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ENGLISH FOR STUDENTS OF PHYSICS AND ASTRONOMY

(PART 2. ELECTRICITY AND MAGNETISM, OPTICS, ATOMIC AND NUCLEAR PHYSICS)

МЕТОДИЧНІ ВКАЗІВКИ

до практичних та самостійних занять
з навчальної дисципліни «Іноземна мова
(за професійним спрямуванням)»
для здобувачів першого (бакалаврського) рівня вищої освіти
спеціальності 104 «Фізика та астрономія»

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Укладач:
Г. П. Кузнєцова, старший викладач кафедри іноземних мов професійного спрямування ОНУ імені І. І. Мечникова

Рецензенти:
Т. Л. Караваева, к. філол. н., доц. кафедри іноземних мов професійного спрямування ОНУ імені І. І. Мечникова;
Г. В. Ткаченко, к. філол. н., доц. кафедри лексикології та стилістики англійської мови ОНУ імені І. І. Мечникова

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Е56 **ENGLISH** FOR STUDENTS OF PHYSICS AND ASTRONOMY. (PART 2. ELECTRICITY AND MAGNETISM, OPTICS, ATOMIC AND NUCLEAR PHYSICS) : метод. вказівки до практичних та самостійних занять з навчальної дисципліни «Іноземна мова (за професійним спрямуванням)» для здобувачів першого (бакалаврського) рівня вищої освіти спеціальності 104 «Фізика та астрономія» / уклад. Г. П. Кузнєцова. – Одеса : Олді+, 2025. – 104 с.

Методичні вказівки до практичних занять містять тексти за спеціальністю, списки слів та термінів, вправи для виконання практичних завдань, теми для обговорювання.

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ВСТУП

Методичні вказівки «ENGLISH FOR STUDENTS OF PHYSICS AND ASTRONOMY. (PART 2. ELECTRICITY AND MAGNETISM, OPTICS, ATOMIC AND NUCLEAR PHYSICS» розроблені до практичних та самостійних занять з навчальної дисципліни «Іноземна мова (за професійним спрямуванням)» для здобувачів першого (бакалаврського) рівня вищої освіти денної форми навчання спеціальності 104 «Фізика та астрономія».

Метою курсу «Іноземна мова (за професійним спрямуванням) є формування у здобувачів комунікативної компетентності, необхідної для спілкування у знайомих / типових ситуаціях, які зустрічаються в академічному та професійному контекстах.

Методичні вказівки складаються з 10 розділів, в кожному є автентичний текст за спеціальністю, питання до тексту, перелік слів та термінів для удосконалення фахової лексики, лексичні вправи та вправи на переклад, а також завдання спрямовані на вдосконалення навичок пошуку інформації в Інтернеті, її відбору і критичного оцінювання.

Методичні вказівки допомагають створити умови для обговорення важливих питань з фізики та астрономії англійською мовою, допомагають підвищити ефективність професійного спілкування та формування у здобувачів комплексу знань, умінь, необхідних для подальшої професійної діяльності.

Unit 1.

I. Read and translate the text. Learn the new vocabulary

The History of Electricity

Learning about the history of electricity is a great way of putting into perspective how advanced modern technology really is. Who discovered electricity? Benjamin Franklin is credited for discovering electricity in the 1700s with his kite experiment, in which he flew a kite with a metal key tied to it during a thunderstorm.

In science, electricity and its history is a fascinating topic that can help understand how life has changed because of electricity.

600 BC	A Greek named Thales discovered that amber when rubbed with silk, attracted feathers and other light objects. This is static electricity. The Greek word for amber is 'ëelectron', which is where words such as 'electricity' and 'electron' come from.
1600	William Gilbert, who was a scientist and physician to Queen Elizabeth I, invented the term 'electricity'. He was the first person to recognise that there was a connection between magnetism and electricity, and the first to describe the Earth's magnetic field.
1700s	In the 1700s, machines to produce static electricity were first introduced. At first, they were just for fun and nicknamed 'parlour trick machines'. Over the century, they developed and advanced.
1705	Francis Hauksbee invented neon light. He created electrical effects by placing mercury into a glass globe, pumping out the air and spinning it.

	When he did this in the dark and then rubbed it with his bare hand, it glowed. He had invented neon light, without even knowing it.
1752	Benjamin Franklin, a famous U.S. politician, proved that lightning is a form of electricity by flying a kite with a metal tip into a thunderstorm.
1780	An Italian man named Luigi Galvani discovered that when he touched a dead frog's leg with a knife, it twitched violently. Later, Alessandro Volta showed that this was because electricity is created when moisture (from the frog) comes into contact with two different types of metal (the steel knife and a tin plate), then electricity is created.
1800	Alessandro Volta created the very first simple battery using pure silver and zinc discs, placed between muslin which was dampened with a salt solution. This was developed from Galvani's experiment with the frog's legs. During the same year, Sir Humphry Davy discovered electrolysis. When he passed an electrical current through some substances, they'd begin to decompose. This became known as electrolysis. Davy's experiments later led to the discovery of a range of elements, including calcium, magnesium, strontium, and barium.
1820	Magnetic fields caused by electricity were discovered. Hans Christian Oersted, from Denmark, found that when electricity flows through a wire, it generates a magnetic field which affects the needle of a nearby compass.
1821	Michael Faraday discovered that when a magnet is moved inside the coil of a copper wire, a tiny electric current flows through the wire. This discovery led to the invention of electric motors.

	In the same year, Thomas Johann Seebeck discovered thermo-electricity. He found that when the junctions of certain metals are heated, electricity flows through them.
1826	André Ampère published his theories about electricity and magnetism, explaining the electro-dynamic theory. He was the first person to explain this theory. The unit for electrical currents, ampere or amps, is named after him.
1827	A German college teacher named George Ohm published his complete mathematical theory of electricity. Now, the unit of electrical resistance (ohm) is named after him.
1829	Joseph Henry showed that a wire wrapped in coils produces a greater electromagnetism than a straight one.
1830	Joseph Henry discovered the principles of the dynamo — an electrical generator.
1831	Michael Faraday demonstrated electromagnetic induction by passing a magnet through a coil of wire. Charles Wheatstone and William Fothergill Cooke also created the first telegraph machine.
1834	Using a revolving mirror and four miles of wire, Charles Wheatstone successfully measured the velocity of electricity.
1838	Samuel Morse invented Morse Code at an exhibition in New York. He demonstrated sending 10 words a minute by his new telegraph machine.

1870s	Thomas Edison built a DC (direct current) electric generator. After this, he provided all of New York's electricity.
1876	Alexander Graham invented the telephone using electricity.
1878	A British scientist named Joseph Swan demonstrated the first electric light with a carbon filament lamp. Thomas Edison made the same discovery a few months later in America.
1880s	Nikola Tesla developed an AC (alternating current) motor and a system of AC power generation. Thomas Edison believed this to be a threat to his DC supply, so he spread stories that it wasn't safe to use. However, after Tesla's system was used to power 100,000 electric lights at Chicago's World Fair in 1893, AC became the established power supply in the USA. Tesla also invented the Tesla Coil. He used this coil to make ordinary household currents produce extremely high-frequency currents. This was used to develop some of the first neon and fluorescent lights. Between 1880 and 1883, the Wimshurst machine (an electrostatic generator) was developed for generating high voltages of electricity. It was invented by a British inventor named James Wimshurst.
1881	The first public electricity supply in the UK was generated in Godalming, Surrey, using a waterwheel at a mill.
1883	Magnus Volks built the first electric railway. It was opened on Brighton seafront. Named the Volks Railway, it was built just for pleasure rides, is one mile long and still runs during summer.

1884	Charles Parsons built the first turbine, a type of engine which uses jets of high-pressure gases to operate. This type of engine was later developed to drive boat propellers, including the ones on the Titanic.
1886	Heinrich Hertz produced and detected electric waves in the atmosphere.
1890	Turbine-driven generators were introduced to produce electricity.
1892	A Dutch physicist named Hendrik Lorentz published his electron theory.
1895	Wilhelm Fein invented the first electric hand drill. Wilhem Roentgen, a German physicist, discovered invisible rays that made a screen glow and passed through objects. These rays were X-rays.
1896	Nikola Tesla's hydroelectric power generators at Niagara Falls come into operation. Within a few years, these generators were supplying electricity to New York City for the elevated railways, the subways, and the lights on Broadway.
1897	Guglielmo Marconi sends a radio message from the Isle of Wight to Poole, which is 20 miles (ca. 32 km) away. He later sends a message across the Atlantic.
1905	Albert Einstein demonstrated that light energy could be used to produce electricity.
1918	Electric refrigerators and washing machines first become available.
1926	The first National Grid was introduced in the Electrical Supply Act.

1930s	In the 1930s and 1940s, hydroelectric power stations were built in Scotland and Wales, even though most electricity still came from burning coal. Household electrical appliances were introduced, and mains powered radios, vacuum cleaners, fridges, and irons became a part of almost every household by the 1940s.
1936	The television was invented by John Logie Baird.
1956	At Calder Hall in Cumbria, the world's first large-scale nuclear power station was opened. The reactors were a prototype of the Magnox gas-cooled reactor.
1960s	The UK developed advanced gas-cooled reactors to improve on the previous Magnox stations. France and the USA adopted water-cooled reactor technology.
1994	The UK's first pressurised water reactor (PWR) was opened at Sizewell B in Suffolk. It had taken 7 years to build.
2000	The world's first commercial wave power station, located on the Scottish island of Islay, began to generate electricity. Devices on the shoreline or out at sea use motion from the waves to compress air to drive a turbine or hydraulic pumps. It can provide energy for around 400 homes.

(From https://www.twinkl.com/teaching-wiki/the-history-of-electricity)

Vocabulary

amber [ˈæm.bər] бурштиновий

a feather [ˈfeð.ər] перо

'parlour trick machines'	"машини для фокусів у салонах"
mercury [ˈmɜː.kjə.ri]	ртуть
to twitch	смикатися
moisture [ˈmɔɪs.tʃər]	волога
muslin [ˈmʌz.lɪn]	муслін (тонка м'яка шовкова або бавовняна тканина)
dampen [ˈdæm.pən]	зволожити
a salt solution	розчин солі
substance [ˈsʌb.stəns]	речовина
coil	котушка
ampere [ˈæm·pɪər]	ампер
velocity [vəˈlɒs.ə.ti]	швидкість
a carbon filament lamp	лампа з вугільною ниткою
an AC (alternating current) motor	двигун змінного струму
fluorescent light [flɔːˈres.ənt laɪt]	флуоресцентне світло
neon [ˈniː.ɒn]	неон
a mill	млин
a turbine [ˈtɜː.baɪn] US[ˈtɝː.bɪn]	турбіна
an electric hand drill	електрична ручна дриль
the elevated railways	надземні залізниці

a subway	метро
to become available	стати доступним
the national grid	національна мережа
a hydroelectric [ˌhaɪ.drəʊ.ɪˈlek.trɪk] power station	гідроелектростанція
mains powered radios	радіостанції з живленням від мережі
a nuclear [ˈnjuː.klɪər] power station	атомна електростанція
a hydraulic pump [haɪˈdrɒl.ɪk pʌmp]	гідравлічний насос

Exercise 1. Answer the following questions

1. Who discovered electricity? 2. Why is “The History of Electricity” a fascinating topic? 3. Who discovered that amber when rubbed with silk, attracted feathers and other light objects? 4. Who invented the term 'electricity'? 5. What happened in the 1700s? 6. Who invented neon light? How was it done? 7. What did Benjamin Franklin, a famous U.S. politician, prove? 8. What can you say about Luigi Galvani and Alessandro Volta? 9. How was electrolysis discovered? 10. What did Hans Christian Oersted find? 11.What did Michael Faraday find? 12. Thomas Johann Seebeck discovered thermo-electricity, didn’t he? 13. Did André Ampère publish his theories about electricity and magnetism, explaining the electro-dynamic theory? 14. Who published his complete mathematical theory of electricity in 1827? 15. What did Joseph Henry show? 16. What happened in 1831? 17. Who created the first telegraph machine? 17. How was the velocity of electricity measured? 18. What can you say about Morse Code? 19. What happened in 1870s? 20. When was the telephone invented? 21. A British scientist named Joseph Swan demonstrated the first electric light with a carbon filament lamp, didn’t he? 22. What do ypu come to know about

Nicola Tesla and James Wimshurst? 23. How was the first public electricity supply in the UK generated? 24. Did Magnus Volks build the first electric railway in 1883? 25. What did the first turbine use? 26. Who detected electric waves in the atmosphere? 27. Who was the author of the electron theory? 28. What was discovered in 1895? 29. Did Nikola Tesla's hydroelectric power generators at Niagara Falls come into operation in 1897? 30. What happened in 1897? 31. What did Albert Einstein demonstrate in 1905? 32. When did electric refrigerators and washing machines first become available? 33. What important events in the history of electricity could be mentioned while speaking about 1930s? 34. What did John Logie Baird invent? 35. When was the world's first large-scale nuclear power station opened? 36. France and the USA adopted water-cooled reactor technology in the 190s, didn't they? 37. What happened in 1994? 38. What began to generate electricity in 2000?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

передові сучасні технології, вважати, захоплююча тема, статична електрика, генерувати магнітне поле, бути представленим, скляна куля, вступати в контакт, з'єднання певних металів, опублікувати свою теорію, бути названим на честь к-н., одиниця електричного опору, дріт, намотаний на котушки; електричний генератор, демонструвати електромагнітну індукцію, котушка дроту, вимірювати швидкість розповсюдження електрики, забезпечити електрику, розробити двигун змінного струму, бути загрозою для, поширювати історії, бути безпечним у використанні, джерело живлення, виробляти надзвичайно високочастотні струми, використовувати водяне колесо на млині, тип двигуна, приводити в рух гвинти човнів, виявляти електричні хвилі в атмосфері, німецький фізик, змусити екран світитися, проходити крізь об'єкти, надіслати повідомлення через Атлантику, стати доступним, Закон про електропостачання, гідроелектростанції, перша в світі великомасштабна атомна електростанція, газоохолоджуваний реактор, перший реактор з водою під тиском, перша в світі комерційна хвильова електростанція для виробництва електроенергії, стиснення повітря, забезпечення енергією.

Exercise 3. Match the sentences

1. Electrical energy has always been around us, but for most of human history,	a) but at that point, the circuits still had to be wired by hand.Greeks, Romans, and Egyptians reportedly used electric fish as a treatment for epilepsy and gout.
2. The 20th century also brought breakthroughs in the realm of electricity generation, with	b) to describe objects that attracted dust “like amber,” and this eventually led to the modern usage of the word “electricity.”
3. The first attempt to use electrical energy may have been in medicine:	c) we haven’t understood it or been able to control it.
4. An English scientist named William Gilbert came up with the word “*electricus*”	d) but he also played a major role in the history of electricity.
5. Benjamin Franklin might be best known as one of America’s Founding Fathers,	e) that could be used to protect tall buildings.

6. This wasn't the first time anyone had identified the link between electricity and lightning,	f) but he's credited with developing the idea of the electromagnetic field.
7. He used this knowledge to invent a lightning rod	g) wind power, nuclear power, and tidal power all making their way onto the scene.
8. Michael Faraday may not be as famous as some of the other names in the history of electricity,	h) including the Tesla coil, a high-voltage, low-current transformer that's often used for entertainment.
9. One of Thomas Edison's biggest achievements	i) which uses uranium to generate power through nuclear fission.
10. Tesla also developed several different types of transformers,	j) as rolling blackouts and extreme weather events put a strain on regional power grids.
11. One of the most promising ideas was nuclear power,	k) was opening the first power plant in New York City in 1882, the Pearl Street Station.
12. There's one more technology that wouldn't exist without electricity:	l) but he was the first to put the pieces together and explain how it worked.
13. The first circuit board was invented by Albert Hanson in Germany in 1903,	m) computers and other electronics.

14. We may also see a trend towards more self-reliance,	n) Greeks, Romans, and Egyptians reportedly used electric fish as a treatment for epilepsy and gout.

Exercise 4. Translate the following sentences into English

1. Сучасне життя просто неможливо уявити без світла та електроприладів.
2. Тому відкриття електрики - найважливіша подія в історії людства.
3. Електрика - це рух заряджених часток під дією електромагнітного поля або в одному напрямку (постійний струм), або з періодичною зміною напрямку (змінний струм).
4. Перший конденсатор, який отримав назву Лейденська банка, був створений голандським фізиком Пітером ван Мушенбруком.
5. Цей пристрій складався зі скляної колби, що була обшита шаром олова ззовні і всередині.
6. Банка закривалася дерев'яною кришкою, і в неї вставлявся металевий штир.
7. При подачі електроенергії Лейденська банка могла накопичувати доволі потужні заряди.
8. Також за її допомоги була отримана перша електрична іскра.
9. Вольт і гальванічний елемент - ці добре знайомі нам означення насправді походять від прізвищ двох вчених - Александро Вольта і Луїджі Гальвані.
10. Фарадей відкрив явище електромагнітної індукції, зібрав перший в світі генератор електроенергії і електродвигун, вивів закони електролізу і зіграв чи не головну роль в становленні теорії електрики.

(From https://watt-shop.com/ua/blog/226-who-invented-electricity-and-how-its-operating-principle.html; https://energy365.com.ua/tpost/m72pardfz1-storya-elektriki-v-svt)

Exercise 5. Read the following interesting pieces of information. Share your opinion with your classmates

- Iceland is the country that uses the most electricity annually. Their consumption is about 23% more than the U.S.
- The world's biggest light bulb is located in Edison, New Jersey. It's 14 feet tall, weighs eight tons, and sits on top of the Thomas Edison Memorial Tower.
- Electricity is present in our bodies – our nerve cells use it to pass signals to our muscles.

(*https://www.oliverheatcool.com/about/blog/news-for-homeowners/13-fun-electrical-facts/*)

Speaking

- Create a lecture about milestones in the history of electricity and present it to the class.
- Speak about the problems in modern electricity supply.
- Speak about the future of electricity.
- Choose an outstanding physicist and speak about his achievements.

Unit 2.

I. Read and translate the text. Learn the new vocabulary

Electrostatics

Electrostatics, as the name implies, is the study of stationary electric charges. A rod of plastic rubbed with fur or a rod of glass rubbed with silk will attract small pieces of paper and is said to be **electrically charged**. The charge on plastic rubbed with fur is defined as **negative**, and the charge on glass rubbed with silk is defined as **positive**.

Electric charge

Electrically charged objects have several important characteristics:

- Like charges repel one another; that is, positive repels positive and negative repels negative.
- Unlike charges attract each another; that is, positive attracts negative.
- Charge is conserved. A neutral object has no net charge. If the plastic rod and fur are initially neutral, when the rod becomes charged by the fur, a negative charge is transferred from the fur to the rod. The net negative charge on the rod is equal to the net positive charge on the fur.

A **conductor** is a material through which electric charges can easily flow. An **insulator** is a material through which electric charges do not move easily, if at all. An **electroscope** is a simple device used to indicate the existence of charge. As shown in Figure 1, the electroscope consists of a conducting knob and attached lightweight conducting leaves—commonly made of gold foil or aluminum foil. When a charged object touches the knob, the like charges repel and force the leaves apart. The electroscope will indicate the presence of charge but does not directly indicate whether the charge is positive or negative.

Fig. 1. An electroscope reports the presence of charge.

A large charge near a neutral electroscope can make the leaves move apart. The electroscope is made of conducting material, so the positive charges are attracted to the knob by the nearby (but not touching) negatively charged rod. The leaves are left with a negative charge and therefore deflect. When the negative rod is removed, the leaves will fall.

Now, consider touching the electroscope knob with a finger while the charged rod is nearby. The electrons will be repulsed and flow out of the electroscope through the hand. If the hand is removed *while the charged rod is still close*, the electroscope will retain a charge. This method of charging is called **charging by induction** (see Figure 2).

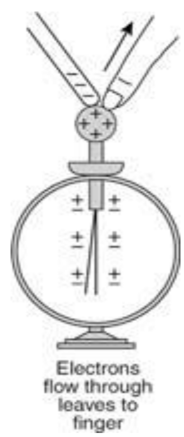

Fig.2. Charging an electroscope by induction.

When an object is rubbed with a charged rod, the object shares the charge so that both have a charge of the same sign. In contrast, charging by induction gives an object the charge opposite that of the charged rod.

Even though the charges are not free to travel throughout the material, insulators can be charged by induction. A large charge nearby—not touching—will induce an opposite charge on the surface of the insulator. As shown in Figure 3, the negative and positive charges of the molecules are displaced slightly. This realignment of charges in the insulator produces an effective induced charge.

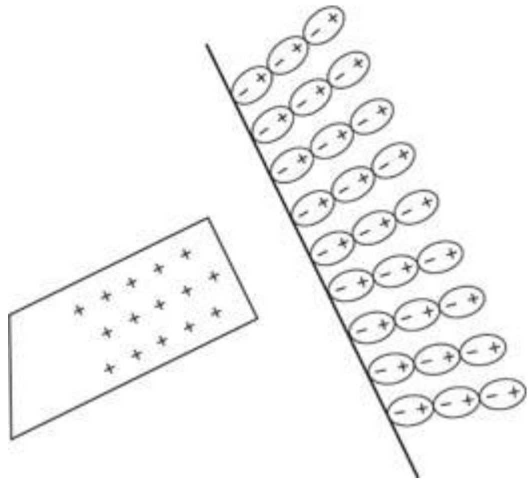

Fig. 3. Induction of surface charge on an insulator by a nearby charged object.

Coulomb's law

Coulomb's law gives the magnitude of the electrostatic force (*F*) between two charges:

$$F = \frac{kq_1 q_2}{r^2}$$

where q_1 and q_2 are the charges, *r* is the distance between them, and *k* is the proportionality constant. The unit for charge is the coulomb. If the charge is in coulombs and the separation in meters, the following approximate value for *k* will give the force in newtons: $k = 9.0 \times 10^9$ N · m ^{2}/C ^{2}. The direction of the electrostatic force depends upon the signs of the charges. **Like charges repel, and unlike charges attract.**

Coulomb's law can also be expressed in terms of another constant (ε_0), known as the **permittivity of free space:**

$$\varepsilon_o = \frac{1}{4\pi k} = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$$

When the permittivity constant is used, Coulomb's law is

$$F = \frac{1}{4\pi\varepsilon_o} \frac{q_1 q_2}{r^2}$$

The most fundamental electric charge is the charge of one proton or one electron. This value *(e)* is $e = 1.602 \times 10^{-19}$ coulombs. It takes about 6.24×10^{18} excess electrons to equal the charge of one coulomb; thus, it is a very large static charge.

Electric fields and lines of force

When a small positive test charge is brought near a large positive charge, it experiences a force directed away from the large charge. If the test charge is far from the large charge, the electrostatic force given by Coulomb's law is smaller than when it is near. This data of direction and magnitude of an electrostatic force, due to a fixed charge or set of fixed charges, constitutes an electrostatic field. The **electric field** is defined as the force per unit charge exerted on a small positive test charge (q_0) placed at that point. Mathematically,

$$E = \frac{F}{q_o}$$

Note that both the force and electric field are vector quantities. The test charge is required to be small so that the field of the test charge does not affect the field of the set charges being examined. The SI unit for electric field is newtons per coulomb (N/C).

Figure 5 is a pictorial representation of the electric fields surrounding a positive charge and a negative charge. These lines are called **field lines** or **lines of force**.

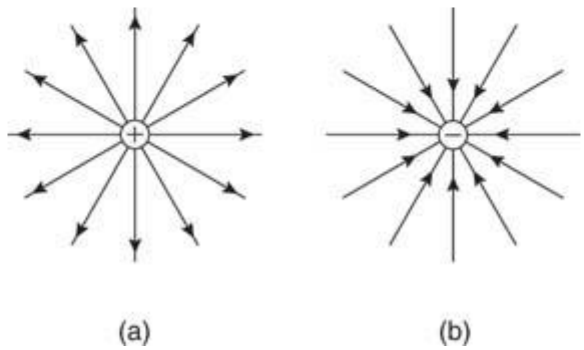

Fig. 5. Electric field lines of (a) positive and (b) negative point charges.

Figure 6 shows the electric fields for opposite charges, similar charges, and oppositely charged plates.

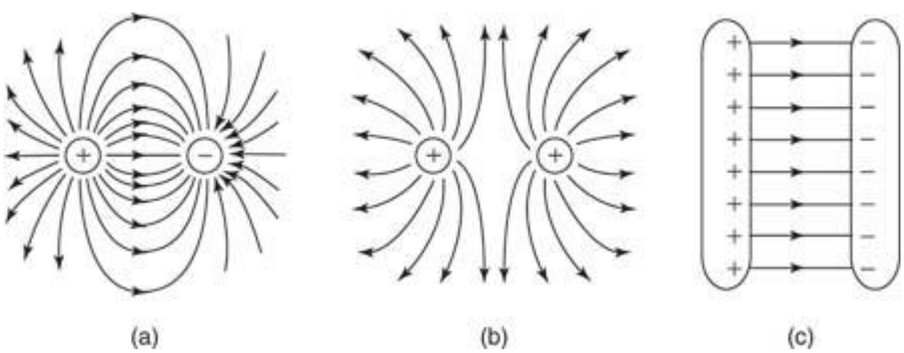

Fig. 6. Electric field lines of (a) two opposite charges, (b) two like charges, and (c) two oppositely charged plates.

Electric flux

Electric flux is defined as the number of field lines that pass through a given surface. In Figure 7, lines of electric flux emerging from a point charge pass through an imaginary spherical surface with the charge at its center.

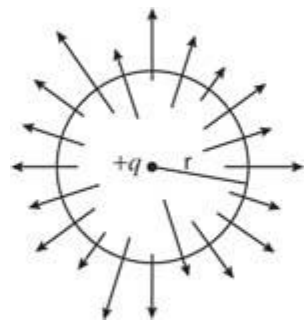

Fig. 7. Electric flux due to a point charge + *q*.

This definition can be expressed as follows: $\Phi = \sum E \cdot A$, where Φ (the Greek letter phi) is the electric flux, **E** is the electric field, and **A** is area perpendicular to the field lines. Electric flux is measured in $N \cdot m^2 / C^2$ and is a scalar quantity. If the surface under consideration is not perpendicular to the field lines, then the expression is $\Phi = \sum EA \cos \theta$.

(From www.cliffsnotes.com/study-guides/physics/electricity-and-magnetism/electrostatics)

Vocabulary

rod	стрижень
conserved	збережений
net charge	результуючий заряд
fur [fɜː(r)]	хутро
a conducting knob [nɒb]	провідна ручка
conducting leaves	провідні листки
deflect [dɪˈflekt]	відхиляти
repulse [rɪˈpʌls]	відсікати
insulator [ˈɪn.sjʊ.leɪ.tə]	ізолятор
realignment [ˌriː.əˈlaɪnmənt] of charges	перегрупування зарядів

Coulomb's [ˈkuː.lɒmz] law	Закон Кулона
magnitude [ˈmæg.nɪ.tjuːd]	величина
permittivity [pɜːmɪˈtɪvɪtɪ] of free space	діелектрична проникність вільного простору
excess [ɪkˈses] electrons	надлишок електронів

Exercise 1. Answer the following questions

1. What is electrostatics? 2. When is the rod said to be electrically charged? 3. When is the charge defined as negative? 4. When is the charge defined as positive? 5. What several important characteristics do electrically charged objects have? 6. What is a conductor? 7. What is an insulator? 8. An electroscope is a simple device used to indicate the existence of charge, isn't it? 9. What happens when a charged object touches the knob? 10. What will the electroscope indicate? 11. What is electroscope made of? 12. When will the leave of electroscope fall? 13. When will the electroscope retain a charge? What is this method of charging called? 14. Does the charging by induction give an object the charge opposite that of the charged rod? 15. How can insulators be charged? 16. The negative and positive charges of the molecules are displaced slightly, aren't they? 17. What does the Coulomb's law give? 18. What does the direction of the electrostatic force depend upon? 19. How can Coulomb's law also be expressed? 20. What is Coulomb's law, when the permittivity constant is used? 21. What is the most fundamental electric charge?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

дослідження стаціонарних електричних зарядів, бути електрично зарядженим, визначений як негативний, електричний заряд, мати кілька важливих характеристик, не мати підсумкового заряду, провідник, ізолятор, електроскоп, вказувати на наявність заряду, ручка електроскопа, зберегти заряд, трохи змістити, перегрупування зарядів, величина електростатичних сил, кулон, діелектрична проникність вільного простору, електростатичне поле, векторні величини, силові лінії, електричний потік, можна виразити наступним чином.

Exercise 3. Match the sentences

1. Electrostatics is a branch of physics	a) because it acts along the line joining two charges.
2. The attraction of the plastic wrap to your hand after you remove it from a package and the attraction of paper to a charged scale	b) play a very large role in how atoms and molecules behave.
3. Electrostatic forces play a large role at the nanoscale; for instance, the force between an electron and a proton, which together make up a hydrogen atom,	c) the work done on the charge is independent of the path taken.
4. Because they are large at small scales, Coulomb forces between electrons and the positively charged nuclei	d) are the examples of electrostatics.
5. Coulomb's law states that: 'The magnitude of the electrostatic force of attraction or repulsion between two point charges	e) equal the numbers of negative ions.

6. If the two charges have the same sign, the electrostatic force between them is repulsive;	f) equal numbers of protons and electrons.
7. Electric field lines are useful	g)and terminate on negative charge.
8. Field lines begin on positive charge	h) is more than 39 orders of magnitude stronger than the gravitational force acting between them.
9. Neutral particles include	i) if they have different signs, the force between them is attractive.
10. They have both protons, neutrons and electrons; however, the numbers of positive ions	j) is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distance between them.
11. The electrostatic force is conservative in nature because	k)for visualizing the electric field.
12. The electrostatic force is called a central force	l) that studies slow-moving or stationary electric charges.

Exercise 4. Translate the following sentences into English

1. Шарль Огюстен де Кулон (1736 – 1806) (Charles Augustin de Coulomb), французький фізик, розпочав свою кар’єру як військовий інженер у Вест-Індії.

2. У 1776 році він повернувся до Парижа і усамітнився в невеликому маєтку, щоб займатися науковими дослідженнями.

3. Він винайшов крутильні ваги для вимірювання величини сили і використовував їх для визначення сил електричного притягання або відштовхування між малими зарядженими кульками.

4. Таким чином у 1785 році він прийшов до закону оберненого квадрата, який тепер відомий як закон Кулона.

5. Прістлі, а також Кавендішем (Cavendish) раніше працювали над законом, хоча Кавендіш ніколи не публікував свої результати.

6. Кулон також знайшов закон обернених квадратів сили між різнорідними та однаковими магнітними полюсами.

8. Кавендіш раніше Кулона встановив (але не опублікував) закон зворотних квадратів для взаємодії електричних зарядів, займався механічною теорією теплоти, розрахував середню щільність і масу Землі.

9. Кавендішу належить кілька робіт по вивченню властивостей електрики, написаних для королівського суспільства, але більша частина його експериментів була зібрана й опублікована Джеймсом Максвеллом тільки в 1879 році.

10. В 1935 р. Міжнародний астрономічний союз присвоїв ім'я Генрі Кавендіша кратеру на видимій стороні Місяця.

(*https://uk.wikipedia.org/wiki/*)

Exercise 5. Read the following interesting pieces of information. Share your opinion with your classmates

- A spark of static electricity can measure thousands of volts, but has very little current and only lasts for a short period of time. This means it has little power or energy.
- Lightning is a powerful and dangerous example of static electricity.
- As dangerous as lightning is, around 70% of people struck by lightning survive.
- Temperatures in a lightning bolt can hit 50,000 degrees F.
- Static electricity will build up faster on a dry non-humid day.

(*https://www.ducksters.com/science/static_electricity.php*)

Speaking

- Speak about Electrostatics.
- Speak about Henry Cavendish and his discoveries.
- Speak about Charles Augustin de Coulomb and his discoveries in physics.
- Speak about Electric field.

Unit 3.

I. Read and translate the text. Learn the new vocabulary

The Electric Current

Electric current, any movement of electric charge carriers, such as subatomic charged particles (e.g., electrons having negative charge, protons having positive charge), ions (atoms that have lost or gained one or more electrons), or holes (electron deficiencies that may be thought of as positive particles).

Electric current in a wire, where the charge carriers are electrons, is a measure of the quantity of charge passing any point of the wire per unit of time. In alternating current the motion of the electric charges is periodically reversed; in direct current it is not. In many contexts the direction of the current in electric circuits is taken as the direction of positive charge flow, the direction opposite to the actual electron drift. When so defined the current is called conventional current.

Current is usually denoted by the symbol I. Ohm's law relates the current flowing through a conductor to the voltage V and resistance R; that is, $V = IR$. An alternative statement of Ohm's law is $I = V/R$.

Current in gases and liquids generally consists of a flow of positive ions in one direction together with a flow of negative ions in the opposite direction. To treat the overall effect of the current, its direction is usually taken to be that of the positive charge carrier. A current of negative charge moving in the opposite direction is equivalent to a positive charge of the same magnitude moving in the conventional direction and must be included as a contribution to the total current. Current in semiconductors consists of the motion of holes in the conventional direction and electrons in the opposite direction.

Currents of many other kinds exist, such as beams of protons, positrons, or charged pions and muons in particle accelerators.

Electric current generates an accompanying magnetic field, as in electromagnets. When an electric current flows in an external magnetic field, it experiences a magnetic force, as in electric motors. The heat loss, or energy dissipated, by electric current in a conductor is proportional to the square of the current.

A common unit of electric current is the ampere, which is defined as a flow of one coulomb of charge per second, or 6.2×10^{18} electrons per second. The centimetre–

gram–second units of current is the electrostatic unit of charge (esu) per second. One ampere equals 3×10^9 esu per second.

Commercial power lines make available about 100 amps to a typical home; a 60-watt lightbulb pulls about 0.5 amp of current and a one-room air conditioner about 15 amps.

Difference between voltage and current

Voltage is another term that's used in regards to electronic circuits about as often as current. Voltage is measured in volts (V). Like current, voltage is also related to the flow of electrons in a circuit. Current refers to the flow of electrons, while voltage refers to the amount of force pushing the flowing electrons.

The higher the voltage, the more current will flow; a lower voltage means a weaker current.

Resistance also has a significant impact on current flow. Think of resistance as the width through which electrons flow. The greater the resistance, the narrower the width through which the electrons must flow, and therefore the lower the current. By contrast, a lower resistance increases the width through which electrons can flow, allowing more current to flow at once.

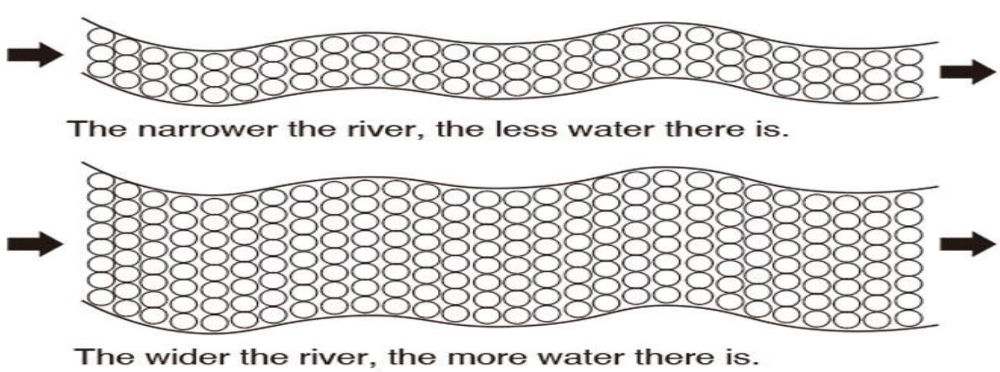

Fig.1. Resistance and current can be compared to the flow of a river

If you want more current to flow at a given resistance value, you can accomplish that by raising the voltage. Power is generally calculated by multiplying current (A) by voltage (V), yielding a result that is expressed in watts (W). In this way, current and voltage are completely different, but both are important elements in the world of electricity.

A typical example of direct current is the electricity provided by dry cells and the lithium-ion batteries used in cars. With a direct current, the voltage is always positive (or always negative), and the current always flows in the same direction. As a result, a device may not operate if its battery is installed with the poles reversed.

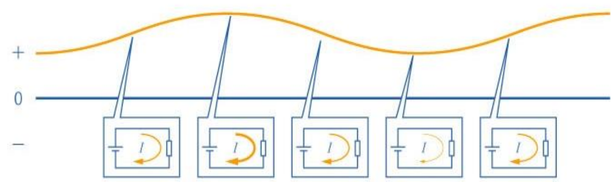

Fig.2. Direct current

By contrast, alternating current (AC) refers to current and voltage whose direction and magnitude vary regularly over time. AC current waveforms are distinguished by a variety of shapes, including sine waves, square waves, sawtooth waves, and triangular waves.

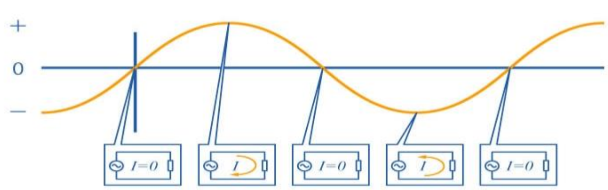

Fig. 3. Alternating current

AC electricity is used by the power grid, for example in household outlets. However, most standard electronic devices convert it into DC current with their internal circuitry. Why, then, does the power grid use AC current?

The reason has to do with transmission. Resistance in power lines causes losses when current is transmitted, but that loss can be reduced by increasing the voltage. However, it’s difficult to create high-voltage DC current, so electricity is transmitted as AC current and then stepped down to a lower voltage by transformers before being supplied to electric devices via the power grid. Then those devices, in most cases, convert the AC current into DC current with their internal circuitry so that it can be used.

(From https://www.britannica.com/science/electric-current; https: www.hioki.com/us-en/learning/electricity/current.html)

Vocabulary

ion [ˈaɪ.ɒn]	іон
deficiency [dɪˈfɪʃ.ən.si]	дефіцит
alternating current [ˈɒl.tə.neɪ.tɪŋ ˈkʌr.ənt]	змінний струм
direct current [daɪˈrekt] [dɪˈrekt ˈkʌr.ənt]	постійний струм
to denote [dɪˈnəʊt]	позначати
conductor [kənˈdʌk.tər]	провідник
magnitude [ˈmæg.nɪ.tʃuːd]	величина
semiconductor [ˌsem.i.kənˈdʌk.tər]	напівпровідник
pion ['paɪɔn]	піон
muon ['mjuːɒn, -ɑːn]	мюон; важкий електрон; баритрон
accelerator [əkˈsel.ə.reɪ.tər]	прискорювач

to dissipate [ˈdɪs.ɪ.peɪt]	розсіюватися
in regards to	відносно
resistance [rɪˈzɪs.təns]	опір
to accomplish [əˈkʌm.plɪʃ]	досягати
to yield [jiːld] a result	дати результат
pole	полюс
sawtooth wave ['sɔ:tu:θ weɪv]	пилкоподібна хвиля
triangular wave [traɪˈæŋ.ɡjə.lər weɪv]	трикутна хвиля
power grid	енергосистема
household outlet	побутова розетка
transmission [trænzˈmɪʃ.ən]	спосіб передавання
internal circuitry [ɪnˈtɜː.nəl ˈsɜː.kɪ.tri]	внутрішні схеми

Exercise 1. Answer the following questions

1. What is electric current? 2. What is electric current in a wire? 3. What is the difference between alternating current and direct current? 4. How is current usually denoted? 5. What can you say about current in gases and liquids? 6. What does current in semiconductors consist of? 7. Currents of many other kinds exist, such as beams of protons, positrons, or charged pions and muons in particle accelerators, doesn't it? 8. What does electric current generate? 9. What is the common unit of electric current? 10. What does ampere equal? 11. What is the difference between current and voltage? 12. Does resistance have a significant impact on current flow? Comment upon it. 13. What do you have to do if you want more current to flow at a given resistance value? 14. How is power generally calculated? 15.What is a typical example of direct current? 16. How are AC current waveforms distinguished? 17. Where is AC

electricity used? 18. Do most standard electronic devices convert it into DC current with their internal circuitry? 19. Why does the power grid use AC current? 20. Why is electricity transmitted as AC current and then stepped down to a lower voltage by transformers before being supplied to electric devices via the power grid?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

будь-який рух носіїв електричного заряду, субатомні заряджені частинки, міра кількості заряду, у змінному струмі, періодично реверсований, потік позитивного заряду, звичайний струм, зазвичай позначається символом, закон Ома, негативний заряд, у прискорювачах частинок, магнітна сила, загальна одиниця електричного струму, потік електронів у ланцюзі, яка має значний вплив на сухі елементи та літій-іонні батареї, що використовуються в електромережі, шляхом підвищення напруги, множення, внутрішні схеми, збільшити напругу.

Exercise 3. Match the sentences

1. The current is a physical	a) *Amp* and is abbreviated by the unit symbol **A**.
2. As a physical quantity, current is the rate	b) passing through a cross section of a wire every 1 second.
3. The current is simply the ratio of	c) flowing into, along, and out of a slide per unit of time.
4. The standard metric unit for current is the ampere. Ampere is often shortened to	d) quantity that can be measured and expressed numerically.

5. A current of 1 ampere means that there is 1 coulomb of charge	e) a closed conducting loop through which the charge can move.
6. The particles that carry charge through wires in a circuit	f) negatively charged electrons.
7. Charge will not flow in a circuit unless there is an energy source capable of creating an electric potential difference and unless there is	g) at which charge flows past a point on a circuit. passing through a cross section of a wire every 1 second.
8. By convention, the electric current direction is the direction	h) which positive charge would move.
9. In wires, the actual charge carriers are	i) are mobile electrons.
10. The average speed of an electron within a circuit is very, very slow. This is due primarily to the	j) the quantity of charge and time.
11. Electric current is the rate at which electric charge flows past a point on the electric circuit. Water current is the rate	k) countless collisions with the fixed atoms in the wire.
12. As such, current is analogous to the number of gallons of water	l) at which water flows past a point on the water circuit.

Exercise 4. Translate the following sentences into English

1. Електричний струм — це потік електричного заряду в колі.

2. Точніше кажучи, електричний струм – це швидкість потоку заряду через дану точку електричного кола.

3. Зарядом можуть бути негативно заряджені електрони або позитивні носії заряду, включаючи протони, позитивні іони.

4. Величина електричного струму вимірюється в кулонах за секунду, загальною одиницею для цього є ампер, який позначається літерою «A».

5. Потік струму в ланцюзі зазвичай позначається літерою «I», і ця буква використовується в рівняннях, таких як закон Ома, де V=I·R.

6. Основна концепція струму полягає в тому, що це рух електронів усередині речовини.

7. Електрони — це дрібні частинки, які існують як частина молекулярної структури матеріалів.

8. Електрони є зарядженими частинками – вони несуть негативний заряд.

9. Якщо вони рухаються, то рухається кількість заряду, і це називається струмом.

10. Струм є одним із найважливіших і фундаментальних елементів електричних та електронних технологій.

(From https://futurenow.com.ua/shho-take-elektrychnyj-strum/)

Exercise 5. Read the following interesting piece of information. Share your opinion with your classmates

Electric cars actually date back as far as 1832

While most see electric vehicles as a relatively new invention, they actually date back as far as the 1800s. Between 1828 and 1835, Hungarian and American innovators were the first to experiment with small-scale electric cars. Budding inventor, Robert Anderson, developed the first crude electric vehicle in 1832; however, it wasn't until the 1870s that the car became 'driveable' and able to transport passengers from A to B.

More than 60 years after its first invention, the electric vehicle started to grow in popularity. Models were finally easy to drive and no longer gave off a pungent smell of pollutants. They were particularly sought-after amongst women, who wanted a stylish vehicle to travel around the city. By the next century, it is thought that electric cars accounted for up to one-third of all vehicles on the roads!

(https://www.heathelectricalservices.com/news/10-fun-facts-about-electricity)

Unit 4.

I. Read and translate the text. Learn the new vocabulary

Electric power

Electric power, energy generated through the conversion of other forms of energy, such as mechanical, thermal, or chemical energy. Electric energy is unrivaled for many uses, as for lighting, computer operation, motive power, and entertainment applications. it is competitive, as for many industrial heating applications, cooking, space heating, and railway traction.

Electric power is characterized by current or the voltage or the potential of charge to deliver energy. A given value of power can be produced by any. If the current is direct, electronic charge progresses always in the same direction through the device receiving power. If the current is alternating, forth in the device and in the wires connected to it. For many applications either type of current is suitable, but alternating current (AC) is most widely available because of the greater efficiency with which it can be generated and distributed. A direct current (DC) is required for certain industrial applications, such as electroplating and electrometallurgical processes and for most electronic devices.

The wide-scale production and distribution of electric power was made possible by the development of the electric generator, a device that operates on the basis of the induction principle formulated in 1831 by the English scientist Michael Faraday and independently by the American scientist Joseph Henry. The first public power station employing an electric generator began operation in London in January 1882. A second such station opened later that same year in New York City. Both used DC systems, which proved inefficient for long-distance power transmission. By the early 1890s the first practical AC generator was built at the Lauffen power station in Germany, and service to Frankfurt am Main was initiated in 1891.

There are two primary sources for driving generators—hydro and thermal. Hydroelectric power is derived from generators and turbines driven by falling water. Most other electric energy is obtained from generators coupled to turbines driven by steam produced either by a nuclear reactor or by burning fossil fuels—namely, coal, oil, and natural gas.

Until the 1930s, hydroelectric-power plants equipped with water-turbine generating units produced the largest percentage of electric energy because they were less expensive to operate than thermal-power plants using steam-turbine units. Since that time, major technological advances have reduced the cost of thermal-power generation, while the cost of developing more remote hydroelectric sites has increased. By 1990, hydroelectric-power production constituted only 18 percent of global electric energy output. Thermal plants using nuclear energy or gas turbines to run steam-electric units are among these technological advances. Alternative electric energy sources include solar cells, wind turbines, fuel cells, and geothermal-power stations.

Electric energy generated at a central power station is transmitted to bulk delivery points, or substations, from which it is distributed to consumers. Transmission is accomplished by an extensive network of high-voltage power lines, including overhead wires and underground and submarine cables. Voltages higher than those suitable for power plant generators are required when transmitting alternating current over long distances in order to reduce the power losses that result from the resistance of transmission lines. Step-up transformers are employed at the generating station to increase the transmission voltage. At the substations other transformers step down the voltage to levels suitable for distribution systems.

All the principles of generating electricity had been worked out in the 19th century, but by its end these had only just begun to produce electricity on a large scale. The 20th century witnessed a colossal expansion of electrical power generation and distribution. The general pattern has been toward ever-larger units of production, using steam from coal- or oil-fired boilers. As the market for electricity increased, so did the distance over which it was transmitted, and the efficiency of transmission required higher and higher voltages. Hydroelectric power, using a fall of water to drive water turbines, was developed to generate electricity where the climate and topography make it possible to combine production with convenient transmission to a market. Remarkable levels of efficiency were achieved in modern plants. One important consequence of the ever-expanding consumption of electricity in the industrialized countries has been the linking of local systems to provide vast power grids, or pools, within which power can be shifted easily to meet changing local needs for current.

(From https://www.britannica.com/technology/history-of-technology)

Vocabulary

thermal [ˈθɜː.məl]	теплові
unrivaled [ʌnˈraɪ.vəld]	неперевершений
motive power [ˈməʊ.tɪvˈpaʊə(r)]	рушійна сила
railway traction	залізнична тяга
current [ˈkʌrənt]	струм
voltage values [ˈvɒl.tɪdʒ ˈvæl.ju z]	значення напруги
direct [dəˈrekt]	прямий
alternating	змінний

to move back and forth	рухатися вперед-назад
electroplating process	процес гальванічного покриття
electrometallurgical [iˈlek.trəʊˌmet.əlˈɜː.dʒɪ.kəl] process	електрометалургійний процес
long-distance power transmission	передача електроенергії на великі відстані
turbines [ˈtɜː.baɪnz]	турбіни
to obtain	отримати
coupled to [ˈkʌp.l̩d]	у поєднанні з
fossil fuels	горючі корисні копалини
coal	вугілля
steam-turbine units	паротурбінні установки
solar cells	сонячні елементи
wind turbines	вітрові турбіни
fuel cells	паливні елементи
geothermal-power stations [ˌdʒiː.əʊˈθɜː.məl]	геотермальні електростанції
bulk delivery points	пункти оптової доставки
distribute	поширювати
consumer	споживач
high-voltage power lines	високовольтні лінії електропередач
overhead wires	повітряні дроти
underground and submarine cables	підземні та підводні кабелі
to reduce the power losses	зменшити втрати потужності

step-up transformers	підвищувальні трансформатори
step down the voltage	знизити напругу

Exercise 1. Answer the following questions

1. What is electric power? 2. What kinds of energy are used to generate electric power via conversion? 3. How many uses of electrical power do you know? 4. What is the difference between direct and alternating current? 5. What is the principle of electric generator operation? 6. Who formulated the principle of induction first in the world? 7. The DC electric power stations proved to be inefficient for long distance power transmission, didn't they? 8. How many primary sources for driving generators do you know? 9. In what way does a nuclear reactor take part in electricity production? 10. What was the percent of hydro electrical power production of global electrical power output in 1990? 11. Are natural gas, coal and oil used in electrical power production? 12. Where is electric power of the central power station transmitted to? 13. Substations are the bulk delivery points, aren't they? 14. What is the reason of electrical power losses during transmission? 15. What is the structure of electric power distribution network? 16. What types of cable are used for electric energy transmission? 17. What transformers are employed at generating power station to increase the transmission voltage? 18. Why did the efficiency of transmission require higher and higher voltages? 19. What is the principle of hydroelectric power station operation? 20. What was the reason for creating vast electric power grids or pools in modern industrial countries?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

перетворення інших форм енергії, неперевершена, рушійна сила, розважальні програми, потік електричного заряду, комбінація значень струму та напруги, змінний струм (AC), необхідний для певних промислових застосувань, широкомасштабне виробництво, розробка електричного генератора, перша електростанція з використанням електричного генератора, системи постійного струму, передачі електроенергії на великі відстані, первинні джерела для приводу генераторів, з'єднані з турбінами, електростанції теплової енергії, паротурбінні установки, об'єднання локальних систем, забезпечити великі електромережі, потужність може бути легко розподілена, задовольнити мінливі місцеві потреби.

Exercise 3. Match the sentences

1. In an electric circuit under steady-state conditions,	a) semiconductors according to their electric conductivity.
2. Materials are classified as conductors, insulators, or	b) that reduces the voltage because of its effect on the electric field.
3. Electrostatics is the study of electromagnetic phenomena that occur when there are no moving charges—	c) the flow of charge does not change with time and the charge distribution stays the same.
4. Alternating current, flow of electric charge that periodically reverses. It starts, say, from zero, grows to a maximum, decreases to zero, reverses, reaches a maximum in the opposite direction, returns again to the original value,	d) i.e., after a static equilibrium has been established.

5. Eddy current, in electricity, motion of electric charge induced entirely within a conducting material	e) generally following a direction parallel to the Earth's surface.
6. John Hopkinson was a British engineer and physicist who invented the three-wire system for electricity distribution and	f) the electric energy stored in such capacitors maintains the information during the temporary loss of power.
7. Telluric current, natural electric current flowing on and beneath the surface of the Earth and	g) improved the design and efficiency of electric generators.
8. Capacitors have many important applications. They are used, for example, in digital circuits so that information stored in large computer memories is not lost during a momentary electric power failure;	h) for example, by bending, twisting, or squeezing it.
9. One method for increasing capacity is to insert between the conductors an insulating material	i) wire and radio communication, the stored-program electronic computer, radar, and automatic control systems.
10. Piezoelectricity (literally "pressure electricity") is observed if a stress is applied to a solid,	j) by a varying electric or magnetic field or by electromagnetic waves.
11. Electrical engineering deals with electric light and power systems and apparatuses; electronics engineering deals with	k) and repeats this cycle indefinitely.

Exercise 4. Translate the following sentences into English

1. Електричний заряд — це властивість тіл, що проявляється, насамперед, у здатності створювати навколо себе електричне поле і за допомогою нього впливати на інші заряджені тіла.

2. Електричні заряди поділяють на позитивні та негативні.

3. Вибір, який саме заряд назвати позитивним, а який негативним, вважається у науці суто умовним, за кожним із зарядів закріплено цілком певний знак.

4. Тіла, заряджені зарядом одного знака, відштовхуються, а протилежно заряджені притягуються.

5. Найбільш загальна фундаментальна наука, що вивчає електричні заряди, їх взаємодію та поля, що ними породжуються та діють на них - це електродинаміка.

6. Зазвичай для виробництва електроенергії застосовуються електромеханічні генератори, що приводяться в дію або за рахунок спалювання викопного палива, або з використанням енергії від ядерних реакцій, або через силу повітряних або водних течій.

7. Ближче до кінця XIX століття був винайдений трансформатор, що дозволило більш ефективно передавати електроенергію при вищій напрузі та меншій силі струму.

8. Загалом, починаючи з XIX століття, електрика щільно входить у життя сучасної цивілізації.

9. Електрику використовують не тільки для освітлення, а й для передачі інформації (телеграф, телефон, радіо, телебачення), а також для приведення

механізмів руху (електродвигун), що активно використовується на транспорті (трамвай, метро, тролейбус, електричка) та у побутовій техніці (праска, кухонний комбайн, пральна машина, посудомийна машина).

10. У міру того, як триває модернізація та розвивається економіка тієї чи іншої держави, попит на електрику швидко зростає.

(From https://uk.wikipedia.org/wiki)

Exercise 5. Read the following interesting piece of information. Share your opinion with your classmates

In the 1880's, there was a "war of currents" between Nikola Tesla and Thomas Edison. Tesla helped invent AC current and Edison helped invent DC current, and both wanted their currents to be popularized. Tesla developed the alternating-current power system that provides electricity for homes and buildings. He also pioneered the field of radio communication and was granted more than 100 U.S. patents.

(https://en.wikipedia.org/wiki/War_of_the_currents)

Speaking

- Speak about electrical power.
- Speak about Nikola Tesla and his inventions.
- Speak about outstanding scientists who contributed to the development of electrical theory.
- Speak about the production of electricity in Ukraine.

Unit 5.

I. Read and translate the text. Learn the new vocabulary

The electron theory

The understanding of the behavior of electrons in solids is one of the keys to understanding materials. The electron theory of solids is capable of explaining the optical, magnetic, thermal, as well as the electrical properties of materials. In other words, the electron theory provides important fundamentals for a technology which is often considered to be the basis for modern civilization. A few examples will illustrate this. Magnetic materials are used in electric generators, motors, loudspeakers, transformers, tape recorders, and tapes. Optical properties of materials are utilized in lasers, optical communication, windows, lenses, optical coatings, solar collectors, and reflectors. Thermal properties play a role in refrigeration and heating devices and in heat shields for spacecraft. Some materials are extremely good electrical conductors, such as silver and copper; others are good insulators, such as porcelain or quartz. Semiconductors are generally poor conductors at room temperature. However, if traces of certain elements are added, the electrical conductivity increases.

Since the invention of the transistor in the late 1940s, the electronics industry has grown to an annual sales level of about five trillion dollars. From the very beginning, materials and materials research have been the lifeblood of the electronics industry.

For the understanding of the electronic properties of materials, three approaches have been developed during the past hundred years or so which differ considerably in their philosophy and their level of sophistication. In the nineteenth century, a phenomenological description of the experimental observation was widely used. The laws which were eventually discovered were empirically derived. This "continuum theory" considered only macroscopic quantities and interrelated experimental data. No assumptions were made about the structure of matter when the equations were formulated. The conclusions that can be drawn from the empirical laws still have validity, at least as long as no oversimplifications are made during their interpretation. Ohm’s law, the Maxwell equations, Newton’s law, and the Hagen-Rubens equation may serve as examples.

A refinement in understanding the properties of materials was accomplished at the turn to the twentieth century by introducing atomistic principles into the description of matter. The "classical electron theory" postulated that free electrons in metals drift as a response to an external force and interact with certain lattice atoms. Paul Drude was the principal proponent of this approach. He developed several fundamental equations that are still widely utilized today.

A further refinement was accomplished at the beginning of the twentieth century by quantum theory. This approach was able to explain important experimental observations which could not be readily interpreted by classical means. It was realized that Newtonian mechanics become inaccurate when they are applied to systems with atomic dimensions, i.e., when attempts are made to explain the interactions of electrons with solids. Quantum theory, however, lacks vivid visualization of the phenomena which it describes. Thus, a considerable effort needs to be undertaken to comprehend its basic concepts; but mastering its principles leads to a much deeper understanding of the electronic properties of materials.

Electron theory states all **matter** is comprised of molecules, which in turn are comprised of atoms, which are again comprised of protons, neutrons and electrons. A molecule is the smallest part of matter which can exist by itself and contains one or more atoms.

If you turn on a light switch for example you will see the light bulb glow and emit light into the room. So what caused this to happen? How does energy travel through copper wires to light the bulb? How does energy travel through space? What makes a motor turn, a radio play?

To understand these processes requires an understanding of the basic principles. For the light to glow requires energy to find a path through the light switch, through the copper wire and this movement is called electron flow. It is also called current flow in electronics. **This is the first important principle to understand.**

The word **matter** includes almost everything. It includes copper, wood, water, air....virtually everything. If we were able to take a piece of matter such as a drop of water, divided it by two and kept dividing by two until it couldn't be divided any further, we would eventually have a molecule of water.

An atom is also divisible - into protons and electrons. Both are electrical particles and neither is divisible. Electrons are the smallest and lightest and are said to be **negatively** charged. Protons on the other hand are about 1800 times the mass of electrons and are **positively** charged. Each are thought to have lines of forces (electric fields) surrounding them. In theory, negative lines of force will not join other negative lines of force. In fact, they tend to repel each other. Similarly positive lines of force act in the same way.

The fact that electrons repel electrons and protons repel protons, but electrons and protons attract one another follows the basic law of physics:

Like forces repel and unlike forces attract.

When an electron and proton are brought in close proximity to one another it is the electron which moves because the proton is 1800 times heavier. It is the electron which moves in electricity. Even though the electron is much smaller, its field is quite strong negatively and is equal to the positive field of the proton.

Since the electric-field strength of an electron varies inversely with the distance squared, the field strength a centimetre away would be quite weak. The fields surrounding protons and electrons are known as electrostatic fields. "Static" means stationary or not moving.

When electrons are made to move, the result is dynamic electricity. "Dynamic" means movement. To produce a movement of an electron it is necessary to either have a negatively charged field "push it", a positively charged field "pull it", or, as normally occurs in an electric circuit, a negative and positive charge (a pushing and pulling of forces).

Most atoms have a nucleus consisting of all the protons of the atom and also one or more neutrons. The remainder of the electrons (always equal in number to the nuclear protons) are whirling around the nucleus in different layers. The first layer of electrons outside the nucleus can only accommodate two electrons. If the atom has three electrons then two will be in the first layer and the third will be in the next layer. The second layer is completely filled when eight electrons are whirling around it. The third is filled when eighteen electrons are whirling around.

Don't think these electrons whirl around in some haphazard manner, they don't. The electrons in an element of a large atomic number are grouped into rings having a definite number of electrons. The only atoms in which these rings are completely filled are those of inert gaseous elements such as Helium, Neon, Argon, Krypton, Xenon and Radon.

All the other elements have one or more uncompleted rings of electrons.

Some of the electrons in the outer orbit of atoms such as copper or silver can be easily dislodged. These electrons travel out into the wide open spaces between the atoms and molecules and may be termed **free electrons**. It is the ability of these electrons to drift from atom to atom which makes **electric current** possible. Other electrons will resist dislodgement and are called **bound electrons**.

(From https://what-when-how.com/electronic-properties-of-materials/fundamentals-of-electron-theory; https://www.electronics-tutorials.com)

Vocabulary

solids	тверді речовини

thermal [ˈθɜː.məl]	тепловий
solar collectors	сонячні батареї
heat shield [ʃiːld]	теплові екрани
lattice [ˈlæt.ɪs]	решітка
conductor [kənˈdʌktər]	провідник
insulator [ˈɪn.sjə.leɪ.tər]	ізолятор
annual sales	річний обсяг продажів
sophistication [səˌfɪs.tɪˈkeɪ.ʃən]	витонченість
empirically [ɪmˈpɪr.ɪ.kəl.i]	емпірично
interrelated [ˌɪn.tə.rɪˈleɪ.tɪd]	взаємопов'язані
validity [vəˈlɪd.ɪ.ti]	термін дії
refinement [rɪˈfaɪn.mənt]	уточнення
proponent [prəˈpəʊ.nənt]	поборник
equation [ɪˈkweɪ.ʒən]	рівняння
matter	матерія
to be comprised of	складатися з
divisible [dɪˈvɪz.ə.bəl]	подільний
to repel [rɪˈpel]	відбивати
to whirl [wɜːl]	кружляти
to dislodge [dɪˈslɒdʒ]	витісняти

Exercise 1. Answer the following questions

1. What is one of the keys to understanding materials? 2. What can the electron theory explain? 3. Where are magnetic materials used? 4. Where are optical properties

of materials utilized? 5. Are some materials extremely good electrical conductors? 6. Semiconductors are generally poor conductors at room temperature, aren't they? 7. When does the electrical connectivity increase? 8. How much does the electronic industry cost? 9. What approaches have been developed in the past hundred years to understand the electronic properties of materials? 10. How were the laws of physics discovered in the 19th century? 11. Were any assumptions made about the structure of the matter? 12. What happened at the turn to the 20th century? 13. What does the classical electron theory postulate? 14. What did quantum theory explain? 15. What does the electron theory state? 16. What is a molecule? 17. What is the first important principle to understand? 18. What does the word "matter" include? 19. What is an atom divisible into? 20. What are electrons? What are protons? 21. What is the basic law of physics? 22. Is it electron or proton that moves electricity? 23. What are electrostatic fields? 24. What happens when electrons are made to move? 25. What do most atoms have? 26. How are free electrons and bound electrons different?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

розуміння поведінки електронів, електронна теорія твердих тіл, електричні властивості матеріалів, оптичні властивості матеріалів, сліди певних елементів, річний рівень продажів, життєва сила електронної промисловості, електронні властивості матеріалів, експериментальне спостереження, макроскопічні величини та взаємопов'язані експериментальні дані, дрейфувати як відповідь на зовнішню силу, фундаментальні рівняння, ставати неточними, розуміти основні поняття, світитися та випромінювати світло, потік електронів, подільний, електричні поля, відштовхувати, змінюються обернено, електростатичні поля, в безпосередній близькості, ядро, обертаючись навколо, якимось випадковим чином, може бути легко витіснено, зв'язані електрони.

Exercise 3. Match the sentences

1. Joseph John Thomson (J. J. Thomson, 1856-1940)	a) stainless steel, high speed steel from which our drill bits are made and in common use in electronics.
2. The object from which electrons move to another object	b) becomes negatively charged due to an excess of electrons.
3. The object from which electrons come to another object	c) was proposed by Drude and Lorentz.
4. The classical free electron theory	d) are moving freely and randomly moving in the entire volume of the metal like gas atoms in the gas container.
5. According to this theory the electrons	e) becomes positively charged due to a lack of electrons.
6. When an electric field is applied	f) are found on the outer shell of the atom.
7. Quantum theory states that there are only certain allowed energy states for an electron and	g) because of their behavior in an electric field.
8. The protons and neutrons are found in the middle of the atom in the nucleus. Meanwhile, the electrons	h) is widely recognized as the discoverer of the electron. Thomson was the Cavendish professor of Experimental Physics at Cambridge University and director of its Cavendish Laboratory from 1884 until 1919.
9. An electron	i) that these are quantized.
10. Electrons are referred to as negative	j) is a subatomic particle that is negatively charged.

11. The existence of the electron showed that	k) the free electrons gets accelerated.
12. Most metals in use today are in fact alloys. Common examples are	l) the 2,000-year-old conception of the atom as a homogeneous particle was wrong and that in fact the atom has a complex structure.

Exercise 4. Translate the following sentences into English

1. На початку 20 століття була створена класична електронна теорія провідності металів, в основі якої лежать наступні положення:

2. Метали мають кристалічну решітку, у вузлах якої знаходяться позитивні іони, а між ними рухаються вільні електрони, які називають електронами провідності.

3. Електрони провідності поводяться подібно ідеальному одноатомному газу.

4. При відсутності зовнішнього електричного поля електрони провідності здійснюють хаотичний рух з середньою квадратичною швидкістю, що залежить від температури.

5. При своєму русі електрони провідності відчувають зіткнення з іонами кристалічної решітки, якими визначається їх довжина вільного пробігу λ - відстань, яку проходить електрон між двома послідовними зіткненнями.

6. Якщо метал помістити в електричне поле, то електрони рухаються упорядковано, утворюючи електричний струм.

7. Надпровідність – це явище стрибкоподібного зменшення електричного опору металів до нуля при температурах, близьких до абсолютного нуля. Відкрита у 1911 р. Камерлінг – Оннесом.

8. Сила струму I в однорідному металевому провіднику прямо пропорційна різниці потенціалів на кінцях цього провідника і обернено пропорційна його опору R (закон Ома для однорідної ділянки кола).

9. До напівпровідників відносять речовини, які за одних умов є провідниками, а при інших - діелектриками.

10. Якщо електрони з якої-небудь причини залишають поверхню металу, то на поверхні виникає нескомпенсований електричний заряд, який повертає електрони назад.

(https://naurok.com.ua/lekciya-elektrichniy-strum-u-riznih-seredovischah-163215.html)

Exercise 5. Read the following interesting pieces of information. Share your opinion with your classmates

- Electrons are subatomic particles found in the shells around the nucleus in an atom
- There are four sub-shells. Sub-shell s has one orbital, p has three orbitals, d has five orbitals, and f has seven orbitals.
- The number of protons and electrons are equal in an atom but different in cation and anions.
- Ionisation energy is the energy change measured when one electron is removed from a gaseous atom.
- An electron has a larger angle of deflection than a proton.
- Electrons play a very important role in bonding.
- Electron affinity is the addition of one electron into a gaseous atom

(https://alevelchemistry.co.uk/definition/electrons/)

Speaking

- Speak about Joseph John Thomson.
- Speak about the theory of electrons.
- Speak about atoms.
- Speak about the difference between classical and free electron theory.

Unit 6.

I. Read and translate the text. Learn the new vocabulary

Magnetism

Magnetism, phenomenon associated with magnetic fields, which arise from the motion of electric charges. This motion can take many forms. It can be an electric current in a conductor or charged particles moving through space, or it can be the motion of an electron in an atomic orbital. Magnetism is also associated with elementary particles, such as the electron, that have a property called spin.

Basic to magnetism are magnetic fields and their effects on matter, as, for instance, the deflection of moving charges and torques on other magnetic objects. Evidence for the presence of a magnetic field is the magnetic force on charges moving in that field; the force is at right angles to both the field and the velocity of the charge. This force deflects the particles without changing their speed. The deflection can be observed in the torque on a compass needle that acts to align the needle with the magnetic field of Earth. The needle is a thin piece of iron that has been magnetized—i.e., a small bar magnet. One end of the magnet is called a north pole and the other end a south pole. The force between a north and a south pole is attractive, whereas the force between like poles is repulsive. The magnetic field is sometimes referred to as magnetic induction or magnetic flux density; it is always symbolized by ***B***. Magnetic fields are measured in units of tesla (T). (Another unit of measure commonly used for ***B*** is the gauss, though it is no longer considered a standard unit. One gauss equals 10^{-4} tesla.)

A fundamental property of a magnetic field is that its flux through any closed surface vanishes. (A closed surface is one that completely surrounds a volume.) This is expressed mathematically by div ***B*** = 0 and can be understood physically in terms of the field lines representing ***B***. These lines always close on themselves, so that if they enter a certain volume at some point, they must also leave that volume. In this respect, a magnetic field is quite different from an electric field. Electric field lines can begin and end on a charge, but no equivalent magnetic charge has been found in spite of many searches for so-called magnetic monopoles.

The most common source of magnetic fields is the electric current loop. It may be an electric current in a circular conductor or the motion of an orbiting electron in an atom. Associated with both these types of current loops is a magnetic dipole moment, the value of which is *iA*, the product of the current *i* and the area of the loop *A*. In addition, electrons, protons, and neutrons in atoms have a magnetic dipole moment associated with their intrinsic spin; such magnetic dipole moments represent another important source of magnetic fields. A particle with a magnetic dipole moment is often referred to as a magnetic dipole. (A magnetic dipole may be thought of as a tiny bar magnet. It has the same magnetic field as such a magnet and behaves the same way in external magnetic fields.) When placed in an external magnetic field, a magnetic dipole can be subjected to a torque that tends to align it with the field; if the external field is not uniform, the dipole also can be subjected to a force.

All matter exhibits magnetic properties to some degree. When placed in an inhomogeneous field, matter is either attracted or repelled in the direction of the gradient of the field. This property is described by the magnetic susceptibility of the matter and depends on the degree of magnetization of the matter in the field.

Magnetization depends on the size of the dipole moments of the atoms in a substance and the degree to which the dipole moments are aligned with respect to each other. Certain materials, such as iron, exhibit very strong magnetic properties because of the alignment of the magnetic moments of their atoms within certain small regions called domains. Under normal conditions, the various domains have fields that cancel, but they can be aligned with each other to produce extremely large magnetic fields. Various alloys, like NdFeB (an alloy of neodymium, iron, and boron), keep their domains aligned and are used to make permanent magnets. The strong magnetic field produced by a typical three-millimetre-thick magnet of this material is comparable to an electromagnet made of a copper loop carrying a current of several thousand amperes. In comparison, the current in a typical light bulb is 0.5 ampere. Since aligning the domains of a material produces a magnet, disorganizing the orderly alignment destroys the magnetic properties of the material. Thermal agitation that results from heating a magnet to a high temperature destroys its magnetic properties.

Magnetic fields vary widely in strength. Some representative values are given in the Table.

(From https://www.britannica.com/science/magnetism)

Typical magnetic fields

inside atomic nuclei 10^{11} T

in superconducting solenoids 20 T

in a superconducting coil cyclotron 5 T

near a small ceramic magnet 0.1 T

Earth's field at the Equator $4(10^{-5})$ T

in interstellar space $2(10^{-10})$ T

Magnetic fields produced by electric currents can be calculated for any shape of circuit using the law of Biot and Savart, named for the early 19th-century French physicists Jean-Baptiste Biot and Félix Savart. A few magnetic field lines produced by a current in a loop are shown in Figure 1.

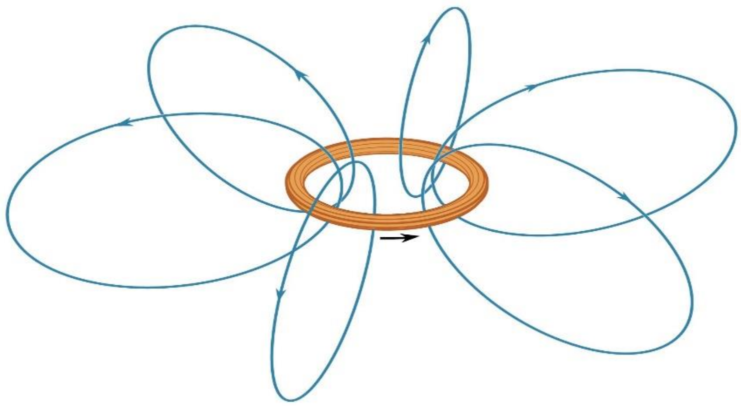

Fig. 1. Magnetic field from current loop

These lines of ***B*** form loops around the current. The Biot–Savart law expresses the partial contribution *d**B*** from a small segment of conductor to the total ***B*** field of a current in the conductor. For a segment of length and

$$d\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{i d\boldsymbol{l} \times \hat{\boldsymbol{r}}}{r^2}. \qquad (1)$$

orientation ***dl*** that carries a current *i*,

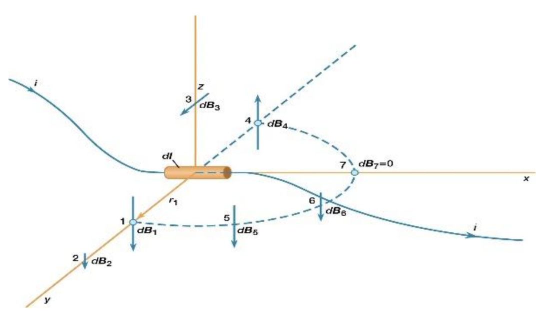

Fig. 2. Magnetic field produced by electric current

(From https://www.britannica.com/science/magnetism)

Vocabulary

phenomenon [fəˈnɒm.ɪ.nən]	явище
deflection [dɪˈflek.ʃən]	відхилення, заломлення
torque [tɔːk]	крутний момент
velocity [vəˈlɒs.ɪ.ti]	швидкість
to align [əˈlaɪn]	вирівнювати
vanish [ˈvæn.ɪʃ]	зникати
loop [luːp]	петля
neutrons [ˈnjuː.trɒn]	нейтрони
dipole [ˈdaɪ.pəʊl]	диполь
neodymium [ˌniːəʊˈdɪmɪəm]	неодим
exhibit [ɪɡˈzɪbɪt]	експонат
repel [rɪˈpel]	відбивати
susceptibility [səˌsep.tɪˈbɪl.ɪ.ti]	сприйнятливість
domain[dəˈmeɪn]	домен, галузь, ділянка
alloy[ˈæl.ɔɪ]	сплав
comparable [ˈkɒm.pər.ə.bl̩]	порівнянний
spin	кружляти, крутитися
interstellar	міжзоряний
superconducting	надпровідний

contribution внесок

Exercise 1. Answer the following questions

1. What is the name of the phenomenon which is associated with magnetic fields? 2. How do we name the fields which arise from the motion of electrical charges? 3. What forms can this motion take? 4. What is the evidence for the presence of a magnetic field? 5. Does the magnetic force deflect the particles without changing their speed? 6. Why does the compass needle act to align with the magnetic field of Earth? 7. What units are magnetic fields measured in? 8. A magnetic field is quite different from an electrical field, isn't it? 9. What is the fundamental property of the magnetic field? 10. Is it right to suppose that all matter exhibits magnetic properties to some degree? 11. What is the most common source of magnetic field? 12. Why does iron exhibit one of the most strong magnetic properties? 13. Why is an alloy of neodymium, iron and boron used for production of permanent magnets? 14. Does the heating of material magnet to high temperature destroy the magnetic properties of the magnet? 15. Can the motion of an electron in an atomic orbital be a source of magnetism? 16. What law can be used for calculation of magnetic fields produced by electric currents of any circuit shape? 17. What is the value of Earth magnetic field at the Equator? 18. What is the value of magnetic field in interstellar space? 19. Is the magnetic field sometimes referred to as magnetic induction? 20. What are some typical magnetic fields?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

магнітні поля, рух електричних зарядів, стрілка компаса, заряджені частинки, основа магнетизма, зовнішні магнітні поля, що рухаються в просторі; обертаючий момент, свідоцтво присутності, швидкість заряду, міжзоряний простір, відхиляє частки, відноситься до магнітної індукції, магнітні властивості, постійний магніт, північний полюс, південний полюс, у математичному вираженні, в цьому випадку, замість, джерело магнетизму, ступінь намагнічування речовини, вплив на матерію, асоціюється з, більше не розглядається як, щільність магнітного потоку, залежить від ступеня намагничування.

Exercise 3. Match the sentences

1. Magnetism	a) each electron to act like a microscopic magnet.
2. Magnetism	b) the nucleus, or core, of an atom.
3. Every substance	c) electrons, particles that carry electric charges.
4. Each atom has	d) is made up of tiny units called atoms.
5. Spinning like tops, the electrons circle	e) is caused by the motion of electric charges.
6. Their movement generates an electric current and causes	f) creates a magnetic field.
7. In most substances, equal numbers of electrons spin in opposite directions,	g) but they are not yet magnets.
8. That is why materials such as cloth or paper are said	h) most of the electrons spin in the same direction.
9. In substances such as iron, cobalt, and nickel,	i) to be weakly magnetic.
10.This makes the atoms in these substances strongly magnetic —	j) which cancels out their magnetism.
11.To become magnetized, another strongly magnetic substance must	k) line up in the same direction.

12.The magnetic field is the area around	l) while the same poles repel each other.
13.All magnets have	m) is the force exerted by magnets when they attract or repel each other
14.The force generated by the aligned atoms	n) enter the magnetic field of an existing magnet.
15.Opposite poles are attracted to each other,	o) a magnet that has magnetic force.
16.When you rub a piece of iron along a magnet, the north-seeking poles of the atoms in the iron	p) north and south poles.

Exercise 4. Translate the following sentences into English

1. Магнетизм — це сила, з якою діють магніти, коли вони притягують або відштовхують один одного.

2. Магнетизм зумовлений рухом електричних зарядів.

3. Кожна речовина складається з крихітних одиниць, які називаються атомами.

4. Кожен атом має електрони, частинки, які несуть електричні заряди.

5. Коли магнітне поле стає сильнішим приблизно за 500 000 Гаусс, об'єкти інтенсивно розриваються на шматки силами.

6. З цієї причини вчені не можуть побудувати машину, яка створює магнітне поле, потужність якого перевищує 500 000 Гаусів, і живе довше частки секунди.

7. Магнетизм виникає внаслідок двох типів руху електронів в атомах: один — це рух електронів по орбіті навколо ядра, подібний до руху планет нашої

Сонячної системи навколо Сонця, а інший — обертання електронів навколо своєї осі, аналогічно обертанню Землі навколо своєї осі.

8. Було виявлено та класифіковано п’ять основних типів магнетизму на основі магнітної поведінки матеріалів у відповідь на магнітні поля при різних температурах. Ці типи магнетизму: феромагнетизм, ферімагнетизм, антиферомагнетизм, парамагнетизм і діамагнетизм.

9. Магнітне поле або щільність потоку вимірюється в метричних одиницях гаус (Г) і відповідній одиниці міжнародної системи тесла (Т). Напруженість магнітного поля вимірюється в метричних одиницях ерстед (Ое) і міжнародних одиницях амперах на метр (А/м).

10. Для вимірювання величини магнітного поля використовують прилади, які називаються гаусметрами та магнітометрами.

(*https://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics9%20-Magnetism/Useful%20papers/Magnetism.htm#:~:text=Magnetism%20arises%20from%20two%20types,the%20Earth%20about%20its%20own)*

Exercise 5. Read the following interesting piece of information. Share your opinion with your classmates

Animal Magnetism

Some animals, such as pigeons, bees, and salmon, can detect Earth's magnetic field and use it to navigate. Scientists aren't sure how they do this, but these creatures seem to have magnetic material in their bodies that acts like a compass.

(*https://education.nationalgeographic.org/resource/magnetism/)*

Speaking

- Speak about electromagnetic radiation.

- Speak about electricity and magnetism.
- Speak about Michael Faraday and his discoveries.
- Speak about magnetic properties.

Unit 7.

I. Read and translate the text. Learn the new vocabulary

Optics

Optics was started many centuries ago as the science dealing with the properties of light – a part of the discipline of physics. It also became more and more important for practical applications and can therefore now also be regarded as an important field of technology. As the properties of light have already been known quite precisely for several decades, most of current optics research focuses on applications. For example, one can study technical optics, which focuses on the operation principles and further optimization of various optical components and devices.

Optics plays a crucial role in the area of photonics, mainly concerning various properties of light and on its propagation e.g. through transparent optical materials. It also has a very substantial economical importance as an enabler for many other modern technologies. However, many details of the generation and detection of light lie outside the field of optics, which deals mainly with the propagation of light. Photonics contains other important fields like laser physics which interface with optical physics.

Nowadays, optics deals not only with visible light, but also with infrared and ultraviolet light, as these have many properties in common with visible light, and are often utilized with similar optical components.

Classical Optics

Geometrical Optics

To some extent, the propagation of light can be described with ray optics or geometrical optics, where light is considered to consist of rays which propagate along straight lines, at least in homogeneous optical media. The effects of optical components on light rays is often described with an ABCD matrix algorithm.

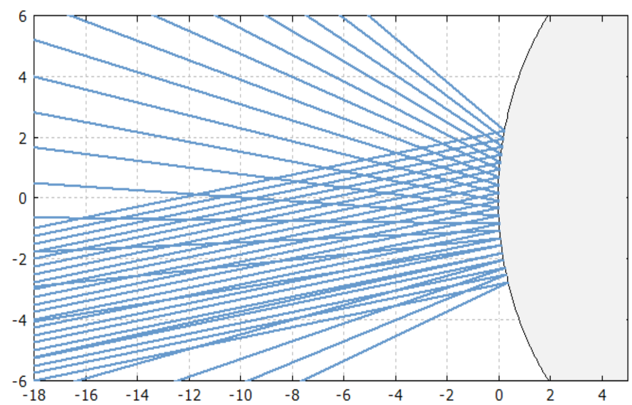

Figure 1: Reflection of light rays at a spherically curved mirror.

Although geometrical optics has serious limitations – it cannot describe various important physical phenomena involving diffraction or interference, for example – it is still useful. For example, many properties of optical imaging systems containing mirrors, lenses, prisms etc. can be well understood with geometrical optics, although their performance limitations can not be completely explained with ray optics.

Physical Optics, Wave Optics

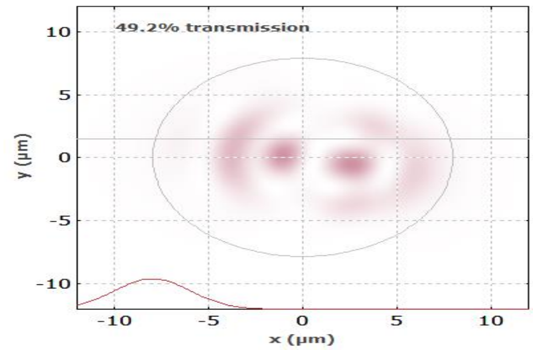

Figure 2: Intensity profiles at the end of a multimode fiber for a variable input beam position, shown as animated graphics. Such calculations need to be based on wave optics; ray optics are not sufficient. The image is from a case study with the software RP Fiber Power.

Some physical phenomena show quite clearly that light has properties of waves, although the rather short wavelengths of light do not always make that obvious. However, interference and diffraction processes in particular are hard to explain without optical waves. Around 1865, James Clerk Maxwell managed to demonstrate that light can indeed be identified with transverse electromagnetic waves of frequencies of the order of hundreds of terahertz. This quickly explained many phenomena e.g. in the context of diffraction and polarization. Some of the first practical results were explanations for the limited optical performance e.g. of microscopes and telescopes, and hints towards further optimization of their performance.

Light propagation in optical fibers can also be well described only with ray optics; see Figure 2 for an example.

Beyond an improved understanding, many new kinds of devices and operation principles have resulted from the evolution of physical optics and wave optics. For example, powerful spectrometers based on diffraction gratings have been realized, dielectric coatings (thin-film coatings) have become very important in various fields of photonics, and optical resonators play important roles e.g. as optical filters and as laser resonators.

Large parts of physical optics require quite sophisticated and partly abstract mathematical methods, although greatly simplified mathematical methods are still sufficient for many purposes. Numerical computation methods have become very important, greatly simplifying the work in many cases.

Quantum Optics

Although the description of light as classical electromagnetic waves, as developed in the 19th century, has been extremely successful, it became apparent in the early 20th century that there are phenomena which are hard to explain on that basis. For example, Albert Einstein realized that the photoelectric effect seemed to suggest that light energy is not delivered continuously, but in certain discrete packages, which are nowadays called photons. The further development of quantum mechanics led to a physical description which reconciles quite well the wave nature and apparent particle properties of light, although the resulting physical model is hard to bring together with intuitive ideas, and some aspects of quantum physics are still a matter of debate, essentially concerning interpretations. Note, however, that there seem to be no logical flaws or gaps of understanding in the sense that phenomena could not be properly described or predicted.

The field of optics which is specifically dealing with quantum effects is called quantum optics. In recent years, quantum optics has led to interesting technological developments; important keywords are quantum cryptography (for secure data transmission based on physical principles) and quantum computing.

Technical Optics

Technical optics is based on optical physics, but focuses on optical components and systems for transforming and utilizing light, not on studying the properties of light itself. Some examples of areas of activity and technical optics are:

Modeling and design methods for developing optical systems are still being further refined and optimized. Optical materials and their fabrication are further optimized, and occasionally new materials are developed.

Various optical components and devices are also developed further, and new concepts are introduced. Some progress in optical technology is based on new materials or improve fabrication technologies, which can be utilized e.g. for improving the performance of optical systems or making them simpler, more compact and less expensive. For example, new fabrication techniques for aspheric optics and high-quality plastic optics allow one to realize extremely compact photo cameras with astonishing performance figures.

Much of technical optics is based on classical optics, i.e., not involving quantum effects.

Modern optics deals with light propagation not only in "simple" artificial media, but also for example in the atmosphere (atmospheric optics) and in strongly scattering biological materials.

(From https://www.rp-photonics.com/optics.html)

Vocabulary

property of light [ˈprɒp.ə.ti əv laɪt]	властивість світла
precisely [prɪˈsaɪs.li]	точно

photonics [fəʊ'tɒnɪks]	фотоніка
transparent [trænˈspær.ənt]	прозорий
enabler [ɪˈneɪ.blər]	активатор
homogeneous [ˌhɒm.əˈdʒiː.ni.əs]	однорідний
diffraction [dɪˈfræk.ʃən]	дифракція
interference [ˌɪn.təˈfɪə.rəns]	втручання
ray [reɪ]	промінь
transverse [trænzˈvɜːs]	поперечний
diffraction gratings [dɪˈfræk.ʃən]	дифракційні решітки
thin-film coating ['θɪnfɪlm 'kəutɪŋ]	тонкоплівкове покриття
reconcile [ˈrek.ən.saɪl]	примиритися
logical flaw [ˈlɒdʒ.ɪ.kəl flɔː]	логічний недолік
quantum cryptography [ˈkwɒn.təm krɪpˈtɒg.rə.fi]	квантова криптографія
fabrication [ˌfæb.rɪˈkeɪ.ʃən]	виготовлення
aspheric optics [eɪ'sfɛrɪk ˈɒp.tɪks]	асферична оптика
astonishing performance figures [əˈstɒn.ɪ.ʃɪŋ pəˈfɔː.məns ˈfɪg.ərz]	дивовижні показники продуктивності
scattering [ˈskæt.ər.ɪŋ]	розсіювання

Exercise 1. Answer the following questions

1. When was optics started? 2. Why can it also be regarded as an important field of technology? 3. Why do most of current optics research focuses on applications? 4. What area does optics play a crucial role in? 5. Why does it have a very substantial economical importance? 6. What other important fields does photonics contain?

7. What does optics deal with nowadays? 8. How can the propagation of light be described? 9. What serious limitations does geometrical optics have? 10. What do some physical phenomena show quite clearly? 11. What processes are hard to explain without optical waves? 12. What did James Clerk Maxwell manage to demonstrate? 13. What were some of the first practical results? 14. How can light propagation in optical fibers also be well described? 15. What has resulted from the evolution of physical optics and wave optics? 16. What do large parts of physical optics require? 17. Have numerical computation methods become very important? 18. What became apparent in the 19th century? 19. What did Albert Einstein realize? 20. What did the further development of quantum mechanics lead to? 21. What is called quantum optics? 22. What has quantum optics led to in recent years? 23. What is technical optics based on? 24. Modeling and design methods for developing optical systems are still being further refined and optimized, aren't they? 25. What do new fabrication techniques for aspheric optics and high-quality plastic optics allow one to realize? 26. How does modern optics deal with light propagation?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

мати справу з властивостями світла, важливішими для практичних застосувань, важлива галузь технології, більшість сучасних досліджень оптики, подальша оптимізація різних оптичних компонентів і пристроїв, відігравати вирішальну роль у галузі фотоніки, прозорі оптичні матеріали, генерація та детектування світла, видиме світло, певною мірою однорідне оптичне середовище, мати серйозні обмеження, променева оптика, властивості хвиль, інтерференція та дифракційні процеси, еволюція фізичної оптики та хвильової оптики, діелектричні покриття, оптичні фільтри та лазерні резонатори, частково абстрактні математичні методи, чисельні методи обчислень, опис світла як класичних електромагнітних хвиль, фотоелектричний ефект, певні дискретні пакети, предмет дебатів, квантова оптика, квантова криптографія, для покращення продуктивності оптичних систем, високоякісна пластикова оптика, надзвичайно компактні фотокамери з приголомшливими показниками продуктивності, квантові ефекти.

Exercise 3. Match the sentences

1. Optics, science concerned with the genesis and propagation of light, the changes	a) is formed inside an instrument at the point where diverging rays would cross if they were extended backward into the instrument.
2. Originally, the term optics	b) and the hologram as an optical element.
3. In 1604 Johannes Kepler, a German astronomer, published a book on optics in which he postulated that	c) consists of two lenses.
4. An optical image may be regarded	d) by the development of the laser in the 1960s.
5. A new era in optics commenced in the early 1950s following	e) an intermediate record is made of the complex optical field associated with the object. and information theory.
6. This impetus was sustained	f) as the apparent reproduction of an object by a lens or mirror system, employing light as a carrier.
7. Nonlinear effects in optics are	g) the impact of certain branches of electrical engineering—most notably communication
8. The basic system required for coherent optical processing	h) an extended object could be regarded as a multitude of separate points, each

	point emitting rays of light in all directions.
9. Regular reflection, which follows a simple law,	i) now quite readily observable using the highly coherent and highly energetic laser beams.
10. The applications are in three groups: image-forming applications, non-image-forming applications,	j) was used only in relation to the eye and vision.
11. Holography is a two-step coherent image-forming process in which	k) occurs at plane boundaries.
12. A real image is formed outside the system, where the emerging rays actually cross; a virtual image, on the other hand,	l) that it undergoes and produces, and other phenomena closely associated with it.

Exercise 4. Translate the following sentences into English

1. Оптична фізика вивчає світло та його взаємодію з речовиною.

2. Більшість із нас вважає світло освітлюючою енергією.

3. За допомогою світла ми можемо бачити речі. Без цього ми в темряві.

4. Однак для фізиків-оптиків світло — це серія електромагнітних хвиль, частота та довжина яких дуже різняться.

5. Радіохвилі, мікрохвилі, радар і рентгенівське випромінювання є іншими формами світла, і кожен має унікальний спосіб взаємодії зі склом та іншою речовиною.

6. Інфрачервоне випромінювання, наприклад, виявляє тепло — і, отже, ознаки життя та активності.

7. Ця наукова галузь має природне поєднання з технологією скла, оскільки успішне виконання багатьох спеціальних скляних застосувань — оптичних волокон, панелей дисплеїв, напівпровідникових систем і деяких інструментів для розробки ліків — це лише деякі з них — залежить від того, як вони програми передають, обробляють або маніпулюють світлом.

8. Наші оптичні комунікаційні продукти є найвідомішим прикладом досвіду Corning у галузі оптичної фізики, але вони також відіграють важливу роль у мобільній побутовій електроніці.

9. Смартфон у вашій кишені має надзвичайно маленькі світлодіоди, що дає змогу підсвічувати екрани, які споживають неймовірно малу кількість заряду акумулятора.

10. Поєднання цієї тепер уже всюдисущої інновації зі спеціальними окулярами, які її оточують, назавжди змінило наш спосіб спілкування зі світом.

(*https://www.toppr.com/guides/physics/ray-optics-and-optical-instruments/optics/*)

Exercise 5. Read the following interesting pieces of information. Share your opinion with your classmates

- Hyperspectral imaging is a growing field in which invisible light is used in highly sophisticated detection programs. Law enforcement and security teams are turning to hyperspectral imaging for covert fingerprint analysis and detection of explosive materials. There are also growing applications in monitoring food and drug safety. And the medical field is finding growing success with diagnosing some early-stage illnesses through hyperspectral imaging.

- Corning's leadership in optical physics earned prestigious recognition in 2000 when three Corning scientists were awarded the National Medical of Technology for their invention of low-loss optical fiber. Dr. Don Keck, Dr. Robert Maurer and Dr. Peter Schultz developed the monumental technical breakthrough that paved the way for the commercialization of optical fiber and the everyday use of the Internet.

(https://www.corning.com/cala/pt/innovation/materials-science/optical-physics/optical-physics-facts.html)

Speaking

- Speak about people who contributed a lot to the development of optics.
- Speak about light rays, waves, and wavelets.
- Speak about reflection and dispersion.
- Speak about optical systems.

Unit 8.

I. Read and translate the text. Learn the new vocabulary

Atomic structure of matter

The history of atomic structure and quantum mechanics dates back to the times of Democritus, the person who first proposed that matter is composed of atoms. The study of the structure of an atom gives a great insight into the entire class of chemical reactions, bonds and their physical properties. The first scientific theory of atomic structure was proposed by John Dalton in the 1800s.

The English chemist **John Dalton** suggested that all matter is made up of atoms, which were indivisible and indestructible. He also stated that all the atoms of an element were exactly the same, but the atoms of different elements differ in size and mass.

Chemical reactions, according to Dalton's atomic theory, involve a rearrangement of atoms to form products. According to the postulates proposed by Dalton, the atomic structure comprises atoms, the smallest particle responsible for the chemical reactions to occur.

Matter cannot be separated individually, but it is an arrangement of several atoms. Atoms are the smallest unit of matter that is having protons, neutrons, and electrons and cannot be divided. The arrangement of numerous atoms decides the size, shape, and color of matter.

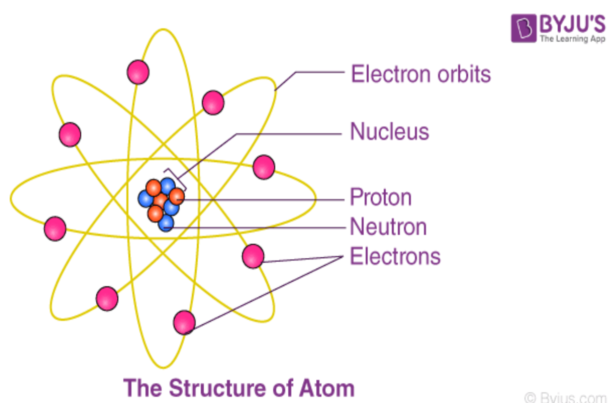

Fig.1. The atomic structure of matter

(From https://byjus.com/jee/atomic-structure/)

Matter can either be a pure substance or a mixture. Pure substances can either be elements or compounds. Mixtures can either be homogeneous or heterogeneous.

An element is matter made of only one kind of atom. There are 115 known elements. Ninety elements are naturally occurring. The elements are organized according to their properties in the Periodic Table. For example, Hydrogen, Carbon, Nitrogen, Calcium, Sodium, Oxygen.

Compounds are two or more elements that are chemically combined. Compounds cannot be easily separated into their elements. For example, H2O Water, NaCl Salt, C6H12O6 Sugar/Glucose H2 N2 O2. The gases of hydrogen, nitrogen and oxygen naturally exist as compounds of two atoms of their element.

Mixtures are made of different compounds that are mixed together. Mixtures can be easily separated into the original compounds. Homogeneous – substances evenly mixed, heterogeneous – substances not evenly mixed.

Atoms interact through the electromagnetic force and create molecules. Molecules can include atoms of the same or different elements. Each type of molecule has its own properties which also define how it reacts with other molecules. The use and role of each type of molecules in nature is based on its properties.

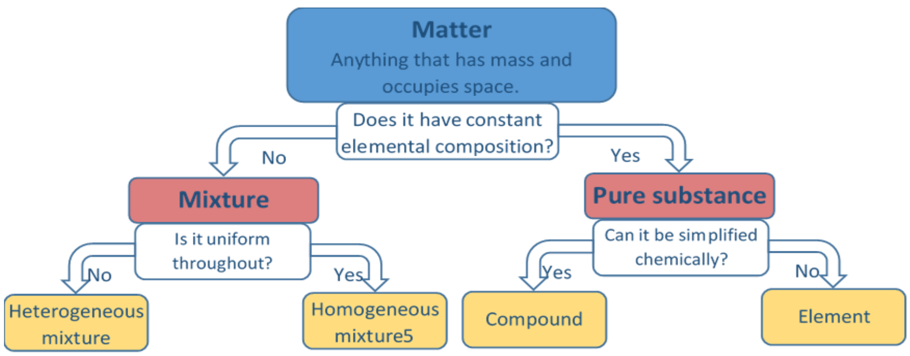

Fig.2. The structure of matter

(From https://ukrayinska.libretexts.org)

Physical properties of matter can be observed and measured without changing the kind of matter being studied. These physical properties can be used to identify a substance; i.e. melting point, boiling point, density (heaviness), color, ph.

Chemical properties of matter are not usually visible and, a change in the matter does occur. Chemical properties can also help identify a substance. Chemical properties can only be seen when there is a chemical reaction like burning, rusting, chemical reactivity.

The three classical states, solid, liquid, and gas of matter, can be distinguished macroscopically in terms of the properties of density, compressibility, and rigidity related to the motion of atoms or molecules. What are elements in structure of matter? All matter is made up of substances called elements, which have specific chemical and physical properties and cannot be broken down into other substances through ordinary chemical reactions.

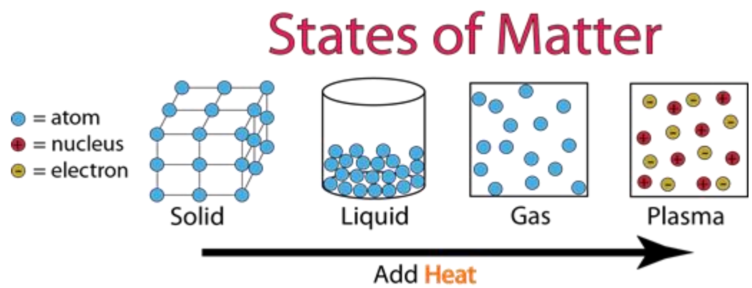

Fig.3. The four states of matter at the molecular level

(From https://www.hiclipart.com/free-transparent-background-png-clipart-mwpjm/download)

Primarily, the atomic structure of matter is made up of protons, electrons and neutrons. The protons and neutrons make up the nucleus of the atom, which is surrounded by the electrons belonging to the atom. The atomic number of an element describes the total number of protons in its nucleus.

Any characteristic that can be measured, such as an object's density, colour, mass, volume, length, malleability, melting point, hardness, odour, temperature, and more, are considered properties of matter. Chemical reactions are the processes through which atoms and/or molecules interact and are combined. There are different types of chemical reactions but they are mainly categorized depending on whether the system releases or absorbs energy.

(From https://www.uomus.edu.iq/img/lectures21/MUCLecture_2022_123047822.pdf)

Vocabulary

matter [ˈmætə(r)] матерія

to be composed of	складатися з
insight [ˈɪn.saɪt]	в поле зору
entire [ɪnˈtaɪə(r)]	цілий
bond [bɒnd]	зв'язь
indivisible [ˌɪn.dɪˈvɪz.ɪ.bl̩]	неподільний
indestructible [ˌɪn.dɪˈstrʌk.tɪ.bl̩]	непорушний
postulate [ˈpɒs.tjʊ.leɪt]	постулат
to occur [əˈkɜː(r)]	відбуватися
substance [ˈsʌbstəns]	речовина
homogeneous [ˌhɒm.əˈdʒiː.ni.əs]	однорідний
heterogeneous [ˌhet.ər.əˈdʒiː.ni.əs]	неоднорідний
the periodic table	таблиця Менделєєва
hydrogen [ˈhaɪ.drɪ.dʒən]	водень
carbon [ˈkɑː.bən]	вуглець
nitrogen [ˈnaɪ.trə.dʒən]	азот
compound [ˈkɒm.paʊnd]	сполука
evenly [ˈiː.vən.li]	рівномірно
density [ˈden.sɪ.ti]	щільність
ph [ˌpiːˈeɪtʃ]	пі аш; рівень кислотності
rust [rʌst]	іржа
compressibility [kəmpresɪˈbɪlɪtɪ]	стисливість
rigidity [rɪˈdʒɪd.ɪ.ti]	жорсткість
malleability [ˌmæl.i.əˈbɪl.ɪ.ti]	пластичність

odour [ˈəʊ.dər] запах

Exercise 1. Answer the following questions

1. What did Democritus propose? 2. What does the study of the structure of an atom give? 3. Who was the first scientific theory of atomic structure proposed by? 4. What did the English chemist John Dalton suggest? What did he state? 5. What do chemical reactions involve according to Dalton's atomic theory? 6. What is matter? 7. What are the smallest units of matter? 8. What decides the size, shape, and color of matter? 9. What can matter be? 10. What can pure substances be? 11. What can mixtures be? 12. What is an element? 13. How are elements organized? 14. What are compounds? Give examples. 15. What are mixtures made of? 16. How do atoms interact? 17. What can you say about types of molecules? 18. How can physical properties of matter be observed? 19. What can you say about chemical properties of matter? 20. What are the three classical states of matter? 21. What is all matter made up of? 22. What does the atomic number of an element describe? 23. What are the properties of matter? 24. What are chemical reactions? 25. How can chemical reactions be categorized?

Exercise 2. Find the English equivalents in the text

історія атомної структури, квантова механіка, сходить до, дати велике розуміння, фізичні властивості, перша наукова теорія, відрізнятися за розміром і масою, найменша частинка, чиста речовина або суміш, може бути однорідною або неоднорідною, бути організованими відповідно до їхніх властивостей, бути хімічно поєднаними, рівномірно змішані речовини, взаємодіяти через електромагнітну силу, можна спостерігати та вимірювати, ідентифікувати речовину, хімічна реакція, тверда, рідка та газоподібна речовина ; розпадатися на інші речовини, складатися з протонів, електронів і нейтронів; ядро, в основному класифікуватися залежно від, вивільняти або поглинати енергію.

Exercise 3. Match the sentences

1. At the most fundamental level, matter is composed of elementary particles known	a) astronomical observations that began in the 1930s and that show that a large fraction of the universe consists of “dark matter.”
2. Quarks combine into protons and neutrons and,	b) whose roots go back to Max Planck’s explanation in 1900 of the properties of electromagnetic radiation emitted by a hot body.
3. Depending on temperature and other conditions,	c) prevents a material body from responding instantaneously to attempts to change its state of rest or motion.
4. At ordinary temperatures, for instance, gold is a solid, water is a liquid, and nitrogen is a gas, as defined by certain characteristics:	d) the particles annihilate each other.
5. However, all matter of any type shares the fundamental property of inertia, which—as formulated within Isaac Newton’s three laws of motion—	e) scientists finally announced in 2012 the discovery of the Higgs boson.
6. Another universal property	f) matter may appear in any of several states.
7. Einstein’s theory of special relativity (1905) shows that matter (as mass) and energy	g) is gravitational mass, whereby every physical entity in the universe acts so as to attract every other one, as first stated

	by Newton and later refined into a new conceptual form by Albert Einstein.
8. The concept of matter is further complicated by quantum mechanics,	h) an elementary subatomic particle known as the Higgs boson imparts mass to all known elementary particles.
9. Additional complexity in the meaning of matter comes from	i) solids hold their shape, liquids take on the shape of the container that holds them, and gases fill an entire container. These states can be further categorized into subgroups.
10. Although a fully satisfactory grand unified theory (GUT) has yet to be derived, one component, the electroweak theory of Sheldon Glashow, Abdus Salam, and Steven Weinberg (who shared the 1979 Nobel Prize for Physics for this work) predicted that	j) can be converted into each other according to the famous equation $E = mc^2$, where E is energy, m is mass, and c is the speed of light.
11. After years of experiments using the most powerful particle accelerators available,	k) along with electrons, form atoms of the elements of the periodic table, such as hydrogen, oxygen, and iron.
12. When matter meets antimatter,	l) as quarks and leptons (the class of elementary particles that includes electrons).

Exercise 4. Translate the following sentences into English

1. Матерія складається з крихітних частинок, які називаються атомами, що утримуються разом силами, званими зв'язками.
2. Матерія класифікується як чиста речовина, якщо вона має постійний і незмінний склад типу атомів. Наша матерія - це або елемент, або з'єднання.
3. Традиційно у фізичній картині світу виділяють два фундаментальні види матерії — речовину та фізичні поля.
4. Однак, такий поділ є умовним, оскільки в рамках квантової теорії поля будь-яка частинка описується квантованим фізичним полем.
5. Останніми роками для пояснення прискорення розширення Всесвіту, про що свідчать астрономічні спостереження, виникла необхідність гіпотезувати існування нового виду матерії, яка отримала назву темної енергії.
6. Природа темної енергії залишається нез'ясованою.
7. Нейтронна речовина — складається переважно з нейтронів і позбавлена атомної будови.
8. За сучасними уявленнями квантове поле є універсальною формою матерії,
9. Класична речовина може перебувати в одному з декількох агрегатних станів: газоподібний, рідкий, твердий кристалічний, твердий аморфний або у вигляді рідкого кристала.
10. Елементи представлені символами, першим алфавітом їх англійської або неанглійської назви, написаним великими літерами. Наприклад, C — для вуглецю, O —для кисню, а H — для водню.

(From https://uk.wikipedia.org/wiki/Матерія_(фізика); https://ukrayinska.libretexts.org/)

Exercise 5. Read the following interesting pieces of information. Share your opinion with your classmates

- Oxygen is made up of a single atom.
- Pure liquid helium can be converted into solid by heating at -272c.
- Compound gases like CO_2 are made up of more than two particles.
- A vacuum is an area containing no matter.
- Plasma can be found in polar auroras.
- The volume of gas is not constant.
- 97% of the water present on earth is salt water.
- When water freezes, it expands up to 9%.

(From https://abbasqaisar313.medium.com/the-amazing-facts-about-the-states-of-matter-abfe5849c3a5)

Speaking

- Speak about the atomic structure of matter.
- Speak about states of matter.
- Speak about matter and energy.

Unit 9.

I. Read and translate the text. Learn the new vocabulary

The Discovery of X-rays

X-ray, electromagnetic radiation of extremely short wavelength and high frequency, with wavelengths ranging from about 10^{-8} to 10^{-12} metre and corresponding frequencies from about 10^{16} to 10^{20} hertz (Hz).

X-rays were discovered in 1895 by German physicist Wilhelm Konrad Röntgen while investigating the effects of electron beams (then called cathode rays) in electrical discharges through low-pressure gases. Röntgen uncovered a startling effect—namely, that a screen coated with a fluorescent material placed outside a discharge tube would glow even when it was shielded from the direct visible and ultraviolet light of the gaseous discharge. He deduced that an invisible radiation from the tube passed through the air and caused the screen to fluoresce. Röntgen was able to show that the radiation responsible for the fluorescence originated from the point where the electron beam struck the glass wall of the discharge tube. Opaque objects placed between the tube and the screen proved to be transparent to the new form of radiation; Röntgen dramatically demonstrated this by producing a photographic image of the bones of the human hand. His discovery of so-called Röntgen rays was met with worldwide scientific and popular excitement, and, along with the discoveries of radioactivity (1896) and the electron (1897), it ushered in the study of the atomic world and the era of modern physics.

X-rays are commonly produced by accelerating (or decelerating) charged particles; examples include a beam of electrons striking a metal plate in an X-ray tube and a circulating beam of electrons in a synchrotron particle accelerator or storage ring. In addition, highly excited atoms can emit X-rays with discrete wavelengths characteristic of the energy level spacings in the atoms. The X-ray region of the electromagnetic spectrum falls far outside the range of visible wavelengths. However, the passage of X-rays through materials, including biological tissue, can be recorded with photographic films and other detectors. The analysis of X-ray images of the body is an extremely valuable medical diagnostic tool.

X-rays are a form of ionizing radiation—when interacting with matter, they are energetic enough to cause neutral atoms to eject electrons. Through this ionization process the energy of the X-rays is deposited in the matter. When passing through living tissue, X-rays can cause harmful biochemical changes in genes, chromosomes, and other cell components. The biological effects of ionizing radiation, which are complex and highly dependent on the length and intensity of exposure, are still under active study (*see* radiation injury). X-ray radiation therapies take advantage of these effects to combat the growth of malignant tumours.

The defining characteristics of X-rays—their ability to penetrate optically opaque materials, their wavelengths of atomic dimension, the high energy of individual X-ray photons—lead to a wide range of industrial, medical, and scientific applications. Specialized X-ray sources, detectors, and analysis techniques have been developed to address a range of questions from the study of the interactions of the simplest molecules to the structure of the human brain.

X-ray images of the body are an indispensable diagnostic tool in modern medicine. Medical imaging allows for the nonintrusive detection of dental cavities, bone fractures, foreign objects, and diseased conditions such as cancer. Standard X-ray images easily differentiate between bone and soft tissue; additional contrast between different areas of soft tissue is afforded by the injection of a contrast medium—a liquid or gas that is comparatively opaque to X-rays. In the 1970s a powerful new X-ray imaging technique, computed tomography (CT), was developed. Now in widespread use, CT scans produce detailed high-resolution cross-sectional images of internal organs and structures.

X-rays are a powerful diagnostic tool for revealing the structure and composition of materials. The great utility of X-ray images derives from the differential absorption of X-rays by materials of different density, composition, and homogeneity. In a common application, X-rays are used for quick examination of the contents of airline baggage. In industry, X-ray images are used to detect flaws nondestructively in castings that are inaccessible to direct observation.

(From https://www.britannica.com/science/X-ray)

Vocabulary

wavelength [ˈweɪv.leŋθ]	довжина хвилі
ranging from	від
accelerator [əkˈsel.ə.reɪ.tər]	прискорювач
interacting	взаємодіючи
beam of electrons	пучок електронів
electromagnetic radiation	електромагнітне випромінювання
to pass through	проходити через
living tissue [ˈtɪʃ.uː]	жива тканина
ultraviolet light [ˌʌl.trəˈvaɪə.lət laɪt]	ультрафіолетове світло
to deduce [dɪˈdjuːs]	виводити
glow	світіння
shield [ʃiːld]	щит
coated	з покриттям
invisible [ɪnˈvɪz.ɪ.bl̩]	невидимий
transparent [trænsˈpærənt]	прозорий
penetrate [ˈpen.ɪ.treɪt]	проникати
applications	програми, застосунки
a wide range of	широкий асортимент
indispensable [ˌɪn.dɪˈspen.sə.bl̩]	незамінний
computed tomography [kəmˈpjuːtɪd təˈmɒg.rə.fi]]	комп'ютерна томографія
derive [dɪˈraɪv]	вивести
density [ˈden.sɪ.ti]	щільність

homogeneity [ˌhɒm.əˈdʒiː.ni. tɪ] однорідність

Exercise 1. Answer the following questions

1. What is the X-Ray? 2. Is the wavelength of X-Ray extremely short or not? 3. How are X-Rays commonly produced? 4. Why can no one actually see X-Rays? 5. How can the passage of X-Ray through living tissue be recorded? 6. Why is the analysis of human body X-Ray images so important for a doctor? 7. What happens when X-Rays interact with matter? 8. Can X-Ray be harmful for a human body? 9. Whom were X-Rays discovered by? 10. Where did Rontgen place the opaque objects to prove the existence of new invisible rays? 11. What areas of human activities may X-Rays be used in? 12. What are the defining characteristics of X-Rays? 13. X-Ray images of the body are an indispensable diagnostic tool in modern medicine, aren't they? 14. Does X-Ray medical imaging allow for the nonintrusive detection of dental cavities and bone fractures? 15. When was the computed tomography developed? 16. What is the main difference between X-Ray images and computed tomography scans? 17. How are X-Rays used in welding, casting and luggage inspection in airports as well?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

рентгенівські промені, комп'ютерна томографія, електромагнітна радіація, високі частоти, фрагменти кістки, рентгенівські знімки, матеріали різної щільності, складу та однорідності; непрозорі предмети, поміщені між трубкою та екраном; сучасна медицина, електромагнітний спектр, видимі довжини хвиль, довжини хвиль у діапазоні, при взаємодії з матерією, рентгенівські промені можуть спричинити небезпечні біохімічні зміни в генах, рентгенівські промені є потужним діагностичним інструментом, спільно з відкриттям радіоактивності та електрона, структура та склад матеріалів, детальний знімок з поперечним перерізом і високою роздільною здатністю.

Exercise 3. Match the sentences

1. There are three common mechanisms for the production of X-rays: the acceleration of a charged particle, atomic transitions between discrete energy levels,	a) a definitive tool in the determination of atomic numbers in the early days of atomic physics.
2. In the most common terrestrial source of X-rays, the X-ray tube, a beam of high-energy electrons	b) are currently under intense scientific scrutiny; in some cases the exact mechanisms of X-ray production are still uncertain or unknown.
3. Far more powerful (and far larger) sources of a continuum of X-rays	c) and the radioactive decay of some atomic nuclei.
4. In 1913 the English physicist Henry Moseley discovered a simple relationship between the wavelengths of the X-ray emission lines from a target and the atomic number of the target element—	d) impinges on a solid target.
5. Known as Moseley’s law, this relationship proved to be	e) the wavelengths are inversely proportional to the square of the atomic number.

6. Many astronomical sources of X-rays have been discovered over the past 50 years;	f) and this simple technique remains in wide use in medical applications.
7. X-rays are emitted by the Sun's hot corona (outer atmosphere)	g) and by the coronas of other ordinary stars in the Milky Way Galaxy.
8. Powerful extragalactic sources of X-rays, including active galaxies, quasars, and galactic clusters,	h) are synchrotron particle accelerators and storage rings.
9. Photographic film was used by Röntgen as one of the first X-ray detectors,	i) collectively they are a rich resource of information about the universe.
10. Their common detection schemes rely on the ability of X-rays	j) to produce visible fluorescence in crystals and charge separation in semiconductors.

Exercise 4. Translate the following sentences into English

1. Вільгельм Конрад Рентген повідомив про відкриття рентгенівських променів у грудні 1895 року після семи тижнів наполегливої роботи, протягом якої він вивчав властивості цього нового типу випромінювання, здатного проходити крізь екрани помітної товщини.

2. Він назвав їх рентгенівськими променями (X-rays), щоб підкреслити той факт, що їх природа невідома.

3. Звістка про це відкриття негайно викликала величезний інтерес у громадськості, а також поклала початок інтенсивним дослідженням у кількох напрямках.

4. Лікарі та фізики почали використовувати рентгенівські промені на пацієнтах ще в січні 1896 року для дослідження скелета, а згодом легенів та інших органів.

5. У червні 1896 року перший пацієнт був вилікуваний за допомогою радіотерапії.

6. Й.Й. Томсон (Кембридж, Великобританія) показав, що рентгенівські промені здатні іонізувати газ, і дослідження цього явища призвело до відкриття електронів у 1897 році.

7. Крім того, взаємодія частинок, випромінюваних радіонуклідами і атомами, дозволила спочатку вивчити структуру атома, а згодом і його ядра.

8. Матерія, енергія, електрика, світло, які раніше вважалися безперервними величинами, виявилися дискретними: існують частинки речовини (елементарні частинки), енергія (кванти), електрика (електрон), світло (фотони).

9. Комп'ютерний томограф (КТ) — це особливий тип рентгенівського апарату, в якому рентгенівська трубка створює промінь у формі віяла та рухається навколо пацієнта по колу.

10. Рентгенівське випромінювання виявляється електронним способом, і комп'ютер використовує інформацію для реконструкції зображення ділянки тіла.

(https://pubmed.ncbi.nlm.nih.gov/8696882/#:~:text=W.C.,that%20their%20nature%20was%20unknown; https://www.arpansa.gov.au/understanding-radiation/what-is-radiation/ionising-radiation/x-ray#whatisthedifferencebetweengammaraysandx-rays)

Exercise 5. Read the following interesting piece of information. Share your opinion with your classmates

Do you know that Mari Curie was the first woman to receive a Ph.D. in France? The first female professor at the Sorbonne. The first woman to win the Nobel Prize. The first *person* to win more than one Nobel Prize (and to this day, the only woman to win more than once). And the first person to win a Nobel in more than one scientific field.

(*https://science.howstuffworks.com/dictionary/famous-scientists/physicists/marie-curie-family.htm)*

Speaking

- Speak about the discovery of X-rays.
- Speak about Marie and Pierre Curie and their discoveries.
- Speak about some uses of X-rays in our life.
- Speak about some other heroes of progress in radiography.

Unit 10.

I. Read and translate the text. Learn the new vocabulary.

Basic facts of nuclear physics

The world is made up of exceedingly small units called atoms and of groups of atoms called molecules that exist in dazzling variety. At the center of each atom is a tiny core called a nucleus that is surrounded by a cloud of electrons—electrically charged particles that move in the outer regions of the atom. Nuclear physics is the study of the properties of nuclei and their relationship to the fundamental constituents and laws of nature. Its numerous applications—in the generation of electrical power, in the treatment of cancer and other diseases, and in the development of nuclear weapons, among many others—have been a major influence in the course of human history.

The size of the atom is about ten billionths of an inch (about 25 billionths of a centimeter). In 1911 the New Zealand–born British physicist Ernest Rutherford discovered that at the center of the atom lurked an object about 100,000 times smaller, the nucleus. By bombarding a piece of gold foil with alpha particles (now known to be the nuclei of helium atoms), Rutherford noted that while the large majority of the particles went straight through the foil, occasionally one of them bounced almost backward. If the gold atoms were made up only of the very light electrons, the heavy alpha particles would not have bounced back. The fact that they sometimes did led to the conclusion that a small and heavy mass, the nucleus, resided at the center of the atom.

In 1919 Rutherford bombarded nitrogen atoms with alpha particles. He observed that oxygen atoms were produced, along with hydrogen ions—hydrogen atoms with the sole electron removed. Soon Rutherford realized that the hydrogen ions actually represented a new particle, which he named the proton. A basic building block of the nuclei of all atoms, the proton was found to carry a positive electrical charge equal in magnitude to the negative charge of an electron. The number of protons in a nucleus is the same as the number of electrons surrounding it, thus making the atom electrically neutral. The proton has a mass of 1.6726×10^{-27} kilograms, more than 1,800 times that of an electron.

Scientists realized that the nucleus of most atoms was about twice as massive as the protons they contained.

The number of protons (Z) plus the number of neutrons (N) in a nucleus equals its atomic mass number (A): $A = N + Z$. Some elements have atoms that have the same Z number as each other but a different N number. These different nuclear species of an element are called isotopes. For example, the isotope heavy hydrogen (deuterium) contains one proton and one neutron, whereas regular hydrogen has one proton and no neutrons.

Nuclei reveal their nature by emitting rays, or fast-moving particles. This process of nuclear decay is called radioactivity. In 1896 the French physicist Henri Becquerel discovered that uranium emitted mysterious rays that exposed film. Later, another French physicist, Marie Curie, found that these rays were emitted in proportion to the number of uranium atoms present. She also found other, even more radioactive elements, such as polonium and radium.

By 1900 other researchers (including Rutherford) had found that the rays emitted by nuclei come in three varieties, called alpha, beta, and gamma in order of increasing power to penetrate matter. Soon it was found that alpha rays are helium nuclei (two protons and two neutrons bound together) and that beta rays are electrons. Gamma rays were found to be very high-energy electromagnetic radiation, or photons—essentially very energetic light. Alpha and beta decay, the most common radioactive processes, change the nucleus to that of a different element. Gamma decay leaves the original nucleus in a lower energy state.

In 1938 the German scientists Lise Meitner, Otto Hahn, and Fritz Strassmann found that bombarding uranium with neutrons yielded elements with smaller nuclei. This meant that large nuclei could be induced to fission, or split into smaller pieces. It soon became apparent that a chain reaction was also possible, with fragments of fissioning nuclei striking other nuclei and causing them to break apart as well. Very heavy nuclei can also fission spontaneously, without anything striking them.

Nuclear fission releases a large amount of energy. It was introduced to the world in a dramatic way in 1945, in the form of two atomic bombs dropped on Japan by the United States. In such bombs the fissionable nuclei of uranium or plutonium are highly concentrated, leading to an explosive chain reaction. Fission chain reactions are carried out in a controlled manner in nuclear reactors, which are used to produce about 20 percent of the world’s electricity. Heat from the reactor boils water, and the resulting steam rotates turbines that are connected to generators.

Physicists have found that the world obeys a rather strange set of rules called quantum mechanics, which is especially important in describing very small objects such as nuclei. One rule of quantum mechanics is that many quantities can take on only certain discrete (definite) values. An example is the property called spin, which is in some ways like the spin of a rotating top. However, unlike a top—which can have any amount of spin—the spin of a nucleon can have only two values: and −.

Some general properties of nuclei are fairly easy to understand. For example, the strong interaction attracting nucleons together acts only at very short distances, while the electrical repulsion between protons continues to act even at long distances.

Generally, scientists find what things are made of by breaking them apart, which takes energy. To probe more deeply into the structure of matter, more energy is required. Fire is sufficient to break apart molecules, but more energy is needed to break electrons away from nuclei. Still higher energies are needed to break apart or otherwise probe the structure of the nucleus. The primary tool for doing this is the particle accelerator, which uses electrical forces to accelerate projectiles—such as protons, alpha particles, or other ions—to nearly the speed of light and crash them into targets, including nuclei. Devices called particle detectors track the fast-moving particles resulting from such collisions, and the results provide much information on the structure and properties of nuclei. Even higher energies enable scientists to probe the structure of protons and neutrons. At this point, the field is more properly called particle physics than nuclear physics.

(From https://kids.britannica.com/students/article/nuclear-physics/276132)

Vocabulary

exceedingly [ɪkˈsiː.dɪŋ.li] надзвичайно

dazzling [ˈdæz.lɪŋ]	сліпуче
nucleus (nuclei) [ˈnjuː.kli.əs] (['njuːkliaɪ, 'nuːk-])	ядро (ядра)
core [kɔː(r)]	ядро
constituent [kənˈstɪt.ju.ənt]	складова
lurk [lɜːk]	причаїтися
bounce [baʊns]	відскочити
backward [ˈbækwəd]	назад
to lead to the conclusion	підвести до висновку
nitrogen [ˈnaɪ.trə.dʒən]	азот
oxygen [ˈɒk.sɪ.dʒən]	кисень
hydrogen [ˈhaɪ.drɪ.dʒən]	водень
to emit rays	випромінювати промені
nuclear decay	ядерний розпад
induced to fission [ˈfɪʃ.ən]	індукований до поділу
apparent [əˈpærənt]	очевидний
to ignite [ɪɡˈnaɪt]	запалювати
to obey [əˈbeɪ]	підкорятися
a discrete (definite) value	дискретне (визначене) значення
spin (n.)	обертання (і.)
repulsion [rɪˈpʌl.ʃən]	відштовхування
to probe [prəʊb]	зондувати
the structure of matter	будова речовини
to accelerate projectiles	розганяти частинки

[əkˈsel.ə.reɪt prəˈdʒek.taɪlz]

collision [kəˈlɪʒ.ən] зіткнення

property [ˈprɒp.ə.ti] властивість

Exercise 1. Answer the following questions

1. What is the world made up of? 2. What is a nucleus? 3. What does the nuclear physics study? 4. What are numerous applications of nuclear physics? 5. What is the size of the atom? 6. What did Ernest Rutherford discover in 1911? How did he do that? 7. What conclusion did it lead to? 8. What particle did Rutherford name "proton"? 9. What can you say about proton? 10. What does the formula "A = N + Z" tell us? 11. What are isotopes? 12. What is called radioactivity? 13. What did Henri Becquerel discover? 14. What did Marie Curie find? 15. What had other researchers found by 1900? 16. What was also soon found? 17. What discovery was made in 1938? 18. What releases a large amount of energy? 19. Was it introduced to the world in a dramatic way? 20. What are fission chain reactions used for? 21. What kind of a process is nuclear fission? 22. What set of rules does the world obey? 23. What is one of the rules of quantum mechanics? 24. What are some general properties of nuclei? 25. What do scientists find? 26. What is the particle accelerator? 27. What do particle detectors do? 28. What is more properly called "particle physics"?

Exercise 2. Find the English equivalents in the text. Use them in your own sentences

складатися з, існувати в сліпучому різноманітті, крихітне ядро, електрично заряджені частинки, у зовнішніх областях атома, вивчення властивостей ядер, фундаментальних складових, законів природи; генерування електроенергії, переважна більшість частинок, перебувати в центрі атома, основний будівельний блок ядер усіх атомів, різні ядерні види елемента, розкривати їх природу, випромінюючи промені; процес ядерного розпаду, випромінювати таємничі промені, проникати в матерію, найпоширеніші радіоактивні процеси, спонукати до поділу, призводити до вибухової ланцюгової реакції, проводитися контрольованим чином, обертати турбіни, ядерний синтез, виділяти енергію, підкорятися досить дивному набіру правил, квантова механіка, приймати лише певні дискретні (визначені) значення, бути досить легким для розуміння, розпадатися, досліджувати структуру ядра, електричні сили, прискорювати частки, фізика елементарних частинок.

Exercise 3. Match the sentences

1. The nucleus of an atom consists of neutrons and protons, collectively referred to as nucleons	a) to penetrate matter.
2. The neutron, discovered in 1932 by the English physicist James Chadwick (1891–1974), carries no electric charge	b) These particles and photons are collectively called “rays.”
3. The number of protons in the nucleus is different in different elements	c) It carries no electric charge and has a mass slightly larger than that of a proton.
4. In an electrically neutral atom, the number of nuclear protons	d) and has a mass slightly larger than that of a proton.
5. Nuclei that contain the same number of protons, but a different number of neutrons,	e) and consists of six protons and six neutrons.
6. Carbon, for example, occurs in nature in two stable forms. In most carbon atoms (98.90%), the nucleus is the 6/12C isotope	f) for treating certain problems of the brain, including benign and cancerous tumors as well as blood vessel malformations.

7. The gravitational force of attraction between nucleons is too weak to counteract the repulsive electric force,	g) and is given by the atomic number Z.
8. This force is the strong nuclear force and is one of only three fundamental forces	h) that have been discovered, fundamental in the sense that all forces in nature can be explained in terms of these three.
9. When an unstable or radioactive nucleus disintegrates spontaneously, certain kinds of particles and/or high-energy photons are released.	i) equals the number of electrons in orbit around the nucleus. The number of neutrons in the nucleus is N.
10. Three kinds of rays are produced by naturally occurring radioactivity: $\boldsymbol{\alpha}$ rays, $\boldsymbol{\beta}$ rays, and $\boldsymbol{\gamma}$ rays. They are named according to the first three letters of the Greek alphabet, alpha (α), beta (β), and gamma (γ), to indicate the extent of their ability	j) so a different type of force must hold the nucleus together.
11. Gamma Knife radiosurgery is becoming a very promising medical procedure	k) is the determination of the age of archaeological or geological samples as in the case of the mummified remains of Queen Hatshepsut.
12. One important application of radioactivity	l) are known as isotopes.

Exercise 4. Translate the following sentences into English

1. Фізика атомного ядра – розділ сучасної фізики, у якому вивчаються специфічні форми існування матерії та її рух, а саме, атомні ядра та їхні взаємоперетворення.

2. Дослідження з ядерної фізики відіграли визначну роль у формуванні сучасного погляду на перебіг процесів у природі та обов'язкові обмеження – закони збереження, за яких вони можуть відбуватися.

3. Кожна як фундаментальна, так і елементарна частинка характеризується деяким набором дискретних значень певних фізичних величин (квантовими числами) і масою.

4. У природі існують чотири типи фундаментальних взаємодій – сильна, електромагнітна, слабка і гравітаційна.

5. У фізиці атомного ядра вивчаються явища, які відбуваються на малих відстанях і за великих енергій, що припадають на одну частинку.

6. Вироблення енергії атомними станціями і створення атомної та термоядерної зброї макроскопічно наочно підтвердило отримане у спеціальній теорії відносності співвідношення між масою та енергією.

7. Ядерна фізика давно вже вийшла на інженерний рівень розвитку. Дослідження у цій галузі суттєво вплинули на розвиток суспільства і викликали як великі сподівання, так і значні побоювання, що пов'язані з використанням ядерної енергії.

8. Фізика атомного ядра є науковою базою атомної енергетики та ядерної техніки.

9. Розвиток її власних теоретичних, експериментальних і технологічних розділів істотно впливає на інші дисципліни і сприяє виникненню нових розгалужень науки.

10. Курс фізики атомного ядра зазвичай вивчається студентами одночасно з курсом квантової механіки. Це дає змогу використовувати квантово-механічні поняття і формули, оскільки саме на таких уявленнях і базується ядерна фізика.

(From https://atom.univ.kiev.ua/2016/prof/kadenko_pluyko.pdf)

Exercise 5. Read the following interesting piece of information. Share your opinion with your classmates

Nuclei come in different sizes and shapes. The observed densities of different nuclei are all about the same, so the volume of a nucleus is proportional to the mass number (A). Some nuclei are spherical, like a basketball; others are shaped like a pancake or a football.

(https://kids.britannica.com/students/article/nuclear-physics/276132)

Speaking

- Speak about nuclear physics.
- Speak about nuclear physics applications.
- Speak about outstanding scientists who made a great contribution in the development of nuclear physics.

INFORMATION RESOURCES

1. *https://www.twinkl.com/teaching-wiki/the-history-of-electricity*
2. *https://watt-shop.com/ua/blog/226-who-invented-electricity-and-how-its-operating-principle.html*
3. *https://energy365.com.ua/tpost/m72pardfz1-storya-elektriki-v-svt*
4. *https://www.oliverheatcool.com/about/blog/news-for-homeowners/13-fun-electrical-facts/*
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29. *https://uk.wikipedia.org/wiki/Матерія_(фізика); https://ukrayinska.libretexts.org/)*
30. *https://abbasqaisar313.medium.com/the-amazing-facts-about-the-states-of-matter-abfe5849c3a5*
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ДЛЯ НОТАТОК

Навчальне видання

ENGLISH FOR STUDENTS OF PHYSICS AND ASTRONOMY (PART 2. ELECTRICITY AND MAGNETISM, OPTICS, ATOMIC AND NUCLEAR PHYSICS)

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Видавництво: Олді+
65101, м. Одеса, вул. Інглезі, 6/1,
тел.: +38 (095) 559-45-45,
e-mail: office@oldiplus.ua
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тел.: +38 (050) 915-34-54, +38 (068) 517-50-33
e-mail: book@oldiplus.ua

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