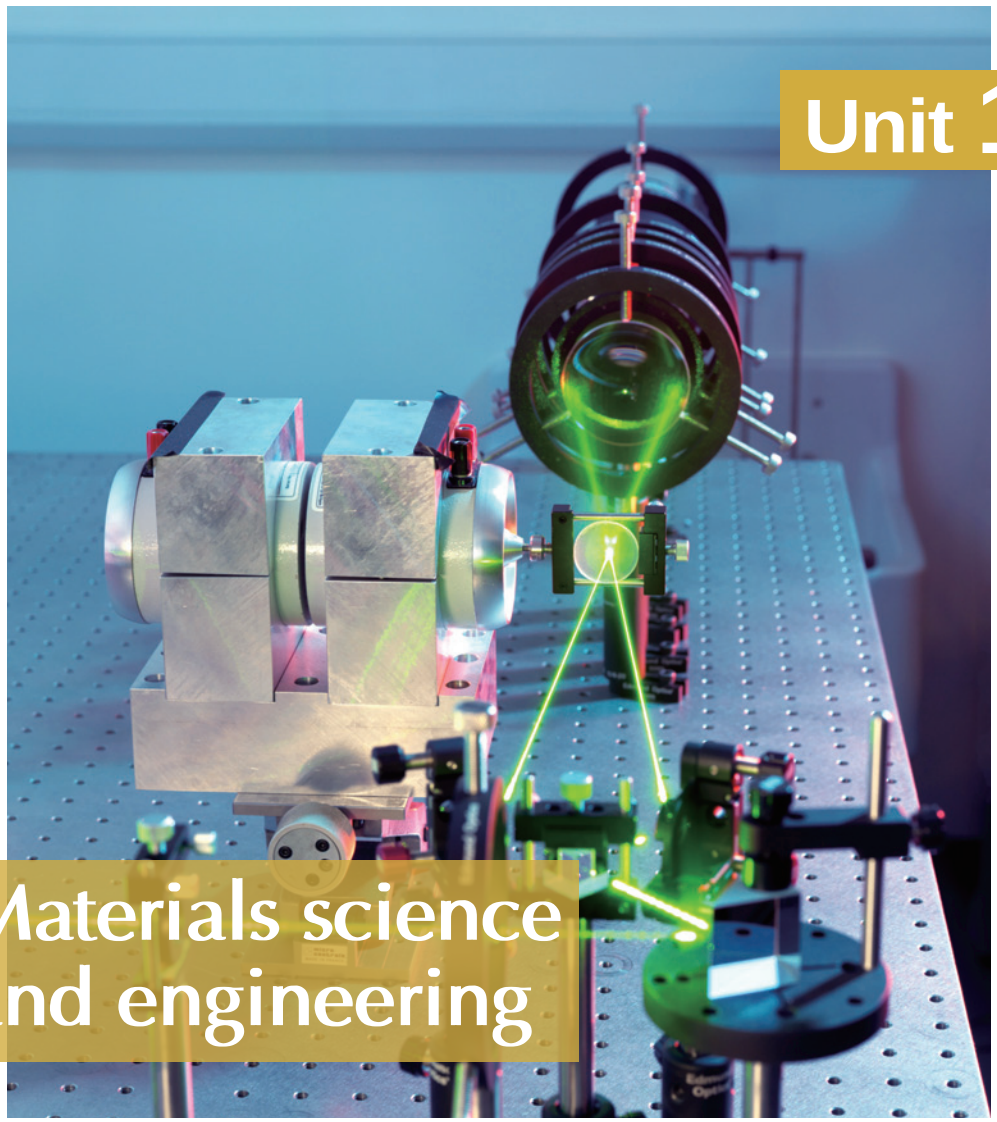


Unit 1

Materials science and engineering

In this unit, you will learn:

- **Subject-related knowledge:** The history and major concerns of materials science
  Materials engineering and engineers
- **Academic skill:** Searching for information
- **Reading strategy:** Dealing with unknown words (Part I)

Section A

Pre-reading

1 Study the six groups of materials in the right column and try to match them with the corresponding ages listed chronologically in the left column.

Age	Material
Stone Age	high strength alloys
Bronze Age	iron (powered) ore
Iron Age	copper, tin
Steel Age	special rocks, wood, bones, fur
non-ferrous & polymer age	aluminum, titanium, nickel, silicon, plastics, composites
exotic materials age	nanomaterials, biomaterials

2 Discuss the following questions in groups.

1. What are materials according to your understanding?
2. What do you know about the classification of materials?
3. Try to list five commonly encountered engineering materials.

1 From a practical standpoint, material objects are essentially substances that humans use to build things, including solids, liquids, and gases. The properties of materials might not be an exact image of those that their elements possess. Thus, we especially concern ourselves with how elements are structured in macroscopic bodies, what treatments are used during the elaboration of materials, or the physicochemical aggregation of different elements – all activities that condition the properties of materials.

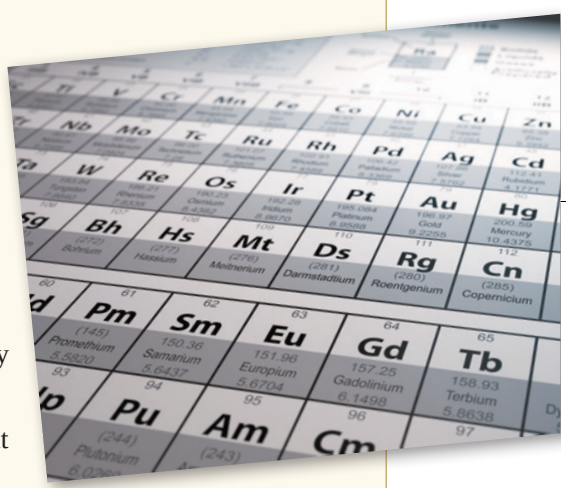
2 The selection, modification, and elaboration of materials to satisfy our needs merge in the foundations of human culture. From the very beginnings of prehistory, humans have manipulated substances so that they would be more useful. To create more useful materials, our forebears wanted to understand and control the composition of materials, and they often succeeded in modifying a material's behavior and properties and in predicting the effects of such manipulations.

3 This task developed over time, beginning as a handicraft that employed empirical and speculative knowledge. The history of materials science and engineering had already begun in the Stone Age

An introduction to materials science

Text A

when stones, wood, clay, and leather began to be manipulated. In the Bronze Age, mankind discovered the value of temperature and used it to modify materials by thermal treatments or by adding other substances. Yet, in spite of technological improvements, materials science remained empirical until the end of the 19th century. Materials science, as we now understand it, began with the appearance of Mendeleev's periodic table.



4 Since that time, some properties of elements that are related to their position in the periodic table began to be explained scientifically. Since the end of the 19th century, the introduction of chemistry, physics, calculus, and modern experimentation has brought the use and profits of materials to a mature status. Currently, thanks to more reliable knowledge of the structure of matter, we can design new materials atom by atom to achieve the properties we want. At last we would have materials that not only satisfy our requirements, but also permit us to create new ones that were hitherto unthinkable.

5 Thanks to this science, we can even speculate about using new, alternative materials to solve socioeconomic problems by avoiding the decimation of natural resources or trying to reach long-range sustained economic development. Conversely, the solution of unsolved problems improves our theoretical knowledge as well as the scope of materials in science and engineering.

6 In this context, materials scientists must analyze how the structure and composition of materials relate to their properties, and the effect of the method

of preparation of a material. Materials engineers examine the preparation, selection, and application of materials in agreement with known and desired properties. Engineers also incorporate technical and structural analysis and examine key concerns: energetic, economic, ecological, aging, etc.

7 For materials science and engineering, changes in physicochemical properties in response to a stimulus are highly significant. These properties can be classified into groups according to the kind of stimulus: mechanical, thermal, electromagnetic, chemical, and scattering.

8 In brief, mechanical properties, such as deformation and fracture, among others, are responses to applied mechanical forces. Thermal properties, like thermal conductivity and heat capacity, are affected by heat fluxes or temperature changes. Electrical properties such as the dielectric constant or conductivity occur in response to electromagnetic fields. Magnetic properties, like different types of magnetism, are also a response to electromagnetic fields. In a similar sense, optical properties, such as the refractive index or absorption, among others, respond to electromagnetic fields having high frequency. Chemical properties, like the chemical affinity, are responses to the existence of reagents in the environment. And the scattering properties are responses to the impact of particles depending on the material's structure.

9 In thinking about properties as a response to determined stimuli, we can group materials into families that facilitate a common analysis to determine the origin of the properties. For example, materials can be classified according to their electrical properties; hence, there are good or poor electrical conductors. This brings us to a taxonomy that permits us to see common features among materials in a family, to understand the basis of a property, and to predict the origin of new materials.

10 In the selective process of materials engineering, the choice of material is limited by the required properties and the available budget. The requisite properties are imposed by what we wish to make from the material, by

environmental conditions, and by the degradation of the material. In this selection, we have to take into account that the usage of materials and environmental conditions will provoke their degradation, which determines the required properties in an environment. When environmental conditions can be controlled, material selection is defined by its usage and the budget. That is, the economy plays a key role in materials engineering.

11 Materials science itself tries to analyze phenomena by the usual activities of contemporary science, and, without relying on economic aspects, to determine how structure, the presence of impurities and defects, production, purification, or mechanical transformation affects material properties.

12 Materials science can also do the converse: As desirable properties are defined, the material that can display them, although it might not exist in nature, is designed. There are well-known examples of this: stainless steel, powders used in metallurgy, ceramic materials with a controlled coefficient of expansion (which can even be zero), conducting plastics, plastics with a high resistance to friction, such as the one used in some aircraft radomes (a word formed from radar dome), or glasses with a saturable transmission coefficient.

13 The continuous development of new materials has also prompted the growth of an innovative industrial sector whose products, such as microelectronics or photonics, have greatly transformed the relationship between humans and their environment. Suffice it to say that with the many appliances that are electronically controlled, with the computer industry, with the substitution of copper by optical fibers in telephone conductors, or with satellite communications, we are challenged to make sense of the socioeconomic impact that these changes imply. Countries need to modify their industrial structure so they can survive the modifications that the new materials technology generates.

New words and expressions

macroscopic /ˌmækrəʊ'skɒpɪk/ *adj.*
large enough to be seen and examined without the aid of magnifying equipment 肉眼可见的；宏观的

elaboration /ɪˌlæbə'reɪʃən/ *n.*
the process of improving and refining sth. 加工

clay /kleɪ/ *n.* 黏土

thermal /'θɜːməl/ *adj.*
relating to heat 热的；热量的

Mendeleev's periodic table 门捷列夫元素周期表

calculus /'kælkjʊləs/ *n.* 微积分

decimation /ˌdesɪ'meɪʃən/ *n.*
the killing or destruction of a large population of a group or species 毁灭；削减

stimulus /'stɪmjʊləs/ *n.*
sth. that makes sth. or someone move or react 刺激；刺激物

electromagnetic /ɪˌlektrəʊmæg'netɪk/ *adj.*
电磁的

scattering /'skætərɪŋ/ *adj.* 散射的

deformation /ˌdiːfɔː'meɪʃən/ *n.*
a change in the shape or form 变形

fracture /'fræktʃə(r)/ *n.*
a break, split, or crack in an object or a material 折断；断裂

conductivity /ˌkɒndʌk'tɪvətɪ/ *n.*
the ability to allow electricity, heat, etc. to travel along or through 传导性

flux /flʌks/ *n.*
a flow or discharge 流量；流出

dielectric constant 介质常数

magnetism /'mægnɪtɪzəm/ *n.*
the physical force that makes two metal objects pull towards each other or push each other apart 磁性；磁力

optical /'ɒptɪkəl/ *adj.* 光学的

refractive /rɪ'fræktɪv/ *adj.* 折射的

reagent /riː'eɪdʒənt/ *n.*
a substance that shows that another substance in a compound exists, by causing a chemical reaction 试剂

taxonomy /tæk'sɒnəmɪ/ *n.*
the system of organizing things into different groups that show their natural relationships, esp. plants or animals（动植物等的）分类学

degradation /ˌdegrə'deɪʃən/ *n.*
the process of changing to a simpler form 分解；降解

impurity /ɪm'pjʊərətɪ/ *n.*
a substance of a low quality that is contained in or mixed with sth. else, making it less pure 杂质

metallurgy /me'tælədʒɪ/ *n.* 冶金（学）

ceramic /sɪ'ræmɪk/ *adj.* 陶瓷的；制陶的

coefficient /ˌkəʊɪ'fɪʃənt/ *n.* 系数

resistance /'rɪ'zɪstəns/ *n.* 抗性；阻力

radome /'reɪdəʊm/ *n.* 天线罩；天线屏蔽器

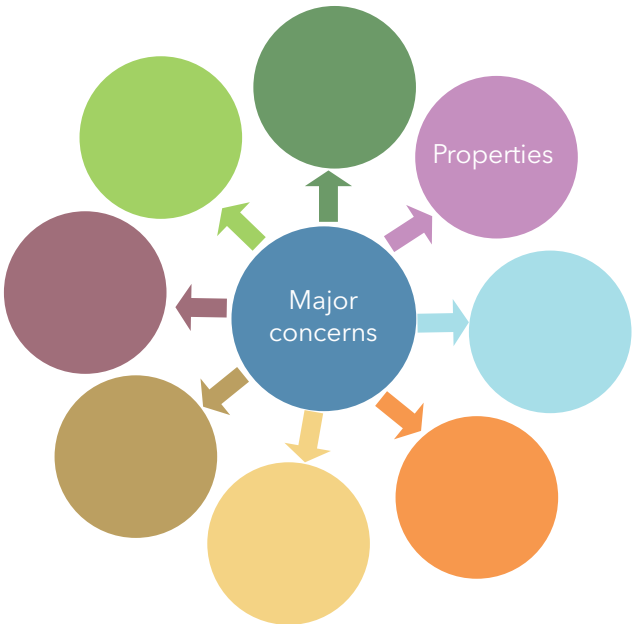
saturable /'sætʃərəbl/ *adj.*
capable of being saturated 能浸透的；可饱和的

microelectronics /'maɪkrəʊɪˌlek'trɒnɪks/ *n.*
微电子学

photonics /fəʊ'tɒnɪks/ *n.* 光子学

Reading comprehension

1 Read Text A and fill in the following graph with major concerns of materials science and engineering.



2 Materials can be classified into five properties according to the kind of stimulus. Read Text A and write down the five properties of materials and find examples as many as possible.

Property of materials	Example

Language focus

1 The words in bold in Column A have different meanings in general English and English for materials science. Discuss with your partner and match them with their possible meanings in Column B.

Column A	Column B
___ 1. We especially concern ourselves with what treatments are used during the **elaboration** of materials.	A. the process in which particles are deflected or diffused
___ 2. They often succeeded in modifying a material's **behavior** and properties.	B. a number expressing a relation or property which remains the same in all circumstances, or for the same substance under the same condition
___ 3. These properties can be classified into groups according to the kind of stimulus: mechanical, thermal, electromagnetic, chemical, and **scattering**.	C. the process of developing sth. in further detail
___ 4. Electrical properties such as the dielectric **constant** or conductivity occur in response to electromagnetic fields.	D. a material or device that conducts or transmits heat or electricity, especially when regarded in terms of its capacity to do this
___ 5. Hence, there are good or poor electrical **conductors**.	E. the way in which a machine or natural phenomenon works or functions

2 Read the following paragraph and fill in the blanks with the common phrases in the field of materials science below.

materials paradigm　properties and performance
science and engineering　failure analysis

In recent years, materials science has become more widely recognized as a specific and distinct field of 1) _____. Many of the most pressing scientific problems humans currently face are the results of the limitations of available materials. Materials scientists emphasize understanding how the processing of a material influences its structure, and thus its 2) _____. This understanding of processing-structure-properties relationships is called the 3) _____. It is used to advance understanding in a variety of research areas, including nanotechnology,

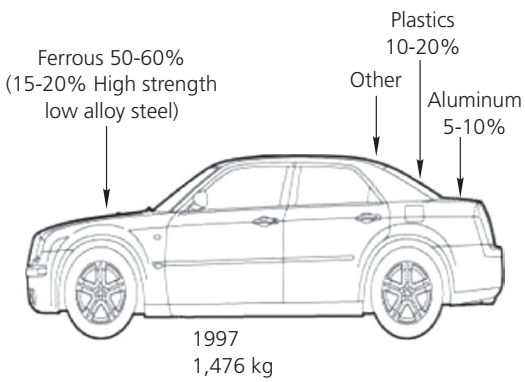
biomaterials and metallurgy. Materials science is also an important part of forensic engineering (法医工程) and 4) _____ – investigating materials, products, structures or components which do not function as intended, causing personal injury or damage to property.

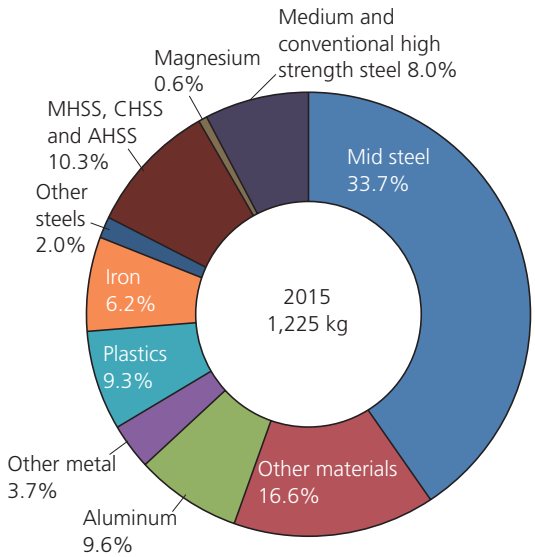
3 **Translate the following paragraph into English.**

人类对材料的选择通常可以定义一个时代，例如石器时代、青铜时代、铁器时代和钢铁时代等。现代材料科学源于冶金业，而冶金业源于采矿业和制陶业，所以说，材料科学是一门历史悠久的工程与应用科学。20世纪以来，材料科学已推动了多项技术的革新。例如，利用金属合金、硅及碳材料的特性来建造空间飞行器，从而实现对太空的探索。诸如塑料、半导体、生物材料等新技术，极大地方便了人类的生活，促进了工业的发展。同时，由于生活和工业的需求，材料科学本身也在不断发展。

Critical thinking

Materials scientists and engineers have to prepare for the constant changes in materials usage. Compare the two pictures and answer the following questions in groups.





1. Describe the changes of major materials used in producing an automobile in the U.S. from 1997 to 2015.
2. Give another example of changes of materials used in some manufactured products over a period of time.
3. What factors may motivate the development and application of new materials?

Researching task

Academic skill: Searching for information

Information can come from virtually anywhere – media, blogs, personal experiences, books, journal and magazine articles, expert opinions, encyclopedias, and web pages, etc.

1. Types of information

Type	Use
Magazine	• To find information or opinions about popular culture. • To find up-to-date information about current events. • To find non-scholarly articles about topics of interest within the subject of the magazine.
Academic journal	• To get help for your scholarly research. • To find out what has been studied on your topic. • To find bibliographies that point to other relevant research.
Database	• To find articles on specific topics. • To find online journals or news articles.
Newspaper	• To find editorials, commentaries, expert or popular opinions. • To find current local, national or world news.
Library catalog	• To find virtually any topic. • To find hard copies of current or back issue of journals, books, newspapers or magazines.
Website	• To find information from all levels of government – central to local. • To find expert or popular opinions. • To find information of various types of media, e.g. illustrations, audio and video information.

2. Searching for information

Author / Title search

Searching by author and / or title obviously assumes that you are searching for a particular author, book or article, probably in either a database or a library catalog. Here are some tips:

- When searching by author, put the author's last name first, e.g. "Kotler, Philip", not "Philip Kotler", if he is from an English-speaking country. Search the author's full name in Chinese order if he is a Chinese. Sometimes, the author could be an organization, so give the full name of the organization as it commonly appears, e.g. "World Bank".
- When searching by title, it helps if you enter the title as correctly as possible.

Keyword search

It is basically a way of searching through subject or topic. Most library catalogs and databases will include an option to search by keyword as an alternative to author and title. The first step of keyword search is to decide the key word(s) or phrase(s). Normally, the word(s) or phrase(s) which can cover the topic you search can be selected as keyword(s). A good research topic usually contains two or three concepts. For example, you need to write a paper on "The Impact of Cognitive Styles on Design Students' Spatial Knowledge". We can break the topic into concepts, like "cognitive styles" and "spatial knowledge", which can be used as keywords. Then type them in a search bar in a database, EBSCOhost for instance. In a database, there are usually two ways of search, i.e., basic search and advanced search.

Basic search (see Fig. 1) generates a large number of sources for you to differentiate, which is an exhausting task. But advanced search (see Fig. 2), which provides more choices for further conditioning, can make the work lighter. There are many variables that can be chosen to refine the search. And you can define the relationship between the keywords by choosing "and", "or" or "not" based on the results you intend to obtain.

Fig. 1 Basic search

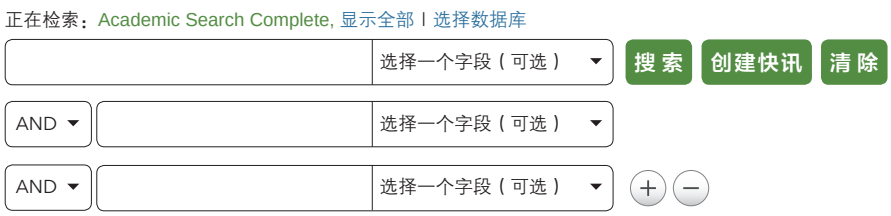


Fig. 2 Advanced search

As "cognitive styles" is a broader topic and "spatial knowledge" is more specific, they can be typed in the upper and middle search bars respectively. More relevant results will appear. You can then refine the search by selecting a specific variable. In this case, "subject" (主题语) can be chosen to filter the results (See Fig. 3).

Fig. 3

Snowball search

It is a good way if your topic has a key work or author. You can trace the citations of that author using a specialized citation database, such as the Social Science Citation Index to obtain other key works or authors. You will follow the stream of research up to the near present and see the way in which the work or the author has influenced the subsequent studies.

3. Evaluating information

Once you have found information that satisfies the requirements of your research, you should evaluate it. Evaluating information encourages you to think critically about the reliability, validity, accuracy, authority, timeliness, point of view or bias of information.

When evaluating information, you can use the five criteria AAOCC, namely, Authority, Accuracy, Objectivity, Currency and Coverage. They can be applied to check all information.

1) Authority of information
   - Who published it?
   - What institution published it?
   - Does the publisher list his or her qualifications?
2) Accuracy of information
   - Who provided it, and can you contact him or her?
   - Does it provide enough details?
   - Has it been cited correctly?
3) Objectivity of information
   - What is the purpose of it, or why was it published?
   - Is it biased?
   - What opinions (if any) are expressed by the author?
4) Currency of information
   - When was it published?
   - When was it updated?
   - How up-to-date is it?
5) Coverage of information
   - Do citations in it complement the research?
   - Is it all text or a balance of text and image?
   - Is it free or is there a fee to obtain it?

Task

Most engineering materials can be divided into five major classes: metallic materials, polymeric materials, ceramic materials, composite materials, and electronic materials. Make use of the Internet and search information of the applications of the five materials with the help of keywords. Then report your findings to the class.

Section B

Reading strategy

Dealing with unknown words (Part I)

The ability to deal with unknown words is a key reading skill in the reading process. It is a vital skill because you are almost certain to find unknown or unfamiliar words in any text. The skill is not necessarily to "know" the words, but to guess the meaning of them so that you can read and understand the whole text. Here are several different ways that can help you guess the meaning of an unknown word.

Guessing by explanation

Sometimes, you will find that the meaning of an unfamiliar word is given to you in the text. In this case, what you need to do is keep on reading and do not stop at the moment when you find an unfamiliar word. And you will find that the meaning of it has already been given to you in the text. For example:

> *The history of materials science and engineering had already begun in the Stone Age when stones, wood, clay, and leather began to be manipulated.*

You might feel confused at the first sight of "Stone Age". But there is a clause immediately after the unfamiliar phrase, that is, "when stones, wood, clay, and leather began to be manipulated". Then you will understand what age the "Stone Age" is.

Guessing by synonyms and antonyms

This is a very useful skill to learn. What you should do here is look at other words which relate to that word and work out what it may mean. These words may be either synonyms (words with a similar meaning) or antonyms (words with an opposite meaning). For example:

> *This brings us to a taxonomy that permits us to see common features among materials in a family, to understand the basis of a property, and to predict the origin of new materials.*

Here you can work out the meaning of "taxonomy" by its synonym "family". All you need to do is read the rest part of the sentence and think of the meaning of it.

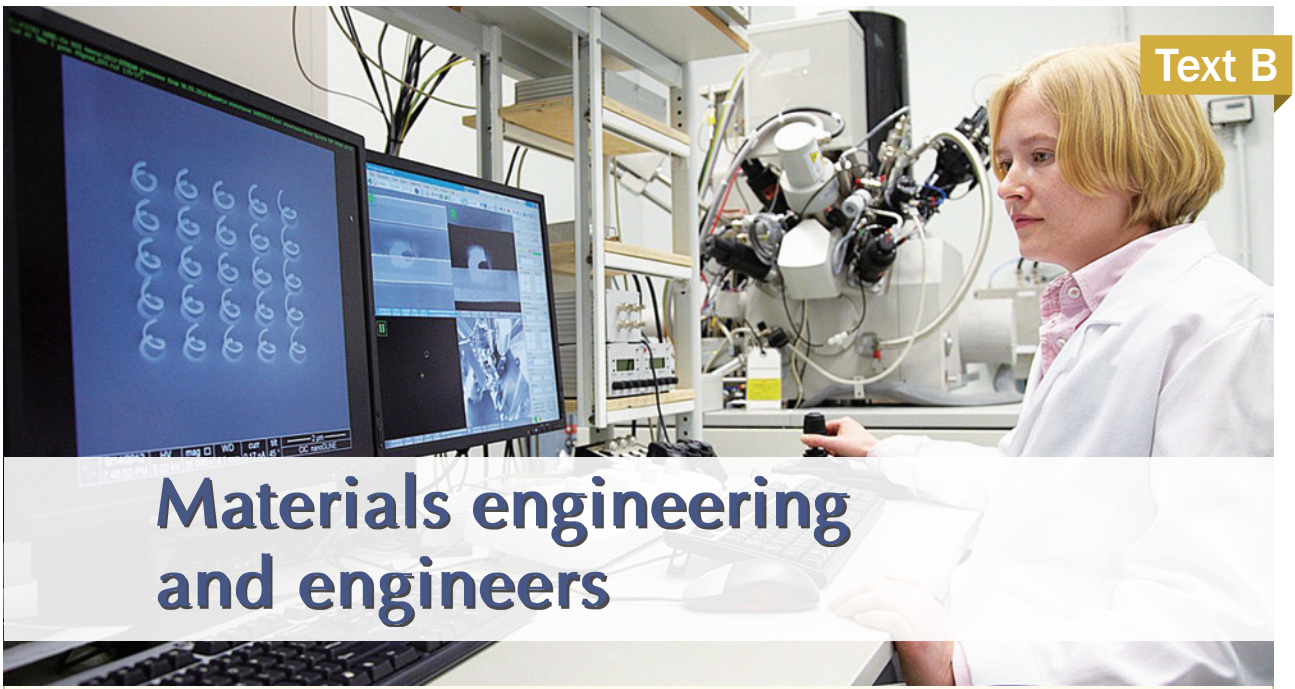
Sometimes, when you come across an unknown word, besides guessing it, you can also ignore the word, especially when the word starts with a capital letter or is in italics, which means that it is in all probability a proper name or a loanword. In this case, you should waste no time in trying to understand the exact meaning of the word. For example:

> *Materials science, as we now understand it, began with the appearance of Mendeleev's periodic table.*

The word "Mendeleev's" is a word that you should learn to ignore because it starts with a capital letter and is therefore a name of a certain person.

Task

Read Text B and apply the skills above to deal with the underlined words.



Text B

Materials engineering and engineers

1 Materials science is primarily concerned with the search for basic knowledge about the structure, properties, and processing of materials. Materials engineering is mainly concerned with the use of fundamental and applied knowledge of materials so that the materials can be converted into necessary products desired by society. Materials science is at the basic knowledge end of the materials knowledge spectrum and materials engineering is at the applied knowledge end. And there is no demarcation line between the two.

2 Materials science heavily relies on physics, chemistry, and engineering fields such as mechanical and electrical engineering. Physical properties of materials are usually the deciding factor in choosing which material should be used for a particular application. Such factors also include composition and structure of materials (chemistry), fracture and stress analysis (mechanical engineering), conductivity (electrical engineering), optical and thermal properties (physics), to name a few. Materials science also deals with processing and production methods,

and many peripheral areas such as crystallography, microscopy, mineralogy, photonics, and powder diffraction. Due to the diversity of the subject areas covered by materials science, the study of it has taken an interdisciplinary trend.

3 The production and processing of materials into finished goods constitutes a large part of our present economy. Engineers, who are knowledgeable about the structure and properties of materials, design manufactured products, select suitable materials and develop the required processing systems for the production.

4 Materials engineers may specialize in understanding specific types of materials. Ceramic engineers develop ceramic materials and the processing methods of making them into useful products, from high-temperature rocket nozzles to glass for LCD flat panel displays. Composites engineers develop materials with special, engineered properties for applications in aircraft, automobiles, etc. Metallurgical engineers specialize in metals, such as steel and aluminum, usually in the alloyed form with additions of other elements to provide specific properties. Plastics engineers develop and test new plastics, known as polymers, for new applications. Semiconductor processing engineers develop new microelectronic materials for computing, sensing, etc. Research and development engineers work to create new materials or modify the properties of existing ones, while design engineers use existing, modified, or new materials to design new products or systems.

5 For engineers, the search for new materials never ends. For example, mechanical engineers search for higher-temperature materials so that jet engines can operate more efficiently. Electrical engineers search for new materials so that electronic devices can operate faster and at higher temperatures. Aerospace engineers search for materials with higher strength-to-weight ratios for aircraft and space vehicles. Chemical engineers look for more highly corrosion resistant materials. These are only a few examples of the

crystallography *n.* 晶体学；结晶学
microscopy *n.* 显微镜学
mineralogy *n.* 矿物学
powder diffraction 粉末衍射
rocket nozzle 火箭发动机喷嘴
flat panel display 平板显示器

search by engineers for new and improved materials. In many cases, what was impossible yesterday is a reality today!

6 Materials engineers generally work in offices where they have access to computers and equipment. Others work in factories or research and development laboratories. Materials engineers may work in teams with scientists and engineers from other backgrounds. They typically work full time and may work overtime hours when necessary.

7 It's not easy to become a materials engineer. In America, materials engineers must have at least a bachelor's degree in materials science and engineering or a related engineering field. Completing internships and cooperative engineering programs while in school can be helpful in getting hired as a materials engineer.

8 Besides, the following five skills are necessary for a materials engineer.

9 Analytical skills. Materials engineers often work on engineering projects, so they have to determine what materials should be used and how they should be structured to withstand different conditions.

10 Math skills. Materials engineers use the principles of calculus and other advanced topics in math for analysis, design, and troubleshooting in their work.

11 Problem-solving skills. Materials engineers are supposed to figure out why a product might have failed, design a solution, and then conduct tests to make sure that the product does not fail again. That means they should be able to identify the root cause when many factors could be at fault.

12 Communication skills. While working with technicians, technologists, and other engineers, materials engineers should be able to state concepts and directions clearly. When speaking with managers, who may not have an engineering background, they should also be able to communicate effectively.

13 Writing skills. More often than not, materials engineers need to make plans and reports, both of which should be clearly understood. Therefore, a materials engineer is always a good writer.