensive life-support machines or concerns for their safety, and no consideration needs to be given for its return to Earth. Robots can also be used instead of staff in places like hospitals to carry equipment between areas, thereby reducing exposure to disease for staff and patients, as was done during the Covid-19 pandemic.

Robots with actuators can be used in artificial limbs (prosthetics) that enhance the quality of life for people who have missing limbs. Prosthetics enable athletes with missing limbs to take part in sports that were previously closed off to them. Prosthetics that include computing devices to analyse and control the shape and movement of the limb can make movements and appearance more natural.

The manufacturing industry has been impacted the most by the introduction of robotics. Robots increase productivity because they can carry out tasks very quickly and accurately, such as the assembly and testing of components. They are also more efficient than human workers because robots can work continuously without breaks or vacations. The numbers of workers required to produce goods is therefore reduced, so a manufacturer will reduce the costs of employment. However, companies may have to employ specialised workers or technicians to maintain and repair the robots. These technicians will be expensive as they need to be trained and qualified in the use of the robots. Also, workers who work with the robots, for example ensuring that the raw materials are in place, have to be trained and skilled in the use of robots to make goods. While using robots can make working environments safer for humans, robots cannot carry out tasks that they are not programmed to do. They cannot be creative, cannot respond to unexpected conditions and can create hazards that were not present before, for example fast-moving heavy robot arms can be hazardous in factories.



▲ **Figure 13.6** Robots in car manufacturing



▲ **Figure 13.7** Nano robot with camera for passing through blood vessels

In health care, robots have a wide range of uses. Autonomous robots carry out tasks normally done by health care workers such as nurses, like taking temperatures, and can move between patients. This was especially useful during the Covid-19 pandemic, where these autonomous robots supplemented patient care when health care workers were in short supply or needed elsewhere. Surgeons use robotic tools for operations all over the body and can even control them remotely from another part of the world. Using small but accurate robotic tools means surgery is less invasive, therefore reducing the recovery time of patients. Health care professionals can even use extremely small robotic devices, micro- or nanorobots, inside the human body to carry cameras and tools to explore and carry out tasks within the body.

Activity 13c

1. Explain why autonomous delivery drones may present hazards.
2. Explain how autonomous delivery vehicles can assist in health care facilities.

13.1.5 Computer-assisted translation

Computer-assisted translation (CAT) translates one human language into another. **Machine translation** attempts to translate languages without human input and is used as part of computer-assisted translation. It makes use of large, customised dictionaries and tools.

Translation of human languages using only human translators always has the risk of mistranslating words and sentences or altering the context. Computer-assisted translation is less likely to do this since it relies on vast dictionaries and a variety of software tools, has no mechanism or programming to do so, and is overseen by human translators.

Computer-assisted translation uses software tools to convert one language into another. Translation memory uses a large database of words and segments of the source language along with the equivalents in the target language. Translated sections of documents are stored in the database and are reused for subsequent documents. Software **alignment tools** are used to divide the documentation into sections so that the source text and the target text can be kept together and stored for use in future translations.

Activity 13d

1. What is the main difference between machine translation and computer-assisted translation?
2. State two reasons why a research student would use computer-assisted translation, instead of relying on machine translation, for translating an ancient religious document.

Impacts of computer-assisted translation

Computer-assisted translation is used by companies to adapt user and technical documentation for various devices and products that are sold in different countries, from printers to computer games and simulations. Games can be adapted to suit different languages and cultures by localisation of menus and currencies or removal of culturally inappropriate phrases. The use of CAT improves the consistency of terminology and instructions in the translations, and reduces the need for human input, which reduces costs.

Creative documents such as novels are not easily translated by CAT because CAT is not good with context and expressions in language. For these, humans are required to proofread and correct errors.

CAT is used by global organisations, businesspeople, tourists, diplomats and embassy personnel to overcome the language barrier. Apps for smartphones or other devices can translate words and documents in real time with no need for interpreters.

In health care, CAT has enabled medical records, documentation, data and research information to be made available to health care providers in different countries to enhance the treatment of patients who may be travelling between countries. Research can be shared between doctors and surgeons around the world. Co-operation between doctors and surgeons who do not speak each other's language is made easier with CAT. A drawback is that care must be taken to ensure the accuracy of the translation of technical words and terms.

CAT can be used by law enforcement or in judicial courts when foreign-language speakers are present. However, there is always the danger that an inaccurate translation may lead to misunderstandings and miscarriages of justice.

Using computer-assisted translation has drawbacks. CAT software produces a literal word-for-word translation without any understanding of the context or nuances shown by the languages, and therefore all text translated by CAT software has to be reviewed and edited by a skilled human translator to take account of context, dialect and words with several meanings. Any use of slang or colloquialisms in the source material needs to be translated properly by humans. High degrees of accuracy usually require expert knowledge of the systems by translators. Also, as the CAT software may store translations for future use in memory translation systems, there are security concerns if the documents being translated are confidential.

Activity 13e

1. Why are automatic translations of text for globally available computer games checked by humans?
2. Identify one other aspect that must be checked for global audiences.

13.1.6 Holographic imaging

Holographic imaging uses computer science, electrical engineering and optics to create three-dimensional images. Holograms are recordings of the interference and diffraction patterns in light fields that describe how light moves in every direction through points in space. Holographic images can be viewed from different angles whereas photographs cannot. **Holograms** are recorded using **laser** beams, but photographs can be recorded using normal light.

Creating a holographic image uses two laser beams made by splitting a main beam. One laser beam, the reference beam, is used to illuminate the recording medium, and the second beam, the object beam, illuminates the object to be recorded and is reflected or scattered onto the recording medium. The interference pattern created by the two beams is recorded. Computer-based holography overcomes some of the problems with photographic holography because specialised photographic recording media are not required and computers can create the optical wave patterns from digital data.

▲ **Figure 13.8** A hologram on a bank note

Impacts of holographic imaging

Because holograms are very difficult to copy and forge, they are printed onto labels on goods, bank notes and bank cards, for example credit and debit cards. Counterfeiters making copies of original goods cannot copy the holograms properly, so holograms are a useful way to tackle fraud. The use of holographic imaging on labels reassures buyers that they are purchasing original goods and not cheap copies.

Holographic imaging is used in many branches of medicine and health care. X-ray holography produces images of internal body structures that can be viewed in 3D, such as the eyes or skeleton, and anatomy can be taught using such images. Holographic images can also be created to show 3D views of healthy and diseased organs. Doctors and surgeons can use them to diagnose, plan and carry out treatments and surgical procedures with greater accuracy.

Activity 13f

Explain why holographic labels are not often counterfeited.

13.1.7 Holographic and fourth-generation optical data storage

Optical data storage systems were first introduced to store music and computer software. The compact disc (CD) and MiniDisc were the first generation; the digital versatile disc (DVD) and a high-capacity MiniDisc (Hi-MD) were the second generation. These replaced vinyl records and tape systems. Third-generation optical storage is used for high-definition movies, which are distributed as Blu-ray discs.

Fourth-generation optical discs can store much more data because they use holographic imaging. **Holographic data storage**, or three-dimensional data storage, can store up to hundreds of gigabytes and has faster data-transfer times because it uses the depth of the recording medium, unlike CD and DVD optical disc storage systems that use only the surfaces. A CD can hold about 783 megabytes and a DVD can hold up to almost 16 gigabytes of data, but holographic data storage offers capacities of 300 gigabytes or more per disc. Capacities of several terabytes per disc are hoped for in the future.

Holographic data storage uses two laser beams: a signal beam and a reference beam. The signal beam is shone through a liquid crystal display to produce the binary information, which is then shone onto the recording medium. The second beam (the reference beam) is guided along a separate path onto the recording medium, and where the two beams meet they create an interference pattern. The interference pattern is recorded as a hologram of the data at different depths in the layers of the medium.

Impacts of holographic and fourth-generation storage

The massive amount of storage available on holographic and fourth-generation optical storage systems can provide the capacity required for storing things like holographic images and the long-term safety of the data. This has some advantages for storing medical images, computer game data and business data.

Holographic and fourth-generation optical storage systems have a projected life of over 50 years, compared to a typical life of 5 years for magnetic storage devices, so medical data can be stored for a very long time. They have very large capacities and very fast access rates, with transfers approaching 40 times that of DVD storage. Low power consumption of these storage devices means that they can be used in small, portable devices suitable for use in health care facilities. These features make this form of storage highly suitable for the archiving of medical data.

The cost per gigabyte of storage is much higher than that of other systems such as magnetic hard disks, solid state devices (SSDs) or external USB storage devices. Moreover, the development of reliable, high-bandwidth internet connections into homes, enabling video streaming and online gaming, has made the need for expensive high-capacity data storage systems for movies or computer games unnecessary.

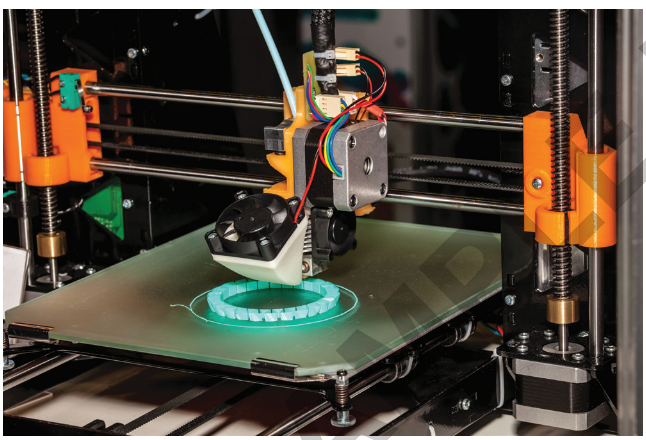
A more important drawback to the use of holographic systems is that external ultraviolet light sources can erase the data on some CD-RW and DVD-RW discs if exposed to sunlight. The UV light acts on the media in the same way as the recording laser, meaning data can be corrupted and lost.

Activity 13g

Explain why users are advised not to place rewritable CDs, DVDs and Blu-ray discs in direct sunlight but the same advice is not given for commercially produced CDs, DVDs and Blu-ray discs.

13.1.8 3D printing

Three-dimensional (3D) printing uses sets of instructions sent to a 3D printer to add successive layers of materials to create three-dimensional objects. 3D printing may use polymers, metals and ceramics to create the objects. It is also called **additive manufacturing**, in contrast to **subtractive manufacturing** where materials are cut away to create objects.



▲ **Figure 13.9** 3D printer

To create an object by 3D printing, the instructions for the printer have to be written. Computer-aided design (CAD) software is used to create a model and export the required set of instructions. Also, a digital camera can be used and software using photogrammetry techniques analyses the images and extracts the data needed to create the instructions.

3D scanners can be used to scan original objects from many different angles and create digital representations. The instructions for creating the digital object can be exported to CAD to produce a copy of the original object.

Activity 13h

Explain the difference between additive manufacturing and subtractive manufacturing.

Impacts of 3D printing

3D printing has a wide range of applications. Manufacturing companies use 3D printing to produce both the tools and the parts needed for manufacturing goods, such as cars or domestic appliances, as well as spare parts for manufactured items. In the car manufacturing industry, underbody chassis structures and fuselages can be printed and made as one continuous structure to avoid the need for complex joins and welding of several parts. The aviation industry manufactures parts for aircraft using 3D printing because it produces less waste and reduces the manufacturing costs; 3D-printing can produce the parts to exact requirements as and when required anywhere in the world without the need for keeping vast numbers in stock. In construction, concrete can be laid in layers by 3D printing, as well as 3D printing being used to create walls, doors and windows.

In health care, 3D printing can have extensive uses. Patients can now have customised, and robotic, computer-controlled prosthetics that fit perfectly and vastly improve their quality of life. Hip and knee replacements can now be 3D printed to fit exactly to existing bone structures and created out of materials that are inert in the body, increasing comfort and reducing pain. Body movements and functions can be almost completely restored. Additionally, 3D printing has enabled health care professionals to create specialised surgical and medical instruments with great precision, including recreating body parts to plan, and to practise and train for surgical procedures without touching the actual patient.

3D printing can be used in tissue engineering. Tissue engineering combines a base material, the 'scaffold', with cells and other biological materials to make working biological tissues. Some tissues have been engineered successfully, but fully working biological organs, such as hearts and kidneys, have not yet reached the stage where they can be implanted into bodies. 3D-printed very thin layers produce the scaffold for cells to grow on, for example to grow artificial skin for grafts to treat skin burns. The thin layers are 3D printed using a 'biological ink' made from blood plasma and skin cells. In a similar way to making artificial skin and bone, artificial blood vessels can be 3D printed. Using biological polymers, a base can be printed with small holes and channels along which cells can be arranged and grow. 3D printing may overcome the problems that exist in making extremely small blood capillaries, because polymer strands are not fine enough and the live cells do not arrange themselves as in real live tissue.

Hospitals, drugstores and pharmacies will be able to 3D print customised drugs for individual patients. Individuals may one day even be able to print their prescription drugs at home, making customised drugs on-demand, using data files provided by their doctor or pharmacist. However, there are drawbacks. The home user must have access to a specialised 3D printer, have access to the required files to instruct the printer, and have a supply of the required chemical constituent of the drugs. The drug supply to the individual is not under the control of the medical professionals and mistakes in dosage or use may have an adverse impact on the individual's health.

Beyond health care, sculptors and prop-makers in the film and theatre industry use 3D printing to make quick, cheap props. In law enforcement and forensic pathology, evidence can be recreated for study by scientists. In a similar way, archaeological artefacts can be reproduced for study purposes. Scanning fragile artefacts and making 3D-printed copies allows scientists to study them while protecting the artefacts themselves from damage or loss.

3D printing removes the need for the skilled, complicated and time-consuming chiselling, milling and grinding of shapes of new parts and items during development stages. New shapes and objects can be formed quickly and relatively cheaply by printing compared to hand- or machine-tooling methods. Iterations are quicker and cheaper to make. There is no need to wait for the creation of new expensive tools or moulds that are then discarded.

Activity 13i

Explain why governments do not want prescription drugs to be 3D printed at home by patients.

13.1.9 Vision enhancement

Vision enhancement technology and devices aim to improve the quality of life of people with vision impairment. Vision enhancement technology can also assist other groups of people, for example those in health care, and assist drivers of vehicles and the military in their operations.

Impacts of vision enhancement

Combining technology can provide remote assistance to people who are completely blind. Headsets connect blind people to an operative who sits at a computer screen that displays the view taken by cameras in the headset and guides the wearer around their environment. The details are then communicated to the wearer with a small earbud that speaks out the details in real time. Using AI operatives would enable the visually impaired user to be more independent.

▲ **Figure 13.10** Vision enhancement glasses for macular degeneration

For people who have some vision, visors (**smartglasses**) are available that cover the eyes and display images and information on small screens. These devices use augmented reality to add to the visual experience of the wearer. With 5G or Wi-Fi connections, smartglasses can enable visually impaired people to take part in video calls and video conferencing.

Implanting devices directly into the human eye can help to enhance vision. A small part of the retina can be replaced by a small electronic array that sends signals to the optic nerve and then to the brain, which 'sees' the objects being viewed. The device in the retina is wirelessly connected to a small video camera that is worn by the wearer as eyeglasses. A computer chip artificial retina that replaces part of the retina with light-sensitive sensors is also used in some patients in an attempt to restore or improve some sight.

Vision enhancement can be useful for people who are not visually impaired too. For example, the use of augmented reality and head-up displays in cars provide drivers with more information, such as GPS navigation, as they are driving. Head-up display warnings are detected and processed more quickly by drivers, resulting in a safer journey. Similarly, head-up displays in the cockpits of aircraft assist pilots by displaying information in their line of view. Pilots of aircraft that fly very fast and are highly manoeuvrable, for example fighter jets, have to gather and process a huge amount information very quickly. The use of 3D head-up displays can provide all the data that the pilots need within their field of view. Additionally, as humans have poor night vision, visual enhancement can improve the ability to see in low light conditions. Night-vision goggles or glasses that use sensors to capture low levels of light and display the results on screens are used by the military and by many others who wish to see in the dark, including workers in the mining sector.

▲ **Figure 13.11** Head-up display in a car

Activity 13j

1. As well as augmented reality and artificial intelligence, describe other technologies that smartglasses depend upon.
2. Describe how a tourist might use smartglasses.

13.1.10 Wearable computing

Wearable computing, or body-worn computing, refers to the wearing or attaching of computing devices onto the body. The devices may be small, for example fitness trackers, an Apple watch and head-mounted displays like Google Glass™, or larger electronic systems that help in manufacturing environments. Wearable devices are usually worn on the wrist, hung around the neck, worn as eyeglasses or strapped to the body in some other way. Referring to smartphones and personal digital assistants (PDAs) as wearable devices is not accurate because smartphones are carried rather than worn.

Impacts of wearable computing

Wearable computing provides useful information or services to the wearer. For example, fitness trackers can sense movement and activities and monitor heart rate and distance travelled; smartwatches often combine fitness trackers with functions from other devices like smartphones and media players. Smartwatches are more portable than a tablet or smartphone and can be worn on the wrist. However, they are usually too small to allow easy use with fingers, meaning a smartphone is often still required. Moreover, the battery life can be short and unpredictable and the connectivity raises security issues. The personal data stored on the smartwatch may become accessible to unauthorised users.

Activity 13k

1 Explain why a smartphone or tablet is not considered to be a wearable device despite being carried by users.
2 Describe how a smartwatch can assist in preparing an athlete for a race.

Smartglasses or head-mounted devices have operating systems built into them and work almost independently of other mobile devices. Video screens, sensors, wireless communications systems and internet capability may be included, but some features may depend on the smartglasses being connected to a smartphone. A modern smartglass system consists of a wearable frame with a pair of video screens that can display images but can be seen through. An embedded computer system provides the functions, the wireless connectivity and in some cases access to the mobile (cell) telephone networks. Smartglasses are designed to add data and information to the views seen by the wearer.

Wearers can interact with and control their smartglasses using a connected smartphone, physical touch by buttons or touchpads fitted onto the frame of the device, gestures that are recognised by the glasses, or voice recognition systems that respond to spoken commands. Eye tracking can also be used where movements of the eye, the focus or direction of a gaze can control the glasses' functions. Most systems aim to enable a completely hands-free operation of the smartglasses.

Smartglasses can use augmented reality systems to enhance the wearer's experience of the real world or to assist in carrying out tasks. Navigation systems enable wearers to find their way to locations, identify locations and have additional information shown to them. Information is superimposed on to the view seen by the wearer and shows details of the objects in view, identifies objects, adds information about landmarks and applies facial recognition to viewed people to identify them to the wearer. Law enforcement officers can use smartglasses as body cameras to view and record incidents and people. Images of faces can be sent to a central database and compared to facial recognition software to identify suspects, retrieve their details and track the movements of individuals.

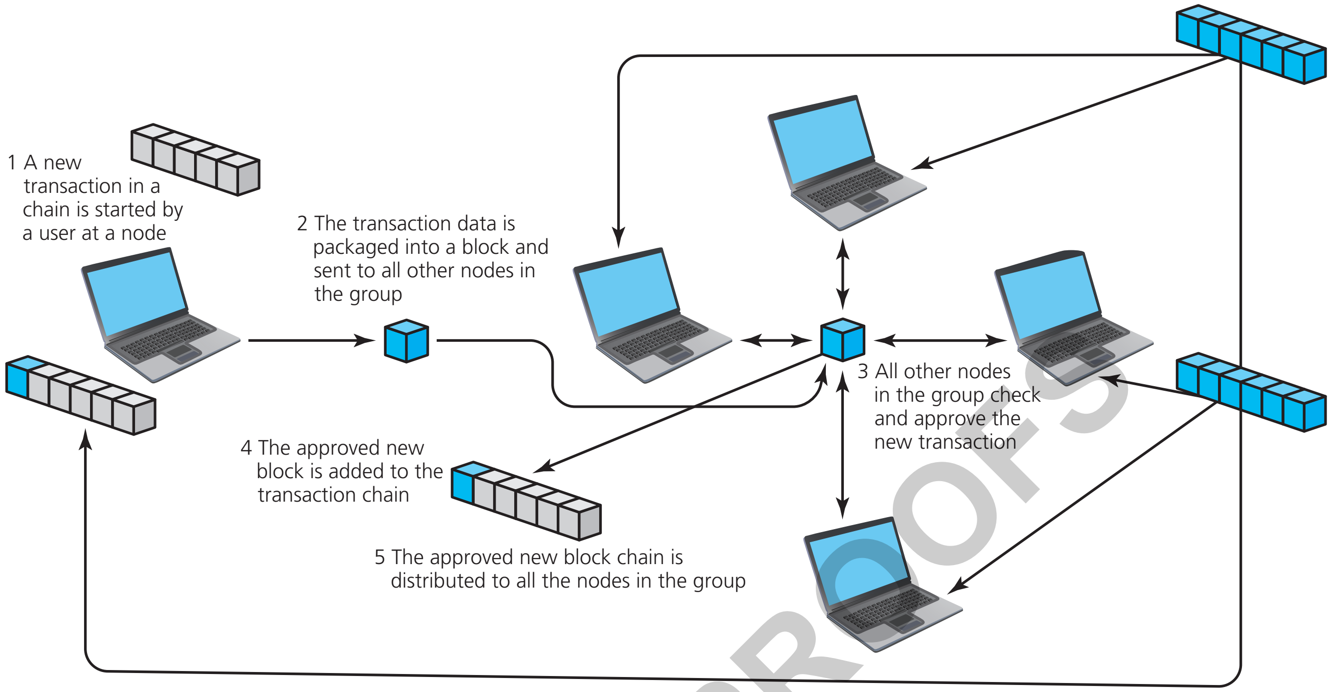
Wearable devices can be worn by ill or elderly people to monitor them continuously. Data can be collected and sent to health care providers or to emergency services by wireless or mobile networks. Responses to changes in the patient's condition can be very fast and, in the case of an emergency, because the device will also show the location of the patient, first responders can be sent very quickly. Devices can allow patients to monitor body parameters, such as blood sugar level, to easily decide if they need to eat or take medication. Similarly, devices worn by children who experience seizures at night can quickly alert parents if the child is in distress. Smartglasses are used in health care to augment the view of surgeons during procedures and to assist patients in their recovery.

Activity 13l

Explain how wearable computing devices communicate with other devices.

13.1.11 Blockchain technology

A blockchain consists of a list of records, known as 'blocks', that grows with every transaction. The blocks are linked to create a chain.



▲ **Figure 13.12** How a blockchain is made

Blockchains are created using cryptography and, because each block contains details of the previous block, a timestamp and a record of the transactions, they cannot easily be altered once they are made. This makes blockchain systems very secure since any alterations mean that all the other blocks also have to be changed. Altering blockchains after they are created is difficult as it requires all subsequent blocks to be amended and needs the consent of all other creators of the blocks. A blockchain system allows the integrity of the previous blocks to be confirmed all the way back to the original block in the chain.

Blockchain technology uses a decentralised record or ledger of transactions on a peer-to-peer network. It is used in cryptocurrency systems and smart contracts, and could be used in digital voting systems and for securing medical records. A smart contract allows for agreements to be made and carried out between two parties without the involvement of a third party to check that each side has fulfilled their obligations. The transactions are set up and processed using blockchains, and contracts cannot be altered without both parties agreeing. Transactions are automatically carried out only when pre-set conditions in the contracts are met. Using blockchains to record votes could stop voter fraud but, while votes could not be altered and would be verified by everyone, individual votes could become visible to all voters. Storing medical records, or other records such as digital identities, using blockchains ensures that the records cannot be tampered with or used by unauthorised persons.

13.1.12 Internet of Things

The **Internet of Things (IoT)** describes the interconnection of devices to exchange data over any communications network. The network does not have to be the 'internet' itself but can be any network, such as a home WLAN or company LAN or WAN, so the term is slightly inaccurate. Devices can be any object that can connect and exchange data, such as a laptop, smartphone, smart watch, smart television set, home appliance, camera and many more. The development of new technologies has allowed the IoT to emerge and develop. Technologies include high-speed data communications systems such as 5G mobile (cell) phone networks, high-bandwidth broadband connections, embedded computing systems in home appliances such as robotic cleaners, room thermostats, lighting systems, external doors, smart speakers and home security systems like smart doorbells. The use of remote-controlled or autonomous robotics in industry or health care is part of the IoT, where high-speed communications allow the devices to exchange data in almost real-time situations so an instruction sent from far away is carried out almost immediately and the result seen almost at once.

Impact of the IoT

The IoT has made an impact in many ways. Individuals can use a smartphone to monitor and control devices in their home. The introduction of everyday devices with embedded computing systems and the use of high-speed **mobile communications** systems linking the devices into the IoT has created smart homes, where individuals make use of their smartphone as a controller at home, from remote locations and when travelling. For example, a smartphone can be used to:

- monitor home security sensors and cameras
- monitor room temperatures
- monitor the contents of a smart refrigerator
- control home entertainment devices
- open and shut doors
- switch lights on and off
- turn on kettles and ovens
- control heating and climate control systems.

Wearable computing devices, such as smart watches and fitness trackers, can connect into the IoT to collect and present data, including text messages from smartphones or health information from sensors worn on the body, to the individual. Smartglasses using augmented reality can provide a continuously updated head-up display overlaying information onto the view of the real world.

Organisations use devices connected into an IoT to:

- automatically load and unload goods, for example from ships and trucks into warehouses
- monitor their products while they are in operation, for example aircraft engines while in flight
- monitor and control remote gas and oil extraction in remote or dangerous areas.

The IoT has enabled devices to be connected together and reduces the costs of operating workplaces with the use of embedded sensors that detect room occupancy. The data from the sensors can be sent to remotely connected microprocessors to control the lighting and climate in the room. There is no need for physical wiring, which also cuts costs. In medicine and health care, devices connected to the IoT allow patients to be monitored remotely, medical and delivery robots to function, and surgeons to remotely carry out or oversee procedures.

13.1.13 Molecular data storage

Molecular memory attempts to store data using chemical molecules as the storage medium instead of using electronic circuitry. While currently in the experimental and development stages, **molecular data storage** promises to eventually be able to store vast amounts of data in extremely small spaces. It may soon be possible to store terabytes of data in only a few cubic millimetres of space. Data is stored in mixtures of customised molecules. These molecules could be long-chain polymers, DNA or much smaller molecules such as aldehydes or carboxylic acids. The data is encoded in several ways. The molecule may hold an electric charge, change its capacitance or change its behaviour towards light beams. In the same way that HHDs use magnetic forces and SSDs use electrical charges, these are reversible so can be used repeatedly to store, retrieve and rewrite data. The technology is in its infancy, very expensive and currently confined to research laboratories.

13.1.14 Autonomous transport systems

The term **autonomous transport system** includes any vehicle or system that moves people, resources such as construction materials, or baggage such as goods, suitcases or luggage, from one place to another with little or no input or control by a human operator or driver. Autonomous vehicles are usually used for human transport or goods delivery and are single, solitary vehicles such as a driverless car or truck, but an autonomous transport system consists of numerous vehicles that are interconnected and can communicate with each other and with a central control system. Autonomous robot vehicles can deliver goods to homes or deliver materials around, for example, a factory or hospital with very little human intervention.

Autonomous vehicles, such as driverless cars, are equipped with sensors to provide data that can be used by the computer system to 'build' a 3D model of the environment and surroundings in which it is operating. The sensors include cameras and detectors for the two systems that are found in driverless cars:

- millimetre-wave radar
- light detection and ranging (LiDAR).

The autonomous vehicle uses computer systems, often including AI, to analyse and act upon the input from the sensors and learn how to react to the data, and uses a navigation system, which may be GPS, to travel between pre-determined locations. The system must be able to react extremely quickly to previously unknown occurrences and to learn from them, so the use of AI will enable the vehicle to avoid people, objects and dangerous situations.

The use of autonomous vehicles can significantly reduce the number of collisions between vehicles so increasing passenger safety, enable people who are unable to drive to travel independently of others and so reduce their social isolation, and enable passengers to do other tasks while travelling.

Autonomous transport systems reduce traffic congestion while increasing traffic throughput, so there are fewer traffic jams but more cars, buses or trains passing through, and may reduce the use of land for more roads or parking facilities. Robotic vehicles may increase the speed and reliability of delivery of goods. The impact on the environment may be positive as there will be less pollution and less power may be needed for the newer generations of vehicles.

13.1.15 Energy from wireless signals

Electromagnetic waves, including those that carry Wi-Fi signals, have energy that can be captured, turned into DC (direct current) electricity and used to power devices. **Wireless transmission of power** is not new; it was first demonstrated by Nikola Tesla in 1899, but it has not often been used. Cordless toothbrushes and mobile phones can be charged using wireless methods, but few other devices use it. The charging methods used for these require the devices to be in close contact with the charger. The benefit of wireless charging here is really only safety and convenience. Charging from wireless signals enables charging at greater distances. As the IoT grows and more devices, all needing to be powered, are connected, wireless charging with energy extracted from 4G, 5G, Wi-Fi and other wireless telecommunication signals is becoming practicable. The location of the device may mean physical cables are difficult to install, solar energy may not be available, or batteries are difficult to replace, so the devices will be made to power themselves via wireless. Also, devices inserted inside the human body, such as heart pacemakers or medicine-release systems, may be powered by the wireless signals that pass though human bodies all the time.

13.1.16 The impact of new and emerging technologies on scientific research

New and emerging technologies have changed and enhanced the way scientific research is carried out. Computing technology can be used in observation, experimentation and analysis of data to produce hypotheses that are then tested in scientific research.

Observation using augmented reality systems, artificial intelligence and robotic devices can add to the data collected in traditional ways. Image enhancement can remove imperfections and compensate for missing pixels in the data, and the addition of false colours to images helps humans to understand the images. Artificial intelligence is used in data mining. It can analyse and collate massive amounts of data found in scientific research publications in short time periods. It can discover trends and patterns that help to discover many things, such as new materials for construction and engineering, new chemicals for industry to make products such as cleaning materials, and new drugs for combatting disease. AI can also analyse images, like those of stars and galaxies from telescopes collected by space observations, to discover patterns to aid the research. AI requires high-performance computers, cloud computing, vast amounts of data storage and high-speed communications systems to mine and analyse data from all over the world and from space-based research tools.

In research for new medicines, robots have been used to mix together chemicals to find out what new compounds can be created. Robots can speed up the work, work repetitively and more consistently and produce results quicker. New drugs can become available sooner. Remote control robotic devices or robot arms can be used to handle hazardous or dangerous chemicals and materials without putting the scientists at risk.

Scientific research documents placed on the internet or accessible cloud storage are automatically translated using computer-assisted translation into different languages, making them available to others all over the world. Human corrections may have to be made as CAT is not ideally suited to technical documentation, but the time taken to translate the documents is much reduced. This makes research available more quickly to other scientists for review, comment and use.

Holographic imaging is used to visualise objects in three dimensions. When used with virtual reality, it can enable scientists to move around and inside objects in ways that are not physically possible. Chemical molecules, for example new drugs, can be examined and researched. Parts of the molecules can be moved to find out the effect of doing so. Biological structures can be digitised and the images studied.

Scientists use holographic and fourth-generation storage because their research can generate huge amounts of data and this must be kept safe. Current holographic and fourth-generation storage is expensive, but it may be the only choice for saving and archiving massive quantities of data for future study. The reduced data-access times of holographic and fourth-generation storage are useful for accessing and analysing the large amounts of data.

3D printing of scanned and digitised objects, for example fossils, enables the study of objects that are too fragile to touch. The printed models can be handled and moved without fear of damage to the originals. Multiple copies can easily be made available to different scientists or the 3D printer files sent across the world for printing.

Vision enhancement, with smartglasses, headsets or display screens, can allow scientists to study very small or very distant objects, or objects that reflect light outside the range of human vision. Robotic devices with cameras can enhance the images in various ways to study the environment in which the robotic device is operating.

Activity 13m

Explain why scientific research often requires the use of high-performance computer systems.

13.1.17 The impact of new and emerging technologies on the environment

E-waste and recycling

E-waste, or electronic waste, is discarded electronic devices. The discarded devices can be recycled, reused or dismantled. **Recycling** of complete devices often means they are reused by others without being dismantled for parts. Dismantling and recovering parts and components to be used in new devices is true recycling. Gold, silver, nickel and aluminium, used in circuitry and connections, are not usually directly hazardous to health, but high levels of them are to be avoided. Cadmium, lithium, manganese, copper and lead, and many others, are used in electronic components, circuit boards and solder joints in varying quantities, and all can cause environmental damage. Components and parts that cannot be reused or recycled, either because it is not economic to do so or because they are no longer suitable, have to be disposed of. Rare, dangerous and other metals are often left in the discarded waste. Eventually these metals will leach into the environment and water supplies and may cause damage to crops, animals and human health.

Polymers and plastics used to make cases, supports, covers, wiring and switches are difficult to reuse and recycle. These remain in the environment for many years without degrading. When plastics are burnt or do eventually degrade, they may release noxious compounds or elements into the environment. Chlorine is used in the manufacture of, and is found in, some plastics and its release is harmful to life.

The disposal of e-waste can be by mechanically stripping the material from the device, or by burning the materials and attempting to recover some materials from the ashes. Burning destroys the components and releases noxious fumes into the atmosphere unless carried out safely and carefully. Industrial containment and safe plants are required to prevent contamination of the air, water supplies and surrounding lands.

Vast quantities of components and parts that cannot be recycled or recovered are shipped from one country to another for disposal and may end up buried in landfill. Sometimes, this may be because other countries have better disposal facilities, lower costs or fewer regulations regarding waste disposal. However, the shipping of e-waste around the world can add to the environmental damage.

People living near recycling facilities, or near to landfill areas where e-waste is dumped, may feel the effects of hazardous materials, and may become ill or suffer other health problems. Exposure to hazardous e-waste has been known to affect unborn children.

Power consumption

As previously discussed, all new and emerging technology requires power to work. The increase in computing power demanded by new technologies used in manufacturing and by businesses, organisations and individuals increases the demand for electrical power. The incorporation of microprocessors, internet capability and communications systems into new areas, for instance home appliances, telecommunications with mobile devices, health care, scientific research and many other areas, has led to further increases in demand for electrical power.

Manufacturing processes

The use of new and emerging technology in manufacturing has reduced costs, increased productivity and increased the consistency and quality of goods. However, there has been an impact on the environment. New technologies in manufacturing often require more electrical power as they run continuously through the day and night. They use raw materials that are already scarce, for example rare metals, and that require extensive mining to extract. New technologies in manufacturing also create waste materials that are difficult to dispose of without considerable cost, and create goods that do not degrade so their components remain in the environment for many years. Plastics are a major component of many new technologies, for example robotic devices that are used in many manufacturing processes.

Beneficial impacts are that manufacturing waste has been reduced, goods last longer so do not need to be replaced so often, working environments are safer for workers, and workers do not need to work very long hours to produce as many goods so they have a healthier lifestyle. For example, using 3D printers in a manufacturing process can reduce overall production times because there is no need for complex milling or drilling of complex shapes, but only the removal of the support materials and final clean-up. This produces longer-lasting goods in a safer workplace. Waste is reduced and there is less power consumption. Robotics also reduces waste as there are fewer errors in production and goods are more consistently assembled. Using robotics with AI can help to detect production problems, for example by more quickly recognising and comparing the production items with pre-set values of perfect objects, so fewer imperfect goods are made and then rejected.

Practice questions

1. Describe how analysing social-media posts can be used to target users with advertisements. (5)
2. Describe how shoppers could make use of augmented reality (AR) when buying clothes in a store. (6)
3. Explain why surgery from remote locations using robotic devices is more risky than surgery carried out by a surgeon in person. (6)
4. Discuss the impact of wearable computing devices in health care. (6)
5. Discuss the benefits and drawbacks of using robotic devices to manufacture automobiles. (8)
6. Discuss the benefits and drawbacks of the use of computer-aided translation by a company that produces TV sets for the global market. (6)
7. Describe the impact of holographic imaging on commerce. (6)
8. Describe how the disposal of computing devices that are old and no longer usable can pose a danger to the environment. (6)

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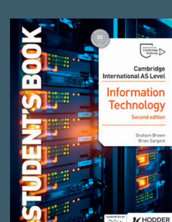

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