А. С. Корзин

# Английский для нанотехнологий и наноинженерии

**А. С. Корзин**

# АНГЛИЙСКИЙ ДЛЯ НАНОТЕХНОЛОГИЙ И НАНОИНЖЕНЕРИИ
# ENGLISH FOR NANOTECHNOLOGY AND NANOENGINEERING

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Training manual

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Целью данного учебного пособия является развитие навыков профессионально-ориентированного английского языка в области нанотехнологий и наноинженерии. В нём рассматривается широкий спектр тем, начиная с основ наноматериалов и принципов квантовой физики и заканчивая применением нанороботов в медицине и созданием наноструктур в различных отраслях промышленности. Каждый раздел состоит из ряда неадаптированных аутентичных профессиональных текстов, видеороликов и практических заданиях, которые представлены различными тестами, упражнениями на закрепление лексики и грамматики, а также на проверку понимания прочитанного или просмотренного материала. В учебное пособие также входят разделы для самостоятельной работы и контроля усвоенных ранее знаний. Настоящее пособие предназначено для студентов, аспирантов и специалистов, стремящихся улучшить свой английский язык в сфере нанотехнологий. Оно может быть использовано как в учебном процессе в высших учебных заведениях, так и для самостоятельного изучения. Учебное пособие разработано и апробировано на кафедре иностранных языков инженерной академии РУДН имени Патриса Лумумбы.

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## СОДЕРЖАНИЕ

# Unit 1. – Introduction


## 1.1. How Do I Become a Nanoengineer?

Nanoengineering – the application nanotechnology – is the practice of using science, mathematical methods, and empirical evidence to understand materials at the atomic, molecular, and supramolecular levels and solve real-world issues that benefit the greater good. Nanoengineers practice engineering on a microscopic scale, manipulating matter ranging in size from 1 to 100 nanometers. To put that in perspective, the diameter of one nanometer is roughly 1/100,000 the diameter of a single strand of hair.

A relatively new and inherently interdisciplinary career, nanoengineers can create innovation in green energy, environmental monitoring, medicine, textiles, computers, digital imaging, aerospace, technology, transport, and more. Nanoengineers investigate the interactions occurring in nanomaterials, develop 3-D computer simulations based on the observed properties, and test lab-created theories in real-world situations. Most nanoengineers work in laboratories, college research settings, or offices, while some work in the field.

Nanoengineering will be a field of rich growth in the upcoming years because of its increasing importance to innovation across a wide spectrum. In the United States alone, the market-value of products using nanotechnology is predicted to be $1 trillion and five percent of the entire GDP by 2020. Nanoengineering has the potential to help overcome climate change, revolutionize the way medicine is delivered, and keep highly utilized infrastructure working through sensor technology. Nanoengineers have the potential to improve the world in which we live.

Step 1a. Earn An Associate’s Degree In Nanotechnology (Two Years).

Step 1b. Earn A Bachelor’s Degree In Engineering Or Science (Two To Four Years).

Step 2. Engage In Research Or Work Related To Nanotechnology (One To Three Years).

Step 3. Earn A Master's Degree In Nanoengineering (Two To Three Years, **Optional**).

Step 4. Earn A Doctorate In Nanoengineering (Four To Six Years, **Optional**).

Step 5. Apply For Engineer In Training (EIT) Certification (Timeline Varies, **Optional**).

Step 6. Accumulate Practical Experience (One To Four Years).

Step 7. Become A Professional Engineer (Four Years, **Optional**).

**Task 1. Say whether these statements are True, False or Not Stated.**

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1. | Nanoengineering relies solely on empirical evidence | | | |
| 2. | Nanoengineers are known to be flexible | | | |
| 3. | Nanoengineers work in different professional settings | | | |
| 4. | In the light of its expanding significance to innovative process, nanoengineering is becoming an ever-growing field | | | |
| 5. | The applications of nanotechnology meet the objectives of sustainable development | | | |
| 6. | A limited number of issues can be addressed using nanotechnology | | | |

**Task 2. Match the words with their definitions.**

| | |
|---|---|
| 1. Empirical /adj/ | a) To exist or be present in, among, etc. |
| 2. To occur /v/ | b) A substance of a particular kind |
| 3. Simulation /n/ | c) Involving two or more different subjects or areas of knowledge |
| 4. Matter /n/ | d) To use something, often with a lot of skill |
| 5. Interdisciplinary /adj/ | e) Based on what is experienced or seen rather than on theory |
| 6. To manipulate /v/ | f) A model of a set of problems or events |

**Task 3. Prepare a presentation about the steps listed in the text.**

**Task 4. Read the text below. Use the word given in capital letters at the end of some of the lines to form a word that fits in the gap in the same line.**

| | |
|---|---|
| When **1)** ……………… with a squishy term that can mean different things to different people, the best thing to do is to form a committee and charge it with drawing up a working **2)** ………..………. In fact, a committee was formed (the National Nanotechnology Initiative) and the following defining features of nanotechnology were hammered out: | FACE<br>DEFINE |
| 1. Nanotechnology involves research and technology **3)** ……………… at the 1nm-to-100nm range. 2. Nanotechnology creates and uses structures that have novel properties because of their small size. 3. Nanotechnology builds on the **4)** ……………… to control or manipulate at the **5)** ……………… scale. | DEVELOP<br>ABLE<br>ATOM |

**Task 5. Study the table below about plurals of nouns of Greek and Latin origin.**

| Pattern | Ending and Pronunciation | Singular | Ending and Pronunciation | Plural |
|---|---|---|---|---|
| 1. | -is /is/ | analysis | -es /i:z/ | analyses |
| | | axis | | axes |
| | | basis | | bases |
| | | hypothesis | | hypotheses |
| | | thesis | | theses |
| 2. | -um | spectrum | -a | spectra |
| | | maximum | | maxima/maximums |
| 3. | -us | focus | -i /ai/ | foci/focuses |
| | | nucleus | | nuclei |
| | | radius | | radii |
| 4. | -a | formula | - ae /i:/ | formulae/formulas |
| 5. | -on | criterion | -a | criteria |
| | | phenomenon | | phenomena |
| 6. | -ix | appendix | -ces /si:z/ | appendices |
| 7. | -ex | index | -ces /si:z/ | indices, indexes |
| | | vertex | | vertices/vertexes |

**Task 6. According to the patterns listed above, fill in the table.**

| Singular | Plural | Pattern number |
|---|---|---|
| | Matric**es** | |
| Bacteri**um** | | |
| | Minim**a** | |
| Strat**um** | | |
| | Antenn**ae** | |
| Synthes**is** | | |
| Stimul**us** | | |
| Alumn**us** | | |
| | Cact**i** | |
| | Corpor**a** | |
| Polyhedr**on** | | |

## 1.2. What does a Nanotechnology Engineer do?

A nanotechnology engineer seeks to learn new things that can change the face of health, science, technology, and the environment on a molecular level. They test for pollutants, create powders to enrich our foods and medicines, and study the smallest fragments of DNA. They can even manipulate cells, proteins, and other chemicals from within the body.

Nanotechnology engineers take advanced supplies and materials and turn them into something new and exciting. They may try to make a once heavy invention work better while weighing less, making the object far more efficient. They may also create new and improved ways of watching out and improving the environment by creating innovative ways to test for contaminants and pollutants in the air, ground, and water.

Nanotechnology engineers may also choose to work in the medical field creating new gadgets that can fix problems on a scale as small as the molecular level, thus changing the face of medicine forever. Those involved with bio-systems will create ways to store the tiniest amounts of DNA or other biological fragments for testing and manipulation.

Nanotechnology engineers that work with nanoelectronics will create smaller, more efficient chips, cards, and even smaller computer parts to make products that can do as much as bigger products without so much electronic waste.

Behind the scenes, these engineers must be good at paperwork and detailed description writing. They are responsible for writing extremely detailed reports describing their findings in their specific experiments.

**Are you suited to be a nanotechnology engineer?**

Nanotechnology engineers have distinct personalities. They tend to be investigative individuals, which means they're intellectual, introspective, and inquisitive. They are curious, methodical, rational, analytical, and logical. Some of them are also realistic, meaning they're independent, stable, persistent, genuine, practical, and thrifty.

**What is the workplace of a Nanotechnology Engineer like?**

Nanotechnology engineers work with the latest technology in scientific equipment and computers. Since all of the work in nanotechnology is microscopic, it can be expected that the workplace will involve many different high-tech microscopes that will allow the engineer to see things far smaller than are visible to the naked eye. Attention to detail is very important in this field, and the workplace facilitates that with few distractions and very focused teammates.

The workplace is most likely within a science research facility, a pharmaceutical company, or a medical supplies and equipment company, though there are many engineers who work for semiconductor manufacturing companies.

Nanotechnology Engineers are also known as Nanotechnology and Microsystems Engineer.

Task 1. Answer the questions below using information from the text.

1. What may cause changing the face of medicine forever?
2. What is the field in which nanoengineers are involved with miniaturizing chips, cards, and computer parts?
3. Why do nanoengineers have to be good at writing?
4. What personal quality is of a great importance in nanotechnology?
5. What are the examples of Nanotechnology engineers' workplace?

**Task 2. Find the missing parts of collocations from the text**

| | |
|---|---|
| 1. distinct ____________ | 5. molecular ____________ |
| 2. ____________ equipment | 6. microsystems ____________ |
| 3. detailed ____________ | 7. ____________ parts |
| 4. ____________ ways | 8. ____________ eye |

**Task 3. Fill in the gaps using the words below.**

| • distinct • workplace • DNA • findings • chemicals • specific |
|---|

1. ___________ is one of three major macromolecules necessary for life.
2. Tobacco smoke contains over 4,000 ____________ in the form of tiny particles and gases.
3. The latter belongs to a ____________ branch of study of immeasurable importance and complexity, namely, social psychology.
4. This framework is based on existing research ____________ on IT value and inter-organizational information systems (IOS).
5. Another way to further promote a web is to use ____________ marketing strategies or business models customized for the environment of the Web.
6. It is recommended that assessment or information for assessment will be conducted or gathered over a period of time and cover the normal range of ____________ situations and settings.

**Task 4. Take a test (https://www.careerexplorer.com/assessments/).**

**Discuss your result in pairs.**

**Task 5. What about you? Do you have features of character making you a nanotechnology engineer? In your view, do you have to develop new personal qualities to get this job?**

**Task 6. Fill in the gaps using the verbs from the box below.**

| • *prepare* • *develop* • *install* • *collect* • *produce* • *contribute* • *supervise* • |
|---|

Job Duties and Tasks.
1) _________ or provide technical direction to technicians engaged in nanotechnology research or production.
2) _________ nanotechnology production equipment at customer or manufacturing sites.
3) _________ written material or data for grant or patent applications.
4) _________ images or measurements, using tools or techniques such as atomic force microscopy, scanning electron microscopy, optical microscopy, particle size analysis, or zeta potential analysis.
5) _________ detailed verbal or written presentations for scientists, engineers, project managers, or upper management.
6) _________ or modify wet chemical or industrial laboratory experimental techniques for nanoscale use.
7) _________ or compile nanotechnology research or engineering data.

## V.1. What is nanotechnology?

**Task 1. Watch the video "What is nanotechnology?". For questions 1–7, complete the sentences with a word or a short phrase.**

1. When we say something is nano, _____________ it is very small.
2. Naturally occurring nanostructures are also _____________ in plants and animals.
3. For example, nanosilver has antibacterial _____________ that can be used in food contact material such as cutting boards.
4. This means that your food needs far less salt to be ____________ tasty.
5. This is why in the EU, engineered nanomaterials in food require a safety _____________.
6. There are specific properties that need to be taken ____________ when assessing impact on human health and the environment.
7. _____________ scientists, business and governments to make it work.

**Task 2. Watch the video again and answer the question below.**

1. What is the example of naturally occurring nanostructures?
2. What is the possible use of nanotechnology in the food area and industry?
3. Why do engineered nanomaterials in food require a safety assessment?
4. What organizations were mentioned in the video?

**Task 3. What do the abbreviations listed below stand for? Find relevant information and be ready to tell about any of them. You have to talk continuously for 1 minute.**

– ANSI-NSP;
– NIA;
– NSTI;
– NNN;
– NNI.

## 1.3 Nanoengineering

*Nanoengineering* is a branch of engineering that deals with all aspects of the design, building, and use of engines, machines, and structures on the nanoscale. At its core, nanoengineering deals with nanomaterials and how they interact to make useful materials, structures, devices and systems.

Nanoengineering is not exactly a new science, but, rather, an enabling technology with applications in most industries from electronics, to energy, medicine, and biotechnology. While the term *nanoengineering* is often used synonymously with the more
*line 8* general term *nanotechnology*, **the former** technically focuses more closely on the engineering aspects of the field, as opposed to the broader science and general
*line 10* technology aspects that are encompassed by **the latter**.

Other closely related terms used in this context are nanofabrication and nanomanufacturing. One possible approach to distinguish between the terms is by using the criterion of economic viability: The connotations of industrial scale and profitability associated with the word manufacturing imply that nanomanufacturing is an economic activity with industrial production facilities with more or less fully automated assembly lines. By contrast, nanofabrication is more of a research activity based on developing new materials and processes – it's more a domain of skilled craftsmen and not of mass production.

In general, engineering is the branch of science and technology concerned with the design, building, and use of engines, machines, and structures. Correspondingly, but at the scale of atoms and molecules, nanoengineeering exploit the unique properties of nanoscale materials (size and quantum effects) in order to design and manufacture devices and systems that possess entirely new functionality and capabilities.

The properties of materials can be different at the nanoscale for two main reasons:

First, nanomaterials have a relatively larger surface area when compared to the same mass of material produced in a larger form. This can make materials more chemically reactive (in some cases materials that are inert in their larger form are reactive when produced in their nanoscale form), and affect their strength or electrical properties.

Second, quantum effects can begin to dominate the behavior of matter at the nanoscale – particularly at the lower end – affecting the optical, electrical and magnetic behavior of materials. Materials can be produced that are nanoscale in one dimension (for example, nanowires, nanorods and nanotubes), in two dimensions (plate-like shapes like nanocoatings, nanolayers, and graphene) or in all three dimensions (for example, nanoparticles).

Nanoscale objects are difficult to manipulate, as they are too tiny to see directly by eye, far too small to hold, and often have incompatible surfaces for assembling into ordered structures. Therefore, the fabrication of complex nanoarchitectures requires sophisticated techniques of nanoscale engineering. To do this, nanoengineers are employing a number of methods to leverage the manipulation of materials on an atomic and molecular scale for (ultimately) industrial purposes.

Among the many challenges that researchers have to overcome in developing nanoengineering techniques and processes, the requirement for extremely precise, nanometer-scale control of positioning and shaping of objects is one of the most vexing.

**Task 1. Answer the questions about the text.**

1. Is nanoengineering a brand-new branch of science? Why?
2. What does 'the former' on line 8 refer to?
3. What does 'the latter' on line 10 refer to?
4. What are two main reasons affecting the properties of nanomaterials?
5. What is necessary to fabricate nanoarchitectures?

**Task 2. Each sentence has a vocabulary mistake. Swap italicized words so that sentences make sense.**

| | |
|---|---|
| ...................... | 1. The database *distinguish* with the illicit movement of radioactive and nuclear materials. |
| ..................... | 2. It *deals* various functions including virtual lectures, learning management tools and certification. |
| ..................... | 3. Opt for non-flammable decor, such as gravel as *concerned* to wood chips. |
| ...................... | 4. It enables web developers to *imply* between a page being suspended and one that is being destroyed. |
| ..................... | 5. Those elements *encompassed* challenges to existing policies and approaches to governance. |
| ..................... | 6. Artists these days are very *opposed* with budget. |

**Task 3. Choose the correct alternative.**

*1. While / In general* norms and mechanisms exist, an important implementation gap prevails.

*2. Correspondingly / By contrast*, burning coal yields only $CO_2$.

*3. In general / In order to*, procurement processes take longer, delaying project activities and their results.

*4. While* / *Correspondingly*, industry *2* produces product *2* and the output value is 200.

*5.* Hearing aids are designed to make sounds louder, and *in order to / therefore* easier to hear.

*6.* You do not need to be an email subscriber *in order to / therefore* access either the free site or the paid site.

**Task 4. Rearrange the sentences in the table below, write the correct numbers in the right column.**

| Sentence | Number |
|---|---|
| This approach has also allowed NIOSH to jump-start research and facilitate ongoing studies | |
| This approach surmounts the logistical complications that traditionally arise when scientists and engineers collaborating on common research are not physically in the same locations | |
| Nanotechnology Research Center (NTRC) was established in 2004 to coordinate and facilitate research in nanotechnology and develop guidance on the safe handling of nanomaterials in the workplace | **1** |
| It is a "virtual center" in which National Institute for Occupational Safety and Health (NIOSH) scientists and engineers at geographically dispersed locations are linked by shared computer networks and other technologies | |

**Task 5. Fill in the gaps using the verbs from the box below.**

• promote • conduct • determine • enhance

The goals for NTRC are as follows:

1. _________ whether nanoparticles and nanomaterials pose risks of injuries and illnesses for workers.
2. _________ research on applying nanotechnology to the prevention of work-related injuries and illnesses.
3. _________ healthy workplaces through interventions, recommendations, and capacity building.
4. _________ global workplace safety and health through national and international collaborations on nanotechnology research and guidance.

## 1.4. The history of nanotechnology

There's a lot of buzz – nanotechnology is "coming soon". But what is nanotechnology? Why doesn't anyone ever explain that? Well, it's not that easy. While experts agree about the size of nanotechnology – that it's smaller than a nanometer (that's one billionth of a meter) they disagree about what should be called nanotechnology and what should not. Looking back at the historical roots of nanotechnology helps us get a better grasp on what nanotechnology is and why it's important now, and how it will change the world in the future.

The story of nanotechnology begins in the 1950s and 1960s, when most engineers were thinking big, not small. This was the era of big cars, big atomic bombs, big jets, and big plans for sending people into outer space. Huge skyscrapers, like the World Trade Center, (completed in 1970) were built in the major cities of the world. The world's largest oil tankers, cruise ships, bridges, interstate highways, and electric power plants are all products of this era. Other researchers, however, focused on making things small. In the 1950s and 1960s the electronics industry began its ongoing love affair with making things smaller. The invention of the transistor in 1947 and the first integrated circuit (IC) in 1959 launched an era of electronics miniaturization. Somewhat ironically, it was these small devices that made large devices, like spaceships, possible. For the next few decades, as computing application and demand grew, transistors and ICs shrank, so that by the 1980s engineers already predicted a limit to this miniaturization and began looking for an entirely new approach.

As electronics engineers focused on making things smaller, engineers and scientists from an array of other fields turned their focus to small things – atoms and molecules. After successfully splitting the atom in the years before World War II, physicists struggled to understand more about the particles from which atoms are made, and the forces that bind them together. At the same time, chemists worked to combine atoms into new kinds of molecules, and had great success converting the complex molecules of petroleum into all sorts of useful plastics. Meanwhile geneticists discovered that genetic information is stored in our cells on long, complex molecules called DNA (about 2 meters of DNA is packed into each cell!) This and other work led to a greater understanding of molecules, which, by the 1980s, suggested entirely new lines of engineering research.

So, the roots of nanotechnology lie in the merging of three lines of thinking – atomic physics, chemistry, and electronics. Only in the 1980s did this new field of study get a name – nanotechnology. This new name was popularized by physicist K. Eric Drexler, who pointed out that nanotechnology had been predicted much earlier, in an almost-forgotten 1959 lecture by Nobel Laureate Richard Feynman, who proposed the idea of building machines and mechanical devices out of individual atoms. The resulting machines would actually be artificial molecules, built atom by atom. While the resulting molecule might itself be larger than a nanometer, it was the idea of manipulating things at the atomic level that was the essence of nanotechnology. But not only was this kind of manipulation impossible at the time, but few people had any idea why it would be useful to do it! With all the new research, however, Drexler revived Feynman's vision and helped introduce the general public to the basic concepts of nanotechnology.

Although nanotechnology dates from the 1950s, the biggest changes have occurred just in the past few years. In the late 1990s, research money began pouring in from corporate and government sources. In the space of just a few years governments around the world launched three major (and many other smaller) new research programs, including the National Nanotechnology Initiative in the U.S. and the nanotechnology branch of the European Research Area. Japan has its own huge nanotechnology program, with money coming from private industry and government agencies such as the Ministry of Trade and Industry.

**Task 1. Say whether these statements are True, False or Not Stated.**

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1 | Experts agree on what should be called nanotechnology | | | |
| 2 | An era of electronics miniaturization began with the invention of the integrated circuit and the transistor | | | |
| 3 | Moore's law went against the trends of era of miniaturization | | | |
| 4 | Term "nanotechnology" originated in the 1980s | | | |
| 5 | The resulting molecule cannot exceed a nanometer in size | | | |
| 6 | Each country has its own nanotechnology program | | | |

**Task 2. Find in the text examples of inversion** *(Not only* **did he spill** *coffee everywhere, but he also broke my favorite vase)* **and cleft sentences (It was** *these advantages of the method* ***that*** *made it possible to achieve such outstanding results.)*

**Task 3. Choose the correct alternative.**

**1.** The ____________ *spread of the Novel Coronavirus has become one of the biggest threats to the global* economy and financial markets.
*a) going* *b) ongoing* *c) resulting*

**2.** In other words, we must get to the ____________, which in most cases are social problems.
*a) roots* *b) ideas* *c) dilemmas*

**3**. The ____________ report is expected be completed in 2020.
a) result b) summary c) resulting

**4.** Physics have stopped being the first, leading ____________ of science – it has become simple everyday work.
*a) idea* *b) advancement* *c) branch*

**5.** Google Brain is a deep learning ____________ intelligence research team at Google.
*a) artificial* *b) essential* *c) augmented*

**6.** Those studies show ____________ contrasting results.
a) in particular b) somewhat c) certain extent

### Task 4. Match the beginnings and endings of the sentences.

| | |
|---|---|
| 1. These shared **historical** | a) physics had gone from a position of quiet confidence to total chaos |
| 2. The principle entitles the **general** | b) space for the third time in a month |
| 3. The panel is to develop a common understanding of **basic** | c) molecules to behave like virus antibodies |
| 4. Within just a few years, **atomic** | d) roots provide a strong basis for regional economic integration |
| 5. During the summer program students learn real-life skills to achieve **great** | e) concepts and explore options for access and benefit-sharing |
| 6. Astronauts will brave the extreme conditions of **outer** | f) public to access official documents |
| 7. The most impressive projects are using **artificial** | g) approach to controlling and operating quantum processors |
| 8. Quantum Orchestration Platform enables an **entirely new** | h) success with the help of TED and TEDx speakers |

### Task 5. Each line has an extra word. Find and write it down on the same line.

**The future of nanotechnology: within 20 years**

**Sustainable Energy.**

| | | |
|---|---|---|
| Line 1 | In 2038, the population will exceed over 9 billion, and the sales of | …… |
| Line 2 | electric vehicles will reach over 18 million. Sustainable energy will | …… |
| Line 3 | account it for at least 80% of the world's energy and supply by 2050. | …… |
| Line 4 | The only problem is – the technology that will enable energy to be | …… |
| Line 5 | captured better isn't there yet. They don't exist naturally and have to | …… |
| Line 6 | be done designed to capture the sun more even efficiently. | …… |

**3D Printing.**

| | | |
|---|---|---|
| Line 7 | 3D printers will print out a lot of more in 2045. It's predicted that at | …… |
| Line 8 | this point, humans beings will be able to print out full and functioning | …… |
| Line 9 | organs, not just their tissue containing with protein-based engineering. | …… |
| Line 10 | They'll also be able to can print medicine and food, although, Bartmoss St. | …… |
| Line 11 | Clair, a nanotechnology enthusiast, states that advancements in a this sector | …… |
| Line 12 | could be held back or limited in due to outdated regulations. | …… |

## V.2 What does a nanotechnology engineer do?

**Task 1. Find the second part of word combinations. The first one is done for you.**

| | | |
|---|---|---|
| **1.** | mechanical → | generation |
| **2.** | research and | fathers |
| **3.** | to solve | impacts |
| **4.** | space | → engineering |
| **5.** | nanotechnology | problems |
| **6.** | discover | the gaps |
| **7.** | founding | engineering |
| **8.** | multidisciplinary | exploration |
| **9.** | to bridge | field |
| **10.** | next | development |
| **11.** | environmental | new properties |

**Task 2. Fill in the gaps using the words from the box below.**

• essentially • extend and elevate • industrially feasible • research and development • job description • lay the foundations • two and twenty • degree of education

1. Unlike mechanical engineering for example, nanotechnology is one of those engineering fields where a clear ___________________________ is hard to find because those jobs are yet to come into the market.

2. On the big picture this is an age of smart devices better communication, space exploration and an effort to ____________________ the human life experience.

3. That is somewhere between ________________________ atoms wide.

4. There are __________________ four things a nanotechnology engineer can do after graduating depending on what ___________________ is earned.

5. As an extension to ___________________________________ you can become a professor of nanotechnology at a university.

6. You will be designing tools and processes to make manufacturing nanotechnology products __________________________________.

7. Yet it is a field at a primitive stage in its development and the nano engineers of today will ___________________________________ for human advancement that will take effect far into the future.

**Watch the video and check yourself.**

***Task 3. Which of these options suits you most? Give reasons for your answer. You have to talk continuously for 1 minute.***

– research and development;
– teaching;
– business;
– nano consultant in a company.

## Revision and consolidation (Unit 1)

**Grammar revision (Present Simple vs Present Continuous)**

**Task 1. Choose the correct alternative and explain your choice.**

1. Properties *are changing/change* also according to their size and this is the magic of the technology.
2. Nanosized carriers *are increasing/increase* absorption of nutrients.
3. Nanotechnology *is being/is* a very multidisciplinary field.
4. A nanoengineer's work can be highly varied but will typically revolve around the development of nanomaterials. Examples *are including/include* carbon nanotubes, nanocomposites and quantum dots.
5. The Nanotechnology graduate student *is choosing/chooses* the field of his future research at the moment.
6. Nanoengineers *are not working/do not work* at the office all the time, sometimes they make field trips.
7. The laboratory equipment *is becoming/becomes* more and more sophisticated each year.
8. Graduates *are not always knowing/do not always know* what to do with their future career.
9. Currently this area of research with huge potential to revolutionise our lives *is rapidly expanding/rapidly expands*.
10. Nanotechnology as a science *is dealing with/deals with* extremely small things and can be used across all the other science fields.

**Vocabulary revision.**

**Task 2. Complete the collocations below, use the words from the box below.**

| |
|---|
| • *people* • *an experiment* • *a problem* • *the meetings* • *the foundation for* |

| | | | |
|---|---|---|---|
| to lay | | to solve | |
| | the books | | a mystery |
| | the ground for | | a conflict |
| to deal with | a problem | to conduct | |
| | an inquiry | | tests |
| | | | |

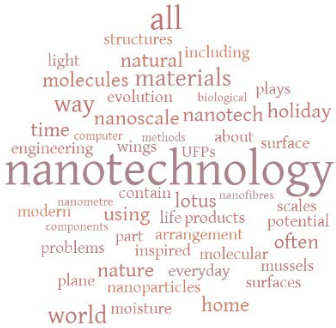
## Task 3. Match the words with their definitions.

| | |
|---|---|
| **1.** equipment /n/ | **a)** the simplest unit of a chemical substance, usually a group of two or more atoms |
| **2.** workplace /n/ | **b)** a range of different positions, opinions, etc. between two extreme points |
| **3.** career /n/ | **c)** the set of necessary tools, clothing, etc. for a particular purpose |
| **4.** research /n/ | **d)** a building or room where people perform their jobs, or these places generally |
| **5.** molecule /n/ | **e)** a detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding |
| **6.** spectrum /n/ | **f)** the job or series of jobs that you do during your working life |

## Task 4. Fill in the gaps, use dictionary if necessary.

| | | |
|---|---|---|
| 1 | It seriously **traumatized** a small random group of ………… drifting through the empty sterility of space and made them cling together in the most extraordinarily unlikely patterns | Это серьезно …………… маленькую группу *атомов*, что плавали в стерильной космической пустоте, и это привело к тому, что они стали объединяться в самые невероятные молекулы |
| 2 | **Antimatter** is identical to physical matter except that it is composed of particles whose ……… are opposite to those found in normal matter | ……… идентично обычному веществу, за исключением того, что его частицы имеют **электрические заряды**, противоположные зарядам знакомой нам материи |
| 3 | Agarose is a polysaccharide …………… seaweed used for **nanoencapsulation** of cells and the cell/agarose …………… can be modified to form **microbeads** by reducing the temperature during preparation | Агароза представляет собой полисахарид, **полученный из** морских водорослей, используемых для …………… клеток и клеток агарозной **суспензии**, которые могут быть изменены, чтобы сформировать …………… путём снижения температуры во время приготовления |
| 4 | The separately fluorescent visible molecules and **nanoparticles** are periodically formed in different object part | В разных участках объекта периодически создаются видимые раздельно флуоресцирующие молекулы и ……………… |
| 5 | The small size of nanoparticles endows them with ……………… that can be very useful in oncology, particularly in **imaging** | Малый размер наночастиц наделяет их **свойствами**, которые могут быть очень полезными в онкологии, в особенности для ………………. |
| 6 | Since ……………… would be microscopic in size, it would probably be necessary for very large numbers of them to work together to perform microscopic and **macroscopic** tasks | Так как **нанороботы** имеют микроскопические размеры, то их, вероятно, потребуется очень много для совместной работы в решении микроскопических и ……………… задач |
| 7 | Well, Bob Russell was telling us about his work on **nanotubes** in his …………… at the microscopic level | Боб Расселл рассказывал нам о своей работе над ……… в ходе **исследований** на микроскопическом уровне |

# Unit 2. – Nanotechnology in different fields




## 2.1. Nanotechnology in everyday life

*From the clothes and sunglasses you wear to computer hard drives and even cleaning products, nanotechnology – often inspired by the natural world – plays a big part in the manufacture of many familiar products.*

You're going on holiday. Off the plane and checked into your hotel, you don the wrinkle-free shirt you packed so you wouldn't have to do any ironing. Grabbing your scratch-resistant sunglasses and your sunscreen you dash to the hotel pool, not forgetting to pick up your camera phone so you can send that boastful photo home. Poolside, you relax listening to summery tunes on your MP3 player, before taking a plunge into the cool refreshing water.

As you soak up the sun, nanotechnology is probably the furthest thing from your mind. Yet throughout every step of your trip you've unknowingly encountered it. From the nanoparticles that coated the surface of your plane to reduce drag, to the way the hotel pool was cleaned, nanotechnology was there. It boosted your sunscreen's ability to reflect harmful ultraviolet radiation, rendered your shirt with that just-ironed look and armoured your designer shades against unwanted scratches. Your gadgets also used nanotechnology to store your snaps and songs on their respective hard-drives and flash memory.

Nanotechnology is an inescapable part of modern everyday life, both on holiday and at home. "There are things we've been using for a long time which contain nanosize components, like the lasers in DVD and CD players," says Milo Shaffer, head of the London Centre for Nanotechnology. Yet most of the time it goes unnoticed. "On the whole people aren't very aware of the nanotechnology all around them," Shaffer explains.

So if you stretch out an arm you'll almost certainly be able to grab something that employs nanotechnology. But you might also be breathing in nanoparticles that have been around for many years. Ultrafine particles (UFPs) are airborne nanoscale materials that originate from many sources, including traffic pollution. UFPs can deposit in your lungs with the potential to cause respiratory problems including asthma and lung disease.

Although not all nanotech is the result of human activity, evolution has had at least a 3bn-year head-start when it comes to manipulating materials on the smallest scales. "Nature is all about nanoscale structures. It starts with the cell", explains Julian Vincent, a former biologist and now professor of mechanical engineering at the University of Bath. "Biology plays around with the molecular scale all the time, it's the level at which all biological reactions occur", he adds.

Silk is a prime example of naturally occurring nanotechnology. "Silk is strong because of the way its molecules are aligned into a set of cross-links", says Vincent. Kevlar, used in everything from flak-jackets to frying pans, was constructed by engineering its constituent molecules in a similar fashion.

Mimicking nature's nanotech is becoming big business. Teams of researchers have turned to geckos and mussels in order to develop adhesives that bind to dry and wet surfaces alike. They've drawn inspiration from nanofibres in the geckos' foot hairs, which allow the lizards to cling upside down on inclined surfaces, and the nanoscale structures used by mussels to "glue" themselves to rocks despite being underwater.

Similarly, non-reflective materials have been improved by imitating the nanostructures found in the wings of cicada insects. Their wings contain small projections, spaced about 200 nanometres apart, which allow 98% of light to pass through them. Nanostructures are also responsible for the brilliant white colouring of the cyphochilus beetle. The arrangement of molecules within the beetle's scales scatter almost all incoming light. Mimicking this molecular arrangement in made-made materials would eliminate the need for potentially toxic pigments, which are often currently used to create white paint and paper.

Plants too are big exploiters of natural nanotech. Nanostructures on the surface of lotus leaves repel water which carries away dirt as it rolls off the leaf, allowing the lotus to remain spotless despite growing in muddy water. This "lotus effect" is the basis behind self-cleaning windows. But rather than shedding water, beetles in the Namib desert are using a series of alternating waxy and non-waxy nanostructures to capture precious moisture from the early morning fog. Applying the idea to buildings could allow them to trap moisture for use inside.

Whether in your office, home or while sunning yourself on holiday, it is impossible not to encounter technology based on the manipulation of the very small. Many technologies in the modern world rely on nanostructures, often inspired by evolution in the natural world. But there is much untapped potential left to explore. "The overlap between the way nature solves these problems and the way we do, using technical solutions, is only 10-20%", Vincent explains. "I'd like to see a world where we can truly utilise the tried and tested methods nature has employed", he says.

**Task 1. Say whether these statements are True, False or Not Stated.**

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1 | Nanoparticles are used to reduce air drag | | | |
| 2 | According to Shaffer, people generally know about nanotechnology around them | | | |
| 3 | UFPs are known to cause respiratory problems | | | |
| 4 | Julian Vincent is currently working on nanoscale structures | | | |
| 5 | Imitating nature's nanotech is a steady trend | | | |
| 6 | Trapping moisture will cause additional dehumidification | | | |

**Task 2. Find the missing parts of collocations from the text.**

1. ________________ solutions
2. naturally occurring _________
3. Ultrafine _________________
4. to ____________ harmful ultraviolet radiation
5. prime _________________
6. ____________ activity
7.
8. to ____________ ____________ from nanofibres
9. waxy and non-waxy __________
10. _________________ methods
11. to __________ the nanostructures
12. _________________ potential

**Task 3. Fill in the gaps using the verbs from the box below.**

| |
|---|
| • mimic • employ • occur • rely on • capture • encounter • boost |

1. This is not the first time nor the last that we _____________ this influential organization.

2. These products _____________ the internet speed of your PC, enhance the speed performance of your system.

3. Apart from information provided by you in emails and in our feedback form, this web site does not _____________ or store any personal information.

4. First was the attempt to _____________ well-established indicators.

5. Both encoders and decoders ____________ these graphs extensively.

6. The active ingredient in Cinnamon known as MHCP (methylhydroxy-chalcone polymer) has been shown to ____________ the activity of insulin.

7. Accidents frequently ____________ following this pattern.

**Task 4. Fill in the gaps with the correct articles where necessary.**

One of 1) ____ most significant potential applications of single-walled nanotubes (SWNT) is believed to be in 2) ____ domain of nanoelectronics. This is as 3) ____ result of SWNT's being highly-conductive. In fact, according to 4) ____ single-walled nanotube ropes are 5) ____ most conductive carbon fibers known. Alternative configurations of 6) ____ carbon nanotube can result in the resultant material being semi-conductive like silicon. 7) ____ conductivity in 8)____ nanotubes is based on 9) ____ degree of chirality – i.e. 10) ____ degree of twist and size of 11) ____ diameter of 12) ____ actual nanotube - which results in 13) ____ nanotube that is actually extremely conductive (making it suitable as 14) ____ interconnect on 15) ____ integrated circuit) or non-conductive (making it suitable as 16) ____ basis for semi-conductors).

## 2.2. The Basics of Molecular Nanotechnology

MNT or molecular nanotechnology is a manufacturing technology that is currently being researched and is said to be something that will allow the precise control and assembly of building blocks that are molecule sized – and this is done with the help of manipulator arms that come in nano-scale sizes. While nanotechnology in general is considered a term that is used to describe the technological and scientific projects that revolve around the different properties and phenomena that are at the nanometer scale, *molecular nanotechnology* is considered a distinct science apart from this general term.

**Bottom-Up Manufacturing.**

The idea for molecular nanotechnology first took shape in the hands of Richard Feynman who was a Nobel-Prize-winning physicist. He first talked about this in 1959 and discussed the possibility of regular-sized robot arms building one-tenth-sized replicas of themselves. These smaller replicas will then repeat the process of building smaller copies of themselves until the replicas that were being produced were of a molecular scale. He further expounded on the use of these miniscule manufacturing arms in what was to be called a *bottom-up manufacturing method* where things are built from the ground up.

**Continuing Development and Research.**

While the idea had its merits, it was not until the 1980s when an MIT engineer named K. Eric Drexler took the concept up again and wrote a book about it, outlining the possibilities of molecular nanotechnology. He stated that since this will enable people to manufacture products from the molecular base upwards and with molecular precision, a whole lot of chemically possible structures could actually be created with this method. The process is called molecular manufacturing, and the idea that each molecule of the substance being created is put in its specific place with utmost precision means that the end-result can be products that are efficiently and very cleanly put together.

**From Concept to Realization.**

This idea called molecular nanotechnology is still in its research stage with scientists trying to find ways to make the creation of products from the ground up a reality. This concept is seen as something that can benefit the human race in many ways and these include the creation of what is called smart materials, materials that are made to react differently to the different molecules they encounter. These can be seen applied to such fields like medicine and is seen to be ideal for such ideas like self-healing products.

**Other Possible Applications**

Other possibilities that seem to be considered ideal with the use of molecular nanotechnology include the creation of medical nanorobots and replicating nanorobots. The reason why these nanorobots are appealing to a lot of researchers is the fact that these miniscule robots that can be tasked to help with medical problems can help prevent diseases by helping keep certain parts of your body free of the disease-carrying factors that you have in your body. An example of what these medical nanorobots could do is the concept of their being able to repair tissues and cells when they get damaged. These are also viewed as possible "repairmen" that can help repair physical injuries from the inside out.

**Task 1. Read the text and choose the correct alternative.**

*1. Terms "nanotechnology" and "molecular nanotechnology".*
a) are used interchangeably;
b) represent the same field of science;
c) describes different but related fields of science.

*2. A bottom-up manufacturing method means that*
a) larger nanostructures are made from smaller building blocks;
b) nano-scale objects are made by processing larger objects;
c) building blocks at the beginning are smaller than the resulting ones.

*3. The idea for molecular nanotechnology was shaped by*
a) Eric Drexler;
b) Richard Feynman;
c) Julian Vincent.

*4. Molecular nanotechnology*
a) is long gone now;
b) is still under research;
c) is now a reality.

*5. Smart materials are materials that*
a) have one or more properties that cannot be changed;
b) have more than one property and different molecular structures;
c) can react in a different way depending on the type of molecules they encounter.

*6.Medical nanorobots could*
a) repair tissues and cells;
b) repair physical injuries;
c) both a) and b).

**Task 2. Cross the odd one out and explain your choice.**

1. phenomenon, physical process, success, event;
2. source, replica, copy, reproduction;
3. study, investigation, research, implementation
4. tiny, enormous, miniscule, small;
5. virtue, merit, fault, dignity;
6. idea, reality, concept, notion.

**Task 3. Fill in the table below.**

| Noun | Adjective | Adverb | Verb |
|---|---|---|---|
| | | phenomenally | — |
| | replicative / repli-cable | — | |
| | | — | research |
| minuscule | | — | — |
| merit | | — | |
| | | conceptually | |

**Task 4. Fill in the gaps using adverbs from the box below.**

| • radically (x3) • extremely • especially (x2) • remarkably |
|---|

Molecular nanotechnology describes engineered nanosystems (nanoscale machines) operating on the molecular scale. It is _________ associated with the molecular assembler, a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis – mechanically guided chemical synthesis – is fundamental to molecular manufacturing. It is a branch of engineering that deals with the design and manufacture of _________ small devices, that is, nanosystems or devices, built at the molecular level of matter.

The projected applications of Molecular Nanotechnology include: Smart materials and Nanosensors (material engineered and designed at nanometer scale for a specific task), Replicating nanorobots, Medical nanorobots and Phased-array optics. Nanotechnology will replace our entire manufacturing base with a new, _________ more precise, _________ less expensive, and _________ more flexible way of making products.

The potential social impacts of Molecular Nanotechnology include: The maintenance of historical trends in manufacturing right up to the fundamental limits imposed by physical law, producing _________ powerful molecular computers. Although have potential benefits, the technology concerns risks, having daunting risks, _________ some analysts believe that this technology could lead to a Technological Singularity. The other risk highlights Self-replicating machines. Molecular nanotechnology might permit weapons of mass destruction that could self-replicate.

## V.3. Tutorial / Nanoparticle Characterization

**Task 1. Have a look at some abbreviations and phrases mentioned in the video. Have you heard about them before? Can you explain how these techniques work or are used?**

− QC – Quality control;
− TEM – Transmission Electron Microscopy;
− UV-Vis – UV-Visible spectroscopy;
− DLS – Dynamic Light Scattering;
− ICP-MS – Inductively coupled plasma mass spectrometry;
− CCD – Charge-Coupled Device;
− in vivo – in the living body of a plant, animal, or human.

**Task 2. Watch the video. For questions 1–8, complete the sentences with a word or short phrase.**

1. Today, I'm going to be giving a ____________________ overview of the instruments that we use to characterize our nanomaterials.
2. TEM is a technique that is used to image materials that are smaller than ___________ and thus cannot be seen on a conventional optical microscope.
3. UV-Vis is a critical characteristic of all our products, _________________ the extremely bright noble metal plasmonic particles.
4. If there's endotoxin present, a series of clotting reactions will ____________________ that causes the sample to become turbid.
5. ICP-MS is the most ____________________ we have to identify and measure the concentration of metals.
6. ICP-MS measurements are ____________________ in determining the concentration of our products.
7. The Brownian ___________________ of the particles creates a pattern of light at the detector that fluctuates at a rate that is a function of their size.
8. Particles migrate towards the electrode of ____________________ charge at a rate that is proportional to their zeta potential.

**Task 3. Find the second part of word combinations from the video.**

| | |
|---|---|
| **1.** certificate of | **a)** contamination |
| **2.** core | **b)** content |
| **3.** broad-spectrum | **c)** size |
| **4.** electron | **d)** part |
| **5.** particle's | **e)** colloids |
| **6.** particle | **f)** stream |
| **7.** endotoxin | **g)** beam |
| **8.** blood | **h)** analysis |
| **9.** bacterial | **i)** concentration |
| **10.** the stability of | **j)** light sources |

## 2.3. The Basics of Medical Nanotechnology

Man has gone so far in terms of coming up with ways to preserve human life. Although there are still diseases that remain an enigma to medical science, still, treating illnesses from simple to severe conditions has become a lot easier. Among the most notable medical triumphs of modern-day science is the evolutionary concept and application of medical nanotechnology.

Medical nanotechnology or *nanomedicine* is the medical aspect or application of nanotechnology using different approaches such as nanoelectronic biosensors, nanomaterials, and a very futuristic but underdeveloped molecular nanotechnology that includes molecular manufacturing. Medical nanotechnology aims to provide cheaper yet quality health and medical equipment, facilities, and treatment strategies through continuous research and studies. A lot of pharmaceutical and medical companies all over the world have already adhered to medical nanotechnology because of its numerous benefits and practical uses.

**What Are the Benefits of Medical Nanotechnology?**

Although some are still skeptical about the technology, scientists and researchers over continents have been practicing medicine using nanotechnology due to its numerous benefits. Some of these benefits to the medical field include the following:

With nanotechnology, tools and equipment for surgery and diagnostic would be a lot cheaper yet remain to be effective and state of the art. Medical research and processes require highly advanced equipment that could be very expensive but once the equipment is fully developed, its manufacturing would be a lot easier and faster with the use of nanotechnology. The creation of complex tools that can diagnose serious diseases with a single laboratory test would minimize diagnostic costs and treatment. Using tiny nano-built sensors inserted to the human body for direct contact with the source of ailment would definitely make medical treatments easier and cheaper.

With medical nanotechnology, treatment would be more efficient and precise. Instead of opening the whole body area for surgical purposes, a microscopic nanotool would spare the patient from bloody and risky surgical process. With nanotechnology in the medical field, treatment would be precise, eliminating trial-and-error drug prescription. With a single laboratory test and highly technical computers, a detailed image of the body's system and processes can be automatically spotted including the cause of the disease and its possible treatment. With nanotechnology in the fields of medicine, medical malpractice would be eliminated and the side effects of taking medicines out of sheer guessing from the physicians would be avoided.

With highly advanced medical equipment, potential diseases can easily be detected and prevented.

Since diseases can be prevented, the quality of life for mankind would be improved and lifespan would be increased.

With the application of nanotechnology in medicine, replacement of body organs using machines smaller than body cells can be possible. Because of advanced nanotechnology, candidates for organ replacement and augmentation will receive far better body organs enhanced by tiny machines introduced to the body for better organ performance and functions.

Medical nanotechnology can largely contribute to genetic therapy and improvement. Diseases can be easily treated if approached at the genetic level. So instead of treating diseases based on the symptoms, nanotechnology will help medical practitioners treat the problem by looking at the root cause.

**Task 1. Answer the questions about the text below.**

1. What is another name for medical nanotechnology?
2. What is the objective of medical nanotechnology?
3. What is necessary for medical research and processes?
4. How would medical nanotechnology affect treatment?
5. What enables replacement of body organs?
6. What should be done so that diseases can be easily treated?

**Task 2. Fill in the gaps using the verbs from the box below.**

| • spare • spot • preserve • contribute • adhere • prevent |
|---|

1. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and ______________ this capacity.

2. The differing abilities of substances to ____________ to the surfaces of various solids such as paper and starch can also be used to separate mixtures.

3. I want to ______________ you from the bloodletting about to hit Langley.

4. This helped ______________ hackers from cracking the game until two months after release.

5. We believe that this will _____________ to regional peace and stability.

6. One has to have the capacity to ______________ talent early and subsequently provide the resources and facilities that young people need to reach their potential.

**Task 3. Find the second part of word combinations from the text.**

| | |
|---|---|
| 1. severe | research |
| 2. continuous | guessing |
| 3. practical | costs |
| 4. serious | prescription |
| 5. to minimize | use |
| 6. source of | conditions |
| 7. drug | effects |
| 8. side | cause |
| 9. sheer | ailment |
| 10. root | diseases |

**Task 4. Read the text below. Use the word given in capital letters at the end of some of the lines to form a word that fits in the gap in the same line.**

| | |
|---|---|
| **Nanotechnology in Medicine Application: 1)** ………… **Techniques** | DIAGNOSE |
| Researchers at Worcester Polytechnic Institute are using antibodies **2)** ………… to carbon nanotubes in chips to detect | ATTACH |
| cancer cells in the bloodstream. The researchers believe this method could be used in simple lab tests that could provide early **3)** ………… of cancer cells in the bloodstream. | DETECT |
| A test for early detection of kidney damage is **4)** ………… . The | DEVELOP |
| method uses gold nanorods functionalized to attach to the type of protein generated by **5)** ………… kidneys. When protein | DAMAGE |
| accumulates on the nanorod the color of the nanorod shifts. The test is designed to be done quickly and **6)** ………… for early detection of a problem. | EXPENSE |

## 2.4. Applications of Nanotechnology in Perfumes: Thrills and Threats of Smelling Nano

**Nanotechnology** has entered the production and application of various personal care and cosmetics products, such as sunscreens, anti-aging creams, toothpastes, hair care and perfumes.

Due to blurred definition of applied nanotechnology in terms of production procedures and ingredients, as well as due to loose regulatory and safety control systems, is the current scope and scale of nano-based personal care and cosmetics products only a wild guess.

However, one such estimation shows there is currently around 1000 personal care and cosmetics products on the global market that are nano-based.

While nanotechnology is widely applied and marketed in certain groups of cosmetic products such as sunscreens, anti-aging skin care and hair care products, much less is known about **nanotechnology in perfumes**; their production and application.

**Applications of Nanotechnology in Perfumes.**

Currently known applications of nanotechnology in perfume production and application are predominantly based on nano-encapsulation methods (coating of nanoparticles with different substances).

**1.** Production of perfume (aroma) compounds. Application of nanotechnology enables reduction of costs of perfume compounds manufacture, while at the same time making it possible to produce purer and completely natural perfume compounds.

This can be achieved by using nanoparticles such as gold-palladium that can replace expensive and potentially toxic reagents that promote oxidation of aromatic primary alcohols to aldehydes, which is one of the crucial processes in the perfume production.

Another nano-encapsulation procedure proposes the use of nanoparticles coated in natural enzymes in the process of manufacturing expensive perfume compounds. There are no unwanted or harmful residuals.

Further, the acquired scent compounds are of higher purity and can be labeled as completely natural since they are derived from reaction catalyzed by enzymes from natural organisms. This procedure could replace expensive extraction of perfume compounds from natural materials or their expensive purely chemical synthesis.

**2.** Time-controlled and prolonged release of scents. Nano-encapsulation (nano-delivery systems) can also help improve the attributes and performance (durability, stability) of substances such as fragrances that can be negatively affected by changed conditions of the environment (light, air). Application of nano-encapsulation in fragrance products enables more efficient (prolonged) and time-controlled release of the scents.

This can be used in the manufacture of more durable fragrance samples used for marketing purposes, in textile and accessories fashion (e.g., embedding perfume into textiles, shoes, jewelry) and other materials (e.g., ceramics, baby dippers). Release of scents can be time-controlled by stimuli such as diffusion, pressure or temperature sensitivity.

**3.** Use of nano-encapsulation procedures in development of ‘nanotechnology electronic noses’ (replication of human olfactory sense) promises detection and absorption of variety of odors, which could be used in detection and absorption of unwanted or hazardous odors (e.g., carbon monoxide).

Further, this could facilitate electronic sampling and testing of fragrance products, thus reducing the costs of fragrance and fragrance products development, and it could even enable development of artificial noses for people who lost the sense of smell.

Recently, one type of electronic appliances in this direction, nano perfume ejectors, has been put on market. They are designed to mix nanoparticles with perfume and / or water particles and enable sterilization of air, absorption of unpleasant and release of pleasant odors.

Considering the wide range of places where it could be used (e.g., homes, hospitals, public places) this type of nano-appliances undoubtedly has a bright commercial future.

**Task 1. Read the text and choose the correct alternative.**

**1.** The scope of nano-based personal care and cosmetics products is uncertain because

a) the definition of applied nanotechnology is vague;
b) the regulatory and safety control systems are not restricting;
c) both a) and b).

**2.** Applications of nanotechnology in perfumes are

a) numerous;
b) relatively scant;
c) evaluated incorrectly.

**3.** One of the critical processes in the perfume manufacturing is

a) oxidation of aromatic primary alcohols;
b) nano-encapsulation;
c) using gold-palladium nanoparticles.

**4.** The acquired scent compounds can be named completely natural since

a) their properties resemble natural compounds;
b) they cause no harm to nature;
c) they are caused or accelerated by substances from natural organisms.

**5.** One of the stimuli controlling the time of release of scents is

a) humidity;
b) pressure;
c) neither a) nor b).

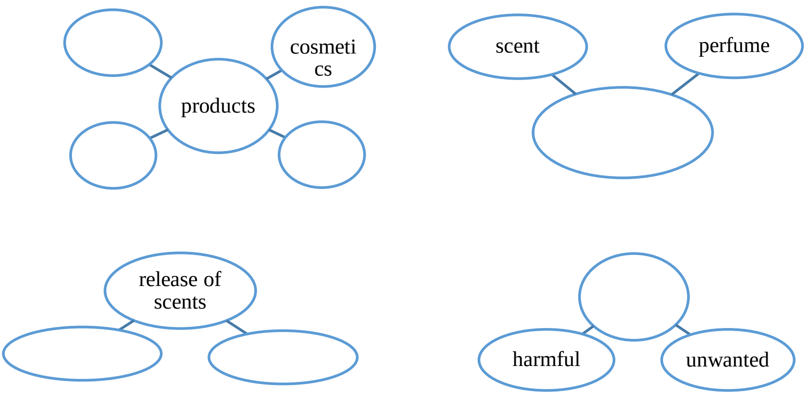
**6.** The device used to combine nanoparticles with perfume and / or water particles is called

a) nano perfume ejector;
b) electronic noses;
c) nano-delivery systems.

**Task 2. Match the words with their definitions.**

| | |
|---|---|
| 1. scope /n/ | a) a layer or film spread over a surface for protection or decoration |
| 2. coating /n/ | b) a pleasant natural smell |
| 3. compound /n/ | c) that characteristic of a substance which makes it perceptible to the sense of smell; a smell, whether pleasant or unpleasant; fragrance, stench, etc |
| 4. oxidation /n/ | d) the range or extent of action, inquiry, etc., or of an activity, concept, etc |
| 5. enzyme /n/ | e) (of a gas or liquid) the process of spreading through or into a surrounding substance by mixing with it.\ |
| 6. scent /n/ | f) what is left at the end of a process; something remaining |
| 7. residuals /n/ | g) a substance that consists of two or more elements. |
| 8. diffusion /n/ | h) a process in which a chemical substance changes because of the addition of oxygen |
| 9. odor /n/ | i) a chemical substance found in living creatures that produces changes in other substances without being changed itself |

**Task 3. Find the words in the text to complete the word bubbles.**




Task 4. Find information about Potential Risks of Nano-based Perfumes.

**Task 5. Put the verbs into the correct form.**

**Why Does The Cosmetics Industry Use Nanoparticles?**

The processes ……………… *(to become)* so cheap that major cosmetic companies including L 'Oreal, Avon, Lancome, The Body Shop, and Revlon all use nanoparticles when …………… *(to make)* their products. It's all about profit, and while various scientific studies …………… *(to show)* that nanoparticles may be dangerous when ……………… *(to use)* in cosmetics, the industry still …………… *(not listen)*. Why? Because most are only interested in …………… *(to push)* production costs as low as possible, while ……………… *(to benefit)* from a "new technology" which their marketing departments can advertise as "revolutionary", encouraging people to buy without ……………… *(to realize)* the danger they are putting themselves in.

The problem is that more testing needs ……………… *(to do)* to understand the long-term effects of nanoparticles in cosmetics when ……………… *(to apply)* to the skin, and right now we only have a few studies. What's worse, those studies specifically point out how detrimental to a person's health nanotechnology seems ……………… *(to be)*.

## V.4. Nanotechnology: Hacking Humans, Its Potential, and Real Risks

**Task 1. Match the words with their definitions.**

| | |
|---|---|
| **1.** Futuristic /adj/ | **a)** the quality of being able to be easily hurt, influenced, or attacked, or something that is vulnerable |
| **2.** Chemotherapy /n/ | **b)** a hacker who violates computer security for little reason beyond maliciousness or for personal gain |
| **3.** Vulnerability /n/ | **c)** strange and very modern, or intended or seeming to come from some imagined time in the future |
| **4.** Penetration testing /noun phrase/ | **d)** is the concept of connecting any device (so long as it has an on/off switch) to the Internet and to other connected devices |
| **5.** Black hat hacker /noun phrase/ | **e)** is an authorized simulated cyberattack on a computer system, performed to evaluate the security of the system |

| | |
|---|---|
| **6.** White hat hacker /noun phrase/ | **f)** the treatment of diseases using chemicals |
| **7.** Internet of Things /noun phrase/ | **g)** computer security expert, who specializes in penetration testing and in other testing methodologies that ensures the security of an organization's information systems |

**Task 2. Find the second part of word combinations from the video. The first one is done for you.**

| | |
|---|---|
| 1. to mitigate | vulnerabilities |
| 2. cyber | field |
| 3. carbon | the risk |
| 4. experimental | tool |
| 5. treatment | the risks |
| 6. diagnostic | time |
| 7. fatal | nanotubes |
| 8. to lessen | plan |
| 9. to find | threat |
| 10. matter of | phase |
| 11. cutting-edge | consequences |

**Task 3. Watch the video and choose the correct alternative.**

**1.** The level of technology enabled scientists to work at a nanoscale
a) in the late 1950s;
b) in the late 1980s;
c) in the late 1960s.

**2**. Developments in medical field bring about
a) risk of infection;
b) risk of hacking;
c) risk of accidents at work.

**3.** The vulnerability of nanotechnology in medicine is
a) low efficiency;
b) limited access;
c) security.

**4.** The term ‘bio hacking’ actually refers to
a) do-it-yourself biology;
b) hacking medical technology;
c) both a) and b).

**5**. Which term refers to any new advance in biological technology?
a) Nanomedical hacking;

b) Internet of Things;
c) Neo-biology.
**6.** One of the best ways to find vulnerabilities in medical devices is
a) black hat hacking;
b) penetration testing;
c) error modelling.

## 2.5. Use Of Nanotechnology In Lighting

The way we see, feel, and touch things is about to change. In fact, the change has already begun and though it hasn't touched our lives in any significant manner yet the day when that happens is around the corner.

From self-cleaning windows to super energy efficient lighting, nanotechnology is revolutionizing the way we live.

Lighting has been an important aspect of our lives, of our existence.

Due to the awareness that the world is fast running out of fossil fuels and other natural sources of energy, the need for finding green and efficient lighting sources has become even more important.

CFL and LED or light emitting diodes lights are just two of the most common examples of green lighting sources.

However, as technology improves, and newer grounds are covered in science, the use of nanotechnology to further increase the efficiency of LED lighting has started looking more realistic.

**LED Lighting.**

LEDs were first discovered in the 1920s. They are semi-conductors that have the capability to change electricity into light. Once the light switch is turned on, electrons journey through an area with larger numbers to an area with lesser numbers, and release small pools of energy or photons (which is the lowest form of light).

The best part about LED lights is that they don't release any heat unlike traditional tungsten bulbs.

So also, LED lighting uses only a small percentage of energy as required by regular bulbs and they don't contain any toxic metals like mercury that are used in CFL (compact fluorescent light) bulbs. All this makes LED lights efficient, durable, and longer lasting.

**LED Lighting Colors.**

You've probably seen LED lighting in colors like blue, green, yellow, and white. The color of the LED lights is dependent on the type of semiconductors used. Red colored LEDs were the first on the scene, followed by orange.

After many years, the most commonly used, blue LED lights used in mobiles, laptops, CD players, and other electronic appliances, were developed. However, the most important of all LED lights are the white LEDs.

There is no such thing as a true white LED. The white LED used is actually blue LED filtered through a coating of yellow phosphorus that emits faux-white light that has a perceptible bluish hue.

Experts believe that if white LEDs are paired with green LEDs, we should be able to get lighting in almost every visible color.

– If a high performing green LED light can be developed, it would pave the way for high performing, energy efficient electronic devices like LED TVs, Computer monitors, and many others;

– Unfortunately, green LEDs are a lot more difficult to develop than perceived. Ongoing studies in the US are aiming to create LEDs in green color, which would be at par with red/blue LEDs.

**Nanotech LED Lighting.**

1. As explained above, passing electrons through nano semiconductors, also known as ‘quantum dots,’ emit light which has many applications in fields like biology, computers, medicine, solar heating, and lighting.

2. Perhaps, that is why there is a huge focus on related R&D and scientists are researching the use of different nanotechnologies to create more energy efficient LEDs.

3. Companies like Nanosys are using semiconductors of remote phosphorous to develop LEDs that turn blue light into a warmer shade of white that is similar to the currently used traditional white of fluorescent bulbs. The phosphorous used in this experiment is created from ‘nano-materials.’

4. Since human eyes are hyper-sensitive to the color green, the LEDs have an increased level of green to give us a false sense of brightness, without actually heightening the brightness level of the display.

5. This helps create an excellent picture quality, but by using only very little energy, making it the primary method to be employed in devices that have display panels.

6. This is promising news for those following the use of nanotechnology in various fields. With this attempt by Nanosys, the company believes it will be able to design LEDs in just about any color, which is going to be a huge leap forward from the currently used LED displays as well as in other electronic devices that emit stronger hues.

7. While the company has created many experimental LED bulbs, these LED quantum dots will firstly be used for TV and laptop displays to offer

consumer a wider range of colors. However, a larger range of colors may lead to poor battery life, especially in case of laptops etc.

8. The day when nanocrystals can be 'painted' on flat surfaces to create paper-thin displays are not far!

9. Furthermore, not too far from now, we'll be able to use LED to paint walls in colors of our choice, rather than actual paint. Yes, truly with use nanotech, life is only going to be more exciting and, dare we say, vibrantly colorful!

**Task 1. Answer the questions about the text below.**

1. Why is it crucial to find green and efficient lighting sources?
2. What are the most common examples of green lighting sources?
3. What is the main advantage of LED lights?
4. Where are blue LED lights used?
5. Why was it possible for the LEDs to give us a false sense of brightness?
6. What is the possible outcome of a larger range of colors?
7. What does LED stand for?
8. What does CFL stand for?

**Task 2. Match the beginnings and endings of the sentences.**

| | |
|---|---|
| 1. There is no way that the Government can protect the natural forests unless alternative **sources of** | **a)** color shifts and possible damage to your TV |
| 2. Loudspeaker components influence the magnetic field in the TV, resulting in **visible** | **b)** with a private actor for the purpose of allocation of loss |
| 3. In fact, reducing the risks of proliferation could **pave** | **c)** method for the international community to review the incident |
| 4. State should be treated **at par** | **d)** sense of complete freedom, power, and anonymity |
| 5. We continue to regard that panel as the **primary** | **e)** energy are available at affordable rates |
| 6. To most of Web surfers, the Internet provides a **false** | **f)** the way for more widespread use of peaceful nuclear applications |

**Task 3. Each sentence has a vocabulary mistake. Swap italicized words so that sentences make sense.**

| | |
|---|---|
| ……………. | In the space industry, there is always a deadline or unforeseen problem promising. |
| ……………. | Plug in display and test a huge leap forward the for pixels, colour, contrast and brightness. |
| ……………. | Nonetheless, a number of battery life approaches are emerging. |

| | |
|---|---|
| ................ | It is a small moment in the film, but it is dare say for the film industry. |
| ................ | Picture quality can be easily extended with the use of an external battery. |
| .................. | I around the corner, Scylla and Charybdis could not have torn us asunder. |

**Task 4. Fill in the gaps using word combinations from the box below**

| |
|---|
| • hence • most recently • at nanoscale • in terms of • due to (x3) • like • particularly • as the name indicates |

___________ continuous miniaturization of electronic devices nanotechnology is a ray of hope for semiconductor industries ___________ peculiar properties of nano-materials that changes significantly the efficiency of the devices. Research in nanoscale materials get started because of the unique properties that are obtain at this scale, by changing the shape or size of these materials. ___________, the behavior of materials drastically get changed and ___________ their properties. ___________ in semiconductors, it results ___________ the motion of electron to a length scale that is equal or smaller to the length scale of the electron Bohr radius that is generally a few nanometers. Continuous efforts are being made to explore the new physical properties of materials and to engineer them to fit for various technological applications. Scientific community has paid much attention to study various aspects of variety of nanostructured materials ___________: fullerenes, nanotubes (NT), nanoribbons (NR), nanowires (NW) and ___________, the nanocrystals (NCs). ___________, NCs are the structures exhibiting crystalline structure but with one, two or all the three dimensions within the range of 1-100 nm. NCs enjoys advancement of crystalline periodicity at nano regime ($10^{-9}$ m) and often possesses new properties, most of the time reverse from those of the equivalent bulk materials ___________ their large surface to volume ratio, quantum size effect, and confinement effects.

## Revision and consolidation (Unit 2)

**Grammar revision (Past Simple vs Present Perfect/Present Perfect Continuous).**

**Task 1. Choose the correct alternative and explain your choice.**

1. They *have tested/tested* all the samples in the laboratory so far.
2. Governments of different countries *have already started/already started* Nanoscience and Nanotechnology initiatives and various funding agencies like the Department of Science and Technology.
3. The laboratory *has been renovated/was renovated* two years ago and since then *has become/became* well-known.
4. We *have been doing/have done* this test since morning but *haven't received/didn't receive* even two more or less equal results.
5. Much new information *has been accumulated/was accumulated* on nanomaterials and nanosize components in the past few decades.
6. We first *have observed/observed* this effect in 2019 and we *have been studying/have studied* it since then.
7. I have lately been busy writing my doctoral theses. I *have completed/completed* it this year.
8. *Have you ever tried/Did you ever try* to combine optical, thermal and mechanical properties in the same test?
9. The Graduate Student *has joined/joined* the National Physical Laboratory last year.
10. When being enrolled into the University the Student *has opted/opted* for multidisciplinary natural science course with physics, chemistry, mathematics and molecular biology.

**Vocabulary revision.**

**Task 2. Fill in the gaps using the words from the box below.**

| |
|---|
| • monitor • core • concentration • sensor • consequences • electron • endeavor • light • nanotubes • applications |

1. Nanotechnology is any technological _____________ that deals with anything with the dimension of fewer than 100 nanometers.
2. Everything is a _____________ part of our QC process and is why we pride ourselves on highly characterized nanomaterials.
3. Nanotechnology has several _____________ including food, technology, fuels, batteries, environmental causes, chemical sensors, and even sporting goods.

4. In a TEM, one side has an ______________ beam, and the other side has a detector, in this case a CCD camera.

5. Build a new muscle with carbon ______________ is one such possibility.

6. It's a quick way to verify changes in surface chemistry, and to ______________ the stability of colloids.

7. Some ideas include a tiny device that gets injected into the body as a ______________ or medical delivery device.

8. The rate of movement is calculated by the fluctuations in scattered light as the particles pass through a 632-nm ______________ source.

9. The hacker took over your inner nanotechnology devices they could demand a ransom with fatal _____________ .

10. This, in turn, aids in the calculation of particle _____________ and surface area.

**Task 3. Choose the correct alternative.**

The Carbon nanotubes (CNT) are tubular structures made of carbon atoms, having diameter of nanometer order but length in micrometers.

Right from its *discovering/discovery/discover*, Qian D. et al. (2002) shows exciting quotations about CNT, viz.

– «CNT is 100 times *as strong as/strongest/stronger* than stainless steel and six times lighter...».

– «CNT is as hard as diamond and its *thermic/thermal/thermally* capacity is twice that of pure diamond...».

– «CNT's current-carrying *capable/capability/capacity* is 1000 times higher than that of copper...»

– «CNT is thermally stable *up/beyond/over* to 4000K ...»

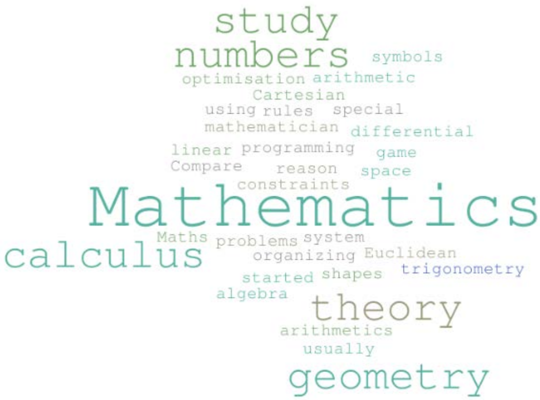
– 2CNT can be *metalware/metallic/metal* or semiconducting, *dependable/depends/depending* on their diameter and chirality...».

However, it is important to note that all those superlative properties were predicted for an atomically-perfect ideal CNT which is far from the CNTs we are *practically/practical/practice* producing today.

## Task 4. Fill in the gaps, use dictionary if necessary.

| | | |
|---|---|---|
| 1 | Scientists …………… a transistor to the size of a single atom bringing closer the day of microscopic electronic devices that will **revolutionise** computing, engineering and medicine | Учёные **уменьшили** размеры транзистора до одного атома, приблизив эру микроскопических электронных устройств, которые ………… в информационных технологиях, инженерии и медицине. |
| 2 | …………… at Cornell University, New York, and Harvard University, Boston, **fashioned** the two "nano-transistors" from purpose-made molecules | **Исследователи** из Корнельского университета (Нью-Йорк) и Гарвардского университета (Бостон) …………… два «нано-транзистора» из специально подготовленных молекул. |
| 3 | When voltage **was applied**, electrons flowed through a single atom in each molecule | Когда …………… напряжение, электроны передавались посредством одного атома каждой молекуле |
| 4 | The ability to use individual atoms as components of **electronic circuits** marks a key …………… in nanotechnology, the creation of machines at the smallest possible size | Возможность использования отдельных атомов в качестве компонентов …………… знаменует ключевой **прорыв** в области нанотехнологий – создание устройств минимального размера |
| 5 | Prof Paul McEuen, a physicist at Cornell, who reports the breakthrough, said the …………… transistor did not have all the functions of a **conventional** transistor such as the ability to ……………. | Профессор Пол Макуин, физик из Корнелла, который рассказал о прорыве в современных исследованиях, сообщил, что транзистор **из одного атома** не обладает функциями …………… транзистора, например, способностью **к усилению** |
| 6 | But it had potential use ……………. a **chemical sensor** to any change in its environment | Однако он имеет потенциал использования **в качестве** …………, реагирующего на любые изменения в окружающей среде |

# Unit 3. – Mathematics basics




## 3.1. Metric Unit Prefixes

Metric or SI (Le Système International d'Unités) units are based on units of ten. Very large or very small numbers are easier to work with when you can replace any scientific notation with a name or word. The metric unit prefixes are short words that indicate a multiple or fraction of a unit. The prefixes are the same no matter what the unit is, so decimeter means 1/10th of a meter and deciliter means 1/10th of a liter, while kilogram means 1000 grams and kilometer means 1000 meters.

Decimal-based prefixes have been used in all forms of the metric system, dating back to the 1790s. The prefixes used today have been standardized from 1960 to 1991 by the International Bureau of Weights and Measures for use in the metric system and the International System of Units (SI).

**Examples Using Metric Prefixes.**

1. The distance from City A to City B is 8.0 x $10^3$ meters. From the table, $10^3$ can be replaced with the prefix 'kilo'. Now the distance could be stated as 8.0 kilometers or shortened further to 8.0 km.

2. The distance from Earth to the Sun is approximately 150,000,000,000 meters. You could write this as 150 x $10^9$ m, 150 gigameters or 150 Gm.

3. The width of human hair runs on the order of 0.000005 meters. Rewrite this as 50 x $10^{-6}$ m, 50 micrometers, or 50 µm.

**Metric Prefixes Chart.**

| Prefix | Symbol | x from $10^x$ | Full Form |
|---|---|---|---|
| yotta | Y | 24 | 1,000,000,000,000,000,000,000,000 |
| zetta | Z | 21 | 1,000,000,000,000,000,000,000 |
| exa | E | 18 | 1,000,000,000,000,000,000 |
| peta | P | 15 | 1,000,000,000,000,000 |
| tera | T | 12 | 1,000,000,000,000 |
| giga | G | 9 | 1,000,000,000 |
| mega | M | 6 | 1,000,000 |
| kilo | k | 3 | 1,000 |
| hecto | h | 2 | 100 |
| deca | da | 1 | 10 |
| base | | 0 | 1 |
| deci | d | -1 | 0.1 |
| centi | c | -2 | 0.01 |
| milli | m | -3 | 0.001 |
| micro | µ | -6 | 0.000001 |
| nano | n | -9 | 0.000000001 |
| pico | p | -12 | 0.000000000001 |
| femto | f | -15 | 0.000000000000001 |
| atto | a | -18 | 0.000000000000000001 |
| zepto | z | -21 | 0.000000000000000000001 |
| yocto | y | -24 | 0.000000000000000000000001 |

**Interesting Metric Prefix Trivia.**

Not all of the metric prefixes that were proposed were adopted. For example, myria- or myrio- ($10^4$) and the binary prefixes double- (factor of 2) and demi- (one-half) were originally used in France in 1795, but were dropped in 1960 because they were not symmetrical or decimal.

The prefix hella- was proposed in 2010 by UC Davis student Austin Sendek for one octillion ($10^{27}$). Despite receiving significant support, the Consultative Committee for Units rejected the proposal. Some websites did, however, adopt the prefix, notably Wolfram Alpha and Google Calculator.

Because the prefixes are based on units of ten, you don't have to use a calculator to perform conversions between different units. All you need to do is move the decimal point to the left or right or add/subtract exponents of 10 in scientific notation.

For example, if you want to convert millimeters to meters, you can move the decimal point three places to the left: 300 millimeters = 0.3 meters

If you have trouble trying to decide which direction to move a decimal point, use common sense. Millimeters are small units, while a meter is large (like a meter stick), so there should be lots of millimeters in a meter.

Converting from a large unit to a smaller unit works the same way. For example, converting kilograms to centigrams, you move the decimal point 5 places to the right (3 to get to the base unit and then 2 more): 0.040 kg = 400 cg.

***Task 1. Answer the questions about the text.***

1. What are the metric unit prefixes?
2. What organization was responsible for standardizing the prefixes we use today?
3. How far is the Sun from the Earth? What are the ways this distance can be written?
4. What proposed prefixes were rejected eventually?
5. What do you need to do when performing conversions between different units?

**Task 2. Fill in the gaps using the words from the box below.**

| • scientific notation • subtract • fraction • add • multiple • exponent |
|---|

1. They fuse to make a food vacuole which then fuses with a lysosome to _______________ digestive chemicals. (+)
2. To convert a stellar or galactic absolute magnitude into a planetary one, _______________ 31.57. (-)
3. In mathematical terms, the _______________ for the radix (base) of ten increases by one (to the left) or decreases by one (to the right).
4. For example, the revolution period of Jupiter 's moon Io is 152853.5047 seconds, a value that would be represented in standard-form _______________________ as 1.528535047 seconds.
5. If F is algebraically closed and p(x) is an irreducible polynomial of F[x], then it has some root a and therefore p(x) is a _______________ of x − a.
6. Alkarb contained 21 % rubidium while the rest was potassium and a small _______________ of caesium.

**Task 3. Fill in the table.**

| Noun | Adjective | Adverb | Verb |
|---|---|---|---|
| | | convertibly | convert |
| proposal; proposition | | proposedly | |
| approximation | | | |
| | standard | | standardize |
| | wide | | widen |
| shortness | short | | |
| | original | | originate |

**Task 4. Find the first part of terms matching the definitions below, use dictionary if necessary.**

| Term | Definition | Term | Definition |
|---|---|---|---|
| ………… numbers | number that when divided by two, leaves a remainder | a ……… number | A number generated using a large set of numbers and a mathematical algorithm which gives equal probability to all numbers occurring in the specified distribution. |
| ………… numbers | if the integer is divided by 2, it yields no remainder | the …… number | the maximum amount, quantity, etc. is the largest that is possible or allowed |
| ………… numbers | A natural number greater than 1 that cannot be formed by multiplying two smaller natural numbers | a ……… number | an integer that is the square of an integer; |
| a ……… number | those numbers, values of which never change | a …… number | something which is separate and cannot be divided in smaller numbers of the same thing |

## 3.2. Numbers and mathematical operations

**Fractions [= Rational Numbers]**

| | |
|---|---|
| $\frac{1}{2}$ = one half | $\frac{26}{9}$ = twenty-six ninths |
| $\frac{1}{3}$ = one third | $-\frac{5}{34}$ = minus five thirty-fourths |
| $\frac{1}{4}$ = one quarter [= one fourth] | $2\frac{3}{7}$ = two and three sevenths |
| $\frac{1}{5}$ = one fifth | $-\frac{1}{17}$ = minus one seventeenth |
| $\frac{3}{8}$ = three eighths | $\frac{4}{1000}$ = four thousandths [or four over one thousand] |

## Real Numbers

| |
|---|
| − 0.067 = minus nought point zero six seven |
| 81.59 = eighty-one point five nine |
| $-2.3 \cdot 10^6$ =minus two point three times ten to the six |

**Task 1. Write the numbers in words:**

a) 1.894 — ;
b) 1/100 mm — ;
c) 1/1000 cm — ;
d) 0 — ;
e) 8’456.25 — .

**Task 2. Study the following data and read the examples:**

| Symbol | Meaning | Example | Spoken |
|---|---|---|---|
| + | Addition | a + b = c | **a** plus **b** equals **c** |
| - | subtraction | a – b | **a** minus **b** |
| X | multiplication | a x b | **a** multiplied by/ times **b** |
| ÷ | division | a ÷ b | **a** divided by/over **b** |
| | | (a – b)(a + b) = c | **a** minus **b** in brackets times **a** plus **b** in brackets equals **c** |
| | | a(7 – b) = c | **a** open brackets **7** minus **b** close brackets equals **c** |
| $x^2/x^3/x^n$ | | | **x** squared/ **x** cubed/ **x** to the power of **n (x** to the **n)** |
| ≠ | not equal to | a ≠ b | **a** is not equal to **b** |
| ≡ | equivalent to | a ≡ b | **a** is equivalent to **b** |
| → | tends to | x → 0 | **x** tends to **nought** |
| < | less than | x < 10 | x is less than 10 |
| > | greater than | x > 10 | x is greater than 10 |
| ∞ | infinity | y → ∞ | **y** tends to **infinity** |
| ≤ | less than or equal to | x ≤ 5 | **x** is less than or equal to **5** |
| ≥ | greater than or equal to | y ≥ 10 | **y** is greater than or equal to **10** |
| ± | plus or minus | x = ±5 | **x** equals plus or minus **5** |

**Task 3. Complete the calculations using the words in the box. Sometimes there is more than one possible answer.**

| | | | | | |
|---|---|---|---|---|---|
| divided | minus | plus | square root | subtract | times |
| less | multiplied | square | squared | sum | |

a) 15 + 7 = 22 Fifteen ……………… seven equals twenty-two.
b) 200 x 10 = 2’000 Two hundred ……………… ten is two thousand.
c) 9 x 11 = 99 Nine ……………by eleven equals ninety-nine.

| | |
|---|---|
| d) $400 \div 8 = 50$ | Four hundred ……………. by eight equals fifty. |
| e) $83 + 2 = 85$ | The ……… of eighty-three and two is eighty-five. |
| f) $7^2 = 49$ | The …………… of seven is forty-nine. |
| g) $60 - 40 = 20$ | If you ………… forty from sixty, it equals twenty. |
| h) $\sqrt{100} = 10$ | The …………………… of a hundred is ten. |
| i) $12^2 = 144$ | Twelve …………….. is a hundred and forty-four. |
| j) $87 - 25 = 62$ | Eighty-seven …… twenty-five equals sixty-two. |

**Task 4. Decipher the equations and write them down in words.**

1) (a+b)/(c-10) = ______________________________________
2) $4^x \times 100^y$ = ______________________________________
3) $z^{-2}$ = __________________________________________
4) $\frac{3}{4} \geq -q$ = _______________________________________
5) $\frac{-73.067}{\sqrt[2]{o^3}} \pm 1.095$ = ___________________________________

***Task 5. Put the verbs into the correct form.***

**Example 1.**

The general equation of all conics with center at origin can …………… (to write) as

$$ax^2 + 2hxy + by^2 + c = 0.$$

(Divide) by '*a*', we get

$$x^2 + (2h/a)xy + (b/a)y^2 + (c/a) = 0$$

Since, it has three arbitrary constants. So, the differential equation is of order 3.

**Example 2.**

Let $y = \sin^{-1}x$ then prove that $(1-x^2) \cdot y_2 - xy_1 = 0$. Where $y_1$ and $y_2$ are first and second order derivatives of $y$ with respect to $x$ respectively.

**Answer.**

……………… (Give), $y = \sin^{-1}x$

Now ……………… (differentiate) both sides we get,

$$y_1 = \frac{1}{\sqrt[2]{1 - x^2}}$$

Now ……………… (square) both sides we get,

$$(1-x^2) \cdot y_1^2 = 1$$

Now again …………… (differentiate) both sides with respect to $x$ we get,

$$(1-x^2) \cdot 2y_1y_2 - 2xy_1^2 = 0$$

$$\text{or, } (1-x^2) \cdot y_2 - xy_1 = 0. \ [\text{ Since } y_1 \neq 0]$$

## V.5. Where do math symbols come from?

**Task 1. Fill in the gaps using the words from the box below**

| • an exponent • calculations • communicate • subscripts • originated • |
|---|

1. Math is full of symbols – lines, dots, arrows, English letters, Greek letters, superscripts, ________________________ .

2. Another example of that is the plus sign for addition, which _________________ from a condensing of the Latin word ‘et’ meaning ‘and’.

3. A number multiplied by itself is indicated with ____________________ that tells you how many times to repeat the operation.

4. Symbols can also provide succinct instructions about how to perform ________________________ .

5. Sometimes, as with equals, these symbols ______________________ meaning through form.

**Task 2. Answer the question about the video.**

1. Who first introduced our modern ‘equals’ sign?
2. What is the symbol used to represent a factorial?
3. What can Letters from the Greek or Latin alphabet represent?
4. What does capital Sigma represent?
5. Is the meaning of mathematical symbols suggested by the symbol itself or arbitrary?

**Task 3. Discuss the questions below in pairs.**

– Is the mathematical notation we have inherited still adequate to the needs of students and researchers?

– Is there any way it could be improved, perhaps, to make it more accessible?

## 3.3. What Maths Do You Need to Be an Engineer?

Obtaining an engineering degree requires you to successfully complete a multitude of math courses. In the days before computers, engineers used slide rules and pencils to work out math problems, such as determining the stresses a dam must withstand, or the most efficient operating weight of an airplane. Although computers can solve many math problems, engineers still need a solid foundation in math and a good understanding of mathematical principles. Each university develops its own degree plan and course catalog, but certain types of math courses are typically required.

**Algebra.**

Requirements vary by university, but since a thorough understanding of algebra is crucial to success in advanced math courses, you may need to take one or two semesters of algebra and trigonometry in college. At some schools, if you had high school algebra and trigonometry, you are deemed proficient enough to begin your math with calculus. Other schools look at your placement test scores or your math scores on your SAT (Scholastic Assessment Test) or ACT (American College).

**Calculus.**

Most engineering degree plans require three semesters of calculus. In conjunction with advanced calculus, or as a separate course, you will also need to take analytic geometry. Analytic geometry uses the principles of calculus and trigonometry to determine limits, vectors, integrals, mean values and derivatives. One of the more advanced math functions engineers must understand is differential equations.

**Trigonometry.**

Trigonometry is one of the more usual maths for engineers. By applying the principle of trigonometry, engineers can calculate such data as the height of an existing structure, the measurement of an angle, or the distance between two points. In many ways, trig is similar to plane geometry in that it relies heavily on formulas and logarithms, rather than solving complex equations. Trigonometry and calculus, together, form the basis for another math-heavy class: engineering physics.

**Probability and Statistics.**

Some universities separate probability and statistics into two separate courses, but other schools combine them. Probability teaches you how to calculate the odds of an event occurring, with random variables and the various theories on limits. Statistics covers sampling techniques, estimation, margin of error and other skills needed to analyze data.

**Other.**

Depending on the engineering specialty and the university, engineers may take additional mathematics courses. For example, you might have to devote an entire class to vectors. Some universities offer engineering math courses that combine elements of multiple classes. Discrete mathematics uses the theory of sets, along with equations and graphs to describe algorithms and data.

***Task 1. Correct the mistakes in sentences below so that they are True.***

1. If you are majoring in engineering, it does not mean that you have to take various mathematics courses.
2. Three semesters of algebra are mandatory in most engineering degree plans.
3. Engineering physics is based on analytic and plane geometry.
4. Probability and statistics form one inseparable course and they are not split into two.
5. Engineers have to take obligatory mathematics courses such as discrete mathematics.

**Task 2. Find the missing parts of collocations from the text.**

1. plane ____________________
2. Discrete __________________
3. _____________ of sets
4. to rely _____________ on
5. _____________ geometry
6. to _____________ math problems
7. to _____________ equations
8. differential _____________
9. thorough _____________
10. slide _____________
11. to form the basis

**Task 3. Find words in the text to match the following definitions.**

1. _______________ – an area of advanced mathematics in which continuously changing values are studied
2. _______________ – the space between two lines or surfaces at the point at which they touch each other, measured in degrees:
3. _______________ – also called the expected value or average, is the central value of a discrete set of numbers: specifically, the sum of the values divided by the number of values.
4. _______________ measures the sensitivity to change of the function value (output value) with respect to a change in its argument (input value).
5. _______________ – the study of the mathematics of calculating the likelihood that particular events will happen.
6. _______________ – a representation of something that has both direction and size.
7. _______________ – a group of objects with stated characteristics.
8. _______________ – a structure amounting to a set of objects in which some pairs of the objects are in some sense "related".

**Task 4. Find information about the topic 'What Math Skills Are Needed to Become an Engineer'?**

**Task 5. Match the verbs and their definitions.**

| | |
|---|---|
| 1) **Calculate** a number | a) make a rough guess |
| 2) **Estimate** a figure | b) make a fraction to the nearest whole number e.g. round 0,85 up to 1 |
| 3) **Round** a figure **up/down** | c) add up |
| 4) **Total** a set of numbers | d) work out |
| 5) **Tally** numbers/my figures do not **tally** with yours | e) take away, subtract |
| 6) **Deduct** one number from another number | f) match, agree |

**Task 6. Complete the sentences below using the words from the table above:**

1. If there's a continual turnover of material we can actually ………………... its residence time, that is the average length of time a particular molecule of substance X spends in the ocean.

2. The "Dash Cart" looks like any other grocery cart, but uses a mix of cameras, sensors and a built-in scale to work out a person's purchases and then ……………. the amount from the card associated with their Amazon account.

3. This should offer a boost to Uber's revenue, which analysts ………………... will be $3.9 billion in the quarter, and may also lead to a smaller loss on the bottom line.

4. Please note that normal rounding is used, where digits 1–4 ……………… and 5–9 ……………… .

5. Cases in Texas now ………… 240,111 with 9,765 new cases since yesterday.

6. The 46-year-old care worker, from Longsight, says his Universal Credit payments never ………………. with what he was originally assessed to receive.

## Revision and consolidation (Unit 3)

**Grammar revision (Future tenses).**

**Task 1. Choose the correct alternative and explain your choice.**

1. Two or more components *will be/will have been designed* to be complementary and mutually attractive by the end of this experiment.

2. The conference *is going to/starts* next week on Monday.

3. When these methods *are used/will be used*, a wide variety of useful chemicals will be manufactured.

4. Next year he *will manage/will have been managing* this laboratory for 10 years.

5. Come round in the morning, I *will be doing /will have done* this experiment.

6. More experiments are *to be conducted/to conduct* later during the academic year.

7. Applying 3D printing concepts to nanotechnology *is going to bring/will bring* a few advantages to nanoengineering – speed, less waste, economic viability.

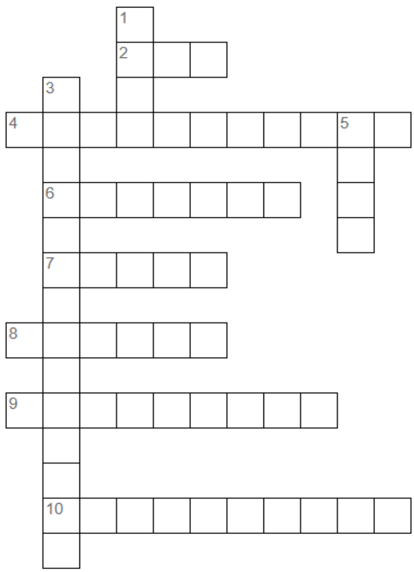
8. He *will leave/is leaving* for the conference tonight – he already has the ticket.

9. The Research Assistant *is going to do/will do* the experiment tonight – he has just become aware that the laboratory will be available.

10. This material *is not going/will not work* to work – I have tested it already.

**Vocabulary revision.**

**Task 2. Do a crossword puzzle using words from the unit.**



**Across.**

**2** number that when divided by two, leaves a remainder
**4** the process of removing one number from another
**6** to add up
**7** A natural number greater than 1 that cannot be formed by multiplying two smaller natural numbers
**8** 90 [written as a word]
**9** four _______ (4! [= 1 · 2 · 3 · 4])
**10** one _______ = one fourth

**Down.**

**1** the cube _______of 64 is 4.
**3** the process of adding a number to itself a particular number of times, or a calculation in which this is done:
**5** a/100 = a ______ one thousand

**Task 3. Find the words given after the box. The words can be written in different directions.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | T | F | R | A | C | T | I | O | N | I | Q | M | C |
| O | N | E | A | H | U | I | R | E | T | A | E | R | G |
| L | P | O | T | N | E | I | C | I | F | F | E | O | C |
| N | A | U | I | I | A | E | C | N | E | U | Q | E | S |
| H | G | N | L | T | N | R | E | G | E | T | N | I | F |
| T | S | S | O | A | A | I | J | T | N | I | O | P | N |
| Y | L | C | O | I | M | U | F | O | W | D | E | F | D |
| N | T | I | E | L | T | I | Q | N | T | I | T | I | J |
| E | E | R | N | P | U | A | C | E | I | A | T | R | M |
| L | Q | C | E | U | A | T | R | E | V | M | S | F | A |
| C | U | U | F | P | M | H | I | R | D | E | D | Q | T |
| R | A | L | H | C | O | B | S | O | I | T | K | N | H |
| I | L | A | N | Z | O | R | E | A | N | E | W | L | I |
| C | R | R | A | T | I | O | P | R | U | R | A | S | G |

CIRCLE
CIRCULAR
COEFFICIENT
DECIMAL
DIAMETER
EQUAL
EQUATION
FRACTION
GREATER
INFINITE
INTEGER
IRRATIONAL
MATH
NUMBER
POINT
PROPERTY
RATIO
SEQUENCE
SHAPE
SOLUTION

## Task 4. Fill in the gaps, use dictionary if necessary.

| | | |
|---|---|---|
| **1** | Statistics is the …………… of mathematics that is concerned with analyzing and interpreting large quantities of **data** | Статистика – это **раздел** математики, который занимается анализом и интерпретацией большого объема ……… |
| **2** | Its …………… were laid **in the late** 1800s, principally by British polymaths Francis Galton and Karl Pearson | Её **основы** были заложены …………… 1800-х годов, главным образом крупными британскими учеными Фрэнсисом Гальтоном и Карлом Пирсоном |
| **3** | Statistics **investigates** whether the pattern of recorded data is …………… or random | Статистика …………… является ли структура полученных данных **значимой** или случайной |
| **4** | Its **origins** lie in the efforts of 18th-century mathematicians such as Pierre-Simon Laplace to identify …………… in astronomy | Её …………… – попытки математиков 18-го века, таких как Пьер-Симон Лаплас, обнаружить **ошибки измерений** в астрономии |
| **5** | In any …………… of scientific data, most errors are likely to be very small, and only **a few** are likely to be very large | В любом **наборе** научных данных большинство ошибок, вероятно, будут очень незначительными, и только …………… , вероятно, будут очень большими |
| **6** | So when observations are **plotted on** a graph, they create a bell-shaped curve with a peak created by the most …………… result, or “norm,” in the middle | Поэтому, когда данные наблюдений …………… на график, они образуют кривую нормального распределения с пиком, созданным наиболее **вероятным** результатом, или «нормой», посередине |
| **7** | In 1835, Belgian mathematician Adolphe Quetelet **posited** that characteristics, such as body mass, within a human population **follow** a bell curve pattern, in which …………… around the mean are most frequent | В 1835 году бельгийский математик Адольф Кветле ……………, что такие характеристики населения, как масса тела, …………… закону кривой нормального распределения, в котором **значения** вокруг среднего являются наиболее частыми |
| **8** | …………… and lower values are less frequent | Значения **выше** и ниже среднего встречаются реже |
| **9** | He **devised** the Quetelet Index (now called the BMI) to …………… body mass | Он …………… индекс Кетле (теперь называемый ИМТ) для **обозначения** массы тела |

**Task 5. Choose any law of physics, chemistry, mathematics, etc. which contains formulae or just any formula you like and explain it using vocabulary from the unit.**

Example

Kepler's 3rd Law of Periods:
The square of the time period of the planet is directly proportional to the cube of the semimajor axis of its orbit.
$T^2 \propto a^3$

So, there has to be a force of gravitation between the Sun and the planet.

$$F = \frac{GmM}{r^2}$$

Since it is moving in an elliptical orbit, there has to be a centripetal force.

$$F_c = \frac{mv^2}{r^2}$$

Now,

$$F = F_c \Rightarrow \frac{GM}{r} = v^2$$

Also,

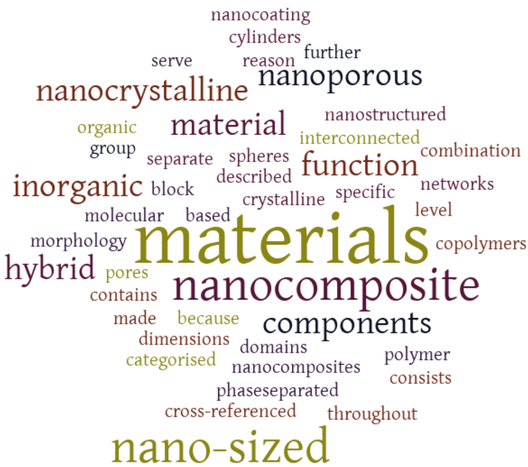
$$v = \frac{\text{circumference}}{\text{time}} = \frac{2\pi r}{t}$$

Combining the above equations, we get

$$\Rightarrow \frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

$$T^2 = \frac{4\pi^2 r^3}{GM} \Rightarrow T^2 \propto r^3$$

# Unit 4. – Nanomaterials




## 4.1. Overview of nanomaterials

Nanoscience will impact the design and fabrication of new materials with innovative properties and functions. Contributions to this field are very widespread, and include enhancing the properties of plastics, ceramics, coatings, composites, fibres and many more. Nanoscience also introduces an entirely new concept in material design, the bottom-up approach of material self-assembly, which is directly inspired from how organic and inorganic materials are created in nature.

The question: *What is a 'nanostructured material'?* must be considered before discussing examples of various functional nanomaterials. Nanostructured materials are solids or semi-solids (e.g. hydrogels, liquid crystals) characterised by a nano-sized inner structure. They differ from crystalline, microstructured and amorphous solids because of the scale order. In crystalline solids, the atoms are neatly arranged in a grid where the distance between neighbouring atoms is well defined, and this order extends to macroscopic dimensions. In contrast, microstructured materials show structural variation only on a micron scale, whereas amorphous materials exhibit short-range order only. In nanostructured materials, the spatial order is at the nanoscale, which lies between the microscopic and the atomic scale.

**The size of the nanostructures and the scale order within them in the solid impacts the properties of a material.** Nanostructured materials differ from conventional polycrystalline materials in the size of the structural units of which they are composed. They can exhibit properties that are drastically different from those of conventional materials, and this is often a direct consequence of the large fraction of grain boundaries (i.e. the space between the nanostructures) in the bulk material. **This means that in a nanostructured material there is a large**

**proportion of surface atoms** (i.e. atoms that are located at or near a surface). Due to the large surface area, bulk properties become governed by surface properties. This surface – also called an **interface** – can form a border with the embedding matrix, a nanoparticle, air or vacuum in the case of a pore or defect.

Examples of nanostructured materials are nanoporous, nanocrystalline, nanocomposite and hybrid materials: **nanoporous** materials have nano-sized pores; a **nanocrystalline** material consists of many nano-sized crystalline domains; a **nanocomposite** material contains two or more phaseseparated components with morphology of spheres, cylinders or networks with nano-sized dimensions (further divided into **inorganic and polymer nanocomposites**); and **hybrid materials** are made of a combination of organic and inorganic components interconnected at a molecular level (e.g. block copolymers). The materials within this chapter were categorised based on the function they serve, and for this reason, throughout the text, they are often cross-referenced: a nanocoating can be a nanocomposite but, because of its specific function, is described in a separate group.

One of the distinguishing features of **nanostructured materials is that they can have properties that differ significantly from those displayed in bulk**. This means that scientists have the opportunity to design new materials with specific functions by exploiting the intrinsic properties of nanomaterials. As a result, **coatings, plastics and metals with new properties can be made to fulfil specific functions**. As discussed in this chapter, numerous new materials are being developed with exciting properties. Although much research is still needed in this field, numerous commercial realities already exist and exciting new materials should be expected in the future. These materials have numerous applications that extend from the medical sector (e.g. antibacterial coatings) to improved cutting tools.

**Task 1. Answer the questions about the text.**

1. What inspired the bottom-up approach of material self-assembly?
2. Why do nanostructured materials differ from crystalline, micro-structured and amorphous solids?
3. Why can nanostructured materials exhibit properties that are drastically different from those of conventional materials?
4. What governs bulk properties in nanostructured material?
5. What are hybrid materials made of?
6. What enables scientists to design new materials with specific functions?
7. What does ‘which’ on line 5 refer to?

**Task 2. Match the beginnings and endings of the sentences.**

| | |
|---|---|
| **1.** Our interdisciplinary research group on **functional** | **a)** properties of the chemicals involved |
| **2.** These functors are called hom-functors and have **numerous** | **b)** function are the D-cache and I-cache (data cache and instruction cache) |
| **3.** The system of classifying hazards in the GHS is based on the **intrinsic** | **c)** materials, in particular for producing fibres from mineral rocks |
| **4.** One of the **distinguishing** | **d)** order in a system of particles |
| **5.** Examples of caches with a **specific** | **e)** applications in category theory and other branches of mathematics |
| **6.** This parameter is usually used in physics to characterize the degree of **spatial** | **f)** nanomaterials is developing novel strategies to synthesize size and shape-controlled metal |
| **7.** The invention relates to chemical engineering used for producing **inorganic** | **g)** properties (even the coefficient of friction between the surfaces) |
| **8.** The work done by friction can translate into deformation, wear, and heat that can affect the contact **surface** | **h)** features of our nuclear-free zone is its environmental aspect |

**Task 3. Choose the correct alternative.**

1. According to the definition by IUPAC, the former two are alkanes, *whereas/where* the third group is called cycloalkanes.
2. Aristotle did, *however/whereas*, perform original research in the natural sciences.
3. *In contrast/Although* many alternative therapies and interventions are available, few are supported by scientific studies.
4. The size of the sun is greater than *that of/that* the earth.
5. *When/In contrast*, in physics a comparison with experiments always makes sense, since a falsified physical theory needs modification.
6. All of the 366 trolleybuses are equipped to enable them to run on diesel *in case of/in case* power failure.

**Task 4. Fill in the gaps using the words below.**

| |
|---|
| • synthesized • observed • developed • caused • manufactured • formed • known • used • made |

Nanomaterials are interesting in many respects. Some have been ________ (or developed) over a considerable time and have been ________ by chance without any understanding of the microscopic structure of matter. This is, for example, the case of the "Lycurgus cup", a glass cup with a mythological scene ________ probably in Rome around the fourth century AD. It is a vessel ________ as a cage-cup, which was made by blowing or casting a thick glass blank. The glass was then cut and ground away leaving a decorative cage at the surface. The cup is made with a dichroic glass probably ________ by accident. A change of color of the cup is ________ when it is illuminated from inside: the opaque green cup becomes glowing translucent red. This phenomenon is ________ by gold and silver nanoparticles, which were ________ during the fabrication of glass. The technique was further ________ during the medieval age to make stained glass windows. The so-called "Ruby glass" is still used today in order to make cadmium free intensely red glass.

## 4.2. Some types of nanomaterials

Nanomaterials exist in different dimensions, not only because they can be one atomic layer thick, but by how their electrons can be confined to flow in a certain number of dimensions. For example 2D materials have their electrons confined in one direction, so the electrons then move in two directions, hence the name. The same principle applies for 1D and 0D materials which have their electrons confined in 2 and 3 dimensions respectively; and their electrons can move in 1 and 0 directions respectively. So, let’s look at some examples.

**2D Materials.**

***Uniatomic 2D Materials.***

There are many types of uniatomic 2D materials, such as germanene (made from germanium atoms), stanene (tin), silicene (silicon), phosphorene (phosphorous) and, of course, graphene (carbon).

Graphene is by far the most useful and the closest material to commercialization within this list, especially as some of these are still theoretical materials. However, graphene and the various other 2D atomic materials possess an excellent array of optical, physical and electrical properties that make them useful for a wide range of applications. Once graphene has been successfully used across many applications at a commercial level, it is expected that many of the other 2D materials will follow suit, although it could take a while.

**MXenes.**

Outside of graphene, the class of MXene 2D materials show some of the best electronic properties. The most common MXene is boron nitride, which exhibits a hexagonal array of alternating boron and nitrogen atoms. Many people think that the MXenes show better properties than graphene, but they are much harder to synthesize. As such, they have not been as widely studied as graphene. However interest in them is significantly growing.

Whilst boron nitride is the most common, and the most widely researched, MXenes come in many forms and are often made from a combination of early transition metals (M), such as Titanium, Vanadium, Chromium and Niobium, alongside carbon or nitrogen (X). Future applications involving the MXenes could include EMI shielding, water purification and in energy storage systems.

**TMDCs.**

Transition metal dichalcogenides (TMDCs) are one of the oldest and longest studied class of 2D materials. They are widely used in semiconducting and electronic applications, but do not have as wide a range in properties in each material as other 2D materials. However, there are over 100 TMDCs to date, with the most common being tungsten diselenide ($WSe_2$), tungsten disulphide ($WS_2$), molybdenum disulphide ($MoS_2$) and molybdenum diselenide ($MoSe_2$), although many other transition metals and chalcogen atoms can be used.

One characteristic feature of TMDCs, is that one monolayer is composed of three atomic layers, where a layer of metal atoms is sandwiched between two layers of chalcogen atoms (note that these layers are physically bonded and are not held by van der Waals forces).

**1D Materials.**

***Nanotubes.***

Nanotubes, be it a carbon nanotube or inorganic nanotube, are materials which are elongated in one dimension, with a length-to-diameter ratio of up to 132,000,000:1. Nanotubes direct electrons along the elongated axis and come in many forms, including single-walled nanotubes (SWNT), multi-walled nanotubes (MWNT), chiral nanotubes, armchair nanotubes and zigzag nanotubes.

There has been a lot of hype about how carbon nanotubes could be used for many applications, especially in structural applications. However, issues with dispersing and aligning carbon nanotubes led to them to go out of favour for a while. They have recently been making a resurgence as many of these issues have been negated.

***Nanowires.***

Nanowires, otherwise known as quantum wires, are another well-known 1D material. Again, nanowires are elongated in one direction, albeit with a much lower width to length ratio of 1:1000. The most common nanowires are silver nanowires, which are also known to be highly electrically conductive. Nanowires are known for exhibiting many different quantum effects, which alongside their unidirectional electron movement, have made them ideal materials for various electronic applications.

Task 1. Say whether these statements are True, False or Not Stated.

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1 | 1D materials have their electrons confined in 1 dimension and their electrons can move in 1 direction | | | |
| 2 | Graphene is useful for numerous applications due to its properties | | | |
| 3 | TMDCs were discovered in the previous century | | | |
| 4 | There is only one existing form of nanotubes | | | |
| 5 | Carbon nanotubes are mostly used in structural applications | | | |
| 6 | Various quantum effects are observed in nanowires | | | |

**Task 2. Fill in the gaps using the words from the box.**

• transition metals • elongate • resurgence • atomic layer • exhibit • follow suit

1. Each full period corresponds to formation of a single ______________ thin film.
2. I'm worried other states might _________________ .
3. Several studies indicated an important role for _________________ in increasing the hazardousness of PM [Particulate Matter].
4. A heavy atomic nucleus in a strong magnetic field would ___________ into a cylinder, whose density and " spin " are enough to build a time machine.
5. Investigations must _________________ objectivity and accuracy.
6. Semiconductors are cyclical by nature, but the 5G revolution and a _________________ in hyperscale computing are pushing these stocks to the stratosphere.

**Task 3. Fill in the table.**

| Noun | Adjective | Adverb | Verb |
|---|---|---|---|
| | | — | to exhibit |
| conductor | | conductively | |
| | structural; structured | | |
| | | thick; thickly | |
| favour | | | to favour |
| | | quantumly | to quantize |
| | negative | | to negate |

Task 4. Read the text below. Use the word given in capital letter at the end of some of the lines to form a word that fits in the gap in the same line.

| | |
|---|---|
| **Nanoparticles** | |
| Overall, nanoparticles come in many forms. There are too many to **1)** ………. discuss, but some of the most common are: | INDIVIDUAL |
| single element nanoparticles, such as silver and gold nanoparticles which are used in medical **2)** ………. ; metal | IMAGE |
| oxide nanoparticles, including titanium dioxide nanoparticles used in white paint formulations; and amphiphilic nanoparticles such as Janus particles, which are used as **3)** ………. . Janus particles are an interesting class of | STABLE |
| nanoparticle, as one half of the surface is different to the other, and these two surfaces can **4)** ………. in their external | DIFFERENT |
| receptors, hydrophobicity or hydrophilicity, surface charge, and even in their **5)** ………. . | MAGNETIC |

**Task 5. Find information about 0D Materials and get ready to report your findings.**

## V.6. Functional nanomaterials made easy

**Task 1. Fill in the gaps using the words from the box below**

| |
|---|
| • the atomic motion • piqued the interest of • alternative • subjected • to fabricate • a revolutionary approach to • a game-changer • |

1. This is a really a new way __________________ nanomaterials that impossible for other chemical synthesis approach, so this is ____________ .

2. The technology has _______________________ science, industry, and venture capital groups.

3. This is _______________________ the dynamic compression of nano materials and the concept of actually forming nano structures from nano particles under this type of loading condition.

4. Sandhya's technology is an environmentally friendly ______________________ – simple compression and no chemicals.

5. So, we can use the mechanical compression to induce ______________________ of the defect so that we can squeeze the defects away from the crystal.

6. The team ______________________ materials to different levels and durations of pressure at Sandhya's dynamic compression facility.

Task 2. Firstly, fill in the gaps using the words from the box below. Then, watch the video and number sentences as they appear in the video.

| • therefore • consequently • sky's the limit • for example • however • given the fact that • |
|---|

| Sentence | Number |
|---|---|
| ……………………… this pressure induced fabrication can initiate you know phase changes being gap changes miscibility changes. | |
| I think the ……………………… | |
| ……………………… , we can achieve some wavelength that is not possible in these materials | |
| ……………………… , using this powerful technique under the compression we can tune this semiconductors bandgap as we want it | |
| ……………………… , the energy and trial chart transfer so that they can show new physics that impossible for current chemical synthesis approach | **1** |
| And, ……………………… , applied to nano and nano pressure sensors optical components | |

## 4.3. Types and Preparation of Nanomaterials

Nanomaterials are, as defined by Standford University's Environmental Health & Safety Department as "materials with a minimum of one external dimension that ranges in size between 1–100 nanometers" Yet according to the National Institute of Environmental Health Sciences, the definition of what nanomaterials are is not unanimous in the scientific world. Further, there are two basic types nanomaterials – those that are natural in occurrence and those that are man-made. Manmade nanomaterials include four families. – Carbon based, metal based, dendrimers, and composites. From those many industries benefit including food and manufacturing and biomedical and pharmacology, naming but a few.

**A Closer Look at the Four Families of Manmade Nanomaterial/**

Carbon Based Nanomaterial – generally speaking, carbon-based nanomaterials are made up of mostly carbon and form a variety of shapes.

Mostly hollow tubes, cylinders, and ellipsoids. They include nanotubes and fullerenes.

**Carbon-based nanomaterials**, such as nanotubes are simply the reconfiguration of carbon from a flat plane into a rolled tube shape. Consider carbon as a chemical. It is denoted by the letter C. The chemical formula for a diamond is C. The two minerals very widely in strength, yet as a nanomaterial, soft graphite, become stronger simply by manipulating graphite's crystalline structure.

The creation or synthesis of nanotubes can occur in a variety of ways. Pattern Growth nanotubes are "grown". There are processes for ordered creation, Electric-field-directed growth and patterned growth. The benefit of carbon nanotubes is that they offer amazing strength and structure to products and they conduct heat and electricity, which is beneficial to technology development such as improved batteries.

**Metal Based Nanomaterials –** These are metal based materials that we commonly regarded as quantum dots, nanogold, nanosilver and oxides with metal bases. Titanium dioxide is one such example. Metal based Nanomaterials are a focus of the biomedical and pharmaceutical industries. The power here is the chemical binding or conjugated properties that metal-based nanoparticles offer. That power if found in the ability of multi-bond materials to be joined chemically with antibodies or pharmaceuticals.

Preparation of metal-based nanomaterials synthesis through a variety of means such as microemulsions. According to the Journal of Pharmacy & BioAllied Sciences, the main technique used to create magnetic metal-based nanoparticles is through the manipulation of iron salts via chemical coprecipitation. Metal based nanomaterials are used in healthcare such as contrast dyes that work with MRI and scanning devices for diagnostic purposes.

**Dendrimers** – Branched components that form polymers and whose surface exhibit chain ends suited for chemical manipulation as tools. Dendrimers are combinable to create hollow cavities or used as part of a catalysis. Dendrimers represent a half step between molecular chemistry and polymer chemistry. A fitting place considering that we prize these nanoparticles for their branched appendages. The creation or preparation of dendrimers is either via divergence or convergence. Either the branches grow and then attach to the core or the branches grow from the core.

The process is via cascade reaction that is a natural reaction that nanotechnology has stolen from simply biology [6.] In the human body, protein synthesis is the building of more complex structures from parts. That is the same concept for Dendrimers. Dendrimers have an amazing capability, and their current application is through biomedicine with applications as anticancer drugs, pain management, and timed released medications such as a transdermal patch or in gene therapy.

**Composites** – As the word describes, this is a combination of nanoparticles or nanoparticles and other materials to form unique nanomaterials, that then go into the creation of products. Thus far, the synthesis and properties of the first three families of nanomaterials and nanoparticles remain orderly and scientific. Composite nanomaterials remain orderly, but perhaps at a twisted level. These are not a single or group of particles – they are individuals of a population of particles with families, genus, and a ton of potential. These are the nanomaterials that make unique solutions possible – no pun intended.

Composites, like metallurgy, is a craft. The preparation of composites involves thermal reduction of metallic oxides and polyamide 6. Yet the use of PA6 is just one method of preparing composite nanomaterials. Electrospinning that morphs the physical object with the chemical solution to create single dimension composites that are somehow both organic and inorganic.

Within these four families of nanomaterials exists a wide array of properties. Do you need a material that enables electrical configuration or that uses both mechanical and magnetic properties? Those are samples of the array of usefulness that nanomaterials bring to manufacturing, military technology, pharmaceuticals, and environmental industries.

There is much more to discover in the world of nanoparticles, and the potential of this industry is a doubled-edged sword. For example, while metallic nanomaterials make internal diagnostics work, metals are typically harmful. More research can lead to better understanding and a more informed decision about how to use nanotechnology to benefit the planet, and mankind.

**Task 1. Read the text and choose the correct alternative.**

1. Carbon based, metal based, dendrimers, and composites are the examples of

a) manmade nanomaterials;

b) naturally occurring nanomaterials;

c) functional nanomaterials.

2. The strength of soft graphite can be enhanced by

a) electric-field-directed growth;

b) manipulating its structure;

c) patterned growth.

3. One of the ways to prepare for the synthesis of nanomaterials based on metals is
a) microemulsion;
b) chemical coprecipitation;
c) contrast dye.
4. The example of the building of more complex structures from parts in the human body is
a) gene therapy;
b) anticancer drugs;
c) protein synthesis.
5. Composite nanomaterials enable creation of
a) thermal reduction;
b) unique solutions;
c) electrospinning.
6. The potential of nanomaterials is
a) unfulfilled;
b) unlocked;
c) controversial.

**Task 2. Match the words with their definitions.**

| | |
|---|---|
| **1.** reconfiguration /n/ | **a)** consentaneous, consentient, unanimous; in complete agreement; acting together as a single undiversified whole |
| **2.** polymer /n/ | **b)** connected with the industrial production of medicines |
| **3.** crystalline /adj/ | **c)** the use of an electric charge to pull very fine fibres from a liquid |
| **4.** electrospinning /n/ | **d)** is a chemical compound with large molecules made of many smaller molecules of the same kind |
| **5.** divergence /n/ | **e)** arranged or disposed in some order or pattern |
| **6.** convergence /n/ | **f)** a new or different relative arrangement of parts or elements |
| **7.** unanimous /adj/ | **g)** the act of moving away in different direction from a common point |
| **8.** orderly /adj/ | **h)** made of crystal; composed of crystals |
| **9.** pharmaceutical /adj/ | **i)** the fact that two or more things, ideas, etc. become similar or come together |

**Task 3. Find the second part of collocations from the text.**

| | |
|---|---|
| **1.** doubled-edged | configuration |
| **2.** informed | solution |
| **3.** scientific | nanomaterials |
| **4.** electrical | intended |
| **5.** chemical | synthesis |
| **6.** no pun | decision |
| **7.** protein | therapy |
| **8.** gene | potential |
| **9.** manmade | sword |
| **10.** ton of | world |

**Task 4. Choose the correct alternative.**

To manage the risks of nanoparticles, employers need to understand / to realise the:

– hazardous properties of products which contain engineered nanomaterials

– potential for exposure to engineered nanomaterials what / which may be harmful

– effectiveness of workplace controls to either prevent or / and minimise exposure.

Although the level of risk is uncertain / certain, we know that products that can become airborne, such as fine powders, are more likely to give / to pose a risk than products that are bound to other materials, such as those used in computer memory chips and storage gadgets / devices.

Methods, including using local exhaust ventilation (extraction), have developed / have been developed to prevent exposure to fumes such as those generated from high-energy processes, e.g. welding and grinding which contain / contains some nanoparticles.

## 4.4. Top-down vs Bottom-up Approach in Nanotechnology

*There are two design approaches in nanotechnology known as top-down and bottom-up. Both approaches are useful in different types of applications.*

**Top-down Approach.**

In top-down approach, nano-scale objects are made by processing larger objects in size. Integrated circuit fabrication is an example for top down nanotechnology. Now it has been grown to the level of fabricating nano electromechanical systems (NEMS) where tiny mechanical components such as levers, springs and fluid channels along with electronic circuits are embedded to a tiny chip. The starting materials in these fabrications are relatively large structures such as silicon crystals. Lithography is the technology which has enabled making such tiny chips and there are many types of them such as photo, electron beam and ion beam lithography.

In some applications larger scale materials are grinded to the nanometer scale to increase the surface area to volume aspect ratio for more reactivity. Nano gold, nano silver and nano titanium dioxide are such nano materials used in different applications. Carbon nanotube manufacturing process using graphite in an arc oven is another example for top-down approach nanotechnology.

**Bottom–up Approach.**

Bottom-up approach in nanotechnology is making larger nanostructures from smaller building blocks such as atoms and molecules. Self assembly in which desired nano structures are self assembled without any external manipulation. When the object size is getting smaller in nanofabrication, bottom-up approach is an increasingly important complement to top-down techniques.

Bottom-up approach nanotechnology can be found from nature, where biological systems have exploited chemical forces to create structures for cells needed for life. Scientists and engineers perform research to imitate this quality of nature to produce small clusters of specific atoms, which can then self assemble into more complex structures. Manufacturing of carbon nanotubes using metal catalyzed polymerization method is a good example for bottom-up approach nanotechnology.

Molecular machines and manufacturing are a concept of bottom-up nanotechnology introduced by Eric Drexler in his book Engines of Creation in 1987. It has given early views of how nano-scale mechanical systems can be used to build complex molecular structures.

| **Difference between Top-down and Bottom-up approach in nanotechnology** |
|---|
| 1. Manufacturing process starts from larger structures in top-down approach where starting building blocks are smaller than the final design in bottom-up approach<br>2. Bottom-up manufacturing can produce structures with perfect surfaces and edges (not wrinkly and does not contain cavities etc.) though surfaces and edges resulted by top-down manufacturing are not perfect as they are wrinkly or containing cavities.<br>3. Bottom-up approach manufacturing technologies are newer than top-down manufacturing and expected to be an alternative for it in some applications (example: transistors).<br>4. Bottom-up approach products have a higher precision accuracy (more control over the material dimensions) and therefore can manufacture smaller structures compared to top-down approach.<br>5. In top-down approach there is a certain amount of wasted material as some parts are removed from the original structure contrast to bottom-up approach where no material part is removed. |

**Task 1. Decide which approach (bottom-up or top-down) is described and give the title to each column.**

| | |
|---|---|
| Using this approach, you would use nanotechnology to assemble the chip atom by atom, placing each type of atom in a specific location to build the circuit | With this approach, you would instead create the computer chip by carving away at bulk material – much like a sculptor and his artwork – to create nano-sized features, never dealing with the atomic level of matter |
| This method is in the theoretical stage, with researchers doing initial experiments to develop these techniques | This method is currently in use to manufacture computer chips as well as other products you use every day |
| This approach has better chances of producing more homogeneous nanostructures with less defects | This approach may give better control of the successive steps but has an important drawback: it is limited to a "fixed" number of structures arising from it |

**Task 2. Fill in the gaps and provide your own example(s). Do you know any other quantifiers and rules related to their use?**

| |
|---|
| We use number of before a plural _____________ noun:<br>The chart shows the number of hours/passengers/people/times, etc.<br>Your own example(s): ________________________________________<br>We use amount of before an ________________ noun:<br>If we look at the amount of energy/food/information/money/waste, etc.<br>Your own example(s):<br>_____________________________________________________ |

**Task 3. Choose the correct alternative.**

1. Time codes are usually published in the form of UTC, which differs from TAI by a well-known integer __________ seconds.

**a)** amount of **b)** number of

2. This region has a tremendous __________ variety in precipitation.

**a)** amount of **b)** number of

3. In practical terms, the ampere is a measure of the __________ electric charge passing a point in an electric circuit per unit time.

**a)** amount of **b)** number of

4. Educational levels in France reflect __________ general trends.

**a)** amount of **b)** number of

5. Nonetheless, __________ promising approaches are emerging.

**a)** amount of **b)** number of

6. Reaction with oxygen (if an __________ the least is enough to meet the reaction stoichiometry) leads to combustion without any smoke.

**a)** amount of **b)** number of

**Task 4. Fill in the gaps using the verbs from the box below.**

| • exploit • ground • to process • arise • embedded • remove |
|---|

1. This allows digital devices to communicate with each other and _______ , store, and communicate character-oriented information such as written language.

2. Security Recent developments in the coding of applications including mobile and _________ systems have led to the awareness of the security of applets.

3. The product can be _________ up and used as a pigment.

4. We thought we would _________ this idea in order to study whether we could predict phenomena within networks.

5. Please _________ any programs that are not necessary.

6. Data protection and human rights issues _________ in relation to the storage and disclosure of biometrical data.

**Task 5. For questions 1 — 8, read the text below and decide which answer (A, B, C or D) best fits each gap.**

Northwestern University researchers have figured **(1) ………** how to create an electricity conductor on a nanotechnological scale. It's a solid nanoparticle that can be **(2) ………** to direct electrical currents in different, opposing directions. The official study cites "current rectifiers, switches, and diodes" among the electrical elements that each nanoparticle can emulate. Each 5-nanometer-wide particle is coated with a **(3) ………** charged chemical and surrounded by negative atoms. The electrical charge **(4) ………** reconfigures the negative atoms around the nanoparticles.

The potential is **(5) ………** . The materials created "can rearrange themselves to meet different computational needs at different times," as the University press release puts it. **(6) ………** this nanomaterial, future electronics can be reprogrammed to direct electric pulses differently. Hardware could be updated as **(7) ………** as software. The concept of "obsolete" technology would itself become obsolete.

The nanoscale conductor has another potential application: serving as a three-dimensional bridge between different technologies. It's the perfect adapter, since its **(8) ………** can be programmed. Maybe this means you won't need to buy that new phone-charging cord after all.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **1** | **A** | out | **B** | on | **C** | for | **D** | with |
| **2** | **A** | configured | **B** | reconfigured | **C** | configurative | **D** | reconfigurative |
| **3** | **A** | positive | **B** | negative | **C** | negatively | **D** | positively |
| **4** | **A** | to | **B** | then | **C** | than | **D** | towards |
| **5** | **A** | amused | **B** | amazed | **C** | amazing | **D** | amusing |
| **6** | **A** | Using | **B** | Use | **C** | To use | **D** | Have used |
| **7** | **A** | easiness | **B** | easy | **C** | easily | **D** | ease |
| **8** | **A** | comparison | **B** | comparative | **C** | compatible | **D** | compatibility |

## V.7. Engineered nanomaterials in aerospace

***Task 1. Find the second part of word combinations from the video. The first one is done for you.***

| | | |
|---|---|---|
| **1.** | optical → | contribution |
| **2.** | magnetic | energy |
| **3.** | far-reaching | sensing |
| **4.** | promising | advancements |
| **5.** | to transmit | challenges |
| **6.** | delicate | properties |
| **7.** | a significant | radiation |
| **8.** | air | properties |
| **9.** | biological | maneuvers |
| **10.** | harmful | applications |
| **11.** | financial | supply |

**Task 2. Fill in the gaps using the words from the box below.**

• however • utilized • bizarre • form • moreover • punched • necessarily • envision • monitor • advances

1. At very small scales matter exhibits _______________ behavior.

2. The journey into space ______________ begins with successful liftoff.

3. Researchers must _______________ balance this reactivity with careful handling and storage.

4. _______________ in nanoengineering have allowed scientists to develop increasingly efficient and long-lasting silicon based solar cells.

5. _______________, research on carbon composites has led to the development of flexible solar cell designs.

6. Scientists have shown that nanometer sized holes can be _______________ into a single sheet of carbon a material called graphene to _______________ a super thin water filter.

7. And fully functional electronic noses or e-noses built using carbon nanotubes could help _______________ levels of toxic chemicals such as carbon monoxide and nitrogen oxides.

8. Scientists _______________ using this technique to process materials excavated from planetary surfaces.

9. From liftoff to re-entry nanomaterials can be _______________ in numerous ways to improve the current state of human spaceflight.

**Task 3. Answer the question about the video listed below.**

1. What do aeronautical systems need?
2. What system was developed in 2014?
3. In which area can nanomaterials make a significant contribution?
4. What can be harnessed to heat ceramic and polymer-based materials containing multi-walled carbon nanotubes?
5. What journal is being cited throughout the video?

## Revision and consolidation (Unit 4)

**Grammar revision (Past tenses)**

**Task 1. Choose the correct alternative and explain your choice.**

1. Many technologies that *had descended/descended* from conventional solid-state silicon methods for fabricating microprocessors were capable of creating features smaller than 100 nm.

2. Trousers and socks lasted longer and kept people cool in the summer because they *had been infused/were infused* with nanotechnology.

3. The project listed all of the products in a publicly accessible online database. Most applications *were limited/had been limited* to the use of "first generation" passive nanomaterials.

4. Controversies regarding the definitions and potential implications of nanotechnologies emerged straight after the article *was published/had been published*.

5. The concepts that seeded nanotechnology were first discussed in 1959 by renowned physicist Richard Feynman in his talk *There's Plenty of Room at the Bottom*, in which he *described/had described* the possibility of synthesis via direct manipulation of atoms.

6. While the 3D printer *was working/worked* the electricity *was cut off/was cutting off*.

7. The Scientist *was conducting/had been conducting* the experiment for a couple of days already when he got the first results.

8. While the team based at Harvard University *worked/was working* on lithium-ion microbatteries their colleagues from the University of Illinois *made/were making* huge progress with tiny battery electrodes, each less than the width of a human hair.

9. In his book he *addressed/was addressing* concerns regarding the use of nanomaterials and *discussed/was discussing* the advantages of nanocomposites versus conventional materials.

10. I *had already finished/was already finishing* the last series of experiments when the fire alarm went off.

**Vocabulary revision.**

**Task 2. Fill in the gaps using the words from the box below.**

| |
|---|
| • composites • quantum • phases • following • basis • |

**Classification of Nano Materials.**

Nano materials can be classified dimension wise into ____________ categories:

Classification Examples.

Nano rods, nano wires have dimension less than 100 nm.

Tubes, fibers, platelets have dimensions less than 100 nm.

Particles, ____________ dots, hollow spheres have 0 or 3 Dimensions < 100 nm.

On the ____________ of phase composition, nano materials in different ____________ can be classified as:

The nano material is called single phase solids. Crystalline, amorphous particles and layers are included in this class.

Matrix __________, coated particles are included in multi-phase solids.

Multi-phase systems of nano material include colloids, aero gels, Ferro fluids, etc.

**Task 3. Match a word from each box to form collocations from the unit.**

| | |
|---|---|
| ● to pique ● atomic ● revolutionary ● to fabricate ● chemical ● electrical ● surface ● theoretical ● to provide ● novel | ● motion ● the nanomaterials ● proof ● interest ● synthesis ● charge ● characteristics ● area ● stage ● approach |
| **1.** ________________________ | **2.** ________________________ |
| **3.** ________________________ | **4.** ________________________ |
| **5.** ________________________ | **6.** ________________________ |
| **7.** ________________________ | **8.** ________________________ |
| **9.** ________________________ | **10.** ______________________ |

**Task 4. Fill in the gaps, use dictionary if necessary.**

| | **Liposomes** | **Липосомы** |
|---|---|---|
| 1 | These have been …………… explored and most developed nano carriers for **novel** and targeted drug delivery due to their small size, these are50–200 nm in size | Эти частицы **тщательно** изучены, и являются самыми развитыми из большинства разработанных наноносителей для ………… и целевой доставки лекарств из-за их небольшого размера, размером 50–200 нм |
| 2 | When dry phospholipids are **hydrated**, closed vesicles …………… | Когда сухие фосфолипиды …………… , **образуются** закрытые везикулы |
| 3 | Liposomes are …………… , versatile and have good **entrapment** efficiency | Липосомы **биосовместимы**, универсальны и имеют хорошую эффективность …………… |
| 4 | It finds application as long …………… and in passive and active delivery of gene, **protein** and peptide | Они находят применение, как в длительном **кровообращении**, так и в пассивной и активной доставке генов, …………… и пептидов |
| | **Dendrimers** | **Дендримеры** |
| 5 | Dendrimers are hyper branched, **tree-like** structures | Дендримеры представляют собой гиперразветвленные …………… структуры |
| 6 | It contains three different ……………: core moiety, **branching units**, and closely packed surface | Они содержат три разных **области**: ядро, ………… и плотно упакованную поверхность |
| 7 | It has **globular** structure and encloses internal …………… | Они имеют …………… структуру и охватывают внутренние **полости** |
| 8 | Its size is ……………. 10 nm | Их размер составляет **менее** 10 нм |
| 9 | These are used for long circulatory, controlled delivery of bioactive material, targeted delivery of bioactive particles to **macrophages** and …………… targeted delivery | Они используются для длительной циркуляции, контролируемой доставки биоактивного материала, целевой доставки биоактивных частиц к ………. и адресной доставки **в печень** |

# Unit 5. – Quantum and Mesoscopic Physics


## 5.1. Quantum Physics Overview

*How Quantum Mechanics Explains the Invisible Universe.*

Quantum physics is the study of the behavior of matter and energy at the molecular, atomic, nuclear, and even smaller microscopic levels. In the early 20th century, scientists discovered that the laws governing macroscopic objects do not function the same in such small realms.

**What Does Quantum Mean?**

"Quantum" comes from the Latin meaning "how much". It refers to the discrete units of matter and energy that are predicted by and observed in quantum physics. Even space and time, which appear to be extremely continuous, have the smallest possible values.

***A***

As scientists gained the technology to measure with greater precision, strange phenomena were observed. The birth of quantum physics is attributed to Max Planck's 1900 paper on blackbody radiation. Development of the field was done by Max Planck, Albert Einstein, Niels Bohr, Richard Feynman, Werner Heisenberg, Erwin Schroedinger, and other luminary figures in the field. Ironically, Albert Einstein had serious theoretical issues with quantum mechanics and tried for many years to disprove or modify it.

***B***

In the realm of quantum physics, observing something actually influences the physical processes taking place. Light waves act like particles and particles act like waves (called wave particle duality). Matter can go from one spot to another without moving through the intervening space (called quantum tunnelling). Information moves instantly across vast distances. In fact, in quantum mechanics we discover that the entire universe is actually a series of probabilities. Fortunately, it breaks down when dealing with large objects, as demonstrated by the Schrodinger's Cat thought experiment.

***C***

One of the key concepts is quantum entanglement, which describes a situation where multiple particles are associated in such a way that measuring the quantum state of one particle also places constraints on the measurements of the other particles. This is best exemplified by the EPR Paradox. Though originally a thought experiment, this has now been confirmed experimentally through tests of something known as Bell's Theorem.

**Quantum Optics**

Quantum optics is a branch of quantum physics that focuses primarily on the behavior of light, or photons. At the level of quantum optics, the behavior of individual photons has a bearing on the outcoming light, as opposed to classical optics, which was developed by Sir Isaac Newton. Lasers are one application that has come out of the study of quantum optics.

**Quantum Electrodynamics (QED)**

Quantum electrodynamics (QED) is the study of how electrons and photons interact. It was developed in the late 1940s by Richard Feynman, Julian Schwinger, Sinitro Tomonage, and others. The predictions of QED regarding the scattering of photons and electrons are accurate to eleven decimal places.

***D***

Unified field theory is a collection of research paths that are trying to reconcile quantum physics with Einstein's theory of general relativity, often by trying to consolidate the fundamental forces of physics. Some types of unified theories include (with some overlap):

- Quantum Gravity;
- Loop Quantum Gravity;
- String Theory / Superstring Theory / M-Theory;
- Grand Unified Theory;
- Supersymmetry;
- Theory of Everything.

***E***

Quantum physics is sometimes called quantum mechanics or quantum field theory. It also has various subfields, as discussed above, which are sometimes used interchangeably with quantum physics, though quantum physics is actually the broader term for all of these disciplines.

***F***

Earliest Findings.
− Black Body Radiation;
− Photoelectric Effect.
Wave-Particle Duality.
− Young's Double Slit Experiment;
− De Broglie Hypothesis.
The Compton Effect
Heisenberg Uncertainty Principle
Causality in Quantum Physics – Thought Experiments and Interpretations.
− The Copenhagen Interpretation;
− Schrodinger's Cat;
− EPR Paradox;
− The Many Worlds Interpretation.

**Task 1. The Reading Passage has six paragraphs A–F with missing headings.**

**Choose the correct heading for each paragraph from the list of headings below.**

| | |
|---|---|
| ***List of Headings.*** | |
| ***i*** | *What is Quantum Entanglement?* |
| ***ii*** | *Other Names for Quantum Physics* |
| ***iii*** | *Quantum Effects* |
| ***iv*** | *Major Findings, Experiments, and Basic Explanations* |
| ***v*** | *Who Developed Quantum Mechanics?* |
| ***vi*** | *Special Relativity Theory* |
| ***vii*** | *What's Special About Quantum Physics?* |
| ***viii*** | *Unified Field Theory* |

1. Paragraph A ..........
2. Paragraph B ..........
3. Paragraph C ..........
4. Paragraph D ..........
5. Paragraph E ..........
6. Paragraph F ..........

**Task 2. Find the missing words in the text to complete the collocations.**

| | |
|---|---|
| ………. | *mechanics* |
| | *electrodynamics* |
| | *optics* |
| | *tunnelling* |
| | *physics* |

| | |
|---|---|
| quantum | …………. |
| Unified | |
| String | |

**Task 3. Fill in the gaps using the words from the box.**

| |
|---|
| • realms • multiple • constraints • decimal places • reconcile • in the realm of |

1. Attempts to ______________ the molecular and fossil evidence have proved controversial.
2. It is appropriate for applications with a fixed number of _______________ that do not then require this adjustment – particularly financial applications where 2 or 4 digits after the decimal point are usually enough.
3. Giddens examines three _______________ in particular: the experience of identity, connections of intimacy and political institutions.
4. The CPU ______________ are so great that every CPU cycle counts.
5. China had made great progress _______________ space technology and space science research in the past year.
6. IAEA also produces ______________ printed and electronic materials and videos illustrating its activities.

**Task 4. Rearrange the sentences in the table below so that the passage makes sense.**

| Number | Sentence |
|---|---|
| **1** | Why do we not ordinarily observe wave behavior for light, such as observed in Young's double slit experiment? |
| | Why did Young then pass the light through a double slit? |
| | Furthermore, Young first passed light from a single source (the Sun) through a single slit to make the light somewhat coherent |
| | The answer to this question is that two slits provide two coherent light sources that then interfere constructively or destructively |
| | First, light must interact with something small, such as the closely spaced slits used by Young, to show pronounced wave effects |
| | By coherent, we mean waves are in phase or have a definite phase relationship. Incoherent means the waves have random phase relationships |
| **7** | Young used sunlight, where each wavelength forms its own pattern, making the effect more difficult to see |

**Task 5. Find information about any phenomenon or law mentioned in the text and prepare a brief presentation about it.**

## 5.2. Some concepts of quantum physics

**Measurement.**

A measurement generally makes a strong perturbation of a quantum system except if it is already in a quantum state that is an eigenvalue of the observable. Indeed, before the measurement we have some probability to obtain an eigenvalue of the operator but, after the measurement, we are sure of the result (a subsequent similar measurement would lead to the same result) which means that the wave function has been changed by the measurement: after measurement it is the eigenvector of the operator associated to the measured eigenvalue.

**Wave function.**

A wave function is complex (it has a real and an imaginary part). However, we know that any measurements performed on a system in our world always gives real numbers. This is why the operators describing an observable are hermitic. Indeed, these operators have real eigenvalues and the result of any measurement on the system is an eigenvalue of the operator associated to the observable. If we consider a particle, the wave function, $\Psi (x, y, z, t)$, is the *probability amplitude* for finding the particle at a given point in space and at a given time. The probability of finding the particle at point $(x, y, z)$ and at time $t$ is the square of the modulus of the wave function $\Psi$ or of the product $\Psi \Psi^*$, where $\Psi^*$ is the complex conjugate of $\Psi$:

*Probability* $\sim | \Psi |^2 = \Psi \Psi^*$

Since the probability of finding the particle somewhere in space is 1, the wave function should be normalized: the sum of the probability over all space should be equal to 1.

**Quantization.**

The most striking feature of the quantum world is the fact that some observables have discontinuous values. In classical mechanics, the kinetic energy of a corpuscle confined within a harmonic oscillator (a classical spring is an example of harmonic oscillator) or confined within a cubic box can have any value starting from zero to the maximum value we can give to it. This means that energy values are continuous. In quantum mechanics this is no longer true. The energy can only take fixed values.

This comes from the fact that the Schrödinger equation is a partial differential equation that has to be solved with boundary conditions. As a result all energies are, in most cases, not allowed and discrete values only are possible. This is exactly what happens at the macroscopic level with a guitar that can only produce sounds of discrete frequencies. This reflects once more the wave character of particles.

**Spin.**

A degree of freedom of a particle is an internal degree of freedom if it does not depend on its spatial position. This is the case for *spin,* which is an internal degree of freedom with no classical equivalent. It has the properties of an angular momentum and follows the rules of angular momenta in quantum physics. Electrons or protons, for example have a spin $S = s\hbar = \frac{1}{2}\hbar$. It is said that their spin is $s = \frac{1}{2}$. It is like a vector but its projections on an axis are quantized. The value of the projection of this vector on an axis can take only two values: $-\frac{1}{2}\hbar$ and $+\frac{1}{2}\hbar$. Spintronics (spin transport electronics) is a new technology exploiting the spin of the electron and its associated magnetic momentum. Spintronics allows an efficient treatment of information at low energy cost.

**Quantum Tunneling.**

If a classical particle is on one side of a potential barrier and has a kinetic energy lower than the top of the barrier it cannot go to the other side. At the microscopic level this is no longer true and a particle has some probability to escape even if its kinetic energy is smaller than the top of the potential barrier. This phenomenon, called *quantum tunneling,* does not exist for a classical corpuscle. The escape probability depends on the properties of the particle, on the difference between the height of the barrier and the energy of the particle, and on the thickness of the barrier. This probability increases, for example, if the width of the barrier decreases.

We know that classical waves can also penetrate "forbidden" regions. A so-called *evanescent wave* is for example observed for electromagnetic waves in the microwave region or in optics and acoustics. An evanescent wave is a standing wave with an intensity decaying, in the forbidden region, exponentially with the distance to the boundary where it has been formed. Since a particle can behave like a wave, it can also go into the forbidden region and eventually escape to another allowed region if the conditions are fulfilled. A *scanning tunneling microscope* is based on the tunneling of electron waves.

**Task 1. Say whether these statements are True, False or Not Stated.**

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1 | It is impossible to obtain an eigenvalue of the operator before the measurement | | | |
| 2 | The probability of finding the particle somewhere in space is hard to estimate | | | |
| 3 | Values the energy can take are proportional to the particle charge | | | |
| 4 | It is possible to treat information efficiently thanks to Spintronics | | | |
| 5 | Properties of the particle are among the factors that determine escape probability | | | |
| 6 | In classical mechanics, waves cannot penetrate “forbidden” regions | | | |

**Task 2. Find the missing parts of collocations from the text.**

| | |
|---|---|
| 1. __________ part | 6. __________ momentum |
| 2. potential __________ | 7. kinetic __________ |
| 3. __________ function | 8. __________ of information |
| 4. Schrödinger __________ | 9. standing __________ |
| 5. real __________ | 10. __________ frequencies |

**Task 3. Choose the correct alternative.**

1. A parabolic element has only a single ___________ , which is either 1 or -1.

a) eigenvalue b) intensity

2. The mass spectrometer can determine the proportion of each isotope in the sample by measuring the ___________ of the different beams of ions.

a) eigenvalue b) intensity

3. In the Einstein model, each atom oscillates independently – a series of equally spaced ___________ states for each oscillator.

a) quantized b) discrete

4. An algorithm operating on data that represents continuous quantities, even though this data is represented by ___________ approximations.

a) quantized b) discrete

5. Almost all matter ___________ from the Earth seems to be made of matter rather than antimatter.

a) observation b) observable

**Task 4. Read the text and fill the gaps in the tables after it.**

**What are quantum dots?**

Quantum dots (QDs) are man-made nanoscale crystals that can transport electrons. When UV light hits these semiconducting nanoparticles, they can emit light of various colors. These artificial semiconductor nanoparticles that have found applications in composites, solar cells and fluorescent biological labels.

Nanoparticles of semiconductors – quantum dots – were theorized in the 1970s and initially created in the early 1980s. If semiconductor particles are made small enough, quantum effects come into play, which limit the energies at which electrons and holes (the absence of an electron) can exist in the particles. As energy is related to wavelength (or color), this means that the optical properties of the particle can be finely tuned depending on its size. Thus, particles can be made to emit or absorb specific wavelengths (colors) of light, merely by controlling their size.

| **Word** | **Antonyms from the text** |
|---|---|
| | man-made, artificial |
| absorb | |
| | various |
| finally | |
| | limit |

| **Word(s)** | **Synonyms from the text** |
|---|---|
| | initially |
| restrict | |
| | to tune |
| hence | |
| | specific |

## V.8. Schrödinger cat: a thought experiment in quantum mechanics

**Task 1. Watch the video. For questions 1–6, complete the sentences with a word or short phrase.**

1. ___________________ suggests that the cat is either alive or dead.

2. The quantum phenomenon of superposition is a consequence of the __________________________ particle and wave nature of everything.

3. This shows that the ___________________________ is a result of each electron going through both slits at the same time.

4. This superposition of ___________________________ also leads to modern technology.

5. An electron near the nucleus of an atom exists in a spread-out, wave-like ___________________________ .

6. This is how some ___________________________ bonds form.

**Task 2. Answer the questions below.**

1. Why can quantum particles occupy more than one state at the same time?

2. Why do we see wave behavior in electrons but not in cats?

3. What an electron in the vicinity of two nearby atoms will be orbiting?

4. What determines the behavior of electrons moving through solid objects?

5. Why is quantum physics important for computer technology?

**Task 3. Discuss the question below in pairs.**

Physicists have spent decades arguing about the philosophical implications of Schrödinger's cat. What is the best way to reconcile these with everyday reality?

## 5.3. Mesoscopic Physics

"Mesoscopic Physics" is a relatively new branch of physics dedicated to the world between the macroscopic and the microscopic world. "Meso" is Greek and means "in between". Macroscopic and mesoscopic objects have in common that they both contain a large number of particles. While a macroscopic object obeys the laws of classical mechanics and can be described by the properties of the material from which it is made, when scaled down to the mesoscopic level this is no longer true. As we decrease the dimension of a system, changes in the behavior of the system can occur, so some effects which were negligible can become prominent. Indeed, surface, adhesive, and friction effects become significant. At low dimensions, the surface becomes more and more important compared to the volume. For example, a lump of aluminum is difficult to burn, but when ground into a powder of fine particles – with a much larger global surface area – it burns easily and may even explode due to the much larger surface in contact with oxygen molecules.

To obtain a feeling for the evolution of physical quantities as we scale down the dimension of a system, we shall suppose that it is characterized by a "length" $L$. As the size of a system decreases, the surface becomes more and more important compared to the volume. Indeed, the surface varies with $L^2$ whereas the volume varies with $L^3$. Therefore the volume/surface ratio scales with $L$, so that the volume properties dominate for large $L$ and the surface for small $L$. Surface effects are dominating the physics at low dimensions. The example below illustrates this point.

**Reducing the size of objects enhances surface effects**

*The surface of a cube with a side of 1 cm has an area of 6 cm*$^2$*. If this cube is cut into nanocubes with a side of 1 nm, there will be* $10^{21}$ *nanocubes with an area of* $6 \times 10^{-14}$ *cm*$^2$ *each. This will represent a global area of 6,000 m*$^2$*, even though the total overall volume of material is the same as our original cube.*

At the nanoscale, the gravitational force (responsible for the weight of objects, for example) becomes negligible compared to the adhesive forces between two surfaces. This is due to the fact that adhesive forces vary with $L^2$ while gravitational forces vary with $L^3$. The main adhesive forces between two surfaces separated by a distance ≈ 2–10 nm comes from the van der Waals forces. Pinch forces, which correspond to adhesive and friction phenomena, are also more and more important at low dimensions compared to gravitational forces. In that case, resonating nanoscale objects are also characterized by larger frequencies compared to macroscopic objects.

If we now consider fluids, viscous forces are more important. This explains in particular why a micro- or nanoparticle standing in calm air remains motionless. For macroscopic fluids, we know that when the speed of a fluid increases, turbulence appears and there is a transition from laminar to turbulent flow. Turbulence is important to mix fluids of different nature. At the micro- or nanoscale level turbulence cannot be reached anymore and, compared to the macroscopic scale, a fluid behaves more like honey than like water. This makes it difficult to mix different fluids by standard methods.

**Task 1. Read the text and choose the correct alternative.**

**1.** At low dimensions, the surface becomes

a) is less important than the volume.

b) more important than the volume.

c) as important as the volume.

**2.** Volume properties are more significant with

a) a large size.

b) a small size.

c) a constant size.

**3.** At the nanoscale gravitational force

a) is crucial.

b) can not be neglected.

c) can be neglected.

**4.** Van der Waals forces between two surfaces separated by a distance ≈ 2–10 nm

a) affect adhesive forces.

b) cause adhesive forces.

c) dominate adhesive forces.

**5.** Viscous forces are of significance

a) in solid bodies.

b) in liquids.

c) in nanoparticles.

**6.** What makes mixing different fluids by standard methods difficult at the nanoscale level?

a) absence of turbulence.

b) presence of turbulence.

c) neither a) nor b).

**Task 2. Find the words in text matching the definitions below.**

1. ______________ = effects associated with, or only encountered near, a surface.

2. ______________ = attractive forces between unlike substance, such as mechanical forces (sticking together) and electrostatic forces (attraction due to opposing charges).

3. ______________ = weak intermolecular forces that are dependent on the distance between atoms or molecules.

4. ______________ = the weakest of the four fundamental forces of nature, being the attractive force that arises from gravitational interaction.

5. ______________ = the forces between a body and a fluid (liquid or gas) moving past it, in a direction so as to oppose the flow of the fluid past the object.

6. ______________ = disturbance in a gas or fluid, characterized by evidence of internal motion or unrest.

**Task 3. Fill in the gaps using the words from the box.**

| |
|---|
| • resonated • negligible • ratios • motionless • prominent |

1. The difference between the two products is __________.
2. She plays a __________ role in the organization.
3. The company was performing well according to all the key __________.
4. The noise of the bell __________ through the building.
5. If the channel termination were __________, a wave would be reflected away from the termination when a wave was incident upon it.

**Task 4. For questions 1–8, read the text below and decide which answer (A, B, C or D) best fits each gap.**

Modern technology **(1)** ………. more and more at a scale where quantum effects are important and significant. **(2)** ………. our everyday life interaction with macroscopic objects, we have built our intuition for the physics of everyday life. At the micro- or nanoscale, new concepts, which were not **(3)** ………. at our macroscopic scale in **(4)** ………. physics, become important and our intuition may often be misleading. This does not mean that the physical **(5)** ………. are different, but that some effects, negligible at the macroscopic scale, become prominent at the nanoscale. Quantum effects can become significant **(6)** ………. to a profound change in the technologies by imposing substantial restrictions or new possibilities. Downscaling systems can give **(7)** ………. to novel opportunities useful for everyday life applications and we **(8)** ………. present some of them in the rest of the book.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***1*** | ***A*** | *works* | ***B*** | *operates* | ***C*** | *uses* | ***D*** | *plays* |
| ***2*** | ***A*** | *Past* | ***B*** | *Over* | ***C*** | *Across* | ***D*** | *Through* |
| ***3*** | ***A*** | *visual* | ***B*** | *virtual* | ***C*** | *visible* | ***D*** | *vivid* |
| ***4*** | ***A*** | *classical* | ***B*** | *convenient* | ***C*** | *ordinary* | ***D*** | *casual* |
| ***5*** | ***A*** | *rules* | ***B*** | *amendments* | ***C*** | *laws* | ***D*** | *norms* |
| ***6*** | ***A*** | *causing* | ***B*** | *leading* | ***C*** | *resulting* | ***D*** | *affecting* |
| ***7*** | ***A*** | *peak* | ***B*** | *rise* | ***C*** | *height* | ***D*** | *rocket* |
| ***8*** | ***A*** | *shall* | ***B*** | *will* | ***C*** | *are going to* | ***D*** | *are to* |

## Revision and consolidation (Unit 5)

**Grammar revision (Passive).**

**Task 1. Choose the correct alternative and explain your choice.**

1. Chemistry, material science, biotechnology – *this is what is offered/this is what will be offered* in this master programme.

2. Platinum *is being used/is used* in both the reduction and the oxidation catalysts.

3. The term "nano-technology" *had been first used/was first used* by Norio Taniguchi in 1974.

4. A various number of multifunctional particles for medical *applications has finally been successfully produced/were finally produced* in manufacturing quantities.

5. A new type of electronic equipment *had been given/was being given* much attention to even before it was first presented at the conference.

6. The final test *will be conducted/will be conducting* as soon as we receive the missing chemicals.

7. Currently much new information *has been accumulated/is being accumulated* on solar radiation.

8. While this *article had been written/was being written* few controversies occurred and test had to be carried out again.

9. We were assured that the temperatures *will have been estimated/will be estimated* by the end of the month.

10. *The electric motor may be relied upon/Upon electric motor may be relied,* for it is of the latest design.

**Vocabulary revision.**

**Task 2. Fill in the gaps using the words from the box.**

| |
|---|
| • dual • momentum • existence • founders • probability • slits • thought • instant |

1. Austrian physicist Erwin Schrödinger is one of the __________ of quantum mechanics, but he's most famous for something he never actually did: a __________ experiment involving a cat.

2. Until then, the cat is a blur of __________, half one thing and half the other.

3. We don't see these wave properties for everyday objects because the wavelength decreases as the __________ increases.

4. A tiny particle, like an electron, though, can show dramatic evidence of its __________ nature.

5. If we shoot electrons one at a time at a set of two narrow __________ cut in a barrier, each electron on the far side is detected at a single place at a specific __________, like a particle.

6. At a very deep level, though, the Internet owes its __________ to an Austrian physicist and his imaginary cat.

**Task 3. Choose the correct alternative to match the definition.**

1. A vector quantity that is a measure of the torque exerted on a magnetic system when placed in a magnetic field is called

**a)** electric moment. **b)** magnetic moment. **c)** spin.

2. A long narrow cut is called

**a)** gap. **b)** slit. **c)** crack.

3. A substance that has an electrical conductivity that increases with temperature and is intermediate between that of a metal and an insulator is called

**a)** conductor. **b)** insulator. **c)** semiconductor.

4. Tiny semiconductor particles a few nanometres in size that having optical and electronic properties that differ from larger particles are called

**a)** quantum dots. **b)** nanoparticles. **c)** quantum wires.

5. The principle in quantum physics where multiple objects exist in states that are linked together across space is called

**a)** wave-particle duality, **b)** quantum tunnelling. **c)** quantum entanglement.

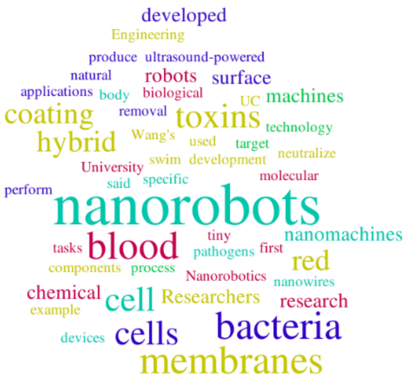
6. The combination of two distinct physical phenomena of the same type (such as spin or wavelength) so that they coexist as part of the same event is called

**a)** probability. **b)** superposition. **c)** overlapping.

## Task 4. Fill in the gaps, use dictionary if necessary.

| Latest Developments | | Последние разработки |
|---|---|---|
| 1 | Further **advances** since 2014 show that new technologies which utilize quantum behavior for ……………. and other applications are closer to being realized | Дальнейшие ………… начиная с 2014 года показывают, что новые технологии, использующие квантовое поведение для **вычислений** и других приложений, стали ближе к реализации |
| 2 | These advancements will help to create highly powerful computers as well as **highly sensitive** detectors which can be used to ……………. biological systems | Эти достижения помогут создать очень мощные компьютеры, а также ……………. детекторы, которые можно использовать для **исследования** биологических систем |
| 3 | There are two other significant ……………. . | Есть два других важных **прорыва**. |
| 4 | The first is the ability to control quantum **units of information** called quantum bits, or ………… at room temperature | Первый прорыв – это способность контролировать квантовые ……………. , называемые квантовыми битами или **кубитами** при комнатной температуре |
| 5 | Previously, temperatures close to **absolute zero** were required, but the creation of new ……………. material has allowed spin qubits to be operated at room temperature | Ранее требовались температуры, близкие к ……………. ………, но создание нового материала **на основе алмаза** позволило работать с кубитами при комнатной температуре |
| 6 | The **imaging** of single molecules has therefore been made possible by diamond-based sensors – as demonstrated by Awschalom ……………. researchers at Stanford University and IBM Research | Таким образом, ……………. отдельных молекул стала возможной благодаря сенсорам на алмазной основе, что продемонстрировали Авшалом, **а также** исследователи из Стэнфордского университета и IBM Research |
| 7 | The second breakthrough is the **ability** to control these quantum bits for several seconds before they ……………. normally | Вторым прорывом является ……………. контролировать эти квантовые биты в течение нескольких секунд, прежде чем они будут **вести себя** нормально |
| 8 | **Highly pure** forms of silicon have helped researchers control a quantum mechanical property called ……………. | ……………. формы кремния помогли исследователям контролировать квантово-механическое свойство, называемое **спином** |
| 9 | At Princeton, a team of researchers showed spin could be controlled in ……………. of electrons for several seconds **using** highly pure silicon-28 | В Принстоне команда исследователей показала, что вращение можно контролировать в **миллиардах** электронов в течение нескольких секунд ……………. высокочистого кремния-28 |

# Unit 6 – Nanorobots




## 6.1 Nanorobots: Where We Are Today and Why Their Future Has Amazing Potential

**Different Types of Nanorobots and Applications.**

There are many different types of nanorobots – here are just a few.

1. Smallest engine ever created: "A group of physicists from the University of Mainz in Germany recently built the smallest engine ever created from just a single atom. Like any other engine, it converts heat energy into movement – but it does so on a smaller scale than ever seen before. The atom is trapped in a cone of electromagnetic energy and lasers are used to heat it up and cool it down, which causes the atom to move back and forth in the cone like an engine piston".

2. 3D-motion nanomachines from DNA: "Mechanical engineers at Ohio State University have designed and constructed complex nanoscale mechanical parts using 'DNA origami' – proving that the same basic design principles that apply to typical full-size machine parts can now also be applied to DNA – and can produce complex, controllable components for future nanorobots".

3. Nanoswimmers: "ETH Zurich and Technion researchers have developed an elastic 'nanoswimmer' polypyrrole (Ppy) nanowire about 15 micrometers (millionths of a meter) long and 200 nanometers thick that can move through biological fluid environments at almost 15 micrometers per second…The nanoswimmers could be functionalized to deliver drugs and magnetically controlled to swim through the bloodstream to target cancer cells, for example".

4. Ant-like nanoengine with 100x force per unit weight: "University of Cambridge researchers have developed a tiny engine capable of a

force per unit-weight nearly 100 times higher than any motor or muscle. The new nano-engines could lead to nanorobots small enough to enter living cells to fight disease, the researchers say. Professor Jeremy Baumberg from the Cavendish Laboratory, who led the research, has named the devices ‘actuating nanotransducers’ (ANTs). ‘Like real ants, they produce large forces for their weight…’"

5. Bacteria-powered robots: "Drexel University engineers have developed a method for using electric fields to help microscopic bacteria-powered robots detect obstacles in their environment and navigate around them. Uses include delivering medication, manipulating stem cells to direct their growth, or building a microstructure, for example".

6. Nanorockets: "Several groups of researchers have recently constructed a high-speed, remote-controlled nanoscale version of a rocket by combining nanoparticles with biological molecules…The researchers hope to develop the rocket so it can be used in any environment; for example, to deliver drugs to a target area of the body".

**Key Applications of Nano and Micro-Machines.**

The applications of these nano and micro-machines are nearly endless.

Cancer Treatment: Identifying and destroying cancer cells more accurately and effectively.

Drug Delivery Mechanisms: Targeted drug delivery mechanisms for disease control and prevention.

Medical Imaging: Creating nanoparticles that gather in certain tissues and then scanning the body with a magnetic resonance imaging (MRI) could help highlight problems such as diabetes.

New Sensing Devices: With near limitless customizable sensing properties, nanorobotics would unlock new sensing capabilities we can integrate into our systems to monitor and measure the world around us.

Information Storage Devices: A bioengineer and geneticist at Harvard’s Wyss Institute have successfully stored 5.5 petabits of data – around 700 terabytes – in a single gram of DNA, smashing the previous DNA data density record by a thousand times.

New Energy Systems: Nanorobotics might play a role in developing more efficient renewable energy system. Or they could make our current machines more energy efficient such that they’d need less energy to operate at the same or high capacities.

Super-strong Metamaterials: There is lots of research going into these metamaterials. A team out of Caltech developed a new type of material, made up of nanoscale struts crisscrossed like the struts of a tiny Eiffel Tower, that is one of the strongest and lightest substances ever made.

Smart Windows and Walls: Electrochromic devices, which dynamically change color under applied potential, are widely studied for use in energy-efficient smart windows – these can control the internal temperature of a room, clean themselves, and more.

Ocean-cleaning Microsponges: A carbon nanotube sponge capable of soaking up water contaminants such as fertilizers, pesticides and pharmaceuticals more than three times more efficiently than previous efforts has been presented in a study published in IOP Publishing's journal Nanotechnology.

Replicators: Also known as a "Molecular Assembler," this is a proposed device able to guide chemical reactions by positioning reactive molecules with atomic precision.

Health Sensors: These sensors could monitor our blood chemistry, notify us when something is out of whack, detect spoiled food or inflammation in the body, and more.

Connecting Our Brains to the Internet: Ray Kurzweil believes nanorobots will allow us to connect our biological nervous system to the cloud by 2030.

Task 1. Say whether these statements are True, False or Not Stated.

| | Statement | True | False | Not Stated |
|---|---|---|---|---|
| 1 | The smallest engine ever created resembles already existing type of engine | | | |
| 2 | The nanoswimmers can be used for drug delivery and medical examination | | | |
| 3 | Ant-like nanoengines may enable creating nanorobots small enough to fight diseases in vivo | | | |
| 4 | Bacteria-powered robots are widely used on an everyday basis | | | |
| 5 | Nanorobotics has unlimited potential in various fields | | | |
| 6 | Electrochromic devices change their colour depending on the temperature | | | |

**Task 2. Find the second part of collocations from the text.**

| | |
|---|---|
| 1. engine | struts |
| 2. unit | energy |
| 3. nanoscale | cells |
| 4. water | weight |
| 5. stem | precision |
| 6. atomic | piston |
| 7. data | contaminants |
| 8. renewable | density |

**Task 3. Fill in the table.**

| Noun | Adjective | Adverb | Verb |
|---|---|---|---|
| | conical | | – |
| | controllable | | control |
| function | | functionally | |
| | | – | replicate |
| integrity; integral | | | integrate |
| sensing; sensor | | sensibly | |

**Task 4. Fill in the gaps using the word combinations from the box below.**

• reach • at scale • sustainable development • fruitful • attention • diminish • faces • markets

Nanotechnology has the potential to solve some of the biggest problems that the world ________________ today.

A National Science Foundation report notes, "…Nanotechnology has the potential to enhance human performance, to bring ________________ for materials, water, energy, and food, to protect against unknown bacteria and viruses, and even to ________________ the reasons for breaking the peace".

If this wasn't exciting enough, the ________________ for nanotechnology are, as you might imagine, massive.

It has been forecasted that the global nanotechnology industry will grow to ________________ $75.8 billion (USD) by 2020.

As an entrepreneur, you need to be paying ________________ to these developments – there will be extraordinarily ________________ opportunities in actually building business cases around these technological developments and deploying them ________________.

## 6.2. Cell-like nanorobots clear bacteria and toxins from blood

Engineers at the University of California San Diego have developed tiny ultrasound-powered robots that can swim through blood, removing harmful bacteria along with the toxins they produce. These proof-of-concept nanorobots could one day offer a safe and efficient way to detoxify and decontaminate biological fluids.

Researchers built the nanorobots by coating gold nanowires with a hybrid of platelet and red blood cell membranes. This hybrid cell membrane coating allows the nanorobots to perform the tasks of two different cells at once – platelets, which bind pathogens like MRSA bacteria (an antibiotic-resistant strain of Staphylococcus aureus), and red blood cells, which absorb and neutralize the toxins produced by these bacteria. The gold body of the nanorobots responds to ultrasound, which gives them the ability to swim around rapidly without chemical fuel. This mobility helps the nanorobots efficiently mix with their targets (bacteria and toxins) in blood and speed up detoxification.

The work, published in Science Robotics ("Hybrid biomembrane-functionalized nanorobots for concurrent removal of pathogenic bacteria and toxins"), combines technologies pioneered by Joseph Wang and Liangfang Zhang, professors in the Department of NanoEngineering at the UC San Diego Jacobs School of Engineering. Wang's team developed the ultrasound-powered nanorobots, and Zhang's team invented the technology to coat nanoparticles in natural cell membranes.

"By integrating natural cell coatings onto synthetic nanomachines, we can impart new capabilities on tiny robots such as removal of pathogens and toxins from the body and from other matrices", said Wang. "This is a proof-of-concept platform for diverse therapeutic and biodetoxification applications".

"The idea is to create multifunctional nanorobots that can perform as many different tasks at once", said co-first author Berta Esteban-Fernández de Ávila, a postdoctoral scholar in Wang's research group at UC San Diego. "Combining platelet and red blood cell membranes into each nanorobot coating is synergistic – platelets target bacteria, while red blood cells target and neutralize the toxins those bacteria produce".

The coating also protects the nanorobots from a process known as biofouling – when proteins collect onto the surface of foreign objects and prevent them from operating normally.

Researchers created the hybrid coating by first separating entire membranes from platelets and red blood cells. They then applied high-frequency sound waves to fuse the membranes together. Since the membranes were taken from actual cells, they contain all their original cell surface protein functions. To make the nanorobots, researchers coated the hybrid membranes onto gold nanowires using specific surface chemistry.

The nanorobots are about 25 times smaller than the width of a human hair. They can travel up to 35 micrometers per second in blood when powered by ultrasound. In tests, researchers used the nanorobots to treat blood samples contaminated with MRSA and their toxins. After 5 minutes, these blood samples had three times less bacteria and toxins than untreated samples.

The work is still at an early stage. Researchers note that the ultimate goal is not to use the nanorobots specifically for treating MRSA infections, but more generally for detoxifying biological fluids. Future work includes tests in live animals. The team is also working on making nanorobots out of biodegradable materials instead of gold.

***Task 1. Answer the questions about the text.***

1. What does hybrid cell membrane coating make possible?
2. What are the targets that nanorobots are supposed to mix with?
3. What did Wang's team develop?
4. What is the result of combining platelet and red blood cell membranes into each nanorobot coating?
5. Why is it important to protect the nanorobots from biofouling?
6. What was used to fuse the membranes together?
7. What can replace gold in producing nanorobots?

**Task 2. Fill in the gaps using the words from the box.**

| • scholar • pioneered by • detoxify • fuse • coated • synthetic |
|---|

1. Ozone can be used to __________ cyanide wastes by oxidizing cyanide to cyanate and eventually to carbon dioxide.
2. Modern smokeless powder is __________ in graphite to prevent the buildup of static charge.
3. So the problem is, those two nuclei, they are both positively charged, so they don't want to __________.
4. However, one classic __________ offers an alternative interpretation
5. Some __________ polymers such as polyethylene and polypropylene are alkanes with chains containing hundreds of thousands of carbon atoms.
6. Electrothermal atomizers using graphite tube atomizers was __________ a Russian scientist.

**Task 3. Match the beginnings and endings of the sentences.**

| | |
|---|---|
| **1.** This hybrid design approach significantly reduced the development | **a)** and plastids bound in one or more membranes. |
| **2.** Hypercoagulable state (thrombophilia) results from defects in regulation of platelet | **b)** and tooling cost and time for the new model. |
| **3.** Some phagocytes kill the ingested pathogen | **c)** to attachment by macrofoulers living in the seawater. |
| **4.** Medical acoustics Anisotropy is also a well-known property in medical ultrasound | **d)** with oxidants and nitric oxide. |
| **5.** All true algae therefore have a nucleus enclosed within a membrane | **e)** or clotting factor function and can cause thrombosis. |
| **6.** Additionally, they have a high inherent biofouling resistance | **f)** imaging describing a different resulting echogenicity of soft tissues. |

**Task 4. Match the words with their definitions.**

| | |
|---|---|
| 1. variable /n/ | a) a formal set of ideas that is intended to explain why something happens or exists |
| 2. source /n/ | b) closely connected with the subject you are discussing or the situation you are thinking about; having ideas that are valuable and useful to people in their lives and work |
| 3. relevant /adj/ | c) made of many different things or parts that are connected; |
| 4. theory /n/ | d) a situation, number or quantity that can vary or be varied |
| 5. sustainable /adj/ | e) a person, book or document that provides information, especially for study, a piece of written work or news |
| 6. complex /adj/ | |

## V.9. Nanorobots propel through the eye

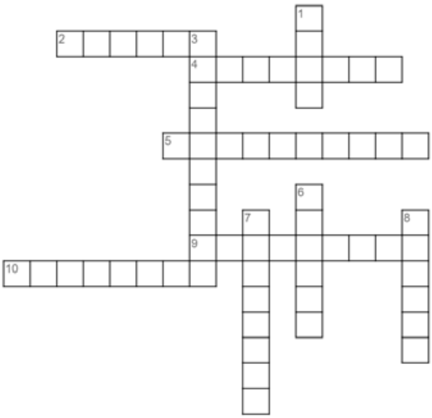
### Task 1. Match the words with their definitions.

| | |
|---|---|
| **1.** vitreous | **a)** the area at the back of the eye that receives light and sends pictures of what the eye sees to the brain |
| **2.** tissue | **b)** the ability to stick |
| **3.** vision | **c)** (a piece of) material like a net with spaces in it, made from wire, plastic, or thread |
| **4.** to translate | **d)** to cause something to move forward |
| **5.** retina | **e)** the largest structure within the eye, comprising 80% of its volume |
| **6.** to propel | **f)** an idea or mental image of something |
| **7.** adhesion | **g)** a group of connected cells in an animal or plant that are similar to each other, have the same purpose |
| **8.** to steer | **h)** a force that pushes something forward |
| **9.** propulsion | **i)** to change something into a different form; to transform or convert |
| **10.** mesh | **j)** to make something or someone go in a particular direction |

**Task 2. Answer the questions about the video.**

1. Were nanopropellers able to travel through real tissue?
2. What is an important part of a modeled nanopropeller?
3. What company developed a sophisticated 3D process of manufacturing different types of nanorobots?
4. Why is it difficult to add a special coating to nanorobots?
5. Why is Teflon coating crucial for the efficient propulsion of the robots inside the eye?

**Task 3. Fill in the gaps and do a crossword puzzle. Use the words from the video and Task 1.**




| Across | | Down | |
|---|---|---|---|
| 2 | Turning that ________ into a practical reality is not easy | 1 | Here we show that a membrane composed of a covalent molecular _____________ can filter mixtures of small molecules in a liquid |
| 4 | At this stage a resin is used with a high level of _____________ | 3 | Nanomedicine would make use of these _____________, introduced into the body, to repair or detect damages and infections |
| 5 | Instead – without the rocket _____________ provided by the engines – the craft is falling freely | 6 | Soft _____________ , such as flesh, allows X-rays through |
| 9 | Reforming Warsaw's stagnant economy requires harsh measures that would __________ into job losses | 7 | The electricity creates its own _____________ field |
| 10 | The _____________ was removed and the retina was cut in half | 8 | They are then placed on an artificial membrane which is inserted in the back of the _____________ |

## Revision and consolidation (Unit 6)

**Grammar revision (Gerund&Infinitive).**

**Task 1. Choose the correct alternative and explain your choice.**

1. Nanotechnology may have the ability to make existing medical applications cheaper and easier *to use/using* in places like the general practitioner's office and at home.
2. Scientists are now turning to nanotechnology in an attempt *developing/to develop* diesel engines with cleaner exhaust fumes.
3. Nanobots are capable of *carrying/to carry* out logic functions to achieve targeted drug delivery
4. Further applications allow tennis balls *to last/lasting* longer, golf balls *to fly/flying* straighter, and even bowling balls *to become/becoming* more durable and have a harder surface.
5. The contacts between metals and insulators are likely *being small enough/to be small enough* for any current to pass.
6. After finishing with the graphene samples, he went on *testing/to test* the carbon nanotubes.
7. The author *went on giving/went on to give* his speech after a few questions.
8. I can't help *wondering/to wonder* what the future will be like with all new nano advancements.
9. I remember *locking/to lock* the door and *closing/to close* the windows when leaving the laboratory.
10. He chanced *to have observed/having observed* this phenomenon.

**Vocabulary revision.**

**Task 2. Fill in the gaps using the words from the box.**

| • vision • bound • tissue • retina • coating • steer |
|---|

1. For the first time ever, scientists have been able to ______________ nanorobots through dense tissue prevalent inside the vitreous of the eye.
2. Nanopropellers were only able to travel through models or fluids, but not through real ______________.
3. Now that it is possible to magnetically steer robots through an eye towards the ______________.
4. It's still a ______________ but the scientists are working hard to soon make this a reality.
5. The ______________ is very important and was developed by Zhiguang Wu and it consists of two layers.
6. There is first a solid layer, which is chemically ______________ followed by a liquid oil layer.

**Task 3. Read the text below. Use the word given in capital letters at the end of some of the lines to form a word that fits in the gap in the same line.**

| | |
|---|---|
| The use of **1)** ……………… nanorobots for health care and | PRACTICE |
| surgery instrumentation is an emerging technology considered | |
| as an advanced product currently in development to reach the | |
| marketplace in the **2)** ……………… years with potentially | COME |
| broad biomedical applications. The ongoing developments of | |
| molecular-scale electronics, sensors and motors are predicted | |
| to enable microscopic robots with dimensions | |
| **3)** ……………… to bacteria. | COMPARE |
| Recent developments on the field of biomolecular | |
| **4)** ……………… and nanoelectronics circuitry have | COMPUTE |
| demonstrated positively the **5)** ……………… of processing | FEASIBLE |
| logic tasks by bio-computers, which are promising steps to | |
| enable nanoprocessors with increasingly **6)** ……………… . | COMPLEX |
| Studies in the sense of building biosensors and nano-kinetic | |
| devices, which is required to enable practical nanorobot | |
| operation and locomotion, have been advanced recently too. | |
| Moreover, classical **7)** ……………… related to the real | OBJECT |
| feasibility of nanotechnology, such as quantum mechanics, | |
| thermal motions and friction, have been considered and resolved | |
| and discussions about the manufacturing of nanodevices is | |
| growing up. Developing nanoscale robots presents difficult | |
| fabrication and control challenges. The development of complex | |
| **8)** ……………… nanosystems and manufacturing of devices | INTEGRITY |
| with high performance can be well **9)** ……………… and | INVESTIGATION |
| addressed via computer aided manufacturing analysis, helping | |
| pave the way for future use of nanorobots in biomedical | |
| **10)** ……………… problems. | ENGINEER |

## Task 4. Fill in the gaps, use dictionary if necessary.

| | | |
|---|---|---|
| 1 | **Nanomedicines** used for drug delivery, are …………… nano scale particles or molecules which can improve drug bioavailability | …………… , используемые для доставки медикаментов, **состоят** из наноразмерных частиц или молекул, которые могут улучшить биодоступность лекарства |
| 2 | For …………… bioavailability both at specific places in the body and over a period of time, **molecular** targeting is done by nano engineered devices such as nano robots | Для **максимизации** биодоступности как в определенных местах тела, так и в течение определенного периода времени, …………… нацеливание осуществляется с помощью наноустройств, таких как нанороботы |
| 3 | The molecules are targeted and delivering of drugs is done with cell …………… | Молекулы нацеливаются, и доставка лекарств осуществляется с **точностью до** клетки |
| 4 | In vivo imaging is another area where …………… and devises are being developed | Визуализация in vivo — это ещё одна область, в которой разрабатываются **наноинструменты** и устройства |
| 5 | Using nano particle images such as in …………… and MRI, nano particles are used **as** contrast | Изображения наночастиц, полученные при помощи **ультразвука** и магнитно-резонансной томографии (МРТ), используются ……………  контраста |
| 6 | The nano engineered materials are being developed for effectively …………… illnesses and diseases such as cancer | Наноинженерные материалы разрабатываются для эффективного **лечения** болезней и заболеваний даже таких как рак |
| 7 | With the …………… of nanotechnology, **self-assembled** biocompatible nano devices can be created which will detect the cancerous cells and automatically …………… the disease, will cure and prepare reports | С **развитием** нанотехнологий могут быть созданы …………… биосовместимые наноустройства, которые будут обнаруживать раковые клетки, автоматически **оценивать** заболевание, лечить его и подготавливать отчеты |

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