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Передмова

У сучасних умовах розвитку вищої освіти особливого значення набуває забезпечення її якості та відповідність міжнародним освітнім стандартам. Однією з ключових вимог, задекларованих у рамках Болонського процесу, є формування у випускників закладів вищої освіти високого рівня володіння іноземною мовою, що дає змогу ефективно використовувати її у професійній та науковій діяльності. Відтак, метою навчання іноземної мови спеціального вжитку є не лише засвоєння мовних знань, а й формування здатності використовувати іноземну мову як ефективний інструмент професійного спілкування. Важливим аспектом такого навчання є розвиток умінь працювати з фаховими текстами, опрацьовувати науково-технічну інформацію, брати участь у професійно-орієнтованому спілкуванні, а також презентувати результати власної діяльності іноземною мовою.

Запропонований навчальний посібник спрямований на формування у студентів навичок читання та розуміння оригінальної науково-технічної літератури, розширення професійного словникового запасу, а також розвиток умінь реферування, анотування та усного мовлення в межах опрацьованої тематики. Окрема увага приділяється розвитку навичок самостійної роботи з текстовими матеріалами та вмінню аналізувати й інтерпретувати інформацію іноземною мовою.

Структурно посібник складається з 11 розділів, кожен з яких містить тематичні тексти, систему вправ, лексико-граматичний коментар і словниковий мінімум. Запропоновані завдання спрямовані на поступове формування навичок розуміння та використання лексики науково-технічного стилю, а також сприяють активізації лексичного матеріалу, закріпленню граматичних конструкцій та розвитку мовленнєвих компетентностей студентів.

Посібник розрахований на студентів закладів вищої освіти, які вивчають іноземну мову з професійною метою, і може бути використаний як у навчальному процесі під час практичних занять, так і для самостійної роботи студентів. Він також стане у пригоді викладачам іноземних мов як допоміжний матеріал для організації навчального процесу та розвитку професійно-орієнтованої іншомовної комунікативної компетентності здобувачів освіти.

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Dear Student,

The material in front of you is both a student's book and a workbook with lots of, hopefully, interesting and varied exercises (the symbol of a pencil will lead you into exercises: K) - *there will always be an example to help you solve these exercises more easily,* and also some homework (a symbol of a hard-working student means you have obligations to fulfil and tasks to perform at home - Ш - you will do this through e-classroom if you are already using it otherwise in the old-fashioned way, on paper) which will help you understand and learn more about the area of mechanical engineering and also revise a little grammar.

The book includes different chapters, from more general ones to extremely specific and field-oriented, such as: introduction, different kind of companies, engineering, numbers and shapes, computer science, materials, tools, health and safety at work, automotive etc. As mentioned above, there are plenty of different exercises included. At the end of each chapter there is a short summary and a few revision tasks. This way you will be able to revise each chapter before moving onto a new topic.

We hope the material in front of you will help you enter the world of technical English and be a challenge for further learning in this field.

1. INTRODUCING AND MEETING PEOPLE

After this unit you will be able to introduce yourself properly, especially in business situations and learn how certain countries and different nations behave in business situations. You will be also able to use present forms and express ability, obligation, and permission and give advice.

So, how do we introduce ourselves? Have you ever met a person from another company and introduced yourself to them? Or have foreigners been introduced to you?

You can introduce yourself in different ways, for example you can say a few sentences about yourself:

Hello, my name is Jana Novak. I come from Ravne. I am 19 years old. I am a student at the college for mechanical engineering. I like my studies as I learn something new every day. I have several hobbies, I like swimming, skiing and other outdoor sports

.

Hi, I'm Jure Vesel. I'm an engineer and I work in a very successful company, Metal Ravne. I have been employed for two years now. I really enjoy going to work in the morning as my job is challenging and there is never a dull moment. In my free time I like going out and socializing

Introduce yourself in a similar way.

English people do not usually introduce themselves, except in impersonal introductions. For example:
I am Police Officer James, and I am arresting you for speeding along the motorway at 120 miles an hour.
"I'm Bill Rightwing, your co-pilot on this flight to New York.
I'm Samantha, your tour guide on this exciting tour to Cappadocia.

When you meet foreigners, it is common to shake hands and use some polite phrases, such as: *How do you do*? (This is very formal and used with certain nations: such as the British or Japanese or when you are introduced to people who are much older or very high in the company hierarchy), *It's a pleasure to meet you.*; *Nice to meet you.; I've been looking forward to meeting you*. We use formal introductions on formal occasions. For important business situations, meeting important people or (some!) weddings and funerals, formal language is safest. For example:
Mr Thimes, this is Professor Jackson.
Professor Jackson. I'm pleased to meet you.

Mr Thimes, may I present Professor Jackson.
How do you do?

Allow me to present Professor Jackson.
I'm delighted to meet you, Professor. My name is Bill Thimes.

General/Neutral introductions
Mr Thimes, do you know Professor Jackson?
How are you, Professor?
Bill, this is Jessica Jordan.
I'm pleased to meet you.
Bill Thimes, Jessica Jordan.
It's nice to meet you.

Sometimes it is hard to know if you should use the first name, (Tom); the title (Professor) or the formal name (Professor Jackson). English people have the same problem! When you are not sure, use the more formal name, or just call the other person "you". Sometimes the other person will help you and say (for example) "Please call me Jessica". We use general introductions for people we might never meet again, for meetings which are not very important, or for meeting people like ourselves - for instance the people we will work with.

Role play a scene of introducing your schoolmates to one another: try to be formal

Look at this dialogue between Martin, a student of mechanical engineering from Munich, Germany, who has come to Birmingham to do his work placement there. He is introduced to Mr. Brown by David Lynch, his mentor at the company. The dialogue is mixed up (except for the first line), try to put it in the correct order. After that, practice it in groups of three:

David: Mr. Brown, this is Martin Schiller from Munich. Martin, this is Mr. Brown, head of this department.
Mr. Brown: I'm glad you liked it. And I hope you enjoy your time with us, too. Have you been shown around yet?
Martin: Yes, I did. It's very lovely here.
Mr. Brown: Hello Martin. Nice to meet you. Welcome to Birmingham. When did you get here?
Martin: No, not yet.
Mr. Brown: Good. And how was your journey?
Martin: It's a pleasure to meet you. Thank you. I arrived at 8 o'clock last night.
Mr. Brown: Well, then, I suggest David gives you a tour first and then we can discuss what you are going to do while you're here.
Martin: Oh, very good, thank you for asking. I came by car so I managed to see a bit of the country already.
Mr. Brown: I see. I hope you liked it.
Martin: Right. I'll see you later, then.

Visit a web page that you know or like and try to find an example of proper business introduction (you can also make it up).

1.1 MEETING PEOPLE

We already mentioned that different nationalities have different rules and several specifics. Below you can read a story that might help you behave appropriately when you travel on business. Although there are certain rules how to behave in a certain country it also depends on people you will be meeting, especially now when the globalization process brings all a lot closer day by day.

Reading (from New International English, Jones and Alexander, 2000)

Nobody actually wants to cause offence but, as business becomes ever more

international, it is increasingly easy to get it wrong. There may be a single European market but it does not mean that managers behave the same in Greece as they do in Denmark.
In many European countries, handshaking is an automatic gesture. In France good manners require that on arriving at a business meeting a manager shakes hands with everyone present. This can be a demanding task and, in a crowded room, may require gymnastic ability if the farthest hand is to be reached.
Handshaking is almost as popular in other countries - including Germany, Belgium and Italy. But Northern Europeans, such as the British and the Scandinavians, are not quite as fond of physical demonstrations of friendliness. But the situation is changing also in these countries and handshaking has become a routine. It is also not true that people from these countries are reserved and cold, but the fact is they are more and more open and extremely friendly.
In Europe the most common challenge is not the content of the food, but the way you behave as you eat. Some things are not just done. In France is a not good manner to raise tricky questions of business over the main course. Business has its place: after the cheese course. Unless you are prepared to eat in silence you have to talk about something - something, that is, other than business deal which you are chewing over in your head.
Italians give similar importance to the whole process of business entertaining. In fact, in Italy the biggest fear, as course after course appears, is that you entirely forget you are there on business. If you have the energy, you can always do the polite thing when the meal finally ends, and offer to pay. Then, after a lively discussion, you must remember the next polite thing to do - let your host pick up the bill.
In Germany, as you walk sadly back to your hotel room, you may wonder why your apparently friendly hosts have not invited you out for a meal. Don’t worry, it is probably nothing personal. Germans do not entertain business people with quite the same enthusiasm as some of their European counterparts.
The Germans are also notable for the amount of the formality they bring to business. As an outsider, it is often difficult to know whether colleagues have been working together for 30 years or have just met in the lift. If you are used to calling people by their first names, this can be a little strange. To the Germans, titles are important. Forgetting that someone should be Herr Doktor or Frau Direktorin might cause serious offence. It is equally offensive to call them by a title they do not possess.
In Italy the question of title is further confused by the fact that everyone with a University degree can be called Dottore - and engineers, lawyers and architects may also be called by their professional titles.
The cultural challenges exist side by side with the problems of doing business in a

foreign language. Language, of course, is full of difficulties - disaster may be only a syllable away. But the more you know of the culture of the country you are dealing with, the less likely you are to get into difficulties. It is worth the effort. It might be rather hard to explain that the reason you lost the contract was not the product or the price, but the fact that you offended your hosts in a light-hearted comment over an aperitif. Good manners are admired: they can also make or break the deal.

Decide whether these statements are true or false according to the story you have just read:

- In France you are expected to shake hands with everyone you meet. *Yes, at meetings.*
- People in Britain shake hands as much as people in Germany.
- In France people prefer talking about business during meals.
- It is not polite to insist on paying for meal if you are in Italy.
- Visitors to Germany never get taken out for meals.
- German business people don't like to be called by their surnames.
- Make sure you know what the titles of the German people you meet are.
- Italian professionals are usually addressed by their titles.
- A humorous remark always goes down well all over the world.

Write a few sentences how we meet, great and entertain business partners or guests in Slovenia.

1.2 PRESENT FORMS

You have been learning about the rules of present forms all your school life, so you should be quite aware of them. That is why there are no rules included in this book, but quite a few exercises that might help you revise and thus improve also your speaking skills. To make your work easier I just included a few examples (I live in a block of flats. She goes to work every day. They always travel to work by car. I don't have any experience. He doesn't like team work. Where do you come from?

When does she get up in the morning? What are you doing? I'm reading these sentences now. It isn't raining outside.)

I. Answer these questions:

What do you do? And what are you doing at this moment?

I'm a student. I'm doing an exercise at the moment - I'm answering questions.

Do you use a computer? Are you using it now?
How often do you use it?
When do you work/study long hours?
Why do people go back to school?
What do you most enjoy about your school/work? Is there anything you don't enjoy?
Do you come from a big family?
How many siblings do you have?
Do you get on well with them?
Do you go on holidays with your family? Where do you usually go?
Do you meet a lot of different people?
Do you have a lot of money? If so, how do you spend it?
Where does your best friend work/study?

II. Complete the dialogue using the verbs in brackets:

A: Where ____________ (you come) from? *Where do you come from?*
B: I ____________ (come) from Manchester.
A: ____________ (you live) in Manchester?
B: No, I ____________ (not live) in Manchester. I __________ (live) in London.
A: What _________________________ (you do)?
B: I'm an engineer. I __________ (work) for Ben Johnson & Son Ltd.
A: How often __________ (you travel) abroad?
B: I __________ (not do) it very often. I very seldom go anywhere.

III. Fill in the correct present form:

1.It's 10 o'clock on Monday morning in Atomic Ltd. In the Research and development department they *are having* (have) a meeting at the moment. Everybody who is involved in the new project __________ (attend) it. At the moment Bob _________ (present) his ideas. He has prepared an interesting PowerPoint presentation and while showing it, he______ (explain) several features. They ______________(organize) such meetings every Monday morning. After these meetings, they all (return) to their desks where they continue with the tasks. In the production department the foreman ________ (walk) around the production plant and ________ (control) the process. He always ______(make) sure that things

______ (not go) wrong as that __________ (be) usually very costly.
Outside, at the loading ramp a van is parked. Some workers _______ (load) the truck with the faulty components they received yesterday. They _______ (send) them back to the manufacturer.

2. I *work* (work) for an electric company, called New Electrics. It is located in Kent and it ________ (supply) a lot of households with electricity. We also (provide) other services as we want to have satisfied customers. If something (break) somewhere in the system, we always ______(send) a specialist right away. If he ______ (not know) what to do, another expert _____ (come) and_____ (have) a look at the fault or damage. We usually have most work after different kinds of storms when lines are broken and whole areas are left without electricity. That also happened last night when we had this huge storm. So, I really___________ (not have) much time as I must rush off to help people in trouble.

3.Hello, I am Bob Livingston. I *am* (be) the Technical and Quality Manager at GBS in Berlin and I______ (work) within the Materials Testing Division which ______ (make) equipment used by different companies. They use our equipment to test different properties of materials, such as strength, durability, softness, resilience and so on. GBS ____ (employ) about 2,800 people and_____ (be) a leading supplier of this type of equipment.
I'm responsible for operations which ____ (mean) that I'm in charge of Research & Development and Quality. If something ____ (go) wrong I'm the one who ______ (have) (provide) answers to the Board.
Currently we ____(work) with our new clients from Japan. They have just placed a huge order so we ____ (have) some difficulties fulfilling it. We have called in all workers, also the ones taking a holiday so we can finish the work on schedule.

4. Jonathan Black *is* (be) an executive recruitment specialist who has turned to writing. The result is the book 'Bosses Speak', based on interviews with 30 Chief Executives. Each top manager - none of them very famous - is given a chapter and there is also some introductory material and a conclusion. This ______ (mean) you can jump from one person to another which is good for people who ______ (be) too busy to read a book from cover to cover. It ______ (not be) expensive although

whether it's good value for money it's doubtful.
Some of the interviewees started their own business while others joined a company and worked their way up. Some ______ (be) fairly new in their position while others have had years of experience. However, Jonathan _______ (not seem) interested in these differences. They work in different area, from retailing to airlines, engineering, construction and software. This variety also _______ (form) the main theme of the book.
I have to say that Jonathan's approach_________ (annoy) me. He rarely _______(stay) at a distance from his interviewees, who are mostly presented in their own, positive words. However, he _________ (seem) to dislike certain interviewees. As a result, I __________ (not know) whether to accept any of his opinions or not. It also means that the book________ (give) no clear lessons. At the very least, I expected to learn what ________(make) a successful Chief Executive. But these people seem to share two types of qualities. Some of them are very common, suggesting that anyone can be equally successful, which definitely is not true. And the other qualities are the ones that most successful bosses I've seen or met definitely _______ (not have). Soб in the end, I'm not much wiser what _________ (go) on. Perhaps I'm being unfair. As long as you __________ (not think) about whether you would like them as friends, and pay no attention to what they say, the most readable parts are where bosses describe their way to their present position.
Nevertheless, Jonathan _____________ (seem) to think that his book would be useful for people who ____________ (aim) for the top.

IV. Look at these job descriptions and underline the activities people normally do, there are two correct answers:

An architect

a) works shifts

b) *negotiates prices and schedules with builders*

c) *inspects the quality of the construction work.*

A quality controller

a) visits companies

b) inspects samples

c) analyses data and writes reports.

A warehouse manager

a) inspects new shipments

b) checks and controls inventories

c) writes and tests new codes.

An electrical engineer

a) designs circuits

b) keeps records of inventories

c) inspects and checks wiring and power supplies.

A maintenance engineer

a) repairs and maintains customers' machines

b) replaces damaged parts

c) produces plans and drawings.

V. Correct these sentences:

Engineers has to work closely with production. *Engineers have to work closely with production.*

What does they talk about, is it the new project?

Does your company produce electronics?

I'm thinking this is your design. Do I right?

What does these mechanics do?

An engineer is using the computer every day.

How often does you have to work overtime?

Engineers usually aren't working in shifts.

1.3 EXPRESSING OBLIGATION, ABILITY, ADVICE, PERMISSION

You can do all that with the use of modal verbs. We can express strong obligation or prohibition with must - mustn't (I must go now, I'm very late. You must start exercising if you want to be healthier. You mustn't mix it, it can cause an explosion.). Mild obligation is expressed with the correct form of the verb have to (I have to go to a meeting this afternoon. She has to get up early to get to work on time. Next week they will have to work long hours to fulfil all the orders. She had to recharge her mobile this morning as the battery went dead. Mike doesn't have to commute to the factory as he lives five minutes away.). We express ability with can - can't, could - couldn't, be able to (I can speak English but I can't speak French. When she was only two, she could swim like a fish. When I finish this book, I will be able to speak English much better.) Can, could are besides may, might (which are also used to express possibility) also used for permission (Can I use your computer for a while, mine has crashed? Could she attend the meeting? May I borrow your car? I may be able to help you.). To express advice and sometimes criticism *should* is used (You shouldn't touch that, it can kill you! She should go home and stay in bed if she's ill.

If you wanted to pass the test, you should have studied more!).

I. Complete these sentences with the correct modal verbs:

We *will have to* go to school by bus as we seem to have car trouble.
I'm really up to my eyes today. I wonder if I _________ call you back tomorrow.
€300,000! You __________ be right. It __________ be a mistake.
Give me ten minutes. I'll call you back. We ____________ be able to send you the shipment today.
You ____________ think twice before making accusations!
We ___________ all open our eyes and pay more attention to the dangers around us.
I'm sorry but I _______________ help you anymore.
Each member of a team __________ do their share of work.
Be careful, the floor is slippery, you _________ slip and break an arm or leg or even worse.
___________ I have a beer, please?
If I want to earn some holiday money, I __________ work overtime.
______________ you ___________ go now? It's running late.
Look, you seem ill to me. I think you ___________ go home early today.
You ________________ use a metal ladder here. You ________ get killed.
It's easy to do that and you __________ spend a lot of money.
You __________ leave any machine running if there's no one present.
We _________ stay at work all night yesterday as we had so many urgent orders.

II. Two friends are discussing what is allowed to carry on the plane. Complete the dialogue with the missing modal verbs:

Pete: *Can* I bring this laptop on board?
Jack: Yes, but I'm afraid you ________ take those scissors with you.
Pete: _________ I pack this camera in my suitcase?
Jack: No, you ________. You __________ take it in your hand luggage.
Pete: Do I __________ leave the knife in my suitcase?
Jack: Yes, of course, you __________ carry anything sharp on board of the plane.
Pete: What about an umbrella?
Jack: You __________ worry about an umbrella. It is allowed to have one in your carry-on luggage.
Pete: And finally, what about drinks?
Jack: Liquids are only allowed if they are less than 100 ml. You __________ buy something to drink either after you pass the security controls or on the plane.

Pete: Thanks so much. You've really been very helpful.
Jack: It's always a pleasure.

SUMMARY

In this chapter we learned how we can introduce ourselves in not very formal and also business situations. We also read about the ways of greeting and entertaining guests in different countries which we found are very different and we tried to establish what the situation is like in Slovenia. And finally, we revised the use of present forms and some modal verbs.

SHORT REVISION

1. Compare the informal and formal ways of introducing yourself or other people.
2. Analyze the differences between meeting and entertaining guest in different countries and compare them with those in Slovenia.
3. Can you describe your daily obligations at home?

2. JOBS AND HOW TO GET ONE

After studying this Unit, you will know more about different kind of jobs in general and in your field, learn about the rules of formal writing, be able to write a letter of application and a CV and also revise past forms. You will also be able to give instructions.

Have you ever thought about how many work areas and different jobs are available on the job market? Have you ever tried to find a job or at least part-time employment? If so, what did you do? Did you contact the Employment Agency or went through the small adds in the papers or the Internet? Are you aware of the rules that apply to formal writing? Do you know how to write a good letter of application or a CV?
I'm sure we are all aware of the crisis and the recession consequences so we know it's extremely difficult to find a job these days. So, when we face the so-called real world, we need to be prepared and we need to know exactly what we are capable of and what we are looking for.

In the beginning of this unit we will discuss different jobs and do a few exercises, learning new vocabulary this way.

There are thousands of different jobs out there. Here are just some job areas possible: accounting and finance, insurance, advertising, aerospace and aviation, art and entertainment, publishing, law enforcement or security, automotive, legal, banking, management or executive, business development, manufacturing, clerical & administrative, construction, engineering, quality control, real estate, transportation and logistics, maintenance, green jobs and many more.
You might want to find a job for yourself by checking different web pages where you might come across different application forms which you complete with your information - if this happens, take your time and think hard before writing any information.

I. Use one of the words to complete each sentence: *deal, work, responsible, of, manage, under, responsibility*:

1. I *work* for Engineering & Warehouses.
2. I ____ the production process in a subsidiary in Leeds.

3. I am in charge ____ the Research and Development.
4. About 280 people work ____ me.
5. Coordination between marketing and sales is my ____.
6. I ____ with a lot of difficult customers.
7. I'm ____ for a marketing budget of over €245 thousand.

II. Match these jobs to their job description:

- a development engineer,
- a geologist,
- a field engineer,
- a software programmer,
- a civil engineer
- a product planner,
- a quality controller,
- mechanic,
- an architect,
- a chemical engineer

e.g. Works for an IT company, writes codes, updates and debugs programmes. *a software programmer*

Repairs and services machines and equipment, works for a steel producer
Works with pharmaceuticals, food, mineral processing and chemicals
Works for an oil company, analyses rocks and minerals from the sea bed
Works for a car producer, checks and inspects the finished ca rs and writes reports
Builds roads, bridges and viaducts
Designs new parts and products, works with CAD technology, and works for an aerospace company
Works for a construction company and is responsible for planning and designing new factories and buildings
Works for an engineering company and organizes and checks production schedules
Works for a telecommunications company, spends a lot of time travelling to companies to repair and replace or install telephone systems

Which professionals from above have to use a foreign language on a daily basis?

III. Complete the exercise below with the correct word (*stay, installed, working, installing, work, design, install, travelling, travel, develops, involves*):

I'm Tom Packman and I *work* for a company called Plugs and Lights, Ltd. We __________ and __________ exterior and interior lighting systems for architectural applications, mostly in large buildings. At the moment we're __________ on new lighting for York Cathedral. Last year we __________ a new lighting system outside the Westminster Abbey.

My name is Magdalena Smith. I'm an engineer in the software industry. I work for a company called Ideas and more, Ltd., that __________ language recognition software. My work __________ developing products for the telecommunications industry. We sell our software to almost every country in the world. That is why I __________ a lot to have meeting with our existing and potential customers. At the moment, I'm __________ a new system in China for their mobile phone network. Several specialists, especially engineers will __________ there for about three months, but I'm __________ back and forth all the time to keep an eye on the work and to keep up with the current situation back at the office.

IV. Choose the best word from the brackets to fill the gap:

I had a 9-to-5 *job* (job, work) when I left school but I didn't do it for long because I hated getting up early and the boredom of the routine.

We have a _____ (flexible, repetitive) system, but everyone must be here between 11 and 4.

I work from __________ (house, home) and simply send my work over the Internet; I only sometimes visit my co-workers at the company.

I sit in front of the computer all day, just drawing different kind of plans. This work is mentally __________ (tiring, routine).

This is the most __________ (stimulating, repetitive) job I've ever had. There is never a boring minute; I really like it a lot.

We all look forward to 5 o'clock because then we can __________ (shift, clock) off for the day and finally go home.

The 7.15 train is always full of __________ (commuters, telecommuters) who travel to London for work.

I'm at _________ (work, job) by 8.45 and I leave for home at exactly 5 o'clock.

I clock ___ (in, at) at 8.50 every day and I'm at my desk ___ (until, for) 5 pm.

The difficult thing is that my home is my office so I'm there 24 __________ (hours, minutes) a day.
We turned one of our rooms into an __________ (office, storage) and that's where I do all my work which is sometimes rather boring.
If you want to get a good job, you need the right _____ (papers, qualifications).
My job is really _____ (mentally, physically) demanding as I work in the mine.

2.1 RULES OF FORMAL WRITING

Since you probably (at least a bit) discussed some of these rules in secondary school, we will only revise them shortly.
Business correspondence writing belongs to the most important and exacting of professional activities. A correspondent is a professional who knows well all the problems of business events about which he/she wants to inform his/her partner.
Business correspondence is formed according to established rules, and expressed in a lively language. There is an emphasis on the vocabulary of the special branch of business.
We have to say more about the so-called business style: a more frequent use of foreign words is concerned and many times concessions to grammar have to be made, connected with the requirements for professional expression.
Grammar rules also have to be applied in business writing. Wrongly made sentences cannot clearly express our thoughts, and in business writing such mistakes could be fatal.
It is important to line up your ideas systematically - with the use of paragraphs which separate different thoughts and ideas.
What you always have to remember is that not contractions are allowed in formal writing (can't - cannot, don't - do not, isn't - is not ...). Think also about the correct salutation (Dear Sir or Madam - Yours faithfully, Dear Mr. Brown - Yours sincerely). The punctuation is also very important - there are no exclamation marks in formal letters.
Layout is very important! The letter should also be attractive for the reader.
Look at this model letter:

5, High Street OXFORD
7th October, 2009

The Sales Manager Carrick-Gateway 34 Waterloo Bridge Road LONDON SE2G 1ED
Dear Sir or Madam,
Would you please send me details of your copying machines which were advertised

in the May edition of Business World magazine?
I am especially interested in the Super fax A3 types.
I look forward to hearing from you.
Yours faithfully,
Ben Kingsley

2.2 APPLICATION FORMS AND LETTERS

If you want to be even considered as a potential candidate for a certain job opening or vacancy, you have to be able to write a good and persuasive letter of application. Although we all use computers nowadays, sometimes it is still expected from you to send in a handwritten application as some managers, especially the ones of the 'old school' still believe that handwriting is the reflection of someone's personality. Sometimes the company might want to fill in an application form (that is listed somewhere in the advertisement) but usually they would want you to write a letter of application.

Below you can see an example of an appropriate letter of application which should neither be too short and nor too long but needs to include all the right and expected or even demanded information. It always has to be attractive for the reader (usually someone in the Human Resources department or even the manager or director, especially in small private companies). If you are not persuasive and your letter is full of grammatical mistakes, you will not be taken seriously and your application will be thrown away and usually not answered at all.

You also have to be extra careful about the addresses and titles not to offend anybody.

Celjska cesta 12 1420 Trbovlje
Termoelektrarna Trbovlje

22nd October, 2009
Ob Zeleznici 27 1420 Trbovlje
Dear Sir or Madam,
With reference to your advertisement in the Zasavec of the 19th of this month, I am writing to apply for the position of an engineer.
I have all the right qualifications as I finished the college programme for mechanical engineers in Celje two years ago. In the meantime, I have been working in Pivovarna Lasko as the head of maintenance department. My mentor during my traineeship, Mr. Zmazek, can be approached at any time to provide references for me. But as I would like to work closer to home and as I believe that the job you are offering will

be more suitable for me. I am applying for this position. I am polite and friendly and used to working with people. I am able to use the computer, especially Microsoft programmes and I am excellent with CAD. I can speak English fluently as I have passed the First certificate exam and also some German which will be useful when dealing with customers and suppliers from abroad.
I hope you will find me a suitable candidate and grant me an interview.
I look forward to hearing from you soon.
Yours faithfully,
Tomaz Straser
Enclosures: CV, photocopies of my diploma, reference from Mr. Zmazek

Go to www.ess.gov.si or www.iskaniedela.si. find an advertisement from a Slovene company looking for an engineer and write a letter of application.

2.3 CV

An application letter is usually accompanied by a CV or a resume (your own biography). Never make things up (you can't say that you can speak a language fluently unless you really do) as most data that you state can be verified and, I can assure you, that it usually is.

Look at this example:

Name	Tomaz Straser
Present address	Celjska cesta 12, Trbovlje
Telephone number	041 896 111
Email address	tomaz .straser@gmail .com

Marital status	Single
Education and qualifications	1998-2002 Secondary technical school - machine engineering, Trbovlje 2002- 2005 College for Mechanical engineering in Celje Diploma of a mechanical engineer
Work experience	Different summer jobs in my secondary school years (Coal mine Trbovlje, Rudis Trbovlje, Cement works Trbovlje) Somrak, d. o. o.: work placement Sepultura: import-export company: work While working I attended various evening courses for English and German. My interests include different sports, socialising and travelling. placement Pivovarna Lasko, Head of
Other information	maintenance (2007-2009) Still employed
References	Mr. J. Zmazek, Assistant manager, Pivovarna Lasko

Write your own CV to accompany the letter of application.
If you did well, you have to wait patiently for a reply. If you are lucky enough, you may be granted an interview and even offered the job. In that case, prepare well for your first day at work (you should be a bit early, dress appropriately, ask only intelligent questions, don't take long breaks, and write down important information

The people below are all looking for a job for a short period of time. Read about them, and then read some advertisements from companies who would like to employ people for some time - then match the people with the jobs. (Be careful - there are more advertisements than are the candidates). Explain why each candidate is

suitable for a certain position:

1. Peter has just finished school and is taking a year off before he starts a food technology course. He would like to gain some experience in this area.
2. Nancy is considering a career in nursing the elderly but wants to know what the job involves before she starts training. She doesn't mind helping someone for free. She just wants to get some valuable experience.
3. Jacky has just dropped out of studying languages at the university in Germany but is still planning to do a teaching qualification next year. She really enjoyed living abroad and would like to do it again.
4. Stuart gave up his job as an engineer because of low payment and is now doing a fulltime computer course. He would like to earn some money but can only work before 9 a.m. or after 5 p.m.
5. Alison has just returned from the States where she was working with teenagers in a summer camp. She's going back shortly (probably in 6-7 months) but she needs money for the plane so she would like to work in the meantime.

A **Mick's Supermarket**
We are looking for additional staff in checkout sales and customer services. Daytime only (part-time hours possible). No experience essential. Staff benefits include free food in the restaurant, food discounts and travel allowance.
B **Oasis**
Volunteers needed in our friendly old people's home. Suitable for anyone wanting unpaid experience in care work. Light duties only, such as serving drinks and meals, helping our old residents getting out on the lawn and playing games with them. Temporary assistance is also welcome.
C **Cheerful Hours - after-school care**
Play leaders are needed for the after-school club. We run a number of play schemes in the area. Ages range from 5-15. Candidates must have previous experience of working with children and plenty ideas for entertainment.
D **Clothes for Little Ones**
Children's clothes shop is looking for a part-time shop assistant. The hours are 9 a.m. - 6 p.m. on Tuesdays, Wednesdays, Thursdays and Fridays. Benefits include discounts. Experience is desired. If you are interested, phone Sally on 894675.
E **Helping Hands**
Part-time mini-bus drivers wanted for a small local service providing transport for the disabled and elderly people. Hours can be arranged by agreement and there's reasonable payment. Evening work is also available. Sometimes help is required at

weekends - for day trips.

F **Let's Make Our City Cleaner**

Part-time cleaners are required in busy offices around the city. Monday to Friday from 6 a.m. to 10 a.m. We pay €75 per week and provide uniforms and all equipment. We also have a mini-bus that will pick you up. But we expect good quality work.

G **Six-Month Au-Pair Position in Germany**

Are you friendly, patient and cheerful? We need someone to look after three children (9, 6 and 3 years old) in return for food, accommodation and €45 pocket money a week. Evenings and weekends are free. The children already speak a little English but would like to learn more.

H **Telco's Hypermarket**

A fresh food assistant is wanted for the fish counter to prepare and display quality fish and to provide friendly and efficient service to our valued customers. Some basic training will be provided. Morning hours only, good pay, friendly and helpful staff.

Example: 1 H: Peter would be appropriate as he would gain valuable experience about fresh food before he goes studying.

2.4 PAST FORMS

As we have already stated, grammar rules are not included in this book, but again just a few exercises to help you revise the past forms. Here are just a few examples (I worked hard last week. She opened the door but she didn't say anything. He was watching TV when I came home. After I had finished all my obligations, I went home.).

I. Think of an interesting holiday you went on or an exciting trip you made. Tell others about it:

Where did you go? *I went to Egypt.*

Who was with you?

How did you travel?

What did you take with you?

Did everything go according to plan?

How did you feel when you got back?

II. Complete these stories with the correct form of the verb (Past forms only):

Music legend Michael Jackson *died* (die) at the age of 50 on the 26th June 2009. He __________ (suffer) a cardiac arrest at his home in Beverly Hills. Jackson, who __________ (have) a history of health

problems, had been due to stage a series of comeback concerts.
His body was airlifted from the hospital to the coroner's office in downtown Los Angeles. TV stations _________ (carry) live coverage of the helicopter's journey. An autopsy was carried out later that day to establish the precise cause of his death.
Paramedics had been called to the Beverly Hills mansion Michael Jackson _________ (rent) while he _________ (prepare) for a series of fifty sold-out concerts in London. The singer's brother, Jermain Jackson _________ (tell) at the news conference that after they_________ (fail) to resuscitate him, Michael was transferred to a nearby hospital where a team of doctors _________ (work) for more than an hour in a vain attempt to revive him.
His voice _________ (be) back and he again____ (enjoy) performing dancing steps with his group.

2. On Wednesday, July 24th, 2006, a team of gold miners *were* (be) hard at work in Forrester mine in Arrow Town, New Zealand.
They _________ (have) a map so they knew that there was another mine shaft nearby. But they _________ (not know) that their map was wrong and the old mine was much closer than they (think).
At 8.50 p.m., a terrible thing happened. Some miners _________ (break) through the connecting wall and over 350 million litres of water poured in the old mine. They managed to escape the rushing water, but they were cut off from the surface, trapped 75 metres below ground.
The miners _________ (try) to find higher ground, but it was impossible. They found a small air pocket, but the water continued to rise. The water was very, very cold and there was only a limited amount of air, so breathing became extremely difficult.
Above the miners the rescue team _________ (not know) if they were alive or dead, but they _________ (try) to reach them all the time. They drilled small holes to where the miners were and at 3.45 a.m. they lowered a pipe down to the miners. Fresh, heated air _________ (come) down through the pipe.
So, the miners had warm air, but the water was another problem. It _________ (rise) all the time. Fitzpatrick, the miners' leader, estimated that they would be all dead in an hour. They _________ (write) notes saying goodbye to their wives and children and put them in an airtight plastic bucket. The water _________ (still rise) and it _________ (rise) to their necks, but then it stopped. The men were still alive.
The rescuers on the surface______ (still work) and they worked all the next day and into the night. They ______ (have) to drill a tunnel to get them out. They drilled 34,5 metres into the ground but at 2.35 a. m. on Friday the drill _______ (break). They had to remove it but they couldn't continue. The rescue team started the second

tunnel, 15 metres from the first. And after a 16-hour shutdown, the first tunnel was back in business. But this was 46 hours from the accident. Was it too late?
The breakthrough came on Saturday at 10.25. The first rescue drill finally _________ (cut) through to the trapped miners. All miners escaped to safety after they _________ (be) trapped for 78 hours.

NOW decide if the sentences below are true or false, correct the false ones:
The map the miners had didn't show the correct location of the old mine. *True*
The accident happened at ten to nine in the morning.
The miners couldn't find higher ground.
The miners' leader thought the rising water would kill them all in an hour.
Two rescue tunnels were started at the same time.
The drill broke again on Saturday at 10.15 p.m.

III. Fill in the correct past forms of the verbs in this interesting story below:
My perfect holiday used to be two weeks in a hotel with no cooking, no cleaning and staff waiting on me. After we *had had* (have) children, we _________ (find) it easier to choose places where kitchen facilities were included and we _________ (do) the cooking. It was a generally more convenient option although we ___ (tend) to stay in Britain because of the cost. Then friends of mine ______ (introduce) us to the idea of house-exchange holidays.
At first, we ______ (think) that staying in someone else's house was unthinkable. I also ____ (not like) the idea of complete strangers wandering about in my home, using my bathroom and sleeping in my bed. However, my friend _______ (tell) me how she, her husband and two children _____ (spend) two lovely weeks in the heart of Florida just for the price of the flight. They also _____ (not have) any problems with the family who stayed in their house in London.
Because they _____ (be) so positive, we decided to try it ourselves. We joined a house-exchange agency, _________ (choose) the countries we were interested in visiting and were soon sent information on possible exchanges. We chose a family from Vancouver in Canada, _________ (go) away and had the best holiday we'd ever had in our lives. That was six years ago. Since then we've been to Hungary, Finland, Scotland, the USA, Slovakia and even Australia.

IV. Fill in the correct form of the verb and then do the multiple choice exercise below:
One day, when I *was sitting* (sit) in a huge traffic jam on the way to school, I _____ (start) thinking about how miserable everybody ______ (look) stuck in their cars.

Why _______ (they do) it, I ______ (wonder). Why didn't they walk instead? What were all these cars doing to the environment? I _______ (imagine) the world in fifty years' time. What would it be like? If people _______ (carry) on driving, pollution would get worse and worse.
When I _____ (get) to school that day, I ______ (ask) a few of my friends to start a club with me. We ____ (call) ourselves 'The Environment People'. We ______ (know) we couldn't change the world or make the government improve public transport, but we decided we could at least change our own lifestyle. We also decided to think about all sort of ways we could help protect our environment.
First of all, we _________ (make) a list of things we could do, such as walking to school, saving paper, recycling bottles and cans. Then we made posters and _________ (stick) them up all over the school. Soon lots of other students were really interested in what we _________ (do) and groups started meeting up to walk to school instead of going by car.
I think other young people should do more to protect the environment; after all, it's our future.

What is the writer trying to do in the story?
A Encourage other to think about the environment.
B Give information about the environment.
C Advise people to use public transport.
D Warn young people about their lack of fitness.

What is the writer afraid will happen in the future?
A People will no longer walk anywhere.
B Car drivers will become completely depressed.
C There will be more pollution.
D Traffic jams will get even longer and will take too much time.

Which of the following did the members of the club realise they couldn't do?
A Start a club.
B Help protect the environment.
C Improve bus and train services.
D Change the way we live.

What did 'The environment People' decide to do?
A Write a letter to the government.
B Write down what actions they could take.

C Persuade people to use public transport.
D Join up with other similar clubs.

2.5 GIVING INSTRUCTIONS

In our everyday but also professional life we have to give and follow certain instructions. Have a look at this example about how to change an oil filter:
Check the handbrake is on and jack up the front of the car. Put a shallow pan on the ground under the engine.
Make sure that's directly underneath the engine's drain plug.
Unscrew the drain plug and wait for the oil to drain completely. It will flow out easily. Replace the plug and tighten it with a wrench.
Then locate the oil filter.
Remove the filter by rotating it slowly counter clockwise. Pour any remaining oil into the pan. Screw in the new filter, rotating it clockwise. Do not screw it too tightly.
Remove the drain pain and carefully pour the oil into a special container that can be sealed off.
Lower the car to the ground again. Do it slowly. Then pour new oil in. Check for any leaks under the car.
Repeat this process every 5,000 kilometres to keep your car in a good condition.

Write down another instruction: for example how to operate your mobile, TV, DVD, a washing machine ...

Can you guess which devices these instructions are for?

Put on this suit before going for a ride. In a crash it swells with compressed gas and protects your body. *Protective jacket and trousers.*
Lose weight by using this. It has sensors that time your mouthfuls. When the red light comes on, wait. When the green light comes on again, you can eat another mouthful.
Keep cool on hot days by wearing this. It protects your head and because of the size also your upper body.

SUMMARY

We could find out that finding the right job is not easy. We also discussed some rules of formal writing and how to write a good letter of application and a CV. So, if we know how to write a good and persuasive letter of application which is accompanied by a thorough and detailed CV (or your own biography), this is the first step towards finding a job you will like doing and will be challenging enough for you to keep studying and improving yourself. And thus we might be able to start a successful career. These steps are: look for advertisements, write a good application form and a detailed CV, prepare well for a job interview, and act smartly and businesslike on your first day at work. We also revised past forms and learned how to give instructions.

SHORT REVISION

1. Do you happen to remember where can people looking for jobs find information about vacancies?
2. Summarize in a sentence what the first step towards finding a job is.
3. Explain and analyze what kind of information you have to include in your CV.
4. Try to think of an interesting invention that you know and give instructions how to operate or use it

3. DIFFERENT KIND OF COMPANIES

After this unit you will be able to describe certain companies and the three different sectors. You will also learn much more about engineering. Besides you will be able to use Present perfect more correctly and know how to give directions.

What do you know about different kind of companies? How familiar are you with the different sectors or different sizes of companies?

Companies are a very important part of a country's economy. They produce goods and services and they come in every shape and size.

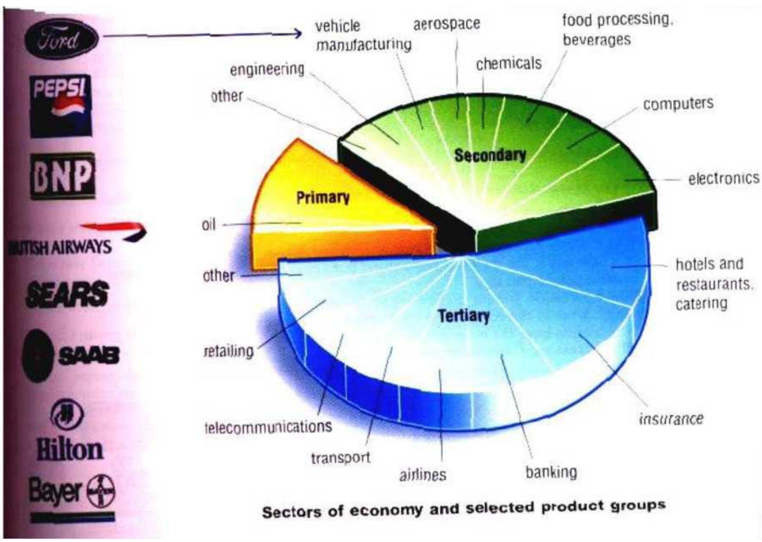
There will be many occasions when you will have to talk about the company you work for. This may be when you are actually showing someone around the place of work or premises or when you give presentations to future clients, customers or business partners.

You may also need to explain to someone how your department or your company is organized or how it is run, who is responsible for different aspects of business and similar.

The first step towards this is to decide or explain which sector your company belongs to.

Look at the picture below and then answer the questions in exercise 2:
Which of these companies do you know?

Picture 1: Different kind of companies



Source: Jones, Alexander, New International Business English, 2000, page 43

If we compare the three sectors, we can say that primary sector grows or takes different kind of things directly from the ground or water or in general our surroundings and mainly deals with raw materials; secondary sector produces or manufactures and tertiary sector companies offer services.

Companies can be further divided according to the size (small, medium, big or large), ownership (private, public, national), type (engineering, insurance, joint-stock ...) etc. They also have very different organizational structure (from only one manager to boards of managers, supervising committees ...) and can have only a few or several different departments (production, purchasing-sales, export-import, advertising, marketing, finance, accounting ...).

I. Look at the logos of different companies below. Divide them into the three sectors: if you have never heard of them or if you are not sure, check them out on the Internet:

Picture 2: Company logos

Source: www.epsvectorlogosoncd.com

II. Answer these questions:

Which are the five largest or most important companies in your region (country)?

For example: Prevent, Lek, Krka, Mercator, TAP

Which sectors of industry or product group do they belong to?
Make a list of the products they make or services they supply.
Which sector do you (you intend to) work for?
Which areas of the economy are changing the most?
Which sectors can we not do without?
Has the rate of unemployment in your country increased or decreased in the past years? In which economic sectors have jobs disappeared?
In which economic sectors have jobs been created?

III. Describing a company: complete the sentences with one of these expressions: *famous, established, high, reliable, owner, quality (not all of them are used):*
Ford is a *long- established* company.
Harrods only sells high- ________________________ products.
Sony is ______________________ for their televisions.
Philips make ________________________ electrical goods.

Try to find as many logos of Slovene companies (at least 5-10) from each sector (like this example: secondary and tertiary sector: *prevent)*

3.1 ENGINEERING

Engineering is based on many other sciences, such as physics, chemistry, mathematics but also mechanics, thermodynamics and analysis.
It is a science, discipline, art and profession of acquiring and applying technical, scientific and mathematical knowledge to design and implement materials, structures, machines, devices, systems, and processes that safely realize a desired objective or inventions. Its main focus is to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property. This broad discipline can be further divided into sub disciplines, each with a more specific emphasis on certain fields and particular areas, for example: civil,

mechanical, electrical, electronic, marine, automotive, aeronautical, heating and ventilation, mining and medical engineering.
One who practices engineering is called an engineer.

Watch an episode on 'How is it made?' or 'Mega structures' or 'Extreme engineering' on Discovery or National Geographic Channel about the work the engineers do and describe it to your classmates.

Here is an extract from a speech to a group of students who are yet to decide which programme they want to choose and study. Complete it by choosing one of the words: machines, highway, mechanical, civil, physics, electrical, develop, production, electronic, chemical:
Engineering students need to have an understanding of math, *physics* and chemistry. Working with pharmaceuticals, food, mineral processing and chemical manufacturing, a ________ engineer is trained to understand, design, control and investigate material flows. If you like problem solving and find projects for building tunnels or dams interesting, ________ engineering is the right choice for you. This way you will produce creative designs at competitive prices and you will be actively taking care of the environment. If your interest lies in road building, then you can decide to specialize in ________ engineering. By studying ________ and ________ ________ engineering you learn about the design of complete systems, such as computers, power or transport systems. ________ engineers plan, design and ________ a wide range of things, such as white goods (for example: washing machines) cars and even spacecrafts. ________ engineers work closely with mechanical engineers to make a new product at the reasonable price, on time and at the right quality. Besides designing and selecting ________ and materials, they are expected to organise people and finances.

II. Look at the text below about a company that has an office also in Ljubljana (find where) and then answer the questions below:

ABB

Welcome to ABB

The ABB Group

ABB is a global leader in power and automation technologies that enable utility and industry customers to improve their performance while lowering environmental impact.

Technology

Technology plays a key role for ABB. We have activities all over the world working to develop unique technologies that make our customers more competitive, while minimizing environmental impact.

Sustainability

Sustainability is integral to all aspects of our business. We strive to balance economic, environmental and social objectives and integrate them into our daily business decisions. **Where to find us**

ABB operates in more than 100 countries and has offices in 87 of those countries to give its global and local customers the support they need to develop and conduct their business successfully.

(Source: www.abb.com)

1. What do they produce? *They are involved in power and automation technologies.*
2. What is their main goal? What is the purpose of their activities?
3. What's their attitude towards environment?
4. Where does the company operate?

3.2 COMPANY PROFILE

Very often you will have to talk about your or any other company, so you need to know how to do it well. Look at this example:

CRANE engineering, Ltd. is a small, private company, employing a staff of 55 workers who are all fully and highly qualified.
We are located in the industrial zone of Manchester and we employ mostly local workforce.

It all started in 1980 when Mr. Jack Crane decided to start his own company after he had been made redundant at his previous company. It was rather difficult at the beginning as the company that employed only 10 people had to face the competition of large companies that dominated the market and could offer, if necessary, more competitive prices of different machines used in the industry. The turning point came in 1985 when the company landed a big contract with British Railways. The success of the company has continued ever since and the company personnel and their products have earned good reputation.

The company is run by Mr. Graham Crane, the son of the founder, who is the managing director. He gets help from the finance, design, production and marketing department.
Their main plan is to maintain the same market share also in the future and to get more involved in the environmentally friendly production.

Read this short company description and complete it with the missing expressions: name, promote, solar, burgundy, Ltd., exotic, ranges, built-in, promotional, items, plastic, conference

Promotions in Plastic, *Ltd.* (better known as P.I.P.) is a small company, specializing in producing personalized ________ for companies wishing to ________themselves or their products. One of their most popular ________ is promotional pens, but they also produce ________ desk organizers, golf balls with your company ________ printed on them, personalized computer discs, ________ folders and ________ calculators. One of their fastest-growing ranges is the ________ mousepads. They come in four different colours: black, grey, ________ and green. There is also a version with a ________ calculator.
They can also be made in unusual or _____ shapes (for example: a car or a fruit).

Find an engineering company on the World Wide Web and prepare a similar presentation.

3.3 PRESENT PERFECT

Present perfect is a tense that we don't have in our mother tongue so it often causes problems to the Slovene learners of English (I have already done the exercise. I've never tried something so dangerous. She has just finished her work. They haven't returned our call. She hasn't seen something like that before. I've been teaching for a very long time. She's been working too much lately.)
Below are a few exercises that may help you be more confident when using it.

I. Answer these questions:
What have you done so far today? *I have had breakfast, I have driven to school.*

Why have you decided to study engineering?

Have you been doing anything interesting lately?
Where have you been on your holiday?
Who has influenced you most so far?
How long have you been learning English?
Who have you always been able to rely on?

II. Complete the dialogue using the verbs in the list: *called, installed, has, had, have promised, haven't, have, done, come, have installed*:

A: *Has* all the equipment arrived yet?
B: Yes, it has already ________. It came this afternoon.
A: Oh, good. ________ you ________ everything?
B: No, I haven't. I ________ enough cable to connect everything.
A: And have you connected the PCs to the printers and photocopiers?
B: Yes, I ________, but there's a problem with photocopiers.
A: Can you fix it?
B: I don't know. I ________ the software and everything seemed OK, but then they called me and told me that they couldn't print.
A: Have you ________ he company that sold us the photocopiers?
B: Yes, of course. I've just___________________ that.
A: And what did they say?
B: They ________ to send a technician round tomorrow.
A: OK. Let's hope they can fix it.

III. Complete this extract from an advertisement about Emerging Markets Fund with the correct form of the verb:

Over the past few years, before the world's crisis, caused by the recession, the capital returns from many emerging Asian markets *have been* (be) much higher than those of the developed world. The same can be seen also in the countries of the Latin America. For example, the markets in Argentina _____ (rise) by almost 800% and Mexico ________ (increase) by more than 600%. In Asia, the booming market in Thailand ________ (go) up by 300% and investors in the Philippines have earned more than 200%. The situation has worsened a little in the past few months, but still looks much more promising than in the rest of the world.
The developed nations _______ (not manage) to make anything closely similar.
Although the USA market ________ (grow) a lot before the crisis, it all went downhill last year with the start of the recession.
The growth rates that these emerging markets ______ (enjoy) in the recent years is phenomenal. Experts say that we can expect positive results also in the future.

IV. Which of the options in the brackets is correct - explain why?

I (have played/*played)* tennis when I was younger.

I (passed/have passed) the written test but I (haven't taken/didn't take) the practical part yet.

He was a service engineer and then he (has joined/joined) the production department.

She (has qualified/qualified) as a mechanical engineer two years ago.

The first job Bob (has had/had) was at a small logistics company in Dublin.

(Have you ever been/Did you ever go) to Japan?

She (studied/has studied) civil engineering from 2007-2009.

These plans have been written/were written last month when their creative team was working/has been working together with ours.

3.4 GIVING DIRECTIONS

It doesn't really matter whether you live in a small town or a big city (it can also happen within your own company), there will always be someone who can't find their way around, and so you will need to give them precise and clear directions.

Look at these examples:

A: Sorry to bother you, but could you tell me how to get to the Human Resources department?

B: Sure. It's on the third floor of the main building. Just continue down the corridor to the elevator and go to the ground floor. When you get out of this building, turn right, go through the small park and you will see the main building in front of you.

A: Thank you. You are very helpful.

A: I'm sorry but I forgot how to get to the conference centre tonight. Could you tell me again?

B: Will you walk or go by taxi?

A: If it's not too far, I'd rather walk.

B: No, it's not that far. You will need about half an hour.

A: That's great. So, where do I go?

B: From your hotel just turn left and go down the main shopping street. When you come to the church, turn left and continue uphill. When you come to the monument, turn right and take the bridge across the river. The conference centre will be on your left. I wish you a pleasant walk.

A: Thanks again.

A: Excuse me, please, how do I get from Mislinja to Ravne?
B: It will take you about 40 minutes. Just follow the main road and when you come to Slovenj Gradec and you see the sign for the centre, turn left. Carry along through two traffic lights and when you come to the roundabout, take the third exit. Continue straight on, through Stari trg, Sele to Kotlje where you turn right and drive for another 5 minutes before you reach Ravne. It's easy, just pay attention to the traffic signs.
A: Thank you so much.
B: You're welcome.

Obtain a map of your town/city and practice giving directions to people who have no idea where to go.

SUMMARY

If we summarize in a few sentences, we can say that there are three main sectors of companies that are further divided into private or public, small, medium or large, have different management and also very different organizational structure.
Engineering is a science that is closely connected with other areas and is essential in our modern life. In this unit we have also learned about Present perfect and how to give directions.

SHORT REVISION

1. Can you explain how we divide companies, according to the sectors?
2. Can you name some companies that belong to each of the sectors, what kind of products they make or what services they provide? Would you like to work for any of them? If yes, why?
3. What is engineering? Who is an engineer? Which sciences are closely connected with the engineering? Is working as an engineer an interesting profession? Why/why not?

4. NUMBERS, SHAPES, DISTANCES & DIMENSIONS

After this unit you will know much more about numbers and shapes, distances & dimensions and you will be able to work with them, explain them, draw them and operate with them. You will also be able to use Future forms better and easier.
Do you know the difference between the Roman and Arabic numbers, between Cardinal and Ordinal, have any idea how fractions are spoken? Which types of shapes do you know?

4.1 NUMBERS

You will be working with numbers all the time, so you need to be aware of them, how we pronounce them individually and mathematical formulas. Let's have a closer look.

Cardinal numbers are:

0	zero (oh, nought, nil)	315	three hundred and fifteen
1	one	6,155	six thousand one hundred and fifty-five
2	two	2,340,901	two million three hundred and forty
10	ten	1,901	thousand nine hundred and one
100	one (a) hundred		
1,000	one (a) thousand		
1,000,000	one million		
1,000,000,000	one billion		

+	addition	5+4=9	five plus four equals nine
-	subtraction	5-1=4	five minus four equals one
x	multiplication	5x4=20	five multiplied by four equals twenty
:	division	20:4=5	twenty divided by four equals five

Roman numbers

1 I	100 C
5 V	50 L
9 IX	900 CM
10 X1000 M	
49 XXXXIX	
500 D	

Ordinal numbers and dates. Fractions and decimals

1^{st}	the first
2^{nd}	the second
3^{rd}	the third
4^{th}	the fourth
10^{th}	the tenth
20^{th}	the twentieth
25^{th}	the twenty-fifth
31^{st}	the thirty-first
$1,000,000^{th}$	the millionth
2 '/2	two and a half
3 V	three and one quarter
25%	twenty-five per cent
99%	ninety-nine per cent
1.33	one point thirty-three
6.7895	six point seven eight nine five

1^{st} January the first of January

3^{rd} April the third of April

15^{th} May 2009 the fifteenth of May two thousand and nine

22^{nd} June 1990 the twenty-second of June nineteen and ninety

Picture 3: Colorado River Source: www.sustainabilityninia.com

I. **Read this information about the Colorado River and fill it with the missing numbers:** *900 km, 20 m2, 1935, 4,860 m, 1933, 907 tonnes, 15 m, 23 m2, 2,253 km, 229,359 m3, 5,500 m3*

The Colorado River is *2,253 km* long. When they were building the Hoover dam, they rerouted the river through tunnels. The tunnels had a total length of _________ and they were over ____ in diameter. They were lined with___of concrete. The tunnels could carry over _____ of water per second. They started laying the concrete in Juneand finished in May _________. The dam was built in blocks that varied in size from about ______ at the bottom to about ______ at the top. To set the concrete, they laid more than _______ steel pipe in the concrete and pumped icy water through it. The water came through a refrigeration plant that could produce ____ of ice a day.

II. Write down these numbers or dates and fractions:

1,000,000,000 *one billion*

21st May	35%	8237 654	34.65 g
1/3	$4,320	9.369	

Three minus three plus sixteen divided by four equals four. 3 - 3 + 16 : 4 = 4

Twelve plus six divided by nine times ten minus two equals eighteen.

Sixteen point five plus one point three four minus ten point eight six equals six point nine eight.

The square root of thirty-six multiplied by four cubed equals three hundred eighty-four.

III. Write the following in words not in numbers:

5% of the population owned 85% of the country's wealth in 1995. *Five per cent ....eighty- five per cent... nineteen ninety-five*

About 2,000,000 people live in Slovenia.

55.2% of adults have false teeth.

6x7 = 42

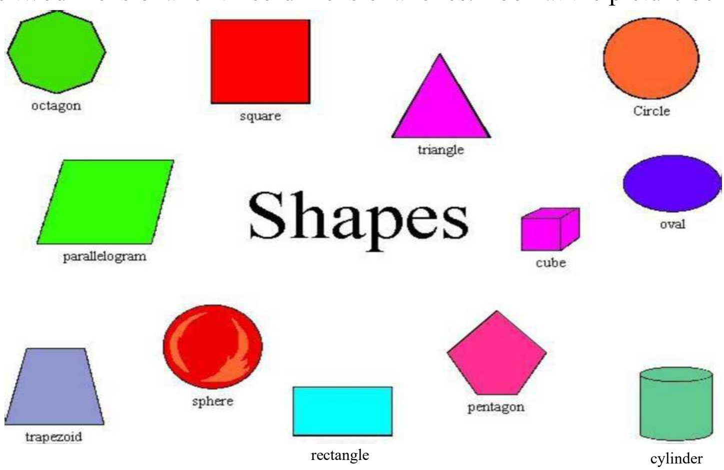
That is 33,923 km from here.

23,250 umbrellas are approximately sold in England every year.

It was extremely cold, about -20 degrees Celsius

4.2 SHAPES

All scientists and technologists need to be able to talk about different shapes; they can be twodimensional or three-dimensional ones. Look at the picture below:

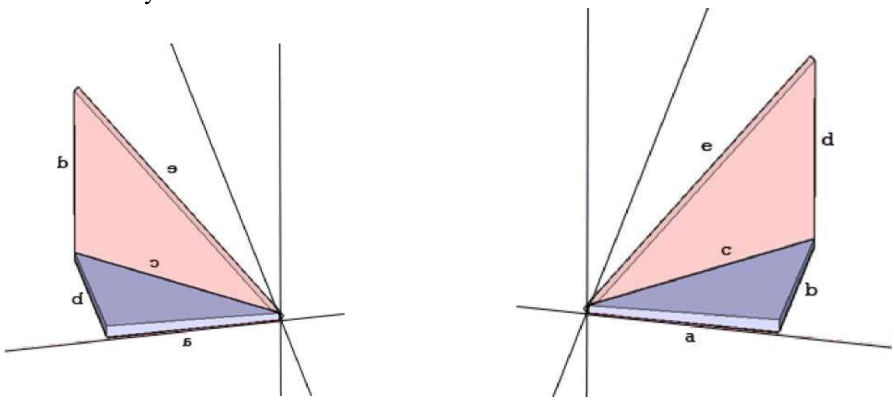


Picture 4: Shapes Source: www.learnc.org

Draw the following:
an ellipse
a rectangle with diagonal lines joining opposite angles
two curved lines, going in the opposite directions
a square with a diagonal going from the centre to the top left corner
a capital E is the wrong way round, its top line extends to the left so that it is six times longer than the bottom line
two parallel lines, the above much longer, there is a semi-circle on the top, not connected to the above line

4.3 DISTANCES & DIMENSIONS

You probably know all the common words for distances and dimensions, such as broad, wide, tall, high, long, short, low, far, deep and also its derivatives (broaden, widen, width, heighten, height, lengthen, length, shorten, lower, faraway, deepen, depth ...). In mathematics you will often come across different pictures like the one below where you have to calculate out all measuremets.



Picture 5: Mathematical dimensions. Source: http/wps.pearsoned.com.au

I. Write down the opposites of the following:

a length of the room - *a width*
a tall person
to shorten

shallow water
a faraway place
a low mountain

II. Complete the sentences below with the correct expression, choose from: *diameter, square, measures, thick, high, long, wide, circumference (some are used more than once):*

This garden *measures* 28.5 metres by 36.
That ball has a ____________ of 65 centimetres and a ____________ of 24.5.
Our classroom _______ 4.65 by 5.8 metres, that's almost 27 _________ metres.
The rug is 1 metre ____________ and 0.7 metres ____________.
The new building is 65 metres ____________
My mouse pad is approximately one centimeter _________.

III. Match the questions to the answers:

1 How long did it take to build?
2 How much does it cost?
3 How much do they weigh?
4 What are its dimensions?
5 What's it made of?
6 What's its operating time?
7 What's the maximum load?
8 How high can it fly?
9 What type of fuel does it use?
10 Why type of engine does it have?
11 What's its maximum speed?
12 What's the fuel tank capacity?

A)100 kg
B) 8 L
C) 1,700 hours
D) 4455 kg
E) over 200 km/h
F) 6.3 hours on a full tank
G) a maximum of 3500 m above sea level
H) 6 m x 1.5 m x 8.5 m
I) wood
J) 4.4 L V8
K) unleaded petrol
L) $655

IV. A quiz:

What is longer: a centimetre or an inch? *An inch* Is one metre as long as a yard?
Which building is taller: 50-metre or 50-feet one?
Who drove faster: the driver who was driving 80 miles/hour or the one who was driving 80 km/h?
Do you get the same if you buy one kilo of cherries or one pound of them?
Which is lighter: one gram or one ounce?
If m is a symbol for 1 metre, should you write two metres as 2 ms?
Which spelling is correct metre or meter?
What is the symbol for litre: L or l?
How should you punctuate this number 6455340000?

Are tons and tonnes the same thing?

Measure your room at home and use different expression when describing and presenting it.
Write the birthdays of your family with Roman numbers.

4.4 FUTURE FORMS

We use different future forms (*Present simple & continuous, Will future, Going to future, Future continuous and Future perfect)* to describe events that are likely to happen in the near or distant future. Here are a few examples (I'm seeing my doctor next week. She's having a meeting later in the afternoon. The match starts at 7 o'clock tonight. When does the sun rise tomorrow? I'll have a cup of coffee, please. They'll go on holiday to Hawaii. She won't accept the job because the salary is too low. I'm going to buy a new car when I save enough money. She's going to have a baby soon. Before the exam I'll be studying a lot. When will you have finished that report?).

Answer the following questions:
What are your plans for this weekend? *I'll go out with my friends; we are going to have a good time. On Sunday I'm seeing my old friend and we will be having a picnic together.*
When is your next birthday?
What will you be doing tonight? Will you be watching TV?
Where are you going to spend your next holiday?
Will you buy a new car soon?
Do you happen to know when the sun rises tomorrow?
When will you have finished this school?
Who will you be working for in 5 years' time?
What position will you have in the company?
What sort of things, do you think, you will be doing as part of your job?
What will you have achieved by 2020? What changes will have taken place in your personal life by then?

II. Make predictions what life will be like in the future - 50 or 100 years from now.
For example: We will all use flying cars. We will develop new

drugs which
will heal or even prevent all illnesses.

III. Complete the conversation below (it takes place at a construction site) with the correct expressions from the list: *won't be able to start work; won't be able to get our lorries; Will the site be ready; will have to widen the door; won't let you come to work; won't have to widen the road; will not be able to start work; it will be*

Jim: OK, let's get over this one more time. *Will the site be ready* for us to start work tomorrow?
Joe: Bob says ______________ and he's in charge.
Jim: If they haven't prepared the site, we ______________ on time and that means unexpected costs.
Joe: We gave clear instruction. Bob says everything is ready.
Jim: What about access to the site? If they haven't taken down the fence, we to the site.
Joe: Don't worry. It's been done already. So we don't need any specific tools because we
Jim: What about the door?
Joe: The door?
Jim: We ______________ to get the compressor in. It was in the plan. And if we can't get the compressor in, we ______________ on time.
Joe: But can they do it?
Jim: They'll have to. But don't worry so much. It'll be OK. If you are so worried about everything, I ______________ tomorrow.

IV. The export manager of an agricultural machinery company is talking to his assistant about the business trip he's going to take. Put the verbs in the conversation in the correct future form:

Nancy: I've booked your flight and hotels for your visit to Vietnam next Friday. You *are leaving* (leave) at 6.30 a.m. and that means you__________ (arrive) there late in the afternoon.
Jason: What about hotels?
Nancy: You _________ (stay) at the Marriott for the first two nights. You _________

(have to) take a taxi from the airport. Your first meeting is on Monday and you ______ (see) Mr. Chin from the Ministry of Agriculture at 10 o'clock.
Jason: _____________ (I need) any vaccinations?
Nancy: I'm not sure. I _____________ (ask) our Health Directorate and I _____________ (let) you know as soon as possible.
Jason: What about the rest?
Nancy: Your next meeting is on Monday afternoon. You _____________ (meet) Mr.Jin of the Vietnamese Agricultural Association.
Jason: And on Tuesday?
Nancy: Then you ________ (have) another meeting with Mr. Ly Tien, the manager of Tractors, Ltd. I've arranged a table for the two of you in the local restaurant.
Jason: Anything else?
Nancy: No, that about covers it.
Jason: Please let me know about the vaccinations as soon as possible so I ______ (able) to make the doctor's appointment.
Nancy: We'll do, don't worry.

V. Fill in the correct future form:

Dear Jane,
Why don't you come with us to Yorkshire? It's all arranged. Jo *is coming* (come) to my house at six so we can go to the station together. The train ______ (not leave) until 6.45, but we don't want to be late. It ________ (stop) a lot on the way so it ________ (not arrive) until three in the afternoon. I imagine we _______ (get) quite tired by the time we get there. We _____________ (stay) in a youth hostel and we _____ (spend) five days there. We can catch a bus on the way from the station, but it _____ (not go) all the way, so we _____ (have) to walk the last two miles from the village. We ______ (have) breakfast and dinner at the youth hostel. It's in a beautiful spot with lots to see. On the way back we need to set off early as there's only one bus and it _______ (leave) at 8.30. The train back is much faster so it arrives just after lunch. As you can see we have everything planned and organised. I hope you _______ (change) your mind and join us.
Write soon.
Love,
Emily

VI. Correct these sentences:

Don't worry. It'll only be lasting a few minutes before the tooth will be out. *Don't worry. It'll only last a few minutes before the tooth is out.*

By the time I get there the chef will cook for three hours.
Next year I work in our factory in Germany.
This year she stays at home for the holidays.
On Saturday Jack will have got married.
Tom will see his doctor next Monday.
I'll call you when I'll know something.
The bus will be leaving at three.
What do you think you are doing next year?

4.5 COMPARISON OF ADJECTIVES

When we talk about distances, dimensions ... we very often have to compare things, items or characteristics: we can do this with suffixes (long - longer than - the longest, easy - easier - the easiest, big - bigger - the biggest; good - better - the best, bad - worse - the worst, far - further, the furthest) or (with longer adjectives) we use more and the most (difficult - more difficult - the most difficult).

Can you complete these sentences with the correct form of an appropriate adjective? Sometimes there are different possibilities.

My brother is the *tallest* in our family. He's 198.
The BMW was the _____________ car in their showroom.
I don't have much money so I'll choose the _______ hotel for my holiday.
These days everything is so _____________. Yesterday I bought some fruit. Bananas were the ___________ while the grapes were _______ than the melon.
Last night I was very tired so I went to bed _____________ than usually.
Their house is the _____________ in our street.
This box is just too _____________. It won't fit into the car.

Compare the characteristics of three means of transport below (use adjectives: fast, expensive, cheap, heavy...):

Price: €150	€1,560	€45,000
Weight: 15 kg	80 kg	1,340 kg
Top speed: 85 km/h	185 km/h	240km/h
Length: 195 cm	245 cm	5,485 cm
Width: 35 cm	45 cm	2,450 cm

Example: The BMW is the most expensive and the bicycle is the cheapest.

Do you have your own motorbike or a car? Can you describe it?

SUMMARY

In this unit we got to know a lot about different numbers (Arabic and Roman, cardinal and ordinal, fractions, percentages and mathematical operations), various shapes (two- and three-dimensional), distances and dimensions. We also revised future forms
and comparison of adjectives.

SHORT REVISION

1. Explain the difference between cardinal and ordinal numbers.
2. Write your birth date in Roman numbers. Can you divide the shapes into two- and three-dimensional?

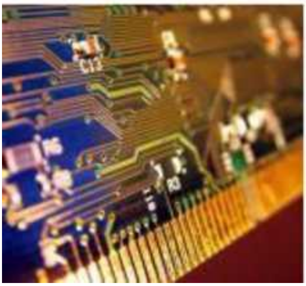
5. TECHNOLOGY, MATERIALS AND TOOLS

After this unit you will have a more detailed knowledge about technology, will be able to talk about different materials, know their properties and features and be able to discuss different tools.

What do you understand under the term technology? Which materials do you know? Do you know the differences between solids and liquids? What is an alloy? Do you have any idea how tools are divided? Have you ever heard about the lathe?

5.1 TECHNOLOGY

Technology is the knowledge of tools and crafts. Technology can refer to machines, hardware or utensils, but can also encompass broader themes, including systems, methods of organization, and techniques. The term can either be applied generally or to specific areas: examples include construction technology, medical technology, or state-of-the-art technology. Recent technological developments, including the printing press, the telephone, and the Internet, have enabled better communication. Unfortunately not all technology has been used for peaceful purposes; the development of weapons of ever-increasing destructive power has progressed throughout history.




Pictures 6, 7: Different technologies
Sources: www.cnq.ca,www.asd-europe.org

Below you have some of the amazing discoveries and achievements of modern times. Match the names on the left with the definitions on the right:

modem	A) a machine which records and plays back sound
photocopier	B) a camera which records moving pictures and sounds
fax machine	C) a machine which records and plays sounds and pictures
tape recorder	D) a machine which makes copies of documents
camcorder	E) a machine which acts like a person
robot	F) a machine which makes copies and sends them down telephone lines
VCR	G) a piece of equipment, necessary to have Internet connection

I. Match each problem with a solution:

1 This wall is very dirty.	A) It needs recharging
2 The window hinges squeak.	B) They need servicing
3 The car's battery is dead.	C) It needs tightening.
4 The car seat is too far back.	D) They need oiling.
5. My two cars both make funny noises.	E) It needs adjusting.
6. This screw doesn't hold the shelf properly.	F) It needs painting.

II. Underline the correct word in the sentences below:

Don't touch that. The wire is lively/living.
I can't use this electric drill; the lead/wire/plug isn't long enough.
There were no lights in that house. Their cable/fuse/safety probably went out.
This gadget is powered by a tiny electric engine/motor/machine.
Most appliances in Britain are fitted with a three point cable/plug/socket.

III. Make a list of things that can get or go - pair work:

dented: *parts of the car in an accident*

rusty	bent
dirty	blocked or clogged
cracked or broken	blunt
torn	flat
scratched	stained

IV. Which inventions are described below?

If you want to get up at a certain time, this will wake you with different ringing sounds. *An alarm clock*

If you need to get somewhere in the city, this is the best way as you avoid traffic jams. It also doesn't pollute.

If you need or want to talk to someone, you just press a few buttons.

If you want to communicate with someone on the other side of the world, you can send them an e-mail with the help of this.

If you want to know the time, you just have a look at this. It can also be a fashion item.

Can you think of more appliances, gadgets or machines that have dramatically changed our world?

Increase your knowledge of vocabulary by reading articles of general science in technology (you shouldn't have problems finding one on the WWW). You can also expand your vocabulary by reading children's book with pictures or flipping through a picture dictionary (Duden picture dictionaries can be very useful.). Present at least 20 new words that you have learned this way.

5.2 MATERIALS

There are different materials that we come across on daily basis. Material is synonymous with substance, and is anything made of matter - hydrogen, air and water are all examples of materials. Sometimes it is used more narrowly to refer to substances or components with certain physical properties which are used as inputs to production or manufacturing. In this sense, materials are the pieces required to make something else, from buildings and art to everyday products, such as computers. A material can be anything: a finished product in its own right or an unprocessed raw material.



Pictures 8, 9, 10: Different materials

Sources: www.treehugger.com,www.piceramic.de,www.photosearch.com

Raw materials are first extracted or harvested from the earth and divided into a form that can be easily transported and stored, then processed to produce semi-finished materials. These can be input into a new cycle of production and finishing processes to create finished materials, ready for distribution, construction, and consumption. They are divided in different ways: nature, artificial, solids and liquids or fluids, each of them having certain properties.

I. Which of these materials do you know? Do you know the meaning of the properties listed?

Iron: heavy, stiff, hard, rigid, rough, non-combustible, brittle, not very corrosion-resistant
Steel: light, stiff, tough, malleable
Aluminium: light, soft, ductile, conductive, highly corrosion resistant
Rubber: flexible, soft
Concrete: rough, hard, non-combustible
Oil: oily, thick, combustible, viscous
Wood: soft, combustible, rigid
Glass: brittle, breakable, transparent, clear
Plastics: tough, good insulator, durable, wear-resistant, stiff

II. Work in pairs: write a list of some things that can be made of:

steel: *products for big kitchens (for cooking), doors, vaults...*

silk	glass
cardboard	wax
silicone	rubber
cotton	gold

III. Match these adjectives to their meaning:

1. transparent
2. porous
3. durable
4. brittle
5. dense
6. pliable
7. translucent

A) able to last a long time
B) hard, but easily broken
C) easy to bend without breaking, flexible
D) light can pass through
E) has many small holes that allow water and air to pass through
F) has a high mass to volume ratio
G) clear, allows to see through it

1. Complete the sentences about materials and their properties: *shatterproof, light, corrosion- resistant, durable, elastic, natural, rigid, flammable, malleable, heat-resistant*

Wood is very often used in interiors because it looks *natural* and warm.
Aluminium and magnesium are important for car makers because they are ________ and therefore good for weight-saving.
Safety regulations require that the foam used in car seats shouldn't be ________.
Rubber should be able to withstand great temperature differences while staying ________. In other words, it shouldn't become brittle.
Windscreens are made of a special ________ glass to protect drivers in accidents.
Fabrics used in cars need to be ________ and not look old too quickly.
Steel is used for load-bearing parts because it is ________.
Sheet metal is used for large car parts because it is ________ and dent-resistant.
Ceramic, which is ________, is used in catalytic converters because of the very high temperatures.
Aluminium is ideal for bumpers and other body parts because it is ________.

2. Complete the sentences below by using one of the following words: *boils, evaporates, burns, stretches, dissolves, contracts, crashes, sinks, ignites, bursts, rusts, condenses, freezes, fades, floats, bounces, softens, freezes, expands, shrinks*

When you heat metal, it *expands* and if you cool it, it *contracts.*
If you leave iron outside in the rain, it ________.
If you wash your T-shirt in too hot water, it ________ and the colour
Water ________ at zero degrees Celsius and ________ at 100 degrees.
Steam ________ if it comes in contact with very cold glass.
Water ________ if you leave it in the sun.
If you need something from the freezer, take it out one day earlier and put it in the

fridge so it ________ slowly. Don’t put it back again. If it ________ one more time, it can be harmful for your health.

A spark from the engine ________ the fuel.

If you put sugar into your tea and mix it gently, it ________.

If you pull this rubber band, it ________.

If you drop the ball, it ________ off the floor.

If you overload your laptop, it ________ and you need an expert to fix it.

If a balloon gets in contact with a cactus, it ________.

The candle ________ for many hours before it goes out.

If you throw a stone into the sea, it __, but if you throw a wooden plank, it _____

Find at least three different materials for these properties:

It can be burned. *Wood, plastics, paper*

It's brittle.

You can't stretch it easily.

It’s a good insulator.

It’s extremely hard.

It’s durable.

It’s non-combustible.

It’s very light.

5.3 TOOLS

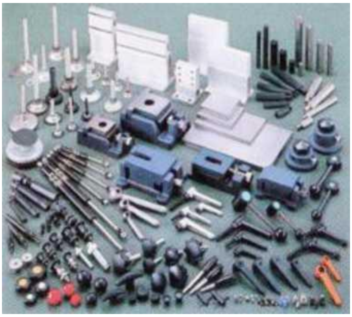
In your work life you will come across many different tools, from hand tools (such as: a hammer, screwdriver, pliers, vices, wrenches; measuring tools: squares, callipers, levels; cutting tools: saws, chisels, punches, snips; finishing and repairing tools: files, scrapers; boring and drilling tools; fastening tools: bolts, rivets; cutters...) to various machine tools (lathe, drilling and boring machines, planning and shaping machines ...).

Pictures 11, 12, 13, 14, 15, 16: Different tools
Source: www.squido.com

Match the descriptions with the tools/instruments/machines (or their parts) and decide which professionals might use them:

lathe	micrometer
pencil	file
bulldozer	jack
computer mouse	knife
drill	ruler

Part of the machine that helps you search the Internet.
Computer mouse A machine used for excavation work.
A metal tool with a rough surface.



An instrument consisting of a thin stick of graphite enclosed in a piece of wood.
A device for lifting heavy weights of the ground.
A small hand tool that is used for cuts.
A measuring instrument used to measure very small distances in metal.
A tool or a machine for making holes.
A tool for measuring, made of wood or plastic.
A machine that shapes pieces of wood or metal.

I. Complete each sentence with the appropriate tool, choose between: *axe, file, scissors, spade, hammer, saw, screwdriver, spanner, drill, knife, pliers*:

You can make these edges smoother with a *file.*
I can't open the back of television without a special _____________.
You can cut that wooden plank in pieces with this _____________.
For twisting electrical wires you will need _____________.
The good thing about this _____________is that it has a very sharp blade.
We could chop the wood for the fireplace if we had an _____________.
I am going to burry that dead bird. Where is the _____________?
Oh dear? I've hit my finger with the _____________. It really hurts.
You will not be able to make a hole without a special _____________.
If you want to wrap that present, you will need the _____________to cut the wrapping paper.
These nuts are very difficult to undo. I might need a larger _____________.

II. Read this story about a tool manufacturer and then answer the questions below:

Astor Industrial Corp. has been in the international trading business since 1979. While we specialize in hand tools, electrical items, and hardware, we are also active in a variety of other industries providing OEM solutions to our customers. We also provide Engineering Solutions and our engineers can assist you in your new product development. **Astor** acts as a sourcing agent for our customers and provides an easy gateway to Asian suppliers in various industries. With facilities in Taiwan, Hong Kong, and China, **Astor** has a good network of suppliers who can fulfill all of your requirements. Our experienced staff can perform, Factory Audit, Contract

Negotiations, Shipment Arrangements, and Inspections for you. Creating great savings in time and money for your company! Please take a look through our website to see a sample of the products we offer. Please keep in mind **Astor's** products is not limited to the items on our website. Send us any inquiries you wish for us to investigate and we will be happy to assist you. We thank you again for your time and hope to be working together in the near future!

Contact Information

Company Name:	**Hstor Industrial Corp.**
Fax	**+886/2-28261385**
Contact Person:	**Elaine** (Exporter, Buying agent, Manufacturer)
Phone:	**+886/2-28277472**

(Source: www.asianproducts.com)

When was Astor Industrial Corporation established? *It was established in 1979.*
What do they specialize in?
Who can assist you in your product development?
Where can you find their subsidiaries or contacts?
Why can their offer help you save money?
Are all their products shown on their website?
Who is the contact person?

Write down the parts of the lathe or the CNC machine and describe its use.

5.4 THE PASSIVE VOICE

The Passive Voice is not much used in our mother tongue, but extremely often in English as the stress is on what has/was/is/will be... done/achieved/frnished/completed...

I. Read these sentences and decide whether they are active or passive:

This is where the crash tests are carried out. *passive* We use crash-test dummies to measure the injuries.

A 1,360 kg barrier is driven into the side of the car at 50km/h.
Side air bags can prevent a lot of serious head injuries.
But a lot of side bags are not designed to protect smaller passengers.
We now use smaller dummies in a lot of our tests.
These tests are expensive to set up and carry out, but they can save a lot of lives.
Over 40,000 people a year are killed in traffic accidents in the USA only.
Boxes should never be lifted manually.
A fork-lift is much safer than manual lifting.
My new set of tools was made in China.
It is of good quality so it can be used all the time.

II. Put these two stories into the Passive Voice:

1 If there is a vacancy we usually advertise it in-house first of all, and if I don't find any suitable candidates, then we advertise the job in newspapers. We ask the applicants to send their CVs and we invite some of the candidates to an interview. After that, we make a list of suitable candidates and ask some of them back for a second interview. We choose the best candidate and then I check his or her references and if everything is OK, we offer the successful applicant the job.

A vacancy is usually advertised in-house first and if no suitable candidates are found, the job is advertised in newspapers.

2 Thieves held the manager of the Ridgeway Hotel at gunpoint last night during a robbery in which they took nearly $50,000 from the hotel safe. They also broke into several of the bedrooms and removed articles of value.

The thieves made their escape through the kitchen where they damaged several pieces of equipment. They injured the chef when he tried to stop them and left him lying unconscious on the floor. But they didn't enjoy in their money long because the police arrested them this morning.

5.5 COUNTABLE AND UNCOUNTABLE NOUNS

When talking about different materials and tools we also need to know whether these nouns are countable or uncountable. In English most nouns are countable and have singular and plural forms: these are the names of separate objects, people, ideas and can be counted (a book - books, a box - boxes, a watch - watches, an idea - ideas, an engineer - engineers, a child - children, a man - men, a mouse - mice ...) but there are also a lot of uncountable nouns which are the names of materials, liquids, abstract qualities, collections and only have singular or plural forms (meat, sugar, water, steel, carbon, money, luggage, paper, information - pliers, glasses, scissors, binoculars, jeans, clothes, police, handcuffs ...). Sometimes the same noun can be both, countable and uncountable (Glass is a fragile material. There are four glasses on the table. I need glasses for reading.)

I. Sort these nouns into two groups: one for countable and the other for uncountable (some may be both):
tip, trip, clothing, work, glass, case, baggage, fact, news, research, job, advice, travel, accommodation, chocolate, costume, equipment, spaghetti, stone, rubber, athlete, patience, tea-bag, concrete, coal, braces, traffic-lights, knife, iron, rain, hair
countable: trip,
uncountable: tip,

II. Are the sentences below correct or wrong? If they are wrong, correct them.
I've just heard a wonderful news. *I've just heard (some) wonderful news.*
I need an pen. Can I borrow yours?
The contents of the house were sold after his death.
Physics were always my favourite subject.
I need scissor to cut this paper.
She has done some research on the life of dolphins.
The people who works there is very well-paid.
The police is looking for a suspect.
He likes playing billiard.
My knowledges in that area are very poor.
In the north of the country most houses are made of stones while in the south bricks are more common.
I have a new leather jacket.
This railing is made of irons.

Look around your house and try to find as many countable and uncountable nouns that you can.

5.6 EXPRESSIONS OF QUANTITY

When we talk about different materials and we want to express how much of them we need, we use different expressions of quantity, such as: some (We need some water to cool this tool.), any (We don't need any more raw materials at present.), a lot of (There's a lot of valuable steel available.), much/many/more (How much time do we need to finish this project? There are many engineers involved in this project.), several (We need several new machines to modernise our production.), every/each (Every engineer should know about this new invention.), a huge amount of (We require a huge amount of plastic to pack all of our finished products.), all/whole (The whole company will benefit from this improvement.), no/none/not (They invested no money in the modernisation, so they were not competitive anymore.), a little/a few (We need a little more time. A few of our workers are on sick leave.), something/somewhere/someone/noone/nobody/nowhere/nothing/anything/anybody /anywhere /everybody/everything/everywhere (I need somebody to help me. Something came up. There's nothing we can do. I couldn't find it anywhere.), both (Both our partners declared bankruptcy.), half (We will invest half of our profits into buying new premises

Fill in the missing expressions of quantity:

Did you make *any* progress at the meeting?

Shall I send you ___________ samples of our latest fabrics?

We only made ____ money on this product so perhaps we should start phasing it out.

I met ___________ potential customers at the trade fair.

___________ has used my files and now I can't find ___________!

___________ told me that this information is confidential.

I'm sorry to hear that ___________ went wrong on your trip to Barcelona.

The flood caused ___________ damage in our warehouse.

___________ person involved in this project should do their best.

Managers spend more than ___________ of their work time at meetings.

Do you have any idea how ___________ material do we still have on stock?

Search your pockets and your bag and describe what you have found - use different expressions of quantity.

SUMMARY

In this unit we obtained a lot of useful vocabulary and learned about technology in general, different types of materials and some tools you will come across on daily basis but also in your professional life. We also revised the Passive Voice and countable and uncountable nouns and expressions of quantity.

SHORT REVISION

1. Try to analyse the importance of technological discoveries and inventions in our daily life.

6. INFORMATION TECHNOLOGIES AND COMPUTER SCIENCE

Describe the tools that are found in your own home, are they mechanical or machine? What do you use them for? How often?

After this unit you will know about the computers, their effect on our life and you will be able to use and discuss them more confidently. You will also learn how to write e-mails and you will be able to use them, not just in your private life but also in professional correspondence.

Do you have a computer at home? Can you imagine life in the modern world without them? What effects do computers have on you in your daily life?

Information systems collect, organise, store, process, retrieve and display formats. Information technology enables easier work, more detailed processes and fast communication. We all know that computers have hardware which does all the physical work the computers are used for (CPU - central processing unit, printer, graphic card, keyboard, monitor, mouse, RAM - random access memory, scanner, modem ...) and software which are instructions for the computer and without which the computer as such is just a useless machine as it cannot function (in Slovenia it's usually Microsoft programmes such as Windows).

If you thought of a computer as a living being, then the hardware would be the body that does things like seeing with eyes, lifting objects, and filling the lungs with air; the software would be the intelligence, interpreting the images that come through the eyes, telling the arms how to lift objects, and forcing the body to fill the lungs with air.




Pictures 17, 18, 19, 20: Different types of computers and their parts
Sources: www.treehugger.com,www.vcs-techs.com

Draw and describe your own computer.

I. Complete the sentences below with the missing expressions, choose between: *icon, website, cursor, mouse, download, reboot, highlight, paste, engine, copy:*

If you are writing something, the text appears at the position of the flashing *cursor.*
If you are unable to find the information that you are looking for on a , ___________ try typing out a key word in the search ___________.
If you want to transfer some text or a picture from one document to another, you can ___________ and ___________.
Sometimes it really takes a long time to ________ something from the Internet.
If you want to open a certain document, just click on the appropriate ________.
With all the viruses, warms and similar, your computer might crash. In that case you might have to ___________it.
If you want to _________ a certain part of the text, hold down the left ___________ button and drag it over the text.

II. Complete this presentation with the missing expressions, choose from the following: *processor, integrated, battery, powerful, graphics, performance*

Incredibly fast graphics processing

MacBook Pro delivers both *powerful* graphics _____ and long battery life. Every MacBook Pro features the NVIDIA GeForce 9400M ___________ graphics processor, which provides an outstanding everyday graphics experience with up to a 5x performance boost. Power your way through the latest 3D games - including Call of Duty and Quake - and enjoy improved performance with iWork '09, iLife '09, and everything you do in Mac OS X. The power-saving NVIDIA integrated ______ also keeps you up and running throughout the day, with up to 7 hours of ________ life on the 13- and 15-inch MacBook Pro and up to 8 hours on the 17- inch MacBook Pro.
(Source: www.apple.com)

III. Read this short message about corporate governance and then answer the questions below:
Message from Our Chairman
At Microsoft, success comes from our passion for creating value—value for customers, shareholders, and partners; value for our employees and the

communities around the world where we do business. Underlying our success is an approach to corporate governance that extends beyond simple compliance with legal requirements. I believe that corporate governance must provide a framework for establishing a culture of business integrity, accountability, and responsible business practices.
Strong corporate governance at Microsoft starts with a Board of Directors that is independent, engaged, committed, and effective. Our Board establishes, maintains, and monitors standards and policies for ethics, business practices, and compliance that span the company. Working with management, we set strategic business objectives, ensure that Microsoft has leadership that is dynamic and responsive, track performance, and institute strong financial controls. We believe in strengthening investor confidence and creating long-term shareholder value so we can continue to deliver technology innovations that provide opportunities for customers and for Microsoft.
— Bill Gates, Microsoft Chairman
(Source: www.microsoftcorporation.com)

Answer:
Who is Bill Gates? *He's the founder and the chairman of Microsoft, he's also one of the richest people in the world.*
What is the basis for the success of Microsoft?
What does corporate governance provide?
What are the characteristics of their Board of Directors?
What does it do?
What are some of the company's values or beliefs?

6.1 E-MAILS

With the explosion of information technology, we use more and more e-mails. E-mail is extremely convenient, with the click of a mouse, an e-mail can be sent to a colleague in the next office or a business partner at the other side of the world. Although you are probably more used to sending quite private e-mails to your friends, you will also have to learn to write formal e-mails to your existing or potential business partners - you need to remember that you have to be polite and follow almost the same rules as for formal letters.
E-mails tend to be less formal, but there are still some points we should consider: address messages carefully: we've all heard stories of messages being sent to unintended recipients: this may be funny, but also disastrous; remember that e-mail messages are not private: you must have in mind that every e-mail you send may be

read by anyone and everyone else; remember that e-mails may be saved and used as a proof of certain communication.

10 Tips for office E-mail:
Carefully read e-mail and answer all questions, to avoid going back and forth.
Avoid sending confidential information via e-mail - make a phone call or ask to discuss sensitive issues in person.
Don't use text message or chat jargon unless it is widely used within your organization. Include a brief greeting that is appropriate for status of sender. Also include a closing.
Watch the tone - remember no body language can be interpreted, only your words.
Use spell check and read message for errors before sending.
Respond promptly; if you cannot respond at the time, indicate that you will do so later.
Use proper colour, fonts, layout, and formatting (those that fit with your work environment). Avoid "casual speak" or slang; use abbreviations wisely.

If you e-mail back and forth three times, and the problem is not resolved, pick up the phone.

Look at this example of a rather formal e-mail:
From: milena.strovs@guest.arnes.si
To: Gab. de Redoes Internacionais [mailto:gri2@iscap.ipp.pt]
Subject: International week in Porto
Dear Ms Carneiro,
Thank you very much for your formal invitation.
I have completed the registry form and I am returning it to you.
If there's anything else, please do not
hesitate to contact me. Yours sincerely,
Milena Strovs-Gagic

I. Read this e-mail and then answer the questions below:

Dear Mr. Philtre,
Thank you for your e-mail and for sending me the specifications.
I have no idea if that is possible but I would like to discuss them in person so if you have any time until the end of the week, we should try to arrange a meeting. Although I'm also quite busy I will try to work my obligation so I can adapt to your availability.

This would be essential as we need to work out the detail for the production line.
I hope to hear from you very soon.
Best wishes,
Tom Young

Why would Tom like to meet Mr. Philtre in person? *Because he 's not sure if what they want to do is possible.*
If Tom is so busy, how can they meet then? Why is it necessary that they meet?

II. You received this e-mail from your customer. Complete it with the right words, choose from: *appreciate, attachment, forward, received, delivery, possible, sending, order, unfortunately, writing*

From: pierre@sr.g.fr
To: francis.brown@dillinger.co.uk
Subject: Order no. 7H325K
Dear Mr. Brown,
I'm *writing* to you because of the problem with the delivery which we ____ from you last week. The _____ was 1,000 dash ____, 50 boxes that arrived were empty. Can you send us the missing items as soon as ______? We would also ____ it if you could look into the problem to make sure this does not happen again. I'm ____ you a scan of the _______ note as an to hearing from you soon.
Best wishes,
Juliann Pierre

III. Use the following words and phrases to complete the e-mail: *I'm attaching, Is there, It would also be good, Please confirm, Thank you so much, There will be, Could, Would you like:*
Dear Mrs. Anniston,
Thank you so much for the project outline. _______ we discuss the specifications of the main unit at your earliest convenience? ______ to discuss the schedule. _______ to have a conference call (you, me and Brad Cooper)? ______ a convenient time at the end of this week, Friday preferably?
___ a draft budget. ___ some changes when we agree all the specifications, of course.
_______ that you've received this message so I can make further arrangements.
Best regards,
Samantha Cook

Name some abbreviations (and explain them) that you use when communicating with your friends.

SUMMARY

In this chapter we talked about some general points of the information technology and we learned how to write formal e-mails (similar rules apply as for formal letters).

SHORT REVISION

1. Discuss the differences between hardware and software.
2. What is RAM?
3. Analyse the differences between informal and formal writing in e-mails.
4. Can you name some tips for successful e-mailing?

7. HEALTH AND SAFETY AT WORK

After this unit you will be able to discuss the rules and regulations about safety at work, build up your vocabulary and know more about verb patterns.

Have you ever worked? Was it in a dangerous environment? Did you have to follow any special regulations? Have you ever passed any kind of exam on health and safety at work? How did it look like - just theory or also a practical part? What did you learn?

Safety and health is an area concerned with protecting the safety, health and welfare of people engaged in work or employment. The goal of all occupational safety and health programs is to foster a safe work environment. As a secondary effect, it may also protect co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are impacted by the workplace environment. The average person finds it difficult to assess risks and that is why work practices need to be regulated.

Safety in the workplace is critical to the success of your business, no matter what size it is. As a business owner you have responsibilities regarding health and safety in your workplace. Even if you don't have any employees, you must ensure that your business doesn't create health and safety problems for your customers and the general public.

Knowing and understanding the Occupational Health and Safety laws can help you avoid the unnecessary costs and damage to your business caused by workplace injury and illness.

There are many examples of dangerous activities at your workplace, such as welding without goggles, working at a construction site without the protection of a hard hat, working in noisy environments without ear plugs or mufflers, working in production with different possibly hazardous materials without protective gloves and/or clothes, smoking near inflammable substances...

There are different risky or hazardous situations, such as: combustion, contamination, dust, the possibility of explosion, poisonous fumes, gas leakages, toxic vapors, the danger of electrical shock ... which can all have effects on us and can cause lethal or very serious damage to our body (for example: vomiting, dizziness, burns, birth defects, cancer, genetic damage).

All around risky environments or materials there are warning signs that people have to take seriously.

Below you can see three such examples:

Pictures 21, 22, 23: Warning signs
Source: www.pharmaininfo.net,www.ehs.uky.edn

Try to find some warning signs and explain them

I. The person in charge of health and safety is trying to explain the rules and regulations to the new employed workers. Complete what he says by filling the blanks with the missing expressions. Choose from: *noise, protection, drowsiness, dust, accidents, smoke, poisonous, fumes, risks, burns, goggles, safety, masks, plugs*:

New government regulations mean that we are all required to be more aware of *risks* in the workplace. As your superiors we will provide you with the necessary _______ equipment. You have to wear __________to protect your eyes when working on the welding machines. You should also wear ear_____________ because the _____________ from the machines is so high that it could damage your hearing. There is also a lot of_____________ in the air, so don't forget to wear _____________ to stop you breathing it _____________ in. You are also personally responsible for your safety and for preventing ________ to happen.
We also have a possibility of fire here. Remember that it is extremely dangerous to _____________ near the chemical storage. That is why, we have a no-smoking policy not just inside the company but also in its proximity. I'm sure you are aware that chemicals are very _____________ so they must never enter your mouth. They could cause _____________ if you get them on your skin. If you forget to put the lid on, __________might escape and cause headaches, ___________ or dizziness.

II. Name the safety items below. Can you add more?

Pictures 24, 25, 26, 27, 28, 29, 30, 31, 32: Protective clothes, shoes and other equipment

Source: www.imbtraining.com

III. Read this report, complete the safety rules and then answer the questions below:

Accident with a ladder

Jason had an accident yesterday and he cut his head badly. He is in hospital now. This is what happened: he took a metal ladder from the storage and carried it into the machine shop. Then he put it onto some boxes next to the main door of the workshop (which was closed but not locked) and climbed the ladder. While he was repairing the electric cable, someone opened the door and walked into the workshop. The door hit the ladder and it fell over. Jason fell from the ladder onto the floor. He landed on his feet, but there was some oil on the floor and he slipped and cut his head on the drilling table.

SAFETY RULES

a) Wet or oily floors must be *cleaned* before a ladder is *put up.*

b) Metal ladders should never be used for _____________ work.

c) When you _________ a drilling machine, always have the work-piece in a vice.

d) When the ladder is near the door, it must be _____________.

e) The ladder must never be _____________ on boxes or drums.

f) Never ___________ a bare electric ___________ when the electricity is on.

Now answer these:

Which of the above rules did Jason break?

Where is he now and why exactly?

7.1 VERB PATTERNS

There are certain rules when we use the gerund and the infinitive, let's mention just a few. The gerund or the -ing form is used as the subject or object of a sentence (Working in this company is very rewarding. She hates being criticised.), after certain verbs (I like travelling on business. I can't stand sitting in a meeting and doing nothing. He started producing this machine two years ago.), after prepositions (On hearing the good news everybody started clapping.), in set and idiomatic expressions (Paris is always worth visiting. It's no use crying over spilt milk.) Infinitive is used after certain verbs (He decided to retire. They want us to lower the prices. They offered to show us how to adapt the production line.), to express purpose (They bought new machinery to modernise their production.), after question words (I don't know what to do or where to start.), after expression too, enough (He was too young to become a manager. This isn't good enough to solve all our problems.), after adjectives (It's impossible to do anything about it now. It was difficult to follow his presentation.).

I. Describe how to do something by using a preposition (by, without) and the -ing form (e.g. Start this machine by pressing the red button.):

I loosened the nut. I didn't use the spanner.
I loosened the nut without using the spanner.
We got rid of the terrible smell. We opened the windows and made a draught.
She managed to separate the two stuck glasses. She didn't break them.
He built a nice bookcase. He didn't look at the instruction manual.

II. Complete these sentences by a suitable ending in -ing:

Thank you for *helping me when I was in such a difficult situation.*
I'm looking forward to _____________.
A new pizza place was opened in town last week. How about _____________?
I'm thinking of _____________.
When I'm too tired I often feel like _____________.
Our clients often insist on _____________.
There's no point in _____________, we'd better wait and do it tomorrow.
I'm afraid the manager is busy at the moment. Would you mind __________ for a few minutes?

III. Fill in the missing infinitives:

Scientists in the Silicone Valley are hoping *to do* a little more about the problems an average consumer has with the computer.

Things are looking good for engineers as there are a lot of companies who want _____________ them.

I'm waiting here ________ the visitors of the company and show them around.

We refused _______ them as the quality of the delivered items was questionable.

He didn't have time so he asked me _____________ back later.

My friend encouraged me _____________ for the position.

They have invited me _____________ at the conference.

IV. Fill in either the -ing form or the infinitive:

Dear Mr. Brown,

Thank you for your letter of 25th March in which you stated that you were considering *placing* (place) an order of our superior cutting machine.

We can arrange ______ (supply) you with your order in 4 weeks' time. If you decide ________ (go) ahead with the order, we will agree _____________ (give) you a 5% discount for payment within one month.

You mentioned that you wanted _____ (try) out the machine yourself. This shouldn't be a problem. Just contact us and we'll arrange when you can see the machine 'in action'.

Please do not hesitate ________ (contact) me if you have any further questions.

I look forward to _____________ (hear) from you again soon.

Yours sincerely,

Peter Harrow Managing Director

7.2 EXPRESSIONS WITH WORK, TAKE, GET, WORK, MAKE AND DO

English is a language that has many set phrases, collocations and idioms. We'll have just a quick look at some of them here.

You can for example take a break, take time, take notes, take a photograph, take someone's temperature, take a seat, take a job, take offence, take action, take size 39 shoes, take an exam, take the bus, take a free kick in football, take a bag, take somebody somewhere ...

You can work with something, work yourself free, work at, on, out, forward.

You can get out, get something, a good grade, punishment, an early retirement, a bad headache, angry, used to something, get on the bus, the phone or the door, help, a promotion, fired .

You can have a job, problems, the nerve to do something, ideas, an illness, an operation, experiences, children, no idea, a good time, a holiday, a meeting, a meal, second thoughts, some time off.

You can make a plan, a point, an excellent suggestion, your bed, a mistake, an offer, a cake, a dent in the roof of your car, a habit out of something, a decision, a profit or a loss, someone's day.

You can do any kind of work (homework, housework, the dishes, the ironing, cooking, writing, acting, a job.), the shopping, someone a favour, nothing, well, aerobics or yoga, 50 km/h, drugs .

Complete the sentences with the correct form of *take, get, do, work or make*:

I'm going *to take* six months maternity leave after the baby is born.
His wife is not very well so he's going to _____________ a few days off.
I'm toying with the idea of ________ an early retirement next year when I'm 59.
Have you _____________ out how to solve this problem, yet?
He _____________ ten years for robbing a bank and wounding the teller.
Hopefully she'll _____________ a promotion when her boss retires.
Would you _____________ a picture of us, please?
These pills are just not _____________ it for me. I'll have to see my doctor again.
I always _____________ my bed in the morning.
I hope you _____________ a great time on your holiday.
She cooked lunch and he _____________ the washing up.
If she keeps going like that, she'll _____________ a heart-attack.
Many girls _____________ aerobics at the gym lessons.
He's _____________ rich by selling all his shares.
Let's go out and _____________ out a good meal from that new restaurant.
If she doesn't start working harder, she _____________ fired.
I don't know where I'll go on holidays. I haven't _____________ any plans yet.
After finishing high school, he decided to __ a year off before going to university.
Come in and _____________ a seat.
_____________ mistakes is human, we all do it.
At the weekends I usually _____________out of the house to meet my friends.
My plan _____________ and they agreed to do it my way.
I'm sick and tired of ______ up so early, I'll have to find a nine-to-five job soon.

Someone crashed my car at the car park. That really _____________ me angry.
When my teacher explains something, I always _____________ notes.
After travelling all day, she _____________ a terrible headache.
I hate to ask you but could you _____________ me a favour?

SUMMARY

In this unit we discussed health and safety at work and found out that there are many risky and dangerous items at almost any workplace. We got to know more about protective clothes, gloves, shoes... We also built up our vocabulary by learning about expressions with take, get, make and do.

SHORT REVISION

1. What are some general health and safety regulations?
2. Demonstrate how you can protect yourself in dusty or noisy environments.
3. Think how you could put out a fire in the classroom and analyse the safety procedures at school.

8. AUTOMOTIVE

After this unit you will definitely have a much better knowledge of the automotive vocabulary, be able to describe the outside and inside of a car, talk about the different types of vehicles, their advantages and disadvantages. You will also revise relative pronouns and relative clauses.

Do you have a car? What make do you have? What would be your ideal vehicle?

8.1 VEHICLES IN GENERAL

A vehicle is a mechanical means of conveyance, a carriage or transport. Most often they are manufactured (e.g. bicycles, cars, motorcycles, trains, ships, boats, and aircrafts).Vehicles may be propelled or pulled. Vehicles that do not travel on land are called crafts, such as watercraft, sail craft, aircraft, hovercraft, and spacecraft. Land vehicles are classified broadly by what is used to apply steering and drive forces against the ground.

I. Can you name the vehicles in the picture? Can you compare them?

Pictures 33, 34: Different types of vehicles
Source: www.london.gov.uk

II. Do you know what these are: *a hatchback, a lorry, a road sweeper, a cab, a people carrier, a carriage, a bus, a sports car, a cross over, a van, an executive car, a bulldozer, a scooter, a tram, a towing vehicle, a road train, a refuse collection vehicle, a trailer*?

III. Choose the correct expression from the possibilities in brackets:

Most big cities were built long before the heyday of the private car. As a result they rarely have enough space for moving traffic or parked vehicles and long queues of *stationary* (standing, settled, stationary, static) vehicles are a common sight. Indeed some cities end up being almost permanently ______ (stuffed, saturated, crammed, suggested) during the day. Those that have a relatively free ______ (flow, current, tide, flood) of traffic at non-peak periods of the day do not escape either. The ______ (push, rush, hasty, hurry) hour of early morning or early evening can easily see traffic brought to a ______ (standstill, hold-up, jam, freeze). The effects of exhaust _____ (smells, odours, fumes, stinks) on air pollution in cities has been well documented. Buses might be seen as the solution, but they move slowly because of the shear _____ (size, volume, breadth, depth) of other traffic, thus encouraging more commuters to abandon _____(civic, mass, public, popular) transport.

IV. Match each person with one of the comments: *commuter, conductor, passenger, driver, traffic warden, hitchhiker, passer-by, pedestrian, steward*

I'll bring you a drink in just a minute, Madam. *steward*

I've been waiting all morning at this roundabout for someone to stop. ________

I was just walking down the street past the bank when I saw what happened. ____

I've spent the last half hour looking for a spot. It's hopeless. ________

I'll tell you when it's time to get off. ________

The sign clearly says two hours only and you've been here all day. ________

It's just impossible to get across the road here. We need a subway. ________

Do you think you could go a little slower? I'm a bit nervous. ________

This train is late every morning. It's been for years. ________

V. Fill the blanks with the appropriate word, choose from the following: *bonnet, run o Go downut, passengers, garage, galleys, mechanic, flight, ferry, boot, check, deckchair, delayed, departure lounge, train, way*

Yesterday John was supposed to take a *flight* from London to Paris. He got up very early, put his luggage in the _____ of his car and tried to start the engine. It wouldn't start. John lifted the _______ of his car but he couldn't see what the matter could be. He immediately called his local ___ to ask them to send a ____ at once. Fortunately, the garage had a man free and he was with John in ten minutes. He quickly saw what the problem w__ everything last night?" he wondered. Despite all this he got to the airport, checked in quite early and then went straight to the ____ to read a newspaper while he was waiting. Soon he heard an announcement. "Passengers on flight BA

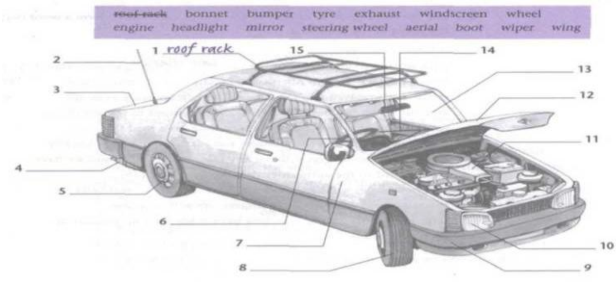
282 to Paris are informed that all flights to and from Paris are ___ because of the heavy snowfall last night." "If only I had decided to go by ___", John thought. "It would probably have been quicker in the end and even if I sometimes feel sick on the ____ across the Channel, it can be quite pleasant sitting in a ________ on the deck, watching the seagulls and the other _____. The ____ on a ship seem to produce much better food than those on an aircraft, too."

VI. Choose the best word from the brackets to fill the gap:

A hundred years ago, most people travelled *on* (by, on, with, to) foot, by train or on horseback. ________ (Tracks, Lines, Ways, Railways) had made it possible to travel faster over long distances. Bicycles were also becoming ________ (popular, invented, then, handlebars), after the invention of the air-filled ________ (boot, brake, tyre, engine) which made cycling a lot more comfortable. Buses, trams and _______ (metro, buried, underground, submerged) railways had also been invented and cities all over the world had traffic ________ (blocks, sticks, knots, jams). There were very few private cars, and city________ (streets, pavements, lawns, carts) were still full of horses. What a difference a hundred years have ________ (taken, done, made, got)! ________ (Presently, Nowadays, Then, Later) we have Got ________ (more, them, motorists, used) to the problem of private cars, and some cities are so noisy and ________ (even, polluted, so, poisoned) that in many places ________ (vehicles, traffic, transport, trips) have been banned from the city centre. How will we be travelling in a hundred years' time? Perhaps ________ (cars, by, even, transport) then there will be only personal helicopters. There may be no need to ________ (have, transport, decide, commute) to work or school in the future, since everyone will have a computer at home. There might even be more people walking and horse-riding, for pleasure and ________ (exercise, keep fit, energy, healthy).

8.2 CARS

An automobile or motor car is a wheeled motor vehicle used for transporting passengers, which also carries its own engine or motor. Most definitions of the term specify that automobiles are designed to run primarily on roads, to have seating for one to eight people, to typically have four wheels, and to be constructed principally for the transport of people rather than goods. However, the term automobile is far from precise, because there are many types of vehicles that do similar tasks.



Picture 35: Car parts
Source: Vince: Advanced language Practice, 1994

Source: www.cartuningcentral.com

I. Complete the sentences with the appropriate expressions, choose between: *bumpers, boot, bonnet, seat belt, indicator, aerial, logo, sunroof, windscreen wipers, tyres, badge*

You open the *bonnet* to look at the engine.

The _______________ absorb small impacts in an accident.

Don’t forget retract the _______________ before using the car wash.

Can you put my suitcase in the _______________, please?

When it starts raining, you need to switch on the _______________.

“What model is that?” “I don’t know I can’t see the _______________ from here.”

It is important to inflate the _______ to correct the pressure for better fuel consumption.

The Mercedes star is a well-known _______________.

Open the _______________ and let some sun and fresh air into the car.

I wish all drivers would use their _________ when they want to turn right or left!
Do not forget to fasten your _________ it can save your life in case of an accident.

II. Match words on the left with those on the right to find the exterior parts of the car:

1 head	A) wipers
2 rear	B) lights
3 exhaust	C) plate
4 front	D) cap
5 petrol	E) bumper
6 windscreen	F) mirror
7 wing	G) handle
8 door	H) pipe
9 number	I) lights

III. Complete the story below with the appropriate expressions: *components, exterior, welded, data, quality, shell, assembly, wirelessly, schedules, date, shop, frame, specific, suppliers, rear*

Almost every car is produced to the customer's *specific* requirements - a built-to-order car. As soon as a car is ordered and a delivery _________ agreed, weekly and daily production _______ are created and sent to outside _______ and the company's own pre-assembly stations. This is to make sure that all the necessary ________ arrive on time.

First of all, a small _________ carrier is attached to the floor pan in the body _________. This data carrier contains all the customer's specifications and communicates _________ with control units along the production line. In the body shop the floor pan, wheel arches, side panels and roof are _________ together by robots to make the ___________of the car. The add-on parts - the doors, boot lid and bonnet – are then mounted to make the body-in-white.

The finished body _________ then goes into the paint shop where the data carrier determines the colour. In final ______________ the _____________ parts (for example the front and ______________ bumpers, headlights, windscreen and other windows) are fitted. After ______________ control and a final check, the finished car can be released. It is now ready for delivery to its new owner.

IV. Complete these sentences with the passive form of the verb in brackets:

This model *is produced* (produce) in the new factory in Poland.

German cars ______________ (sell) all over the world.

Theirs new car ______________ (probably make) in Korea a few years ago.

The orders ______________ (can place) by fax or online.

The cars ______________ (assemble) by robots since the previous century.

Spare parts ______________ (can buy) from your local dealer.

The interiors ______________ (design) by a computer for quite some time.

Tyres ______________ (should replace) before they wear down completely.

The sales of car ______________ (plummet) in the last few months.

V. Read the story and answer the questions below:

Over the last ten years people have got used to the sight of very small cars parked in tiny parking spaces. Smart is one of the world's youngest car makes and yet the *smartfortwo* is such a distinctive car that it has already been included as an exhibit in the Museum of Modern Art in New York - one of only six cars to attain this distinction.

In April 1994, the Micro Compact Car AG was founded in Switzerland as a joint venture between Mercedes-Benz and Swatch. Nicolas Hayek, the inventor of the Swatch watch, brought his idea for an ultra-short small car, and Mercedes-Benz contributed expertise and experiences from more than a hundred years of building cars.

Engineers devised a car which is not only extremely mobile and efficient, but also very economical. Its other key feature is safety, with its unique tridion cell.

After starting development in 1994, the *smart fortwo* celebrated premiere at the Frankfurt Motor Show in 1997. Production in Humpback, France, started in July 1998, and in October sales took off in other European countries. In 1998, smart became a 100% subsidiary of what was then Daimler-Benz AG.

There is no doubt that the *smart fortwo* is a leader in urban mobility. All smart vehicles embody the same brand values and have the same 'DNA': innovation, functionality and 'joie de vivre'. They appeal to people who are sporty, independent and young at heart, people who love clever solutions and are open to new idea.

What are the advantages and disadvantages of the *smart fortwo? Advantages are: it's easy to park, it's mobile and efficient, economical and safe; disadvantages are: it's expensive, it's sometimes too small.*

Where was it exhibited?
Who first got the idea for such a car? Who was he?
When did the car have its first premiere at the motor show?
Who were the owners at the beginning?
Why is it the leader in the urban mobility?
Who are the main customers?
Would you ever buy a *smart fortwo?* Why/why not?

VI. What do you do when:
visibility is poor because of fog? *Turn on the lights.*
your seat is too low?
you think you need oil?
you want to get out of the car?
it's getting dark?
it's warm and sunny?
you think your tyre pressure is low?
your passenger has no leg room in the back?

VII. Look at this extract from a tour of a car factory. Complete the text with the missing words: *clutch, combustion, power, crankshaft, explosion, cylinders, distribution, fuel, piston, spark plug, rotational*
"Now we come to the engine. The principle of the internal *combustion* engine has not changed in the last 100 years. The engine takes in _______ and air which is compressed in a combustion chamber. Then this mixture is ignited by a _____ to produce an ______, which moves the ______ in the cylinder. The up and down motion of the piston in the cylinder is converted into rotation motion by the _________. The ________ force generated by the engine is known as torque.
The size of the engine determines the __________ The more ________ there are, the more powerful the engine. This power is transmitted through the ______, the

gearbox, the propeller shaft and the axles to the wheels. The position of the engine can vary, but generally speaking it is mounted at the front. In some sport cars, the engine is mounted at the rear or in the middle because of weight _________. So, that's enough about the engine for the moment, let's move on to the next stage."

VIII. Match the words with the right description: *accelerator, chain, gear, bonnet, handlebars, reverse, brakes:*

Go into this if you want to go backward. *reverse*
Put your foot on this to make the car go faster. ______________
Change this in a car to change speed. ______________
Hold these when you ride a bicycle. ______________
This might be on your bicycle or around your neck. ______________
Put these on if you want to stop. ______________
Your car engine is usually under it. ______________

IX. Draw a car with the following parts: *roof rack, bonnet, bumper, tyre, exhaust, windscreen, wheel, headlights, mirrors, steering wheel, aerial, boot, wipers, wing*

8.3 RELATIVE PRONOUNS AND CLAUSES

Relative clauses are divided into defining (provide necessary information without which the sentence is incomplete: I know a man who has 10 children. This is the vase which/that I was given for my birthday.) and non-defining relative clauses (they give additional information: Marilyn Monroe, who died very young, is still an icon. Their advertisement, which I saw yesterday, is very impressive. My mother, who will be 80 years old next year, asked me to find her a painter to decorate her house. Jack Jones, whose phone number I can't find, is our loyal customer.).

I. Fill in the missing relative pronouns (*who, whose, what, which, where*):

A quality controller is a person *who* checks the production systems.
Does anyone really know ______________ responsibility this is?
I don't know ______________ happened! Suddenly the fire started!
Do you know the name of the woman __________ is organising the conference?
This is the company _________ offers the most favourable prices for these items.

I don’t know ______________ company to contact first. They all seem to have a wide range of products on offer.
The computers ______________ you ordered last week have just arrived.
Yesterday I was talking to someone __________ brother went to school with you.
The specialists __________ repaired our broken machinery were very efficient.

II. Read the specifications for this car and then complete the relative clauses below:
Tight, light body. Great handling. Excellent brakes. Five-star safety. Six-cylinder refinement and performance. Six-speed automatic works well in any shift mode. More interior space. Low cabin-noise levels. 320i struggles to convince at $50,000-plus. Unforgiving, low-speed ride. Some front-end suspension/tyre noise. Back end can get twitchy on rough roads. Inconsistent steering, with less feedback than before. Tight rear-seat access, and tall adults sit knees up. All seats lack support. Run-flats are expensive (around $2000 a set) and might be difficult to get.
(Source: www.drive.com.au)
This is a car *that has a tight and light* body.
Another good feature is ______________.
It has a six-speed automatic ______________.
The great cabin is ______________ outside noise-levels.
A disadvantage is ______________.
It has a back end ______________.
Run-flats are the part ______________.

8.4 ONE WORD - TWO (OR MORE) MEANINGS

In English there are many words that have more than one meaning - these are the so called homonyms (they can be further divided into homographs and homophones). To name just a few: live, bank, swallow, free, fair, party, see, operation, model, mark, can, wind, house, lead, hard, minute, refuse, wound, read, row ...(sometimes the pronunciation is the same but very often it is different).

I. Fill in the missing words in these pairs of sentences:

I enclose a *free* sample of our latest magazine.
I’m terribly sorry but Ms Cartwright won’t be *free* until 4 p.m.

I just need a _______________ of your time.
Dust is so _______________ that we can't see it with a naked eye.
Unfortunately, we have to _________ your offer. It's just not competitive enough.
After the rave party there was a lot of _______________ in the streets.
BMW now have a huge _______________ in the USA.
He has serious problems with his heart. He's been scheduled for an _______________ next week.
The concert was going on _____________ on all major broadcasting companies.
Where do you suppose to _______________ when you move abroad?
The _______________ singer in that group is gorgeous.
We all know that _______________ pipes are dangerous and should be replaced.
She had a sore throat so she couldn't _______________ the food.
One early _______________ doesn't bring the spring.
I usually got good _______________ in school, except in languages.
He was a clumsy eater, so he had several _______________ on his white shirt.
She usually sits in the front _______________ in the classroom.
If you live near a river, it's useful to learn how to _______________ a boat.

SUMMARY

In this unit we learned a great deal about different kind of vehicles in general and about cars in detail, about the exterior and interior parts which we can name now. We also built our vocabulary with words that have more than one meaning and revised relative clauses.

SHORT REVISION

1. Try to name different types of vehicles.
2. Compare your car with a luxurious one - are there many differences in the exterior or interior.
3. Analyze what might be necessary if you wanted to tune up an old Renault

9. ON THE PHONE

In this unit we will be discussing how to communicate with your business partners, clients, customers on the phone so after studying it you will be able to do that confidently and without being afraid that you might offend someone.

How often do you use your phone? Do you call people or just send them short messages? Are there any differences between private and business calls?

Not just in your private life but also in your professional one you will be using the phone a lot: I'm sure you believe you can communicate over the phone but can you really?

Formal communication in business situations is very much different from private ones and although private phone conversations differ from one nationality to another, there seem to be one common style of business phone calls.

Preparing for the Business Call

Step 1

Remember that a business telephone call is comprised of three components: the beginning introduction, the middle bulk of the call, and the end summing up.

Step 2

Say everything that you need to in order to explain your reason for calling. State when you will return the call or request that the other person call you back. If you have to leave a message, be concise.

Step 3

Let the other person know at the beginning of the call if you plan to use a speaker phone or record any part of the conversation.

Although e-mail and instant messaging are quickly becoming standard forms of office communication, the telephone still plays an important role in business. Just like a face-to-face meeting, telephone conversations are expected to and should follow certain rules of etiquette to help make the experience pleasant and productive for all those involved.

It's easy to forgo manners when talking over the phone. Distractions abound, from impromptu meetings or email notifications blinking on your computer screen. Remember that a conversation over the phone carries just as much weight as a face-to-face meeting, as it is a great opportunity to communicate in real time.

When making a business call, be sure to first identify yourself and your company. If you're routed to a receptionist or operator, also include the name of the person you're trying to reach. A simple, "Hello, this is Ann Smith from General Motors. May I please speak with Jake Pitt?" will do.

Be prepared with a one or two sentence explanation of the purpose for your call.

When you are connected with the person, state the purpose of your call and then be sure to ask if you are calling at a convenient time. This is one of the most overlooked areas of phone etiquette, and allows the person you're calling the opportunity to better address your needs at a later time. If you get the receptionist and he or she asks why you are calling, give a concise but informative statement that can be easily relayed. Do not, however, assume that your message will be communicated; when you speak directly with the person you are trying to call, repeat your message in your own words. Don't be insulted if you're asked to leave a message or call back later - previous engagements do take priority.

People make business phone calls for specific reasons. Very rarely do vendors or clients call just to catch up. Telephone calls usually lead to some action to be taken, so make sure your first vocal impression is a good one by trying to answer the phone as pleasantly and professionally as possible.

Identify yourself and your company when receiving an incoming call. While it's not impolite to say, "General Motors, Ann Smith speaking," it might be easier on the listener to say, "Thank you for calling General Motors. This is Ann Smith. How may I help you?" Variations on this theme can convey your greeting quite effectively. If you work at a large corporation with many departments, it may also help to include your department or section name, "This is Ann Smith, sales department. How may I help you?"

The hold feature is generally considered a double-edged sword in telephone etiquette. No one is usually available at the exact moment of a phone call, and being on hold simply must be tolerated. However, there are many things the caller and the person taking the call can do to make the experience a pleasant one.

If you must put someone on hold, ask first and - most importantly - wait for their answer. If someone expresses reservation about being put on hold, calmly explain why it is necessary. Perhaps the person they are calling for stepped out of the office and needs to be tracked down, or is on another call. Callers like an explanation for their inconveniences, but don't give away too much information.

Remember to keep the person on hold updated on the status of his or her call every 30 seconds. A simple "She's on another call" or "His meeting is running a little late" is sufficient. It's OK to hang up after three minutes on hold. Call back and ask to leave a message instead.

Pictures 39, 40: Different types of phones
Sources: www.thepointega.com,www.deakin.edu.au

Look at this example of a telephone conversation:
A: Good morning. Lights and lamps. Can I help you?
B: Good morning. I would like to speak to Mr. Green, please.
A: One moment, I'll put you through.
C: Sales Department, Green speaking. How can I help you?
B: Good morning. This is Jeff Plant.
C: Oh, good morning Jeff. How are you?
B: Fine, thank you for asking. Busy as always.
C: So, what can I do for you?
B. I'm calling about your last delivery. There seems to be a bad batch as some of the spot lights that we ordered do not work properly.
C: I'm really sorry to hear that. Can you give me some details?
B: Well, they seem to be weak or they keep breaking down all the time.
C: So, what do you suggest we do?
B: I think it would be best if we sent you the whole shipment back and you in return send us a new one. How does that sound?
C: Good. As soon as we receive this shipment back, we'll check them once again and if you're right, we'll send a new batch as soon as possible. Is that all right with you?
B: Well, we'd really need these spot lights for the venue we're organizing this Friday. So, your suggestion is not really acceptable.
C: What about sending you a specialist who could inspect them on the spot? He might figure out what's wrong and repair them.
B: That sounds better. When can it be done?
C: I'll send someone over to you right away.
B: Great. But what if he can't fix them?
C: Let's wait and see. If he can't do it, he'll give me a call and we'll try to find the best solution for you then.

B: Right. I hope everything works out well.
C: I'm sure it will.
B: OK, thanks for your time.
C: No problem. I'll talk to you later. Bye.
B: Bye.

Write down a telephone conversation, follow these clues: *you call your business partner, Robert Scoffed, from Motors and Machines, but he's not there, you just want to leave a message for him to call you back as soon as possible as one of the machines you bought from them is making a strange, vibrating noise.*

A: Good morning, Motors and Machine. How can I help you?
B: Good morning, I would like to speak to Mr. Robert Scoffed.
A:
B:
A:

I. Read this text about iPhone and then answer the questions below.

It's three devices in one. iPhone is more than just a phone. It combines three devices in one: a revolutionary mobile phone, a widescreen iPod, and a breakthrough Internet device. All that and more makes it the best phone you'll ever use. With the Multi-Touch interface on iPhone, you can make a call simply by tapping a name or number in your contacts or favorites list, your call log, or just about anywhere. Visual Voicemail lets you select and listen to messages in whatever order you want — just like email.

iPhone shows off your content - music, movies, TV shows, and more - on a beautiful 3.5-inch display. Add to your collection by downloading music and video wirelessly from the iTunes Store. Scroll through songs and play lists with the touch of a finger. Even browse your album artwork using Cover Flow. iPhone uses fast 3G and Wi-Fi wireless connections to deliver rich HTML email, Maps with GPS, and Safari - the most advanced web browser on a mobile device. It has Google and Yahoo! search built in. And since iPhone

multitasks, you can make a phone call while emailing a photo or surfing the web over a Wi-Fi or 3G connections.
iPhone comes with some amazing applications. And you can choose from thousands more on the App Store and download them with a tap. Your iPhone gets even better with every new app. Play games. Be more productive. Keep yourself entertained. No matter what you want to do on iPhone, there's an app for that. Stay connected from anywhere. Apps like Facebook let you use iPhone to share photos, status updates, and more with a few taps. Play games a whole new way. With iPhone, you can tilt and tap your way through groundbreaking games like Rolando. Find out what's for dinner. Discover new restaurants on *Urbanspoon* by shaking your iPhone. What other phone does that? With iPhone, Apple combined innovative hardware features with the world's most advanced mobile operating system to redefine what a mobile phone can do. Applications work together seamlessly and they sync with your computer — whether you're on a Mac or a PC. From its revolutionary Multi-Touch display to its intelligent keyboard to its smart sensors, iPhone is years ahead of any other mobile phone.
(Source: www.apple.com/iphone)

1. Why is iPhone so special? *Because it's three devices in one.*
2. How can you make a call? *By tapping a name or number in your contact or favourite list.*
3. What kind of display does it have and what can you see on it? *3.5-inch one.*
4. How can you download the music? Where from? *Wirelessly, from i-Tunes.*
5. What all can you do with it? *Make phones, use internet, play games, share photos...*
6. Would you buy it if you had the money? Why/why not?

II. Telephone role-play:
You need to telephone your partner at his/her office at Smith and Jones Machinery Limited.
You planned to have a lunch meeting but now you can't make it because of an emergency at your workplace. Telephone your partner and tell him/her about this. Try to set a new date.
You need to travel from Leeds to Aberdeen tomorrow on an urgent business. Your company has a travel agent who can help you organise a flight. Call him/her to arrange the details: you need to be in Aberdeen by 10 o'clock and travel back to Leeds the next day, in the afternoon.

You work for CDD Engineering. You need to ask United Express Delivery service to collect a package from your company. Call them to arrange it, have your office address and details about the package ready to give them. Enquire about the price.
You want to stay at the Royal Palace Hotel in London during your business trip - you are attending a three-day conference, from 15th to 18th June: call them and book a single room with the view of the river.
Call Mr. Flawless, whom you met at the trade fair in Bonn last month. He was interested in your products. Remind him where you met. Ask him if he was still interested in your products. Arrange a lunch meeting. Ask him to suggest a good restaurant. Promise to reserve a table there.

9.1 REPORTED SPEECH

We very often have to report what other people have told or asked us or ordered us to do and we can't do it by using the direct speech, so we have to use the reported speech. There are some rules to follow, such as the rule of one tense back (present forms become past, present and past change into past perfect, will into would, can into could and may into might). We also have to be careful about the word order, especially in questions (He said, 'I live in Slovenia.' - He told me he lived in Slovenia.; She explained, 'These products will be available next year.' - She explained that those products would be available the following year.; He wanted to know, 'When did you start working here?' - He wanted to know when I had started working there.; She asked, 'Do they know anything about this?' - She asked if they knew anything about that.; He said, 'Please do this today.' - He asked me to do that that day.)

I. Read these sentences that a candidate said at an interview. Put them into Reported Speech:

Miss Bridgwater said, 'I'm very interested in working for you.'
She said *that she was very interested in working for us.*
Miss Bridgwater explained, 'I've been working in the city for three years.'
She explained ________________________________.
She said, 'I like what I do, but I want more responsibility.'
She also said ________________________________.

She told me, 'I have a degree in Mechanical Engineering.'
She told me ____________________________________.
She made it clear, 'I can't leave my present position for another month.'
She made it clear _________________________________.

II. You were a speaker at the conference on new machinery that took place last month in Munich, Germany. You were asked the following questions:

When will the new product be ready?
How much are you going to spend on promotion?
Will you offer any discounts to your distributors?
Why has it taken so long to develop?
Who will the target consumers be?
Did you have any problems developing this machine?
Who is the contact person?

Now report the above questions to your superior:
They asked me *when the new product would be ready.*
They asked me _________________________________.
They asked me_________________________________.
They asked me_________________________________.
They asked me_________________________________.
They asked me_________________________________.
They asked me_________________________________.

III. Change these sentences from direct into Reported Speech:

'Where have you been so long?'
He asked me *where I had been.*
'I'm writing my CV.'
He told me _________________________________.
'I'll phone you at seven o'clock tonight.'
She promised _________________________________.
'He's never made such a stupid mistake before.'
Rebecca said _________________________________.
'Don't overtake here.'
The sign warned us _________________________________.
'Can I get your latest catalogue?'
Their potential client asked _________________________________.
My superior said, 'Don't work too much or you'll get ill.'

My superior advised me ________________________________.

SUMMARY

In this unit we learned how to make a proper and polite business phone call and obtained some useful new vocabulary, especially polite phrases. We also revised Reported speech.

SHORT REVISION

1. Can you answer a phone call (at your work) with Yes, Yeah, Tell me...?
2. Name some polite phrases that you use while making business phone calls.
3. Describe the steps towards a good phone call. Can you explain how we deal with the ‘hold on’ situation?

10. THE ENVIRONMENT AND ECOLOGY

After this unit you will be able to discuss the environmental problems, know more about the ecology and be able to describe and explain graphs.

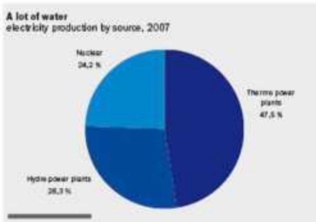
Have you ever thought about some things that we should all do to protect our environment? Are you environmentally conscious and try to separate waste? Do you recycle? If you do, what is it? Do you walk to a shop nearby or do you always go by car?
How often do you have to draw charts or graphs? What for? Is that easy for you or do you have to put in a lot of effort?

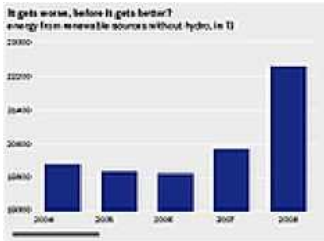

Pictures 41, 42, 43: Recycling, taking care of our environment
Sources: www.chelmsford.gov.uk,www.videogoogle.com,www.ehom.com

The rapid development of environmental science requires interdisciplinary research programmes encompassing ecology in the primary sense of this word, including environmental protection and physiological processes.
Metal recycling is the process of reusing old metal material, mainly aluminium and steel, to make new products. Recycling old metal products uses 95% less energy than manufacturing it from new materials. Aluminium is an ore, which is a mineral, and it usually exists by combining with oxygen. To make an aluminium product an electrical current is run through the metal and separates the oxygen from the aluminium. The aluminium is then melted and shaped into various products. Steel is created in a chemical reaction process located in a hot blast furnace. During this process the iron ore is freed from the oxygen and is then used to make steel. Both of these metal recycling processes consume millions of tons of energy. If we recycle metal products we only have to use 4% of this total energy, which can save our natural resources and reduce our greenhouse gas emissions.
Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. The term is used as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development ties together concern for the carrying

capacity of natural systems with the social challenges facing humanity. Ecologists have pointed to the “limits of growth” and presented the alternative of a “steady state economy” in order to address environmental concerns. The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability.

Have a look at the text below, read it, write down the words you might not understand, try to work out their meaning in groups and then do the exercise below:





Looking for Green Shoots
Perhaps you have not noticed yet, but there has not been much talk lately of energy efficiency, climate change and environmental sustainability. As the economic crisis takes hold, these issues have receded into the background. The greening of products and services can still be a fairly expensive process; when focusing on cost-cutting, however, it is easy to lose sight of the fact that green can be cheaper in the long run. Cars are a favourite pastime of Slovenes. However, not so long ago few bothered to consider how much greenhouse and other gases their autos emit into the atmosphere. This might soon change. Not only are governments implementing increasingly tougher standards on car emissions, the taxes on more-polluting vehicles might soon be considerably higher than on environmentally-friendly ones.
True, implementation of tougher emission standards is expensive for car makers, especially for those selling the heavy SUVs and other gas-guzzlers that have become a regular sight on Slovenian roads. However, this should be a boom to Slovenia’s economy. Revoz, the country’s largest exporter and a subsidiary of French car producer Renault, is the only factory in Europe making Renault’s Clio II and Twingo models, renowned for their fuel-efficiency and low emissions. With heavier, more powerful vehicles becoming more expensive as a result of higher taxes and the costs of implementing tighter standards, the demand for cleaner, lighter cars is set to grow; Revoz has been one of the few firms in the country to hire, rather than lay off workers

since the onset of the crisis.
Alternative driving
Those car producers that do not have a strong foothold in the small cars market are, of course, fighting back. Hybrid vehicles, running on conventional fuels as well as electricity, are all the rage. Biofuels such as biodiesel and ethanol are being introduced as car fuels. This opens up numerous business opportunities for Slovenian companies, and not just those from the automotive sector. The port of Koper, Slovenia's only port, for example, has been touted as a possible regional entry point for Brazilian ethanol.
Eco-certified
Experts emphasize, however, that the most efficient and the quickest way towards reducing Slovenia's carbon footprint is energy efficiency. Making renewable energy work is expensive; the investment needed to set up wind farms and solar farms is often prohibitive, especially when the prices of conventional sources of energy like oil and coal are low.
However, major energy savings can be realized by making household appliances more energy efficient. The burden on the environment can be reduced by making production processes more sustainable. This is what Slovenia's second biggest exporter, Gorenje, a household appliances producer, has been doing.
Tougher times
Looking ahead into the future, investment in clean technologies and processes will be even more of a competitive advantage for companies. The European Union's emission trading scheme in which companies buy the permits to emit CO2 into the atmosphere was not a success in the first years of its existence. The permits were given away at no charge and there were obviously too many of them on the market as their prices were dropping constantly.

The European Commission has therefore decided to clean up its act and to reduce the number of permits available. This makes the emissions more expensive; companies that emit less pay less. This is an important advantage in a time of crisis when firms increasingly compete on price.
(Source: Marko Vukovic, The Slovenia Times, 2009, www.sloveniatimes.com)

I. Words that are new to me are:

II. Answer the following questions:

Why haven't the ecological issues been discussed lately? *Because of recession and economical problems associated with it.*

Are we, as a nation, aware of the damage that our cars cause to the environment?
Are we 'car crazy'?
Is your car a 'gas-guzzler'?
What are some alternative fuels for future cars?
How can we save energy?
What has Gorenje been doing?
What do you have to do if you pollute the environment with CO_2?

III. Read this advertisement about a device that provides sustainable energy and complete it with the missing expressions, choose between: *farm, gallons, seeds, cooking, $400, expensive, biodiesel, warehouse*

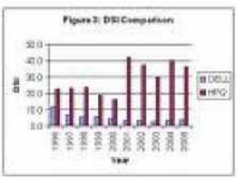
discount sale! Only *$400* Squeeze oil out of and nuts - even make your own . Processes up to 120 pounds per day - up to 4 of oil. Handy around the or homestead, a life-changing innovation in developing countries where cooking oil is not available or extremely . We can ship now for a limited time at this fraction of our normal price because we're moving out of a .

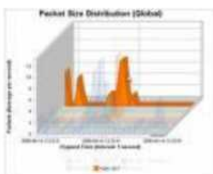
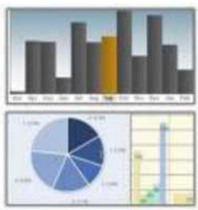
Manual Oil Press -super
(Source: www.thesustainablevillage.com))

10.1 GRAPH

Graphs and charts can be used to illustrate many different data and are not limited to simple types only, such as line, bar or chart graphs. All of them, tables and graphs, plans or diagrams, are used to organize data more methodologically, are a visual presentation of two or more variables, each objective and initiative has a corresponding graph and report. Graphs provide a visual representation of the actual values recorded.
Below you can see some typical graphs.

Pictures 44, 45, 46, 47: Different types of graphs or charts



Sources: www.iimnovo.com,www.iavin.com, www.designerveb.com

Perform a class survey: how many students come to school by car, how many of them recycle, how many want to have more free time, how are they satisfied with the school facilities ... and show the results in the form of a chart or graph.

I. Draw the graphs that describe the information in the sentences below:

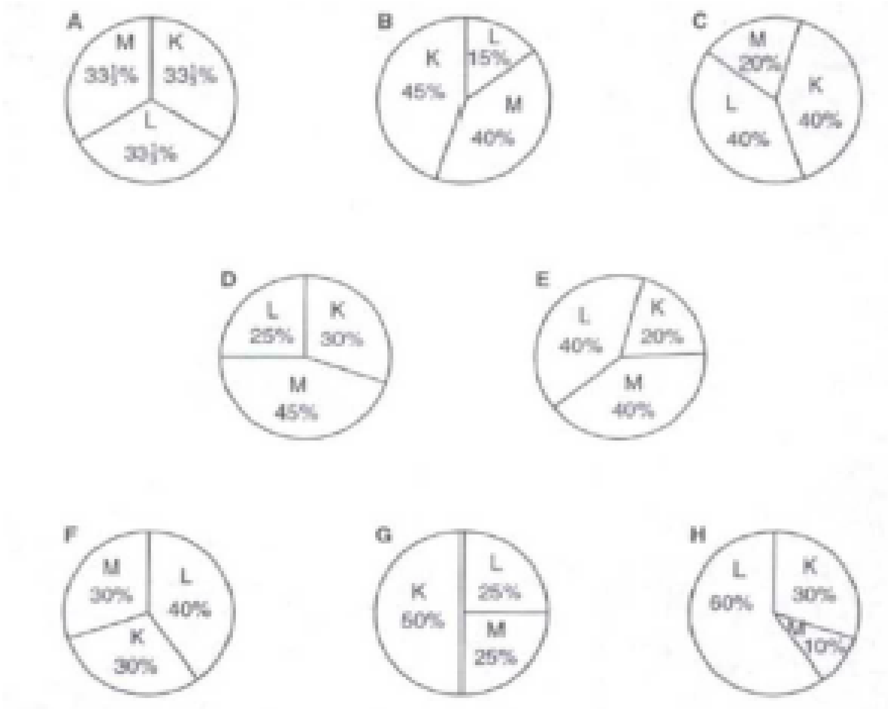
Oil prices skyrocketed last year.
The euro-dollar exchange fluctuates slightly all the time.
Exports to the countries of the former Soviet Union have stagnated over the past few years. All stock-exchange indexes dived dramatically again yesterday.
People want to save money so demand for low-fair flights has increased dramatically over the past three years.
Their share prices rose slightly in the morning, fell several times during the day and again rose in the evening.
Their profits went down all through the year and bottomed down in November.

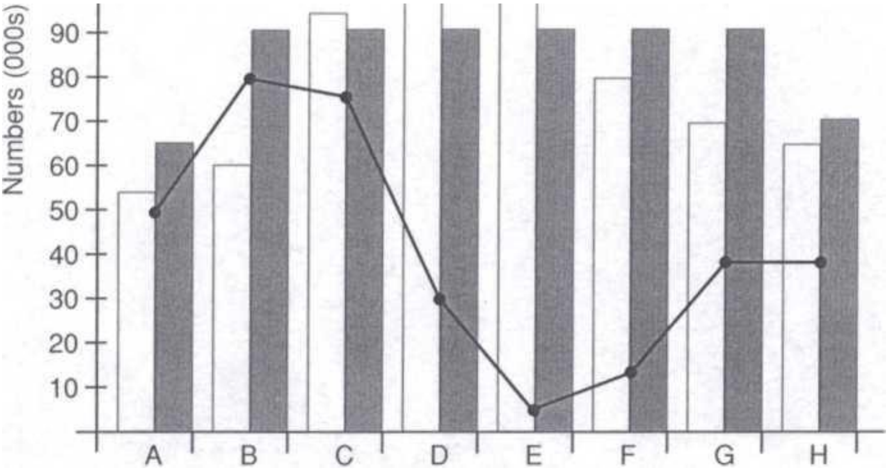
II. Have a look at the exercises below about the graphs, answer the questions:

Look at the charts below. They show the sales figures of three furniture companies. K. L and M for eight different products A-H
Which chart (toes each sentence 11-15 describe?

• For each sentence, mark one letter A-H, • Do not use any letter more than once.

11 Sales of this product were higher at M than at K or L.
12 L has more than half of the market for this product.
13 All three companies have an equal share of the market for this product
14 K s sales of this product have not been as high as those of the other two companies
15. K has done as well with this product as the other two companies together


A
M 33⅓%
K 33⅓%
L 33⅓%
B
L 15%
K 45%
M 40%
C
M 20%
K 40%
L 40%
D
L 25%
K 30%
M 45%
E
L 40%
K 20%
M 40%
F
M 30%
L 40%
K 30%
G
L 25%
K 50%
M 25%
H
L 60%
K 30%
M 10%



Look at the chart below. It shows the sales, production and stock levels of a computer manufacturing company over an eight-month period.

Which month does each sentence **(11 - 15**) describe?
For each sentence, mark **one** letter **(A -** Do not use any letter more than once.
150 140 130 120 110 100
Month
Monthly sales (000s)
Monthly production (000s)
Stocks at month end (000s)

1. In this month, production reached a higher level than sales for the first time since the peak selling period.
2. Sales and production both fell in this month, while stock levels were unchanged from the previous month.
3. In this month, sales reached a new high, leading to stocks dropping sharply by the end of the month.
4. Production was raised to its maximum capacity in this month to meet an expected increase in demand.
5. As a result of continuing high sales figures, this month saw a further reduction in stocks before the company began to build them up again.

Source: www.bbc.com.uk

10.2 CONDITIONALS

We use conditionals all the time as we want to express something what is always true, what will probably happen in the future, what is very unlikely to happen in the present and also when we wish we could change the past. According to this we divide them into zero conditionals (Whenever I have time, I go out with my friends. The raw egg breaks if you drop it.), first degree conditionals - real possibilities (If the weather is fine tomorrow, I'll go for a walk. We'll be late unless you hurry. She'll pass the exam when she studies more. As soon as he knows something, he'll let me know.), second degree conditionals - unreal possibilities in the present or future (If I had money, I would buy a new car. She would be afraid if she got lost. She could travel on business if her knowledge of languages was better.), and third conditionals - unreal or imaginary situations in the past (If they had known about their problems, they would have helped them. That wouldn't have happened if someone had warned us. Someone could have been hurt if we hadn't been careful enough.).

I. Complete the following conditionals:

If she has some free time this weekend, *she will go to the mountains.*
My friend would travel to Australia if ________________________
They would have sold their shares if ________________________
As soon as they have the right figures, ________________________
If there was an interesting job opening, ________________________
He'd be extremely upset ________________________.
Would you mind ________________________?
When they return from the holidays, ________________________
If their product wasn't so expensive, ________________________
If you mix these flammable components, ________________________
If he worked harder, ________________________.
If they had tested the prototype once again, ________________________
They have meetings when ________________________
If I could live somewhere else, ________________________
If I had applied for that job abroad, ________________________
Oil boils over if ________________________.
We would have bought that new machine if ________________________

II. Match the parts of the sentences to make correct conditionals:

1. If Jack enters the competition,	A) it wouldn't have been stolen.
2. She will not go to work	B) if he hadn't been late.
3. If he had taken the map,	C) you will manage to do it in time.
4. If he had locked his new car,	D) if she doesn't feel better.
5. I would buy that beautiful painting	E) he'll win and get the first prize.

6. He wouldn't have missed the meeting F) if I had more money.
7. If you post the invitations today, G) if you finished your report.
8. We could start the meeting H) they will arrive tomorrow.
9. If you start now, I) he wouldn't have got lost.

III. Rewrite the following sentences in the form of conditionals:

She isn't at the annual meeting because she wasn't informed about it.

If *she was informed about the annual conference, she would be there.*

If he doesn't pay the fine, he may go to prison.

Unless ____.

I didn't apply for that job as I don't want to work there.

If ____.

You can take photos here if you don't use the flash.

Unless ____.

I don't know her very well, so I didn't talk to her.

If ____.

It rained heavily so we didn't see much of the city.

If ____.

I learnt about this program because you helped me.

If ____.

You feel so tired because you work too much.

If ____.

She's too nervous. Her presentations are usually boring.

If ____.

SUMMARY

In this unit we learned about taking care of the environment, recycling, sustainability and graphs. We also revised conditionals.

SHORT REVISION

1. Describe some ways of taking care of our environment.
2. Analyze different methods of recycling - check your waste at home and decide what could be better used as a sustainable resource.
3. What do we use graphs, tables, charts or diagrams for?

11. RENDERING

RENDERING THE TEXT

Rendering the text is an art which requires a lot of skills and knowledge of reconstructing and rearranging (paraphrasing by using synonyms and paraphrasing by changing grammar) a written passage without any considerable damage to its context and idea(s). It is a text based on the notional compression of the original, which presupposes the elimination of all types of redundancy, i.e. elements that repeat each other. The key to the compression of the passage is dividing the text into logical parts and singling out the main idea of each of them.

The material in a rendering is presented from the point of view of the author of the original and does not include any elements of interpretation or evaluation. However, sometimes it is necessary to give personal opinion of the original text at the end of your rendering.

A rendering is usually kept to the following **structure**:

- introduction, where you provide all necessary background information such as the title, the author and the source of the passage and state the main idea;
- the body, where the main idea is revealed and supported by major and minor details;
- the conclusion on the passage;
- your opinion of the problem (position) introduced in the passage.
- glossary - a list of special words (terms) and explanations of their meanings

The plan for rendering the text

	The plan	**Some expressions to be used while rendering the text**
1.	The title of the article	The article (text) is head-lined … The head-line of the article (text) I have read is…
2.	The author of the article; where and when the article was published	The author of the article (text) is … The article (text) is written by … It is (was) published in … It is (was) printed in … The text is taken from …

3.	The main idea of the article	The main idea of the article (text) is … The article (text) is about … The article (text) is devoted to … The article (text) deals with … The article (text) touches upon … The article (text) points out … The article (text) draws out attention to … The article (text) reviews … The key-note of the article is … The purpose of the article (text) is to give the reader some information on … The aim of the article (text) is to provide the reader with some material (data) on …
4.	The contents of the article (major and minor details)	The author of the article starts by telling the reader about … / believes … / considers … / explains … / describes … / points out … / emphasizes … / reviews … / states … / stresses … / thinks … / writes … The article describes … The plot of the article is … The climax of the article … According to the text … Further the author reports (says) that … The article goes on to say that …

5.	The conclusion of the article	In conclusions … The author comes to the conclusion that …
6.	Your opinion of the article	I found the article interesting (important, dull, of no value, too hard to understand). I think that the facts given in the article … Comparing the given situation with real situation (with situation in my country, abroad) … To my mind, … In my opinion, …

There are several **basic principles** you are to follow in order to make a successful rendering:

- You have to develop your power of judgment, so that you may be able to decide rightly what must be expressed and what must be suppressed.
- In rendering, facts should be expressed as plain statements, with constant reference to the author of the passage. Try to avoid evaluative words and phrases in the body of the rendering, keep them for expressing your own opinion;
- Figurative language is in most cases unsuitable.

To master rendering you will need certain ***skills***:

1. Identifying the topic, main idea(s) and supporting details

Identifying the topic (sentence), main idea(s) and supporting (major/minor) details of a paragraph is crucial to reading. The ***topic*** is the broad, general theme or message. The ***main idea*** is the «key concept» being expressed. ***Details***, major and minor, support the main idea by telling how, what, when, where, why, how much, or how many. Locating the topic, main idea, and supporting details helps you understand the point(s) the writer is attempting to express. Identifying the relationship between these will increase your comprehension.

A typical paragraph is organized like this:

1. The main idea sentence (the topic sentence):

- supporting detail #1
- supporting detail #2
- supporting detail #3

2. Concluding (or summary) sentence

Of course, the paragraphs, as a rule, are the part of some longer piece of writing – a textbook chapter, a section of a chapter, or a newspaper or magazine article. There are four types of paragraphs: ***introductory, expository, transitional***, and ***summarizing***. ***Introductory*** paragraphs tell you, in advance, such things as (1) the main ideas of the chapter or section; (2) the extent or limits of the coverage; (3) how the topic is developed; and (4) the writer's attitude toward the topic. The bulk of an ***expository paragraph*** is made up of supporting sentences (major and minor details), which help to explain or prove the main idea. These sentences present facts, reasons, examples, definitions, comparison, contrasts, and other pertinent details. They are most important because they sell the main idea. The last sentence of a paragraph is likely to be a concluding sentence. It is used to sum up a discussion, to emphasize a point, or to restate all or part of the topic sentence so as to bring the paragraph to a close. The last sentence may also be a transitional sentence leading to the next paragraph. ***Transitional*** paragraphs are usually short; their sole function is to tie together what you have read so far and what is to come – to set the stage for succeeding ideas of the chapter or section. ***Summarizing*** paragraphs are used to restate briefly the main ideas of the chapter or section. The writer may also draw some conclusion from these ideas, or speculate on some conclusion based on the evidence he/she has presented.

2. Summarizing

To write a good summary it is important to thoroughly understand the material you are working with. Here are some preliminary steps in writing a summary.

1. Skim the text, noting in your mind the subheadings. If there are no subheadings, try to divide the text into sections.
2. Read the text, highlighting important information.
3. In your own words, write down the main points (ideas) of each section. There are two ways of paraphrasing: paraphrasing by using synonyms and different grammar structures, paraphrasing by using relative clauses.
4. Write down the major supporting details for each main point, but do not include minor details.

5. Go through the process again, making changes as appropriate.

3. Identifying the author's opinion

Because writers don't always say things directly, sometimes it is difficult to figure out what a writer really means or what he or she is really trying to say. You need to learn to «read between the lines» – to take the information the writer gives you and figure things out for yourself.

You will also need to learn to distinguish between ***fact*** and ***opinion***. Writers often tell us what they think or how they feel, but they don't always give us the facts. It's important to be able to interpret what the writer is saying so you can form opinions of your own. As you read an author's views, you should ask yourself if the author is presenting you with an established ***fact*** or with a personal ***opinion***. Since the two may appear close together, even in the same sentence, you have to be able to distinguish between them.

Facts are objective, concrete bits of information expressed in concrete language or specific numbers. They can be verified, or checked for accuracy and are generally agreed upon by people. In contrast, Opinions are based on subjective judgement and personal values rather than on information that can be verified. Opinions are what someone personally thinks or how he/she feel about an issue. Opinions by definition are subjective and relative. Even experts who have studied the same issue carefully often have very different opinions about that issue.

Although opinions cannot be verified for accuracy, writers should, nevertheless, back their opinions with evidence, facts, and reason – by whatever information supports the opinion and convinces the reader that it is a valid opinion. A *valid* opinion is one in which the writer's support for his or her opinion is solid and persuasive, and one in which the writer cites other respected authorities who are in agreement. If a writer presents an extreme or unconvincing opinion, the reader should remain wary or unconvinced.

Some opinions obviously deserve more attention than others do. When expert economists, such as John Kenneth Galbraith or Paul Volcher, discuss the U.S. economy, their opinions are more informed and therefore more reliable than the opinions of people who know very little about economic policy.

4. Giving your own grounded opinion

The final paragraph of rendering usually introduces your own opinion on the problem discussed in the article. Your conclusion should:

- be up to the exact subject of the article and touch upon the idea, NOT the theme
- be clearly formulated
- contain reasons supporting your viewpoint
- be deep and serious

5. Linking ideas

Categorizing and including

Japanese visitors **comprised/made up** 70 % of the hotel's guests last year. [70 % consisted of]

The course **is comprised of** two elements: reading and writing. [is composed of]

These two approaches can be **subsumed** under one heading. [brought together / united]

The book **embraces** a number of issues, from the economic to religious ones. [covers / includes]

Her philosophy is difficult to **categorize**. [label as belonging to a particular type or class]

For more information see: Linking words.

11. 2 TEXTS FOR RENDERING

Materials science

(Written by John D. Venables, Louis A. Girifalco)

Materials science, the study of the properties of solid materials and how those properties are determined by a material's composition and structure. It grew out of an amalgam of solid-state physics, metallurgy, and chemistry, since the rich variety of materials properties cannot be understood within the context of any single classical discipline. With a basic understanding of the origins of properties, materials can be selected or designed for an enormous variety of applications, ranging from structural steels to computer microchips. Materials science is therefore important to engineering activities such as electronics, aerospace, telecommunications, information processing, nuclear power, and energy conversion.

This article approaches the subject of materials science through five major fields of application: energy, ground transportation, aerospace, computers and communications, and medicine. The discussions focus on the fundamental requirements of each field of application and on the abilities of various materials to meet those requirements.

The many materials studied and applied in materials science are usually divided into four categories: metals, polymers, semiconductors, and ceramics. The sources, processing, and fabrication of these materials are explained at length in several articles: metallurgy; elastomer (natural and synthetic rubber); plastic; man-made fibre; and industrial glass and ceramics. Atomic and molecular structures are discussed in chemical elements and matter. The applications covered in this article are given broad coverage in energy conversion, transportation, electronics, and medicine.

Materials for energy

An industrially advanced society uses energy and materials in large amounts. Transportation, heating and cooling, industrial processes, communications—in fact, all the physical characteristics of modern life-depend on the flow and transformation of energy and materials through the techno-economic system. These two flows are inseparably intertwined and form the lifeblood of industrial society. The relationship of materials science to energy usage is pervasive and complex. At every stage of energy production, distribution, conversion, and utilization, materials play an essential role, and often special materials properties are needed. Remarkable growth in the understanding of the properties and structures of materials enables new materials, as well as improvements of old ones, to be developed on a scientific basis, thereby contributing to greater efficiency and lower costs.

Classification of energy-related materials

Energy materials can be classified in a variety of ways. For example, they can be divided into materials that are passive or active. Those in the passive group do not take part in the actual energy-conversion process but act as containers, tools, or structures such as reactor vessels, pipelines, turbine blades, or oil drills. Active materials are those that take part directly in energy conversion—such as solar cells, batteries, catalysts, and superconducting magnets.

Another way of classifying energy materials is by their use in conventional, advanced, and possible future energy systems. In conventional energy systems such as fossil fuels, hydroelectric generation, and nuclear reactors, the materials problems are well understood and are usually associated with structural mechanical properties or long-standing chemical effects such as corrosion. Advanced energy systems are in the development stage and are in actual use in limited markets. These include oil from shale and tar sands, coal gasification and liquefaction, photovoltaics, geothermal energy, and wind power. Possible future energy systems are not yet commercially deployed to any significant extent and require much more research before they can be used. These include hydrogen fuel and fast-breeder reactors, biomass conversion, and superconducting magnets for storing electricity.

Classifying energy materials as passive or active or in relation to conventional, advanced, or future energy systems is useful because it provides a picture of the nature and degree of urgency of the associated materials requirements. But the most illuminating framework for understanding the relation of energy to materials is in the materials properties that are essential for various energy applications. Because of its breadth and variety, such a framework is best shown by examples. In oil refining, for example, reaction vessels must have certain mechanical and thermal properties, but catalysis is the critical process.

APPLICATIONS OF ENERGY-RELATED MATERIALS

High-temperature materials

In order to extract useful work from a fuel, it must first be burned so as to bring some fluid (usually steam) to high temperatures. Thermodynamics indicates that the higher the temperature, the greater the efficiency of the conversion of heat to work; therefore, the development of materials for combustion chambers, pistons, valves, rotors, and turbine blades that can function at ever-higher temperatures is of critical importance. The first steam engines had an efficiency of less than 1 percent, while modern steam turbines achieve efficiencies of 35 percent or more. Part of this improvement has come from improved design and metalworking accuracy, but a large portion is the result of using improved high-temperature materials. The early engines were made of cast iron and then ordinary steels. Later, high-temperature alloys containing nickel, molybdenum, chromium, and silicon were developed that did not melt or fail at temperatures above 540° C (1,000° F). But modern combustion processes are nearing the useful temperature limits that can be achieved with metals, and so new materials that can function at higher temperatures—particularly intermetallic compounds and ceramics—are being developed.

The structural features that limit the use of metals at high temperatures are both atomic and electronic. All materials contain dislocations. The simplest of these are the result of planes of atoms that do not extend all through the crystal, so that there is a line where the plane ends that has fewer atoms than normal. In metals, the outer electrons are free to move. This gives a delocalized cohesion so that, when a stress is applied, dislocations can move to relieve the stress. The result is that metals are ductile: not only can they be easily worked into desired shapes, but when stressed they will gradually yield plastically rather than breaking immediately. This is a desirable feature, but the higher the temperature, the greater the plastic flow under stress—and, if the temperature is too high, the material will become useless. In order to get around this, materials are being studied in which the motion of dislocations is inhibited. Ceramics such as silicon nitride or silicon carbide and intermetallics such as nickel aluminide hold promise because the electrons that hold them together are highly localized in the form of valence or ionic bonds. It is as if metals were held together by a slippery glue while in nonmetals the atoms were connected by rigid rods. Dislocations thus find it much harder to move in nonmetals; raising the temperature does not increase dislocation motion, and the stress needed to make them yield is much higher. Furthermore, their melting points are significantly higher than those of metals, and they are much more resistant to chemical attack. But these desirable features come at a price. The very structure that makes them attractive also makes them brittle; that is, they do not flow when subject to a high stress and are prone to failure by cracking. Modern research is aimed at overcoming this lack of ductility by modification of the material and how it is made. Hot pressing of ceramic powders, for example, minimizes the number of defects at which cracks can start, and the addition of small amounts of certain metals to intermetallics strengthens the cohesion among crystal grains at which fractures normally develop. Such advances, along with intelligent design, hold the promise of being able to build heat engines of much higher efficiency than those now available.

Diamond drills

Diamond drill bits are an excellent example of how an old material can be improved. Diamond is the hardest known substance and would make an excellent drill bit except that it is expensive and has weak planes in its crystal structure. Because natural diamonds are single crystals, the planes extend throughout the material, and they cleave easily. Such cleavage planes allow a diamond cutter to produce beautiful gems, but they are a disaster for drilling through rock. This limitation was overcome by Stratapax, a sintered diamond material developed by the General Electric Company of the United States. This consists of synthetic diamond powder that is formed into a thin plate and bonded to tungsten-carbide studs by sintering (fusing by heating the material below the melting point). Because the diamond plate is polycrystalline, cleavage cannot propagate through the material. The result is a very hard bit that does not fail by cleavage when it is used to drill through rock to get at oil and natural gas.

Oil platforms

An important example of dealing with old problems by modern methods is provided by the prevention of crack growth in offshore oil-drilling platforms. The primary structure consists of welded steel tubing that is subject to continually varying stress from ocean waves. Since the cost of building and deploying a platform can amount to several billion dollars, it is imperative that the platform have a long life and not be lost because of premature metal failure.

In the North Sea, 75 percent of the waves are higher than two metres (six feet) and exert considerable stresses on the platform. Cyclic loading of a metal ultimately results in fatigue failure in which surface cracks form, grow over time, and eventually cause the metal to break. Welds are the weak spots for such a process because weld metal has mechanical properties that are inferior to steel, and these are made even worse by internal stresses and defects (such as tiny voids and oxide particles) that are introduced in the welding process. Furthermore, the tube geometry at the weld consists of T- and K-shaped joints, which are natural stress concentrators. Fatigue failure in oil platforms therefore takes place at welds.

Fatigue occurs because cyclic stress causes dislocations to form and to move back and forth in the metal. Dislocation motion can be impeded by the presence of barriers such as small voids, grain boundaries, other dislocations, impurities, or even the surface itself. When dislocations are thereby pinned down, they stop the motion of other dislocations created by the stress, and a tangled dislocation network forms that results in a hard spot in the weld. The stress is then not easily relieved, and types of dislocation motion that are characteristic of the fatigue process initiate a crack at the weld surface. This phenomenon is a direct result of the microstructure of the weld and could be minimized by making the weld very uniform, preferably of the same material as the tubing, and having a very gently curved geometry at the joint. But, in spite of the sophistication of modern welding techniques, this is not yet feasible. An alternate strategy is therefore used in which the progress of the weld crack is monitored so that repairs can be made in time to avoid catastrophic failure. This can be done because, given the geometry of the joint, the depth of the crack is proportional to time until the crack is quite large. By contrast, in laboratory tests in which simple strips of metal are subject to cyclic stress, the growth rate increases as the crack becomes larger. In the T or K configuration in oil platforms, stress is much more evenly distributed, and the crack does not grow at an increasing speed until it is close to being fatal.

A technique for measuring the crack depth is based on the skin effect, the phenomenon in which a high-frequency alternating current is confined to the surface of a conductor. This makes it possible to measure the surface area of a small region with a simple meter, since an increase in crack depth means an increase in current path, and this in turn causes an increase in voltage drop. Measurement over time then allows the time to failure to be estimated; repairs can be effected before failure occurs. In this case, a knowledge of microstructure, the materials science of fatigue, and the study of crack formation have led to a simple testing technique of great economic importance.

Mathematical modeling of mass motion and heat transfer (including convection), along with studies of solidification, gas dissolution, and the effects of fluxes, are providing a much more detailed understanding of the factors controlling weld structure. With this knowledge, it should be possible to make welds with far fewer defects.

Radioactive waste

A different example is provided by the disposal of radioactive waste. Here the issue is primarily safety and the perception of safety rather than economics. Waste disposal will continue to be one of the factors that inhibit the exploitation of nuclear power until the public perceives it as posing no danger. The current plan is to interpose three barriers between the waste and human beings by first encapsulating it in a solid material, putting that in a metal container, and finally burying that container in geologically stable formations. The first step requires an inert, stable material that will hold the radioactive atoms trapped for a very long time, while the second step requires a material that is highly resistant to corrosion and degradation. There are two good candidates for encapsulation. The first is borosilicate glass; this can be melted with the radioactive material, which then becomes a part of the glass structure. Glass has a very low solubility, and atoms in it have a very low rate of migration, so that it provides an excellent barrier to the escape of radioactivity. However, glass devitrifies at the high temperatures resulting from the heat of radioactive decay; that is to say, the amorphous glassy state becomes crystalline, and, during this process, many cracks form in the material so that it no longer provides a good barrier against the escape of radioactive atoms. (This problem is more severe in rock than in salt formations, because salt has higher thermal conductivity than rock and dissipates the heat more easily.) The problem can be eased by storing the waste above ground for a decade or so. This would allow the initially high rate of decay to decrease, thereby lowering the temperature that would be reached after encapsulation. Handled in this way, borosilicate glass would be an excellent encapsulation material for reactor waste that had been aged for a decade or so.

The other candidate is a synthetic rock made of mineral mixtures such as zirconolite and perovskite. These are very insoluble and, in their natural state, are known to have sequestered radioactive elements for hundreds of millions of years. They are crystalline, ceramic materials whose crystal structures allow radioactive atoms to be immobilized within them. They are not subject to devitrification, since they are already crystalline.

Once encapsulated, radioactive waste must be put into canisters that are corrosion-resistant. These can be made of nickel-steel alloys, but the best candidate so far is a titanium material containing small amounts of nickel and molybdenum and traces of carbon and iron. Even though they are meant to be buried in as dry an environment as possible, these metals are tested by immersing them in brine. Tests show that seawater at 250° C (480° F) would corrode away less than one micrometre (one-thousandth of a millimetre, or four ten-thousandths of an inch) of the surface of the titanium material (known as Ti code 12) per year. This remarkable performance is primarily the result of a tough, highly resistant oxide skin that forms on titanium when exposed to oxygen. It would take thousands of years for the canisters to be penetrated by corrosion.

In order to estimate the effectiveness of such waste disposal, it must be noted that the waste is highly radioactive and dangerous initially but that the danger decreases with time. Radioactivity decays to such levels that the danger is much less after a few hundred years, extremely low after 500 years, and negligible after 1,000 years. In order to breach the triple-barrier system, groundwater must migrate to the canister, eat it away, and then leach out the radioactive atoms from the encapsulating glass or ceramic. This is a process that most probably would take far longer than a single millennium. A careful application of materials science can make radioactive waste disposal safer than current disposal methods for other toxic wastes.

Photovoltaics

Photovoltaic systems are an attractive alternative to fossil or nuclear fuels for the generation of electricity. Sunlight is free, it does not use up an irreplaceable resource, and its conversion to electricity is nonpolluting. In fact, photovoltaics are now in use where power lines from utility grids are either not possible or do not exist, as in outer space or remote, nonurban locations.

The barrier to widespread use of sunlight to generate electricity is the cost of photovoltaic systems. The application of materials science is essential in efforts to lower the cost to levels that can compete with those for fossil or nuclear fuels.

The conversion of light to electricity depends on the electronic structure of solar cells with two or more layers of semiconductor material that can absorb photons, the primary energy packets of light. The photons raise the energy level of the electrons in the semiconductor, exciting some to jump from the lower-energy valence band to the higher-energy conduction band. The electrons in the conduction band and the holes they have left behind in the valence band are both mobile and can be induced to move by a voltage. The electron motion, and the movement of holes in the opposite direction, constitute an electric current. The force that drives electrons and holes through a circuit is created by the junction of two dissimilar semiconducting materials, one of which has a tendency to give up electrons and acquire holes (thereby becoming the positive, or *p*-type, charge carrier) while the other accepts electrons (becoming the negative, or *n*-type, carrier). The electronic structure that permits this is the band gap; it is equivalent to the energy required to move an electron from the lower band to the higher. The magnitude of this gap is important. Only photons with energy greater than that of the band gap can excite electrons from the valence band to the conduction band; therefore, the smaller the gap, the more efficiently light will be converted to electricity—since there is a greater range of light frequencies with sufficiently high energies. On the other hand, the gap cannot be too small, because the electrons and holes then find it easy to recombine, and a sizable current cannot be maintained.

The band gap defines the theoretical maximum efficiency of a solar cell, but this cannot be attained because of other materials factors. For each material there is an intrinsic rate of recombination of electrons and holes that removes their contribution to electric current. This recombination is enhanced by surfaces, interfaces, and crystal defects such as grain boundaries, dislocations, and impurities. Also, a fraction of the light is reflected by the cell's surface rather than being absorbed, and some can pass through the cell without exciting electrons to the conduction band.

Improvements in the trade-off between cell efficiency and cost are well illustrated by the preparation of silicon that is the basic material of current solar cells. Initially, high-purity silicon was grown from a silicon melt by slowly pulling out a seed crystal that grew by the accretion and slow solidification of the molten material. Known as the Czochralski process, this resulted in a high-purity, single-crystal ingot that was then sliced into wafers about 1 millimetre (0.04 inch) thick. Each wafer's surface was then "doped" with impurities to create *p*-type and *n*-type materials with a junction between them. Metal was then deposited to provide electrical leads, and the wafer was encapsulated to yield a cell about 100 millimetres in diameter. This was an expensive and time-consuming process; it has been much improved in a variety of ways. For example, high-purity silicon can be made at drastically reduced cost by chemically converting ordinary silicon to silane or trichlorosilane and then reducing it back to silicon. This silane process is capable of continuous operation at a high production rate and with low energy input. In order to avoid the cost and waste associated with sawing silicon into wafers, methods of directly drawing molten silicon into thin sheets or ribbons have been developed; these can produce crystalline, polycrystalline, or amorphous material. Another alternative is the manufacture of thin films on ceramic substrates—a process that uses much less silicon than other methods. Single-crystal silicon has a higher efficiency than other forms, but it is also much more expensive. The materials challenge is to find a combination of cost and efficiency that makes photovoltaic electricity economically possible.

Surface treatments that increase efficiency include deposition of antireflecting coatings, such as silicon nitride, on the front of the cell and highly reflective coatings on the rear. Thus, more of the light that strikes a cell actually enters it, and light that escapes out the back is reflected back into the cell. An ingenious surface treatment is part of the point contact method, in which the surface of the cell is not planar but microgrooved so that light is randomly reflected as it strikes the cell. This increases the amount of light that can be captured by the cell.

Louis A. Girifalco

Materials for ground transportation

The global effort to improve the efficiency of ground transportation vehicles, such as automobiles, buses, trucks, and trains, and thereby reduce the massive amounts of pollutants they emit, provides an excellent context within which to illustrate how materials science functions to develop new or better materials in response to critical human needs. For the automobile industry in particular, the story is a fascinating one in which the desire for lower vehicle weight, reduced emissions, and improved fuel economy has led to intense competition among aluminum, plastics, and steel companies for shares in the enormous markets involved (40 million to 50 million cars and trucks per year worldwide). In this battle, materials scientists have a key role to play because the success of their efforts to develop improved materials will determine the shape and viability of future automobiles.

Just how seriously suppliers to the industry view the need either to protect or to increase their share of these enormous markets is demonstrated by their establishing of special programs, consortia, or centres that are specifically designed to develop better alloys, plastics, or ceramics for automotive applications. For example, in the United States a program at the Aluminum Company of America (Alcoa) called the aluminum intensive vehicle (AIV), and a similar one at Reynolds Metals, were established to develop materials and processes for making automobile "space frames" consisting of aluminum-alloy rods and die-cast connectors joined by welding and adhesive bonding. Not to be outdone, another aluminum company, Alcan Aluminium Limited of Canada, in a program entitled aluminum structured vehicle technology (ASVT), began to investigate the construction of automobile unibodies from adhesively bonded aluminum sheet. The plastics industry, of course, has a powerful interest in replacing as many metal automobile components as possible, and in order to help bring this about a centre called D&S Plastics International was formed in the Detroit, Mich., area of the United States by three corporations. The specific aim of this centre was to develop materials and a process suitable for forming several connected panels or components (*e.g.,* body panels and bumper fascias) simultaneously out of different types of plastics. The centrepiece of the operation was a 4,000-ton co-injection press that could lead to cost reductions as great as 50 percent and thereby make the use of plastics for automotive applications more attractive.

In programs such as these, and in many more carried out by vendors and within the automobile companies themselves, materials scientists with specialized training in advanced metals, plastics, and ceramics have been leading a revolution in the automotive industry. The following sections describe specific needs that have been identified for improving the performance of automobiles and other ground-transportation vehicles, as well as approaches that materials scientists have taken in response to those needs.

METALS

Aluminum

Since aluminum has about one-third the density of steel, its substitution for steel in automobiles would seem to be a sensible approach to reducing weight and thereby increasing fuel economy and reducing harmful emissions. Such substitutions cannot be made, however, without due consideration of significant differences in other properties of the two materials. This is one important facet of the materials scientist's job—to help evaluate the suitability of a material for a given application based on how its properties balance against load and performance requirements specified by the design engineer. In this case (aluminum versus steel), it is instructive to consider the materials scientist's approach to evaluating the use of aluminum in automotive panels—such components as doors, hoods, trunk decks, and roofs that can make up more than 60 percent of a vehicle's weight.

Two primary properties of any metal are (1) its yield strength, defined as its ability to resist permanent deformation (such as a fender dent), and (2) its elastic modulus, defined as its ability to resist elastic or springy deflection like a drum head. By alloying, aluminum can be made to have a yield strength equal to a moderately strong steel and therefore to exhibit similar resistance to denting in an automobile panel. On the other hand, alloying does not normally affect the elastic modulus of metals significantly, so that automotive door panels or hoods made from aluminum alloys, all of which have approximately one-third the modulus of steel, would be floppy and suffer large deflections when buffeted by the wind, for example. From this point of view, aluminum would appear to be a marginal choice for body panels.

One might attempt to overcome this deficiency by increasing the thickness of the aluminum sheet stock to three times the thickness of the steel it is intended to replace. This, however, would simply increase the weight to roughly that of an equivalent steel structure and thus defeat the purpose of the exercise. Fortunately, as was elegantly demonstrated in 1980 by two British materials scientists, Michael Ashby and David Jones, when proper account is taken of the way an actual door panel deflects, constrained as it is by the door edges, it is possible to use aluminum sheet only slightly thicker than the steel it would replace and still achieve equivalent performance. The net result would be a weight savings of almost two-thirds by the substitution of aluminum for steel on such body components. This suggests that understanding the interrelationship between materials properties and structural design is an important factor in the successful application of materials science.

Another important activity of the materials scientist is that of alloy development, which in some cases involves designing alloys for very specific applications. For example, in Alcoa's AIV effort, materials scientists and engineers developed a special casting alloy for use as cast aluminum nodes (connecters) in their space frame design. Ordinarily, metal castings exhibit very little toughness, or ductility, and they are therefore prone to brittle fracture followed by catastrophic failure. Since the integrity of an automobile would be limited by having relatively brittle body components, a proprietary casting alloy and processing procedure were developed that provide a material of much greater ductility than is normally available in a casting alloy.

Many other advances in aluminum technology, brought about by materials scientists and design engineers, have led to a greater acceptance of aluminum in automobiles, trucks, buses, and even light rail vehicles. Among these are alloys for air-conditioner components that are designed to be chemically compatible with environmentally safer refrigerants and to withstand the higher pressures required by them. Also, alloys have been developed that combine good formability and corrosion resistance with the ability to achieve maximum strength without heat treating; these alloys develop their strength during the forming operation. As a consequence, the list of vehicles that contain significant quantities of aluminum substituted for steel has steadily grown. A milestone was reached in 1992 with a limited-edition Jaguar sports car that was virtually all aluminum, including the engine, adhesively bonded chassis, and skin. Somewhat less expensive and in full production were Honda's Acura NSX, containing more than 400 kilograms (900 pounds) of aluminum compared with about 70 kilograms for the average automobile, and General Motors' Saturn, with an aluminum engine block and cylinder heads. These vehicles and others took their place alongside the British Land Rover, which was built with all-aluminum body panels beginning in 1948—a choice dictated by a shortage of steel during World War II and continued by the manufacturer ever since.

Steel

While the goal of the aluminum and plastics industries is to achieve vehicle weight reductions by substituting their products for steel components, the goal of the steel industry is to counter such inroads with such innovative developments as high-strength, but inexpensive, "microalloyed" steels that achieve weight savings by thickness reductions. In addition, alloys have been developed that can be tempered (strengthened) in paint-baking ovens rather than in separate and expensive heat-treatment furnaces normally required for conventional steels.

The microalloyed steels, also known as high-strength low-alloy (HSLA) steels, are intermediate in composition between carbon steels, whose properties are controlled mainly by the amount of carbon they contain (usually less than 1 percent), and alloy steels, which derive their strength, toughness, and corrosion resistance primarily from other elements, including silicon, nickel, and manganese, added in somewhat larger amounts. Developed in the l960s and resurrected in the late 1970s to satisfy the need for weight savings through greater strength, the HSLA steels tend to be low in carbon with minute additions of titanium or vanadium, for example. Offering tensile strengths that can be triple the value of the carbon steels they are designed to replace (*e.g.,* 700 megapascals versus 200 megapascals), they have led to significant weight savings through thickness reductions—albeit at a slight loss of structural stiffness, because their elastic moduli are the same as other steels. They are considered to be quite competitive with aluminum substitutes for two reasons: they are relatively inexpensive (steel sells for one-half the price of aluminum on a per-unit-weight basis); and very little change in fabrication and processing procedures is needed in switching from carbon steel to HSLA steel, whereas major changes are usually required in switching to aluminum.

Bake-hardenable steels were developed specifically for the purpose of eliminating an expensive fabrication step—*i.e.,* the heat-treating furnace, where steels are imparted with their final strength. To do this, materials scientists have designed steels that can be strengthened in the same ovens used to bake body paint onto the part. These furnaces must operate at relatively low temperatures (170° C, or 340° F), so that special steels had to be developed that would achieve suitable strengths at heat-treatment temperatures very much below those normally employed (up to 600° C, or 1,100° F). Knowing that high-alloy steels would never be hardenable at such low temperatures, materials scientists focused their attention on carbon steels, but even here adequate strengths could not be obtained initially. Then in the 1980s scientists at the Japanese Sumitomo Metal Industries developed a steel containing nitrogen (a gas that constitutes three-quarters of the Earth's atmosphere) in addition to carbon and several other additives. Very high strengths (over 900 megapascals) and excellent toughness can be achieved on formed parts with this inexpensive addition after baking for 20 minutes at temperatures typical for a paint-baking operation.

Plastics and composites

The motive for replacing the metal components of cars, trucks, and trains with plastics is the expectation of large weight savings due to the large differences in density involved: plastics are one-sixth the weight of steel and one-half that of aluminum per unit volume. However, as in evaluating the suitability of replacing steel with aluminum, the materials scientist must compare other properties of the materials in order to determine whether the tradeoffs are reasonable. For two reasons, the likely conclusion would be that plastics simply are not suitable for this type of application: the strength of most plastics, such as epoxies and polyesters, is roughly one-fifth that of steel or aluminum; and their elastic modulus is one-sixtieth that of steel and one-twentieth that of aluminum. On this basis, plastics do not appear to be suitable for structural components. What, then, accounts for the successful use that has been made of them? The answer lies in efforts made over the years by materials scientists, polymer chemists, mechanical engineers, and production managers to combine relatively weak and low-stiffness resins with high-strength, high-modulus reinforcements, thereby making new materials called composites with much more suitable properties than plastics alone.

The reinforcements used in composites are generally chosen for their high strength and modulus, as might be expected, but economic considerations often force compromises. For example, carbon fibres have extremely high modulus values (up to five times that of steel) and therefore make excellent reinforcements. However, their cost precludes their extensive use in automobiles, trucks, and trains, although they are used regularly in the aerospace industry. More suitable for non-aerospace applications are glass fibres (whose modulus can approach 1.5 times that of aluminum) or, in somewhat special cases, a mixture of glass and carbon fibres.

The physical form and shape of the reinforcements vary greatly, depending on many factors. The most effective reinforcements are long fibres, which are employed either in the form of a woven cloth or as separate layers of unidirectional fibres stacked upon one another until the proper laminate thickness is achieved. The resin may be applied to the fibres or cloth before laying up, thus forming what are termed prepregs, or it may be added later by “wetting out” the fibres. In either case, the assembly is then cured, usually under pressure, to form the composite. This type of composite takes full advantage of the properties of the fibres and is therefore capable of yielding strong, stiff panels. Unfortunately, the labour involved in the lay-up operations and other factors make it very expensive, so that long-fibre reinforcement is used only sparingly in the automobile industry.

One attempt to avoid expensive hand lay-up operations involves chopped fibres that are employed in mat form, somewhat like felt, or as loose fibres that may be either blown into a mold or injected into a mold along with the resin. Another method does not use fibres at all; instead the reinforcement is in the form of small, high-modulus particles. These are the least expensive of all to process, since the particles are simply mixed into the resin, and the mixture is used in various types of molds. On the other hand, particles are the least efficient reinforcement material; as a consequence, property improvements are not outstanding.

In choosing the other major constituent in composites, the polymer matrix, one faces a somewhat daunting variety, including epoxies, polyimides, polyurethanes, and polyesters. Each has its advantages and disadvantages that must be evaluated in order to determine suitability for a particular application. Among the factors to be considered are cost, processing temperature (curing temperature if using a thermoset polymer and melting temperature if using a thermoplastic), flow properties in the molding operation, sag resistance during paint bake out, moisture resistance, and shelf life. The number of combinations of resins, reinforcements, production methods, and fibre-to-resin ratios is so challenging that materials scientists must join forces with polymer chemists and engineers from the design, production, and quality-control departments of the company in order to choose the right combination for the application.

Judging by the inroads that have been made in replacing metals with composites, it appears that technologists have been making the right choices. The introduction of fibreglass-reinforced plastic skins on General Motors' l953 Corvette sports car marked the first appearance of composites in a production model, and composites have continued to appear in automotive components ever since. In 1984, General Motors' Fiero was placed on the market with the entire body made from composites, and the Camaro/Firebird models followed with doors, roof panels, fenders, and other parts made of composites. Composites were also chosen for exterior panels in the Saturn, which appeared in 1990. In addition, they have had less visible applications—for example, the glass-reinforced nylon air-intake manifold on some BMW models.

Ceramics

Ceramics play an important role in engine efficiency and pollution abatement in automobiles and trucks. For example, one type of ceramic, cordierite (a magnesium aluminosilicate), is used as a substrate and support for catalysts in catalytic converters. It was chosen for this purpose because, along with many ceramics, it is lightweight, can operate at very high temperatures without melting, and conducts heat poorly (helping to retain exhaust heat for improved catalytic efficiency). In a novel application of ceramics, a cylinder wall was made of transparent sapphire (aluminum oxide) by General Motors' researchers in order to examine visually the internal workings of a gasoline engine combustion chamber. The intention was to arrive at improved understanding of combustion control, leading to greater efficiency of internal-combustion engines.

Another application of ceramics to automotive needs is a ceramic sensor that is used to measure the oxygen content of exhaust gases. The ceramic, usually zirconium oxide to which a small amount of yttrium has been added, has the property of producing a voltage whose magnitude depends on the partial pressure of oxygen surrounding the material. The electrical signal obtained from such a sensor is then used to control the fuel-to-air ratio in the engine in order to obtain the most efficient operation.

Because of their brittleness, ceramics have not been used as load-bearing components in ground-transportation vehicles to any great extent. The problem remains a challenge to be solved by materials scientists of the future.

Materials for aerospace

(John D. Venables)

The primary goal in the selection of materials for aerospace structures is the enhancement of fuel efficiency to increase the distance traveled and the payload delivered. This goal can be attained by developments on two fronts: increased engine efficiency through higher operating temperatures and reduced structural weight. In order to meet these needs, materials scientists look to materials in two broad areas—metal alloys and advanced composite materials. A key factor contributing to the advancement of these new materials is the growing ability to tailor materials to achieve specific properties.

Metals

Many of the advanced metals currently in use in aircraft were designed specifically for applications in gas-turbine engines, the components of which are exposed to high temperatures, corrosive gases, vibration, and high mechanical loads. During the period of early jet engines (from about 1940 to 1970), design requirements were met by the development of new alloys alone. But the more severe requirements of advanced propulsion systems have driven the development of novel alloys that can withstand temperatures greater than 1,000° C (1,800° F), and the structural performance of such alloys has been improved by developments in the processes of melting and solidification.

Melting and solidifying

Alloys are substances composed of two or more metals or of a metal and a nonmetal that are intimately united, usually by dissolving in each other when they are melted. The principal objectives of melting are to remove impurities and to mix the alloying ingredients homogeneously in the base metal. Major advances have been made with the development of new processes based on melting under vacuum (hot isostatic pressing), rapid solidification, and directional solidification.

In hot isostatic pressing, prealloyed powders are packed into a thin-walled, collapsible container, which is placed in a high-temperature vacuum to remove adsorbed gas molecules. It is then sealed and put in a press, where it is exposed to very high temperatures and pressures. The mold collapses and welds the powder together in the desired shape.

Molten metals cooled at rates as high as a million degrees per second tend to solidify into a relatively homogeneous microstructure, since there is insufficient time for crystalline grains to nucleate and grow. Such homogeneous materials tend to be stronger than the typical "grainy" metals. Rapid cooling rates can be achieved by "splat" cooling, in which molten droplets are projected onto a cold surface. Rapid heating and solidification can also be achieved by passing high-power laser beams over the material's surface.

Unlike composite materials (see below Composites), grainy metals exhibit properties that are essentially the same in all directions, so they cannot be tailored to match anticipated load paths (*i.e.,* stresses applied in specific directions). However, a technique called directional solidification provides a certain degree of tailorability. In this process the temperature of the mold is precisely controlled to promote the formation of aligned stiff crystals as the molten metal cools. These serve to reinforce the component in the direction of alignment in the same fashion as fibres reinforce composite materials.

Alloying

These advances in processing have been accompanied by the development of new "superalloys." Superalloys are high-strength, often complex alloys that are resistant to high temperatures and severe mechanical stress and that exhibit high surface stability. They are commonly classified into three major categories: nickel-based, cobalt-based, and iron-based. Nickel-based superalloys predominate in the turbine section of jet engines. Although they have little inherent resistance to oxidation at high temperatures, they gain desirable properties through the addition of cobalt, chromium, tungsten, molybdenum, titanium, aluminum, and niobium.

Aluminum-lithium alloys are stiffer and less dense than conventional aluminum alloys. They are also "superplastic," owing to the fine grain size that can now be achieved in processing. Alloys in this group are appropriate for use in engine components exposed to intermediate to high temperatures; they can also be used in wing and body skins.

Titanium alloys, as modified to withstand high temperatures, are seeing increased use in turbine engines. They are also employed in airframes, primarily for military aircraft but to some extent for commercial planes as well.

Composites

While developments in metals have had an impact on engine design, there is a growing trend toward the application of composite materials to aerospace structures. One of the reasons for this is that alloys do not offer substantial weight savings, which is a primary advantage of composites. Indeed, advanced composites have been used most widely where saving mass results in either significantly improved performance or significantly lower life-cycle costs. The most extensive application, therefore, has been in satellite systems, military aircraft, radomes, helicopters, commercial transport aircraft, and general aviation.

Broadly defined, composites are materials with two or more distinct components that combine to yield characteristics superior to those of the individual constituents. Although this definition can apply to such ordinary building materials as plywood, concrete, and bricks, within the aerospace industry the term composite generally refers to the fibre-reinforced metal, polymer, and ceramic products that have come into use since World War II. These materials consist of fibres (such as glass, graphite, silicon carbide, or aramid) that are embedded in a matrix of, for example, aluminum, epoxy, or silicon nitride.

In the late 1950s a revolution in materials development occurred in response to the space program's need for lightweight, thermally stable materials. Boron-tungsten filaments, carbon-graphite fibres, and organic aramid fibres proved to be strong, stiff, and light, but one problem with using them as fibres was that they were of limited value in any construction other than rope, which can bear loads in only one direction. Materials scientists needed to develop a way to make them useful under all loading conditions, and this led to the development of composites. While the structural value of a bundle of fibres is low, the strength of individual fibres can be harnessed if they are embedded in a matrix that acts as an adhesive, binding the fibres and lending solidity to the material. The matrix also protects the fibres from environmental stress and physical damage, which can initiate cracks. In addition, while the strength and stiffness of the composite remain largely a function of the reinforcing material—that is, the fibres—the matrix can contribute other properties, such as thermal and electrical conductivity and, most important, thermal stability. Finally, fibre-matrix combination reduces the potential for complete fracture. In a monolithic (or single) material, a crack, once started, generally continues to propagate until the material fails; in a composite, if one fibre in an assemblage fails, the crack may not extend to the other fibres, so the damage is limited.

To some extent, the composite-materials engineer is trying to mimic structures made spontaneously by plants and animals. A tree, for example, is made of a fibre-reinforced material whose strength is derived from cellulose fibres that grow in directions that match the weight of the branches. Similarly, many organisms naturally fabricate "bioceramics," such as those found in shells, teeth, and bones. While the designers of composites for the aerospace industry would like to copy some of the features of bioceramics production—room-temperature processing and net-shape products, for example—they do not want to be constrained by slow processing methods and limited fibre and matrix material choices. In addition, unlike a mollusk, which has to produce only one shell, the composites manufacturer has to use rapid, repeatable processing methods that can fabricate hundreds or even thousands of parts.

Modern composites are generally classified into three categories according to the matrix material: polymer, metal, or ceramic. Since polymeric materials tend to degrade at elevated temperatures, polymer-matrix composites (PMCs) are restricted to secondary structures in which operating temperatures are lower than 300° C (570° F). For higher temperatures, metal-matrix and ceramic-matrix composites are required.

Polymer-matrix composites

PMCs are of two broad types, thermosets and thermoplastics. Thermosets are solidified by irreversible chemical reactions, in which the molecules in the polymer "cross-link," or form connected chains. The most common thermosetting matrix materials for high-performance composites used in the aerospace industry are the epoxies. Thermoplastics, on the other hand, are melted and then solidified, a process that can be repeated numerous times for reprocessing. Although the manufacturing technologies for thermoplastics are generally not as well developed as those for thermosets, thermoplastics offer several advantages. First, they do not have the shelf-life problem associated with thermosets, which require freezer storage to halt the irreversible curing process that begins at room temperature. Second, they are more desirable from an environmental point of view, as they can be recycled. They also exhibit higher fracture toughness and better resistance to solvent attack. Unfortunately, thermoplastics are more expensive, and they generally do not resist heat as well as thermosets; however, strides are being made in developing thermoplastics with higher melting temperatures. Overall, thermoplastics offer a greater choice of processing approaches, so that the process can be determined by the scale and rate of production required and by the size of the component.

A variety of reinforcements can be used with both thermoset and thermoplastic PMCs, including particles, whiskers (very fine single crystals), discontinuous (short) fibres, continuous fibres, and textile preforms (made by braiding, weaving, or knitting fibres together in specified designs). Continuous fibres are more efficient at resisting loads than are short ones, but it is more difficult to fabricate complex shapes from materials containing continuous fibres than from short-fibre or particle-reinforced materials. To aid in processing, most high-performance composites are strengthened with filaments that are bundled into yarns. Each yarn, or tow, contains thousands of filaments, each of which has a diameter of approximately 10 micrometres (0.01 millimetre, or 0.0004 inch).

Depending on the application and on the type of load to be applied to the composite part, the reinforcement can be random, unidirectional (aligned in a single direction), or multidirectional (oriented in two or three dimensions). If the load is uniaxial, the fibres are all aligned in the load direction to gain maximum benefit of their stiffness and strength. However, for multidirectional loading (for example, in aircraft skins), the fibres must be oriented in a variety of directions. This is often accomplished by stacking layers (or lamina) of continuous-fibre systems.

The most common form of material used for the fabrication of composite structures is the preimpregnated tape, or "prepreg." There are two categories of prepreg: tapes, generally 75 millimetres (3 inches) or less in width, intended for fabrication in automated, computer-controlled tape-laying machines; and "broad goods," usually several metres in dimension, intended for hand lay-up and large sheet applications. To make prepregs, fibres are subjected to a surface treatment so that the resin will adhere to them. They are then placed in a resin bath and rolled into tapes or sheets.

To fabricate the composite, the manufacturer "lays up" the prepreg according to the reinforcement needs of the application. This has traditionally been done by hand, with successive layers of a broad-goods laminate stacked over a tool in the shape of the desired part in such a way as to accommodate the anticipated loads. However, efforts are now being directed toward automated fibre-placement methods in order to reduce costs and ensure quality and repeatability. Automated fibre-placement processes fall into two categories, tape laying and filament winding. The tape-laying process involves the use of devices that control the placement of narrow prepreg tapes over tooling with the contours of the desired part and along paths prescribed by the design requirements of the structure. The width of the tape determines the "sharpness" of the turns required to place the fibres in the prescribed direction—*i.e.,* wide tapes are used for gradual turns, while narrow tapes are required for the sharp turns associated with more complex shapes.

Filament winding uses the narrowest prepreg unit available—the yarn, or tow, of impregnated filaments. In this process, the tows are wound in prescribed directions over a rotating mandrel in the shape of the part. Successive layers are added until the required thickness is reached. Although filament winding was initially limited to geodesic paths (*i.e.,* winding the fibres along the most direct route between two points), the process is now capable of fabricating complex shapes through the use of robots.

For thermosetting polymers, the structure generated by either tape laying or filament winding must undergo a second manipulation in order to solidify the polymer through a curing reaction. This is usually accomplished by heating the completed structure in an autoclave, or oven. Thermoplastic systems offer the advantage of on-line consolidation, so that the high energy and capital costs associated with the curing step can be eliminated. For these systems, prepreg can be locally melted, consolidated, and cooled at the point of contact so that a finished structure is produced. A variety of energy sources are used to concentrate heat at the point of contact, including hot-gas torches, infrared light, and laser beams.

Pultrusion, the only truly continuous process for manufacturing parts from PMCs, is economical but limited to the production of beamlike shapes. On a pultrusion line, fibres and the resin are pushed through a heated die, or shaping tool, at one end, then cooled and pulled out at the other end. This process can be applied to both thermoplastic and thermoset polymers.

Resin transfer molding, or RTM, is a composites processing method that offers a high potential for tailorability but is currently limited to low-viscosity (easily flowing) thermosetting polymers. In RTM, a textile preform—made by braiding, weaving, or knitting fibres together in a specified design—is placed into a mold, which is then closed and injected with a resin. After consolidation, the mold is opened and the part removed. Preforms can be made in a wide variety of architectures, and several can be joined together during the RTM process to form a multi-element preform offering reinforcement in specific areas and load directions.

The similarity of meltable thermoplastic polymers to metals has prompted the extension of techniques used in metalworking. Sheet forming, used since the 19th century by metallurgists, is now applied to the processing of thermoplastic composites. In a typical thermoforming process, the sheet stock, or preform, is heated in an oven. At the forming temperature, the sheet is transferred into a forming system, where it is forced to conform to a tool, with a shape that matches the finished part. After forming, the sheet is cooled under pressure and then removed. Stretch forming, a variation on thermoplastic sheet forming, is specifically designed to take advantage of the extensibility, or ability to be stretched, of thermoplastics reinforced with long, discontinuous fibres. In this process, a straight preconsolidated beam is heated and then stretched over a shaped tool to introduce curvature. The specific advantage of stretch forming is that it provides an automated way to achieve a very high degree of fibre-orientation control in a wide range of part sizes.

Metal-matrix and ceramic-matrix composites

The requirement that finished parts be able to operate at temperatures high enough to melt or degrade a polymer matrix creates the need for other types of matrix materials, often metals. Metal matrices offer not only high-temperature resistance but also strength and ductility, or "bendability," which increases toughness. The main problems with metal-matrix composites (MMCs) are that even the lightest metals are heavier than polymers, and they are very complex to process. MMCs can be used in such areas as the skin of a hypersonic aircraft, but on wing edges and in engines temperatures often exceed the melting point of metals. For the latter applications, ceramic-matrix composites (CMCs) are seeing increasing use, although the technology for CMCs is less mature than that for PMCs. Ceramics consist of alumina, silica, zirconia, and other elements refined from fine earth and sand or of synthetic materials, such as silicon nitride or silicon carbide. The desirable properties of ceramics include superior heat resistance and low abrasive and corrosive properties. Their primary drawback is brittleness, which can be reduced by reinforcing with fibres or whiskers. The reinforcement material can be a metal or another ceramic.

Unlike polymers and metals, which can be processed by techniques that involve melting (or softening) followed by solidification, high-temperature ceramics cannot be melted. They are generally produced by some variation of sintering, a technique that renders a combination of materials into a coherent mass by heating to high temperatures without complete melting. If continuous fibres or textile weaves (as opposed to short fibres or whiskers) are involved, sintering is preceded by impregnating the assembly of fibres with a slurry of ceramic particles dispersed in a liquid. A major benefit of using CMCs in aircraft engines is that they allow higher operating temperatures and thus greater combustion efficiency, leading to reduced fuel consumption. An additional benefit is derived from the low density of CMCs, which translates into substantial weight savings.

Other advanced composites

Carbon-carbon composites are closely related to CMCs but differ in the methods by which they are produced. Carbon-carbon composites consist of semicrystalline carbon fibres embedded in a matrix of amorphous carbon. The composite begins as a PMC, with semicrystalline carbon fibres impregnated with a polymeric phenolic resin. The resin-soaked system is heated in an inert atmosphere to pyrolyze, or char, the polymer to a carbon residue. The composite is re-impregnated with polymer, and the pyrolysis is repeated. Continued repetition of this impregnation/pyrolysis process yields a structure with minimal voids. Carbon-carbon composites retain their strength at 2,500° C (4,500° F) and are used in the nose cones of reentry vehicles. However, because they are vulnerable to oxidation at such high temperatures, they must be protected by a thin layer of ceramic.

While materials research for aerospace applications has focused largely on mechanical properties such as stiffness and strength, other attributes are important for use in space. Materials are needed with a near-zero coefficient of thermal expansion; in other words, they have to be thermally stable and should not expand and contract when exposed to extreme changes in temperature. A great deal of research is focused on developing such materials for high-speed civilian aircraft, where thermal cycling is a major issue. High-toughness materials and nonflammable resin composite systems are also under investigation to improve the safety of aircraft interiors.

Efforts are also being directed toward the development of "smart," or responsive, materials. Representing another attempt to mimic certain characteristics of living organisms, smart materials, with their built-in sensors and actuators, would react to their external environment by bringing on a desired response. This would be done by linking the mechanical, electrical, and magnetic properties of these materials. For example, piezoelectric materials generate an electrical current when they are bent; conversely, when an electrical current is passed through these materials, they stiffen. This property can be used to suppress vibration: the electrical current generated during vibration could be detected, amplified, and sent back, causing the material to stiffen and stop vibrating.

Materials for computers and communications

(R.L. McCullough, Diane S. Kukich)

The basic function of computers and communications systems is to process and transmit information in the form of signals representing data, speech, sound, documents, and visual images. These signals are created, transmitted, and processed as moving electrons or photons, and so the basic materials groups involved are classified as electronic and photonic. In some cases, materials known as optoelectronic bridge these two classes, combining abilities to interact usefully with both electrons and photons.

Among the electronic materials are various crystalline semiconductors; metalized film conductors; dielectric films; solders; ceramics and polymers formed into substrates on which circuits are assembled or printed; and gold or copper wiring and cabling.

Photonic materials include a number of compound semiconductors designed for light emission or detection; elemental dopants that serve as photonic performance-control agents; metal- or diamond-film heat sinks; metalized films for contacts, physical barriers, and bonding; and silica glass, ceramics, and rare earths for optical fibres.

Electronic materials

Between 1955 and 1990, improvements and innovations in semiconductor technology increased the performance and decreased the cost of electronic materials and devices by a factor of one million—an achievement unparalleled in the history of any technology. Along with this extraordinary explosion of technology has come an exponentially upward spiral of the capital investment necessary for manufacturing operations. In order to maintain cost-effectiveness and flexibility, radical changes in materials and manufacturing operations will be necessary.

SEMICONDUCTOR CRYSTALS

Silicon

Bulk semiconductor silicon for the manufacture of integrated circuits (sometimes referred to as electronic-grade silicon) is the purest material ever made commercially in large quantities. One of the most important factors in preparing this material is control of such impurities as boron, phosphorus, and carbon (not to be confused with the dopants added later during circuit production). For the ultimate levels of integrated-circuit design, stray contaminant atoms must constitute less than 0.1 part per trillion of the material.

For fabrication into integrated circuits, bulk semiconductor silicon must be in the form of a single-crystal material with high crystalline perfection and the desired charge-carrier concentration. The size of the silicon ingot, or boule, has been scaled up in recent years, in order to provide wafers of increasing diameter that are demanded by the economics of integrated-circuit manufacturing. Most commonly, a 60-kilogram (130-pound) charge is grown to an ingot with a diameter of 200 millimetres (8 inches), but the semiconductor industry will soon require ingots as large as 300 millimetres. The ingots are then converted into wafers by machining and chemical processes.

III–V compounds

Although silicon is by far the most commonly used crystal material for integrated circuits, a significant volume of semiconductor devices and circuits employs III–V technology, so named because it is based on crystalline compounds formed by combining metallic elements from column III and nonmetallic elements from column V of the periodic table of chemical elements. When the elements are gallium and arsenic, the semiconductor is called gallium arsenide, or GaAs. However, other elements such as indium, phosphorus, and aluminum are often used in the compound to achieve specific performance characteristics.

For electronic applications, the III–V semiconductors offer the basic advantage of higher electron mobility, which translates into higher operating speeds. In addition, devices made with III–V compounds provide lower voltage operation for specific functions, radiation hardness (especially important for satellites and space vehicles), and semi-insulating substrates (avoiding the presence of parasitic capacitance in switching devices).

III–V materials are more difficult to handle than silicon, and a III–V wafer or substrate usually is less than half the size of a silicon wafer. In addition, a gallium arsenide wafer entering the processing facility can be expected to cost 10 to 20 times as much as a silicon wafer, although that cost difference narrows somewhat after fabrication, packaging, and testing. Nevertheless, there is one major characteristic of III–V materials with which silicon cannot compete: a III–V compound can be tailored to generate or detect photons of a specific wavelength. For example, an indium gallium arsenide phosphide (InGaAsP) laser can generate radiation at 1.55 micrometres to carry digitally coded information streams. (See below Photonic materials.) This means that a III–V component can fill both electronic and photonic functions in the same integrated circuit.

Photoresist films

Patterning polished wafers with an integrated circuit requires the use of photoresist materials that form thin coatings on the wafer before each step of the photolithographic process. Modern photoresists are polymeric materials that are modified when exposed to radiation (either in the form of visible, ultraviolet, or X-ray photons or in the form of energetic electron beams). A photoresist typically contains a photoactive compound (PAC) and an alkaline-soluble resin. The PAC, mixed into the resin, renders it insoluble. This mixture is coated onto the semiconductor wafer and is then exposed to radiation through a "mask" that carries the desired pattern. Exposed PAC is converted into an acid that renders the resin soluble, so that the resist can be dissolved and the exposed substrate beneath it chemically etched or metallically coated to match the circuit design.

Besides practical properties such as shelf life, cost, and availability, the key properties of a photoresist include purity, etching resistance, resolution, contrast, and sensitivity. As the feature sizes of integrated circuits shrink in each successive generation of microchips, photoresist materials are challenged to handle shorter wavelengths of light. For example, the photolithography of current designs (with features that have shrunk to less than one micrometre) is based on ultraviolet radiation in the wavelength range of 365 to 436 nanometres, but, in order to define accurately the smaller features of future microchips (less than 0.25 micrometre), shorter wavelengths will be necessary. The problem here is that electromagnetic radiation in such frequency regions is weaker. One solution is to use the chemically amplified photoresist, or CAMP. The sensitivity of a photoresist is measured by its quantum efficiency, or the number of chemical events that occur when a photon is absorbed by the material. In CAMP material, the number of events is dramatically increased by subsequent chemical reactions (hence the amplification), which means that less light is needed to complete the process.

Electric connections

The performance of today's electronic systems (and photonic systems as well) is limited significantly by interconnection technology, in which components and subsystems are linked by conductors and connectors. Currently, very fine gold or copper wiring, as thin as 30 micrometres, is used to carry electric current to and from the many pads along the sides or ends of a microchip to other components on a circuit board. The capacitance involved in such circuitry slows down the flow of electrons and, hence, of information. However, by integrating several chips into a single multichip module, in which the chips are connected on a shared substrate by various conducting materials (such as metalized film), the speed of information flow can be increased, thus improving the assembly's performance. Ideally, all the chips in a single module would be fabricated simultaneously on the same wafer, but in practice this is not feasible: Silicon crystal manufacture is still subject to an average of one flaw per wafer, meaning that at least one of the many chips cut from each wafer is scrapped. If the whole wafer area were dedicated to a single multifunction assembly, that one flaw would scrap the entire module. Multichip modules are therefore made up of as many as five microchips bonded to a silicon or ceramic substrate on which resistors and capacitors have been constructed with thin films. Typical materials used in a multichip module include the substrate; gold paste conductors applied in an additive process resembling silk screen printing; vitreous glazes to insulate the gold paste conductors from subsequent film layers; a series of thin films made with tantalum nitride, titanium, palladium, and plated gold; and a final package of silicone rubber.

Packaging materials

Several major types of packaging material are used by the electronics industry, including ceramic, refractory glass, premolded plastic, and postmolded plastic. Ceramic and glass packages cost more than plastic packages, so they make up less than 10 percent of the worldwide total. However, they provide the best protection for complex chips. Premolded plastic packages account for only a small but important fraction of the market, since they are required for packaging devices with many leads. Most plastic packages are postmolded, meaning that the package body is molded over the assembly after the microchip has been attached to the fan-out pattern.

Precursors

The starting materials for most semiconductor devices are volatile and ultrapure gaseous derivatives of various organic and inorganic precursors. Many of them are toxic, and many will ignite spontaneously in the atmosphere. These gases are transported in high-pressure cylinders from the plant where they were made to the site where they will be used. One possible method of replacing these precursors with materials that are environmentally safe is known as in situ synthesis. In this method, dangerous reagents would be generated on demand in only the desired quantities, instead of being shipped cross-country and stored until needed at the semiconductor processing plant.

Photonic materials

Computers and communications systems have been dominated by electronic technology since their beginnings, but photonic technology is making serious inroads throughout the information movement and management systems with such devices as lasers, light-emitting diodes, photodetecting diodes, optical switches, optical amplifiers, optical modulators, and optical fibres. Indeed, for long-distance terrestrial and transoceanic transmission of information, photonics has almost completely displaced electronics.

Crystalline materials

The light detectors and generators listed above are actually optoelectronic, because they link photonic and electronic systems. They employ the III–V compound semiconductors described above, many of them characterized by their band gaps—*i.e.,* the energy minimum of the electron conduction band and the energy maximum of hole valence bands occur at the same location in the momentum space, allowing electrons and holes to recombine and radiate photons efficiently. (By contrast, the conduction band minimum and the valence band maximum in silicon have dissimilar momenta, and therefore the electrons and holes cannot recombine efficiently.)

Among the important compounds are gallium arsenide, aluminum gallium arsenide, indium gallium arsenide phosphide, indium phosphide, and aluminum indium arsenide.

Fabricating a single crystal from these combinations of elements is far more difficult than creating a single crystal of electronic-grade silicon. Special furnaces are required, and the process can take several days. Notwithstanding the precision involved, the sausage-shaped boule is less than half the diameter of a silicon ingot and is subject to a much higher rate of defects. Researchers are continuously seeking ways to reduce the thermal stresses that are primarily responsible for dislocations in the III–V crystal lattice that cause these defects. The purity and structural perfection of the final single-crystal substrates affect the qualities of the crystalline layers that are grown on them and the regions that are diffused or implanted in them during the manufacture of photonic devices.

Epitaxial layers

For the efficient emission or detection of photons, it is often necessary to constrain these processes to very thin semiconductor layers. These thin layers, grown atop bulk semiconductor wafers, are called epitaxial layers because their crystallinity matches that of the substrate even though the composition of the materials may differ—*e.g.,* gallium aluminum arsenide (GaAlAs) grown atop a gallium arsenide substrate. The resulting layers form what is called a heterostructure. Most continuously operating semiconductor lasers consist of heterostructures, a simple example consisting of 1000-angstrom thick gallium arsenide layers sandwiched between somewhat thicker (about 10000 angstroms) layers of gallium aluminum arsenide—all grown epitaxially on a gallium arsenide substrate. The sandwiching and repeating of very thin layers of a semiconductor between layers of a different composition allow one to modify the band gap of the sandwiched layer. This technique, called band-gap engineering, permits the creation of semiconductor materials with properties that cannot be found in nature. Band-gap engineering, used extensively with III–V compound semiconductors, can also be applied to elemental semiconductors such as silicon and germanium.

The most precise method of growing epitaxial layers on a semiconducting substrate is molecular-beam epitaxy (MBE). In this technique, a stream or beam of atoms or molecules is effused from a common source and travels across a vacuum to strike a heated crystal surface, forming a layer that has the same crystal structure as the substrate. Variations of MBE include elemental-source MBE, hydride-source MBE, gas-source MBE, and metal-organic MBE. Other approaches to epitaxial growth are liquid-phase epitaxy (LPE) or chemical vapour deposition (CVD). The latter method

includes hydride CVD, trichloride CVD, and metal-organic CVD.
Normally, epitaxial layers are grown on flat surfaces, but scientists are searching for an economical and reliable method of growing epitaxial material on nonplanar structures—for example, around the "mesas" or "ridges" or in the "tubs" or "channels" that are etched into the surface of semiconducting devices. Nonplanar epitaxy is considered necessary for producing monolithic integrated optical devices or all-photonic switches and logic elements, but mastery of this method requires better understanding of the surface chemistry and surface dynamics of epitaxial growth.

Optical switching

Research in this area is driven by the need to switch data streams of higher and higher speed efficiently as customers for computer and communications services demand transmission and switching rates far higher than can be provided by a purely electronic system. Thanks to developments in semiconductor lasers and detectors (described above Epitaxial layers) and in optical fibres (described below Optical transmission), transmission at the desired high speeds has become possible. However, the switching of optical data streams still requires converting the data from the optical to the electronic domain, subjecting them to electronic switching and to manipulation inside the switching apparatus, and then reconverting the switched and reconfigured data into the optical domain for transmission over optical fibres. Electronic switching therefore is seen as the principal barrier to achieving higher switching speeds. One approach to solving this problem would be to introduce optics inside digital switching machines. Known as free-space photonics, this approach would involve such devices as semiconductor lasers or light-emitting diodes (LEDs), optical modulators, and photodetectors—all of which would be integrated into systems combined with electronic components.
One commercially available device for photonic switching is the quantum-well self-electro-optic-effect device, or SEED. The key concept for this device is the use of quantum wells. These structures consist of many thin layers of two different semiconductor materials. Individual layers are typically 10 nanometres (about 40 atoms) thick, and 100 layers are used in a device about 1 micrometre thick. When a voltage is applied across the layers, the transmission of photons through the quantum wells changes significantly, in effect creating an optical modulator—an essential component of any photonic circuit. Variations on the SEED concept are the symmetric SEED (S-SEED) and the field-effect transistor SEED. Neighbouring S-SEEDs could be connected by pairs of back-to-back quantum-well photodiodes, and commercially sized interconnection networks could be built by using free-space

photonic interconnections between two-dimensional arrays of switching nodes. However, even this type of free-space optical interconnection technology would only enhance and extend electronic technology, not replace it.

The move of optoelectronic and photonic integrated circuits out of the research laboratory and into the marketplace has been made possible by the availability of high-quality epitaxial growth techniques for building up lattice-matched crystalline layers of indium gallium arsenide phosphide and indium phosphide (InGaAsP/InP). This III–V compound system is central to the light emitters and detectors used in the 1.3-micrometre and 1.5-micrometre wavelength ranges at which optical fibre has very low transmission loss.

Optical transmission

As the rates of transmission are increased from millions of bits (megabits) per second to billions of bits (gigabits) per second, commercially available lasers encounter a physical limitation called "chirping," in which the optical frequency of the laser begins to waver during a pulse. Future systems, which may require from 2.4 to 30 gigabits per second, are probably going to be based on the use of a continuously operating distributed-feedback laser, whose output will be modulated in intensity by passing it through a modulator. This device consists of a crystal substrate of lithium niobate onto which a titanium channel is diffused to function as a light guide. The signal is encoded onto the light beam via a microwave radio-frequency feed through neighbouring channels in the coupler. Such a device is used only at the transmitter end of the optical path.

Both communications and computer systems rely on silica glass fibres to transmit light signals from lasers and LEDs. For long-distance transmission, optical-fibre cables are usually equipped with electro-optical repeater assemblies approximately every 100 kilometres. A new approach, called optical amplifiers, has been developed for deployment in transoceanic fibre-optic cables. Unlike traditional repeaters, optical amplifiers work by adding photons to a light signal without changing it to an electrical signal and without changing its bit-rate. Since they can be used at any desired transmission bit-rate, a transoceanic cable equipped with these devices can be upgraded to higher bit-rates simply by changing the lasers and photodiodes at each end. No retrofitting of higher bit-rate amplifiers is necessary.

The optical amplifier is a module containing a semiconductor pump laser and a short length of optical fibre whose core has been doped with less than 0.1 percent erbium, an optically active rare-earth element. The pump laser is powered by an electrical conductor that runs the length of the cable. The amplifier functions by converting the optical energy generated by the pump source into signal photon energy. When a signal-carrying stream of laser pulses passes through the optical amplifier, it is combined with the pump light through a wavelength division multiplexer located in the module. The combined signal is fed through the erbium-doped fibre length, where the excited erbium ions contribute photons coherently to the signal. The amplified signal is then fed to the next section of cable for transmission to the next optical amplifier, perhaps 200 to 300 kilometres away.

Materials for medicine

(*C. Kumar N. Patel)*

The treatment of many human disease conditions requires surgical intervention in order to assist, augment, sustain, or replace a diseased organ, and such procedures involve the use of materials foreign to the body. These materials, known as biomaterials, include synthetic polymers and, to a lesser extent, biological polymers, metals, and ceramics. Specific applications of biomaterials range from high-volume products such as blood bags, syringes, and needles to more challenging implantable devices designed to augment or replace a diseased human organ. The latter devices are used in cardiovascular, orthopedic, and dental applications as well as in a wide range of invasive treatment and diagnostic systems. Many of these devices have made possible notable clinical successes. For example, in cardiovascular applications, thousands of lives have been saved by heart valves, heart pacemakers, and large-diameter vascular grafts, and orthopedic hip-joint replacements have shown great long-term success in the treatment of patients suffering from debilitating joint diseases. With such a tremendous increase in medical applications, demand for a wide range of biomaterials grows by 5 to 15 percent each year. In the United States the annual market for surgical implants exceeds $10 billion, approximately 10 percent of world demand.

Nevertheless, applications of biomaterials are limited by biocompatibility, the problem of adverse interactions arising at the junction between the biomaterial and the host tissue. Optimizing the interactions that occur at the surface of implanted biomaterials represents the most significant key to further advances, and an excellent basis for these advances can be found in the growing understanding of complex biological materials and in the development of novel biomaterials custom-designed at the molecular level for specific medical applications.

This section describes biomaterials that are used in medicine, with emphasis on polymer materials and on the challenges associated with implantable devices used in the cardiovascular and orthopedic areas.

General requirements of biomaterials

Research on developing new biomaterials is an interdisciplinary effort, often involving collaboration among materials scientists and engineers, biomedical engineers, pathologists, and clinicians to solve clinical problems. The design or selection of a specific biomaterial depends on the relative importance of the various properties that are required for the intended medical application. Physical properties that are generally considered include hardness, tensile strength, modulus, and elongation; fatigue strength, which is determined by a material's response to cyclic loads or strains; impact properties; resistance to abrasion and wear; long-term dimensional stability, which is described by a material's viscoelastic properties; swelling in aqueous media; and permeability to gases, water, and small biomolecules. In addition, biomaterials are exposed to human tissues and fluids, so that predicting the results of possible interactions between host and material is an important and unique consideration in using synthetic materials in medicine. Two particularly important issues in biocompatibility are thrombosis, which involves blood coagulation and the adhesion of blood platelets to biomaterial surfaces, and the fibrous-tissue encapsulation of biomaterials that are implanted in soft tissues.

Poor selection of materials can lead to clinical problems. One example of this situation was the choice of silicone rubber as a poppet in an early heart valve design. The silicone absorbed lipid from plasma and swelled sufficiently to become trapped between the metal struts of the valve. Another unfortunate choice as a biomaterial was Teflon (trademark), which is noted for its low coefficient of friction and its chemical inertness but which has relatively poor abrasion resistance. Thus, as an occluder in a heart valve or as an acetabular cup in a hip-joint prosthesis, Teflon may eventually wear to such an extent that the device would fail. In addition, degradable polyesterurethane foam was abandoned as a fixation patch for breast prostheses, because it offered a distinct possibility for the release of carcinogenic by-products as it degraded.

Besides their constituent polymer molecules, synthetic biomaterials may contain several additives, such as unreacted monomers and catalysts, inorganic fillers or organic plasticizers, antioxidants and stabilizers, and processing lubricants or mold-release agents on the material's surface. In addition, several degradation products may result from the processing, sterilization, storage, and ultimately implantation of a device. Many additives are beneficial—for example, the silica filler that is indispensable in silicone rubber for good mechanical performance or the antioxidants and stabilizers that prevent premature oxidative degradation of polyetherurethanes. Other additives, such as pigments, can be eliminated from biomedical products. Indeed, a "medical-grade" biomaterial is one that has had nonessential additives and potential contaminants excluded or eliminated from the polymer. In order to achieve this grade, the polymer may need to be solvent-extracted before use, thereby eliminating low-molecular-weight materials. Generally, additives in polymers are regarded with extreme suspicion, because it is often the additives rather than the constituent polymer molecules that are the source of adverse biocompatibility.

Polymer biomaterials

The majority of biomaterials used in humans are synthetic polymers such as the polyurethanes or Dacron (trademark; chemical name polyethylene terephthalate), rather than polymers of biological origin such as proteins or polysaccharides. The properties of common synthetic biomaterials vary widely, from the soft and delicate water-absorbing hydrogels made into contact lenses to the resilient elastomers found in short- and long-term cardiovascular devices or the high-strength acrylics used in orthopedics and dentistry. The properties of any material are governed by its chemical composition and by the intra- and intermolecular forces that dictate its molecular organization. Macromolecular structure in turn affects macroscopic properties and, ultimately, the interfacial behaviour of the material in contact with blood or host tissues.

Since the properties of each material are dependent on the chemical structure and macromolecular organization of its polymer chains, an understanding of some common structural features of various polymers provides considerable insight into their properties. Compared with complex biological molecules, synthetic polymers are relatively simple; often they comprise only one type of repeating subunit, analogous to a polypeptide consisting of just one repeating amino acid. On the basis of common structures and properties, synthetic polymers are classified into one of three categories: elastomers, which include natural and synthetic rubbers; thermoplastics; and thermosets. The properties that provide the basis for this classification include molecular weight, cross-link density, percent crystallinity, thermal transition temperature, and bulk mechanical properties.

Elastomers

Elastomers, which include rubber materials, have found wide use as biomaterials in cardiovascular and soft-tissue applications owing to their high elasticity, impact resistance, and gas permeability. Applications of elastomers include flexible tubing for pacemaker leads, vascular grafts, and catheters; biocompatible coatings and pumping diaphragms for artificial hearts and left-ventricular assist devices; grafts for reconstructive surgery and maxillofacial operations; wound dressings; breast prostheses; and membranes for implantable biosensors.

Elastomers are typically amorphous with low cross-link density (although linear polyurethane block copolymers are an important exception). This gives them low to moderate modulus and tensile properties as well as high elasticity. For example, elastomeric devices can be extended by 100 to 1,000 percent of their initial dimensions without causing any permanent deformation to the material. Silicone rubbers such as Silastic (trademark), produced by the American manufacturer Dow Corning, Inc., are cross-linked, so that they cannot be melted or dissolved—although swelling may occur in the presence of a good solvent. Such properties contrast with those of the linear polyurethane elastomers, which consist of soft polyether amorphous segments and hard urethane-containing glassy or crystalline segments. The two segments are incompatible at room temperature and undergo microphase separation, forming hard domains dispersed in an amorphous matrix. A key feature of this macromolecular organization is that the hard domains serve as physical cross-links and reinforcing filler. This results in elastomeric materials that possess relatively high modulus and extraordinary long-term stability under sustained cyclic loading. In addition, they can be processed by methods common to thermoplastics.

Thermoplastics

Many common thermoplastics, such as polyethylene and polyester, are used as biomaterials. Thermoplastics usually exhibit moderate to high tensile strength (5 to 1,000 megapascals) with moderate elongation (2 to 100 percent), and they undergo plastic deformation at high strains. Thermoplastics consist of linear or branched polymer chains; consequently, most can undergo reversible melt-solid transformation on heating, which allows for relatively easy processing or reprocessing. Depending on the structure and molecular organization of the polymer chains, thermoplastics may be amorphous (*e.g.,* polystyrene), semicrystalline (*e.g.,* low-density polyethylene), or highly crystalline (*e.g.,* high-density polyethylene), or they may be processed into highly crystalline textile fibres (*e.g.,* polyester Dacron). Some thermoplastic biomaterials, such as polylactic acid and polyglycolic acid, are polymers based on a repeating amino acid subunit. These polypeptides are biodegradable, and, along with biodegradable polyesters and polyorthoesters, they have applications in absorbable sutures and drug-release systems. The rate of biodegradation in the body can be adjusted by using copolymers. These are polymers that link two different monomer subunits into a single polymer chain. The resultant biomaterial exhibits properties, including biodegradation, that are intermediate between the two homopolymers.

Thermosets

Thermosetting polymers find only limited application in medicine, but their characteristic properties, which combine high strength and chemical resistance, are useful for some orthopedic and dental devices. Thermosetting polymers such as epoxies and acrylics are chemically inert, and they also have high modulus and tensile properties with negligible elongation (1 to 2 percent). The polymer chains in these materials are highly cross-linked and therefore have severely restricted macromolecular mobility; this limits extension of the polymer chains under an applied load. As a result, thermosets are strong but brittle materials.

Cross-linking inhibits close packing of polymer chains, preventing formation of crystalline regions. Another consequence of extensive cross-linking is that thermosets do not undergo solid-melt transformation on heating, so that they cannot be melted or reprocessed.

APPLICATIONS OF BIOMATERIALS

Cardiovascular devices

Biomaterials are used in many blood-contacting devices. These include artificial heart valves, synthetic vascular grafts, ventricular assist devices, drug-release systems, extracorporeal systems, and a wide range of invasive treatment and diagnostic systems. An important issue in the design and selection of materials is the hemodynamic conditions in the vicinity of the device. For example, mechanical heart valve implants are intended for long-term use. Consequently, the hinge points of each valve leaflet and the materials must have excellent wear and fatigue resistance in order to open and close 80 times per minute for many years after implantation. In addition, the open valve must minimize disturbances to blood flow as blood passes from the left ventricle of the heart, through the heart valve, and into the ascending aorta of the arterial vascular system. To this end, the bileaflet valve disks of one type of implant are coated with pyrolytic carbon, which provides a relatively smooth, chemically inert surface. This is an important property, because surface roughness will cause turbulence in the blood flow, which in turn may lead to hemolysis of red cells, provide sites for adventitious bacterial adhesion and subsequent colonization, and, in areas of blood stasis, promote thrombosis and blood coagulation. The carbon-coated holding ring of this implant is covered with Dacron mesh fabric so that the surgeon can sew and fix the device to adjacent cardiac tissues. Furthermore, the porous structure of the Dacron mesh promotes tissue integration, which occurs over a period of weeks after implantation.

While the possibility of thrombosis can be minimized in blood-contacting biomaterials, it cannot be eliminated entirely. For this reason, patients who receive artificial heart valves or other blood-contacting devices also receive anticoagulation therapy. This is needed because all foreign surfaces initiate blood coagulation and platelet adhesion to some extent. Platelets are circulating cellular components of blood, two to four micrometres in size, that attach to foreign surfaces and actively participate in blood coagulation and thrombus formation. Research on new biomaterials for cardiovascular applications is largely devoted to understanding thrombus formation and to developing novel surfaces for biomaterials that will provide improved blood compatibility.

Synthetic vascular graft materials are used to patch injured or diseased areas of arteries, for replacement of whole segments of larger arteries such as the aorta, and for use as sewing cuffs (as with the heart valve mentioned above). Such materials need to be flexible to allow for the difficulties of implantation and to avoid irritating adjacent tissues; also, the internal diameter of the graft should remain constant under a wide range of flexing and bending conditions, and the modulus or compliance of the vessel should be similar to that of the natural vessel. These aims are largely achieved by crimped woven Dacron and expanded polytetrafluoroethylene (ePTFE). Crimping of Dacron in processing results in a porous vascular graft that may be bent 180° or twisted without collapsing the internal diameter.

A biomaterial used for blood vessel replacement will be in contact not only with blood but also with adjacent soft tissues. Experience with different materials has shown that tissue growth into the interstices of the biomaterials aids healing and integration of the material with host tissue after implantation. In order for the tissue, which consists mostly of collagen, to grow in the graft, the vascular graft must have an open structure with pores at least 10 micrometres in diameter. These pores allow new blood capillaries that develop during healing to grow into the graft, and the blood then provides oxygen and other nutrients for fibroblasts and other cells to survive in the biomaterial matrix. Fibroblasts synthesize the structural protein tropocollagen, which is needed in the development of new fibrous tissue as part of the healing response to a surgical wound.

Occasionally, excessive tissue growth may be observed at the anastomosis, which is where the graft is sewn to the native artery. This is referred to as internal hyperplasia and is thought to result from differences in compliance between the graft and the host vessels. In addition, in order to optimize compatibility of the biomaterial with the blood, the synthetic graft eventually should be coated with a confluent layer of host endothelial cells, but this does not occur with current materials. Therefore, most proposed modifications to existing graft materials involve potential improvements in blood compatibility.

Artificial heart valves and vascular grafts, while not ideal, have been used successfully and have saved many thousands of lives. However, the risk of thrombosis has limited the success of existing cardiovascular devices and has restricted potential application of the biomaterials to other devices. For example, there is an urgent clinical need for blood-compatible, synthetic vascular grafts of small diameter in peripheral vascular surgery—*e.g.,* in the legs—but this is currently impracticable with existing biomaterials because of the high risk of thrombotic occlusion. Similarly, progress with implantable miniature sensors, designed to measure a wide range of blood conditions continuously, has been impeded because of problems directly attributable to the failure of existing biomaterials. With such biocompatibility problems resolved, biomedical sensors would provide a very important contribution to medical diagnosis and monitoring. Considerable advances have been made in the ability to manipulate molecular architecture at the surfaces of materials by using chemisorbed or physisorbed monolayer films. Such progress in surface modification, combined with the development of nanoscale probes that permit examination at the molecular and submolecular level, provide a strong basis for optimism in the development of specialty biomaterials with improved blood compatibility.

Orthopedic devices

Joint replacements, particularly at the hip, and bone fixation devices have become very successful applications of materials in medicine. The use of pins, plates, and screws for bone fixation to aid recovery of bone fractures has become routine, with the number of annual procedures approaching five million in the United States alone. In joint replacement, typical patients are age 55 or older and suffer from debilitating rheumatoid arthritis, osteoarthritis, or osteoporosis. Orthopedic surgeries for artificial joints exceed 1.5 million each year, with actual joint replacement accounting for about half of the procedures. A major focus of research is the development of new biomaterials for artificial joints intended for younger, more active patients.

Hip-joint replacements are principally used for structural support. Consequently, they are dominated by materials that possess high strength, such as metals, tough plastics, and reinforced polymer-matrix composites. In addition, biomaterials used for orthopedic applications must have high modulus, long-term dimensional stability, high fatigue resistance, long-term biostability, excellent abrasion resistance, and biocompatibility (*i.e.,* there should be no adverse tissue response to the implanted device). Early developments in this field used readily available materials such as stainless steels, but evidence of corrosion after implantation led to their replacement by more stable materials, particularly titanium alloys, cobalt-chromium-molybdenum alloys, and carbon fibre-reinforced polymer composites. A typical modern artificial hip consists of a nitrided and highly polished cobalt-chromium ball connected to a titanium alloy stem that is inserted into the femur and cemented into place by in situ polymerization of polymethylmethacrylate. The articulating component of the joint consists of an acetabular cup made of tough, creep-resistant, ultrahigh-molecular-weight polyethylene. Abrasion at the ball-and-cup interface can lead to the production of wear particles, which in turn can lead to significant inflammatory reaction by the host. Consequently, much research on the development of hip-joint materials has been devoted to optimizing the properties of the articulating components in order to eliminate surface wear. Other modifications include porous coatings made by sintering the metal surface or coatings of wire mesh or hydroxyapatite; these promote bone growth and integration between the implant and the host, eliminating the need for an acrylic bone cement.

While the strength of the biomaterials is important, another goal is to match the mechanical properties of the implant materials with those of the bone in order to provide a uniform distribution of stresses (load sharing). If a bone is loaded insufficiently, the stress distribution will be made asymmetric, and this will lead to adaptive remodeling with cortical thinning and increased porosity of the bone. Such lessons in structure hierarchy and in the structure-property relationships of materials have been obtained from studies on biologic composite materials, and they are being translated into new classes of synthetic biomaterials. One development is carbon fibre-reinforced polymer-matrix composites. Typical matrix polymers include polysulfone and polyetheretherketones. The strength of these composites is lower than that of metals, but it more closely approximates that of bone.

SOURCES

1. Методичні вказівки і навчальні завдання для розвитку мовленнєвих компетентностей та навичок самостійної роботи з навчальної дисципліни «Іноземна мова професійного спілкування» для здобувачів вищої освіти другого (магістерського) рівня усіх освітньо-професійних програм спеціальностей НУВГП денної і заочної форм навчання [Електронне видання] / Купчик Л. Є., Літвінчук А. Т. – Рівне : НУВГП, 2022. – 57 с.
2. Методичні рекомендації та навчальні завдання до практичних занять з вибіркової дисципліни «Практична граматика з англійської мови» для здобувачів вищої освіти першого (бакалаврського) рівня усіх освітньо-професійних програм спеціальностей НУВГП денної форми навчання [електронне видання] / Літвінчук А.Т. – Рівне: НУВГП, 2019. – 27 с.
3. Ashley , A. A Correspondence Workbook. Oxford: Oxford University Press, 1992.
4. Ashley, A. A Handbook of Commercial Correspondence. Oxford: Oxford University Press, 1992.
5. Aspinall, T. & Bethell, G. Test Your Business Vocabulary in Use. Cambridge: Cambridge University Press, 2003.
6. Bela, N. Strokovna terminologija v tujem jeziku - Mechanical Engineering. Celje: Visja strokovna sola Celje, 2001.
7. Duckworth, M. Grammar and Practice. Oxford: Oxford University Press, 2001.
8. Duckworth, M. Oxford Business English Grammar & Practice. Oxford: Oxford University Press, 2001.
9. Hollet, V. Tech Talk Intermediate. Oxford: Oxford University Press, 2009.
10. Hollet, V. Tech Talk Pre-Intermediate. Oxford: Oxford University Press, 2005.
11. Kavanagh, M. English for the Automotive Industry. Oxford: Oxford University Press, 2007.
12. MacKenzie, I. English for Business Studies. Cambridge: Cambridge University Press, 1997.
13. McCarthy, M. English Vocabulary in Use. Cambridge: Cambridge University Press, 2001.
14. Murphy, R. English Grammar in Use. Cambridge: Cambridge University Press, 2004.
15. Strovs-Gagic, M. English for Economists. Ljubljana: Ministrstvo za solstvo

in sport, 2008.
16. Vince, M. Advanced Language Practice. Macmillan: Heinemann Publishers, 1994.
17. Vince, M. First Certificate Language Practice. Macmillan: Macmillan Education, 2003.
18. Vince, M. Advanced language Practice. Heinemann: Heinemann English Language Teaching, 1994.
19. Watson-Delestree, A. & Hill, J. The Working Week, Cambridge: Language teaching Publications, 1996.
20. http://www.abb.com
21. http://www.apple.com
22. http://www.apple.com/iphone
23. http://www.asd-europe.org
24. http://www.asianproducts.com
25. http://www.bbc.com.uk
26. http://www.chelmsford.gov.uk
27. http://www.cnq.ca
28. http://www.cartuningcentral.com
29. http://www.deakin.edn.au
30. http://www.designerweb.com
31. http://www.drive.com.au
32. http://www.ehom.com
33. http://www.ehs.uky.edn
34. http://www.epsvectorlogoned.com
35. http://www.iavin.com
36. http://iimnovo.com
37. http://imbtraining.com
38. http://www.learn.org
39. http://london.gov.uk
40. http://www.microsoftcorporation.com
41. http://wps.pearsoned.com.au
42. http://www.pharmaininfo.net
43. http://www.photosearch.com
44. http://www.piceramic.de
45. http://www.sloveniatimes.com
46. http://www.sustainabilitynini a.com
47. http://www.squido.com
48. http://www.thepointega.com

49. http://www.thesustainablevillage.com
50. http://www.treehugger.com http://www.vcs-techs.com
51. http://www.videogoogle.com
52. https://chtyvo.org.ua/authors/Litvinchuk_Alona/Formuvannia_profesiino-komunikatyvnoi_kompetentnosti_maibutnikh_inzheneriv-tekhnolohiv_u_protsesi_hu.pdf
53. https://www.arcjournals.org/pdfs/ijhsse/v1-i8/5.pdf

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