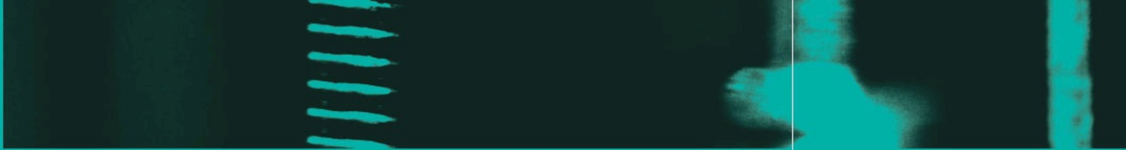

David Bonamy

Technical English 4

SECOND EDITION

Course Book and eBook

Pearson

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David Bonamy

Technical English 4

SECOND EDITION

Course Book and eBook

Contents

1 Innovations

1 Eureka!

START HERE »

1 **Work in pairs. Talk about accidental discoveries or inventions in science or technology which you have heard about, for example Velcro fasteners, microwave ovens, Teflon non-stick coating.**

TASK »

2 **Work in pairs. Match the notes (1–5) and the images (A–D) with the accidental discoveries.**

[1, A] antibiotics	[ ] vulcanised rubber
[ ] inkjet printer	[ ] X-ray
[ ] safety glass	

1 Alexander Fleming – researches bacteria – leaves uncovered petri dish containing bacteria near open window – *penicillium* mould falls on dish – Fleming notices – mould kills bacteria
2 Charles Goodyear – works with raw rubber powder containing sulphur – brushes powder off hands – powder falls onto hot stove – forms tough elastic substance
3 Wilhelm Roentgen – experiments with cathode ray tube – suddenly sees light from tube pass through thick cardboard cover – lights up screen some metres away
4 Ichiro Endo – works with a hot iron and a syringe full of ink – touches neck of syringe with iron – forces ink out
5 Edward Benedictus – puts away glass flask – flask contains liquid plastic – drops flask on floor – flask doesn't break – thin plastic film holds pieces together

3 **Describe the accidental discoveries outlined in the notes in 2. Use the past continuous and the past simple tenses where appropriate.**

Language
page 101

Example: *1 Alexander Fleming was researching bacteria when he accidentally left an uncovered petri dish containing bacteria near an open window and some penicillium mould fell on the dish. Fleming noticed that the mould killed the bacteria. That is how he discovered antibiotics.*

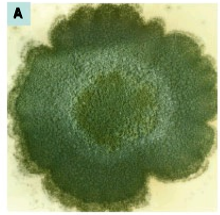
WRITING »

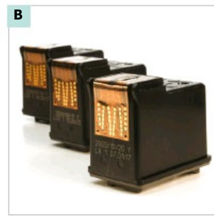
4 **Write about the most interesting discovery or invention you talked about in 1. Use the past simple and continuous, as in the example in 3.**

SCANNING »

5 **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete this text.**

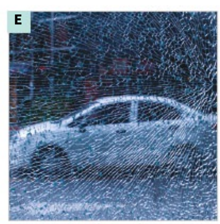
We don't know if Archimedes really stepped into his bath and shouted 'Eureka!' ('I've discovered it!') when the water level (1) ___________. But we do know that he discovered that a body immersed in fluid experiences a (2) ___________ force equal to the weight of the liquid displaced. We also know that Archimedes invented the (3) ___________ and the (4) ___________.

A


B


C


D


E


LISTENING »

6 **🔈1.1 Listen to this talk and choose the picture that illustrates what Jaap (Will's colleague) was looking at when he had his *eureka* moment.**

7 **Listen again and answer these questions.**

1 What is Will's (the speaker's) job title at his petroleum company?
2 What problem has the speaker been trying to solve for the last few years?
3 What was happening when Jaap suddenly had his *eureka* moment?
4 What was the name of the type of drill that Jaap and his team invented as a result?
5 How does this new drill solve Will's problem?

SPEAKING »

Language
page 101 + page 102

8 **In the question and answer session after his talk, Will gives these answers. Write down the questions that were asked. Then practise the questions and answers in pairs.**

1 Well, I would say that the main reason for using this technology is mainly economic. Snake wells allow us to get more oil out of a single field.
2 Yes, it does. The technology has a very big environmental benefit, because snake wells mean that you can build fewer oil platforms and do less drilling.
3 Yes, we are. We're using it right now, at this very moment. We have a number of snake wells in operation as we speak.
4 Well, most of the oil in the field is between 2,000 and 4,000 metres below the seabed, I think.
5 You mean me personally? I've been working at this oilfield for about four years now.
6 Well, our company first started exploring this oil field a long time ago. I believe the first survey was in the 1970s.
7 Yes, we have. In addition to the snake well, we've been expanding our network of sensors that transmit data from the drilling equipment to cloud-based servers.
8 Well, I don't know exactly what my next project is going to be! I think I may be moving to an oil field in Nigeria.

LANGUAGE »

Present perfect continuous

<table>
<tr><td>How long</td><td>have</td><td>you</td><td rowspan="2">been</td><td rowspan="2">using</td><td colspan="2">snake wells?</td></tr>
<tr><td colspan="2">Our company</td><td>has</td><td>them</td><td>for several years.</td></tr>
</table>

SPEAKING »

9 **Work in pairs. Take turns to act the roles of a reporter and an oil company representative. When you are the reporter, use the present perfect continuous in your *first* question about each project and then follow up with different types of questions.**

Student A: Turn to page 116. **Student B:** Turn to page 114.

1 *Fracking project, Oman: how long? how deep? how it works? average gas production? environmental policy? carbon emissions?*

2 *Shale gas project, Saudi Arabia: how long? based where? what is shale gas? process? wasting scarce water? why gas important? effect on environment?*

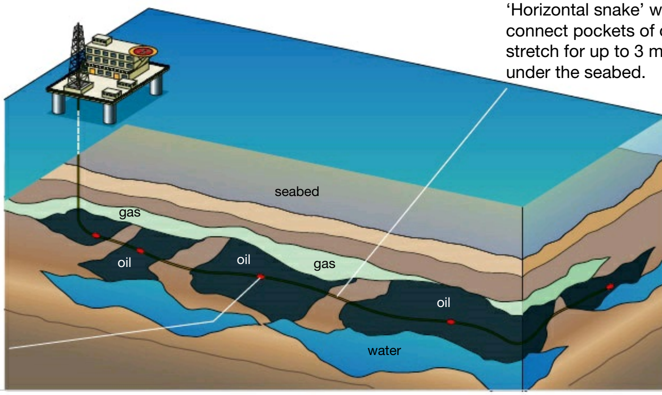
2 Smart wells

START HERE » **1** **Work in pairs. Discuss these questions about the illustration below. Make notes.**

1 What are the advantages of this method of oil extraction compared with vertical wells?
2 How do you think computers and sensors are used in this method?

Extracting oil from small isolated pockets

'Horizontal snake' wells connect pockets of oil that stretch for up to 3 miles under the seabed.



Valves and seals are located in the oil pockets so they can be shut down if too much gas or water enters the pipeline.

READING » **2** **Read this article and check the notes you made in 1.**

DIGITAL Oil Fields

If an oil company discovers a large single reservoir of oil and gas, the solution is relatively simple: drill a vertical well down to the reservoir and bring up the oil. But what can be done when an oilfield consists of hundreds or even thousands of small, **isolated** pockets of oil? It would be too expensive to drill hundreds of vertical wells to reach them all.

An innovative solution to this problem is the 'snake well'. Unlike the **conventional** vertical well, this is a horizontal well that weaves **laterally** back and forth across a number of oil-containing zones. Guided by smart technology, a single snake well can access multiple pockets of oil and achieve output **equivalent** to several individual wells, which has the **dual** advantage of reducing cost and ensuring that no oil is overlooked.

A snake well uses **steerable** drills that can be positioned with great accuracy. Imaging software generates detailed computer models of underground geology and reservoirs. This enables drills to hit a target far underground that is less than two metres across.

Located about 35 km off the coast of Brunei, Shell's Champion West oilfield lay dormant from around 1975 to the mid 2010s. Its rich oil reserves were **locked** 2,000 to 4,000 metres beneath the seabed in a **complex** web of small reservoirs which were too expensive to develop – until Shell's engineers had the idea of using snake well drills, guided by advanced software, to reach them.

Buried deep beneath Champion West's seabed, sensors sent digital information about temperature, pressure and other factors to control centres on land via fibre-optic cables.

For example, if water or gas threatened to break into the well, remote-controlled hydraulic valves could close down the inlet to seal it off from the rest of the system.

Inspired by the snake-well concept, digitalised horizontal wells can be found wherever complex drilling is required, such as in fracking, water injection and geothermal energy. Developments in cloud computing and, more recently, **edge** computing enable drilling equipment to make **autonomous** decisions in real time, responding to conditions underground. For example, the oilfield services group Schlumberger has produced an *at-bit steerable system* (ABSS) that can drill a curved horizontal well in a single run. The ABSS uses edge computing located at the drill bit (not in the cloud) to enable it to change direction with minimal **latency** (that is, immediately) in response to the conditions it meets.

3 Answer these questions about the article.

1 What are the two main economic reasons for drilling a snake well?
2 How accurate is the drill of a snake well when it is guided remotely?
3 For how long was the Champion West oilfield left unused following the discovery of oil there? Why was it left unused?
4 How is data about conditions inside the snake well transmitted to the surface?
5 How do engineers stop the oil in the well being contaminated with water or gas?
6 Explain two advantages of the ABSS compared with a drilled steered remotely by a human operator.

4 Match the reference words 1–6 from the article with the correct words or ideas a–j that they refer to.

1 this (line 12)
2 which (line 22)
3 that (line 26)
4 This (line 30)
5 them (line 43)
6 it (line 52)

a) increased output from many oil zones
b) conventional vertical well
c) engineers
d) snake well
e) latency
f) small reservoirs
g) computer model generation
h) steerable drills
i) drill bit

VOCABULARY »

5 Match these words or phrases with their synonyms (in bold) in the article in 2.

1 independent
2 complicated
3 capable of being guided
4 delay
5 normal
6 having two parts
7 close to the data source
8 separated from one another
9 horizontally sideways
10 equal in value

LANGUAGE »

Linking (past participial phrase)

The **past participle** alone can sometimes replace **subject + passive verb**. It makes the text more concise.

- *The Champion West oilfield, **located** about 35 km off the coast of Brunei, lay dormant …* (= *The Champion West oilfield, **which is located** …*)

The past participle can also be placed at the beginning of a sentence. Find these examples in the text in 2:

- ***Located** about 35 km off the coast of Brunei*, the Champion West oilfield lay dormant …
- ***Guided** by smart technology*, a single snake well can access pockets of oil …
- ***Buried** deep beneath Champion West's seabed*, sensors along the completed well …

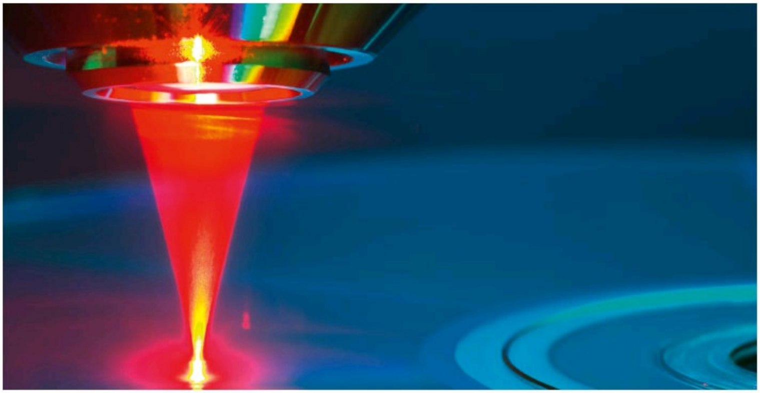
Note that the participle must have the same subject as the verb in the main clause.

6 Join the information in each note into a single sentence in a similar way. Begin each sentence with the past participle in italics.

Example: *1 Isolated in small pockets, the oil can't be extracted using vertical wells.*

1 the oil is *isolated* in small pockets + it can't be extracted using vertical wells
2 the sensors are *connected* by fibre-optic cable + they collect data from inside the snake well
3 the drills are *guided* by remote controllers + they can hit a target only 2 m wide
4 the oil is *locked* 4,000 m beneath the seabed + it couldn't be extracted for 30 years
5 the sensors are *attached* to the drill bit + they allow controllers to guide the drill
6 the ABSS was *developed* by Schlumberger + it enables the drill bit to act autonomously

3 Lasers

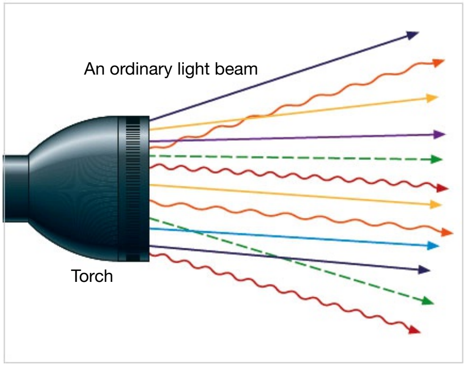


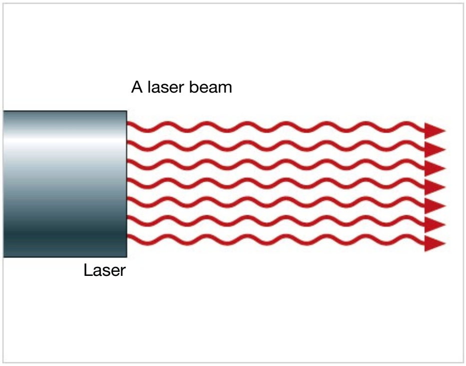
START HERE »

1 Work in pairs. Discuss these questions and make notes. Then share your ideas with the rest of the class.

1 What does LASER stand for?
by ________ ________ Stimulated ________ of ________

2 Study the diagrams below. What are the three main differences between ordinary light and laser light? Use some of the words and phrases in the box.



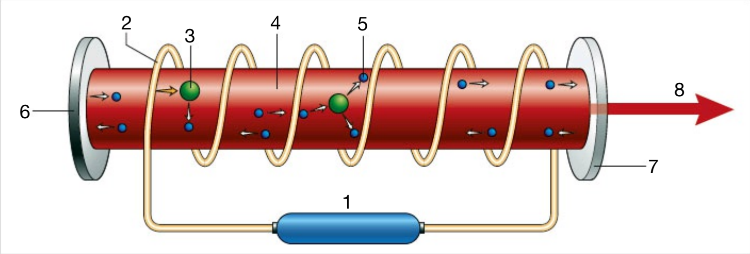


laser   light amplification   stimulated emission of radiation   organised   disorganised   directional   in one direction   in all directions   coherent   concentrated   photon   colours of the spectrum   wavelength   1.2

LISTENING »

2 1.3 **Listen to part of a talk about lasers. Match the words in the box with the labels 1–8 in the diagram on the next page.**

ruby crystal   atom   light tube   mirror   power source   photon   laser beam   partial mirror



3 **Work in pairs or small groups. Before you listen to the next part of the talk, put these notes into the best order.**

Note: The eight items in the notes correspond to the eight points in the diagram above.

A escaping photons form a powerful laser beam ☐
B atom absorbs photon – gets excited – calms down – emits new photon ☐
C tube flashes on / off rapidly – pumps energy (photons) into crystal ☐
D partial mirror lets 1% of photons escape ☐
E power source makes tube flash on / off 1
F new photon hits excited atom – atom emits *two* photons (instead of one) ☐
G photons are reflected by mirror along inside of crystal ☐
H new photons travel inside crystal at speed of light ☐

4 1.4 **Listen to the next part of the talk, and check your answers to 3.**

5 1.4 **Listen again and tick the phrases that you hear. (Note: X is a number, and A is someone's name.)**

1 A has been explaining
2 let's move on to the next section of the talk
3 if you look at point X on the diagram, you will see
4 we can now turn to the next part of the talk
5 as you can see in point X on the diagram
6 I think I've covered the main points
7 I'll now ask A to take over
8 now I'm going to hand over to A

6 **Group the phrases from 5 under these headings.**

Moving to the next topic
Referring to the previous topic(s)
Handing over to the next speaker
Referring to a visual

SPEAKING »

7 **Work in groups to prepare a talk on lasers. Divide into three sub-groups and prepare one section of the talk with your sub-group. Then return to the main group to finalise the talk.**

Sub-group A: Laser light – a brief explanation
Sub-group B: The basic components of a laser machine
Sub-group C: How a laser machine works

8 **Give your talk to another group. Use phrases from 5 to signpost the sections of the talk, to refer to the diagram and to hand over to the next sub-group. Invite and answer questions from the audience.**

WRITING »

9 **Write a description of how a laser machine works, referring to the diagram above. Use past participial phrases where possible.**

Begin: *Here is a brief outline of how a laser machine works. First of all, the high-voltage power source, located below the ruby crystal, makes the tube flash on and off rapidly. These flashes inject particles of light, known as 'photons', into the ruby crystal. …*

2 Design

1 Spin-offs

START HERE »

1 Work in pairs. Discuss the four statements below and decide if they are *true* (T) or *false* (F).

Many everyday applications on Earth are actually spin-offs from technology originally invented for space exploration. But there are many myths (false beliefs) about spin-offs.

1 Teflon is often added to pans to provide a non-stick surface for cooking and frying. It was originally invented to provide a surface for shields on spacecraft. T / F
2 Portable computers were first developed for use on a NASA shuttle mission in 1983. Laptop computers are now widely used for work and play. T / F
3 Velcro is now used for quickly attaching two items together, such as straps on trainers. It was primarily developed for anchoring items in zero gravity. T / F
4 Microwave ovens were originally invented for use on an early Earth-orbiting space station to enable astronauts to warm up their meals safely. They are now commonly used in many kitchens on Earth. T / F

Language
page 100 + page 101

2 Underline four examples of the present simple passive and four examples of the past simple passive in 1.

3 Fill in the gaps in these sentences with the correct form of the verb in brackets. Add an appropriate adverb from the box to each gap.

originally	first	primarily	often	commonly	frequently	usually

1 A new technology was originally developed (develop) to correct errors in signals from spacecraft. Now the same technology is often found (find) in satellite TV to improve the sound and picture quality.
2 Bar coding ____________ (invent) to help space agencies keep track of millions of spacecraft parts. Nowadays bar codes ____________ (see) on parcels and products.
3 A laser sensor ____________ (install) on the Mars Perseverance rover to search for signs of past life on the planet. Now the technology ____________ (use) in hospitals on Earth for identifying bacteria in wounds.
4 A system ____________ (create) to change carbon dioxide on Mars into rocket fuel for return journeys. Now a similar system ____________ (utilise) in oilfields on Earth to convert methane emissions into green energy.

SPEAKING »

4 Work in pairs. Discuss what applications on Earth you think were developed from these space applications.

Example: *Solar panels were originally invented to provide solar power for satellites. Today solar panels . . .*

solar panels on satellites	fireproof fabrics in space suits
UV-resistant visors on space helmets	pixel sensors for tiny space cameras

READING »

5 **Compare your ideas in 4 with the items in the text below. Which ones were similar?**

Web Images Videos News Shopping Books More

Spin-offs from space programmes

1 Fireproof fabrics that were originally developed to protect astronauts from fires on spacecraft are now commonly used in clothing to protect firefighters on Earth.
2 Technology originally designed to prevent astronauts' visors from being scratched by dirt and other particles is now regularly used in manufacturing sunglasses that can resist scratching.
3 High-performance solar panels first used on satellites to optimise output when facing away from the sun are now used on solar-powered racing cars.
4 CMOS active pixel sensors that were designed as components of small, high-definition, low-powered digital cameras for space photography are now found almost everywhere in mobile phones and on selfie sticks.
5 Materials primarily used in spacesuit visors to protect astronauts' eyes from ultra-violet rays are now used in clothing which protects people's bodies from the sun's rays.
6 A drill bit on the Perseverance robot arm designed to drill into rock on Mars, break the rock sample off neatly and keep it for examination, can now be used by geologists on Earth to collect perfect rock samples.

Done

6 **Match the original space technology 1–6 with the uses on Earth a–f.**

1 a visor to protect astronauts' eyes from the sun
2 a fabric for protecting astronauts from fire
3 solar panels that provide power for a satellite
4 a visor which resists cuts and scratches from stones
5 tiny pixels to capture HD images in space
6 a drill bit for collecting rock samples on Mars

a) mobile phone cameras
b) scratch-resistant sunglasses
c) a useful tool for geologists
d) PV panels for solar-powered cars
e) UV-resistant clothing
f) flame-resistant clothing

LANGUAGE »

Expressing the use or function of a device

- *to* + infinitive: *a visor to protect astronauts' eyes from the sun*
- *for* + *-ing*: *a fabric for protecting astronauts from fire*
- *that / which* + present simple: *solar panels that provide power for a satellite*

7 **Say the items 1–6 in 6 in two different ways, using language forms in the box.**

Examples: *Item 1 is a visor for protecting astronauts' eyes from the sun. Item 1 is a visor that protects astronauts' eyes from the sun.*

8 **Make full sentences from these notes. Use a variety of forms from the language box above.**

Example: *1 A solar panel is a panel of PV cells which is used for generating electrical power from the sun's rays.*

1 solar panel – panel of PV cells – use – generate – electrical power from sun's rays
2 stress sensor – instrument – monitor – changes in the load on a structural component such as a girder
3 stress sensors – originally – design – monitor – problems with external systems on spacecraft
4 clean air system – originally – invent – clean – air breathed by astronauts in spacecraft, now – commonly – find – in portable sterile rooms – in hospitals
5 CMOS active pixel sensor – device – converts – light signals – into electric signals – and – main component – phone cameras
6 Perseverance drill bit – located – robot arm – precision tool – used – collection of rock samples – surface of Mars

2 Specifications

START HERE »

1 **Work in pairs. Discuss a product or facility that you and your partner both use. Make notes of any problems or features that you would like to improve in the product or facility. Explain your ideas briefly to another pair.**

Examples: a computer operating system, a mobile phone network, a web browser, a gym or sports centre, a canteen or food court, a transport system

TASK »

2 **Work in small groups. Look at the illustration and the information below. What do you think the complaints were about? Make notes under these headings: *safety, performance*, *appearance* and *ergonomics*. Then compare your notes with the information on page 113.**

ergonomics = adapting a machine (or job) to the user so that it is comfortable, safe and efficient to use

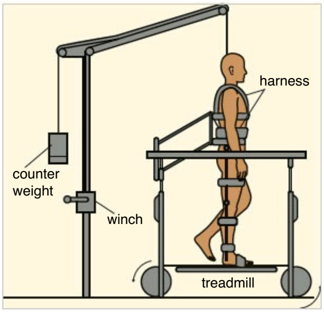
Product: TreadAir

Designed for: people recovering from an accident or injury

Purpose: so that they can exercise on treadmill safely

Method: body is lifted by winch and harness and supported by counter-weight

Feedback: complaints received from users about problems with . . .



LISTENING »

3 2.1 **Listen to a product design team brainstorming how to improve the TreadAir. Complete this form.**

REQUIREMENTS FOR NEW PRODUCT	
Description	An inflatable airbag enclosing the body which can ____________ without ____________
Performance	• Maximum support: ______ % of body weight • Air pressure adjustable in increments of ______% • Maximum speed: ______ kph
Ergonomics	• Display type: (1) ____________ (2) ____________ • Able to control: (1) ____________ (2) ____________ • Able to alter settings during workout without ____________
Dimensions	______ x ______ m footprint
Weight	Compared with normal treadmill: ____________
Operating range	Temperature: ______ to ______ °C
Safety	Standards: (1) ______ (2) ______

4 **Work in groups to discuss this question and make notes. To what extent do you think that the product illustrated here would meet the requirements outlined in the brainstorming session?**

READING » 5 **Mark four items in this draft design specification which were not mentioned in the brainstorming session in 3.**

Draft Product Design Specification

1 Recommended product name: the name should reflect the fact that it is a space spin-off, and suggest weightlessness: for example *MoonWalker* or *SpaceRunner*.

2 Recommended product description: 'an **enclosed** treadmill that utilises air pressure in an inflatable bag to support body weight, without a winch or harness'.

3 Performance requirements for new product:
- reduce user's weight by up to 80%
- give **precise** measured support
- allow **incremental** (1%) adjustment of air pressure
- provide **unrestricted** motion for legs and upper body
- run at a **variable** speed adjustable up to 16 kph
- present a variable incline (or slope) up to 15°

4 Recommended ergonomics features:
- touch button on screen to increase / reduce support for body weight
- adjust speed, incline and air pressure using simple controls
- change settings while running, without needing to stop
- attach body safely to machine using special shorts that zip into airbag

5 Operating environments: machine must be able to function within
- an **ambient** temperature range of 10–29°C
- a **relative** humidity range of 20–95%

6 Dimension and weight requirements:
- maximum 4 x 2.5 m footprint to allow for **adequate** space around machine
- similar weight to a normal running treadmill

7 Safety requirements:
Since the product is intended for export throughout Europe including the UK, compliance with all applicable BS and EU safety standards is essential.

6 **Match these words and phrases with the adjectives (in bold) in the document in 5 which have the same or similar meaning.**

1 changeable
2 sufficient
3 surrounding
4 without constraints
5 sealed
6 step-by-step
7 comparative
8 exact

LANGUAGE »

Expressing necessity, recommendation and ability

A **necessity** *must / have to / need to / have got to*
B **recommendation** *should / ought to*
C **ability** *be able to / be capable of / have the ability to*

SPEAKING » 7 **Work in pairs. Choose eight specifications from the document in 5 which are the most important, in your view.**

8 **Talk about each specification, using a variety of items from the language box above. Use a modal from list A or B, combined with a phrase from list C.**

Example: *The equipment has to be capable of reducing the user's weight by up to 80%.*

WRITING » 9 **Rewrite sections 3 and 4 of the document in 5 as a memo to the manager of your product design team. You want to persuade your manager to support you in designing the product. Describe the product as if it *already exists*. Link the phrases in the document together using present participial phrases where appropriate.**

Language
page 103

It reduces the person's weight. It gives precise measured support. It allows incremental adjustment.

➔ *It reduces the person's weight, **giving** precise measured support and **allowing** incremental adjustment.*

Begin: *The new SpaceRunner is capable of reducing the person's weight by up to 80%, giving . . .*

3 Properties



START HERE »

1 Work in pairs. The architectural fabric used on these buildings is a spin-off from space technology. Discuss these questions.

1 What properties must this roof fabric have (e.g. *tensile strength*, *durability*)?
2 What do you think this fabric was originally used for in space?
3 Do you know any buildings in your own country where this material is used?

LISTENING »

2 2.2 **Listen to a team brainstorming the properties of roof fabric. Write numbers in the boxes to show the order in which these properties are mentioned.**

thermal protection ☐	solar reflectance ☐
kilo for kilo stronger than steel 1	good acoustics ☐
solar translucency ☐	low maintenance ☐
non-flammable ☐	high melting point ☐

VOCABULARY »

3 Match the phrases in italics in this text with the words or phrases in 2 that are closest in meaning.

Tensile roof fabric is a safe, economic and architecturally stunning material for concert hall roofs.

The fabric is extremely fire-resistant. In case of fire, it (1) *will not burst into flames*. Even in a severe fire, the fabric (2) *won't melt until the temperature is very high*, in fact over 650°C.

During the day, when the sun is shining, about 25% of the (3) *sunlight can pass through* it, but the other 75% of the (4) *sunlight is reflected away* from the outside of the fabric. This means that the material (5) *protects the building from the heat* of the sun. As a result, the need for artificial lighting and air conditioning is very low, which means that the building is very cost-effective to run.

The roofing material is lightweight and yet (6) *it has greater strength than steel relative to its weight*. It can easily be formed into sound panels, which means that the (7) *quality of sound is very good* inside the building, which makes it suitable for concerts and gigs.

Finally, we can say that this fabric is durable, and (8) *will not need to be repaired for many years*.

SCANNING »

4 **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to answer these questions.**

1 What are *five* properties of the fabrics used for the outer layer of spacesuits following the fire that destroyed the Apollo 1 command module?
2 What is the melting point of the fabric?

LISTENING »

5 **Listen to the brainstorming session again and tick the phrases you hear.**

(a) Inviting suggestions
Who'd like to kick off? ☐
Let's focus on . . . for a minute. ☐
What do you think? ☐
Any thoughts on that? ☐
Any ideas on that? ☐

(b) Introducing ideas
Why don't we . . .? ☐
What about . . .? ☐
I've got an idea! ☐
I'd suggest that . . . ☐
I know! ☐

(c) Praising contributions
That's very interesting. ☐
Great idea! ☐
Yes, that makes sense. ☐
You're absolutely right. ☐
Good point. ☐

TASK »

6 **Work in small groups. Choose a product that you all know something about and which you think needs design modification.**

For example, you could choose a computer operating system or application, a smart phone, a vehicle, a remote control handset, a building, a machine or a piece of safety equipment. Typical problems could include size, weight, performance, appearance, ergonomics or safety.

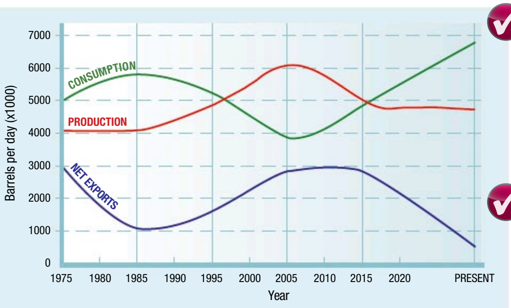
7 **Make a list of the *current* main features, capabilities and properties of the product in 6, both good and bad.**

8 **Brainstorm the features, capabilities and properties that you think an improved product needs to have. Make notes of your decisions. Use some of the phrases in 5 as you brainstorm.**

WRITING »

9 **Work individually. Using your group's notes, write a product design specification for the new product.**

Review Unit A



1 Look at the graph and answer the questions for this country's oil industry.

1 What happened between 1985 and 2015?
Example: *Between 1985 and 2015, consumption fell and then started to rise again. Production during this period . . .*

2 What has been happening since 2020?

2 Make sentences from these situations and events. Use the past continuous + *when* + past simple in each sentence.

Example: *1 The survey team were exploring the eastern region when, on day 3, the aerial photos showed an unusual rock formation.*

1 survey team explores eastern region ➔ day 3 – aerial photo shows unusual rock formation
2 the morning's drilling operation proceeds without incident ➔ at noon – alarm bells start ringing – hydraulic well valves close automatically
3 detonators send sound waves through rock layer as usual ➔ 08.36 – underground sensors detect oil reservoir
4 Jaap conducts research into small pockets of oil ➔ suddenly – one day – he has *eureka* moment – invents snake well
5 drill bit approaches the oil zone laterally ➔ without warning – water and gas break into well
6 we prepare to close the dormant well ➔ unexpectedly – our imaging software indicates network of small oil pockets

3 Explain what Armando was doing and has been doing during his career. Use the past continuous or present perfect continuous as appropriate.

Examples: *1 From 2011 to 2013 Armando was working ... 2 Since 2013 (or From 2013 until the present) he has been ...*

1 2011–2013: works in different jobs on oil rig off coast of Mexico
2 2013–present: does different kinds of jobs, but always within petroleum industry
3 2013–2016: studies for university degree in petroleum engineering
4 2016–present: produces technical articles on oil exploration
5 2016–2018: researches exploration techniques for engineering doctorate
6 2018–present: specialises in consultancy and training for oil industry
7 2018–2020: Armando's consultancy business expands rapidly
8 2020–present: acts as consultant and trainer for the top petroleum companies

4 Provide questions to extract the statements you produced in 3. Use the past continuous or present perfect continuous as appropriate.

Examples: *1 During which period / When was Armando working on an oil rig? 2 How long has he been doing jobs within the petroleum industry?*

5 **Describe what the oil workers were doing when this incident happened.**

At 10.36, the blowout alarm on the oil platform sounded, indicating that the blowout preventer was activating itself automatically to prevent an explosion of gas from the main oil well. The photographs illustrate what some of the workers were doing at that moment.




6 **Make notes about a possible scenario (similar to the one in 5) in your industry or technical field. Describe what the workers were doing when the incident occurred.**

Your notes should include (a) a dangerous incident and (b) six common jobs that workers were possibly doing at the time of the incident.

7 **Combine each pair of these notes into a full sentence using *which* or *who*. The first of each pair becomes the main clause of the sentence.**

Example: *1 The weak light, which was amplified by the telescope, was clearly visible.*

1 weak light was clearly visible + it was amplified by the telescope
2 laser light tube flashes intermittently + it is coiled around ruby crystal
3 photons excite atoms in ruby crystal + they are emitted by flashes of light tube
4 drill is lowered gently into the oil well + it is suspended from a swivel and hook
5 workers began repairing drill pipe + they were organised into groups of four
6 drilling team work in difficult conditions + they are isolated on a rig in the middle of the desert

8 **Say the sentences you made in 7, but change them using past participial phrases. In some of your answers, start with the past participial phrase.**

Example: *1 The weak light, amplified by the telescope, was clearly visible.* (*Or Amplified by the telescope, the weak light was clearly visible.*)

9 **Complete this talk with the words and phrases in the box.**

let's look	hand over to	can be seen	dealing with	as you can	look at
covered the main	like to move on				

For the next part of my talk I'd like you to look at the slides which illustrate my findings. If we (1) ______ the first slide, we can see that photons enter the ruby crystal. My second point, which (2) ______ on the next slide, is that these photons excite the atoms in the crystal. So now (3) ______ at the third slide, which illustrates what happens to the atoms ... All right, now I'd (4) ______ to the next stage, which, (5) ______ see on the fourth slide, is the amplification of the light ... OK, so I think I've (6) ______ points of my part of the talk, so now I'm going to (7) ______ my colleague Esme, who is going to be (8) ______ the next section. Thank you – over to you, Esme ...

10 Complete these texts using the correct form of the verbs in brackets.

The translucent properties of this ceramic (1) were first discovered (first / discover) by NASA ceramic engineers. They (2) ______ (carry out) research to (3) ______ (develop) tough new materials for spacecraft when they suddenly (4) ______ (notice) that light (5) ______ (pass) through one of the ceramics. Now, however, the ceramic (6) ______ (commonly / utilise) by dental engineers for (7) ______ (make) protective braces, or restraints, for children's teeth.

Cordless tools are portable, self-contained power tools which (8) ______ (not / have) a power cable, but (9) ______ (power) by rechargeable batteries. Cordless tools (10) ______ (not / invent) by NASA research engineers. In fact they (11) ______ (first / design) by Black & Decker in the 1960s and a cordless drill (12) ______ (then / manufacture) by the company for Apollo astronauts. The drill (13) ______ (use) for (14) ______ (extract) rock samples from the surface of the Moon. Today, cordless tools such as power drills and vacuum cleaners can (15) ______ (find) in millions of houses around the world.

11 Expand each set of notes into a definition consisting of a single sentence.

Example: *1 RoofAir is a tensile, non-combustible fabric made of fibreglass that has excellent solar reflectance and wind resistance and is used for covering and protecting stadiums.*

1 RoofAir – tensile – non-combustible – fabric – fibreglass – solar reflectance – wind resistance – cover / protect stadiums
2 laser beam – optical device – produce intense beam of coherent light – same wavelength – many applications – example – cut / weld / drill
3 snake well drill – flexible drill string – able – change direction – vertically / horizontally / laterally – access – multiple pockets – oil
4 tungsten – metallic element – very high melting point – make – heat-resistant components – rocket engine nozzles
5 Kevlar® – tough – flexible – polymer fibre – kilo for kilo – strong – steel – lightweight – impact resistant – manufacture – bullet-proof vests
6 fibre-optic cable – group – optical fibres (threads) – glass or polymer – bundled together – cable – capable – transmit – large amounts – digital information – speed of light

12 Make similar definitions about four products used in your industry that you know something about.

13 Rewrite these descriptions of existing products as specifications or requirements for designing new products. Use one item from A and one from B in each description. Use all the expressions in the boxes.

A must have to ought to need to have got to should

B able ability capable capability capacity

Example: *1 The new program has to be capable of remotely controlling the throttle, gears and steering mechanism of the mobile robot.*

1 The new program can remotely control the throttle, gears and steering mechanism of the mobile robot.
2 The improved laser drill for oil well drilling can not only cut into rock, but can also melt it when necessary.
3 The new type of carbon monoxide detector can interconnect with other compatible alarms.
4 The newly designed solar panel can harvest solar power using nano-antennas to absorb the infrared radiation of the sun.
5 The updated internet search engine algorithm can process hundreds of thousands of pages in parallel every second.
6 The modified laser can target a single cell in the human body without damaging the other cells around it.

14 **Work in pairs. Study the photos of the two products below, read the data and then compare the two designs.**

Make notes under these headings: Purpose, Description, Performance, Ergonomics, Aesthetics, Health and Safety.

- air blows and evaporates water off hands
- water vapour disperses around washroom walls and floor
- air velocity: about 380 km/h
- single aperture creates high pressure air flow
- hands dry in 20 seconds in pressurised air blast
- sound level 56 dB (as quiet as normal conversation)
- HEPA filter removes 99.97% of bacteria from air
- sensor turns on power when hands are placed underneath aperture

- air scrapes water off hands like windscreen wiper
- water blown into removable tray inside machine
- air velocity: about 380 km/h
- long thin apertures blow air not too forcefully
- hands dry in 10–15 seconds in comfortable air flow
- sound level 75 dB (as loud as a vacuum cleaner)
- surfaces coated with anti-bacterial resin; filter removes particles from air
- power automatically turns on when hands are inserted

15 **You are in the team that is designing the product on the right. Write a product design specification for the product. Use the headings from 14, adding 'Product Name' after 'Purpose'.**

Where appropriate, use expressions of obligation, recommendation and ability (see 13).

Example: *The machine* ***must be able to*** *dry hands completely within 10–15 seconds.*

PROJECT » **16** **Research one of the following. After writing up your findings, present your main points to the class or to a group.**

1 Research a product in your own industry or technical field which has been extensively re-designed in response to criticisms or complaints from users. Write up your findings, describing the re-design process from beginning to end.

2 Research a product or material used in your industry which was originally researched and designed for use in space exploration or for another purpose. Write up your findings, describing its specifications and properties and comparing its original and current applications.

3 Systems

1 Problems

START HERE »

1 Work in pairs. Discuss these questions, then share your ideas with the class.

1 Why do companies sometimes have to recall their products?
2 What kind of products are more likely to be recalled than others?

LISTENING »

2 3.1 **Listen to this radio news item and complete the information.**

1 The Beamish D25A uses ______ fuel and has an ______ gearbox.
2 The part which has the problem is the ______.
3 The problem is that when you release this part under certain conditions, it may ______.

3 3.1 **Listen again and complete these statements.**

1 More than ten million Beamish cars __around the world.__
2 Beamish agencies __today about the recall.
3 Adverts __in newspapers, and all Beamish drivers ________ personally.

LANGUAGE »

Present continuous (passive)

subject	***is / are***	***being***	**past participle**
A product recall operation	is	being	mounted.
Ten million cars	are		recalled.

If you need to specify the agent, you can use *by*: *A product recall operation is being mounted this week* ***by*** *Beamish, one of the world's largest car manufacturers.*

WRITING »

4 Rewrite this text, changing all verbs in the present continuous from the active to the passive and making any necessary changes. Use *by* + agent only when it gives new or important information.

The Vorpal pharmaceutical company has just announced that they are recalling all stocks of their new drug Manxome around the world. Pharmacies in Asia, Europe and Africa are returning about 25 million packets of the drug. The company is conducting the recall because the drug can cause dangerous levels of tiredness. They are currently gathering information about the drug from thousands of doctors. The company is contacting all hospitals, and a team of five specialists is carrying out an investigation. They are putting adverts in newspapers to warn everyone. The President of Vorpal, Dr Hans Jorgen, is holding several news conferences today.

SPEAKING »

5 Work in pairs. Tell each other about product recalls you know about, or other large-scale operations, which are currently being conducted somewhere in the world.

Examples: environmental clean-ups, military campaigns, peace-keeping operations, top-level negotiations, economic interventions, investigations

6 Read the final draft (on the left) of this product recall notice and compare it with its first draft. Underline the differences between the two drafts. Make a note of how the differences affect you as the reader. Then briefly discuss your ideas with a partner.

Product recall: Beamish D25A

Beamish Motor Company announces the recall of the Beamish D25A due to a potential problem with the accelerator pedal. There is a possibility that, under certain conditions, some accelerator pedals may not operate correctly.

The problem may arise because, in very rare instances, the accelerator pedal mechanism can become worn. There is a slight possibility that this could increase the friction in the mechanism, which might result in the accelerator pedal moving too slowly.

In the unlikely event that this happens, the driver may notice that the pedal returns too slowly to the idle position, or, in a few isolated cases, may remain in a partially depressed position.

Even though no accidents have been reported, we advise all our customers to contact their Beamish dealer, who will carry out a free inspection of their vehicle as a precaution.

At Beamish Motor Company, we take the safety of our cars very seriously and we would like to apologise for any inconvenience caused to our customers.

First draft of product recall notice

Beamish Motor Company announces the recall of the Beamish D25A due to a problem with the accelerator pedal. The problem is that some accelerator pedals do not operate correctly.

The problem arises because the accelerator pedal mechanism becomes worn. This increases the friction in the mechanism, which results in the accelerator pedal moving too slowly.

If this happens, the driver will notice that the pedal returns too slowly to the idle position, or remains in a partially depressed position.

Although no accidents have been reported, we advise all our customers to contact their Beamish dealer, who will carry out a free inspection of their vehicle.

Beamish Motor Company would like to apologise for the inconvenience caused to our customers.

VOCABULARY » 7 **Group the words and phrases you underlined in 6 by writing A, B, C or D next to each one.**

A modal verbs indicating possibility (e.g. *may*)
B other words or phrases indicating possibility (e.g. *potential*)
C phrases suggesting that the fault is unusual or rare (e.g. *under certain conditions*)
D phrases suggesting that the company is concerned about safety (e.g. *as a precaution*)

8 **Discuss with a partner the different effect on the reader of these words and phrases in the final draft.**

1 '*in the unlikely event that* this happens' (instead of '*if* this happens')
2 '*Even though* no accidents have been reported' (instead of '*Although* no accidents')
3 '*any* inconvenience' (instead of '*the* inconvenience')

9 **Change these announcements to suggest that the negative events are very unlikely to happen. Use a variety of expressions from this page, or other similar ones that you know.**

1 Callay Airlines announces that flights are being cancelled or delayed due to bad weather. If your flight is delayed, please contact the check-in staff. We would like to apologise for the inconvenience that you have been caused.
2 Dectron Cars announce that the Frodo D5 model (all years) is being recalled to check a fault in the engine filter. The fault is that engine oil enters the combustion chamber and acts as additional fuel. This leads to maintained or increased engine speed. When you take your foot off the accelerator, the car stays at the same speed, or speeds up. If you notice that your oil level has risen above the maximum, please contact your Dectron agent.

2 Solutions

START HERE »

1 Work in small groups. Study the diagram on the next page and briefly discuss the following points.

- the purpose of the system
- how it works
- what the driver hears or feels when the system is working

SCANNING »

2 You have a few minutes before a meeting to gather the information you need. Scan the briefing documents on the next page quickly, and decide which documents do the following. (Some documents do more than one thing.)

1 describe customers' complaints about the Zoltaro Hybrid car __A__
2 give technical information about the Hybrid braking systems ______
3 suggest the cause of the problem ______
4 suggest a solution to the problem ______

TASK »

3 Study the briefing documents more carefully, and write a summary of the main points. The purpose of the summary is to help you produce the product recall notice in 5 below. The total length of your summary should be no more than 200 words. Use headings to indicate topics.

Tips for writing your summary of main points:

- First, write some headings to reflect the topics covered by the briefing documents, e.g. *Problem*; *Test results*; *Technical background*; *Solution*.
- Read the documents and underline the key points.
- Omit examples and repeated or unimportant information.
- Express the key information using as few words as possible.
- Use bullet points and one or more main verbs; omit full stops and words like *a* and *the*. Example: *customers complain of slight delay using ABS on slippery roads*

4 Work with your group from 1. Compare your summaries, check the main points and decide which ones to use in the product recall notice.

5 Produce your team's product recall notice for the Zoltaro Hybrid to solve the problem outlined in your group's summary of main points.

The product recall notice should be 250–300 words long. Use information from your summary of main points. Refer also to the product recall notice and the vocabulary on page 21. Aim to persuade the reader that, although the fault is rare and not dangerous in itself, the company is taking all necessary steps to make the customer feel safe. Explain technical information (about the braking systems, for example), using language that a non-technical reader can understand. To make the writing more concise, join shorter sentences into longer ones where appropriate. Examples:

LANGUAGE »

Linking (non-defining relative clause + present participial phrase)

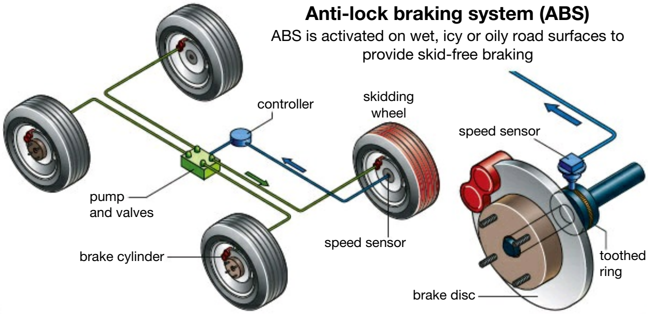
*Full tests have been carried out. **These tests confirm** that all components are working . . .*
➔ *Full tests have been carried out, **which / that confirm** that . . .*
➔ *Full tests have been carried out, **confirming** that . . .*

Expressing contrast

The problem is not serious. The driver may experience some delay in braking.
➔ ***Although** the problem is not serious, the driver may experience some delay in braking.*

Anti-lock braking system (ABS)

ABS is activated on wet, icy or oily road surfaces to provide skid-free braking



- sensor: detects speed from toothed ring and transmits data to controller (computer)
- valve: controls flow of brake fluid into brake cylinder
- pump: applies and releases pressure in brake cylinder rapidly and continuously
- controller: collects data from sensors and controls valves and pumps

During ABS operation, driver experiences rapid pulsing sensation in brake pedal.

A

REPORT ON USER FEEDBACK

Twenty-six drivers of the *Zoltaro* Hybrid have written to us complaining about braking problems on slippery roads. When they brake, according to their reports, they experience a slight delay before the ABS is activated. There have been no reports of accidents and tests confirm that there is no loss of braking power. Here's one example of customer feedback taken from a drivers' blog on the internet: *I love my Zoltaro Hybrid, but it gave me a bad scare last week. Driving down a hill at 50 kph, I hit a patch of oil on a bend in the road. I touched my brakes, but for a split second nothing happened. Aaargh! I almost panicked, then I heard the rumble of the ABS kicking in, then the car slowed down safely . . .*

B

From: Chief Engineer, ABS

Our team has tested all the components of the Hybrid's ABS system (see illustration above). Our results indicate that all components are working correctly. We suggest that the problem is in all probability a software one.

C

From: Chief Engineer, Hybrid

You asked our team to check if the 'braking delay' problem could be caused by a conflict between the hydraulic and the regenerative braking systems.

It's possible. However, most hybrids – not only the Zoltaro – show slight delays while the controller switches from regenerative to ABS braking. The delay does not reduce braking power. I attach a 'Technical Note' with further details.

D

Switching from regenerative to hydraulic braking

The brakes in the Hybrid use three systems: *brake regeneration, hydraulic brakes* and *ABS* (anti-lock braking system).

Under light braking, the callipers don't squeeze the brake discs. Instead, the resistance of the electric motors provides the deceleration. By the way, this is how the Zoltaro Hybrid collects the energy of the moving car and recharges the batteries.

Harder braking engages the callipers in the usual way. Finally, maximum braking while driving on slippery roads engages the ABS system to keep the tyres from skidding. The computer receives inputs from various sensors and then determines the correct braking system.

On a slippery road, there may be a momentary delay while the controller switches from regenerative to ABS braking. The brakes are powerful and the car will still stop. However, the driver may perceive this as a dangerous delay, although the delay is not in actual fact dangerous.

E

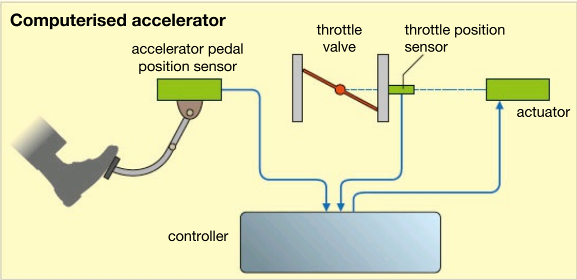
From: Chief Engineer, Software

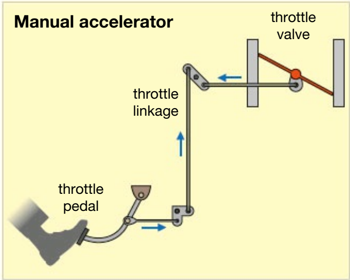
You asked my team to devise a software fix for the 'delayed braking' problem.

We've designed a simple software solution that will speed up the controller's response when it switches between braking systems. A product recall will be needed, as we thought, but you can tell the customers that it will not require new parts to be fitted. The technician will simply connect a laptop to the car's controller and download the new software.

3 Controls

START HERE » **1** **Work in pairs. Briefly discuss the similarities and differences between manual and computerised car acceleration systems.**





READING » **2** **Read this text and answer the questions below.**

Computerised control systems

1 Cars

The illustrations show the difference between a manual (or physically controlled) accelerator system and a computerised one. Computerised systems in cars are sometimes called *drive-by-wire* systems. The word *wire* refers to the cable that carries electronic signals to and from the **controller**. Both systems use the same input **mechanism** (the accelerator pedal) and output mechanism (the valve on the **throttle**). In the manual system, the pedal is directly connected to the throttle valve by cables and springs, which pull and release the valve using physical force. In the computerised system, an electronic sensor detects the movement of the pedal, and sends a signal to the controller. The job of the controller is to **interpret** the data and send instructions to the **actuator**, which then adjusts the throttle using small precise movements in line with the driver's intention.

2 Aircraft

Computerised flight systems in aircraft (also called *fly-by-wire* systems) operate in a similar way. Sensors, controllers and actuators play a similar role in controlling the movement of wing surfaces, for example. An automatic pilot (or *autopilot*) system is a special type of computerised system where a pilot can first **establish** details of the flight (such as altitude, speed and direction) in advance and then **relinquish** control of the flight to the computer. If a pilot later wants to **regain** control of the aircraft, they can **override** the autopilot at any time. When the pilot has control of the aircraft again, they can **retain** that control for as long as they wish until they activate the autopilot again.

1 What is the main similarity between the two car accelerator systems?
2 What is the function of the pedal in a *drive-by-wire* accelerator?
3 What example does the text gives of an aircraft output mechanism?
4 How does an aircraft autopilot system 'know' how fast it should fly?

VOCABULARY » **3** **Match these words and phrases with the words in the text (in bold) which have the same or similar meaning.**

Nouns	Verbs	Verbs
1 small motor	5 take back (or take over again)	9 give away (or hand over)
2 accelerator	6 keep (or maintain)	10 set (or fix)
3 moving part	7 counteract (or cancel)	
4 central computer	8 process	

LISTENING » 4 3.2 Listen to this lecture and complete the notes.

Section 1:
fly-by-wire (aircraft) vs drive-by-wire (car)
Difference: • fly-by-wire: ______________
____
• drive-by-wire: ______________
____
Similarity: ______________
____

Section 2:
fly-by-wire vs automatic pilot
Difference: • fly-by-wire: ______________
____
• automatic pilot: ______________
____
Similarity: ______________
____

Section 3:
automatic pilot (aircraft) vs cruise control (car)
Difference: • automatic pilot: ______________
____
• cruise control: ______________
____
Similarity: ______________
____

LANGUAGE » Ways of contrasting ideas

Conjunctions for linking clauses in the same sentence:

- *Cars use wheels **but** aircraft use wing surfaces. Cars use wheels **whereas / while** aircraft use wing surfaces. **Whereas / While** cars use wheels, aircraft use wing surfaces. Autopilot systems are useful, **but** some experts think they are dangerous. **Although / Though** autopilot systems are useful, some experts think they are dangerous.*

Non-conjunction linkers for linking two different sentences:

- *Cars use wheels. **However**, aircraft use wing surfaces. Cars use wheels. Aircraft, **however**, use wing surfaces. NOT ~~Cars use wheels, however, aircraft use wing surfaces~~.*
- *Autopilot systems are useful. **Nevertheless**, some experts think they are dangerous. / Some experts **nevertheless** think they are dangerous.*

5 Rewrite these sentences to express the same or similar contrasts, using the words in brackets.

1 A manual accelerator system uses cables and springs, but a computerised one uses sensors and actuators. (whereas)
2 While a manual pedal physically pulls and releases the valve, a computerised one simply provides information for the sensor. (however)
3 Both computerised and manual accelerators use throttles and valves. Only the computerised one uses actuators to control the valves. (although)
4 Whereas a car uses a steering wheel as an input mechanism to control direction, an aircraft uses a joystick. (however)

6 Study audio script 3.2 on page 121. Highlight examples of the forms in the language box.

WRITING » 7 Work in pairs. Look at your notes of the final two sections (sections 2 and 3) of the lecture in 4. Discuss ways of expanding the notes into two paragraphs.

8 Work individually. Write up your notes of sections 2 and 3 of the lecture in two paragraphs. Use contrasting linkers where appropriate.

Example:
Fly-by-wire vs automatic pilot
Although both systems use computers, sensors and actuators, they differ in one important way: ...
Automatic pilot vs Cruise control
...

4 Networks

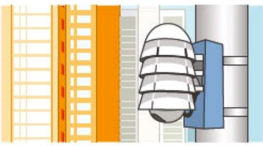
1 Cyberinfrastructure

START HERE »

1 Discuss in pairs.

1 What do you know about (a) internet of things (IoT) (b) edge versus cloud computing?
2 The image in 2 below shows a sensor node that is part of a network of hundreds of IoT sensor nodes located in a city. (a) What do you think they are measuring and why? (b) Could they cause problems with people's privacy? How can these problems be solved?

LISTENING »



A sensor node

2 4.1 Listen to the interview with a technologist. Look at the image of the sensor node. As you listen, tick all the sensors or types of measurement that the technologist mentions.

ambient temperature ☑ ambient noise ☐ ambient (= surrounding) light ☐
magnetic field ☐ humidity ☐ precipitation (= rainfall) ☐
barometric pressure ☐ carbon monoxide ☐ vibration ☐
sulphur dioxide ☐

3 4.1 Listen again and answer the questions.

1 How many (a) sensors are in a node (b) nodes are in the city now (c) nodes are planned?
2 Which directions do the two cameras face? Why do you think they do this?
3 In edge computing, what happens to the original data such as high-resolution images and sounds? What are the main advantages of edge computing?
4 Which of the following can the sensors NOT do: count pedestrians, contact the mobile phones of pedestrians, count cars, send photos of cars to the cloud, detect whether a car is electric or powered by petrol?

SPEAKING »

4 Work in small groups. Discuss the possible applications of the urban measurement project described in audio script 4.1 (see page 113). Decide which application is the most useful. Explain your group's reasons to the rest of the class.

5 With your group, discuss other ways in which a network of sensors with edge computing could improve part of the environment in which you live or work. Choose the most interesting idea. Make some notes about your idea, then explain it to the rest of the class.

VOCABULARY »

6 Work in pairs or small groups. Match the words with their meanings. Share your knowledge of how some of them are used in computer or sensor networks.

1 latency	a in the same place; in its original place
2 bandwidth	b a mechanical device for moving or controlling something
3 resilience	c the amount of delay between a user's action and an app's response
4 actuator	d rotate a camera lens horizontally from side to side
5 pan	e ability of a network to continue working after a fault or damage
6 in situ	f the amount of data that can be transmitted in a specific time

READING »

7 Read the article and answer the questions.

1 In edge computing, where is data analysed?
2 What does an intelligent sensor do with raw data such as images?
3 What kind of data is transmitted by an intelligent sensor to the cloud?
4 How do intelligent sensors protect the privacy of the people they record?

Computing at the edge of the network

Computers are now so small, powerful and relatively inexpensive that they can be embedded inside sensor platforms. This has made it possible for sensors to do their own computing and analysis using their own software. This is known as 'computing at the edge of the network', that is, close to the place where the data are gathered. Intelligent sensors operating at the edge do not simply collect data: the computing systems embedded in the sensor platforms also process the data, analyse them, discover important patterns and features, and actively control and modify their own behaviour.

For example, an intelligent sensor such as a high-definition camera equipped with computer vision software would not simply capture millions of images of vehicles and surface water on a motorway or a crossroads and transfer this huge quantity of data to a remote centre for analysis. Instead, the device can analyse the images in real time, and control its own actuators to make the camera zoom, pan or tilt as needed to capture images of vehicles, rainfall or surface water. The clean, analysed data (such as numbers or routes of vehicles tracked against rainfall patterns) are then transmitted up to the cloud, while the raw data of the actual images of vehicles are deleted in situ.

Edge computing has a number of advantages:

1 Delays in analysing data are reduced or eliminated. Big data are analysed and patterns are extracted in real time. Researchers and modelling systems are able to respond to already cleaned data almost instantly.
2 Only results are transmitted to the central server, not huge quantities of raw data (such as images) which consume a lot of transmission capacity.
3 No individual data (e.g. sounds, images) of people or their property are saved. Instead, they are deleted at the node, with only the analysis extracted.
4 The software at the edge can detect when a sensor is damaged or not operating, and can run a self-repair routine or send an alert automatically. This avoids extended downtime and means that the system operates at full capacity most of the time.

8 Read the four advantages of edge computing again and write the number of the point (1–4) next to each heading.

Low bandwidth ______ High resilience ______

Built-in privacy ______ Low latency ______

SCANNING »

9 Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete the information.

A project using edge computing for measuring animal biodiversity

1 The main type of sensor used in the project is an ______________________ .
2 Both ____________-powered and ____________-powered sensors can be used …
3 The locations we are studying for this project are all in ____________.
4 A single audio recorder may collect up to ____________ samples of audio per second …

TASK »

10 Work in pairs.

Discuss an application for an intelligent sensor network in a technical field you know about. Then prepare a short description (max. 200 words) of how it would work using edge computing. Use paragraph 2 in the reading text in 7 as a model.

2 Applications

START HERE »

1 Work in small groups. Discuss the questions.

1 What is *Industry 4.0* (or *the fourth industrial revolution*)?

2 Brainstorm examples of Industry 4.0 in action.

READING »

2 Scan the report quickly. Did your group in 1 suggest an example similar to the one in the report?

3 Read the report and write the paragraph numbers next to the missing headings.

Background 1

Purpose of experiment ___

Problem with standard procedure ___

Importance of quality control in spot welds ___

Standard quality control procedure ___

Predictive maintenance: Industry 4.0 in action

Predictive maintenance – a rapidly expanding area of Industry 4.0 and smart manufacturing – means you don't just ask *What went wrong?* and *Why did it happen?* but also *What is going to happen?* and *What can we do to prevent it from happening?* This report of an experiment gives an example.

INTRODUCTION

1 An experiment was conducted by a major automotive manufacturer on a production line assembling a new luxury car model. The production line had about 2,500 autonomous robots including about 900 carrying welding guns to do spot welds on the vehicles as they moved down the line. About 1,000 vehicles were assembled every day, and every vehicle had about 5,000 welds.

2 Spot welding is a mission critical process. Since welds hold metal parts together, it is vitally important to ensure the quality of all the welds in each car. However, it is impossible to manually inspect 1,000 cars every day.

3 The usual method used by the car industry is sample inspection. In this procedure, which is standard in the industry, one car is extracted from the line each day, the welding spots are tested by means of ultrasound probes, and the quality of every spot in that car is recorded.

4 The difficulty with sampling is that the procedure is costly, labour-intensive and error-prone. And it raises a question. What about the other 999 cars produced every day? How do we know whether they have good welds?

5 The experiment was designed to answer these questions and solve this problem. Its objective was to create a system to inspect all 5,000 welds in all 1,000 cars while in the production line, and assess the quality of each weld within microseconds so that corrective action could be taken immediately. To achieve these results, the new system would use AI, machine learning and computing at the edge, that is, on the production line.

METHOD

A machine-learning algorithm was created to analyse data from the welding controllers (such as voltage, current, types of metal, health of electrodes) and predict the quality of each weld. The algorithm was trained for accuracy by comparing the predictions it generated with manual inspection data. The system was then deployed on the production line.

RESULT

The system detected 100% of faulty welds and predicted poor welds before they happened. All the predicted faulty welds were later checked manually and were confirmed 100% correct. Every weld (not just a sample) was inspected.

DISCUSSION

This was a successful experiment. In the opinion of the team who conducted the experiment, the success was due largely to the use of machine learning and edge computing, which meant that, whenever the system detected a potentially faulty weld, the data were displayed almost instantaneously on a dashboard, and the technicians were then able to make real-time adjustments to eliminate the fault. The team believe that this is an important development and plan to conduct further experiments in the near future.

4 Answer the questions about the case study.

1 Why is spot welding described as a *mission critical process*?

2 What is the usual method of controlling the quality of welds? What is the problem with it?

3 How did the quality control system in the experiment differ from the usual method?

4 How did people know that the predictions made by the algorithm would be accurate?

5 Why was it necessary for data about a faulty weld to be processed within microseconds?

6 How was edge computing used in this experiment? How did it contribute to its success?

VOCABULARY »

5 Find single-word verbs in the text that have similar meanings to the following phrasal verbs.

1 (was) carried out
2 (were) put together
3 (to) make sure of
4 (is) taken out
5 (to) come up with
6 (was) set up
7 took place
8 (to) get rid of

6 Find 2- or 3-word phrases in the case study that have a similar meaning to the following phrases. Note that some have a hyphen (-) between words.

1 method of maintaining equipment by predicting and preventing faults
2 process which is critical or essential to the success of an operation
3 algorithm that enables a computer to learn to predict outputs from data inputs
4 welding metal sheets together by applying pressure and heat from an electric current
5 probes, or transducers, that emit high-frequency sound waves
6 changes or corrections that can be made in real time
7 needing many people (to do a job)
8 likely to involve many errors

LANGUAGE »

7 Find the phrases in the text. Underline the main verb in each phrase.

1 about 1,000 vehicles <u>were assembled</u> every day
2 one car is pulled off the line each day
3 the welding spots are tested by means of ultrasound probes
4 the quality of every spot in that car is recorded
5 a machine-learning algorithm was created to analyse data from the welding controllers
6 the algorithm was trained for accuracy
7 the data were displayed instantaneously on a dashboard
8 every weld . . . was inspected, and the data were collected and processed

8 Answer the questions about each phrase in 7.

1 Do they use the *active* or *passive* form of the verb? Why do they use this form?
2 Who or what is the *agent* (the person or thing doing the action) in each phrase?
3 Which phrases use (a) the past simple passive and (b) the present simple passive? Why?

9 Which verb tense is mainly used in the METHOD and RESULTS sections of the report? Why?

WRITING »

10 What kind of information goes into the METHOD, RESULTS and DISCUSSION sections of a report of an experiment?

11 Plan to write a report of an experiment.

Think about an experiment in your field of technology that you a) did yourself, b) you know something about, or c) you can find out about. For example, the experiment could be a trial of new equipment. Make notes under the headings and subheadings below. If you like, you can change the subheadings in the INTRODUCTION section. Use the passive where appropriate, and the most suitable verb tense for each section.

INTRODUCTION: Background; Need; Problem; Solution | METHOD | RESULTS | DISCUSSION

12 Write your report using your notes. Write 200–300 words.

3 Developments

START HERE » **1 Work in pairs. Discuss these topics.**

1 What changes have happened in your technical field in the last five years?

2 What developments in digital technology have caused or influenced these changes?

LISTENING » **2 You are going to listen to a presentation. Look at the slides the speaker uses. Number them (1–10) in the best order.**

A ☐

Advanced sensors are great, but …
- big data = huge storage needs
- big data = massive bandwidth needs

B ☐

Early wireless-linked sensors

Problems
- analysis delayed: downloading necessary
- limited data streams

C ☐

Example

A high-resolution camera can generate tens of gigabytes of data a day, or more!

D ☐

Sensors with wireless links

E ☐

Key development 2

Computing power ➔ intelligent sensors ➔ edge computing

Intelligent sensors at the edge
- analyse data in situ
- transmit only results of analysis
- delete raw data

F ☐

Key development 1

Sensor power

G ☐

How Sensors Became Intelligent

Andrew Gyre PhD MSc

Durnford Institute of Technology

H ☐

Sensors ➔ micro-sensors ➔ nano-sensors

I ☐

Advanced sensors
- high-definition cameras
- hyperspectral imagers
- LIDAR
- micro-radar

J ☐

Sensors as simple data loggers
- data sat in devices
- data was downloaded later
- analysis was delayed

3 4.2 **Listen to the presentation. As you listen, check your answers to 2 (the order in which the slides are used).**

4 4.2 **Work in pairs. Try to answer these questions. Then listen again to check your answers.**

1 Which slides contain information that the speaker does not mention?

2 Why do you think the speaker sometimes does not say information that is on the slide?

READING »

5 Work in small groups. Discuss this question. Make notes of your ideas.

The reading text below is about the same topic as the presentation you listened to in 3. In what ways do you expect that the written text will be different from the spoken presentation? Make a list of your group's ideas. You will need them in 8 below.

6 Read the text and make notes of the main points.

How sensors became intelligent

Here is a very brief history of sensors, explaining how they developed into the intelligent sensors that we find all around us today.

Many years ago, sensors were devices that simply collected and recorded data. The data sat inside these devices until they were downloaded to be processed.

Over time, sensors became smaller, turning into micro- or nano-sensors. They were fitted with simple microprocessors, powered by small batteries and linked via wireless networks to local computers or remote cloud servers.

This in itself was not a major development: the data-recording devices were simply replaced with a wireless link. The data could still not be analysed until they were downloaded from the sensors, which could only provide tiny data streams.

A major development was the increased production of low-cost, high-resolution sensors such as high-definition cameras, hyperspectral imagers, LIDAR and micro radar. These sensors were capable of producing huge quantities of data. Some high-resolution cameras could generate tens of gigabytes of images, per day.

This created a new problem, however. The quantity of data could quickly consume all the available storage on local computers or cloud servers, and needed more bandwidth during transmission. All this raw data could not be processed in real time.

The problem of storage and bandwidth was solved by the next major development: the exponential increase in computational power. This meant that microprocessors became smaller, cost less, consumed less power, but became increasingly powerful.

As a result, each sensor platform could now have its own powerful multicore microprocessor. Huge quantities of imaging and other data could be analysed in real time by a single sensor platform, which could then stream the analysis immediately and directly into remote computer modelling systems. This was the beginning of the intelligent sensor at the edge of the network that we are familiar with today in the age of big data.

7 Draw a simple flow diagram (about 6 or 7 boxes) to show the stages in the development of the technology over the years. Organise your notes from 6 in the boxes. Each box should contain a maximum of 10–15 words.

Sensors collect and record data. Data are downloaded later for analysis on local computers. → Sensors become smaller → micro-/nano-sensors →

LANGUAGE »

8 Work in small groups. Compare the reading text in 6 with the script (page 122) of the presentation you listened to in 3. Use your notes from 5. Make a list of the main differences between the reading text and the audio script. Use a table like the following. Add other ideas and examples.

Written	Spoken
complete sentences	incomplete sentences
longer sentences	shorter sentences
makes statements	asks questions: *How did sensors become intelligent? The result?*
fewer signpost phrases	more signposts: *At first, then, next*
less personal	more personal: *Let's look back; My talk*
all the information is in text	some information is on slides
more passive verbs: *data were downloaded*	more active verbs: *scientists had to download the data*
fewer phrasal verbs: *consumed, became*	more phrasal verbs: *used up, turned into*

TASK »

9 Work with the same group. Produce a spoken presentation about a technology you are familiar with. Explain some of the main developments in the technology over recent years. Produce some slides to accompany your talk. Record the presentation.

Review Unit B

1 Complete these texts. Use the present continuous or present simple active or passive of the verbs in brackets.

Every year a quarter of our company cars (1) *are recalled* (recall). During each recall the cars (2) ______ (undergo) a complete check-up and if necessary they (3) ______ (completely / overhaul) However, this year because of safety concerns, at least half of our vehicles (4) ______ (call in). The inspection this year (5) ______ (carry out) by an external company.

An emergency practice drill (6) ______ (conduct) on the oil platform every Saturday. On two Saturdays in the month, a fire drill (7) ______ (hold), with a boat drill on the other two Saturdays. But today, since we have ten new staff in the team, the fire drill and the boat drill (8) ______ (practise) at the same time. At this very moment, as you can hear, the alarm bells (9) ______ (ring) and instructions (10) ______ (give) to all staff via loudspeakers. A full evacuation of the staff quarters and offices (11) ______ (take place) and the lifeboats (12) ______ (lower) into the sea as we speak.

2 Complete this text with the words in the box.

instances conditions event inconvenience complaints subject possibility precaution performance

We regret to inform users of Turbina 1350 series notebook computers that we have received some (1) ______ from users about the (2) ______ of the battery. Some customers report that in certain operating (3) ______ the battery may be (4) ______ to overheating, which, in very rare (5) ______, can cause the computer to shut down suddenly. There is even a slight (6) ______ that data may be lost. As a (7) ______, we recommend that users should save their important data regularly. In the unlikely (8) ______ that their computer shuts down without warning, users are advised not to switch on again, but to contact Turbina for free repairs and data recovery. We wish to apologise for any (9) ______ experienced by our customers.

3 Write five sentences contrasting the cruise control systems used on two different cars. Use *while*, *whereas* and *however* at least once each.

Example: *1 On the Velox, the cruise control is operated by pressing the start / stop button on the steering wheel, whereas on the Tacho it is done by moving a lever on the steering column. To activate the system on the Velox . . .*

Cruise control (CC) system	Velox car	Tacho car
1 activate system	press start / stop button	press lever in
2 raise or lower set speed	press + or – button	move lever up or down
3 speed changed in increments of	1 kph	5 kph
4 deactivate (but retain set speed in memory)	press 0 button	push lever forward
5 reactivate set speed	press refresh button	pull lever towards you

4 Contrast the advantages and disadvantages of the cruise control system on one of the cars. Use *although*, *though* and *nevertheless* at least once each.

Example: *1 Although the Tacho CC control lever is easy to use, it is positioned . . .*

Advantages of Tacho CC system	Disadvantages of Tacho CC system
1 cruise control lever is easy to use	lever positioned too close to indicator lever
2 driver doesn't need to look at lever	easy to move CC lever by mistake instead of indicator lever
3 when engine is off, system remembers last set speed	driver may prefer to set new speed for each journey
4 large increments (5 kph) save time when setting speed	driver may find inconvenient to change speed by small amount

5 Complete this text using the correct form of the verbs in the box.

adjust	indicate	override	interpret	regain	establish	retain	maintain	detect	relinquish

How the autopilot system on an aircraft works

First, the pilot gives an instruction to the autopilot computer, telling it to (1) ______ the wings at a horizontal position. Then they switch on the autopilot system and (2) ______ control of the flight to it.

If the wing moves from the horizontal position which the pilot has (3) ______, the movement (4) ______ by position sensors. The sensors send a signal to the computer, which then (5) ______ the data and 'decides' that the wings are no longer horizontal.

The computer then sends a signal to the actuators, which are small motors used for (6) ______ the position of the wing's ailerons. As a result, the wings move back until they have (7) ______ their original horizontal position.

If the pilot is happy for the autopilot to (8) ______ control for some time, they do not have to take any action and the computer will continue controlling the flight. However, if for any reason they wish to (9) ______ the autopilot, they can do so by simply pressing a switch. A sign then appears, (10) ______ that the aircraft is now under the pilot's manual control once again.

6 Work in pairs, A and B. Study the technical solution to the Beamish 'sticky accelerator pedal' problem outlined in the illustration and notes below. Then discuss it together.

Student A: Talk about the device.
Student B: Talk about the problem and the solution.

DEVICE

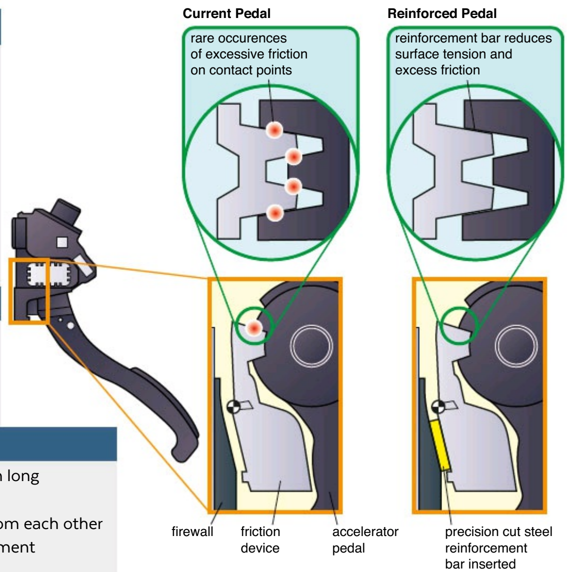
- friction device – moving part – between pedal and firewall
- top of device – set of gear teeth – engage with another set at top of pedal
- pedal pressed towards firewall ➔ teeth move – engage with each other
- no effect on acceleration (acceleration controlled by sensor, computer, actuators, not this device)
- purpose of device – feedback to driver
- friction – driver feels resistance – releases pedal

PROBLEM

- excessive friction – contact points – (rare)
- possible causes – condensation and humidity
- pedal – return too slowly – jam – partially depressed position

SOLUTION

- reinforcement bar – precision-cut steel – few mm long
- insert – pedal – firewall
- bar – change relative position – teeth – further from each other
- less friction – no jamming – no slow pedal movement



7 Work individually. Write your explanation of the problem and solution outlined above.

Use these headings: Description of device, How it works, Purpose of device, Problem with device, Causes of problem, Effects of problem, Solution, Effects of solution

8 Replace the verbs in italics below with phrasal verbs to give similar meanings. Choose a verb from A and a particle from B. Make any necessary changes.

A: carry (x2) push pull switch build press put bring find rule keep use

B: down back up forwards out on off

Example: *1 switch off the cruise control; pushing the lever forwards; …*

1 While driving, you can *disable* the cruise control by *advancing* the lever to a position away from you (or by *depressing* the brake pedal). Then if you want to *enable* it again, you *retract* the lever to its original position close to you.

2 We need to *perform* a stress test on this concrete beam, so that we can *eliminate* the possibility that it will crack under pressure. We need to *determine* exactly how strong it is. So let's do the test right now. We shouldn't *delay* it any longer.

3 Let's practise flying without the autopilot, OK? First, could you *increase* your speed gradually to 200 kph? Right, now please *maintain* that speed for a few minutes. Good, now slowly *reduce* it again to 150 kph. By the way, we have to watch the fuel gauge: we mustn't *finish* all our petrol.

9 Choose the correct option(s) that can fill in the gaps.

1 This program is causing a lot of problems, so I'm going to shut my computer down. I'll wait for a minute or two, and then I'll __________ again.
(a) start it up (b) start up it (c) start the computer up

2 First, you have to climb up that cliff. Then, when you get to the top, you have to __________ on a rope.
(a) slide it down (b) slide down it (c) slide the cliff down

3 Right, first I'm going to show you how to take a car engine apart. We'll have a short break, and then we'll __________ again.
(a) put together it (b) put it together (c) put the engine together

4 The bridge has a major design flaw. One person can use it safely, but if twenty soldiers __________ at the same time, it might collapse.
(a) walk on it (b) walk it on (c) walk the bridge on

5 You don't need to wear your hard hat in the office, but you must __________ when you go back onto the building site.
(a) put it on (b) put your hard hat on (c) put on it

10 Complete the phrasal verbs in the sentences below, using the correct particles from the box.

back away in down up apart over on out off

1 A new team took ______ the management of Beamish Motors two months ago. Since then, sales in the troubled car company have taken ______, rising by more than 10%.

2 Don't take ______ your hard hat yet. I want you to take all these empty crates ______ from the warehouse area.

3 The check-in security procedures are taking ______ so much time that the aircraft may have to take ______ late.

4 Could you take that component ______ from the top shelf, please? I need to take it ______ to the shop because I bought the wrong size.

5 The company has recently taken ______ five technicians to work on the new project. Have you got a pen and paper? You can take ______ their details as I read them out to you.

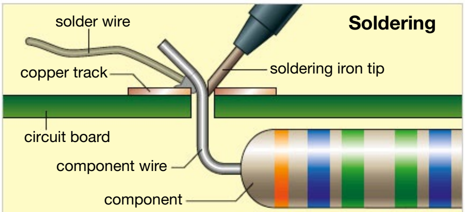
6 The engine is taking __________ water from the cooling system, so we have to take the engine __________, then take __________ each component and clean it carefully.

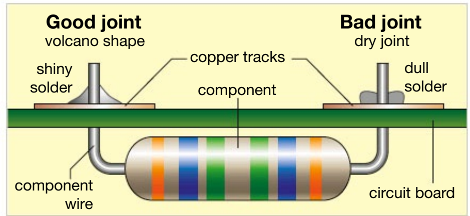
11 **Fill in the gaps in these sentences with nouns made up of a particle and base verb from the box.**

A: out in down up

B: touch thrust build put flow

1 The outflow of water from the lake via the reservoir tunnels is increasing, but there is hardly any ______ into the lake from the hills because of the drought.
2 Air Traffic Control gave the pilot permission for an emergency ______.
3 The ______ of the engines on a vertical take-off aircraft is extremely powerful.
4 We need to install valves on this container to avoid a ______ of pressure inside.
5 The microphone provides the ______ to the sound system, while the loudspeakers provide the ______.





12 **Change the following instructions into steps. Use the present simple passive for the main verbs.**
Example: *1 The soldering iron is held near the base of the handle.*
How to solder a joint

1 Hold the soldering iron near the base of the handle.
2 Apply a small amount of solder to the tip of the iron.
3 Apply the iron to the joint, contacting both the wire and the track.
4 Heat up the joint for a few seconds.
5 Feed the solder wire onto the joint while holding the iron against it. (Do not feed the solder wire onto the iron.)
6 Apply the solder for a few seconds while continuing to heat the joint.
7 You must use the correct amount of melted solder. (You can make a volcano shape at the joint).
8 Remove the solder wire first, and then the iron.
9 Allow the joint to cool before moving the circuit board.
10 Return the iron safely to its stand, and inspect the joint.

13 **Now change the instructions in 12 into a description of what was done. Use the past simple passive. Join some sentences together.**

Begin*: First, the soldering iron was held near the base of the handle, and a small amount of solder was applied to the tip of the iron. Next, the iron was applied . . .*

PROJECT »

14 **Do one of the following tasks.**

1 Work out the basic steps of a procedure in your industry or technical field. Write a user guide giving these instructions, briefly adding reasons and methods where necessary. Then present and explain your user guide to the class or to a group.
2 Research the background to an important product recall in your industry. Find out about the problems, the recall process and the solution to the problem, as well as the long-term effect on the manufacturer (did it improve or weaken its reputation?). Write up your research and present the main points to the class or to a group.

5 Processes

1 Causes

START HERE »

1 Work in pairs. Read the news article and discuss these questions.

1 Why is it difficult to make steel without emitting carbon gases?
2 Can you think of any ways to reduce carbon emissions (in addition to the two ways mentioned)?

Carbon-free steelmaking – from dream to reality

The negative environmental effects of steel production are huge. Steelmaking accounts for roughly 8% of all CO_2 emissions produced by human activity.

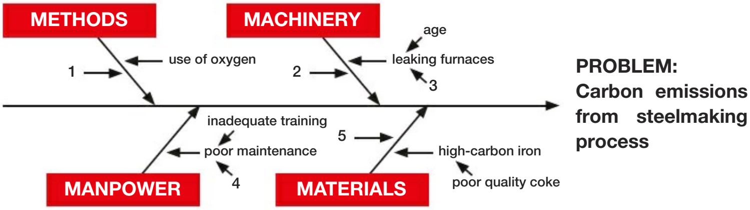
The problem is that in traditional steelmaking carbon is required to provide the high temperatures needed to extract pure iron from iron ore (iron oxide) in the blast furnace. The carbon combines with the oxygen from the ore to form carbon dioxide, which is then emitted from the blast furnace. The iron which emerges from this process still contains about 4% carbon, which makes it too brittle for most applications. To change iron into steel that is tough and ductile enough to be deformed without breaking, most of the remaining carbon has to be removed from the molten iron at a high temperature. The unwanted carbon then leaves the steel furnace in the form of further CO_2 emissions.

The technology for carbon-free steelmaking already exists. One method uses hydrogen instead of fossil fuels to heat up blast furnaces. Another involves a process called molten oxide electrolysis. Such techniques could transform the steelmaking industry, but they are expensive. The question is how soon they can become commercial reality.

LISTENING »

2 Try to complete this fishbone (cause and effect) diagram. Write the numbers of the missing labels 1–5 next to the phrases. An arrow indicates a cause.

high-carbon scrap steel ☐ filtration process ☐ faulty filters ☐
weak supervision ☐ poor maintenance ☐



3 5.1 **Listen to workshop participants discussing the problem outlined in the fishbone diagram and check your answers to 2.**

4 5.2 **Refer to your completed diagram and underline the correct alternatives in these sentences. Then listen and check your answers.**

1 The leaking furnaces might *be caused by / be a cause of* poor maintenance.
2 Yes, poor maintenance could *result in / be due to* leaks not being repaired.
3 The high carbon emissions could *give rise to / be a direct result of* an inadequate filtering process.
4 Maybe high carbon emissions are *due to / a major factor* in the high carbon content of the iron that's often used in steelmaking.
5 So the high carbon emissions could *result from / result in* high-carbon scrap steel being used as the raw material.

LANGUAGE » **Ways of expressing cause and effect**

A causes B

Carbon in steelmaking ***leads to*** */* ***gives rise to*** */* ***results in*** */* ***is the cause of*** */* ***is a (major) factor in*** *CO_2 emissions / emission of CO_2 / furnaces emitting CO_2 / CO_2 being emitted.*

B is caused by A

CO_2 emissions ***are caused by*** */* ***are the (direct) result of*** */* ***result from*** */* ***are due to*** */* ***happen as a result of*** *the use of carbon in steelmaking / carbon use / furnaces using carbon / carbon being used in furnaces.*

The phrases above are often used with modal verbs, e.g. ***could*** *give rise to* / ***may*** *result in*.

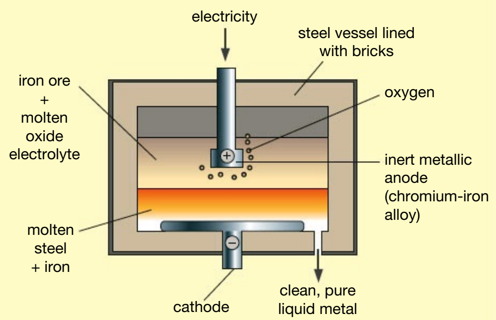
Prepositions after ***result***:

- ***of*** (when *result* is a noun): *Carbon is emitted* ***as a result of*** *the process*.
- ***in*** (when *result* is a verb): *The process* ***results in*** *carbon emissions*.
- ***from*** (when *result* is a verb): *Carbon emissions* ***result from*** *the process*.

5 **Briefly summarise the main causes and effects mentioned in the discussion in 3. Use your completed fishbone diagram to remind you of the main points.**

SPEAKING » **6** **Work in pairs. The diagram shows one of the two methods of carbon-free steelmaking mentioned in 1. Discuss how it works.**

Steelmaking using molten oxide electrolysis



7 **Complete these statements about the process in 6. Use a variety of forms from the language box above. Notice the direction of the causation arrow.**

Example: *The flow of current through the electrolyte leads to the break-up of iron oxide into iron and oxygen.*

1 flow / current / through / electrolyte ➔ break-up / iron oxide / iron and oxygen
2 conversion / molten oxide / molten steel 🡐 separation / oxygen / iron oxide
3 oxygen / separated / iron / in / electrolyte 🡐 electric current / passing / through
4 formation / bubbles / oxygen / anode 🡐 separation / oxygen molecules / electrolyte
5 weight / molten steel ➔ steel sinks / bottom / cell

TASK » **8** **Work in small groups. Research ways of solving the problem of CO_2 emissions from steelmaking. Discuss and then present your group's ideas to the class.**

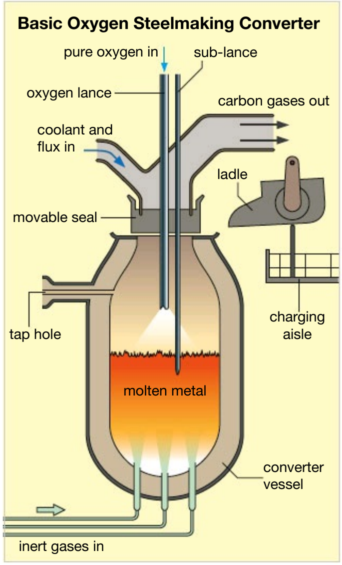
Examples: the use of hydrogen; molten oxide electrolysis; direct reduction of iron; electric arc furnace; carbon capture and storage

2 Procedure

START HERE »

1 **Work in pairs. Discuss the questions about the steelmaking process shown in this illustration.**

1. Why is oxygen pumped into the converter? What are the results?
2. What is the function of the tap hole?
3. Which waste by-product of the process is illustrated?



SCANNING »

2 **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete this specification chart.**

Facts about the BOS converter	
1 Height	
2 Weight	
3 Outside diameter	
4 Working volume	
5 Temperature inside converter	
6 Speed at which oxygen is pumped in	

READING »

3 **Study the text and the notes on the opposite page. A technical writer is halfway through writing the draft of a factsheet on the BOS process. Check your answers to 1 in the draft and the notes.**

4 **Answer these questions about the draft and the notes.**

1. What are (a) the raw materials and (b) the end product of this process?
2. What is the other waste by-product of the process? How is it removed?
3. Why do you think the seal at the top has to be movable?
4. What is the function of (a) the inert gas pipes and (b) the sub-lance?

5 **Match the diagrams A–E on the opposite page with some of the stages in the draft and in the notes. A matches with five consecutive stages. B–E each match with only one stage.**

6 **Write a caption for each of the diagrams A–E, using a Gerund plus noun object.**

Example: *A: Blowing oxygen (or Pumping in oxygen)*

7 **What do these steelmaking terms mean? Find synonyms and/or information in the draft and notes on the opposite page.**

1 hot metal	3 converter	5 lance	7 flux	9 sub-lance
2 scrap steel	4 to charge	6 the blow	8 slag	10 to tap

Language
page 100

8 **Discuss in pairs. Why does the writer choose the active or passive in the phrases in italics in the brochure on the opposite page?**

WRITING »

9 **Write up the notes 6–11 on the opposite page to complete the factsheet. Use the active and passive as appropriate.**

BASIC OXYGEN STEELMAKING

The principal material used in the Basic Oxygen Steelmaking (BOS) process is hot metal, which is what molten iron is often called in the steel industry. This makes up 80% of the total raw material, with scrap, that is, recycled steel, making up the remainder. The process takes place inside a BOS converter, or furnace.

1 First, *the converter vessel is tilted* about 45° towards the charging aisle and *scrap steel is charged* (fed) into the top of the vessel from a scrap box.

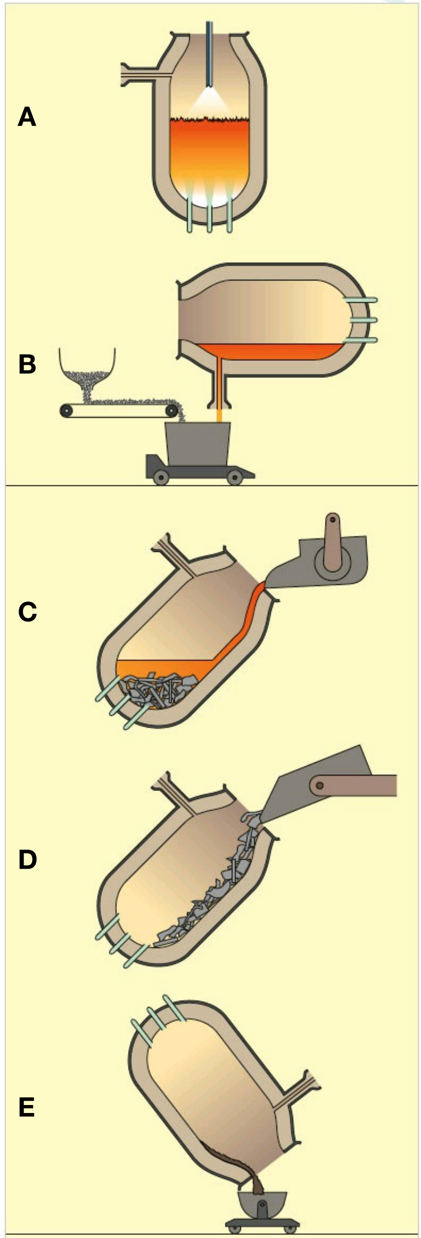
2 Immediately afterwards, *hot metal is charged* directly onto the scrap steel from a ladle. Charging lasts for one or two minutes.

3 Next, *the vessel is returned* to the upright position and *a water-cooled oxygen lance is lowered* into it. *High-purity oxygen is pumped* onto the metal through this special pipe at very high pressure. This important stage is called 'the blow'.

4 *The blow produces a great amount of heat, which melts the scrap*. The temperature is carefully controlled and coolant can be added via a pipe at the top if the temperature needs to be adjusted.

5 The oxygen forms a chemical bond with the carbon and other unwanted elements. This results in the formation of carbon gases *which leave the vessel through a pipe at the top and are collected* for cleaning and recycling.

6 during oxygen blow / add lime / it's a flux (= substance / bonds with impurities / why? – removed easily) / result – oxidised impurities / form / layer of slag / slag floats on liquid steel / pour away easily (later stage)
7 in addition / during blow / inject inert gases / e.g. nitrogen / through base of furnace / why? – agitate mixture / result – better refining process
8 as soon as / blow about 85% complete / lower sub-lance (special sensor) / into converter / why? – measure carbon content + temperature of molten metal / why? – provide data / final adjustment
9 once / steel / completely / refined / remove small sample / test it / why? – check temperature + quality
10 tilt converter / to side / why? – tap (pour out) steel into ladle + add metals, alloys (if required)
11 finally / after / all steel / tapped / rotate converter / upside down / tap slag into ladle / remove + recycle

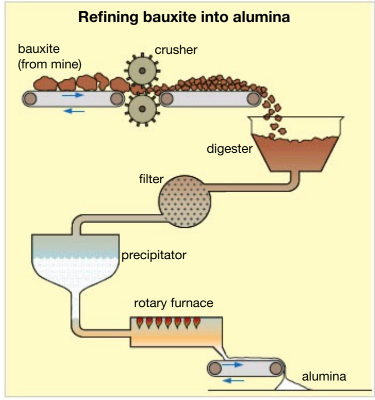


molten iron BOS furnace converter charging aisle ladle oxygen lance
high-purity oxygen oxidised impurities inert gases sub-lance residual slag 5.3

3 Stages

START HERE » **1** **Work in small groups. Discuss what you know about the process of making aluminium. How do you think it compares with steelmaking?**

TASK » **2** **With your group, put these steps into the correct order. Use the diagram to help you.**



Refining bauxite into alumina powder

a The dried-out crystals form a white powder called *alumina*. ☐
b The rock is pulverised, or crushed, into powdered form. ☐
c The raw mineral, bauxite, is extracted from the ground. 1
d The liquid is filtered and the impurities are removed. ☐
e The crystals are dried out, or calcinated, in a rotary furnace. ☐
f The powdered mineral is dissolved in sodium hydroxide in the digester. ☐
g Crystals of alumina form in the solution. ☐

READING » **3** **Read this text and check your answers to 2.**

From bauxite to alumina – the refining process

First of all, bauxite is extracted from the ground and carried from the mine on conveyor belts to crushers, where the rock is ground into powder.

Next, the mineral is fed into the digester tank, where it is dissolved in sodium hydroxide, heated and pressurised. This process dissolves the aluminium oxide, while the impurities remain suspended in a solid state.

From here, the mixture is passed through a filter, which removes the impurities.

The resulting solution is then pumped into 30-metre-high precipitator tanks. As the solution cools down, crystals of pure alumina are formed, which then sink to the bottom.

The crystals formed from the precipitation process are then collected and removed from the solution.

The remaining solution is then siphoned off and returned to the digester to be recycled.

The crystals removed from the solution are then passed through rotary furnaces, where they are heated to 1100°C and calcinated, or dried out.

The end product of this process is a white powder composed of pure alumina. This powder is the raw material used for smelting aluminium.

bauxite alumina aluminium aluminum aluminium oxide precipitator tanks precipitation process siphoned off smelting 5.4

4 **Make a short caption for each stage in the diagram above. For each caption, change a verb or verb phrase from the steps in 2 into a noun or a Gerund.**

Example: *1 Extraction (of bauxite) 2 Crushing (or Pulverisation)*

5 **Find these phrases in the text in 3. What do they refer to?**

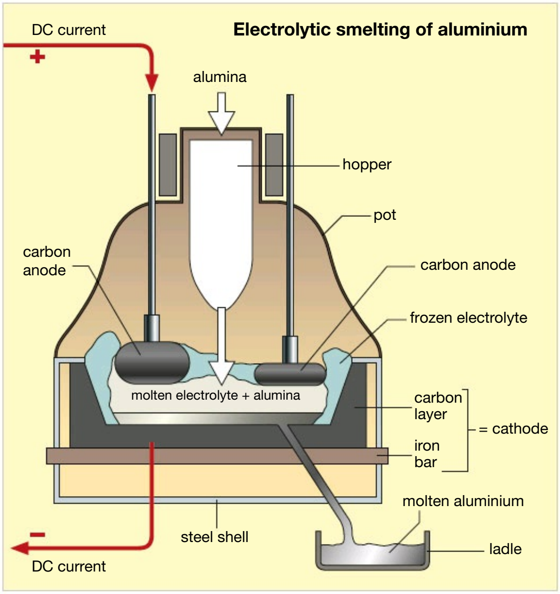
1 This process
2 The resulting solution
3 the precipitation process
4 The remaining solution
5 The end product
6 this process

6 **The raw material is given eleven different names in the text as it goes through the refining process from bauxite to pure alumina. List them all.**

Example: *1 bauxite 2 the rock 3 . . .*

TASK »

7 With your group, discuss the process shown in this diagram. How does it work? What similarities and differences are there with the molten oxide electrolytic process in 6 on page 37?



8 Work individually. Prepare to complete these notes from a lecture about the aluminium smelting process. Fill in as many details as you can based on your discussion in 7.

Smelting (converting) alumina into aluminium using electrolysis

Details of equipment (location, function, materials, properties)

- pot: ______
- carbon layer: ______
- iron bar: ______
- cathode: ______
- anode: ______

Stages in smelting process

1 alumina / hopper: ______
2 frozen electrolyte / crust: ______
3 molten electrolyte: ______
4 direct current: ______
5 temperature / molecule / oxygen: ______
6 weight / molten aluminium: ______
7 tap / tap hole / ladle / furnace: ______

9 5.5 Listen to the lecture. Amend and complete your notes.

10 Write up your notes. Use numbers when describing the stages. Use the active and passive, and the language of cause and effect where appropriate.

6 Planning

1 Risk

START HERE »

1 **Work in small groups. Discuss the consequences of an offshore oil spill.**

READING »

2 **Read the article below and place the events a–e on the chart.**

The effect of the oil spill on . . .

a) the region generally
b) the local seafood industry
c) bird population (if oil doesn't reach land)
d) bird population (if oil reaches land)
e) tourism in the area

RISK ASSESSMENT CHART

Probability → / **Damage ↓**	**very unlikely**	**unlikely**	**possible**	**probable**	**almost certain**
catastrophic					
severe				*a*	
moderate					
minor					
insignificant					

Many readers have posted comments to *The Globe Online* voicing their concerns about the recent offshore oil spill. So our reporters contacted some experts to help us assess the risks. Here are their answers to our questions.

We asked our first specialist: How serious is the oil spill for our region generally?

"If the oil continues to leak from the well for weeks, or even months," he told us, "the effect on the area will probably be very serious indeed."

So it's a calamity for the region?

"I wouldn't say calamitous, but it is likely to be critical," he agreed. "The likelihood of severe damage is very high, I must say."

We then spoke to another expert on oil spills, with some knowledge of the local economy. Can the seafood industry escape the worst of the damage, we wondered?

"No, it can't," he told us. "The spill will be disastrous for the local seafood industry if the oil reaches the main fishing grounds. And it's virtually certain that it will spread that far. The stuff is pumping out of the well at a rate of thousands of barrels a day."

So, it's terrible news for the local fishing community. And what about the wider environment? Will the oil affect the bird population, for example? We asked a marine biologist for her views. She had slightly better news.

"If the oil doesn't reach the land, but stays in the sea, there's a possibility that the oil will do only minimal damage to the bird population," she said. "The negative effect will be quite small."

But if it does reach the land? Here she was less hopeful.

"Well, if it reaches the land," she replied, "there's a chance that it will do a certain amount of damage to the seabirds there."

We turned finally to an expert who has seen many beaches destroyed by oil slicks. If the oil hits the beaches, will it destroy our local tourism industry? His answer was surprisingly upbeat.

"No, I don't think so," he replied. "Even if the oil hits the land, the effect on tourism will be negligible. The damage will be virtually zero, because even in the worst case, the oil can only hit one small beach, not the other larger ones. And anyway, there's only a slim chance that the oil will hit any beaches at all, because of its direction of flow.

VOCABULARY »

3 **Find these words and phrases (used to describe damage) in the news article. Then match each one with the closest synonym in the left-hand column of the risk assessment chart in 2.**

1 very serious indeed	3 critical	5 minimal	7 negligible
2 calamitous	4 disastrous	6 a certain amount of	8 virtually zero

LANGUAGE »

Ways of expressing degrees of certainty

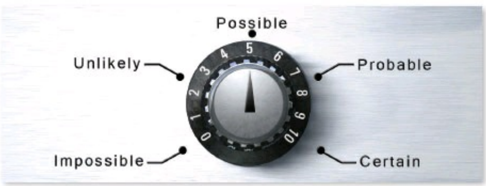
adjective	*It's (**virtually**) **certain** / (**highly**) **probable** / (**highly**) **likely** / (**very**) **possible** / (**highly**) **unlikely** / (**almost**) **impossible** that the oil will spread to the fishing grounds.*
adverb	*It will **definitely** / **probably** / **possibly** / **probably not** / **definitely not** be a disaster for the region.*
***There's* + noun**	*There's (**virtually**) **no doubt** / **a** (**high** / **strong**) **probability** / **a** (**strong**) **possibility** / **a** (**slim** / **slight** / **remote**) **chance** / (**almost**) **no chance** that the oil will hit the beaches.*
noun	*The **likelihood** / **probability** / **chances** that the oil will cause severe damage **is** / **are** (very) **high** / (very) **low**.*

virtually = *almost*   *(un)likely* (adj) = *(im)probable*

slim / slight / remote = *(very) small* (used with *chance*)

Modal verbs *may* and *might* can be used alone or with *possible / possibly* to indicate or emphasise possibility: *We may / might (possibly) be able to clean up the oil quickly*.

4 **Write the closest number 0–10 from the scale below next to these statements. Compare your numbers with a partner.**



1 It's virtually certain that another earthquake will hit our city this year. ☐
2 There's a small chance that serious floods will occur in the next two weeks. ☐
3 We'll probably be able to prevent landslides by building a wall here. ☐
4 There's virtually no chance that underwater robots can repair the well. ☐
5 It's highly unlikely that there will be an avalanche on this mountain. ☐
6 This forest fire will definitely cause severe damage to local wildlife. ☐
7 There's a slim chance that the dam will burst if we don't repair it. ☐
8 The likelihood that the volcano will erupt again this century is very high. ☐

5 **Rewrite the sentences in 4 with different certainty levels, using a variety of forms from the language box above. Write the number of the certainty level 0–10 you have chosen after each new sentence.**

Example: *1 There's a slim chance that another earthquake will hit our city this year.* (2)

SPEAKING »

6 **Draw a risk assessment chart like the one in 2. Make a numbered list of five types of disaster similar to the ones in 4. Write the numbers 1–5 in different boxes on the chart according to your assessment of their risk level *either* in the country you are in now, *or* in your own country.**

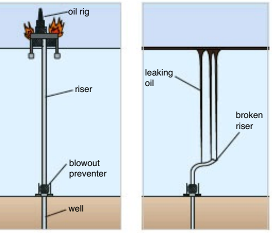
7 **Work in pairs. Explain your five risk assessments and get your partner to write the numbers in their charts (and put a circle round them to distinguish them from their own list). Compare your charts and discuss the risks, giving reasons for your choices.**

WRITING »

8 **Write up your five risk assessments.**

2 Crisis

START HERE »



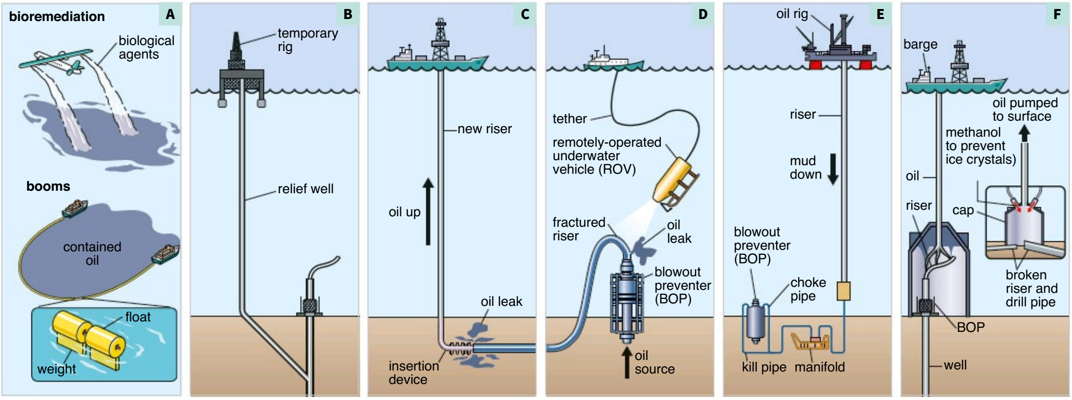
1 **Work in pairs. Discuss this problem and the possible solutions A–F illustrated below. What kind of things might make it difficult for the solutions to work?**

Problem

An offshore oil rig explodes, burns for 36 hours and then sinks over 1,500 m to the seabed. The main riser from the well up to the rig collapses and sinks to the seabed. The riser breaks up and oil begins to leak from the fracture. The blowout preventer (BOP) at the well head fails to activate properly due to a failed battery and as a result oil continues to flow into the broken riser and into the sea. The hurricane season is approaching.

Possible solutions

A Surface containment ☐ D Repair BOP with ROV ☐
B Relief well ☐ E Blocking well with mud ☐
C Insertion device ☐ F Cap over leak ☐



LISTENING »

2 6.1 **Listen to part of a meeting to discuss possible solutions to the crisis. Write numbers in the boxes above to show the order in which the solutions are mentioned.**

3 **Listen again. Write A–F in the boxes below to indicate how likely each solution is to succeed, according to the speakers.**

no chance of success		↔		certain to succeed
1	2	3	4	5

SPEAKING »

4 **Discuss the likelihood of success of each of the six possible solutions, using your completed chart in 3.**

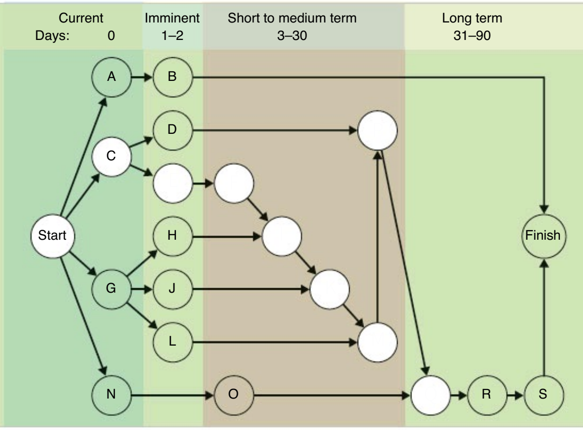
SCANNING »

5 **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to fill in the gaps.**

1 Gulf of Mexico oil spill (2010): __________ millions of litres spilled
2 Orange County, California oil spill (2021): __________ kilometres of coast polluted

TASK » **6** **Work in groups. Study the planning diagram and the list of activities (A–S) for dealing with the crisis. Decide which letters should go into the white circles.**

A Lay booms on sea surface
B Skim, burn and spray sea surface
C Prepare ROVs
D Prepare mud pump
E Send down ROVs
F Use ROVs to activate BOP
G Specify caps and insertion tube
H Build small subsea cap
I Lower small cap
J Build large subsea cap
K Fit large cap over small one
L Construct 2-km insertion tube
M Insert 2-km tube in broken riser
N Plan relief well 1 km away
O Build rig for relief well
P Pump mud to block BOP
Q Transport and install rig
R Start drilling relief well
S Complete relief well



LISTENING » **7** 6.2 **Listen to the next section of the planning meeting and check your answers.**

8 **Complete these sentences. Then listen again and check your answers.**

1 The remote subsea equipment is about _activated.__________
2 The ROVs are on the point of _down to the BOP.___
3 Several attempts are going to _to activate the BOP._
4 Failing that, a larger cap will _over the small one._
5 By this time, the two-kilometre insertion tube will _constructed.________

LANGUAGE » **Future + future perfect**

Immediate future	*The ROVs **are on the point of being sent** down. The subsea operation **is about to be started**.*
Longer-term future	*A small cap **is going to be lowered**. A larger cap **will be fitted** over the small one.*
Future perfect	*By this time, the two-kilometre tube **will have been constructed**.*

9 **Complete these sentences, using the correct form of the words in brackets.**

1 Over the next three weeks, a flexible, 2-km-long tube ____________ (will / make).
2 Methanol ____________ (be / going / pump) into the cap to prevent the formation of crystals.
3 Right now, 50 kilometres of booms ____________ (be / about / drop) into the sea and the BOP ____________ (be / on / point / activate) by two ROVs.
4 Let's assume we've tried the tube and it has failed to work. By then, the mud pump ____________ (will / already / prepare), so it will be able to start operating immediately.
5 The rig for the relief well ____________ (be / about / transport) to the site.
6 We'll be able to start drilling the relief well in six weeks' time, because by then the rig ____________ (will / tow) to the site and ____________ (will / install).

WRITING » **10** **You are the chief executive of the oil company responsible for the oil spill. Write a short statement for a press conference explaining what steps your company is going to take to deal with it. Then read out your statement to a small group of reporters.**

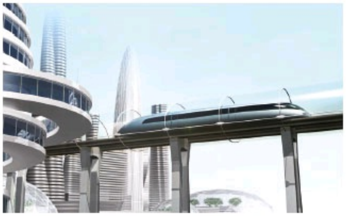
3 Projects

START HERE »

1 Discuss in pairs.

1 What do you know about hyperloop projects? Where are hyperloops being tested or used?

2 How do hyperloops work?



READING »

2 Read the article. Then produce a table with two columns and approximately ten rows summarising the key features of the hyperloop concept in note form. Use all the words in your table. Begin your chart as shown in the example below.

tube	pod	speed	energy consumption	power	propulsion	levitation
air resistance	friction	materials	passenger safety	routes	carbon emissions	

Key features of hyperloop concept	
tube	sealed, air removed, near vacuum created, air resistance minimised

Hyperloop: from concept to project

Although Elon Musk first coined the term 'hyperloop' in 2013, the idea of transport by way of an enormous metal tube is almost two hundred years older. In 1825, engineers put forward a proposal for a 'vacuum tunnel' to connect England and India. They imagined a steam-powered vacuum that would allow carriages filled with passengers to travel through the tunnel at high speed. The project did not go ahead, however, because no suitable materials existed to build such a tube. Since then, advances in materials technology have made the nineteenth-century vision a reality.

A hyperloop is a high-speed, long-distance transportation system in which vehicles (pods) with no wheels move through low-pressure tubes with minimal friction or aerodynamic drag, potentially reaching speeds of over 1200 km/h while using less energy than either air or rail travel. Instead of wheels, pods use magnetic levitation and electromagnetic propulsion to glide through the tube. The whole system is electrically powered.

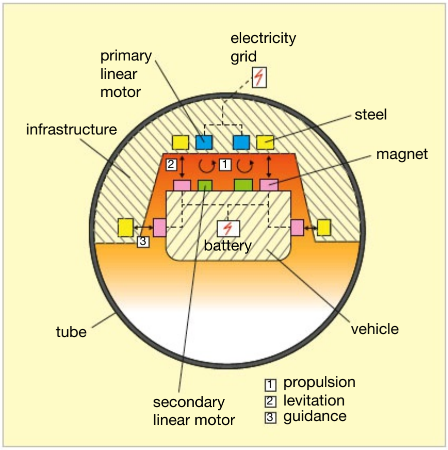
The tube is sealed and air is pumped out to create a vacuum inside the tube. This minimises air resistance as the pod moves through the tube. Electromagnets levitate the pod, making it float or hover above (or below) a guideway. This minimises friction, since the pod does not touch any surface inside the tube. One design ('passive levitation') uses magnets underneath the pod, which repel it upwards away from a guideway on the lower part of the tube. Another ('active levitation') uses electromagnets on top of the pod, which attract the pod upwards towards a guideway on the upper part of the tube. The electromagnets switch on and off thousands of times per second, causing the pod to hover a short distance below the guideway.

A pair of linear induction motors, one along the pod and one along the guideway, interact with each other electromagnetically to propel the vehicle through the tube.

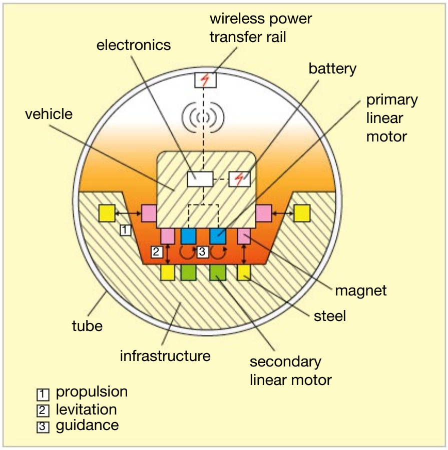
Many tubes are made of steel, although some use reinforced concrete. Tubes can be underground or raised above ground on pylons. Pods are normally made of aluminium. Passengers are protected by an air lock. Pods are not affected by changes in the weather. Passengers experience a smooth, quiet ride. Pods are modular and are not physically connected. This allows each pod to have its own route and destination: pods can travel in convoys, but can split off while the rest of the convoy continues on the original route. Pods create zero direct carbon emissions.

Risk factors and passenger safety will continue to be tested and creative engineering solutions will continue to be tried out over coming years and decades. The first hyperloop passenger journey took place in 2020. If developments continue at their current pace, what will the hyperloop look like in another 200 years?

3 **Look at the diagrams of two engineering concepts for a hyperloop system. Match each one with its description.**



Hyperloop: System A



Hyperloop: System B

1 This system uses propulsion powered from the infrastructure side. The levitation system is active, using electromagnets powered from the vehicle side. The guideway is mounted on the upper part of the tube and the vehicle hangs below it. The electromagnets balance this attracting force against the force of gravity to make the vehicle hover.

2 This system uses propulsion powered from the vehicle side, via a battery charged using contactless power transfer from the electricity grid. The levitation system is 'passive', using the repelling force of permanent magnets with no power supply needed. The guideway is mounted on the lower part of the tube so that the vehicle floats above it.

SPEAKING »

4 **Work in pairs. Choose one of the systems from 3 each. Explain to your partner how your system works, using your diagram and your information.**

TASK »

5 **Work in small groups of 4–6. You are a team of engineers working for a transportation company which is planning a hyperloop project. Prepare for a meeting in which you will decide between Systems A and B (see 3). Follow these instructions.**

- If possible, find out more about hyperloop and MagLev technology.
- Choose a chairperson for your meeting. Decide who will argue (a) in favour of System A, (b) against A, (c) in favour of B, (d) against B, (e) against both systems and in favour of delay because of safety concerns.
- If you are the chairperson, turn to page 116.
- If you plan to argue (a) *for A*, turn to page 111, (b) *against A*, turn to page 112, (c) *for B*, turn to page 113, (d) *against B*, turn to page 114, (e) *against A and B*, turn to page 115.

6 **Have the meeting. Try to agree which system (if any) to use in your project.**

WRITING »

7 **Work individually. Write a memo to your manager in the transportation company. Summarise the main points you discussed in your meeting and recommend which system (if any) should be used.**

Review Unit C

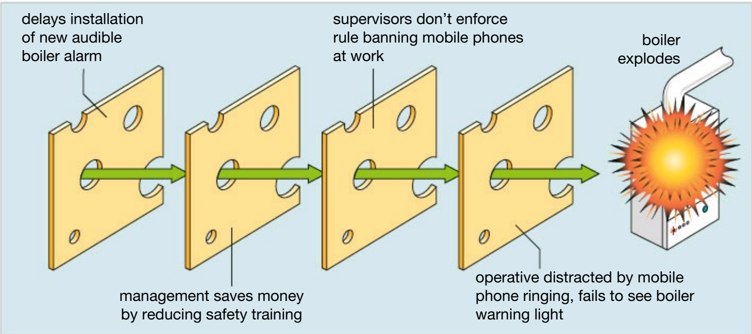
1 Complete these sentences choosing words and phrases from the box. Two of the words/phrases are not needed.

results from as a result of using is caused and as a result causing it to as a direct result of because cause of   caused by results in

1 Oxygen in a steel-making furnace changes the temperature, ______ rise.
2 The rapid melting of scrap steel is ______ the extremely high temperatures.
3 A layer of slag is formed ______ the impurities combine with lime flux.
4 The high temperature in an aluminium smelting pot ______ the electric current.
5 Electrolysis ______ the production of oxygen as a by-product.
6 Carbon gases are emitted ______ carbon anodes and cathodes.
7 Molten aluminium sinks to the bottom of the pot ______ its increased weight.
8 Oxygen is released from alumina in the electrolyte ______ the oxygen becomes heavier.

2 Study this accident scenario. Then produce a similar diagram (if possible as a PowerPoint slide) illustrating the causes of a common type of accident in your own industry or technology. Present your diagram and explain it to your class or group.

An operative working in a boiler room fails to see a warning light when he is distracted by a call on his mobile phone. The boiler explodes soon afterwards.



3 Identify all the words and phrases that can fill each gap in these sentences. The number in brackets indicates the number of possible words / phrases.

A cause   B caused by   C because   D cause of   E was caused by   F the result of   G result in   H as a result of I resulted from   J resulted in   K as a result   L due to   M was due to   N lead to   O gave rise to

1 The oil spill in the sea was ______ oil leaking from a broken underwater pipe. (4)
2 The break-up of the riser ______ an explosion in the blowout preventer. (3)
3 The explosion took place ______ the safety valve failed to close properly. (1)
4 Without doubt, poor maintenance in the past ______ the failure of the valve. (2)
5 The oil spill will certainly ______ widespread pollution of the area. (3)
6 The main ______ damage to wildlife will be the oil that reaches the shore. (1)
7 The disaster will certainly ______ the authorities investigating the accident. (2)
8 The report will be published and ______ the guilty parties will be identified. (1)

4 Combine each pair of sentences into a single sentence with a similar meaning. Use the words in brackets and change the verbs in italics into related nouns. Do not use personal pronouns.

Example: *1 The development of a new technology has resulted in the production of a stronger type of aluminium.*

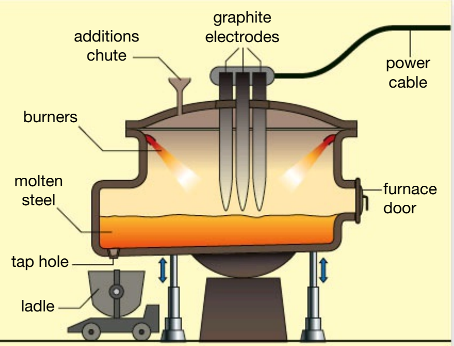
1 A new technology *has been developed*. As a result, a stronger type of aluminium *has been produced*. (result in)
2 Pressure *built up* in the tank. The result was that the mixture *exploded*. (lead to)
3 More wind farms *will be introduced*. This will cause carbon emissions to *be reduced*. (bring about) [Note: the noun from 'reduce' is followed by 'in']
4 The number of accidents *has increased*. This is why a special investigation team *has been formed*. (give rise to)
5 An electrical current *flows* through the electrolyte. As a result, oxygen *is separated* from the mixture. (result in)
6 The maintenance staff were poorly *supervised*. As a result, the project *failed*. (be a major factor in)

5 Rewrite this process description. Change the verbs in italics to the passive or keep them in the active, as appropriate. When you use the passive, decide whether or not to use *by* + the agent.

This is how they *roll* aluminium into a new shape. First, they *heat* the aluminium slab (a thick, rectangular shape) to make it more malleable and then they *pass* it backwards and forwards between large heavy rollers, which *compress* and *squeeze* the metal until it *becomes* thinner and longer. Usually, they *hot-roll* the metal first to a thickness of 2–4 mm, and then they *cold-roll* it into a sheet less than 1 mm thick. Finally, they *anneal* the sheet, that is, they *heat* it and then *slow-cool* it, a thermal process which *toughens* it and *reduces* its brittleness.

6 Complete this description of the process in the illustration, using phrases a–k below.

1 The furnace has a movable roof, through which three graphite electrodes … 9
2 First, the electrodes are pulled out and the roof is swung sideways, to …
3 Steel scrap is then charged into the furnace from a steel basket that is …
4 When this operation is complete, the roof is …
5 A powerful electric current is then …
6 This causes an arc to be created, …
7 Fluxes are added and carbon and oxygen are …
8 This action results in impurities in the metal …
9 Samples of the steel are taken and analysed, to …
10 When they are correct, the molten steel is …
11 Final adjustments can be made by …



a) lowered from an overhead crane.
b) check that the composition and temperature are correct.
c) blown into the melt.
d) tapped into a ladle through the tap hole.
e) generating the heat to melt the scrap.
f) passed through the molten metal.
g) can be raised or lowered.
h) adding alloys during tapping.
i) allow charging to take place.
j) swung back into position and the electrodes are lowered into the furnace.
k) combining to form a liquid slag, which is tapped via the furnace door.

7 What do the following words refer to in the text in 6?

1 which (#1) 2 this operation (#4) 3 This (#6) 4 This action (#8) 5 they (#10)

8 The raw material is given seven different names in the text as it goes through the process above (the first is *steel scrap*). List them all.

9 Rewrite these statements to give the same or similar meaning, using the words in brackets.

Example: *1 It is likely that the trapped miners will be rescued within the next month.*

1 The trapped miners will probably be rescued within the next month. (likely)
2 There's only a remote possibility that the relief well will be completed ahead of schedule. (The likelihood)
3 It's highly likely that deepwater drilling will be banned because of the oil spill. (There's / probability)
4 It's extremely unlikely that new oil will be found in this old oilfield. (remote chance)
5 It's virtually certain that the new tunnel project will be very innovative. (definitely)
6 This new bridge will certainly reduce travelling time between the islands. (doubt)

10 Make statements comparing the risks on this risk assessment chart, without using any of the words in the chart headings (such as *catastrophic*, *medium* or *likelihood*). Use a variety of forms for expressing degrees of certainty.

Example: *1 In both normal and deepwater drilling, it is highly unlikely that there would be an explosion in the well. However, if it happened in normal drilling, the impact would be only moderate, whereas in deepwater drilling, . . .*

RISK ASSESSMENT comparing normal offshore drilling (< 300 m deep) with deepwater drilling (> 700 m deep)

KEY: BLUE = DRILLING AT NORMAL DEPTHS RED = DEEPWATER DRILLING

Likelihood → **Severity ↓**	Extremely low	Low	Medium	High	Extremely high
Catastrophic	1 explosion in well	3 failure of blowout preventer (BOP)		2 oil spill	
Critical					4 fractured pipe
Medium	1 explosion in well	3 failure of BOP			
Minimal			4 fractured pipe		
Negligible	2 oil spill				

11 Complete the text below about a bridge–tunnel construction schedule, using the phrases in the box. Some phrases are used more than once.

going to be   about to be   will finally be   is going to   will be   about to   will already have
is on the point of   will already have been   is ready to

Work is (1) ______ begin (in the next few days, in fact) on reclaiming land from the sea. The idea is to make two artificial islands, which are (2) ______ connected by means of a tunnel. Drilling on the tunnel (3) ______ carried out during the second phase of the project. The intention is that by the time the drilling team (4) ______ start work at the beginning of the second phase, the land (5) ______ reclaimed and the two artificial islands (6) ______ appeared out of the sea.

In addition, work (7) ______ being started (also in the next few days) on digging the foundations for the bridge piers and constructing them. This work (8) ______ continue throughout the second phase and it is expected that by the beginning of the third phase, when the bridge sections are (9) ______ placed on the piers and linked together, the contractors (10) ______ laid all the foundations and constructed all the piers.

By the end of the third phase, all the components – the tunnel, the bridge sections and the approach roads – (11) ______ completed. At that point the bridge (12) ______ linked up to the tunnel and the approach roads.

12 Write a description of this project, using the headings and notes below. Replace percentages with words or phrases expressing degrees of certainty.

Submerged floating tunnels, Norway

PURPOSE OF PROJECT

- part of coastal highway E39 project (tunnels and bridges)
- provide straight route through fjords (sea inlets) in Norway's west coast
- reduce travel time from south to north by 50%
- remove need for ferries across and roads around fjords
- minimise environmental impact of slow traffic and roads around fjords

PLANNED SPECIFICATIONS

- tunnels (tubes) in pairs, submerged 20–50 m below water surface
- made of concrete
- in 1400 m deep fjord
- tunnels buoyant, but not floating on surface
- tethered to seabed by cables
- in places, tethered to pontoons (flat decks) on surface at 240-m intervals
- escape routes for motorists – return to surface using lifts in emergency

EXPECTED OUTCOMES

- completion date for construction of tunnels 2025 (certainty: 50%) – just over 10% completed in 2020
- opening of whole route to traffic 2050 (certainty: 80%)
- cost estimate (for total project including bridges): €40 bn (certainty: 20%)
- the first structure of its kind in the world (certainty: 90%)
- the total network (submerged tunnels, rock tunnels, bridges) the largest in world? (certainty: 40%)
- become tourist attraction (certainty: 60%)
- reduce driving time between Kristiansand and Trondheim by half (certainty: 85%)

RISKS

- effect of wave motion on tunnels
- difficult to estimate exact loads
- deep enough to avoid water traffic, not so deep that submarines a problem
- fire or explosions – e.g. truck carrying dangerous goods – but water pressure may reduce damage
- leaks and breaks in tunnel wall
- engineers planning and testing to reduce these risks

PROJECT » **13** Choose a process in your industry or technical field. Make notes about what you already know and then carry out research to fill any gaps in your knowledge. Write down the main stages in the process and prepare one or two large visuals (or no more than ten PowerPoint slides) to accompany your talk. Prepare your talk, which should be no more than about 500 words long. Give your talk to your class or group. Answer any questions. While you are listening to a colleague's talk, make notes and prepare some questions to ask at the end.

7 Products

1 Developments

START HERE » **1** **Work in pairs or small groups. Discuss the photo. How is augmented reality (AR) being used? What other applications do you know about?**

READING » **2** **Read the review of AR technology and match the items A–H with 1–8 in the table below.**

Augmented reality

Augmented reality (AR), the technology in which digital content appears to be part of the physical world, has been bridging the digital and physical world for some time.

In case you haven't experienced it, here's how it works: if you point an AR-enabled camera at an object, the AR software recognises it and downloads a 'digital twin' of the object from the cloud. It then displays this as a 3D digital image which is superimposed directly onto the real-world image. For example, a satnav route appears not on a map on a separate device but directly on the road ahead, displayed on the car windscreen in the driver's line of sight, as in head-up display (HUD) systems.

AR uses advanced software such as SLAM (simultaneous location and mapping), along with GPS and sensors that measure depth, distance, speed and so on. It requires a camera and hardware to display the images, such as smart glasses, a smartphone or tablet screen, or a projector to project the images onto another surface.

One common application is in retail, where, for example, customers digitally try out new furniture or paint in their own home before they buy. AR is also used in maintenance, where a technician repairing equipment sees the actual equipment overlaid with a digital 3D diagram showing key information.

Current research in AR is directed towards further developing AR in a range of applications, for example in healthcare (e.g. surgery) and in manufacturing (e.g. assembly and maintenance).

A potential issue is that for AR to work the device needs to know exactly where it is located in the physical world. Currently GPS is not 100% accurate, and so more work needs to be done to resolve this issue.

As for the future, the AR industry is likely to migrate from smartphones to smart glasses so that many things that people currently do on their phones will be done on smart glasses via motion and gesture detection.

A aim	1 migrate from smartphones to smart glasses and motion detection
B components	2 device works in this way: (1) software recognises object (2) downloads digital twin of object (3) superimposes digital twin on real-world image
C user operation	3 point AR-enabled camera at object + device displays 3D image superimposed on real-world image
D method	4 further improve AR in healthcare and manufacturing
E applications	5 solve problem of GPS not 100% accurate
F work in progress	6 add digital value to the real world as 3D experience
G work still required	7 retail; maintenance; navigation
H future target	8 camera, GPS, sensors, screen or projector, SLAM software

LANGUAGE »

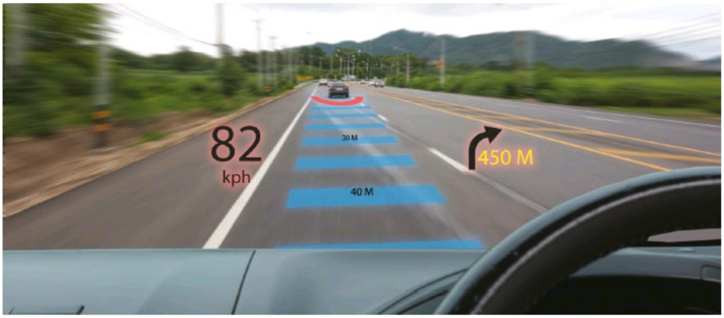
3 What is the most appropriate language from 1–7 to perform the functions in A–H in 2?

1 present continuous + time phrase (e.g. *currently*)
2 *the aim / objective* + *of* + noun + *is* + *to* + infinitive
3 *will (no doubt) / is (probably) going to*
4 *consist of*
5 *have to / need to* + infinitive
6 *by* + verb *-ing*
7 present simple (x 2)

SPEAKING »

4 Describe the AR system shown in the photo in 1, without looking at the text in 2. Use the table in 2 and the language forms in 3. Use the passive where appropriate.

5 Work in groups. Discuss the AR head-up display in the photo. Use the data in the table below and the language in 3. Take turns to talk about different aspects.



aim	display navigation data at eye level, driver keeps attention on road
components	AR software, sensors, infrared cameras, GPS, internet, projector, mirrors, translucent film on windscreen
user operation	switch on, adjust height, configure features (e.g. pedestrians, collision warning)
method	sensors monitor road ahead; software downloads data, adjusts images to 'fit onto' road about 2 metres ahead, projects image onto film on windscreen
work in progress	infra-red cameras display road markings, cars and objects that driver can't see (in fog, rain, snow or darkness)
further work required	in dangerous situation, display safest way to escape collision
future target	ultimate car safety system throughout motor vehicle industry

WRITING »

6 Work individually. Write a description of the AR head-up display in 5 following the order of the information in the table in 5 and using the phrases in the left-hand column as headings. Use the passive where appropriate.

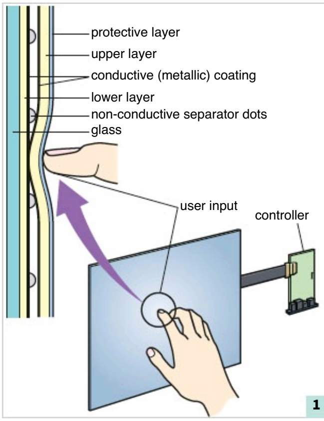
Begin:
Aim
The augmented reality head-up display system aims to project images and data about the road ahead directly into the driver's line of sight, allowing the driver to keep their attention on the road and to process information much faster.
Components
The system consists of . . .

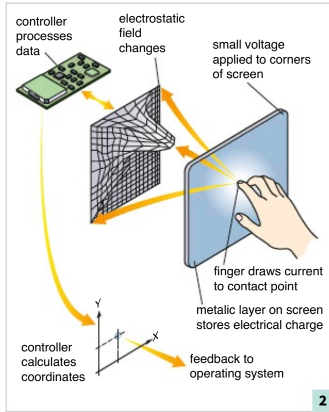
2 Comparisons

START HERE »

1 7.1 **Listen to a discussion about touch screens and answer these questions.**

1 What are the names of the two types of touch screen illustrated below?
2 How many metallic layers does each touch screen have?





LISTENING »

2 Study the diagrams above and write R (resistive), C (capacitive), B (both) or N (neither) next to each feature below.

1 principle:	electrical circuit R	stored electrical charge ___
2 action:	light contact ___	pressure ___
3 result:	pushes metallic layers together to close circuit at contact point ___	pulls current to contact point on screen ___
4 input by:	finger only ___	any object ___
5 clarity:	poor (more light filtered out) ___	less light filtered out ___
6 surface:	good scratch resistance ___	poor scratch resistance ___
7 durability:	wears down less quickly ___	wears down more quickly ___

3 Listen to the discussion again, and check your answers to 2.

LANGUAGE »

Comparing and contrasting

- *The clarity of the capacitive screen is **much greater than that** (= the clarity) **of** the resistive one.*
- ***Unlike** the resistive screen, the capacitive one only has one metallic layer.*
- *With a capacitive screen, **instead of using pressure**, you touch it very lightly.*
- *You can only use your finger with a capacitive screen, **while** / **whereas** you can use any object with a resistive screen.*
- *You could say it's a disadvantage of the capacitive screen. **On the other hand**, you're less likely to scratch the screen surface.*
- ***Compared with** the capacitive screen, the resistive one can wear out very quickly.*

SPEAKING »

4 Work in pairs. Discuss the advantages and disadvantages of the two systems, with one person arguing in favour of the resistive system and the other supporting the capacitive one. Use a variety of language from the box above.

TASK » **5 A technical writer is planning to write a report comparing the two touch screen systems in the factsheets below. Look at the information in the factsheets and study the following notes that the writer has made.**

Introduction

Purpose: compare IR and SAW; help company buy best system

Similarities

Paragraph explaining similarities: 1. good clarity in both systems – because no metallic layers; 2. both systems use signals on or over screen surface

Differences in technology

Paragraph about IR: LEDs / light beams / detectors / touch / interrupts beam / drop in signal / controller / determines location of touch

Paragraph about SAW: transducers / sound waves / reflectors / touch / absorbs energy / controller / wave amplitude / location

Differences in performance resulting from technology

(4 short paragraphs comparing IR and SAW for:)

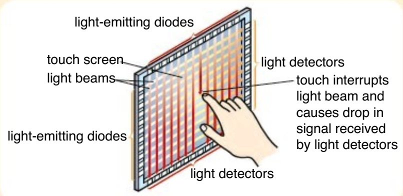
1 Input

2 Effect of bright light / loud music

3 Resistance to moisture and contaminants

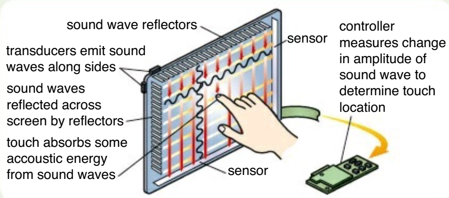
4 Applications

INFRARED (IR) TOUCH SCREEN



- No metallic layer over screen, so high clarity
- Technology: light beams slightly above screen surface
- Method: touch interrupts beams
- Responds to any input: finger, pen
- Affected by bright ambient light
- Can be sealed and protected against weather and contaminants
- Applications: outdoors, medical, industrial

SURFACE ACOUSTIC WAVE (SAW) TOUCH SCREEN



- No metallic overlay: high clarity
- Technology: sound waves on screen surface
- Method: touch absorbs acoustic energy
- Responds to soft objects: finger, soft stylus
- Affected by loud ambient noise
- Cannot be sealed: badly affected by moisture or contaminants
- Applications: indoors, banks, payphones

SCANNING » **6 Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete the information below.**

1 The IR screen has *more / less* clarity (i.e. transmits more light) than the SAW.

2 The SAW screen operates in a *wider / narrower* temperature range than the IR.

WRITING » **7 Write a product comparison report based on the information and the notes in 5, comparing the two touch screen systems. Use language from the box on the opposite page where appropriate.**

Begin:

Introduction

The purpose of this brief report is to compare touch screen systems: infrared (IR) and surface acoustic wave (SAW), to assist in the process of selecting the best touch screen system for our company's needs.

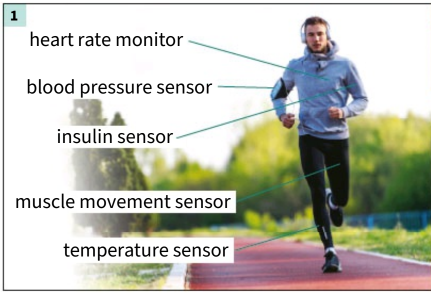
Similarities

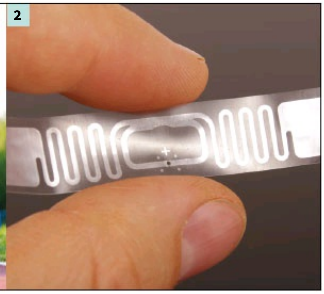
Both touch screen systems have very high clarity because (unlike resistive or capacitive screens) there are no . . .

3 Product launch

START HERE »

1 **Work in pairs. Discuss photo 1. What kind of sensors can be attached to the surface of the body and why? Discuss photo 2. What is it? What is it for? What problem may bending cause?**





LISTENING »

2 7.2 **Listen to a product launch and answer these questions.**

1 What is the device? Where will it be used?
2 What are the two main functions of the device?
3 What are the main parts of the device? What materials are they made of?
4 List five useful properties of the device that are mentioned.
5 What drawback or problem does this type of device generally have?
6 How did the research team solve this problem?

3 7.2 **Listen again and complete the speaker's words with the words and phrases in the box.**

in other words (x2) to put that in everyday language that is another way of putting it is that to understand this in more detail that is to say to put that another way

1 ______________ , it converts energy from radio waves into electricity
2 there is plenty of ambient energy - ______________ , energy around the patient's body
3 ______________ we should harvest that energy
4 this system is then connected to a stretchable rectifying circuit, ______________ the rectenna
5 ______________ , it's stretchable and flexible enough to fit into the human body's constantly changing shape
6 ______________ , let's look at what antennas are and what they do
7 ______________ , an antenna is basically a length of material that can conduct electrical current
8 ______________ , our device is resilient

LANGUAGE »

Words and phrases to signal that you are about to explain something

Explaining single words or short phrases: *or, that is, that is to say, in other words*

Explaining longer passages: *another way of putting it is that, to put that another way, to put this in everyday terms / language, to understand this in more detail*

4 Match the technical terms in italics with their less specialised explanations a–h.

Note: Explanations in a–h are not necessarily scientifically or technically exact.

1 Antennas use an electrical current that *oscillates.*
2 Antennas send out *electromagnetic radiation.*
3 Antennas are made of a *conductive material.*
4 Our team used a *broadband* transmitter
5 The device combines an antenna with a *rectenna*.
6 The antenna is not damaged by *compression*.
7 Wearable antennas must be *resilient*.
8 Radio waves from a fixed-lenth antenna move with a fixed *frequency.*

a) a device that converts radio waves into electricity
b) vibrates
c) speed of vibration
d) resistant to damage
e) magnetic waves caused by an electric current
f) a squeezing or pressing force
g) a substance that can carry electrical current
h) using a wide range of wavelengths

5 Make full statements from the table, using a variety of expressions from the language box on page 56.

Example: *1 Antennas use an electrical current that oscillates, that is, vibrates.*

6 Work in pairs. Discuss the differences between the speaker's *technical* description and *everyday* description. What methods does the speaker use to make the meaning clearer to a non-specialist audience?

Technical

Antennas transmit signals by using an oscillating electrical current in a length of conductive material to generate electro-magnetic radiation.

Everyday

To put that in everyday language, this is what happens. An antenna is basically a rod made of a material, such as copper, which can conduct, or carry, electrical current. The current vibrates at a particular speed, and the vibration sends out magnetic waves, known as radio waves. It's a bit like throwing a stone into a pool of water. The vibration of the stone hitting the water sends out water waves in all directions. Or think of clapping your hands together and sending out sound waves.

LANGUAGE »

To explain technical terms or ideas to a non-technical or non-specialist audience, it often helps to make comparisons with:

- human experience: *ambient energy - in other words, energy around the patient's body*
- everyday objects: *an antenna is basically a rod or length of material that can conduct electrical current*
- everyday actions and events: *we should harvest that energy, just as we harvest food from the ground; it's a bit like throwing a stone into a pool of water; think of clapping your hands together and sending out sound waves*

TASK »

7 Work in pairs. Choose two of the following items from this unit, and prepare brief explanations (max 80 words) for a non-technical audience. Use the strategies above. Then explain your items to another pair, without mentioning the name. Can they work out which ones they are?

Augmented Reality (AR), capacitive touch screen, surface acoustic wave touch screen, flexible antenna and rectenna, capacitor, electrical circuit, electrode

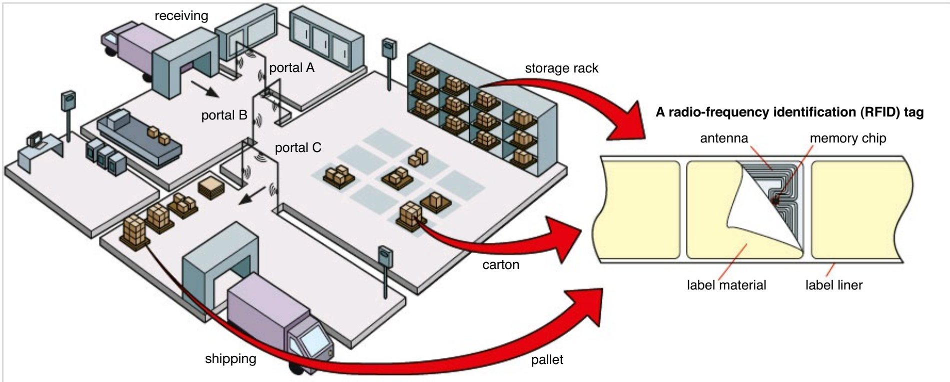
WRITING »

8 Choose a concept, principle, technology or piece of equipment which is important in your technical field or industry. Describe and explain the same information in two different texts – one technical and the other non-technical.

8 Incidents

1 Theft

START HERE » 1 **Work in groups. Discuss the main threats to security in a typical warehouse. What security measures are needed?**



READING » 2 **A theft has occurred at a warehouse. Read this memo about it and mark the following locations on the illustration above.**

1 the place where RFID tags were first attached to the cartons
2 the faulty RFID scanning portal
3 the only two possible locations of the theft

TO: Head, Inventory Dept
FROM: Manager, Warehouse
SUBJECT: Missing cartons: preliminary thoughts

INCIDENT
The three cartons were taken from three pallets. The plastic film over the pallets was torn. There were no signs of a break-in to the warehouse from the outside.

CAUSES
We know for certain that (1) the cartons were RFID-tagged on receipt, (2) all carton tags scanned positive during put-away and picking and (3) one RFID scanning portal (portal C, between the warehouse and staging area) was faulty at the time of the incident.

1 Possibilities:
- goods stolen after picking from storage rack and before staging ☐
- theft occurred in staging area ☐

2 Things we can definitely rule out:
- cartons taken during receiving stage 1
- cartons removed from storage rack prior to picking stage ☐

3 Assumptions we can safely make:
- theft carried out by insider (warehouse worker) ☐
- incident took place 08.30–09.25 ☐

4 Some mistakes identified:
- faulty portal C left out of action for two weeks ☐
- hand scanning not carried out at portal C ☐

RECOMMENDATIONS
- immediately review all CCTV footage in relevant areas ☐
- don't inform police until more information available ☐

NEXT STEP
As soon as the staff have been interviewed (by end of today), I'll brief you on the outcome. Other investigations are in hand. Can we meet first thing tomorrow?

3 **Read the memo again and put the stages of the warehousing process in the correct order.**

☐ put-away	☐ storage
☐ staging	☐ shipping
☐ picking	☐ receiving

4 **Briefly explain what happens in a warehouse, changing the nouns in 3 into passive verbs.**

Begin: *Immediately after the goods have been received, they are put away on racks, . . .*

LISTENING »

5 8.1 **Listen to this discussion and write the numbers 1–10 in the boxes in the memo, according to the order in which the points are mentioned.**

6 **Next to each numbered box in the memo in 2, write the modal form which was used in the discussion. The headings in the memo will help you work this out. Use each of the following modal forms once only. Then listen again and check your answers.**

must have	can't have	should (have)	ought to (have)	couldn't have
might have	could have	has to have	shouldn't (have)	ought not to (have)

LANGUAGE »

Speculating about possibilities in the past: *The cartons* ***may / might / could have*** *been stolen here*.

Speculating about impossibilities in the past: *The cartons* ***can't*** / ***couldn't have*** *been taken out during the receiving stage.*

Speculating about probabilities or near certainties in the past: *The theft* ***must have*** / ***has to have*** *been carried out by an insider.*

Expressing regrets or criticisms about the past: *Hand scanning* ***should (not) have*** / ***ought (not) to have*** *been carried out.*

Recommending an action for the future: *The police* ***should (not)*** *be* / ***ought (not) to*** *be informed yet.*

7 **Change these sentences to give the same meaning using a variety of modals from the box in 6. Don't use the phrases in italics.**

Example: *1 The thieves can't have . . .*

1 *It's not possible that* the thieves stole the cartons from the truck before they were received.
2 *It's certain that* the incident took place in the morning, but it's impossible that it happened before 08.30.
3 *It's possible that* the goods were stolen in the warehouse, and *another possibility* is that they were taken in the staging area.
4 *It's recommended that* we have another look at CCTV footage and that all security procedures are tightened up generally.
5 *It's virtually certain that* someone disabled the scanning portal deliberately.
6 *One mistake, which we regret, is that* the faulty portal was not checked on a daily basis and repaired as soon as the fault was discovered.

SPEAKING »

8 **Work in pairs, A and B. Question each other about the numbered items 1–4 in the memo. Respond using the appropriate modal.**

A: *Were the goods stolen after picking and before staging?*
B: *Yes, that's a possibility. They could have been stolen at that point.*

2 Security

START HERE »

1 Discuss the situation below in pairs. What might / must / can't have happened? If you were the security administrator, what would you like your security system to be able to do?

At 08.12 a sales employee of Avantis plc can't find his company-approved personal mobile phone, which has an app that allows him to download client details from the company database. He immediately phones his office to report the loss. Meanwhile, at Avantis HQ, the security administrator sees an alert on her computer screen, indicating that someone is making repeated multiple incorrect password attempts to access the company database from the employee's mobile phone.

READING »

2 Read part of a memo sent after the incident from the security director to the security administrator, and make a list (in note form) of what the security system can do, or allows you to do. Compare the list with your ideas in 1.

... but at this point I'm not interested in what *might* have happened, what *must* have taken place or what *couldn't* have occurred. I want to know what *actually happened*. Specifically I need to know:

1 how and when you first discovered that an unauthorised user (UU) was trying to use the device to access the company database, what action (if any) you took in response and your reasons for such action
2 at what point you realised that the UU was attempting to install software to download sensitive company files, what action(s) you took to counter this and whether this response was successful
3 whether you attempted to take over control of the mobile device remotely, whether or not such attempts were successful and why
4 whether or not you attempted to wipe downloaded company data from the device remotely and if so, how you did it, and which methods (if any) proved successful
5 if you were able to determine where the mobile was located and in which direction it was moving, if any

Language page 104

3 Make direct questions.

Example: *1 Who was the authorised user of the stolen mobile device?*

1 I would like to know who the authorised user of the stolen mobile device was.
2 Next, I need to find out how our employee lost his mobile and when he found out he had lost it.
3 It's important that we determine whether and when he accessed company files before he lost the phone.
4 We've got to discover whether or not he actually downloaded any files onto his mobile.
5 Tell me which files our employee was authorised to download.
6 Please check whether our employee had already activated the remote wipe and 'find my phone' features.
7 Do we know if the mobile device had the latest GPS app installed?

SPEAKING

4 Work in pairs, A and B. Use the indirect questions in the memo in 2 to ask direct questions to each other to find out about the incident. Make complete notes: you will need them later.

Student A: Turn to page 112.
Student B: Turn to page 115.

READING » 5 Read part of a company policy document and answer the questions below.

GOOD PRACTICE FOR BYOD SECURITY

If employees are allowed to use their personal mobile phones for work (under a 'bring your own device' (BYOD) policy), they should sign an agreement acknowledging that their device will contain sensitive data and therefore allowing the company to remotely wipe all data from the device in an emergency, for example if the phone is stolen. They must also agree to keep the `find my phone' app switched on and activate company software to enable:

1 on-demand wipe, in which the administrator can send a command to an online device to wipe all data instantaneously from the device.
2 pre-scheduled wipe on sight, where the device is programmed to wipe all data the next time the device is detected online.
3 programmed time-based wipe, where an offline or out-of-contact device is programmed beforehand to wipe all data if it does not appear online for a specified number of hours.
4 pre-set event-based wipe, where a wipe action is triggered by a specified action, such as multiple incorrect password login attempts or installation of an unauthorised program.
5 wipe by text message, which permits the administrator to send an encrypted text message to the offline device to execute a wake-up-and-wipe command.

Which of the five wipe methods ...
1 must be programmed in the mobile device in advance, before the device has been stolen?
2 can be executed during the incident itself, for example while the thief is using the phone to access data?
3 can be executed only while the device is connected to the internet?
4 can operate if the thief does an action specified in advance, such as trying to log in more than three times using the wrong security information?
5 can be executed even when the device is disconnected from the internet?

VOCABULARY » 6 Find the seven hyphenated word combinations in the document. Then match them with these phrases with the same or similar meaning. Each hyphenated combination acts as an adjective.

Example: *1 out-of-contact*

1 which cannot be contacted
2 dependent on a specified action being carried out
3 dependent on the passage of a fixed time
4 executed when it is requested
5 which makes the device switch on and remove all data
6 fixed or planned beforehand
7 planned beforehand to happen at a specific moment

7 Find words in the document with the same or similar meaning as the following.

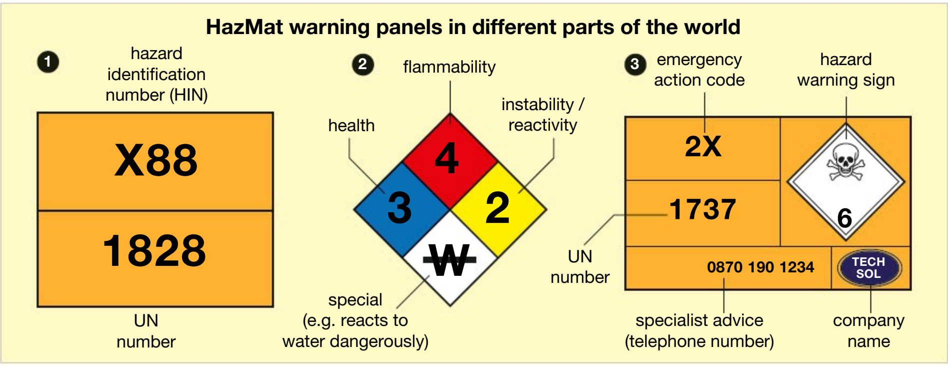
1 needing to be kept secure
2 illegal *or* not allowed
3 carry out
4 from a distance
5 immediately
6 written in secret code

WRITING » 8 You are the security administrator at Avantis. Write a concise report to your security director giving the main points of the data theft incident you worked on in 4. Write the report in five sections, as shown below. Summarise information from your scenario in 4 for sections 1–3. Select items from the document in 5 for sections 4–5 of your report.

1 The incident
2 The security response
3 Outcome
4 Weaknesses in our security system
5 Recommended improvements to the system

3 Emergency

START HERE » **1 Work in pairs. Discuss these labels and answer the questions below.**



1 Which areas of the world use each type of warning panel?
2 What two words is *HazMat* an abbreviation for?
3 What kind of information is found on a European warning panel.

LISTENING » **2** 8.2 **Listen to part of a talk given by a safety officer and check your answers to 1.**

3 Listen again and answer these questions.

1 What is the substance in the warning panel in Fig. 1?
2 What are its properties or dangers?
3 Can water be used when fighting a fire involving this substance? Give reasons.

SCANNING » **4 Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete this information.**

The UN number for:
1 sodium monoxide ______
2 sulphurous acid ______

The HIN for:
3 flammability of liquids ______
4 radioactivity ______

5 8.3 **Listen to the question and answer session at the end of the safety officer's talk. Put a tick next to the questions she answers 'yes' to, and a cross if she answers 'no'.**

1 Does the European panel give all the information needed in an emergency?
2 Does the panel in Figure 3 give the clearest information of the three?
3 Do all large vehicles have to have a warning panel?
4 Has the use of the panels helped to avoid serious accidents?
5 Is the UN numbering system too complex?
6 Do European vehicles ever show hazard symbols, such as the skull and crossbones for toxicity, on the warning panel?

6 8.3 **Listen again. Next to each question in 5, write the words or phrases the training officer uses to introduce each answer (choose from the box below). Then note down the extra information she adds.**

yes and no   in fact   on the contrary   absolutely   certainly not   up to a point   definitely not   to some extent   without a doubt   actually   certainly   absolutely not   definitely

7 **Match each word/phrase in 6 with one of the statements A–E.**

A My answer is a strong YES.
B My answer is a strong NO.
C My answer is partly YES and partly NO.
D My answer is slightly different from the one you are expecting.
E My answer is the opposite of the one you are expecting.

LANGUAGE »

8 **Change the direct questions in 5 into indirect questions. Use a different phrase (such as the words in italics in the example) to introduce each one.**

1 *Could you please explain* whether the European panel gives all the information needed in an emergency?

Language page 104

9 **Work in pairs. Ask your indirect questions from 8. Answer using the items in the box in 6 and the extra information the safety officer gave.**

SPEAKING »

10 **Work in pairs, A and B. Ask your partner questions to find out about a serious incident involving dangerous materials. Make detailed notes. You will need your notes for the next exercise.**

You have a rough idea about your partner's incident. It involves a crashed tanker, the leak of an unidentified substance, a mistake by firefighters (because they did not identify the substance) and serious consequences. Ask questions to find out the details of what happened.

Student A: Find details of your incident on page 111.
Student B: Find details of your incident on page 114.

WRITING »

11 **Work individually. Write an incident report based on the notes you made about your partner's incident. Use these headings. Come up with your own recommendations.**

Incident   Cause(s)   Results   Recommendations

Review Unit D

1 **Rewrite these notes as nine full sentences. Use the language forms in exercise 3 on page 53 as needed. Use the passive where appropriate.**

Example: *1 The aim of RFID tags is to enable all items to be tracked through the supply chain.*

RFID (radio frequency identification) tags

1 **Aim:** enable – track all items – through supply chain
2 **Components:** microchip (read + store data) + antenna (transmit + receive)
3 **User operation:** download product information to tag, attach tag to every item
4 **Method:** receive updated information + transmit – whenever – pass – under portal containing reader (or near mobile reader)
5 **Current research:** Gen2-compatible RFID chip; reduce chip dimensions below 245 X 125 micrometres
6 **Research still required:** new antenna designs - increase range of RFIDs
7 **Future expectations:** electronic printing + conductive ink technologies - companies print own tags - on site

2 **Complete these sentences, choosing words and phrases from the box. Two of the words/phrases are not needed.**

rather   unlike   although   however   than it is   nevertheless
other hand   than that   instead   compared

1 Carbon nanotubes are going to replace copper wires in computer chips, because their electrical resistance is much lower ______ of copper wires.
2 ______ with today's touch screens, those of the future will probably be touchless, using 'predictive touch'. On the ______, perhaps touch screens will be replaced by a totally different technology, able to turn any surface into a touchscreen.
3 Smart devices in future will probably use gestures or finger movements in the air ______ than relying on touch screens.
4 Speech input is already common in many cars today. Background noise, ______, is still a problem with this technology.
5 In the future, laptops will respond to facial gestures ______ of requiring touch screen or mouse-based input.
6 ______ passive RFIDs, most active RFIDs can be read at a range of 100 metres or more. ______, future improvements in antennas will probably increase this.

3 Complete this text with the words and phrases in the box.

that	that is to	other words	put that in everyday terms	i.e.	way of putting this

If you know the exact location and orientation of a camera, in (1) ______, where it is and which direction it is pointing in, and you also know the properties, (2) ______ the characteristics of the lens, it is possible to identify what the camera is looking at.

The prototype, (3) ______ say, the early model, of the AR-enabled smartphone used accelerometers in all three axes to determine orientation. Another (4) ______ is that it used speed sensors operating in three dimensions to work out the direction in which the camera was pointing.

It also used a digital compass for heading, (5) ______ is, direction of movement, and GPS, or global satellite positioning, for exact location.

Since these sensors gave the (approximate) location and orientation, it was possible to superimpose real-world online data on the display screen. To (6) ______, the smartphone could find information about the objects on the internet and place it on or near the images on the screen.

4 Work in pairs. Discuss the differences between a rugged laptop (illustrated below) and a typical laptop used by an office worker. What are the reasons for these differences?

TYPE: rugged laptop
USE: outdoor, physically demanding environments

DURABILITY FEATURES:

- designed using military testing procedures
- sunlight-viewable touch screen
- impact and drop-shock resistant body
- shock-mounted removable hard disk
- strong case and hinges made of magnesium alloy
- moisture and dust-resistant screen, keyboard and touchpad
- connectors (e.g. USB-C ports) sealed against rain, dust and moisture
- replaceable screen film for touch screen protection

OTHER FEATURES:

- integrated GPS
- mobile 5G technology
- automobile power adapter
- HD touch screen

5 Work individually. Write a report for your manager, comparing the rugged model illustrated above with a typical personal laptop and recommending the rugged model for outdoor work connected with an industry you know something about. Give reasons for your recommendation.

6 **Rewrite these sentences to give the same meaning. Use each item in the box once only and do not use the phrases in italics.**

can't have been could have been couldn't have must have been has to have been should be shouldn't have should not have been

Example: *1 The fire could have been caused by faulty electrical wiring.*

1 *There's a possibility that* the fire was caused by faulty electrical wiring.
2 *In my opinion, it was a mistake for* the new sales manager to be given a company mobile phone before he completed his basic IT training course.
3 *It's virtually certain that* the IT system in our factory was infected by a virus.
4 *I believe it's impossible that* the cartons were stolen by our warehouse staff.
5 *We are sure that* your company-issue mobile phone was taken by an unauthorised user.
6 *It's not possible that* such an experienced tanker driver fell asleep at the wheel.
7 *It was wrong for you to* make your password the same as your birthday!
8 *Our recommendation is that* your servers are shut down immediately and your company's files are locked.

7 **Change the first question of each pair into an indirect question and the second into a noun phrase. Use the words and phrases in brackets.**

Example: *1 The manager wants to find out why the warehouse worker removed the RFID tag from the pallet. He would also like to know the exact time of the incident.*

1 Manager: Why did the warehouse worker remove the RFID tag from the pallet? And when exactly did the incident occur? (wants to find out / time)
2 Investigators: How fast was the plane flying when the near-miss took place? And how high was it? (will determine / altitude)
3 Supervisor: Did the maintenance team repair the fault in the jet engine? And what caused the fault? (needs to know / cause)
4 Security official: How did the unauthorised user obtain the employee's password? Who was the unauthorised user? (is trying to discover / identity)
5 Company chairman: Have the police completed their investigation into the loss of the encrypted data? What happened as a result of the investigation? (is keen to find out / outcome)
6 Warehouse manager: Which scanning portal did the carton pass through? And where is the carton right now? (is attempting to find out / current location)

8 **Match the words and phrases in italics in the dialogue below with the phrases in the box with the same meaning.**

Certainly not In fact To some extent Definitely, yes The opposite is the case

A: If I understand you correctly, you prefer capacitive touch screens to resistive ones. Is that right?
B: *Absolutely* (1). Capacitive ones are much more reliable.
A: But both types of screen are quite durable, aren't they?
B: *Up to a point* (2), they are, yes. They're both reasonably durable, but the capacitive screen wears down less quickly.
A: That must be because you don't actually touch the capacitive screen.
B: *Actually* (3), you do have to touch it. But it's true that you only need to touch it lightly, whereas you have to press harder on a resistive screen.
A: But at least both touch screens have equally bright and clear images.
B: *On the contrary* (4). The resistive screen is much darker because the double metallic coating filters out more light.
A: Ah yes, of course. So you won't be buying a resistive screen any time soon?
B: *Definitely not* (5).

9 **Practise both forms of the dialogue with a partner, changing roles for each one.**

10 **You are a safety officer working for a chain of warehouses. Write an incident report for your managing director, based on the notes below. Use these headings in your report: *Incident*, *Causes*, *Results*, *Recommendations*.**

Begin:

Incident

Last Saturday, at approximately 13.35, a forklift truck crashed into rack #24, injuring two staff and destroying an inventory crate.

Workshop report: forklift has two dents from accident --- no serious damage --- truck now in use again

Inventory clerk's statement: clerk admits walking in or near centre of aisle, not in marked pathway along side --- remembers truck swerving --- remembers being struck on back of head, nothing else --- woke up in hospital --- recovering after overnight stay in hospital --- medical report says probably struck by carton

Forklift truck driver's statement: driver admits not wearing seat belt --- admits exceeding speed limit in narrow aisle --- in a hurry --- behind in work schedule --- returning late from lunch break --- made right turn --- suddenly saw inventory clerk --- swerved to left --- sudden sharp turn --- driver thinks he was thrown from right side of forklift truck --- arm broken in two places, recovering

Supervisor's report: last Sat, approx 13.35, supervisor heard crash, ran to accident scene --- she found forklift crashed into rack #24 --- crate #685 destroyed --- stock from crate scattered over floor --- clerk face down on floor, unconscious --- cartons from truck on floor near clerk's head --- driver on ground, holding right arm in pain --- supervisor ran to loading dock --- took four minutes to run there! --- phoned security dept --- security staff arrived five minutes later --- put ropes around area --- assisted driver and clerk --- ambulance arrived approx 13.50, took two staff away --- completed accident report (put in appendix)

Inventory Manager's report: medical bill €1,200 --- value of destroyed crate (#685) €750 --- total accident bill €1,950

Safety implications: line managers need to enforce speed limits --- driver in breach of company safety rules --- monthly safety meetings needed --- clerk broke rule by walking in centre of aisle --- no barrier to separate walking from driving areas --- we need 1-metre-high steel mesh barriers --- critical time lost when supervisor ran to loading dock --- the only emergency phone in warehouse is located there --- we need emergency phones in all locations, not just in loading dock --- cartons flew off truck too easily --- not strapped down on forklift --- but safety rules say you must strap them down --- rule not enforced --- it's time to tighten up on safety in this warehouse!

PROJECT » **11** **Do one of the following tasks.**

1 Describe and / or explain a concept, principle, technology or equipment important in your industry or technical field. Give the same information in two different texts.
Text 1: Part of a technical article for a reader who shares the writer's specialism.
Text 2: Part of a magazine article for a non-specialist reader.

Note: technical texts are often shorter and more condensed than non-technical ones.

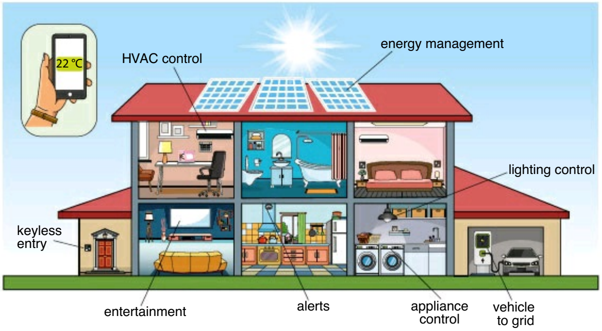
2 Research a major incident in your industry. Write a concise report on the incident, using these headings: Incident / Cause(s) / Results or Outcome / Discussion or Conclusions / Recommendations

9 Agreements

1 Proposals

START HERE »

1 **Work in pairs. Discuss what features of an 'intelligent' or automated building you would like in the place where you live or work.**



LISTENING »

2 9.1 **Listen to these extracts from a meeting between Cygmars technical sales manager and a director of Widgett & Sons, a potential client. Tick the main features below which are mentioned.**

CYGMARSYSTEMS: FOR AUTOMATED COMMERCIAL BUILDINGS

MAIN FEATURES

1 intrusion sensors ☐	3 smoke detectors ☐	5 thermostats ☐	7 radio-enabled sensors ☐
2 light sensors ☐	4 motion sensors ☐	6 moisture detectors ☐	8 self-healing 'mesh' networks ☐

3 **Four of the selling points A–F in these notes are used in the meeting. Listen again and number them in the order in which they are discussed.**

SELLING POINTS TO MAKE TO PROSPECTIVE CLIENT

A ☐ break-in by intruder – intrusion sensors – trigger alarm + series of events: master lights, emergency service, video, activate locks – simultaneously
Proposal: full security package

B ☐ control of network = central computer + mobile input devices – mobile phone / PDA – supervisors walk around factory – input/receive data – system updated automatically – password protected
Proposal: Cygmar mobile input devices

C ☐ one sensor (e.g. smoke detector) in network fails? – no problem – mesh networks – self-healing – repair themselves – rest of network raises alarm – signals by-pass failed device – use different route
Proposal: self-healing mesh network option

D ☐ scalable – (virtually) unlimited number of devices can be connected to network – allows factory to expand after network installed – very wide range – can cover 250 m^2 (large factory)
Proposal: scalable network system option

E ☐ devices – control heating, cooling, lighting, air quality – lights + radio-enabled motion sensors – programmed – turn on / off as staff walk in / out – reduce energy costs
Proposal: utilities package

F ☐ radio chips – use low power – default mode 'asleep' – only activate when needed – transmit, receive small amounts of data – high speed not necessary – batteries last up to 5 years – unlike other systems
Proposal: Cygmar batteries – 5-year-guaranteed life

VOCABULARY »

4 **Match the verbs in the box with the verb phrases in italics below.**

pinpoint	select	enter	tackle	lose power	reduce	go around	monitor

1 How would your system *keep an eye* on security issues?
2 Video cameras would *home in on* the area.
3 How would you *go about* reducing our energy costs?
4 Lights turn themselves on whenever staff *make their way into* a workshop.
5 This would help you to *cut down on* energy costs.
6 I strongly recommend that you *go for* the full utilities package.
7 Some Wi-Fi systems have batteries that *run down* after a few hours.
8 All the signals would *by-pass* the failed device.

LANGUAGE »

Ways of making proposals

We propose that *your company* ***(should) install*** *our system.*

We propose installing *our system in your factory.*

We would like to ***make / submit / put forward a proposal to install / for installing*** *our system.*

- ***propose + that*** specifies who will carry out the proposed action: *We* ***propose that*** *a team of specialists* ***(should) inspect*** *your current system.*
- ***propose + -ing*** does not specify the actor, and is often used when the actor and the proposer are the same: *We* ***propose bringing in*** *a team of specialists.*
- the words ***propose*** and ***proposal*** in business or work contexts often signal a formal (or official) proposal which requires formal acceptance or rejection.
- ***suggest*** or ***recommend*** are commonly used in proposals without signalling a formal proposal: *We* ***(would) (strongly) recommend / suggest installing / that you (should) install*** *our system.*

5 **Complete this text, using a variety of forms from the language box above.**

The planning committee made a number of proposals (1) ______ (deal with) the difficulties of building companies during the economic downturn. First, they proposed (2) ______ (carry out) a large-scale survey of the needs of the building industry in the region. The second proposal was (3) ______ (set up) up a special bank to give cheap loans to struggling builders. The third proposal was (4) ______ (hold) a regional conference of all small and medium-sized building companies to discuss the issues. Fourthly, one of the major building companies proposed (5) ______ (ask / government) to help out with subsidies and loans where necessary. To speed things up, this company suggested (6) ______ (committee / circulate) a draft letter for everyone to sign. They also recommended (7) ______ (contact) local government officials to see if they could help.

SPEAKING »

6 **Work in pairs, A and B. Role play a conversation between the Widgett director (Student A) and the Cygmar technical sales manager (Student B) about points A–F in 3. Use the notes in 3 and language from the box above.**

Student A: Ask questions to elicit the answers in the selling points in 3. Respond to B's answers in a positive way before B makes proposals.

Student B: Use the selling points in 3 to answer A's questions and wait for A's response to your answers before making your proposals.

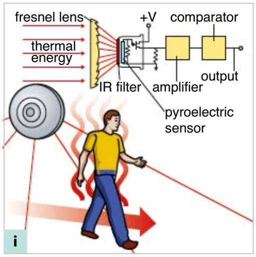
7 **When you have finished, work with a different partner and switch roles.**

2 Definitions

START HERE » **1 Work in groups. Discuss the sensors illustrated below and match them with their main function 1–4.**

For detecting / measuring . . .

1 slight changes in the surrounding temperature
2 bending or other changes of shape in a rigid structural component
3 the movement of any object capable of giving out heat
4 presence of carbon particles arising from combustion



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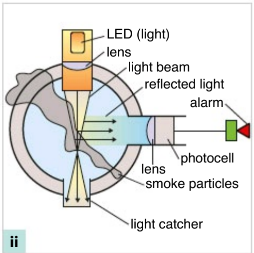

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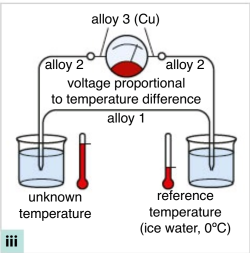

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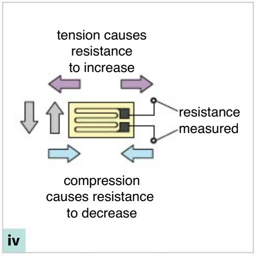


iv

READING » **2 Match the definitions A–D with the sensors above.**

A A photoelectric smoke detector is a security device, containing an LED and a photocell, that detects smoke particles by bouncing light off them onto the photocell.
B A PIR (passive infra-red) motion detector is an electronic sensor, made of pyroelectric material, which detects the movement of a heat-emitting body by generating an electric charge when exposed to infra-red radiation.
C A strain gauge is a device used for measuring the mechanical deformation of a concrete beam or similar structure and consisting of a metal coil and terminals, that changes its electrical resistance when its shape changes.
D A thermocouple is a small heat-sensitive electrical device consisting of two wires made of dissimilar metals, which is used for measuring variations in temperature and is frequently found in heating and cooling systems.

LANGUAGE » **Basic definition of an item**

name	be	generic noun	main function
A thermocouple	is	a device	for measuring temperature.
A PIR motion detector	is	a sensor	which detects human movement.

Definitions normally contain the four elements above, although more complex ones can have optional elements before and after the generic noun. For example:

- *A thermocouple is a* ***simple electrical*** *device for measuring temperature.*
- *A PIR motion detector is an* ***electronic*** *sensor,* ***made of pyroelectric material****, which detects human movement.*

3 Identify the four elements from the language box in A and C in 2.

4 Identify the four elements from the language box in this definition.

Electric Potential Sensors (EPS) are wideband (quasi DC to 200 MHz) ultra-high-impedance sensors used for detecting spatial potential, electric field or charge.

LANGUAGE »

Expanded definition

Note: the white rows are optional and not necessarily in the order shown here.

name	A thermocouple
be	is
appearance	(a) small
property	heat-sensitive
type	electrical
generic noun	(a) device
components	consisting of two wires
material	made of dissimilar metals
main function	which is used for measuring changes in temperature
application	and is frequently found in heating and cooling systems.

Other functions are possible in the white rows (see 5 below).

Clauses can be linked by a variety of forms, such as:

- past participle: *made of dissimilar metals*
- present participle: *consisting of two wires*
- *(which is) (used) for -ing: which is used for measuring temperature*
- *which / that / who: which / that measures temperature*

5 Make similar charts for definitions A–C in 2. Use the headings shown for the white rows.

Definition A: type / material / method
Definition B: type / components / method
Definition C: components / property

VOCABULARY »

6 Complete these definitions with the most appropriate generic noun from the box.

device	system	standard	process	instrument

1 IEEE 802.15.4 is a(n) ________ which was created specifically for control and sensor networks.
2 Basic oxygen steelmaking is a(n) ________ by which raw iron is converted into steel by removing most of the carbon.
3 A voltmeter is a(n) ________ which gives a precise measurement of electrical potential differences between two points in an electric circuit.
4 A sensor is a(n) ________ that detects a change in its surroundings and converts it into a signal which can be read by an observer or by an instrument.
5 Global positioning is a space-based global navigation satellite ________ that provides reliable location and time information at all times and in all weather.

WRITING »

7 Write the definition of this instrument, using the following words and phrases in the correct order.

mounted on | for measuring | a small | a surveying | A theodolite is
telescope | consisting of | horizontal and vertical angles, | a tripod. | instrument

8 Write six definitions from your industry or technical field. Use a variety of generic nouns.

3 Contracts

START HERE » **1 Work in pairs. Discuss briefly when contracts are used and why they are important.**

LISTENING » **2** 9.2 **Listen to this discussion between the Widgett director and the head of his legal team. Complete the notes.**

1 We will only pay them in full on condition that ______________________

2 They'll give us a 15% discount on the total price provided that ______________________

3 They can select the starting date as long as ______________________

4 In case they miss the deadline, ______________________

5 We have the option of cancelling the contract and getting our money back in case ______________________

6 Even if we have to close the factory for a short time, ______________________

READING » **3 Match these extracts from the contract with the completed notes in 2.**

A [ ] The Work shall commence at a date to be nominated by the Contractor with the proviso that the Contractor shall give the Client 14 days' prior warning of the intended date of commencement.

D [ ] The Work shall be carried out only by named direct employees of the Contractor. Should the Contractor breach this condition, the Client shall have the option to terminate this Agreement, in which case the Contractor shall repay all monies received from the Client.

B [ ] In the event that an unforeseen circumstance should force the temporary closure of the Location, there shall be no variation to the deadline stipulated in the Schedule other than as agreed by both Parties in an exchange of letters.

E [ ] In the event that the Contractor fails to complete the Work within the time specified in the Schedule, the Contract Price shall be reduced by the percentage stipulated in the Schedule pro-rata for each week of delay beyond the specified deadline.

C [ ] The Contract Price shall be reduced by the percentage stipulated in the Schedule, provided that the Client allows the Contractor to nominate the date of commencement of the Work.

F [ ] The Client shall pay the Contractor the Contract Price stipulated in the Schedule for the Work, provided that the Work is completed to the satisfaction of the Client and in accordance with the terms of this Agreement.

4 Answer these questions about the contract.

1 Under what circumstances can the deadline be changed?
2 What action would lead to cancellation of the contract?
3 What would happen if the work was completed two and a half weeks late?
4 Where are the details of how much money the client will pay?

5 Find words or phrases in the contract with the same meaning 1–6.

1 chosen 2 earlier in time 3 unexpected 4 specified 5 break 6 compliance

6 Write generic definitions for these terms in the contract.

Example: *1 'The Work' refers to the goods and / or services that will be supplied and / or carried out by the Contractor for the Client.*
2 'The Location' is the site or building where . . .

1 the Work
2 the Location
3 the Client
4 the Contractor
5 the Contract Price

LANGUAGE » Language commonly used when discussing and reading contracts

Conditions	*We will reduce the price* ***provided (that) / on condition that / as long as / so long as / with the proviso that*** *they pay on time.*
Circumstances	***In the event that*** *the factory* ***closes****, the deadline can be changed.* ***In case of / In the event of*** *factory* ***closure****, the deadline can be changed.*
Precautions	*We need to take out insurance* ***in case*** *the factory burns down.*
Regardless of circumstances	***Even if*** *there is a transport strike, the goods must be delivered by the deadline.*
Alternatives	*This offer must be accepted within 14 days;* ***otherwise (= if not)****, the offer will be withdrawn.*
Formal writing	***Should*** *the client* ***fail*** *to pay the balance within 30 days (=* ***If*** *the client* ***fails*** *to pay . . .), there will be a penalty of . . .*

7 Complete these sentences, using each word or phrase once only.

even if   otherwise   provided that   in the event of   as long as   in case

1 I would be happy to take on this new project ________ you agree to raise my salary.
2 The new factory extension must be opened by the end of the year ________ the building is not a hundred per cent complete.
3 The staff have been instructed and drilled in safety procedures ________ fire or other emergency.
4 We need to look for another one or two potential suppliers for these essential goods ________ our current supplier goes bankrupt.
5 The balance of the money you owe us must be paid within one week. ________, we will begin legal action against you.
6 You can make changes to the contract ________ you contact the other party and get their agreement to the changes.

SCANNING » 8 Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to find the meanings of these terms used in contracts.

a) aforementioned   b) notwithstanding   c) hereinafter

WRITING » 9 Write the follow-up memo from the Widgett director to the head of the legal team, confirming the six conditions in the phone call in 2. Add the following conditions.

1 pay Cygmar expenses – condition: must be reasonable, submit receipts
2 pay balance within 30 days of completion – condition: full test of system completed

Begin: *As promised in our phone discussion yesterday, here are the main terms and conditions that I have agreed with Cygmar. Could you turn them into a draft contract for me to look at next week?*
1. Widgett will only pay Cygmar in full on condition . . .

10 Testing

1 Plans

START HERE » **1** **Discuss in pairs. What do you know about methods for making buildings earthquake-proof?**

READING » **2** **Read the article and answer these questions.**

1 What are the long-term aims of the project?
2 What are the immediate objectives of the experiment?
3 How will the force of a powerful earthquake be simulated?
4 What will it mean for the experiment if the building is destroyed?

BUILT TO COLLAPSE

THE TEAM OF ENGINEERS at the Copestone research project would not be worried or even surprised if their new building collapsed under the force of a powerful simulated earthquake. [A]

They have constructed a 150-square-metre, 36,000-kilo, wood-frame, mid-rise experimental building, which they plan to attach to the top of a massive piston-powered shake table. Before the shake begins, the building will be fitted with 240 displacement, strain and acceleration sensors and 50 LED light markers to allow optical monitoring via motion-recording video cameras. [B]

Once secured to the shake table, the building will be subjected to a series of three incrementally-increasing seismic simulations, starting with magnitude 6.7, then 7.1 and finally 7.5. Between tests, no repairs will be carried out to any damage to the building. [C]

The output from the sensor and video data will later be sent for post-test analysis of any displacement and deformation. In addition, visual inspections will assess degree and type of damage. [D]

The building is fitted with seismic dampers, each one about 44 centimetres long and 7.6 centimetres thick, attached to the base of triangular steel frames embedded within the walls of the house. Each fluid-filled damper is capable of absorbing kinetic energy, converting it into heat up to 93 °C and dissipating up to 6,800 kilos of force. [E]

The engineers expect the dampers to absorb much of the energy from the movement of the house, but

An earthquake simulation at the University of California San Diego. This shake table was upgraded in 2021. The table now shakes with six degrees of freedom.

they don't know yet whether this would be enough to protect it from damage, as they hope. The team fully accepts that it could suffer significant damage and could even collapse completely. It is, after all, a destructive test. However, even a total collapse would provide useful data. [F]

The project team have a clear purpose in running this three-test experiment. They hope that the tests will yield significant data about how well the seismic dampers cushion the effects of the three simulated earthquakes on the building. [G]

If successful, the experiment could change the way wood-frame buildings are designed and built in earthquake zones. The experiment is part of a long-running engineering project to design economical easy-to-build wood-frame houses that can withstand powerful earthquakes. [H]

3 **Which paragraphs (A–H) in the article deal mainly with these topics?**

1 the experimental setup, or preparations prior to the test (2 paras) ___ ___
2 the procedure that will be followed during the test (1 para) ___
3 the data that will be studied following the test (1 para) ___
4 the likely effects, or results, of the test on the building (2 paras) ___ ___

4 **Work in pairs. Decide on the best seven headings for the report that will be written about the completed test and its results. Put the headings in the best order.**

Examples: *1 Introduction (or Background) 2 Test objectives*

LANGUAGE »

Concise technical writing

Phrase becoming hyphenated attributive adjective:

- The building, with an area of 150 square metres, is made of wood.

➔ The 150-square-metre building is made of wood.

- The beams are made of concrete reinforced with steel.

➔ The beams are made of steel-reinforced concrete.

Clause becoming noun as attributive adjective:

- There are 240 sensors which measure displacement.

➔ There are 240 displacement sensors.

5 **Complete the boxes below.**

(building) which has an area of 150 square metres

(dampers) which (3) ______

(building) which has a (1) ______ which is made of (2) ______

(building) which contains

(dampers) which are attached

The 150-square-metre, experimental wood-frame building, containing 44-centimetre-long fluid-filled dampers attached to triangular steel frames embedded within its walls, will be attached to a massive piston-powered shake table.

(frames) which (4) ______ within its walls

(shake table) which is (5) ______

(dampers) which (6) ______

6 **Use the descriptions in the boxes to complete the sentence below.**

(simulations) which increase incrementally

(simulations) of earthquakes

(cameras) which are sensitive to LEDs

(sensors) for measuring acceleration

(building) used for the test

(cameras) which record motion

On the shake table, the building will be subjected to a series of (1) ______-______ (2) ______ simulations recorded by (3) ______ sensors and several (4) ______-______, (5) ______ -______ video cameras situated around the outside of the (6) ______ building.

a 150-square-metre, wood-frame building a 36,000-kilogram, mid-rise experimental building a piston-powered shake table motion-recording video cameras incrementally-increasing seismic simulations 44-centimetre-long fluid-filled dampers

10.1

WRITING »

7 **Make the following text more concise, using ideas from the language box above. Reduce the paragraph by more than 50%, retaining all the key information.**

Begin: *Earthquake simulations take place at a special large-scale 3D testing facility …*

Simulations of earthquakes take place at a special facility. The facility does tests. It operates on a large scale. It operates in three dimensions (3D). It has a shake table. The table is operated by pistons. It measures 20 by 17 metres. It can support heavy buildings. The buildings can weigh 1.2 million kilograms. The buildings are secured on the table. People use anchor rods to secure the table. The rods are inserted through holes in the table. The pistons in the shake table are programmed. The program will subject the building to a test. The test is seismic. The test simulates earthquakes. The earthquakes have a magnitude of 8.0.

START HERE » **1** **Discuss in pairs. Why might the wall in Fig. 2 resist an earthquake better than the one in Fig. 1?**

Fig. 1
Normal wall

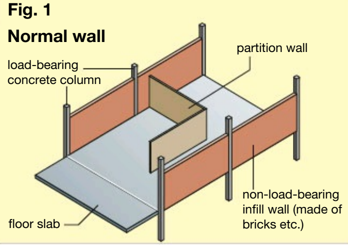
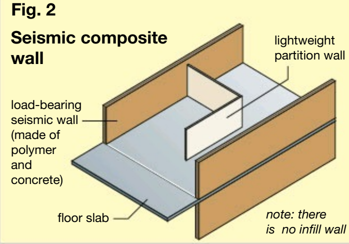


Fig. 2
Seismic composite wall



READING » 2 **Give each section A–H of this report a heading from the box. Then put the sections in the best order.**

Further testing	Procedure	Experimental setup	Test objective	Appendix
Introduction	Conclusions	Results		

A ________ The walls were subjected to push-over tests. First, they were placed side by side and attached to a rigid metal base. They were then pushed sideways, in opposite directions by two 100-tonne jacks. This test simulated the lateral forces acting on shear walls during an earthquake. After the tests, the walls were visually inspected. ☐

B ________ The test was prepared by fabricating two large 2.8-by-3-metre walls, using the composite seismic wall system. One wall was reinforced and the other was unreinforced. Several motion sensors were then attached to the walls and the base to measure wall displacement. In addition, a computer model of the effects of a 7.3-magnitude earthquake on a seven-storey building was produced so that the correct force could be applied to the samples. ☐

C Introduction If load-bearing walls can remain standing after a severe earthquake, deaths and property damage can be minimised. To meet this need, a composite seismic wall has been designed consisting of a polymer outer skin filled with concrete. The result is a ductile, non-brittle polymer-concrete composite which is designed not to collapse even if the concrete inside is fractured.
At the request of the designers, we were engaged to test the composite seismic wall system for use in earthquake zones. This document is the report of the test, which was carried out in April this year. ☐

D ________ The maximum capacity of the reinforced wall will be determined by future tests on the shake table, where it will be subjected to magnitudes up to 8. ☐

E ________ Table 1 (extract): Results of computer modelling

Earthquake simulation	Magnitude 7.3	Time: 7.58 sec
Maximum inter-storey drift demand (mm): L5 (5th storey) 5.18		

☐

F ________ It can be concluded that the unreinforced wall can resist 7.3-magnitude earthquakes without significant damage. ☐

G ________ The purpose of the test was to confirm the adequacy of the composite seismic wall system in resisting sideways forces during earthquakes of up to magnitude 7.3. ☐

H ________ Table 1 in the Appendix indicates that the maximum inter-storey drift demand in a seven-storey building in a 7.3-magnitude earthquake, as shown in our computer model, was 5.18 mm and occurred in the fifth storey. Following the test, no signs of damage were observed. ☐

TASK » **3** **Discuss in pairs. What caused this bridge to sway?**

CASE STUDIES IN STRUCTURAL ENGINEERING

Why did the bridge wobble?

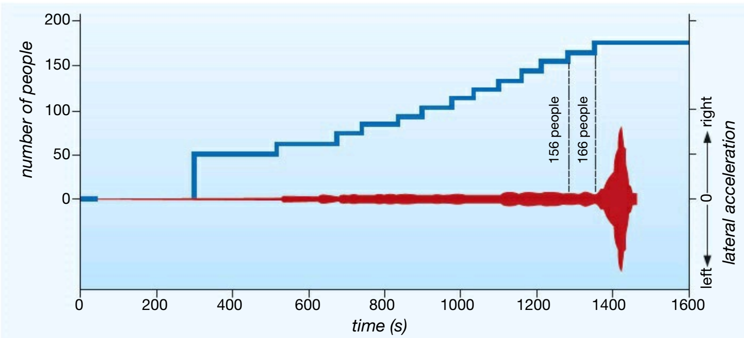
- London Millennium Footbridge opened to public
- when first people walked on it, bridge 'wobbled' from side to side
- people planted their feet wide apart, pushing out with each step
- people instinctively walked in step with bridge and with each other
- sideways movement of bridge increased up to 70 mm
- bridge closed immediately for series of tests

SCANNING » **4** **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete the information about the bridge.**

1 Design principle: ______ suspension
2 Bridge deck made of: ________
3 Original construction cost: £ ________
4 Length and width: ______ x ______ m

5 **This graph shows the result of one of the tests carried out on the bridge. Discuss these questions.**

What can you deduce about (1) the procedure, (2) the objective and (3) the main result of the test?



LISTENING » **6** 10.2 **Listen to this case study described by a consultant engineer about the test illustrated in the graph. Take notes using these headings. You will need your notes for the next exercise.**

Introduction	Experimental setup	Results
Test objective	Procedure	Conclusions

WRITING » **7** **You are the consultant engineer in 6. Use your notes to help you write your report on the test carried out on the bridge. Make your report as concise as possible.**

3 Methods

START HERE » **1 Discuss these questions in pairs.**

1 What do you know about non-destructive testing?
2 Why is it sometimes necessary to test materials non-destructively?
3 Can you think of any non-destructive testing methods?

TASK » **2 Work in small groups (maximum five members). Prepare for a meeting to discuss the agenda below. Divide up the tasks. Read the appendix to the agenda below and scan all the factsheets on the opposite page. Then study your own factsheet in depth.**

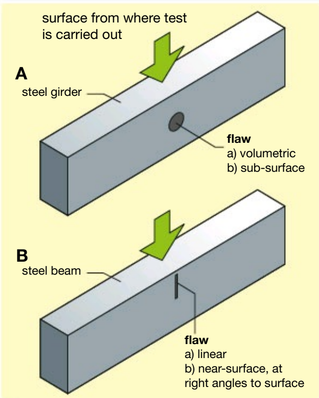
Students A, B, C and D: You are specialists (respectively) in the four types of non-destructive testing. Scan all the factsheets on the opposite page and then study your own in depth so that you can talk about it at the meeting.

Student E: You are the manager of the bridge and high-rise projects and you will chair the meeting. Scan all the factsheets on the opposite page and study the language tips for chairpersons on page 116.

MEETING AGENDA

1 **Non-destructive testing (NDT) for two projects**

1.1 Overview of four methods by NDT specialists (principles, uses, advantages, disadvantages)
1.2 Bridge project: decision on best NDT method (see Appendix)
1.3 High-rise project: decision on best NDT method (see Appendix)



APPENDIX TO AGENDA

Project 1: Steel girders in a bridge
It may be difficult to gain access to some surfaces of the girders for attaching probes, placing film and so on; speed is necessary as there may be several affected girders; cost may be an issue if many checks are needed. Expected flaws: see Fig. A.

Project 2: Steel beams in a high-rise building
Although it is possible to get access to most surfaces for attaching magnets, transducers, films and so on, it may be difficult for a human to get close to some surfaces for visual inspection; speed is necessary as there may be several affected girders; cost may be an issue if many checks are needed. Expected flaws: see Fig. B.

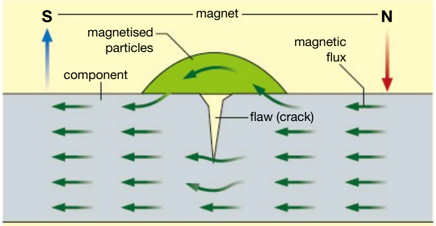
3 Conduct the meeting. Discuss the items on the agenda and reach decisions for items 1.2 and 1.3. Take notes when you are not speaking.

4 In discussion with your group, complete and amend your notes to include what you said at the meeting. You will need a complete set of notes for the next task.

WRITING » **5 Work individually. Write a report of the meeting, summarising the main points.**

MAGNETIC PARTICLE TESTING

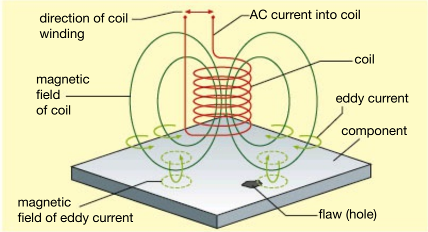
HOW IT WORKS
1 magnet creates magnetic field in component
2 flux cannot pass through flaw
3 flux forced outside component
4 flux attracts magnetic particles (e.g. iron filings) above crack
5 inspector can see visible evidence of flaw



FEATURES
- can be used for inspecting only ferromagnetic materials
- detects flaws (e.g. cracks and holes) on or near surface only
- magnet must be able to contact the surface above the flaw
- inspector has to be able to see the surface above the flaw
- difficult to detect linear flaws which are parallel to flux

EDDY CURRENT TESTING

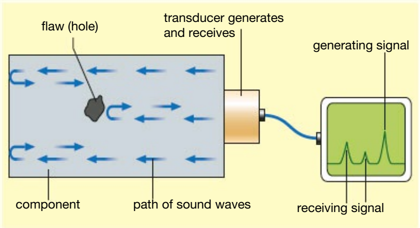
HOW IT WORKS
1 current (AC) magnetises coil
2 coil induces eddy current in component
3 eddy current produces its own magnetic field
4 flaw in material alters eddy current magnetic field
5 flaw detected by analysis of eddy current's field



FEATURES
- detects surface and near-surface flaws
- does not penetrate very deeply into material
- detects flaws in conductive materials only
- test probe (coil) does not need to contact the surface
- hard to detect linear flaw parallel to direction of coil winding

ULTRASONIC TESTING

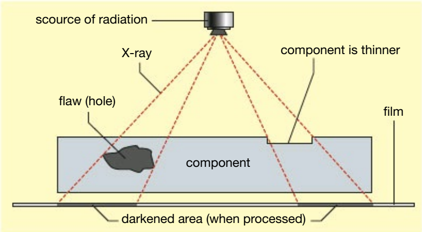
HOW IT WORKS
1 transducer transmits and receives high frequency sound waves
2 amount of energy transmitted and received is analysed
3 times of transmission and reception are analysed
4 waves travel through material, reflected by flaw
5 reflected sound wave indicates location of flaw



FEATURES
- can be used with any material, not just metals
- can locate flaws on, near or below the surface
- not only detects the presence of a flaw, but also its location
- transducer needs to touch one surface of the component
- hard to detect linear flaws parallel to the sound waves

RADIOGRAPHIC TESTING

HOW IT WORKS
1 X-rays used to produce images of objects
2 component placed between radiation source and film
3 density of material affects amount of radiation reaching film
4 variation in radiation produces image of insides of component



FEATURES
- can detect flaws at all depths
- can locate flaw and measure its dimensions
- can be used to inspect virtually all types of material
- operator needs access to top and bottom surfaces of component
- difficult to detect linear flaws which are parallel to X-ray beam

Review Unit E

1 **Complete these sentences. Use the words and phrases in the box once only. Two of the words / phrases are not needed.**

propose that recommend submitted proposals to recommend that you should suggestion that propose put forward a proposal proposal

1 Our technicians ______ supplying your factory with a wireless system.
2 The contractors have ______ for providing a mesh network for the system.
3 Our consultants ______ specifying the IEEE 802.15.4 standard for the network.
4 Our legal team ______ a five-year warranty should be added to the contract.
5 We ______ install heat and smoke detectors throughout your factory.
6 The sales team have ______ overhaul all the motion sensors in our workshops.

NATIONAL POWER GRIDS SHUT DOWN BY CYBER ATTACK

Huge iceberg breaks off Antarctic shelf

EVERY SQUARE KM OF OCEAN HAS 18,000 PIECES OF FLOATING PLASTIC, SAYS UN

Energy and construction costs of Olympic Games soar again

WATER SHORTAGES INCREASE AS POPULATIONS GROW AND CLIMATE CHANGES

2 **Work in pairs. You both work in a problem-solving think-tank. Discuss three of these problems (left) and come up with at least two recommendations for each one. Then tell the class what steps you propose to take and how you recommend solving them.**

3 **Replace the words and phrases in the sentences below with the words and phrases in the box to give the same meaning. Use each word / phrase in the box once only.**

in case if not provided regardless of whether in the event should there be as long as

1 Full payment shall be made *on condition* that the work is completed.
2 We will send your goods by courier so that, *even if* there is a postal strike, you will receive your goods on time.
3 *If there are* any unforeseen manufacturing delays, we must inform our customers within 24 hours.
4 I'm interested in buying your company's products *with the proviso that* you agree to give us a small discount for volume sales.
5 *In case* of accidents or near-miss incidents at work, supervisors must report to management immediately. *Otherwise*, disciplinary action will be taken.
6 Full protective equipment must be worn when handling these containers *to guard against the possibility that* the chemicals leak out.

4 **Complete these sentences, using the correct form of the verbs in the box.**

go make keep put home cut draw follow

1 I would strongly recommend keeping an eye on your energy costs in case they rise too much.
2 We look forward to hearing your proposals for ______ down on carbon emissions.
3 I suggest that you ______ up your phone discussion with your client by ______ forward a formal proposal immediately.
4 So how do you plan to ______ about ______ up the draft contract?
5 If unauthorised persons ______ their way into the factory, digital video cameras will ______ in on them automatically.

5 Read this text and answer the questions below.

Fig. 1

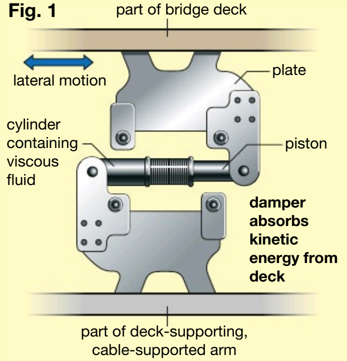
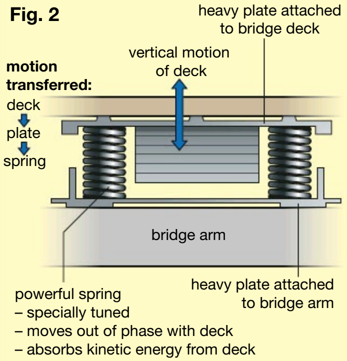


Fig. 2



Solution to London Millennium Footbridge problem

The bridge modification team initially came up with two proposals to reduce the chances of lateral motion. The first was major structural reinforcement in order to make the bridge more rigid. The second was pedestrian volume reduction in which the team recommended installing barriers at key locations along the bridge.

Both were rejected since the modifications would result in major changes in either the bridge's appearance or its usefulness. In response to this, the team submitted a third proposal for inserting dampers between the deck and its supports, explaining that shock-absorbing dampers are commonly used in bridges and buildings around the world, especially in seismic zones. This was accepted, with the proviso that the dampers should not be visible to the general public as they would not be very attractive.

The team decided to use two types, as shown in the illustrations: viscous dampers and tuned mass dampers, both of which were placed at various points between the deck's lower surface and the deck-supporting, cable-supported arms. The viscous dampers, which function in a way similar to a car's shock absorbers, were installed beneath the deck and around the piers to control lateral motion. The tuned mass dampers, which in everyday language can be thought of as weights on springs, were fitted below the deck to absorb any vertical movement.

1 Identify what these words or phrases refer to: (a) The second (line 4), (b) Both (line 7), (c) this (line 9), (d) its (line 10), (e) This (line 13), (f) they (line 15), (g) types (line 16), (h) both of which (line 17–18)
2 Which of the three proposals aimed to (a) limit access and use of the bridge, (b) dissipate the kinetic energy of the bridge deck, and (c) strengthen the bridge and make it more rigid?
3 What condition was stipulated before the final proposal was accepted?
4 Give a caption to Figs. 1 and 2 to identify the type of damper in each one.
5 Look at paragraph 3 (first sentence) and underline the correct alternatives in this sentence: The cables *support / are supported by* the arms, which *support / are supported by* the deck.
6 How does the writer help the non-technical reader understand how the viscous and tuned mass dampers work?

6 Write the following, using data from the text and illustrations in 5.

1 (a) The body of a short email from the bridge modification team to the project director, submitting the first two proposals.
(b) The body of a second email from the team to the director, referring to the rejection of the first two proposals and submitting the third one.
2 Definitions of a *viscous damper* and a *tuned mass damper*.
3 An explanation of how both types of damper work in the bridge. Refer to Figs. 1 and 2.

7 **Rearrange the notes and use linking devices to form definitions consisting of one sentence. Start with the words in italics.**

Example: *1 A hydraulic damper is a device consisting of a piston and a fluid-filled chamber, which decreases the damage to a building in an earthquake by converting seismic energy into heat.*

1 it's a device / *A hydraulic damper* / it decreases damage to a building in an earthquake / it consists of a piston, a fluid-filled chamber / it converts seismic energy into heat
2 it's a radio technology / it enables communications between networked devices / *Bluetooth* / people use it over short distances / it operates in the 2.4 GHz band
3 it subjects a building to controlled mechanical vibrations / it consists of a rectangular platform / it's a machine / hydraulic actuators drive it / it simulates an earthquake / *A shake table*
4 it uses high-frequency radio waves instead of wires / *A WLAN* / it transmits and receives data over short distances / it's a type of local-area network
5 it allows data transfer rates of 10 Gbps / or 'USB-C' / it is supported by all the main PC manufacturers / it's an industry-standard connector / *USB Type-C* / it transmits both data and power on a single cable

8 **Complete the more concise versions of these descriptions to give the same meaning.**

The walls, which measured 3.2 metres by 4 metres, were pushed sideways by two jacks which weighed 98 tonnes.	The (1) 3.2-metre-by-4-metre walls were pushed sideways by two (2) ______-______ jacks.
A building consisting of ten storeys was fixed to a table that simulates earthquakes and subjected to a shake of 7.3 magnitude.	A (3) ______-______ building was fixed to an (4) ______-______ table and subjected to a (5) ______-______ shake.
These walls, which bear loads and resist earthquakes, are made of concrete which has been reinforced by polymer.	These (6) ______-______, (7) ______-______ walls are made of (8) ______-______ concrete.
The frame of the building, which has an area of 200 square metres and rises to a low height, is a structure that is made of concrete which has been reinforced by steel.	The frame of the (9) ______-______-______, (10) ______-______ building is a (11) ______-______ ______ structure.

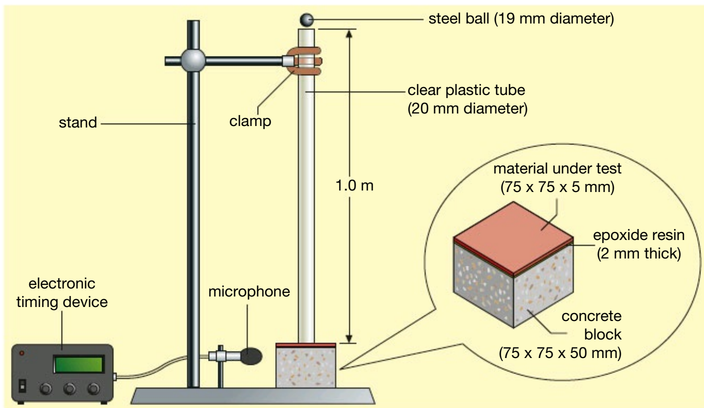
9 **Rewrite these items in the form noun + noun, using the words in italics, changing any verbs into related nouns.**

1 a *sensor* which detects when someone has intruded into a property = a(n) intrusion sensor
2 the *procedure* which is followed when carrying out a test = the ______ ______
3 a device that can *detect* the presence of *moisture* = a(n) ______ ______
4 a special sensor that can *gauge*, or measure, the degree of *strain* on a structure = a(n) ______ ______
5 the *date* when a project or activity will *commence*, or begin = the ______ ______
6 the *price* which will be paid for completing the work described in the *contract* = the ______ ______

10 **You have been asked to test a new polymer and have carried out the test. Write the test report, based on the notes below. Use these headings.**

Introduction   Test objective   Definition   Experimental setup   Procedure   Results   Conclusions   Further testing   Appendix

MATERIAL TESTED – a prototype plastic 'QS54', manufactured by Fortis Sports Inc
PROPERTY TESTED FOR – ability to absorb energy from impact
REASON FOR TEST – requested by manufacturers
PLANNED USE OF MATERIAL – impact-absorbent mats for martial arts (e.g. judo)
AIM OF TEST – find coefficient of restitution (CR) of QS54
DEFINE 'CR' – it's a measurement – energy-absorbent capability of material – drop steel ball onto it – measure height of bounce
PREPARATION FOR TEST



EQUATION: e (coefficient of restitution) = $\sqrt{(h_2 / h_1)}$. Note: h_1 (height of drop) = 100 cm; h_2 (height of rebound in cm) = $122.6T^2$; T = time in secs between first and second impact; CR: 1 = totally elastic; 0 = totally non-elastic (no bounce)
TEST METHOD: clamp tube over centre of material / hold ball, release, drop / microphone – time (T) between bounces / record T / calculate CR (use equation) / material – inspect surface for cracks, etc. / repeat test x 10
WHAT WE FOUND: CR of QS54 = 0.6 (average of ten tests); no cracks or indentations
THEREFORE ...? good energy absorbency – highly suitable for purpose
FUTURE TESTS? impact resistant? slip-proof? fire-retardant?

PROJECT » **11** **Choose one of the following projects and write it up.**

1 Research a test carried out on a piece of equipment or system important in your industry. Write a summary of the test using headings from the box in 10.
2 Design your own test for a piece of equipment, a machine or a system important in your industry. Write a plan for the test. If you are able to carry out the test, write the report.

12 **Prepare a slide presentation of your project and present it to your class or group.**

11 Accidents

1 Investigations

START HERE »

1 **Work in pairs. Study this photograph of a hydroelectric power station, where a serious accident occurred (in the location circled in white). Discuss what happened and where it happened by referring to the three diagrams on the opposite page.**

SCANNING »

2 **Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to complete the data in the notes below.**

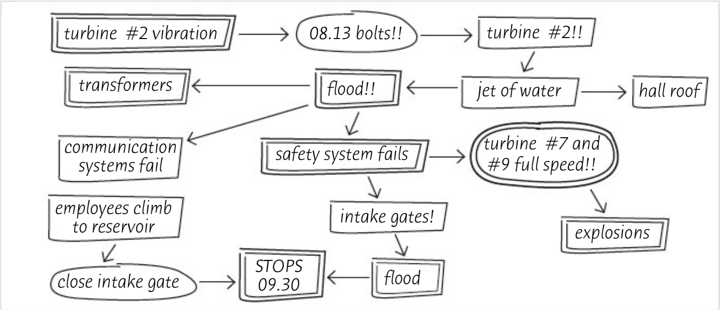
The Accident in Numbers

(1)	____________	weight of each turbine	(4)	____________	population supplied with electricity
(2)	____________	speed of water shooting up to roof of hall		80 storeys	height of dam
	276m litres	extent of flooding		5012 m^3	debris caused by the accident
(3)	____________	length of penstock	(5)	____________	maximum speed of turbines
	6,400 MW	power generated by power station		290 m	total length of turbine hall

TASK »

3 **Work in small groups. The diagrams, notes and cuttings on this and the opposite page belong to a journalist who is assembling data for a report on the accident. Discuss the material and reach agreement on the three questions below.**

1 What happened and in what order? Make notes of the sequence of events referring to the journalist's flow chart below.
2 What caused the accident? Make notes of the known and probable causes.
3 What action(s) could have prevented the accident? What could prevent a repetition of such accidents in the future? Note down some ideas.



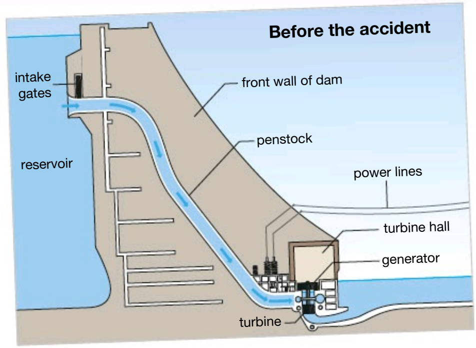
4 **With your group, meet up with another group and compare your notes. Refine them in the light of your meeting. Keep your notes for use on page 87.**

Overview
- Sayano-Shushenskaya HEP station
- Siberia, Russia, 2,000 miles E of Moscow
- major accident 17 August 2009 destroys part of turbine hall
- explosions, flooding, 3 turbines destroyed, 7 damaged, huge oil spill
- 75 deaths, 14 rescued from debris, many injuries

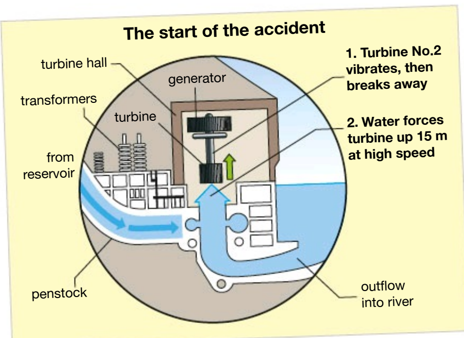
Old news report from the 1980s?

The new automated safety system has been installed to prevent damage in case of flooding. If the turbine hall floods, the system will automatically shut down the turbines to stop them operating under water. This will prevent short circuits and explosions. The system will also close the intake gates to the penstock.

system faulty? or just flooded?

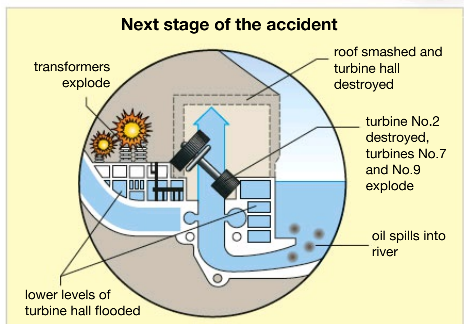


Must interview these people
- technicians – probably knew Turbine 2 wasn't ready for use on 16th
- managers – probably didn't install 2nd safety system as backup
- workers – possibly recorded incidents on mobile phone cameras



Extract from report by search team

Found in debris of accident: 49 large bolts (that secured Turbine 2 to supports in floor of turbine hall). 41 of them contain cracks (metal fatigue); eight have cracks in > 90% of width.



Background – before Aug 17
- Turbine 2 taken offline for repairs (vibrations)
- Turbine 2 offline several months during repairs
- sudden demand for more energy on Aug 16
- Turbine 2 put back online Aug 16 (repairs not complete?)
- still vibrating excessively night of Aug 16

From interview with maintenance technicians
normal service life of turbines: 30 years BUT age of Turbine 2 on 17/8/09: 29 years, 10 months!! (but past use-by date?)

Safety chief resigns after report leak

Report blames faulty brakes

Birds bring down plane, report claims

START HERE » **1** **Discuss in pairs. Why are investigative reports important? Describe an investigation in your industry or technical field, or in any area. What was the outcome?**

READING » **2** **Read this abstract (or summary) section of an investigative report and match the sentences A–F with these report headings.**

Method ☐ Background ☐ Introduction ☐
Conclusions ☐ Recommendations ☐ Findings ☐

ABSTRACT

This report presents and analyses the preliminary findings of our investigation into the disappearance of the XJ1 private aircraft last month (A). After making radio contact for the last time, the aircraft completely disappeared, resulting in an extensive air–sea search, followed by an investigation by our team (B).

The investigative procedure included an examination of debris from the ocean and of in-flight communications prior to the final radio contact (C).

The main physical evidence was a section of buckled fuselage, which after analysis was found to have buckled upwards (D).

From this evidence, the investigators have been able to determine that the fuselage probably hit the water in one piece at high speed, which rules out the possibility of explosion or mid-air break-up (E).

The report proposes that a search should continue for the flight recorder, which has not yet been recovered from the ocean (F).

3 **Where do these sentences belong in an investigative report? Write a heading from 2 after each one. Headings may be used more than once.**

1 The smoke sensors, which were found during the investigation to be faulty, should be replaced without delay and the manufacturers ought to be contacted for a refund under the warranty. ______________________
2 From the detailed results of the tests and the analysis of the other findings, it was concluded that the introduction of contaminated fluids into the main chamber and the poor filtration method were the most likely cause of the accident. ______________________
3 The purpose of this report is to present the findings and conclusions of the investigation into the warehouse fire in January this year. It also recommends some improvements which should be made to the fire prevention equipment. ______________________
4 Analysis of video footage of the accident, confirmed by interviews with staff, indicates that at 05.23, immediately before the fire started, there was a small explosion near the entrance of the storage area. ______________________
5 In the view of the investigators, a serious mistake was made by the supervisors, who should have ensured a safer method for insulating the electrical equipment. If that had been done, there would probably have been no fatalities or serious injuries. ______________________
6 To ensure the accuracy of their findings and conclusions, the investigating team interviewed a large cross-section of the workforce about the incident and listened to over 80 minutes of mobile phone recordings. In addition, managers were asked to suggest recommendations. ______________________

LANGUAGE »

4 Make six concise statements about the Sayano-Shushenskaya accident. Use numbers and units from the 'Accident in Numbers' information on page 84.

Examples: *The 1,360-tonne Turbine 2 broke away from its housing. A 256,000-litre-per-second jet of water shot up to the roof.*

5 Make six speculations about the accident. Use *must have, can't have*, *may have* or *might have*.

Examples: *Turbine 2 must have been put back online before it was fully repaired. Turbine 2 can't have been ready for use on the night of the 16th. Turbine 2 may have been past its use-by date.*

6 Make six criticisms about the accident, using *should* or *ought to* with a perfect infinitive.

Example: *The automated safety system should / ought to have stopped Turbines 7 and 9 from operating.*

Conditionals (third conditional)

*If they **had replaced** the turbine bolts,*	*the accident **would (probably) have been** avoided.*
*If the turbine bolts **had been replaced**,*	
*If turbine 2 **had not been used**,*	*the accident **would / might not have** happened.*

7 Make six statements about the accident, using the third conditional.

Example: *If the bolts on Turbine 2 had been checked and replaced regularly, the turbine would (probably) not / might not have broken away from its supports.*

WRITING »

8 Work in pairs. Sort your notes about the accident from 2 and 3 on page 84 under these report headings.

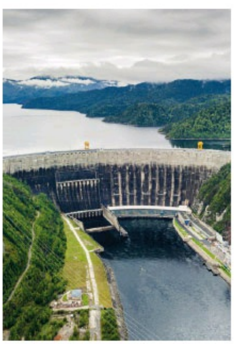
Introduction	Findings
Background	Conclusions
Method	Recommendations

Language
page 103 + page 104

9 Work individually. Write the investigative report of the accident at the Sayano-Shushenskaya hydroelectric power station. Follow these steps.

- Study different ways of linking clauses.
- Use your notes and all the data about the accident and the headings in 8 to write the main body of the report.
- Add an Attachments section, using ideas from pages 84 and 85, as well as your own ideas.
- Write the Abstract: use clause-linking and condensing techniques to reduce each section of the report (except for Attachments) to a single sentence that summarises its main point(s); the Abstract will therefore consist of six sentences.

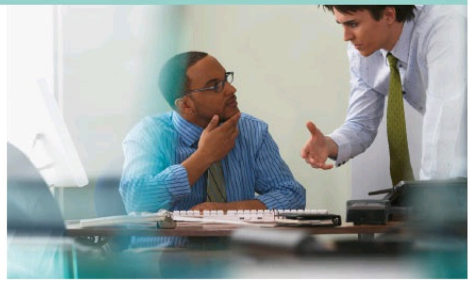
Note: Although the Abstract should be the last thing you write, put it at the beginning of the report.



3 Communication

START HERE »

1 Discuss in pairs. In what circumstances might a junior employee tell a supervisor or manager that he or she is wrong? When and how might you do the same thing?



LISTENING »

2 Listen to three situations where an employee is communicating concerns to his / her senior officer or manager. Look at the information for each situation and decide how effectively the employee communicates his / her concerns.

11.1 **Situation 1**

A passenger plane is taking off. The co-pilot senses that the take-off speed is too slow. But the airspeed indicator is showing 80, the correct speed. And the pilot is the captain, her senior officer.

Note: This situation is fictitious, but based on a real fatal air crash in the 1980s. Ice in a sensor had caused a false reading on the airspeed indicator: the speed on the indicator was higher than the real speed of the aircraft. The pilot didn't apply enough power for take off and the aircraft crashed. Commercial aircraft today have pitot tube heaters to protect the sensor from ice.

11.2 **Situation 2**

This situation begins in the same way as situation 1, but has a different outcome.

11.3 **Situation 3**

In the turbine hall of a hydroelectric power plant, a senior technician senses that the turbine is vibrating in a dangerous manner. But his supervisor has instructions to increase the turbine speed.

3 11.2 11.3 Read these communication guidelines. Then listen to audio 11.2 and 11.3 again and tick when you hear each guideline being followed.

Communicating your concerns in a crisis	Co-pilot	Technician
1 Get the other person's attention (e.g. *Hey, Chief!*)	☐	☐
2 Signal your concern (e.g. *There's a problem.*)	☐	☐
3 State the problem directly* (e.g. *The fire is spreading.*)	☐	☐
4 If you don't succeed, try again more assertively**	☐	☐
5 Step back (e.g. *Let's stop and re-think for a moment.*)	☐	☐
6 Suggest a solution (e.g. *Let's put on breathing gear.*)	☐	☐
7 Obtain their agreement (e.g. *How does that sound?*)	☐	☐

* Refer to the problem (e.g. *The fire is spreading*), not to the person (e.g. *You haven't noticed that the fire is spreading*), which can sound too accusing and emotional.

** *Assertiveness* is a form of communication in which you state your needs or wishes clearly while showing respect for yourself and the other person.

SPEAKING »

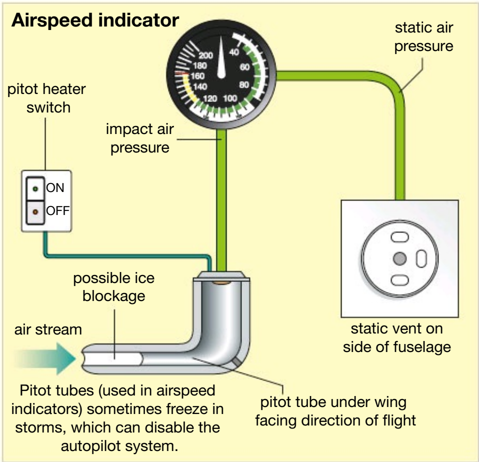
4 Study audio scripts 11.2 and 11.3 on page 127. Notice how the co-pilot and the senior technician follow the steps of the guidelines above.

5 Work in pairs. Prepare two similar crisis situations related to your industry or technical field. Role play the situations, taking turns to be higher / lower in the chain of command.

LISTENING » **6** **Study the photo and the diagram in 7. What do they tell you about why the aircraft may have crashed?**

- Flight 305, Nov 20th, 14.17
- makes final radio transmission
- enters high-altitude thunderstorm
- disappears

7 11.4 **Listen to a reporter interviewing an airline representative about the crash and complete the reporter's notes.**



Airline doesn't know what caused crash. But ...

Two theories
1
2

Evidence
1
2

Future changes
1

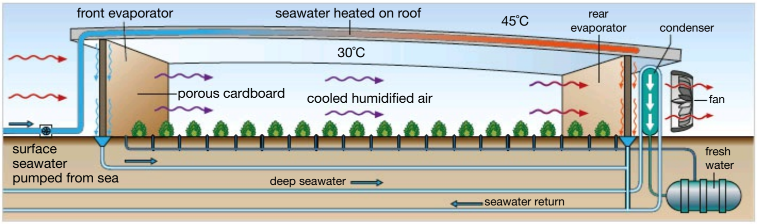
Attachment contains:

WRITING » **8** **Write the abstract (150–200 words) of the report on the crash of the airliner. Add a short attachment explaining in everyday language how the airspeed indicator works and how ice under the wing can cause problems.**

12 Evaluation

1 Projects

START HERE » **1** **Work in small groups. Briefly discuss how the Desert Water system works.**



READING » **2** **Put these paragraphs in the correct order and check your ideas in 1.**

A The air heats up as it travels across the greenhouse, until it reaches the rear evaporator. Here, having been heated by the sun, more seawater trickles down the cardboard evaporator, saturating or filling up the air with water vapour.

B Having been pumped to the top of the greenhouse, the seawater trickles down the cardboard of the front evaporator and evaporates, cooling and humidifying the air inside the greenhouse.

C The warm super-saturated air then passes through the condenser, where the vapour condenses into fresh water, which flows down to an underground tank that stores it until it is needed.

D Seawater is pumped to the greenhouse roof above the front evaporator and the wind blows through the greenhouse, assisted by a simple fan.

E The technology used in a seawater greenhouse consists of two simple evaporators made of cardboard and a basic condenser.

LANGUAGE » **Linking (perfect participial phrase + present participial phrase)**

Having been pumped to the top of the greenhouse,	earlier event
the seawater trickles down the cardboard and evaporates,	main event
cooling and humidifying the air inside the greenhouse.	later event

The earlier event uses a perfect participle and the later event uses a present participle.

3 **Link each group of sentences into a single sentence. Use participles as above, plus linkers such as *which* / *that* and *before* / *after*.**

1 The air is cooled and humidified by seawater. The seawater trickles down the front evaporator. Then the air travels across the greenhouse. It becomes warmer. Then it reaches the rear evaporator.

2 Seawater is heated by the sun on the greenhouse roof. Then the seawater trickles down the rear evaporator. Then it evaporates. This heats and humidifies the air that passes through it to the condenser.

3 The water vapour reaches the cold seawater pipes of the condenser. Then it condenses. It forms drops of fresh water. The drops trickle down the pipes. Then the drops flow into an underground storage tank.

LISTENING »

4 12.1 **Listen to the presentation and answer these questions.**

1 What was the objective of the pilot project when it was first set up?
2 To what extent was the project successful?

5 12.1 **Listen again and take notes.**

Project: Desert Water

Criteria: 1 ______________________
2 ______________________
3 ______________________
4 ______________________

Evaluation: 1 ______________________
2 ______________________
3 ______________________
4 ______________________

Overall: ______________________

criteria is a plural noun
the singular is *criterion*

LANGUAGE »

Necessity in the past

- **necessary:** *They* ***had to*** *do it. It* ***had to be*** / ***needed to be done****. They* ***were obliged*** / ***required to*** *do it.* ***It was necessary*** / ***essential (for them) to*** *do it.*
- **unnecessary:** *They* ***didn't have to*** / ***need to*** *do it.* ***There was no need*** / ***necessity (for them) to*** *do it.* ***It was not necessary*** / ***essential (for them) to*** *do it.*
- **necessary to act (but didn't act):** *They* ***were supposed to*** *follow the rules* (implied: *They should have followed the rules, but they didn't*). Compare this with *They* ***had to*** *follow the rules* (implied: *... and they did*).
- **necessary not to act (but acted):** *They* ***weren't supposed to*** *break the rules* (implied: *They shouldn't have broken the rules, but they did.*)

6 **Rewrite these sentences to give the same meaning, using the words in brackets, but not the ones in italics.**

Example: *1 It was essential (for us) to make the system as simple as possible.*

1 We *had* to make the system as simple as possible. (essential)
2 The system *needed* to use minimal power. (have to)
3 We were not *obliged* to rely on electricity from the grid. (need)
4 We were not *supposed* to use nutrients bought from outside. (should)
5 A generator *had* to be used for the pumps and the fans. (obliged)
6 We didn't *have* to use any fresh water from outside the system. (no need)

WRITING »

7 **Write a concise evaluation report on the Desert Water pilot project, using these headings. Use language from the language boxes above and on the opposite page where appropriate.**

Introduction (outlining the aim and content of the report)
Project objective (as it was at the beginning of the project)
Technology (a concise summary in one or two sentences of how the greenhouse works)
Criteria (the four requirements that had to be met for project to be successful)
Evaluation (of the project according to each criterion in turn)
Conclusion (overall judgement of the success – or otherwise – of the project)

2 Performance

START HERE »

1 **Assess your performance on this course over the last few weeks or months. Give a score from 1 (considerable scope for improvement) to 5 (excellent in every way) for each of the criteria in the table.**

A Knowledge of English ☐
B Skill in using English ☐
C Participation in class ☐
D Participation in groups and pairs ☐
E Effort ☐
F Achievement ☐
G Co-operation ☐
H Assertiveness ☐

2 **Work in pairs. Look at your partner's assessments. Do you agree with them? Why? / Why not?**

LISTENING »

3 12.2 **Listen to part of an appraisal interview at work and complete the line manager's notes 1–7.**

PRE-INTERVIEW SCORES:
E = by employee (self-score); **M** = by manager
SCORE:
1–3 = poor; 4–6 = satisfactory; 7–9 = good; 10 = excellent

Employee's targets for last year ↓	**Score →**	**E**	**M**
Target 1: *roll out new email software to all departments*		*8*	*6*
Put **Y** in box if target has been met **in full**; otherwise put **N**			*N*

1 Extent to which target (not) met? ***roll-out achieved for ___% of depts***
2 Reason for any non-achievement? ***problems with some department heads***
3 Expand on problems? ***no permission to*** ______________________
4 Attempts to solve problems? ______________________
5 Attempts successful? ______________________
6 Lessons learned? ***better to meet senior dept staff in small groups***
7 How to improve next time? ______________________

4 12.2 **Complete these extracts from the interview with the words in the box. Then listen again and check your answers.**

would	wouldn't	could	couldn't	should	shouldn't	have	had

1 And why ________ you reach the other 40%?
2 I reckon that I ________ ________ set up smaller meetings with senior staff in each department.
3 And I ________ ________ gone ahead with the inter-departmental meetings.
4 All right, so how ________ you go about doing things better next time?
5 Next time I think I ________ keep problems to myself. I ________ communicate more openly about them.
6 If I ________ spoken to you earlier, I ________ ________ come up with a solution.

LANGUAGE » **5** **Answer these questions about your performance on this course.**

1 If you could take the course again, is there anything you would do differently? What would you do? Why?
2 Is there anything that you should have done in this course, but didn't do? Why didn't you do it?
3 Is there anything that you did, which there was no need to do?
4 Was there anything that you were unable to do during the course, or anything you couldn't understand?
5 What were your targets in starting this course? To what extent have you met them?

VOCABULARY » **6** **Find the phrasal verbs 1–8 in audio script 12.2 on page 128 and check their context and meaning. Then match them with their synonyms a–h.**

1 hang on	a) continue with
2 get on with	b) attempt the task of
3 go about	c) wait a minute
4 turn out	d) obtain
5 get hold of	e) happen
6 go ahead with	f) have friendly relations with
7 come up	g) think of
8 come up with	h) end

SPEAKING » **7** **Work in pairs, A and B. Practise sections of an appraisal interview using these forms and notes. Take turns to be the manager and the employee. Prepare by reading audio script 12.2 on page 128.**

A

Target: *assess needs, order and install safety equipment for Rig X*	*7*	*5*
Put **Y** in box if target has been met **in full**; otherwise put **N**		*N*

A Extent to which target (not) met? *all equipment ordered, 50% installed*
B Reason for any non-achievement? *two suppliers (Y, Z) unable to deliver*
C Expand on problems? *Y went bankrupt, closed down; Z sent faulty goods*
D Attempts to solve problems? *put Y's order out to new tender; returned goods to Z and requested replacement*
E Attempts successful? *Y; yes, now ordering; Z: yes, but long delay in replacing*
F Lessons learned? *better checks on suppliers; if goods faulty, don't retain supplier*
G How to improve next time? *have plan B ready; allow extra month for problems*

B

Target: *design, construct, test and report on new robot*	*9*	*7*
Put **Y** in box if target has been met **in full**, otherwise put **N**		*N*

A Extent to which target (not) met? *test not complete, report not yet written*
B Reason for any non-achievement? *issues arising from test*
C Conclusions from test? *test showed robot design needed to be modified*
D Attempts to solve problems? *meeting to discuss test results, recalled design team, agreed on modifications, copied you in on decisions*
E Attempts successful? *some delay because designers on leave, modifications successful, new test now under way, report next month*
F Lessons learned? *check holiday schedule of design team, don't wait for all test results before acting*
G How to improve next time? *have contingency plan in case re-design necessary*

START HERE »

1 Work in pairs. What do you know about the nanoscale? Try this quiz.

1 The nanoscale measures dimensions between 1 and ______ nanometres.
A 10 B 100 C 1000

2 A nanometre is one ______ of a metre.
A thousandth B millionth C billionth

3 A sheet of paper is about ______ nanometres thick
A 100,000 B a million C a billion

4 A single gold atom is about a ______ nanometre in diameter.
A tenth of a B third of a C single

SCANNING »

2 Practise your speed reading. Look for the information you need on the SPEED SEARCH pages (117–118). Try to be first to find the answers to the questions in 1.

TASK »

3 Work in small groups (maximum four members). Divide up the work below and then work individually to find out about your technology.

Student A: Study Fig. 1 below and read about nanowires on page 111.
Student B: Study Fig. 2 on the opposite page and read about nanofluid cooling on page 112.
Student C: Study Fig. 3 on the opposite page and read about graphene on page 113.
Student D: Study Fig. 4 on the opposite page and read about smart dust on page 115.

4 Return to your group and meet to decide the following. Make notes of interesting arguments.

You are a team of engineers in a company researching a range of nanoscale technologies, including the four featured on this page. Decide which one of the four technologies to enter for the award described below.

NANO-NOMINATIONS

The Government announces an award of €5 million to the company researching 'the most promising nanoscale technology'. The winner will be chosen by an expert committee using the following criteria: range of potential applications and potential value to humanity.

SPEAKING »

5 Work with the whole class. The whole class is the expert committee choosing the winner of the award. Debate the issue and vote for the winner.

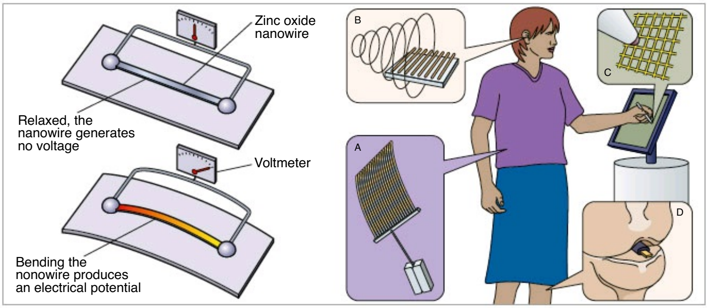


Fig. 1: Nanowires

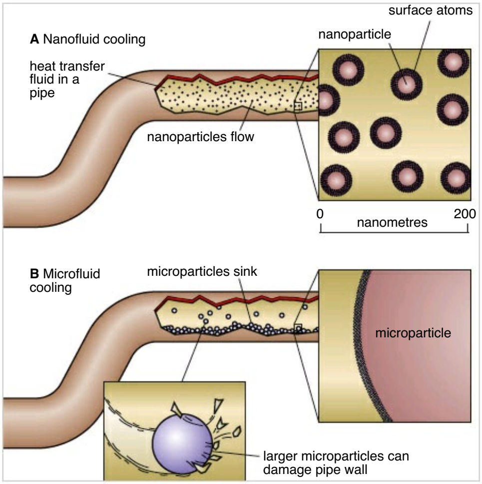


Fig. 2: Nanofluid cooling

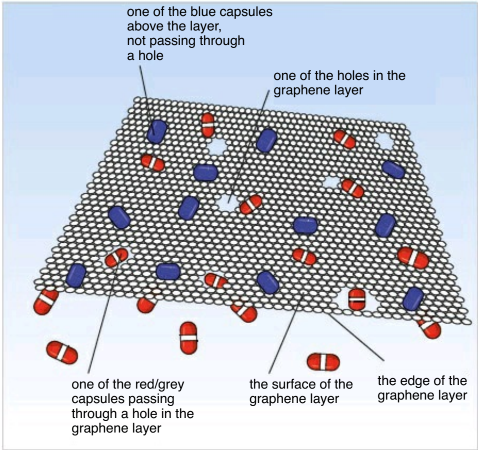


Fig. 3: Graphene filter for carbon capture

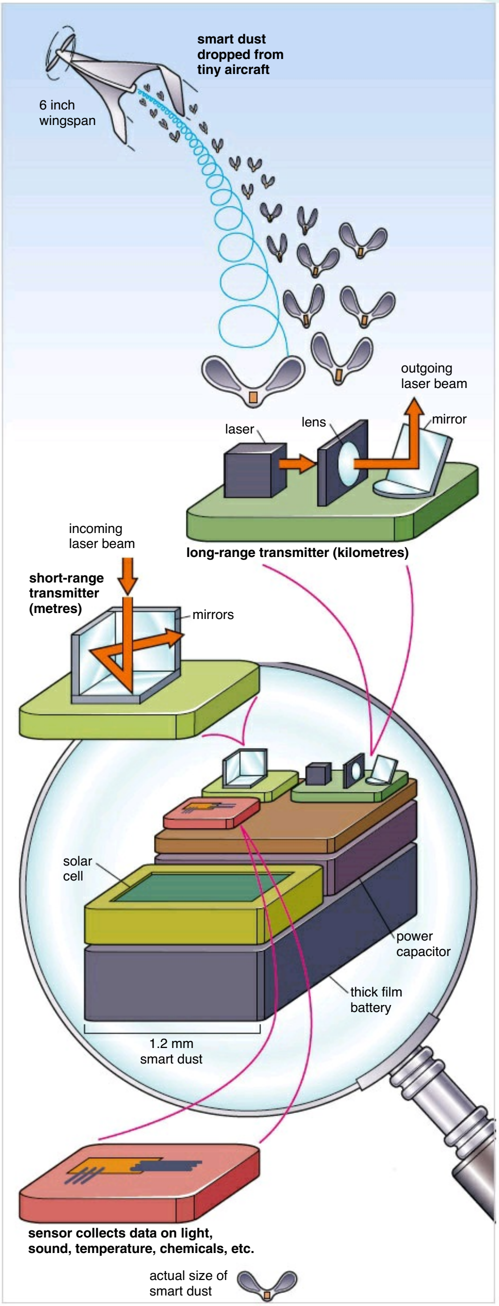


Fig. 4: Smart dust

Review Unit F

1 Reword these statements, using a modal verb + perfect infinitive to give a similar meaning. Use each modal in the box once and don't use the phrases in italics.

may	must	might not	could	can't	should	couldn't	ought not to

Example: *1 CCTV cameras may have recorded the events just before the accident.*

1 *It's possible that* CCTV cameras recorded the events just before the accident.
2 *It's virtually certain that* the explosion was not caused by an electrical fault.
3 *It was a mistake for* the supervisor not to hold a weekly fire drill.
4 *It would have been possible to* put out the fire more quickly if the fire alarm had worked.
5 *In my opinion, it's certain that* the turbines broke away from their supports because the bolts were fatigued.
6 Management *were wrong when they* allowed old turbines to remain in use.
7 *It was impossible for* the emergency services to know the exact location of the people trapped by the earthquake.
8 *There's a possibility that* the employees did not hear the instruction to evacuate the building.

2 Work in pairs. Practise short dialogues based on the notes below.

Example: *1*

A: *The employees shouldn't have evacuated the power station as soon as the 'stand by' warning sounded.*
B: *Why not? What should they have done? / What action should they have taken? / What should have been done instead?*
A: *They should have waited for the 'evacuate' alarm or further instructions.*
B: *What difference would that have made? / What would have happened if they'd done that? / How would that have improved the situation?*
A: *If they'd done that, they would have found out which part of the building to avoid.*

Mistakes made during the emergency:

1 The employees all evacuated the power station as soon as the 'stand by' warning sounded. (Correct action: wait for 'evacuate' alarm or further instructions. Reason: find out which part of building to avoid because of fire or flood)
2 Supervisors sent their employees home as soon as they were outside the plant. (Correct action: gather them together in one area. Reason: count them, check if anyone still inside)
3 The turbines continued working after water started filling up the turbine hall. (Correct action: automatic safety system immediately shuts down all turbines. Reason: prevent possibility of short circuits and explosions)
4 Communication systems all closed down after the first explosion. (Correct action: communication systems powered by independent generators. Reason: systems able to function after power failure; allow managers to direct staff effectively)

3 Work out details (like the ones in the notes in 2) of an error that must be avoided in your own industry or technology. Then work in pairs and practise dialogues like the ones in 2.

4 **Read parts A–M of an inspection report. Write the letters A–M next to these headings to show where the parts belong in the report and put the parts in the correct order.**

Introduction ___ ___ Method ___ Criteria ___ G ___ Findings ___ ___ M ___ Conclusions ___
Recommendations ___ ___

A It was found, firstly, that a new vibration warning system was installed and fully operational. A turbine vibration simulation was carried out, resulting in clear audio-visual warnings, followed by turbine shutdown.

B Secondly, since this inspection covered only three criteria, further inspections using different criteria should be carried out as spot checks during the next 24 months.

C The main results of our inspection were as follows.

D The purpose of the inspection was to check on progress in implementing the recommendations made in the official report on the Belling power plant accident in August last year.

E The final requirement was that two new diesel emergency power supply units had to be installed on top of the dam to allow the penstock gates to be closed automatically in the event of a power cut.

F It is the view of the inspection team that implementation of the three specified recommendations from the accident report is on schedule and has no major problems. In our opinion, the management have carried out an impressive implementation of the original recommendations from the accident investigation.

G Secondly, all bolts attaching turbines to the turbine hall floor needed to be replaced with new sets, which had to be tested ultrasonically to detect any flaws.

H This is the report of our inspection of the Belling hydroelectric power plant, which we carried out in April this year as requested by the government Health and Safety Executive.

I Finally, two new diesel emergency power supply units were observed at the penstock gates. A power shutdown simulation test was carried out, which resulted in the units self-activating and the gates closing automatically within five seconds.

J Our team of three inspectors led by a senior inspector made a single unannounced visit to the power plant earlier this year. The General Manager was given only one hour's notice of the inspection. On arrival, we toured the plant, inspected three items (see criteria in next section), ran tests and interviewed management and staff. The three criteria on our checklist corresponded with three key recommendations from the original accident report.

K First, in view of the successful outcome of this inspection, there should be no change to the planned schedule for repairing the plant. Management should continue their efforts to return the plant to full production within four years.

L The first of the three criteria was that new warning systems had to be installed (a) to sound an alarm in case of potentially dangerous vibrations in turbines, and (b) to automatically shut down the turbines.

M Secondly, during a spot inspection of a sample turbine, a full set of new bolts was observed. An ultrasonic test carried out during this inspection indicated that the bolts were in good condition.

5 **Write an abstract for the above report using six sentences, one per section, as concisely as possible (maximum length: 200 words).**

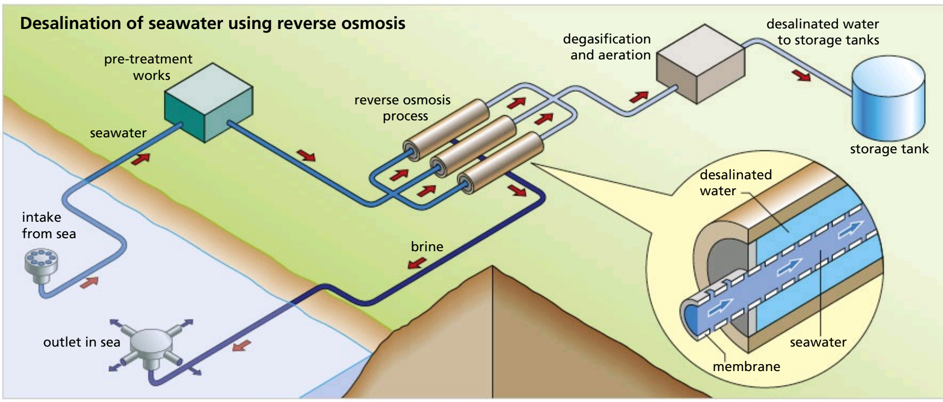
6 **One of the inspectors (B) is discussing what he had to do in the inspection in 4. Complete this dialogue, using the words or phrases in the box in the correct form. Use each word / phrase at least once.**

have to	obliged to	need to	no need	essential	necessary

A: What (1) did you have to do to make the inspection really successful?
B: Well, it (2) ____________ keep it secret. We (3) ____________ arrive without warning.
A: I see. And (4) ____________ visit the whole plant?
B: No, (5) ____________ see everything. We specified three sites which (6) ____________ inspected.
A: Were the managers (7) ____________ show you all the documents?
B: Yes, of course. And all of our instructions (8) ____________ followed.

7 **Complete the description of the desalination plant, using the correct form of the verbs in brackets. Use linking forms where appropriate.**

Note: the verb in **bold** is the *main* verb of each sentence.



A This seawater desalination plant, (1) located (locate) a short distance from the sea, (2) removes (**remove**) salt from seawater, (3) using (use) the 'reverse osmosis' method.

B Before (4) ______ (commence) the desalination process, seawater (5) ______ (**pump**) into the pre-treatment plant where solids (6) ______ (remove) from it by filtration.

C Having (7) ______ (clean), the seawater (8) ______ (**pump**) under pressure into sealed vessels (9) ______ (contain) semi-permeable membranes.

D Each membrane, (10) ______ (contain) millions of microscopic pores, (11) ______ (**act**) as a barrier to salt molecules, while (12) ______ (allow) pure water to pass through.

E Having (13) ______ (block) by the membrane, the remaining water or brine, (14) ______ (contain) a high concentration of salt, (15) ______ (**force**) into the outlet pipe, eventually (16) ______ (flow) back into the sea.

F Having (17) ______ (pass) through the membrane, the pure, desalinated water, now (18) ______ (call) 'product water', (19) ______ (**undergo**) two more processes – degasification and aeration – before finally (20) ______ (flow) to storage tanks for later use as drinking water.

8 **Complete the four unfinished parts of the evaluation report below, using information from the project notes and the photo below.**

Report on evaluation of SeaTidy project

INTRODUCTION: This report presents the results of the recent evaluation of the SeaTidy project carried out by our research team.

BACKGROUND: Oil spills at sea, like the MV Wakashio oil spill off Mauritius, are on the increase and current clean-up methods are time-consuming and expensive because it is difficult to separate oil from water. A new, faster and cheaper way of doing this effectively is urgently needed.

OBJECTIVE: The objective of the SeaTidy project was to produce a membrane capable of absorbing large quantities of oil, while at the same time repelling water. The membrane had to be suitable to be attached to a soft-robotic floating device, similar to the Neusbot.

TECHNICAL SOLUTION: The technology used in the project consisted of ...

CRITERIA: Four criteria were used for evaluating the success of the project ...

EVALUATION: The project was evaluated against the criteria by examining the results ...

CONCLUSION: It is clear from the evaluation that ...

TEST 1

- put membrane in seawater
- leave for one month
- result: membrane totally dry

TEST 2

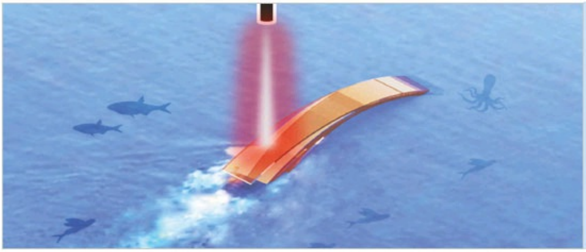
- put membrane in oil
- leave for one month
- result: absorbed oil 20 x own weight

TRIAL

- attached to Neusbot-type soft-robotic floating device
- activated in oily water
- left alone for one month
- no maintenance
- result: still absorbing oil

TECHNOLOGY

- membrane made of nanowire
- water-repellent
- oil-absorbent
- 20 x 5 mm strip attached to Neusbot-type soft-robotic device



The Neusbot three-layered soft-robotic floating device, designed at UC Riverside. Nanorods in the porous middle layer convert light into heat, vaporising water and powering pulsed motion across the surface of the sea.

PROJECT » **9** **Choose one of the following projects.**

1. Research a major project which led to innovations in your industry or technology, and write an evaluation report on it.
2. Research a major accident or breach of safety or security in your industry, where the investigation and report led to major changes. Write a report summarising the accident, the main findings, conclusions and recommendations and explaining what changes arose from the report.

10 **Present your findings to your class or group.**

Language summary

A Grammar

Present simple

The present simple verb form is the most commonly used verb form in technical communication. For example, it is used in technical descriptions, process explanations, scientific laws and principles, job descriptions and regular or routine actions.

Active

*The sensor **consists of** two main components. The fluid **passes** into the chamber, but **does not remain** there. The Seawater greenhouse **uses** natural processes such as gravity, evaporation and condensation. Oil platform workers **work** four days on and four days off.*

Passive

If an active sentence is changed into the passive, (1) the *subject* of the active verb becomes the agent of the passive verb (*is / are* + past participle), and (2) the *object* of the active verb becomes the *subject* of the passive verb.

The insertion of oxygen (subject) *produces* (active) *the high temperature in the furnace* (object). ➔ *The high temperature in the furnace* (subject) ***is produced*** (passive) ***by*** *the insertion of oxygen* (agent).

The agent is often omitted if it contains no new or important information: *First, the vessel **is tilted** towards the charging aisle. Next, scrap steel **is poured** into it.* Here, the reader is not interested in the mechanism which causes the vessel to be tilted, or the machinery that causes the scrap steel to be poured, but is more interested in the stages of the process (*tilting the vessel, pouring in the scrap steel*), and so the agent is omitted.

Using the passive has two effects on the reader: it focuses their attention on

- the *process* or *action* (tilting, pouring)
- the *person or thing affected by the action* (vessel, scrap steel).

Note that the above points are relevant for the passive forms of all verb tenses.

Deciding when to use the active or passive

In texts describing or explaining a technical process, the passive is usually the default verb form. This is because the focus is mainly on the process or action (expressed in the verb) and the thing acted upon (the subject of the passive verb): *First of all, bauxite **is extracted** from the ground and **is carried** from the mine on conveyor belts to crushers, where it **is ground** into powder.*

However, even in texts dealing with a process, the active will sometimes be used:

- if the verb is intransitive, it cannot take an object and therefore cannot be used in the passive. *The bauxite **goes into** / **enters** the crushers, where it is ground and **becomes** powder*. The verbs *go*, *enter* and *become* are intransitive, and therefore have to be active.
- the ability to switch between active and passive (and vice versa) gives more options to the writer for making the meaning clear, especially when a relative clause is linked to the main clause:
  *Archimedes' cylinder **contains** revolving blades, which **are turned** by hand.*
  *The pedal **is connected** to the throttle by a cable, which **releases** the valve.*

Present continuous

The present continuous is used to talk about an activity which is happening while the speaker is speaking, or during the current time frame. It is also used to talk about planned or intended future activities.

(See 'Future')

Active

*The fire alarm **is ringing** continuously, so we must leave the building now. I **am attending** a lot of training courses this year (current time frame). The rescue operation **is starting** in an hour's time.*

Passive

*A product recall operation **is being mounted** at this very moment. Ten million cars **are being recalled** as we speak.*

As with other tenses, the agent is normally specified only if it supplies new information: *A product recall operation **is being mounted** this week **by Komodo, one of the world's largest car manufacturers**.*

(See 'Present simple (passive)' and 'Deciding when to use the active or passive')

Future

The future is expressed in a variety of ways:

- *will* is used to talk about things that you think are certain to happen in the future

- the present continuous is used to talk about planned future events*
- *going to* is used to talk about intended future events*
- *on the point of + -ing* and *about to* are used to talk about events in the immediate future, expected to happen very soon.

* the present continuous and *going to* are often used interchangeably without any important distinction between intentions and plans.

Active

*I **won't** see you next week because I**'ll be** on a training course. The whole technical sales team **is travelling** to the conference tomorrow morning. We**'re going to** pump concrete into the oil well to try to stop the leak. The drills **are on the point of breaking** through into the oil reservoir, perhaps within the next hour.*

Passive

*The oil leak probably **won't be stopped** for many weeks, perhaps months. According to the schedule, the oil clean-up programme **is being started** at dawn tomorrow morning. First of all, robot submarines **are going to be sent down** to examine the damage. An announcement **is about to be made**, so please switch off your machines and listen.*

Past simple

The past simple is used to talk about events and actions in the past which are now finished. The time of the event is either specified using time expressions (*five minutes ago, last month, during the previous inspection*), or understood from the context.

Active

*The inspectors **visited** the damaged turbine hall at 9.30 yesterday morning. During their visit, they **spoke** to the managers, but **did not speak** to the rest of the staff.*

Passive

*The project **was completed** last year. The fault in the brakes **wasn't noticed** when the car **was brought** into the workshop for a routine service.*
(See 'Present simple (passive)' and 'Deciding when to use the active or passive')

Past continuous

The past continuous is used to talk about situations in progress in the past. It is often combined with *when* + past simple to show that a sudden short action interrupted the situation in progress. When used with a time expression, it indicates that the situation was in progress at a specific date or time in the past.

Active

*The miners **were working** at a depth of 150 metres **when** the explosion **occurred**. **At 14.05 yesterday afternoon**, the time of the accident, the morning shift **were starting** to leave the factory.*

Passive

*The last of the oil workers **were being taken off** the drilling platform by the helicopter, **when suddenly** part of the platform burst into flames.*

Present perfect simple

The present perfect is used to talk about actions or events that happened at an unspecified time or date during a period of time lasting from the past right up to the present time.

The present perfect simple is often used with the following adverbs: *for* (focusing on the length of a period of time), *since* (focusing on the starting point of a period of time), *just* (emphasising that the event happened recently), *yet* (in questions and negatives only, emphasising the period of time to the present) and *already* (mainly in positives, emphasising speed of completion before the present, but also in questions, expressing surprise at completion speed).

Active

*We**'ve looked at** the engine, but we **haven't found** the fault **yet**. The forklift truck driver **has worked** here **for** ten years / **since** he left school. The exploration team **have just arrived**, but they**'ve already found** evidence of oil. **Have** they **found** oil **already**? That was quick!*

Passive

*It **has just been reported** that the factory fire **has been extinguished**. Although the project **has been completed**, the report **has not been written yet**. Basic oxygen furnaces **have been used for** many years, **since** the 1950s, in fact.*
(See 'Present simple (passive)' and 'Deciding when to use the active or passive')

Present perfect continuous

The present perfect continuous (*has / have (not) + been* + present participle) emphasises the length of time that an action has continued right up to the present. The present perfect continuous is often used with the following adverbs: *for* (focusing on the length of a period of time) and *since* (focusing on the starting point of a period of time).

Active

Our company ***has been using snake wells for*** *a number of years. I**'ve been working*** *on this project* ***since*** *2009.*

The passive is very rarely used in this tense.

Future perfect

The future perfect is used to make a prediction about an action or situation that will be completed before (or *by*) a specified time in the future.

Active: *will (not)* + *have* + past participle

By the end of next week, *the inspectors* ***will have tested*** *more than 20 components. The engineers* ***won't have finished*** *the job* ***by this time tomorrow****.*

Passive: *will (not)* + *have* + *been* + past participle

By the time the new bridge is ready, *the approach road* ***will have already been constructed****. You can't start the construction work tomorrow, because the materials* ***won't have been delivered by then****.*

Question forms

Note: the first line of examples for each tense is active; the second line is passive.

Present simple

How ***does it work****? When* ***do*** *they* ***come****?*

How ***is*** *the device* ***activated****? When* ***are*** *the machines* ***switched off****?*

Who ***operates*** *the boiler room?* (The question word is the subject)

Present continuous

What ***are*** *you* ***doing****? When* ***are*** *they* ***coming****?*

Why ***is*** *the product* ***being recalled****? How* ***are*** *the parts* ***being shipped****?*

What ***is causing*** *this problem?* (The question word is the subject)

Future with *will*

When ***will*** *the engineers* ***begin*** *the project?*

How ***will*** *the shipwreck* ***be lifted*** *to the surface?*

Who ***will be taken*** *from the shipwreck first?* (The question word is the subject)

Past simple

When ***did*** *they* ***leave****? Why* ***didn't*** *he* ***press*** *the stop button?*

How ***was*** *the drill* ***repaired****? When* ***were*** *the machines* ***built****?*

Who ***went*** *to the conference?* (The question word is the subject)

Past continuous

When ***was*** *he* ***working*** *in the oil industry?*

Why ***were*** *the winches* ***being used*** *at that time?*

Who ***was managing*** *the plant during the crisis?* (The question word is the subject)

Present perfect active

Have *they* ***repaired*** *the car yet? How long* ***has*** *he* ***worked*** *here?*

Have *the safety crew* ***been trained*** *properly?*

How many people ***have applied*** *for the job?* (The question word is the subject)

Present perfect continuous (active only)

How long ***has*** *your company* ***been using*** *snake wells?*

What ***has been going on*** *for the last week?* (The question word is the subject)

Future perfect

When ***will*** *they* ***have finished*** *the repair?*

By what time ***will*** *the repair* ***have been finished****?*

What ***will have happened*** *by then?* (The question word is the subject)

Modal and semi-modal verbs

Modal and semi-modal verbs express functions such as ability, permission, obligation, certainty and possibility.

Modal verbs (*must, may, might, should, can, could, will, would*) do not take *-s* in the third person singular, or *do / does* in the question or negative: *Everyone* ***must*** *wear personal protective clothing on this site.* ***Should*** *she put on her safety goggles now? They* ***cannot*** *repair the fault.*

Semi-modal verbs (*have to, need to*) are like modals in meaning, but have the same form as normal verbs, taking *-s* in the third person singular and using *do / does* in the question or negative: *Everyone* ***has to*** *wear protective clothing on this site.* ***Does she need to*** *put on her safety goggles now?*

The form of *ought to* is similar to that of other modal verbs; in the negative, *not* comes between *ought* and *to*: *People* ***ought not to*** *work with such strong chemicals.*

The negative forms of *have to* and *need to* (but not *ought to*) have a different meaning from the negatives of *must* and *should*:

- *You must / need to / have to do it* = it is essential (necessary) to do it.
- *You mustn't do it* = it is essential (necessary) not to do it.
- *You should / ought to do it* = it is recommended that you do it.
- *You don't have to / don't need to do it* = it is unnecessary to do it.

Passive

Must, should, have to, need to and *ought to* are often followed by passive infinitive verbs (*be* + past participle) in safety rules and procedures. *Hard hats* ***must be worn*** *at all times. This package* ***has to be kept*** *frozen. Mobile phones* ***should not be used*** *here.*

Past tense

Ability in the past: *could / couldn't* or *was / were + able to / not able to / unable to: I'm sorry I* ***couldn't repair*** *your car. I* ***was unable to find*** *the correct parts*. In the passive, only *could/couldn't* is used: *The gate* ***couldn't be closed*** *in time, so the water rushed into the penstock*.

Necessity in the past: *had to / needed to*: *We* ***had to finish*** *the job yesterday. The job* ***needed to be finished*** *yesterday.* Note that *didn't have to / didn't need to* mean *it was unnecessary to*: *Although we* ***had to finish*** *the job yesterday, we* ***didn't have to write*** *the report.*

(See 'Necessity in the past')

(See 'Speculating about the past')

Conditionals

Zero conditional

The *zero conditional* is used for things which always happen (or what to do) under certain conditions.

Clause 1: *if* + present simple	Clause 2: present simple
If *water* ***is heated*** *to 100°C,*	*it* ***boils****.*
Clause 1: *if* + present simple	Clause 2: imperative
If *the alarm* ***sounds****,*	***evacuate*** *the building.*

First conditional

The *first conditional* is used for possibilities in the future.

Clause 1: *if* + present simple	Clause 2: *will (not)*
If *the conference* ***is*** *in Germany,*	*I'****ll go*** *to it.*

Second conditional

The second conditional is used for unreal situations in the present.

Clause 1: *if* + past simple	Clause 2: *would (not)*
If *I* ***had*** *an instruction manual,*	*I'****d*** *be able to repair the fault.*

(But I don't have a manual, so in reality I can't repair the fault.)

Third conditional

The third conditional is used for unreal situations in the past.

Active

Clause 1:	Clause 2:
if + *had (not)* + past participle	*would (not)* + *have* + past participle
If *they* ***had replaced*** *the turbine bolts,*	*the accident* ***would not have happened****.*

Passive

Clause 1:	Clause 2:
if + *had (not)* + *been* + past participle	*would (not)* + *have* + *been* + past participle
If *the turbine bolts* ***had been replaced****,*	*the accident* ***would have been avoided****.*

(But in reality the bolts were not replaced, so the accident actually happened.)

(See 'Conditions')

Linking

Relative clauses and participial phrases are useful ways of linking clauses together to form longer sentences. They are used most often in written language.

Non-defining relative clause

A non-defining relative clause does not provide part of a definition, or limit the meaning of the preceding word. It simply adds further information.

The non-defining relative clause uses relative pronouns such as *which*, *who* and *where*. A comma is used immediately before the relative pronoun.

A test was carried out. The test confirmed the results. ➔ *A test was carried out,* ***which*** *confirmed the results. The goods were taken to the warehouse. Here they were put away.* ➔ *The goods were taken to the warehouse,* ***where*** *they were put away.*

Defining relative clause

A defining relative clause limits the meanings of the preceding words and is often used in definitions.

A sensor is a device ***that*** *detects certain external stimuli and responds in a distinctive manner.*

(The sensor is not any kind of device: it is a limited type of device restricted to detecting certain stimuli and responding in a special way.)

Which is used with things, and *who* is used with people. In defining relative clauses (but not normally in non-defining ones), *that* can replace *which* or *who*. There is no comma immediately before *which / who / that*.

(See 'Definitions')

Present participial phrase

A present participial phrase can sometimes replace a clause or sentence when two actions by the same subject take place at the same time, or one action follows immediately after, or as a result of, another. The present participle ends in *-ing*, and is active in meaning.

The photons move up and down inside the ruby crystal. They travel at the speed of light. ➔ *The photons move up and down inside the ruby crystal,* ***travelling*** *at the speed of light.*

The blowout preventer was automatically activated. (As a result,) it shut down the well. ➔ *The blowout preventer was automatically activated,* ***shutting*** *down the well.*

When events happen in a clear sequence, *before* or *after* can precede the present participle:

The water flows through a network of pipes. Then it finally enters the storage tank. ➔ *The water flows through a network of pipes* ***before*** *finally* ***entering*** *the storage tank.* ***After flowing*** *through a network of pipes, the water finally enters the storage tank.*

Past participial phrase

The past participle can sometimes replace subject + passive verb. This method of linking clauses or sentences is very common in technical writing as it helps to make it more concise. The past participle is passive in meaning.

The oilfield is located 90 km off the coast of Brunei. It is an important resource. ➔ *The oilfield,* ***located*** *90 km off the coast of Brunei, is an important resource.*

The past participial phrase can also occur at the beginning of a sentence: ***Located*** *90 km off the coast of Brunei, the oilfield is an important resource.*

Past participial phrases are sometimes also called 'reduced relative clauses', because *which / who + is / are / was / were* are omitted from a relative clause: *Sensors which are buried deep beneath the seabed send information to the surface.* ➔ *Sensors* ***buried*** *deep beneath the seabed send information to the surface.*

Perfect participial phrase

The perfect participial phrase can be used when two actions by the same subject take place in sequence. It has the same meaning as *after* + present participle. It is commonly found in both active and passive forms.

Active: *having* + past participle

The drillers opened up the well. Then they installed some casing. ➔ ***Having opened*** *up the well, the drillers installed some casing.* (This has the same meaning as: ***After opening*** *up the well, the drillers installed some casing.*)

Passive: *having + been* + past participle

The water is pumped up to the storage tank. Then it flows down to the irrigation channel. ➔ ***Having been pumped*** *up to the storage tank, the water flows down to the irrigation channel.* (This has the same meaning as: ***After being pumped*** *up to the storage tank, the water flows down to the irrigation channel.*)

Indirect questions

Inversion of word order and auxiliaries (e.g. *do, did*) is used in direct questions, but the word order in indirect questions is the same as in statements.

Where are the tools? (direct question) ➔ *Tell me* ***where*** *the tools* ***are***. (indirect question)

When did the fire start? (direct) ➔ *I want to know* ***when*** *the fire* ***started***. (indirect)

Did they run the test? (direct) ➔ *I need to know* ***if / whether they ran*** *the test.* (indirect).

A noun phrase can sometimes be substituted for an indirect question: *I need to know* ***where they are***. ➔ *I need to know* ***their location***.

Phrasal verbs

(See 'Phrasal verbs bank')

A phrasal verb is a combination of verb + particle. The particle is either an adverb or a preposition. The verb–particle combination has a distinct meaning of its own.

The main types of phrasal verb are:

- intransitive: *The main turbine* ***broke down*** *early this morning*. The phrasal verb does not take an object. In this type, the particle is an adverb.
- transitive, separable: a noun object can follow either the verb or the particle: ***Put*** *the tools* ***down***. ***Put down*** *the tools.* However, a pronoun object of a phrasal verb can *only* follow the verb: ***Put*** *them* ***down***. (Not ~~*Put down them.*~~) In this type, the particle is an adverb.
- transitive, inseparable: the object (noun or pronoun) can only follow the particle: *He* ***looks after*** *the machines. He* ***looks after*** *them.* (Not *He* ~~*looks the machines after*~~*. He* ~~*looks them after.*~~) In this type, the particle is a preposition.

There are also some three-part phrasal verbs, consisting of verb + adverb + preposition: *The team have* ***come up with*** *some innovations*. Here the object can only follow the preposition.

B Functions and notions

Use or function

The use, function or purpose of a device or object can be described in various ways:

- present simple: *The carburettor* ***mixes*** *air and petrol.* This indicates the action of the device itself (without human agency) and is often used in definitions with *which / that*: *The carburettor is a mechanism* ***which / that mixes*** *air and petrol.*
- *(used) for* + verb + *-ing*: *Theodolites are (****used****)* ***for surveying*** *the land*. This form is often used to

indicate how the device is used (by a human agent), or to show the main or best-known function of the device.

- *(used / designed) to*: *This polymer was originally (**designed / used**) **to protect** astronauts' eyes from solar rays.*
- *act / function as*: *In a capacitive screen, the finger **acts as** one plate of a capacitor and the screen **functions as** the other.* This is used to compare the function of one object with the function of another.

(See 'Definitions')

Necessity

Necessity, or obligation, can be expressed either using the modal *must* or the semi-modals *have to / need to / have got to: Hard hats **must** / **have to** / **need to be** / **have got to be worn** on this site.*

Necessity in the past

Since there is no past tense of *must*, the following forms are used to express the idea that an action was or was not necessary in the past:

- it was necessary to act: *They **had to do** it. It **had to be / needed to be done**. They **were obliged / required to do** it. **It was necessary / essential (for them) to do** it.*
- it was unnecessary to act: *They **didn't have to / need to do** it. **There was no need / necessity (for them) to do** it. **It was not necessary / essential (for them) to do** it.*
- it was necessary to act, but he / she didn't act: *They **were supposed to** follow the rules* (implied: *They should have followed the rules, but they didn't*). Compare this with *They **had to follow** the rules* (implied: *... and they did*).
- it was necessary not to act, but he / she acted (wrongly): *They **weren't supposed to** break the rules* (implied: *They shouldn't have broken the rules, but they did.*)

(See 'Past modals')

(See 'Recommending, suggesting, proposing')

Ability

In addition to the modal verb *can*, it is also possible to use the following forms:

- *be able to*: *This machine **can / is able to** start and stop itself automatically.*
- *be capable of -ing*: *The lathe **is capable of running** at extremely high speeds.*
- *have the ability/capacity to*: *A laser drill **has the ability / capacity** not only to cut into rock but also to melt it.*
- *have the capability of -ing*: *The search engine **has the capability of processing** hundreds of thousands of pages per second.*

Expressions of ability are often combined with expressions of necessity, for example in product design specifications: *The new design must have / has to have / needs to have / has got to have the capability of starting automatically / be able to start automatically.*

Comparison and contrast

Comparative adjectives (e.g. *stronger / more expensive + than*) are commonly used to compare two items. Note the use of *that / those of* in the following examples:

*The safety record of the hybrid car is better **than that of** most other models.* (= *better **than the safety record of** most other models*)

*The dimensions of this mobile phone are smaller **than those of** the other one.* (= *smaller **than the dimensions of** the other one*)

The following linking words and phrases can be used to compare or contrast two ideas:

- *although / though: **Although / Though** the turbine was heavy, the explosion lifted it into the air.* The clauses can be reversed: *The explosion lifted the turbine into the air **although / though** it was heavy.*
- *while / whereas: Laser light contains one wavelength, **whereas / while** ordinary light contains many.* The clauses can be reversed.
- *however / nevertheless: Cruise control is very convenient. **However / Nevertheless**, many drivers fail to use it. Many drivers, **however**, fail to use it. Many drivers **nevertheless** fail to use it.*
- *on the other hand*: *Deepwater drilling is risky. **On the other hand**, it opens up new oil fields. Ordinary computers have plastic cases. Rugged models, **on the other hand**, have metal ones.*
- *instead*: *The oil is not located in one place. **Instead**, it is broken up into thousands of small pockets.*
- *instead of*: *The atom emits two photos **instead of** one. **Instead of using** pressure, the capacitive screen uses the conductivity of the user's finger.*
- *unlike*: ***Unlike** a normal vertical well, the snake well bends in all directions.* The clause / phrase can be reversed.
- *compared with*: ***Compared with** normal oil clean-up operations, a robotic oil-cleaning device would be very cost effective.* The clause / phrase can be reversed.

Simultaneous actions

The following forms can be used to express the idea that two actions happen at the same time, or simultaneously:

- *simultaneously / at the same time*: *Press the pedal and **simultaneously** push the lever.*
  ***Simultaneously** press the pedal and push the lever.*
- *at the same time as*: ***At the same time as** you press / you're pressing the pedal, push the lever. Press the pedal **at the same time as** you push / you're pushing the lever.*
- *while* + verb + *-ing*: ***While pressing** the pedal, push the lever*. This can only be used if the subject is the same for both verbs. Otherwise, use subject + present continuous: ***While your colleague is checking** the brakes, you can inspect the power steering.*
- *as*: ***As** the piston goes down, the valve opens. The valve closes again **as** the piston rises.*

Cause and effect

Explanations of cause and effect (or result) can mention the cause first and then the effect, or mention the effect first, followed by the cause.

Mentioning the cause first

- *cause … to / make*: *Water from the penstock **makes** the turbine blades **rotate** and the rotation **causes** the generator **to produce** electrical power.*
- *lead to / give rise to / result in / be the cause of / be a factor in* + noun phrase: *The use of carbon **gives rise to** greenhouse gas **emissions**.*
- *lead to / give rise to / result in / be the cause of / be a factor in* + participial phrase: *Global warming can **result in** sea levels **rising** and low-lying areas **being flooded**.*

Mentioning the effect first

- *caused by / the result of / due to* + noun phrase / participial phrase: *Greenhouse gas emissions are partly **due to the use of carbon** / **the result of carbon being used**.*
- *result from / happen as a result of* + noun phrase / participial phrase: *The explosions in the hydro-electric power plant **resulted from** careless supervision / **happened as a result of** a faulty turbine being brought into operation too early.*

Explaining meanings

The following markers indicate that the speaker or writer is about to explain the meaning of a word or phrase.

- introducing an explanation of a single word or short phrase: *or, that is, that is to say, in other words, i.e.*
- introducing an explanation of a longer passage: *another way of putting it is that, to put that another way, to put this in everyday terms / language, to put that in layman's terms / language*

Degrees of certainty

Degrees of certainty are not precise measurements but relative values, depending on the speaker's opinion and the context in which they are used. The categorisations below are for general guidance only.

Certainty or high probability

- adjective: *(almost / virtually) certain, probable, (highly) likely: **It's highly likely that** there will be a repeat of this accident.*
- adverb: *certainly / definitely / probably: This project **will definitely** cost too much.*
- noun: *(high / strong) probability, (strong) possibility, (virtually) no doubt, likelihood (high): **There's a strong possibility that** oil will leak from this well. **The likelihood** that oil will leak from this well is very high.*

Possibility or medium probability

- modal verb: *may, might, could*: *Things **may** go wrong quickly.*
- adjective: ***It's (very) possible that** things will go wrong quickly.*
- adverb: *Things will **(very) possibly** go wrong quickly.*
- noun: ***There's a possibility / chance** that we'll be able to put things right.*

Impossibility or low probability

- adjective: ***It's (highly) unlikely / (virtually) impossible that** the weather will improve.*
- adverb: *The relief well will **(almost) certainly / probably / definitely not** be completed in time.*
- noun: *a (slim / slight / remote) chance, (almost) no chance, (strong) possibility, (virtually) no doubt, likelihood (low)*: ***There's only a slight chance that** the wind direction will change. **The likelihood of** a reduction of carbon emissions **is very low**.*

Speculating about the past

The language forms below are used when speculating, or forming a hypothesis, about what you think happened in the past based on incomplete information or evidence.

Probability

- active: *has to / must* + *have* + past participle: *Someone **must have stolen** the equipment.* (I don't know this as a fact, but the available evidence makes it seem probable.)

- passive: *must have / has to have* + *been* + past participle: *The equipment* ***has to have been stolen***.

Possibility

- active: *may / might / could* + *have* + past participle: *A gas leak* ***may have caused*** *the accident.* (It's possible.)
- passive: *may / might / could* + *have* + *been* + past participle: *The accident* ***could have been caused*** *by a gas leak.*

Impossibility

- active: *can't / couldn't* + *have* + past participle: *Smoking* ***can't / couldn't have caused*** *the fire because no one smokes in this warehouse.* (I don't know for a fact that smoking didn't cause the fire, but the evidence makes it seem impossible.)
- passive: *can't / couldn't* + *have* + *been* + past participle: *The fire* ***can't / couldn't have been caused*** *by smoking.*

Criticising or regretting past actions

The same form is used when criticising or regretting mistakes that were made in the past, by oneself or by others:

- active: *should (not) / ought (not) to* + *have* + past participle: *We* ***should have inspected*** *the turbine last night, but we didn't and the turbine exploded this morning.*
- passive: *should (not) / ought (not) to* + *have* + *been* + past participle: *The turbine* ***ought not to have been brought*** *back into service before it was fully repaired.*

Recommending, suggesting, proposing

The following forms are used when recommending, suggesting or proposing a course of action.

- *should / ought to*: *You* ***should / ought to change*** *your internet service provider. I think all your passwords* ***should be changed***.
- *recommend / suggest / propose* + *that*: this form specifies who will carry out the recommended action: *We* ***propose that*** *a team of specialists (should) inspect your current system*.
- *propose / suggest / recommend* + verb + *-ing*: this form does not specify the actor and is often used when the actor and the proposer are the same: *We* ***recommend hiring*** *a team of specialists.* (This suggests that the proposer will actually hire the team, but also creates some ambiguity.)

Formal proposals

The words *propose* and *proposal* in business or work contexts often signal a formal (or official) proposal which requires formal acceptance or rejection.

Formal recommendations

In reports, recommendations for future action normally use the following forms. Recommendations are often very concise, concrete and ordered in a numbered list.

- active: *All staff* ***should attend*** *at least one safety training course per year.*
- passive: *Annual safety training courses* ***should be set up*** *for all front-line staff.*

Definitions

Most definitions contain at least the following components: (a) the name of the item being defined, (b) is / are, (c) a generic (or type) noun (e.g. *instrument, tool, device*) and (d) a statement of the main function, use or purpose of the item:

A motion sensor (a) is (b) a device (c) for detecting human or animal movement (d).

More complex definitions can also contain one or more of the following optional elements: (e) appearance, (f) property, (g) type, (h) components, (i) material, (j) material, (k) application:

A thermostat (a) is (b) a sensing (g) device (c), consisting of a sensing element and a transducer (h), which controls sources of heating and cooling to maintain a desired temperature (d) and is found in many home and industrial heating systems (k).

(See 'Defining relative clause')

(See 'Linking')

Concise technical writing

There are many ways to make writing more concise, or condensed, including the following methods taught in this book, which all involve giving nouns, phrases and clauses an *adjectival* function. In the examples below, a possible longer version is given in brackets after the concise version:

- noun (+ noun) acting as adjective: *a* ***water inlet*** *pipe (🡐 a pipe that provides an inlet for the water)*
- past participle acting as adjective: *reinforced concrete (🡐 concrete that has been reinforced)*
- present participle acting as adjective: *a heating system (🡐 system used for heating)*. This construction often indicates the function or use of the object being described.
- clause or phrase used as a hyphenated adjective. These fall mainly into the following categories:
- number + unit (+ dimension): *two* ***12-cm(-long)*** *screws (🡐 two screws which are 12 cm long)*
- noun + past participle: *a* ***piston-powered*** *jack (🡐 a jack which is powered by a piston)*
- noun + present participle: *a* ***motion-detecting*** *device (🡐 a device that detects motion)*

- adverb + present participle: *a* ***gradually-increasing*** *speed* (🡸 *a speed which increases gradually)*
- adverb + past participle: *two* ***simultaneously-ignited*** *engines* (🡸 *two engines which are ignited simultaneously)*
- noun + noun: *a* ***polymer-graphite*** *composite* (🡸 *a composite which is made of polymer and graphite)*
- noun + adjective: *a* ***heat-sensitive*** *instrument* (🡸 *an instrument which is sensitive to heat)*

Stating conditions

(See 'First conditional')

The following words and phrases are approximate synonyms of *if* as used in a first conditional sentence. However, as shown below, they carry additional meanings which are used in more formal or official contexts, such as contracts or letters of agreement.

- Formal alternative to *if*: ***In the event that*** *the factory* ***closes****, the deadline can be changed.* ***In case of / In the event of*** *factory* ***closure****, the deadline can be changed.*
- Emphasising conditions for action: *We will reduce the price* ***provided (that) / on condition that / as long as / so long as / with the proviso that*** *they pay on time*.
- Regardless of circumstances: ***Even if*** *there is a transport strike, the goods must be delivered by the deadline.*
- As a precaution: *We need to take out insurance* ***in case*** *the factory burns down.*
- Formal alternative to *if not*: *This offer must be accepted within 14 days;* ***otherwise*** (= *if not*)*, the offer will be withdrawn.*
- Formal alternative to *if*, used in contracts: ***Should*** *the client fail to pay the balance within 30 days (= If the client fails to pay ...), there will be a penalty of . . .*

C Phrasal verbs bank

A phrasal verb is formed with a verb + particle. The particle is either an adverb or a preposition.

(See 'Phrasal verbs')

Sometimes the meaning of the phrasal verb as a whole can be inferred from the meaning of the verb and the particle, as in ***take down*** *the carton* (= move it from a higher to a lower position).

However, sometimes the meaning of the whole phrasal verb is completely different from the meanings of the separate words, as in ***take down*** *these details* (= write them after hearing them).

A further complication is that some phrasal verbs (as in the two examples above) may have more than one distinct meaning. Use a good dictionary, such as the *Longman Dictionary of Contemporary English*, to check the meaning(s) of the phrasal verbs listed below and any others that you meet.

Intransitive phrasal verbs

The phrasal verbs in the following list are intransitive only when used with the meanings specified below.

Phrasal verb	Example
break away	Part of the ship's hull has broken away.
break down	*My car has broken down.*
break out	*A fire has broken out on the oil platform.*
come up	*A new problem has come up.*
kick off	*Let's brainstorm. Who'd like to kick off?*
show up	*The plastic component won't show up on the X-ray.*
take off	*The aircraft took off five minutes ago.*
touch down	*The helicopter will touch down soon.*
turn out	*The oil spill crisis has turned out well in the end.*
turn up	*Don't worry. Something good will turn up.*

Transitive, separable phrasal verbs

Verbs marked with an asterisk (*) can also be used intransitively with the same meaning.

Phrasal verb	Example
back up*	*You should back your files up now.*
bring down	*Bring the temperature down. It should be colder.*
carry out	*He carried out my instructions completely.*
cut out	*The resistive touch screen cuts out more light.*
draw up	*Could you draw up a contract?*
find out	*The test will find out the strength of the metal.*
follow up	*I'm phoning to follow up our meeting last week.*
give off	*The radiator is giving off too much heat.*
give up	*Switch on the autopilot to give up manual control.*
keep down	*Our emissions are low. Let's keep them down.*
keep up	*Keep the speed up! Don't slow down.*
leave out	*We left out one important issue in our meeting.*
let in	*The inlet valve lets the fluid in.*
let out	*The outlet valve lets the fluid out.*
peel off*	*Peel the label off the envelope and use it again.*
pick up	*(1) Pick up your pen. (2) My radio has picked up a signal.*

point out*	*I'd like to point something out here. It's important.*
pull back	*Pull the lever back.*
push down	*Push down the pedal.*
push forward	*Push the lever forward.*
push over	*In the push-over test, we pushed the wall over.*
put away	*I've put the cartons away. They're in storage now.*
put back	*Put the tools back when you've finished with them.*
put forward	*Can I put forward a proposal?*
put off	*We have to put off the meeting. Everyone's on leave.*
put out	*Put that fire out immediately.*
put over	*Did you put over your concerns to your manager?*
put together	*There are the engine parts. Now put them together.*
roll out*	*When are you rolling out the new software to all users?*
rope off	*The police have roped off the area around the accident.*
rule out	*Did a short circuit cause the fire? I can't rule it out.*
run down*	*Plug in your laptop, or you'll run down the battery.*
seal off	*We've sealed off part of the pipeline to check for leaks.*
set off	*The increase in pressure set off the explosion.*
set up	*I've set up a new Wi-Fi network in the office.*
siphon off	*Siphon off the excess oil. Use this flexible tube.*
soak up	*The nano-membrane can soak up large amounts of oil.*
start up*	*We've started up a new contracting business.*
switch off	*Switch off your mobile.*
switch on	*All right, you can switch it on again.*
take apart	*Take the radio apart and search for the fault.*
take away	*Take this wrench away. I don't need it.*
take back	*(1) It's damaged. Take it back. The shop will have to replace it. (2) Switch off the autopilot to take back manual control.*
take down	*(1) Take down the box. (2) Take down the details as I speak.*
take in	*There's a leak. The engine is taking in water.*
take off	*Don't take your hard hat off yet.*
take on	*(1) I've taken on a new project. (2) We've taken on more staff.*
take out	*(1) Take out the DVD. (2) You should take out insurance.*
take over*	*New management have taken over the company.*
take up	*(1) Take the box up. It goes on the roof. (2) Writing this report has taken up a lot of my time.*
turn down	*Turn down the volume, please. It's too loud.*
turn off	*I've turned off the power.*
turn on	*I've turned it on again.*
turn over*	*Turn the laptop over to see the serial number on the bottom.*
turn up	*Turn up the temperature, please. It's too cold.*
wear down*	*You've worn down the brake pads. Replace them soon.*
wear out*	*You've worn out the brake pads. Replace them now.*
work out	*The computer will work out the exact calculations.*
write up	*I've written up the whole testing procedure in this report.*

In the following list of transitive, separable phrasal verbs, the particle adds the meaning of intensity or completeness to the base verb.

Verbs marked with an asterisk (*) can also be used intransitively with the same meaning.

Phrasal verb	**Meaning (as used in this book)**
break up*	break into small parts
clean out	clean (the inside) completely (e.g. *a tunnel*)
clean up*	clean completely (e.g. *an oil spill*)
close down*	close completely (e.g. *a computer network*)
cool down*	reduce temperature a lot, quickly, or to correct level
dry out*	dry completely
filter out	block something completely using a filter
heat up*	increase temperature a lot, quickly, or to correct level
melt down*	melt completely
narrow down	reduce (e.g. *options, possibilities*)
shut down	close completely (e.g. *a factory*)
slow down*	reduce speed a lot, quickly, or to correct level
speed up*	increase speed a lot, quickly, or to correct level
use up	use or consume until completely finished
warm up*	increase temperature a lot, quickly, or to correct level

Transitive, inseparable phrasal verbs

Phrasal verb	Example
go about	*How would you go about preventing future oil spills?*
go for	*Are you buying a new car? Go for diesel, not petrol.*
look after	*Look after this engine. It needs a lot of maintenance.*
look at	*Look at the jagged edge of the pipe.*
look into	*The police are looking into the warehouse theft.*

Three-part phrasal verbs

Phrasal verb	Example
check up on	*The inspectors are coming to check up on progress.*
come up with	*Have you come up with any new suggestions?*
cut down on	*We need to cut down on power consumption.*
get on with	*(1) Right, let's get on with the investigation. No more delays! (2) How well do you get on with your team-mates?*
go ahead with	*We accept your proposal. Please go ahead with the project.*
home in on	*The camera is homing in on the break-in location.*
look forward to	*I look forward to meeting you again soon.*
report back (to)	*I'll carry out the inspection and report back (to you) later.*

Nouns derived from phrasal verbs

Some nouns are derived from verb + particle: *build-up, roll-out, set-up, start-up, shutdown, take-off, touchdown, takeover*

Some nouns are derived from particle + verb: *input, output, inflow, outflow, overflow, upthrust, downthrust, inlet, outlet*

In some cases, the verb takes the same form as the noun: *overhaul, upgrade, downgrade*

8 Incidents 3 Emergency

Speaking exercise 10 page 63

Student A

INCIDENT

- tanker crashes on slippery road, turns upside down, side of tank fractured
- unknown liquid leaks slowly out onto the road
- witness calls emergency services on mobile phone
- liquid mixes with leaking fuel and catches fire
- firefighters arrive and put fire out
- liquid reacts violently with the water from hoses
- liquid corrodes tanker, makes more liquid pour out
- large cloud of burning gas escapes from the mixture

CAUSE(S)

- witness unable to see HazMat panels (covered with debris from crash)
- firefighters unable to identify liquid material
- fire is sprayed with water jets
- liquid was sulphur chloride, but only identified hours later
- reacts violently with water

RESULTS

- emergency staff forced to withdraw
- area of several square kilometres sealed off around incident
- nearby houses evacuated
- 15 emergency staff seriously injured by corrosive gas

6 Planning 3 Projects

Task exercise 5 page 47

Arguments in favour of System A

- the propulsion in this system is energy-efficient because the power supply is from the grid
- the pod has low mass (weighs less) because the propulsion system is not on the pod
- active levitation system produces less drag
- the infrastructure-side propulsion also allows for distances between pods to be shorter, which effectively increases system capacity
- this system uses many existing MagLev concepts and technologies, which minimizes the number of new technology advances needed to make it viable

12 Evaluation 3 Innovations

Task exercise 3 page 94

Student A

NANOWIRES

Technology: nanowires generating electricity from motion

Principle: piezoelectricity = crystalline materials under mechanical stress produce an electrical potential

Process: tiny vibrations all around us – sound waves, wind, human pulse – can bend nanowires, generating electricity

Potential applications (see Fig. 1)

- nanogenerator (A): nanowires in clothing convert movement into current, powering mobile devices
- hearing aid (B): sound waves bend nanowires to generate electrical signal – amplified and sent direct to auditory nerve
- approving signatures (C): nanowires underneath a signature pad record the pressure of a person signing name and check with database
- bone-loss monitor (D): dangerous stress in bone generates current in implanted nanowire device, which triggers alert signal to patient and doctor

12 Evaluation 3 Innovations

Task exercise 3 page 94

Student B

NANOFLUID COOLING

A few nanoparticles added to water can improve thermal conductivity up to 60%

Nanoparticles can be made of zinc, copper or carbon nanotubes

Principle (see Fig. 2): nano-sized particles allow a higher surface-to-volume ratio than microparticles, because more atoms are near the surface of the particle

Why needed? Today's coolants, lubricants and oils have poor heat transfer properties

Potential applications

- reduced cooling costs for engines
- smaller, lighter radiators and pumps
- lighter vehicles using less fuel
- vehicles with fewer carbon emissions and cleaner environment

6 Planning 3 Projects

Task exercise 5 page 47

Arguments against System A

- loss of power or a fault in the propulsion system would affect every vehicle in the system
- any power loss to the levitation system would cause the vehicle to drop dangerously
- need to give pod 'landing wheels' and a runway on the bottom of the tube in case it drops

8 Incidents 2 Security

Speaking exercise 4 page 60

Student A

1 You are the security director at Avantis. Ask the security administrator questions based on the memo on page 60 and make notes of the answers.

2 Switch roles with Student B. You are the security administrator at Avantis. Use the information below to answer the security's director's questions.

Sequence of events

Time	Alert message on security screen	My response
07.45	"6 incorrect password attempts have been made" (on sales employee mobile device)	Tried to contact sales employee – no reply
08.10	"User attempting to install unauthorised software"	Disabled sales employee account remotely
08.16	"Device running unauthorised software"; "Device now online"; "Device attempting to access company server"	Blocked all files on company server – no files accessed or downloaded
08.18	Message from helpline staff: "sales employee has reported lost mobile device"	
08.20	"GPS shows device location"	Forwarded data to Director, Security, to give to police
08.22		Attempted to take over remote control of device – unsuccessful
08.23	"Mobile device is offline"	Attempted to wipe data remotely from device – unsuccessful
08.28	"Mobile device is offline"	Sent encrypted SMS message to device, instructing it to go online and wipe all data from device
08.33	"Mobile device is online"	
08.34	"Wake up and wipe operation has completed successfully"	All data successfully removed from device

6 Planning 3 Projects

Task exercise 5 page 47

Arguments in favour of System B

- it is unnecessary for pods to carry large and heavy battery packs
- passive levitation will not make the pod drop if power is lost
- as the entire propulsion system is provided on-board, any fault is isolated to an individual vehicle
- contactless power transfer is simple (a cable or rail) and hence low-cost
- the bottom-mounted guideway means that a separate runway and wheels are not needed for emergencies

2 Design 2 Specifications

Task exercise 2 page 12

Luis has reported a lot of negative feedback from our customers, both from the patients themselves and from their doctors and therapists. Here is a transcript of Luis's oral report, which was recorded:

'There have been four main complaints from our customers. First of all, there's a minor *safety* issue. Sometimes the harness rubs the patient's skin and causes a little pain.

Secondly, there's a *performance* issue. The equipment supports the patient's body weight, but it has only three settings: maximum, medium and minimum. Maximum means almost all the body weight is supported and minimum means almost none of the weight is supported. Patients want to be able to make many smaller adjustments in between – maybe 30% of body weight today, 32% next week and so on.

Thirdly, the users don't like the *appearance* of the equipment. It actually looks dangerous. They say it looks like a crane. Some of them are a bit frightened of it because of its appearance.

Finally, the customers complain about the *ergonomics* of the equipment. They say it's not very easy to use. It's quite difficult to climb into the harness, for example.'

12 Evaluation 3 Innovations

Task exercise 3 page 94

Student C

GRAPHENE

Graphene = a two-dimensional sheet (1 atom thick) of carbon atoms (see Fig. 3)

Easy to produce: peel a graphene sheet off a piece of graphite (e.g. pencil lead) with a strip of sticky tape

Properties: extremely high electrical conductivity, tens of times stronger than steel, transparent to visible light, doesn't waste any energy as heat

Potential applications

- high-frequency circuits (e.g. in mobile phones) that can contain more data (because of low heat generation)
- nanoscale semiconductors (replacing silicon in future); when graphene is cut into strips less than 10 nanometres wide, it behaves like silicon
- graphene-based solar cells and LCD screens; excellent transparency means more energy-efficient solar cells and display screens
- graphene filters to capture carbon dioxide for storage (CCS) (see Fig. 3); CO_2 molecules flow through nanoscale pores (holes) in a graphene sheet, while larger molecules (e.g. of nitrogen and other gases) are blocked

4 Networks 1 Cyberinfrastructure

Speaking exercise 4 page 26

1. Sensors monitor temperature, air quality, sound and vibration (to detect heavy vehicle traffic), and temperature. The data can be used to suggest the healthiest and unhealthiest routes and times to walk through the city.
2. Sensors measure the micro-climate in different areas of the city, so that residents can get up-to-date, high-resolution weather and climate information.
3. Some cities spend millions of pounds on salt for roads in icy weather. If you have a hundred or a thousand temperature readings throughout the city, you can put the salt where you need it and not put it where you don't need it. That doesn't just save money, but means that less salt runs into rivers, so there is an environmental benefit as well.
4. Observe which areas of the city are heavily populated by pedestrians at different times of the day to suggest safe and efficient routes for walking late at night.

8 Incidents 3 Emergency

Speaking exercise 10 page 63

Student B

INCIDENT

- tanker skids, hits two cars and barrier, turns on side
- container bursts open, unknown dry material pours onto road
- fire breaks out, caused by fuel leaking from cars
- firefighters arrive and put fire out
- water from hoses mixes with dry material
- mixture dispersed, diluted, forced into drains and canal

CAUSE(S)

- HazMat panels covered with debris from crash, cannot be read
- firefighters unable to identify dry material
- fire is sprayed with high-pressure water jets
- dry material was highly toxic fibres, but only identified hours later
- fibres highly toxic, contaminate environment

RESULT

- area of 50 square kilometres sealed off around incident
- canals and drains tested for toxicity
- this process lasts several weeks

1 Innovations 1 Eureka!

Speaking exercise 9 page 5

Student B

Use this information to answer Student A's questions.

PROJECT	TIME SCALE	KEY FEATURES
1 Fracking, Oman	since 2017	5 km deep – pump high-pressure water + sand + chemicals underground – release natural gas from hard rock – 115,000 barrels per day production average – clean well technology reduce CO_2 emissions
2 Shale gas, Saudi Arabia	since 2020	in desert, near Gulf coast – uses seawater + sand in horizontal wells to frack porous rock and release gas – production 550,000 barrels per day – aim to reduce oil burning, carbon emissions

Now find out about the following.

3 GTL project, Qatar: how long? meaning of 'GTL'? how process works? what products? how much fuel produced per day? effect on environment? effect on water supply?

4 Water injection project, USA: how long? offshore? deepwater? how deep? why use water injection? total production? company policy towards net zero carbon emissions?

6 Planning 3 Projects

Task exercise 5 page 47

Arguments against System B

- lower energy efficiency: the vehicle-side motor has high heat loss
- the passive levitation introduces additional drag
- cooling the system is difficult, as all heat-generating components are carried on-board
- contactless power transfer, while promising, has not been validated at scale

8 Incidents 2 Security

Speaking exercise 4 page 60

Student B

1 You are the security administrator at Avantis. Use the information below to answer the security director's questions.

Sequence of events

Time	Alert message on security screen	My response
08.14	Message from helpline staff: "sales employee has reported lost mobile device"	Began monitoring screen for security alerts on sales employee's device
08.45	"4 incorrect password attempts have been made" (using sales employee's mobile)	Concluded must be unauthorised user, so acted to protect server files
08.46		Blocked all files on company server. No files accessed or downloaded
08.50		Disabled sales employee's account remotely
08.53	"GPS shows device location and movement NW at speed of 40 kph"	Forwarded data at regular intervals to Director, Security, to give to police
08.56	"User attempting to install unauthorised software"; "Installation successful"; "Device running unauthorised software"	Attempted to take over remote control of device – successful
08.58		Sent command to device instructing it to wipe all data from device
09.03	"Immediate data wipe operation has completed successfully"	All data permanently removed from device
09.26	"GPS shows no directional movement"	Device must have been thrown away: police now searching

2 Switch roles with Student A. You are the security director at Avantis. Ask the security administrator questions based on the memo on page 60 and make notes of the answers.

12 Evaluation 3 Innovations

Task exercise 3 page 94

Student D

SMART DUST

Smart dust = networks of tiny micro-sensors fitted with wireless communication devices

Sensors powered by vibrations (like a self-winding wristwatch), solar light or changes in barometric pressure

Can detect vibration, chemicals, radiation, explosives, footsteps, climatic changes, seismic shocks, voices, etc. and then transmit them to computers

Can be embedded in roads, walls, packaging; dropped from aircraft like dust, spreading through environment, inter-communicating in networks

Potential applications

- monitoring traffic flow
- monitoring and predicting climatic change
- warnings of imminent disasters, earthquakes, storms from space
- intelligence on military movements

6 Planning 3 Projects

Task exercise 5 page 47

Arguments against both Systems A and B

- a puncture in a vacuum tube could be catastrophic because of air pressure difference
- thermal expansion of steel in the vacuum tube could cause buckling and cracking
- extreme speeds and turning could be uncomfortable because of G forces
- overground tube could be vulnerable to terrorism or sabotage
- emergency stops could be dangerous due to rapid deceleration
- we should use MagLev instead – it's a more mature technology

1 Innovations 1 Eureka!

Speaking exercise 9 page 5

Student A

A: *How long has your company been fracking for gas in Oman?*
B: *We've been fracking there since …*
A: *I see. And how deep are the wells underground?*

Now use this information to answer Student B's questions.

Project	Time scale	SPECIAL features
3 GTL (gas to liquids), Qatar	since 2012	contaminants removed, LPG and ethane (120,000 barrels per day) extracted, then pure methane + oxygen produce clean-burning fuels (140,000 barrels per day) – plant recycles all water from process
4 Water injection, USA	since 2016	deepwater platform – Gulf of Mexico – sea about 1,850 m deep – two wells – injecting water increases pressure, improves oil production – adds total 65 million barrels – aim: use profits to fund transition to net zero

6 Planning 3 Projects

Task exercise 5 page 47

10 Testing 3 Methods

Task exercise 2 page 78

Language for chairing a meeting

Here is a selection of some of the functions and language used by a chairperson.

- **Starting the meeting:** *Right. All right. I'd like to / Let's start the meeting now.*
- **Introducing an agenda item:** *The first item on the agenda is … / Let's move on to the next item (on the agenda), which is …*
- **Bringing in a speaker:** *Alison, could you give us some input here? What did you find out about this subject? Johan, would you like to add anything to that? Who would like to comment at this point?*
- **Thanking a speaker:** *Thank you, Alison, that was an excellent / a very interesting / an extremely useful presentation. / … that was excellent / very interesting / extremely useful input.*
- **Opening a discussion:** *Now, let's / can we throw this item open for discussion.*
- **Closing a discussion:** *I think we've discussed this item enough. Let's move on (to the next item).*
- **Summarising progress at key points:** *Before we continue, I'll briefly summarise what we've discussed so far.*
- **Calling for a decision / vote:** *It's time for us to take a decision / decide on some action / vote for …*
- **Ending the meeting:** *That concludes our meeting. Thank you very much.*

Speed search

Nanotechnology is the understanding and control of matter on the nanoscale, which measures dimensions between about one and one hundred nanometres

A nanometre (nm) equals one billionth of a metre. One human hair is about 80,000 nanometres thick. A sheet of paper is about a hundred thousand nanometres thick. A single gold atom is about a third of a nanometre in diameter. It takes ten atoms of hydrogen side-by-side to equal one nanometre. A DNA molecule is about 2.5 nm wide. A red blood cell is vast in comparison: about 5,000 nm in diameter. Everything on the nanoscale is invisible to the unaided eye and can only be seen by the most powerful microscopes.

At the nanoscale, a material's properties can change dramatically. For instance, carbon in the form of graphite (like pencil lead) is soft and malleable but at the nanoscale it can be stronger than steel and is six times lighter. Aluminium – the material of soft drink cans – can spontaneously combust at the nanoscale and could be used in rocket fuel.

The converter vessels used in the Basic Oxygen Steelmaking process are so huge that they need six-storey buildings to contain them and to house the long oxygen lances that are lowered and raised from the converters.

In a modern steelworks it is common to see basic oxygen vessels which can convert 350 tonnes of metal – from iron to steel – in a single 'blow'. A typical converter vessel is a massive container weighing around 650 tonnes and measuring over ten metres high, with an outside diameter of eight metres. A basic oxygen steelmaking plant normally has two or three converters available for converting iron to steel, with usually one or two in operation at a time and occasional operation of multiple converters simultaneously. Since each converter has a typical working volume of 230 cubic metres, this means that a plant has the capacity to handle several hundred cubic metres of working volume at a time.

The key stage, following the charging of scrap steel and hot metal, is the blow, when the vessel is turned upright and a water-cooled lance is lowered down towards it (without touching the metal). The lance blows 99% pure oxygen onto the steel and iron for periods of around 20 minutes at velocities faster than Mach 1. This ignites the carbon dissolved in the steel and burns it to form carbon monoxide and carbon dioxide, causing the temperature inside the converter to rise to about 1700°C. This melts the scrap, lowers the carbon content of the molten iron and helps remove unwanted chemical elements.

There is a well-known story about Archimedes, the inventor who lived in ancient Greece. Archimedes was asked by his king to find out whether his crown was really made of solid gold or some cheaper metal, and of course, he was not allowed to melt or damage the crown. At first, Archimedes could not solve the problem. Then one day, while he was taking a bath, he noticed that the level of water in the bath tub rose as he got in. His discovery is now known as the 'Archimedes principle'. This states that a body immersed in fluid experiences a buoyant force equal to the weight of the liquid displaced. Archimedes used this principle to calculate the volume of the crown: he simply divided the weight of the crown by the weight of the water displaced by it.

The king also asked Archimedes to design a huge ship. Unfortunately, in those days large ships leaked a lot of water through the hull. To solve this problem, Archimedes invented the 'Archimedes screw', a pump in the form of a cylinder containing revolving blades, which could be turned by hand or by a windmill. This device was placed on the deck of the ship and as the bottom blade of the tube turned, it lifted out a volume of water. The water continued to rise up the cylinder, until it poured out at the top and into the sea. This famous invention is still used for irrigation all over the world. He also invented the 'Archimedes claw', an ancient weapon like a crane, with a hook that could lift ships out of the sea and then drop them into the sea again to destroy them. While Archimedes did not actually invent the lever, he was the first to explain the principle involved behind its working. He once famously remarked, "Give me a place to stand on, and I will move the Earth."

The Client shall make a payment of $3,500 to the Consultant inclusive of all taxes as reimbursement for implementing the installation and testing of the new system, hereinafter[1] referred to as 'the Works', provided that the Consultant performs her duties with due diligence. For the avoidance of misunderstanding, should the Consultant fail to carry out the aforementioned[2] Works in accordance with the agreed schedule, fifty per cent of the payment shall be withheld until such time as the Works have been completed. Notwithstanding[3] this provision, it is hereby agreed that the Consultant shall receive a sum equivalent to ten per cent of the full payment on signature of this Letter of Agreement.

[1] in the rest of this document
[2] already mentioned above
[3] despite

Traditional studies examine small numbers of species in small areas. Large-scale studies tend not to be cost effective or time efficient. However, it is important to accurately monitor the ever-changing patterns of diversity among animal species to help in conservation and animal welfare. In our project, machine learning and artificial intelligence are used to analyse acoustic data to find out the degree of animal biodiversity in specific areas of rain forest. The main type of sensor used in the project is an audio recording device. This is not an ordinary recorder, but one specially designed for collecting bioacoustic data. Both solar-powered and battery-powered sensors can be used since there is adequate sunlight available at most times through the day. Numbers of recording devices, and physical distances between them, can be very great, and some locations may be inaccessible or unsuitable for visiting, and internet connection and bandwidth may be unavailable. The locations we are studying for this project are all in rain forests. For this reason, edge computing solutions are necessary. A single audio recorder may collect up to 50,000 samples of audio per second, so the data has to be processed, often turned into visual images, at the edge by the sensors themselves before transmission to researchers.

	Infrared	Resistive	Capacitive	Sound acoustic wave	Optical
Durability	Scratchproof	Easily scratched	Difficult to scratch	Difficult to scratch	Difficult to scratch
Transmissivity	92%–100%	< 82%	< 90%	< 90%	< 84%
Operating Temp. (°C)	−42 to +70	−10 to +60	−15 to +70	−20 to +50	−10 to +70

The hazard identification number (HIN) consists of two or three figures. In general the figures indicate the following hazards:

2 Emission of gas due to pressure or to chemical reaction
3 Flammability of liquids
4 Flammability of solid or self-heating liquid
5 Oxidising (fire-intensifying) effect
6 Toxic or risk of infection
7 Radioactivity
8 Corrosivity
9 Risk of spontaneous violent reaction

A sample of some UN numbers for HazMat
UN 1818 Silicon tetrachloride, UN 1819 Sodium aluminate, solution UN 1823 Sodium hydroxide, solid UN 1824 Sodium hydroxide, solution UN 1825 Sodium monoxide, UN 1826 Nitrating acid mixtures, spent with more than 50% nitric acid or Nitrating acid mixtures, spent with not more than 50% nitric acid, UN 1827 Stannic chloride, anhydrous UN 1828 Sulphur chlorides, UN 1829 Sulphur trioxide, inhibited or Sulphur trioxide, stabilised UN 1830 Sulphuric acid with more than 51% acid, UN 1831 Sulphuric acid, fuming with 30% or more free sulphur trioxide or Sulphuric acid, fuming with less than 30% free sulphur trioxide, UN 1832 Sulphuric acid, spent UN 1833 Sulphurous acid, UN 1834 Sulphuric chloride

The Sayano-Shushenskaya hydroelectric power station, completed in 1978, is the largest HEP station in Russia, producing enough electricity to power a city of 3.8 million. Extensive repairs were being carried out on the morning of 17th August, so more workers were in the hall than usual: 52 on the main floor and another 63 down in the lower levels of the plant. Nine of the ten turbines were operating at their full capacity – 142 rpm – including the troublesome Turbine 2, which had been offline but which was brought back into service the previous night when electricity production dropped because of a fire at the Bratsk power station, 500 miles to the northeast. Shortly after beginning their work shift, technicians felt the roof begin to vibrate. The vibrations grew louder and gradually turned into an ear-splitting roar, so they climbed onto the roof. At 8.13 am, two massive explosions shook the hall, and then everything went completely dark. Turbine 2, which is a huge piece of machinery around 1,360 tonnes in weight, smashed through the floor of the turbine hall and shot 15 metres into the air before crashing back down. A jet of water from the 190-metre-long penstock that had been spinning the turbine rushed out of the penstock like a geyser at a rate of 256,000 litres per second. The powerful water jet tore down the metal joists over Turbines 1, 2 and 3; the roof of the turbine hall was instantly smashed to pieces and collapsed to the floor in a heap of glass and metal debris.

Over 40 years earlier, NASA's effort to achieve the first manned Moon landing nearly derailed when a fire broke out on the Apollo 1 command module during a test exercise, resulting in the destruction of the module and the deaths of the three astronauts onboard. In the wake of the tragedy, NASA engineers redesigned the Apollo module and searched for ways to enhance the safety performance of the nylon space suits. The suits required an outer layer component that would be strong, lightweight and flexible. Owens-Corning Fibreglass, of Toledo, Ohio – working with DuPont™, of Wilmington, Delaware –proposed a fabric known as 'Beta cloth'. The primary component of this fabric was ultrafine glass filaments, which were twisted into yarns and then woven into the fabric. The manufacturers then coated it with polytetrafluoroethylene (PTFE, more commonly known as Teflon®), a DuPont™ invention. The fabric proved non-combustible (with a melting point over 650°F) and durable enough for NASA's needs. The Agency incorporated the PTFE fibreglass fabric into the outer protective layers of the Integrated Thermal Micrometeoroid Garment (ITMG) of the A7L space suit worn for the Apollo missions and the Skylab program.

An extraordinary account of how the Gulf of Mexico 2010 oil rig disaster occurred emerged soon after the event in interviews with surviving workers from the rig. They said that a methane gas bubble had formed, rocketed to the surface and caused a series of fires and explosions which killed eleven people, destroyed the rig and poured oil into the Gulf of Mexico. An estimated 1,760 km of coastline was polluted and hundreds of thousands of animals were damaged. It is believed that 800,000 birds and 65,000 turtles were killed by the oil spill, in which almost 800 million litres of oil poured into the sea. There have been many marine oil spills since then, such as the oil spill off the coast of Orange County, California in 2021, which poured almost 94,000 litres of oil into the sea and polluted a coastline of 26 km. But the Gulf of Mexico 2010 spill is still widely regarded as the world's worst marine pollution incident.

Opening on 10 June 2000, the London Millennium Footbridge was London's first new bridge over the River Thames for more than 100 years. The bridge, 330 metres long and four metres in width, used the design principle of 'lateral suspension', which was an engineering innovation that allows suspension bridges to be built without tall supporting columns.
In their advance publicity, the designers said that the bridge, with its aluminium decking and steel and concrete piers, would be a "blade of light" across the Thames, "an absolute statement of our capabilities at the beginning of the 21st century". Within a few days, the bridge, which cost £18m to construct, was closed to the public following the famous 'wobble' when it started swaying from side to side. The bridge reopened in 2002 after engineers fitted it with 91 dampers to absorb both lateral and vertical oscillations, modifications which cost an additional £5m.
A scientific study in 2021 threw some doubt on the theory that the wobble was caused by people walking in step with one another.

Audio script

Unit 1 Innovations

1.1

Good morning. My name is Will and I'm the Chief Engineer for Drilling Operations here in Brunei. Thanks for coming.

For the last few years, we've been trying to solve a big problem. The problem is that here in Brunei, in our oilfield, you can't find the oil in one single large reservoir located in one place underground. Instead, the oil is broken up into thousands of small pockets, which are spread over a large area of hundreds of square kilometres. Unfortunately, we cannot build one oil platform for every small pocket of oil. We can't build thousands of oil platforms. That would be too expensive for the company and very bad for the environment. This is the problem that we've been trying to solve for years.

Then, not long ago, a colleague of mine called Jaap took some leave from work and went back from Brunei to his home in the Netherlands. One day he was sitting with his young son in a cafe while his son was finishing his milk shake. Jaap watched his son bend the straw and steer it around the sides of the glass to suck the last drop of milk from it.

Suddenly, while he was watching his son, Jaap had a *eureka* moment. He realised that you could use a flexible drill, just like a bendy straw, to reach all the oil. Instead of drilling down over three kilometres to every tiny pocket of oil using hundreds of wells, you could drill vertically down to one single pocket using only one drill, and then bend it to drill horizontally into the other pockets of oil nearby.

As a result of his *eureka* moment, Jaap and his team invented a new type of flexible drill, called a 'snake well drill'. From a single offshore oil platform the snake drill can bend and twist through many small pockets of oil.

1.2 optional listening

1.3

… and as Jenny said, my name is Lee. So, Jenny has been explaining what laser light is and if there are no questions, we can now turn to the next section of the talk, in which I'm going to outline the basic components of a laser and at this point I'd like you to look at the diagram which is coming up on the screen now.

Right, basically you're looking at a long red cylinder with a yellow zigzag tube coiled around it. Can you all see that? Well, the red cylinder actually represents a ruby crystal and the yellow zigzag represents a tube of lighting, rather like a fluorescent light tube. It coils around the ruby crystal and is of course connected to the power source shown in blue. When the laser is working, this light tube flashes intermittently, on and off, like a series of camera flashes. Anyway, we'll come to that later.

The grey disc to the left of the ruby crystal is a mirror and the one to the right of the crystal is a *partial* mirror, which means that it reflects *part* of the light, about 99% of it, in fact, but allows about 1% of the light to pass through it to the right.

I think I've covered the main components. The large green circles inside the crystal represent atoms and the small blue circles represent photons, or particles of light. Finally, the large red arrow coming out of the right-hand side of the machine is a laser beam.

OK, so before I hand over to Zak, are there any questions at this point? There will be a chance at the end of the complete talk to ask questions, so there's no rush. Right, so now I'm going to hand over to Zak, who's going to cover the next section of the talk, which …

1.4

Thank you, Lee. OK, so if everyone's happy, let's move on to the next section of the talk, section 2, in which I'll try to answer this question: How does the laser machine work?

Well, if you look at point *one* on the diagram, you'll see the power source, which is located below the ruby crystal. This high-voltage electric supply makes the light tube flash on and off.

The light tube, which you can see at point *two* on the diagram, flashes on and off very rapidly and every time the tube flashes, it pumps energy into the ruby crystal. The flashes inject energy into the crystal in the form of photons, which you'll remember are particles of light.

Now, if we move on to point *three* on the diagram, you can see an atom in the ruby crystal is soaking up, or absorbing, the energy from the light tube. When the atom absorbs a photon, it becomes more excited for a few milliseconds and then it returns to its original state and emits a new photon.

As you can see in point *four* on the diagram, the photons which are emitted from the atoms zoom up and down inside the ruby crystal, travelling at the speed of light.

Sometimes, as shown at point *five* on the diagram, one of these photons hits an already excited atom. When this happens, the excited atom gives off two photons of light instead of one. This is called stimulated emission. Now one photon of light has produced two, so the light has been amplified or increased in strength. The light has been doubled. Imagine the light doubling over and over again millions of times.

Now let's look at point *six* on the diagram. The photons keep hitting the mirror at the left-hand side and they keep on bouncing back and forth along the inside of the crystal.

And as you can see at point *seven*, the partial mirror at the other end of the tube reflects most of the photons, about 99% of them, back into the crystal but lets a small number, about 1%, escape from the machine.

And finally, as shown at point *eight* in the diagram, the escaping photons form a very concentrated beam of powerful laser light.

OK, I think I've covered the main points, so would anyone like to ask a question? Would you like me to go over anything again? OK good, so if everyone is clear about how the laser works, I'll now ask Rashida to take over. Rashida's going to move on to the third and final part of our talk, on how we believe that lasers are going to be used in oil drilling in the future and how we think …

Unit 2 Design

2.1

A: So what we need to do now is to brainstorm some ideas for a new product design. Who'd like to kick off? Yes, Kathy?

C: Why don't we use a spin-off from space research? I've heard about a new technology that the space agency has developed. It's like an inflatable bag that encloses the body.

A: That's very interesting, Kathy. Can we brainstorm around that idea?

B: How about using air pressure in the inflatable bag? The inflated bag has to be capable of supporting their weight, without using a winch or harness.

D: And the product should be called something like *MoonWalker* or *SpaceRunner*. That suggests the idea of weightlessness and space walks.

A: Great idea! So what does the new product have to be able to do? Let's focus on performance first.

B: It needs to be capable of supporting the person's weight quite well.

C: You're right. I would suggest it must be able to support up to 80% of body weight, I think.

B: Yes, and the user has to be able to adjust the air pressure in small steps. I'd suggest the increments have to be 1% each.

D: Right! And the speed's got to be adjustable, just like on a normal treadmill. The machine has to be capable of delivering speeds up to 16 kilometres an hour.

A: OK. Can we look at ergonomics now? How can we design the new machine to make it safe and simple for the user to operate?

B: I know! Touch-screen controls!

C: Yes – you've got to be able to control everything by touching a screen. And it needs to have a digital display.

B: And the controls have to allow you to adjust speed and air pressure inside the air bag.

D: And – hang on a minute! – the user has to be able to alter the settings during the workout, without needing to stop the machine.

A: Right. Do we have any ideas about dimensions?

B: Yes. It's got to fit inside a four by two point five metre footprint to allow space around the machine.

C: And it must weigh about the same as a normal running machine.

D: We have to think about the operating environment in which it will work. A normal environment, do you think?

C: Yes, it has to be able to operate in a temperature range of, say, 10 to 29 degrees Celsius.

A: That makes sense. All right, let's move on. What about safety?

B: It's got to be the same as for a normal running machine. The machine needs to comply with BS and EU standards, of course.

A: Great. OK.

2.2

A: OK, we need to brainstorm some ideas for this new tensile roofing fabric that we're going to design. What properties should the fabric have? Who'd like to kick off?

B: Well, I'd suggest that it's got to be lightweight, but also strong. Kilo for kilo, it has to be stronger than steel.

C: You're absolutely right. And it needs to be durable. We want the roof to last at least 30 years without having to be repaired.

D: Right! So, it's got to be low maintenance as well as durable.

A: Good. Now, safety. Let's focus on safety for a minute. Any ideas on that?

B: I know! Non-flammable. It has to be totally non-flammable and non-combustible.

C: I agree, you don't want the roof to burst into flames and start burning. And what about melting point? The fabric has to have a high melting point, so that any fire inside won't melt the roof until it reaches extreme temperatures. Why don't we specify a melting point of over 650 degrees Celsius?

A: Good point. Now, how about sunlight? Any thoughts on that? We want the fabric to reflect sunlight and heat away from it, don't we?

D: Yes, but not all of it! Why don't we allow some of the sunlight to pass through the fabric? Then the building won't need so much artificial lighting.

C: That's very interesting. So the fabric must let *some* of the light and heat come into the building, but reflect *most* of it away.

A: You're dead right. How much sunlight and heat do we want to allow through the fabric? 25%?

B: Yes, that makes sense. So the fabric will reflect the other 75% away from the building.

C: So in other words, the fabric must have approximately 25% solar translucency and 75% solar reflectance. That way it will let in enough natural light, but keep most of the heat out.

A: Brilliant! So you're also saying that the fabric must have good thermal protection?

C: Right! And here's another thing to think about. The fabric will probably be used as roofing for concert halls, so the quality of the sound must be good.

A: Yes, that's right. Good acoustics are essential. So how are we doing on this? Do you think we've covered everything?

Unit 3 Systems

3.1

Beamish Motor Company has just announced that more than ten million Beamish cars are being recalled around the world. This massive product recall operation is being mounted because of fears about the reliability of accelerator pedals in one model. Thousands of Beamish agencies are being informed today about the recall. Adverts are being placed in newspapers and all Beamish drivers are being contacted personally. The affected model is the larger D25A, which has a 2.5 litre diesel engine and an automatic gearbox.

The problem is that, under certain conditions, when you release the accelerator pedal, it may not return fully to the idle position. In other words, it may jam, or become fixed, in the halfway position.

Motorists are being advised to contact their local Beamish dealers for further information.

3.2

Good morning, and thank you very much for coming to this lecture today.

The complete lecture series is about computerised control systems, which, you may recall, are also called *by-wire* systems. That's because they use a wire or cable to carry electronic signals to and from a central computer.

And I'm sure you'll remember that in this series of lectures we're also looking at how these computerised systems are used on both *aircraft* and *land vehicles*.

So let's begin today's lecture. And in this first part, section 1, I want to look at the similarities and differences between the computerised systems used in aircraft and those used in cars and other land vehicles. In other words I want to compare fly-by-wire systems with drive-by-wire ones.

Of course, aircraft and cars use different input and output mechanisms. For example, to change direction, a car uses wheels as the main output mechanism, whereas an aircraft uses wing surfaces. A car uses a steering wheel as an input mechanism to control direction, while an aircraft uses a joystick.

Nevertheless, there is an important similarity between fly-by-wire systems in aircraft and drive-by-wire systems in cars. And that is that both systems use sensors to detect the operator's intentions and, what's more, both systems use computers to tell the actuators, or tiny motors, what to do.

So, to repeat the last point slightly differently, we could put it like this: although computerised cars and aircraft use different input mechanisms, both systems use sensors to detect them. And though they both use different output mechanisms, both systems use computers and actuators to control them.

OK. So now let's move on to the second section. Here I would like to focus on aircraft systems alone and I'm going to compare computerised, or fly-by-wire, controls with the autopilot, or automatic pilot system.

Although both systems use sensors, computers and actuators, they differ in one important way: and that is pilot control. In the fly-by-wire system, the pilot retains control, that is, keeps control of all the movements of the aircraft. The pilot continues to move the input controls and keeps on making all the decisions.

In autopilot mode, however, the pilot establishes the correct course or direction of travel and then hands over control to the aircraft's computer system. The computer then makes all the decisions to maintain the course which the pilot has already set.

So, to recap quickly, we can say that although both fly-by-wire and autopilot systems use sensors, computers and actuators to control the aircraft, they differ in one important feature: in fly-by-wire, the pilot retains full control, whereas in autopilot, the pilot relinquishes control to the computer.

Now finally, I'd like to move on to the third and final section, in which I will very briefly compare the *autopilot* system of an aircraft with the *cruise control* system of a car or other land vehicle.

Essentially, the two systems operate in a similar way, although the specific sensors and mechanisms will differ in detail, of course.

In an aircraft, if the pilot switches on autopilot, they can override the system, that is, they can counteract it at any time, and regain control. Similarly, in a car, when the driver activates cruise control, although the computer controls the speed, the driver can override the system at any time.

One important difference between the two systems is that in autopilot mode, the pilot sets the *direction* of the aircraft and then relinquishes control of direction to the computer, whereas in cruise control of course, the driver retains control over the actual direction in which the car is travelling, at all times.

And that concludes my lecture. Now, does anyone have any questions?

Unit 4 Networks

4.1

[I = interviewer; T = technologist]

I: Tell me something about your project for our city. Are you using sensors as an Internet of Things?

T: Yes, it's an urban measurement project. It consists of a network of interactive, modular devices, or 'nodes' that are installed around the city to collect real-time data on the city's environment, infrastructure and activity. The nodes measure factors that affect life in the city, such as climate, air quality and noise. The measurements are published as open data for research and public use. We based our project on the ground-breaking Array of Things project run in Chicago by researchers at Argonne National Laboratory.

I: How many nodes are there around the city?

T: At the moment over 200, but we hope there will be about 500 eventually.

I: Where are the nodes located?

T: They're mainly at crossroads, about 9 metres above the street, on the sides of buildings, on lamp posts, traffic-light posts and mobile-phone masts.

I: And how many sensors are there inside each node?

T: At the moment each node contains about 30 sensors …

I: 30? Wow.

T: … yes, around 30.

I: And what sort of data do they collect?

T: Well, they measure air quality – you know, particles, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone – and other aspects of the environment – temperature, humidity, precipitation, barometric pressure, vibration, ambient light, and ambient noise levels. There are two cameras, one sky-facing to observe events in the sky, and one street-facing.

I: So the node can observe people and record their sound? That sounds a bit worrying. What about people's privacy?

T: Oh, privacy is built into the system. The nodes use edge computing as well as cloud computing.

I: Can you explain?

T: Sure, edge computing means that the data analysis is done at or near the data source – in this case in the nodes themselves. The nodes can analyse large quantities of data such as high-resolution images and sounds without saving or transmitting the actual data. It transmits the analysis to the cloud, but deletes the data itself – the actual images or sounds. Privacy is guaranteed.

I: Can you give me an example of what the nodes can do?

T: Yes. They can analyze an image from their cameras several times a minute to count the number of pedestrians and the number of vehicles, reporting these numbers and then deleting the images. They can also measure factors such as flooding, recognizing vehicle type – is it a car, a lorry? – and even whether a vehicle is electric or petrol-powered.

I: Can the sensors interact with individual mobile phone apps?

T: They can't communicate in any way with mobile devices. But people can download data from the sensors to their own phones. Imagine you're walking through the city and you're running an app on your phone, that app will see one of our nodes and it will grab all the data from the sensors and store them on your phone. Now at the end of your week you can see the number of steps you took, but you can also see what your exposure to carbon monoxide or to excessive noise was.

I: Well, that's all very interesting. Thank you …

4.2

(Slide 1, please.) Good morning, and thanks for coming. My talk today is about how sensors became intelligent.

Big data needs intelligent sensors that can analyse and stream data directly into computer models in real time.

How did sensors become intelligent? Let's have a quick look back in time.

At first, years ago, sensors only collected and saved data. (Slide 2, please.) Data simply sat inside or near the sensors. Scientists had to download the data and analyse it. This took up a lot of time.

Next, (Slide 3, please) sensors became smaller and turned into micro- and nano-sensors.

Then (Slide 4, please) they were connected to wireless networks which linked the sensors to local computers, and later, to the Cloud.

There were two problems with this. (Slide 5, please.) First, scientists still had to download the data before they could analyse it. Second, the data streams from these early sensors were relatively small.

Two key developments changed this.

First, sensors became more powerful. (Slide 6, please.) Soon they could capture high-definition images and videos. Here are some examples. (Slide 7, please.) They could produce huge quantities of high-quality data. Look at this example. (Slide 8, please.)

But this also created a problem. (Slide 9, please.) These massive amounts of data could quickly use up all the available storage space. Transmitting huge quantities of data took up too much bandwidth.

The second development solved this problem. (Slide 10, please.) Over years, processors became more and more powerful. They became smaller and cheaper. You needed less and less power to run them.

The result? Edge computing. Intelligent and attentive sensors. Imagine a system with hundreds or thousands of sensors. Each sensor analyses huge quantities of data on site. Then it deletes the raw data and streams the analysis in real time straight into the computer modelling system.

Any questions at this point?

Unit 5 Processes

5.1

A: Good morning, I'm Jacek, your workshop leader and I'd like to start by welcoming you all to this conference workshop session entitled *Is carbon-free steelmaking possible*? Time is short, so let's get started. Let's begin by brainstorming the causes of carbon emissions from steelmaking. We can use this fishbone diagram on the whiteboard to help us.

B: What's the fishbone diagram for?

A: It's a useful aid. It'll help us to think of all the possible causes and effects involved in the problem. Right, who wants to kick off?

B: A lot of furnaces around the world are quite old. Carbon gases could be leaking from the furnaces because of their age.

C: Or because of poor maintenance. The leaking furnaces might be caused by poor maintenance. It's a common problem.

B: Yes, poor maintenance could result in leaks not being repaired.

A: All right, I'll put leaking furnaces, and the two causes – age and poor maintenance – under *machinery* on the fishbone. Any other ideas?

B: Well, maybe the real cause of the emissions is the filtration process. The high carbon emissions could be a direct result of an inadequate filtering process.

A: You're right. OK, so I'll just put that on the fishbone. So the filtration process would go under *methods*, right, not machinery?

C: That's right. But perhaps another problem is the actual filters that are used. So faulty *filters* would be a *machinery* problem.

B: Correct. Can I go back to the maintenance issue? Maintenance is not just a machinery issue. It's also a *manpower* issue, isn't it?

C: Absolutely. Poor maintenance is usually the result of poor training.

A: Not only inadequate training. Weak supervision can also result in careless maintenance.

C: Yes, you're right.

A: OK. So we've looked at machinery, methods and manpower. But we haven't considered raw materials yet.

B: Now that's a thought. Maybe high carbon emissions are due to the high carbon content of the iron that's often used in steelmaking.

C: I agree and high-carbon iron could be the result of using poor quality coke.

B: You're right, the fault may lie in the coke. Or maybe the problem is caused by the other raw material – the scrap steel, you know, the scrap steel which is recycled to make the new steel. Perhaps the carbon content of the scrap steel is too high.

A: So the high carbon emissions could result from high-carbon scrap steel being used as the raw material. I'll just write that on the fishbone. So, that covers the main causes of …

🔊 5.2

1 The leaking furnaces might be caused by poor maintenance.
2 Yes, poor maintenance could result in leaks not being repaired.
3 The high carbon emissions could be a direct result of an inadequate filtering process.
4 Maybe high carbon emissions are due to the high carbon content of the iron that's often used in steelmaking.
5 So the high carbon emissions could result from high-carbon scrap steel being used as the raw material.

🔊 5.3 optional listening

🔊 5.4 optional listening

🔊 5.5

In my lecture today, I'm going to explain how alumina is smelted, or converted, into the metal that some of us call *aluminium* and others call *aluminum*, depending on which side of the Atlantic you come from.

The method uses electrolysis, which is the process of using an electrical current to create a chemical reaction and in this way it is similar to green steelmaking.

First, let's look at the equipment which is used in the electrolytic smelting process. The electrolysis takes place inside a huge container, called a *pot*. And as you can see on the diagram, which is on the screen now, the smelting pot has a steel outer shell.

If you look at the lower part of the inside of the pot, you can see the carbon layer. This is a thick layer of carbon blocks, which line the bottom of the pot. Then you can see the iron bar situated below the layer of carbon blocks. The iron and the carbon, of course, are highly conductive of electricity and in fact the carbon layer and the iron bar act together to form the cathode, or negative terminal, for the electrolysis process.

And, of course, you know that if there is a *cathode* there must also be an *anode*, in other words a positive terminal for the electrolysis. Here the anode is in the form of two large carbon blocks suspended from the top of the pot. These blocks are labelled the carbon anode on the diagram.

So now let's go though the seven stages of the aluminium smelting process. In the first stage, the alumina powder is fed into the pot through a large hopper at the top, as you can see at the top of the diagram.

Once it is inside the pot, stage two begins. Here the alumina is inserted through the layer of frozen electrolyte which you can see on the diagram. This layer forms a hard crust on the surface of the electrolyte.

Stage three is where the alumina powder, after passing through the frozen electrolyte layer, is dissolved in the molten electrolyte. In the diagram, this mixture is labelled molten electrolyte plus alumina, just below the layer of frozen electrolyte.

As soon as the alumina has been dissolved in the electrolyte, stage four takes place. In this stage, an electric current, a direct current, flows through the mixture from the anode at the top, through the mixture of electrolyte and alumina, to the cathode formed by the carbon layer and iron bar at the bottom.

Now stage five takes place. As a result of the current flow, the temperature inside the pot rises to approximately 950 degrees Celsius. This causes each molecule of alumina to break down into separate molecules of aluminium and oxygen.

Then in stage six, the pure molten aluminium becomes much heavier, because the oxygen has been released from it. The weight of the pure molten aluminium causes it to be deposited at the bottom of the pot.

Finally, after sinking to the bottom, the molten aluminium is tapped, in other words poured out of the pot through a tap hole into a ladle and then transferred to a furnace where it can be cast or worked into different shapes. Right, so those are the seven stages of the …

Unit 6 Planning

🔊 6.1

A: Right, OK let's look at all the possibilities and quickly assess their chances of success. First, what about sending down some remotely-operated underwater vehicles, you know, ROVs to activate the BOP? What are the chances of success? On a scale of one to five?

B: Only one, I'm afraid. We should try it as a first option, but it's highly unlikely that it will succeed. Once a BOP has failed, it's hard to repair it.

A: OK. So if we can't activate it, what about pumping mud into it, under high pressure?

C: That's also worth trying, but the probability that it will succeed is very low. It takes time to set up the pumps so let's try that once other options have failed.

A: OK. So how about drilling a second well to meet the original well – a relief well? You know, to relieve the pressure of the oil and stop it pouring out?

D: That's definitely the best solution and it's virtually certain that we can stop the leak that way. The only problem is that it'll take two to three months to set up the rig and drill the well. We'll have to try other options while we're drilling.

A: How about lowering a heavy container or cap over the fractured riser? Then we could pump the oil up from the cap to a ship?

C: I'd give that a score of three out of five. It's possible that a container will work. But it's hard to position a large cap correctly. And sometimes hydrate crystals form, like ice, caused by the gas leaking into cold water. The crystals can block up the cap.

A: So, can we lower a smaller container first and use it to pump in methanol to stop the crystals from forming?

C: That might work … yes there's a possibility that it will work, but a small container won't be heavy enough to seal in the oil completely.

A: So we should send down the small cap first, pump in the methanol, then lower the big cap over it?

C: Yep, the two caps together will possibly succeed. But we need to keep drilling at the same time in case they don't.

A: You're right, let's keep the drilling going as a backup plan. Here's a thought … what about just inserting a long pipe or tube inside the broken riser?

D: It's a nice idea, but it will take time to build the tube. We'd need about two kilometres of tubing, and a strong seal.

I'd say that it's highly likely that the tube will work, but we should try other options first.

A: What about solutions on the sea surface? Booms, burning, skimming, spraying?

B: We need to keep on doing them all the time, while we're working subsea. But it's highly unlikely that booms and other surface operations can stop the oil reaching the land.

A: OK, let's start multi-tasking ...

6.2

A: Right, Ken, give me a quick update on the subsea operations, would you?

B: Sure, Sayeed. The remote subsea equipment is about to be activated.

A: That's the ROVs, right?

B: Yeah.

A: OK, so we can get some immediate subsea action?

B: Yes, the ROVs are on the point of being sent down to the BOP. They'll be mobilised at first light tomorrow. When they're at the site of the leak, several attempts are going to be made to activate the BOP remotely.

A: Good. And if the BOP can't be activated ...?

B: Well, if that doesn't work, a small cap is going to be lowered to the site, where it will fit exactly over the broken riser. Methanol is going to be pumped into the cap to stop hydrate crystals forming over the gas leak.

A: And failing that ...?

B: Failing that, a larger cap will be fitted over the small one. We're quite hopeful that the leak will be completely contained by the two caps.

A: Good, but we'll still need the other options.

B: Yes. By this time, the two-kilometre insertion tube will have been constructed, so if the caps have failed to stop the leak, attempts will be made to insert the tube into the broken riser.

A: Well, let's hope that works. But if the tube fails ...?

B: Well, by then, the mud pump will already have been prepared so it will be ready to begin operating. Tons of mud will be pumped under high pressure into the BOP.

A: OK. And the long-term plan?

B: Well, by this time, the rig will have been transported to the site and will have been installed, so if the mud pump fails to stop the leak, drilling on the relief well will be able to start immediately.

A: Good. All right, let's get to it.

Unit 7 Products

7.1

A: So what do you reckon? What kind of touch screen should we install in airports and railway stations? A resistive type, or a capacitive one?

B: Do you need a bright screen with good clarity? If so, you may have problems with the resistive screen. The two metallic layers on the screen filter out more light. The clarity of the capacitive screen is much greater than that of the resistive one.

A: Why is that? Don't capacitive screens have metallic layers?

B: Yes, but, unlike the resistive screen, the capacitive one has only *one* metallic layer, which acts as one plate of a capacitor. Your finger acts as the other plate.

A: Hang on a sec. What's that about capacitors?

B Shall I explain how the two systems work?

A: Good idea, thanks, that would be useful.

B: Basically, the two metallic layers of the resistive screen form an electrical circuit. You press the layers together to complete the circuit at the point of contact ...

A: Aha.

B: ... whereas with a capacitive screen, instead of using pressure, you touch it very lightly. The screen stores an electrical charge and your finger acts as a conductor, pulling current towards the contact point.

A: Yes, I see. And that means that you can only use your finger with a capacitive screen, whereas you can use any object, such as a pen, with a resistive screen, is that correct?

B: Yes, that's right. You could say it's a disadvantage of the capacitive screen. On the other hand, you're less likely to scratch the screen surface, because it only works with a finger.

A: That's a good point. So does the capacitive screen resist scratches better than the resistive type?

B: Not really. Both types will scratch very easily if you attack them with a sharp object.

A: Yeah, that makes sense! OK, the last thing I want to check is durability. Which one is longer lasting?

B: Well, compared with the capacitive screen, the resistive one can wear out very quickly.

A: Oh? Why is that?

B: That's because the metallic layers of a resistive screen are pressed together thousands of times a day. Eventually the circuitry wears down.

7.2

Welcome to this launch of our new product, a flexible wearable device that combines an antenna with a rectenna to be used with wearable medical sensors.

Yes, you heard that right – a rectenna. It's a rectified antenna. While an antenna converts electrical current to radio waves, a rectenna does the opposite. That is to say, it converts energy from radio waves into electricity.

Why do we need such a device? There are two main needs. First, there's a lot of research currently going into flexible wireless sensors that can be worn on a patient's body to collect medical data. So the question is, how do we transmit this data wirelessly? We don't want to burden the patient with lots of wired connections. That's why we need a flexible antenna.

The second need is for new sources of energy to power the sensors. Other energy sources have drawbacks. Solar power? That only works when the device is exposed to the sun. Motion-powered devices? They only work when the body is moving.

But there is plenty of ambient energy – in other words, energy around the patient's body – such as radio waves from 5G wi-fi, mobile phones, microwaves and so on. The energy is always there, even when the patient is asleep. Why not collect it and use it? Another way of putting it is that we should harvest that energy, just as we harvest food from the ground.

To meet these needs, our research team has produced a flexible, wearable rectenna (to power the sensor) and antenna (to transmit the data).

The system consists of two stretchable metal antennas embedded into conductive graphene material with a thin metal coating. This system is then connected to a stretchable rectifying circuit, that is, the rectenna.

The device has a number of important properties: it's safe for use on human skin, it operates at room temperature and, most importantly, it's not damaged by twisting, compression or stretching. To put that another way, it's stretchable and flexible enough to fit into the human body's constantly changing shape. And it can continue harvesting energy and transmitting data even while being stretched, twisted or squeezed.

Now, our researchers had to solve a problem. Flexible antennas generally have one drawback: when they are compressed or stretched, their resonance frequency, or RF, changes. This can make them transmit radio signals with the wrong wavelengths.

To understand this in more detail, let's look at what antennas are and what they do. Antennas transmit signals by using an oscillating electrical current in a length of conductive material to generate electromagnetic radiation. To put that in everyday language, an antenna is basically a rod or length of material that can conduct electrical current. The current vibrates at a particular speed and the vibration sends out magnetic waves, known as radio waves. It's a bit like throwing a stone into a pool of water. The vibration of the stone hitting the water sends out waves in all directions. These waves move at a fixed frequency.

In the same way, the radio waves from a fixed-length antenna move with a fixed frequency, which is called the RF or resonance frequency. But if you change the length of the antenna, you change the RF, and this is the problem with flexible antennas in general.

Our research team decided that the solution was to use a broadband transmitter so that it continues to work at the correct RF even when the antenna is stretched, bent or twisted. In other words, our device is resilient.

Now, are there any questions ...?

Unit 8 Incidents

8.1

A: I've called this meeting so that we can discuss the three inventory items missing from the warehouse. Apologies for the short notice, but this is urgent. So, can you bring me up to speed? What do we know about this? Helen? Any computer data? What do we know about the location of the theft?

B: Well, the RFID tags on the cartons scanned positive at the picking stage, so that means that the cartons can't have been stolen while they were being received from the truck.

A: OK, so we can rule that out. Thanks, Helen. Jeff? What about the time of the incident? What do we know?

C: Well, we know that the incident must have taken place no more than fifty-five minutes before it was reported at 9.25.

D: Another point about location, Bill. The goods certainly couldn't have been removed from the racks before they were picked. Again, data from the RFID tags show that.

A: Well, it's useful to rule out another possibility. So where does that leave us now? Does it tell us who the thief was?

D: Well, yes, to some extent. At least we know it wasn't a trucker, so the theft has to have been carried out by a warehouse worker. It just has to have been an inside job.

A: OK, so are we any closer to knowing the exact location of the theft?

B: Well, it might have taken place in the staging area. But that's just one possibility. The other is that the goods could have been stolen straight after they were picked and just before moving into the staging area.

A: OK, we're narrowing things down now. Is there anything we should do immediately?

C: Yes, all the CCTV footage around the staging area and the picking zone ought to be reviewed right away.

A: OK. While we're all here, have any mistakes been made? We'll have to think about that for the final report.

D: One obvious error was the faulty portal – portal C – between the picking zone and the staging area. That shouldn't have been left unrepaired for so long.

B: Yes, and while the portal was out of action, a hand scanner ought to have been used at the portal.

A: OK. So have we started interviewing staff yet?

C: Yes, that's in hand. By the way, the police ought not to be informed yet. Wait till we get some more information.

A: Right.

8.2

The purpose of this short slide show is to describe the warning panels used to warn people about hazardous materials, or HazMats. By law, these panels have to be attached to containers and vehicles transporting dangerous substances. Most of you already know about these, so I'll move through the slides quite quickly.

Right, so if you look at the first slide, you can see the types of warning panels used in most countries around the world. On the left, Figure 1 shows the orange coloured panel used by most European countries. As you can see, the bottom half gives the UN number, which identifies the substance. Every substance has its own unique number. In this example, 1828 means that the substance is sulphur chloride. The top half of the panel contains the hazard identification number or HIN. This tells you how dangerous or hazardous the substance is. In this example, the number 8 signifies that the substance is corrosive and the double number means *very* – so 88 means that this substance is *highly* corrosive. Is that clear? And the X means that water must not be used with this substance, as it reacts dangerously to the presence of water.

Right, so let's have a quick look at the other two panels. Figure 2, the diamond-shaped one coloured white, yellow, red and blue, is commonly used in the USA. And the third panel, shown in Figure 3, is the one still used in the UK and also some other countries such as Australia, New Zealand and Malaysia.

8.3

A: So now, does anyone have any questions?

B: Yes, erm, does the European panel give all the information needed in an emergency?

A: Up to a point, yes it does. The HIN and UN numbers are all you need, really.
B: Does the panel in Figure 3 give the clearest information of the three?
A: Actually, I think it is too complicated. I prefer the European one.
C: Do all large vehicles have to have a warning panel?
A: Definitely not. Only vehicles carrying dangerous substances have to have a panel.
C: Has the use of the panels helped to avoid serious accidents?
A: Absolutely. Incident reports show that many accidents have been avoided because of the panels.
D: Is the UN numbering system too complex?
A: On the contrary, it's completely simple and each substance has its own number.
B: Do European vehicles ever show hazard symbols, such as the skull and crossbones for toxicity, on the warning panel?
A: In fact, European vehicles *do* show hazard symbols, but they're in a different location on the vehicle, not in the warning panel itself.

Unit 9 Agreements

9.1

A: So how would your system keep an eye on security issues, such as a break-in by an intruder?
B: Well, if someone broke into your factory, intrusion sensors would immediately set off an alarm and trigger a series of events throughout the network.
A: What kind of events?
B: Master lights would turn on, emergency services would be automatically notified, video cameras would home in on the area where the break-in occurred and monitor the intruder, and all the door locks would be activated. All these events would happen simultaneously.
A: That sounds interesting.
B: I would therefore recommend that you purchase the full security package.
A: You mentioned that you could reduce our energy costs if we installed your system. How would you go about doing that?
B: Well, a Cygmar system would control the heating, cooling, lighting and air quality.
A: How would the lighting be controlled?
B: You see, all the lights in the factory could be fitted with radio-enabled motion sensors so that they could be programmed to turn themselves on and off whenever staff make their way into or out of an office or workshop. This would help you cut down on energy costs.
A: Now that is very interesting indeed.
B: Yes, and that's why I strongly recommend going for the full utilities package.
A: Don't all these radio-enabled sensors and inter-communicating devices use up huge quantities of electricity?
B: No, on the contrary, they use very low power. This is because their default mode is 'asleep' and they are only activated when they're needed. They transmit and receive only small amounts of data and so high speed is not necessary. Batteries in a Cygmar network can last up to five years, unlike those in other systems.
A: Five years? That's very impressive. Some Wi-Fi systems have batteries that run down after a few hours.
B: That's quite true. I propose that you purchase Cygmar batteries for all your devices, because they come with a five-year guarantee of long life.
A: All right, I'm impressed. But what would happen if a battery in a smoke detector or other sensor went dead? How would the network operate? Would that close down the whole system?
B: No, not at all. That would not cause a problem. The system uses mesh networks, which are self-healing and repair themselves.
A: What do you mean?
B: Well, if a device failed, the rest of the network would raise the alarm and all the signals would by-pass the failed device, using a different route to the controller.
A: I see, that sounds very clever.
B: Yes, it's a so-called intelligent system. I would definitely recommend that you choose the self-healing mesh network option.

9.2

A: Liam, I've reached agreement with Cygmar about the automated factory project. Can I run through the main points with you? I'll follow up in writing, of course.
B: All right, Joe. Do you want our usual standard clause at the beginning?
A: Yes: we'll only pay them in full on condition that we're happy with their work and they've followed the terms of the contract.
B: That's it. What else do you want in?
A: Well, they'll give us a 15% discount on the total price provided that we let them choose the starting date for the installation.
B: OK, but what if they just turn up without warning?
A: Right, so the next condition is that they can select the starting date as long as they give us a fortnight's notice.
B: Yes, that should do it. Now supposing they finish the job late?
A: Yes, in case they miss the deadline, we can deduct 1% from their payment for every week they're late.
B: Good. That'll give them the incentive to finish the job!
A: Right. Next: we have the option of cancelling the contract and getting our money back in case they sub-contract the work to another company.
B: Aha.
A: And, finally: even if we have to close the factory for a short time, the deadline will stand unless we both agree in writing to change it.
B: Fine. Is that it?
A: Yep.
B: OK, I'll get the team to draw up the contract for you.

Unit 10 Testing

10.1 optional listening

10.2

The London Millennium Footbridge is an interesting case study even today so many years after the event. You may have read that the bridge had to close down soon after opening because of the excessive lateral movement, or swaying, that occurred when pedestrians began walking on the bridge. As a result, we were engaged by the engineers to carry out a test on the bridge and write a report on our findings.

So that brings us to the main objectives of this test. First, we wanted to confirm that the lateral, or sideways, movement was caused by the movements of the pedestrians and not some other issue. And secondly, we wanted to discover the critical, or minimum, number of pedestrians, in other words how many pedestrians would start the bridge moving.

So this is how we set up the experiment. On the day of the test, we opened up the bridge and trained 200 people to act as pedestrians walking across the bridge for 20 minutes. We installed motion sensors to measure the movements of the bridge. We also set up video cameras at various points to record everything.

And this is what happened in the test. First of all, only 50 pedestrians started crossing the bridge, all walking at different speeds. Then, every few minutes, we sent about ten more people, then another ten and so on, gradually increasing the numbers on the bridge. As soon as the bridge started moving significantly, we stopped the test. During the test, our computers received data from the sensors and the video. We then used this data to calculate the lateral forces acting on the bridge.

The results were very clear. You can see the main result on the graph marked Figure 1. The red line represents the bridge's lateral movement. You can see from this that the bridge was stable with 156 people on it, but then with just ten more people, when there were 166, the movement suddenly accelerated.

So what conclusions did we draw? Well, the first thing we concluded from the test results was that the force exerted by pedestrians walking on the bridge had some effect on the movement of the bridge. Secondly, the increase in movement was not gradual, but sudden. And thirdly, the critical number of pedestrians was 166. Below that number, any movement of the bridge was insignificant. But as soon as that number was reached, the bridge began to move significantly.

Why did this happen? We thought that 166 people were enough to make the bridge sway a little. They noticed the slight movement. As a result, they all began walking together, in step, like soldiers. This suddenly increased the force on the bridge and made the bridge start swaying significantly from side to side.

Unit 11 Accidents

11.1

Situation 1

A: Ah, that's not right. The speed.
B: Yes, it is. There. It's showing 80.
A: It feels wrong. Too slow.
B: No, it's right. Hundred and twenty.
A: Nah, I don't think it's right … ah well, maybe it is.
B: Hundred and forty.
A: I don't know.

11.2

Situation 2

A: Ah, that's not right. The speed.
B: Yes, it is. There. It's showing 80.
A: It feels wrong. Too slow.
B: No, it's right. Hundred and twenty.
A: Captain Benson!
B: Yes?
A: I've got a real worry here.
B: What is it?
A: There's not enough power. Maybe the indicator's wrong.
B: Could be the sensor. Ice.
A: Let's disregard the indicator. Does that sound good to you, Captain?
B: Yep. Giving more throttle now.

11.3

Situation 3

A: Raul, turn up the turbine speed to 135, would you?
B: But that's almost maximum.
A: Yes, I know, but we have to. We've been told to increase output.
B: But it's shaking and vibrating like a …
A: These turbines are strong enough to last for years.
B: Hey, Boss!
A: Yes? What is it?
B: I've got a real problem with this.
A: Why, what do you mean?
B: If the turbine vibrates any more, the bolts won't be able to hold it. The turbine will break away.
A: I've made my decision. Just turn it up to 135 right away, please …
B: Look, this is dangerous. The vibration is four times the maximum.
A: … and report back to me in an hour.
B: Could you stop what you're doing and listen, please. This is serious. The vibration is at danger level. Let's turn the speed down to 129 for 15 minutes and monitor it. What do you think? Do you agree with that, Boss?
A: All right, Raul. Turn it down while we watch it.

11.4

A: Are you saying that you don't know what caused the crash?
B: Yes, because we couldn't find the flight recorder, the black box with all the data. But we have been able to come to two main conclusions.
A: Which are?
B: Well, first we think that the pitot tubes must have malfunctioned when the aircraft hit the thunderstorm.
A: Pitot tubes? They're for measuring speed, aren't they?
B: Yes, they're the airspeed indicators. They're 9-centimetre-long tubes located under the wing facing the direction of flight. They tell the autopilot system the speed of the aircraft. We believe they froze over in the storm and disabled the autopilot.
A: And what happened then?
B: The pilot probably didn't know about it until the plane flew too slowly, stalled and fell out of the sky.
A: How do you know this?
B: We don't know for sure. We have weather data and flight data, so we know the plane hit a high-altitude storm. And in his last radio transmission to control centre we hear the pilot shouting that the plane is stalling. Then it goes dead.
A: So the pitot tubes are to blame?

B: Yes, that's one theory. The report recommends that all the pitot tubes should be inspected and replaced if necessary.
A: You mentioned two theories. What's the second one?
B: Poor communication in the cockpit. We think the co-pilot must have realised the speed was too slow, but couldn't convince the pilot to take manual control.
A: And your evidence?
B: In one of the pilot's last radio transmissions to control centre, we hear another voice in the cockpit shouting something about speed, but we don't hear a response from the pilot.
A: Ah, that's tragic. So what can you do about that?
B: Well, in the report we recommend that the airline should train flight crew on how to communicate effectively in an emergency.
A: Fine. Well, thank you very much.
B: You're welcome. There's an attachment to the report with a transcript of all the radio communications and a brief explanation of how pitot tubes work, if you're interested.

Unit 12 Evaluation

12.1

Good morning and thanks for coming. My name is Tina Wilson and I'm an engineer and partner of the Desert Water project. This is a pilot project which we hope to develop into a large-scale food production programme.

In this short presentation, I'm going to tell you about the results of our recent evaluation of the Desert Water pilot project.

Let's quickly remind ourselves about the objective that we specified when we first set up the project. The aim at that time was to pilot a low-energy food production system in a coastal desert region, using only seawater, sunshine and nutrients from the sea.

There were four criteria, or requirements, that the project had to meet in order to be judged a success.

The first was that the system had to be simple, imitating natural processes as far as possible.

Secondly, the system needed to use minimal power, so that we were not obliged to rely on electricity from an electrical grid or masses of generators.

Thirdly, the system had to rely on seawater and sunshine as inputs or raw materials for the soil. No one was allowed to use water from outside on the crops. We were not even supposed to use nutrients bought from outside, but were supposed to extract all the nutrients from the seawater.

The final requirement was that the system needed to be low-cost. Locals had to be able to build them cheaply using local materials, so we set a requirement that you had to be able to build a greenhouse for under 35 euros per square metre.

So how successful was the pilot project? To what extent did it meet the four criteria that I've just mentioned? Let's move on to the evaluation of the project.

Well, on the first requirement, simplicity, we were able to design a process that perfectly imitates the water cycle where seawater heated by the sun evaporates, cools down to form clouds and returns to the Earth as rain, fog or dew.

Using the second criterion, low power, we demonstrated that the system was capable of operating with very little power from outside sources. A generator had to be used for the pumps and the fans, but most of the operation could be carried out using natural processes such as winds, gravity, evaporation and condensation.

Thirdly, concerning inputs, we didn't need to use any fresh water from outside the system on the crops, because the system proved capable of supplying all the water needed. However, at this pilot stage, it turned out to be impossible to use only nutrients extracted from seawater. We were forced to buy in fertilisers.

And on the final criterion, cost, we showed that we were able to build the greenhouse within the per-square-metre target of 35 euros.

So was the project a success? I think on behalf of the project team I can say that it was. Three of the criteria that we set ourselves – simplicity, power and cost – were fully met, while one requirement – inputs – was only partially met because of the nutrients issue. However, we can still say that seawater and sunshine were the principal inputs. Now, does anyone have any questions?

12.2

A: All right, let's look at the first target on the appraisal form. You were supposed to roll out the new email software to every department. You've put 'N' in the box, but you've given yourself a score of eight, or 'good'.
B: Yes, that's right. I managed to roll out the software to most of the departments.
A: But hang on a minute. The software was supposed to be rolled out to all the departments, not just some. So I have to ask, to what extent was this target actually achieved?
B: Well, I was only able to reach 60% of the departments.
A: And why couldn't you reach the other 40%?
B: Well, basically, I wasn't able to get full co-operation from some department heads.
A: What do you mean? Couldn't you get on with the managers? Could you expand on that a little?
B: Really I had no problem with personal relations, but basically I wasn't allowed to meet individual staff to discuss their needs.
A: So how did you go about overcoming the problem?
B: I decided to hold large inter-departmental meetings to explain the roll-out to everyone at the same time.
A: And how did that turn out?
B: It wasn't very successful, because I still couldn't get hold of all the feedback I needed.
A: So, what lessons have you learned? What should you have done?
B: Well, I reckon that I should have set up smaller meetings with senior staff in each department. And I shouldn't have gone ahead with the inter-departmental meetings.
A: All right, so how would you go about doing things better next time?
B: Well, next time I think I wouldn't keep problems to myself. I would communicate more openly about them as soon as they came up. I think that if I had spoken to you earlier, I could have come up with a solution.
A: All right, well at least you've done some thinking about it. Now, I've given you a score of six, which means 'satisfactory'.
B: Yes, I can see why.
A: But I'm pleased that you've given the issue some thought already. So I'll make a note about how you plan to improve next year.

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