С. О. Медведєва, О. Д. Присяжна, Л. В. Тульчак

ЗБІРНИК ТЕКСТІВ ТА ВПРАВ АНГЛІЙСЬКОЮ МОВОЮ: лазерна та оптоелектронна техніка

Частина 1

Міністерство освіти і науки України
Вінницький національний технічний університет

С. О. Медведєва, О. Д. Присяжна, Л. В. Тульчак

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Частина 1

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Рецензенти:
Н.Б. Іваницька, доктор філологічних наук, професор
Ю.В. Колядич, кандидат філологічних наук, доцент
І. С. Степанова, кандидат філологічних наук, доцент

Медведєва, С.О.

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Посібник призначено для студентів, які вивчають оптоелектроніку, оптоінформатику, лазерно-оптичні технології та спеціалізуються в комп’ютеризованих оптико-інформаційних системах. Посібник містить десять розділів, які складаються з лексико-граматичних вправ, спеціалізованих текстів з фаху, а також стислого словника базових термінів з оптоелектроніки та оптоінформатики. Призначений для студентів І–ІІ курсів, що спеціалізуються в комп’ютеризованих оптико-інформаційних системах.

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UNIT 1
BRIEF HISTORY OF OPTICS

EXERCISE 1

Read and translate the international words.

Optics, optoelectronics, optical, optician, infrared, ultraviolent, magnet, magnetic, electromagnetic, magnetism, electromagnetism, lenses, spectrum, spectral, spectrograph, spectrographic, industry, industrial, industrialization, microscope, microscopic, telescope, prism, quartz, quantum, photon, photonics, molecule, molecular, atom, atomic, radar, laser, sensor, component, emission, intensity, technology, experiment, experimental, esperimenter, experimentation, monochromatic.

EXERCISE 2

Make nouns from the following words according to the model and translate them.

a) e.g. verb + -er / -or: to work – a worker, to reflect – a reflector

To write, to lead, to teach, to build, to think, to drive, to use, to publish, to photograph, to found; to refract, to resist, to adapt, to resonate, to process, to numerate, to invent, to translate.

b) e.g. verb + -tion (-ation) / -ssion: to combine – combination, to emit – emission

To polymerize, to demonstrate, to translate, to invent, to reflect, to refract, to compose, to organize, to part, to complete; to extend, to convert, to process, to invert, to expand, to discuss, to transmit, to progress.

c) e.g. verb + ing: to pump – pumping

To advert, to process, to tabulate, to hold, to reason, to begin, to tune, to scatter, to broaden, to build, to warn, to feel, to train, to light, to paint, to mean, to meet, to shop, to end.

d) e.g. verb + ment: to develop - development

To improve, to advertise, to equip, to require, to advance, to move, to announce, to disappoint, to govern, to agree, to pay, to employ, to argue, to punish, to amaze, to appoint, to adjust, to state, to astonish, to entertain.

EXERCISE 3

Read, translate and memorise the most common Latin abbreviations.

Abbreviation	Full form	Meaning
AD	Anno Domini	'in the year of the Lord'
a.m.	ante meridiem	before noon
B.A.	Baccalaureus Artium	Bachelor of Arts
BC	before Christ	before Jesus Christ was born
c. / ca.	circa	around, approximately
C.V. / CV	curriculum vitae	'course of life', resume
etc.	et caetera	and the others
e.g.	exempli gratia	for example
i.e.	id est	that is, in other words
N.B.	nota bene	'note well'
No.	numero	number
Ph.D. / PhD	Philosophiae Doctor	Doctor of Philosophy
p.m.	post meridiem	after midday
P.S.	post scriptum	'After what has been written' (Indicates additions to a text after the signature of a letter.)
vs. / v.	versus	against

EXERCISE 4

Read and translate the sentences, pay attention to the proper pronunciation and translation of the Latin abbreviations.

1. The standard date given for the fall of Rome is AD 476.
2. This antique clock is from c.1900.
3. I need to go to the store and buy some bread, milk, cheese, etc.
4. The United States Civil War began in AD 1861.
5. The elections will take place in September i.e., in two months.
6. All domesticated animals – dogs, cats, birds, etc. – can cause allergies.
7. Norway has many historic sites, e.g., the Kvalvik Fort, the Selje Monastery, and the Urnes Stave Church.
8. This picture dates from ca. 1850.
9. Smoking causes a range of illnesses such as cancer, emphysema, heart disease, etc.
10. The shipping company instituted a surcharge on any items weighing over a ton; e.g., a car or truck.
11. The next football game will be the Knights vs. the Sea Eagles.
12. We will meet the mayor at 2 p.m.
13. P.S. Tell mother I say hello!
14. A PhD is the highest academic degree awarded by universities in most countries.

EXERCISE 5

Answer the questions. Then read the text to see if you were right or wrong.

1. What is optics? What does it study?
2. What branches of optics do you know?
3. What associations do you have when you hear the word ‘optics’?

Optics is the branch of physics that studies light, the nature and propagation of light, how it changes, what effects it produces, and other phenomena associated with it. There are two branches of optics – physical optics and geometrical optics. Physical optics is concerned with the nature and properties of light itself. Geometrical optics deals with the principles governing image-forming properties of lenses, mirrors, and other devices, such as optical data processors.

EXERCISE 6

Match the English words with their Ukrainian equivalents.

1. lens	a) кут
2. vision	b) поверхня
3. to reflect	c) лінза
4. the law of reflection	d) зір, бачення
5. straight line	e) відбивати
6. surface	f) заломлення
7. angle	g) електромагнітне поле
8. ray	h) промінь
9. to magnify	i) збільшувати
10. to employ	j) швидкість світла
11. spectacles	k) розкладати світло
12. to contain	l) використовувати
13. to carry out experiments	m) окуляри
14. to refract	n) видимий спектр
15. refraction	o) містити
16. to decompose light	p) пряма лінія
17. visible spectrum	q) випромінювати
18. wave	r) проводити експерименти
19. velocity of light	s) системи оптичного зв’язку
20. electromagnetic field	t) системи візуалізації
21. optical communication systems	u) поширювати, розповсюджувати
22. to emit	v) закон відбивання світла
23. to propagate	w) заломлювати
24. imaging systems	x) хвиля

EXERCISE 7
Read and translate the text.

The Evolution of Optics

Optics began with the development of lenses by the ancient Egyptians and Mesopotamians. The earliest known lenses were made from polished crystal of quartz and date from as early as 700 BC. These practical developments were followed by the development of theories of light by ancient Greeks.

In around 300 BC the Greek mathematician Euclid wrote the book 'Optics' where he stated that light travels in straight lines and reflects from a smooth surface at the same angle that it hits it.

During the Middle Ages Greek ideas about optics were extended by the researchers from the Muslim world. In the early 11th century an Arab scientist, astronomer and philosopher Alhazen (another name Ibn al-Haytham) wrote the 'Book of Optics' which made important contributions to the understanding of vision, optics and light.

The first wearable eyeglasses were invented in Italy around 1286. In fact, it was the start of the optical industry. The practical developments and experimentation with lenses led directly to the invention of the compound optical microscope around 1595 by the Dutch spectacle-makers Zacharias Janssen and his father Hans Janssen. Their primitive device had two lenses that only allowed them to see objects about nine times larger than normal.

In 1608 a Dutch eyeglass maker named Hans Lippershey invented the telescope. A year later Galileo Galilei perfected this device increasing the magnification up to 30 times, i.e. making it the most powerful instrument of his time.

Optical theory progressed in the 17th century. A French philosopher, mathematician and scientist René Descartes explained a variety of optical phenomena including reflection and refraction by assuming that light was emitted by objects which produced it.

In the late 1660s and early 1670s, Isaac Newton expanded Descartes' ideas into a corpuscle theory of light, determining that white light was a mix of colours which can be separated into its component parts with a prism. He also created the reflecting telescope. By using mirrors instead of lenses, he was able to create a more powerful instrument, 10 times smaller than traditional telescopes of his time.

In 1690, a prominent Dutch mathematician and scientist Christiaan Huygens proposed a wave theory for light. An English astronomer and telescope maker William Frederick Herschell discovered infrared rays in 1800. Some years later ultraviolet radiation was studied and described by the German chemist, physicist and philosopher Johann Wilhelm Ritter. In 1801 an English physician Thomas Young discovered the interference of light and established the wave theory of light. Wave optics was successfully unified with electromagnetic theory by a Scottish scientist James Clerk Maxwell in the 1860s.

The next development in optical theory came in 1899 when Max Planck worked out the quantum theory. In 1905 Albert Einstein published the theory of the photoelectric effect that firmly established the quantization of light itself.

In the 20th century revolutionary advances in optics began with the construction of the first laser in 1960 and have led to the rapid development of optical communication systems, imaging systems and holography, optical data storage and retrieval systems, optical processing, etc.

All these developments are continued in the 21st century, making optoelectronics one of the most promising and quickly developing sciences.

EXERCISE 8

Reread the text and find English equivalents to the following word-combinations.

Відполірований кристал кварцу, практична розробка, зробити внесок, складний оптичний мікроскоп, збільшувати масштаб (зображення), потужний інструмент, оптичні явища, суміш кольорів, видатний математик, інфрачервоні промені, ультрафіолетове випромінення, інтерференція світла, корпускулярна теорія світла, хвильова теорія світла, квантова теорія світла, фотоелектричний ефект, збереження данних, оптична обробка даних.

EXERCISE 9

Fill in the table and get ready to speak about the inventors and their inventions.

Name	Year	Country	Discovery	Importance
	700 BC			
Ibn al-Haytham				
			eyeglasses	
		the Netherlands		

EXERCISE 10

Name three inventions which you consider crucial for the development of optics and optoelectronics. Prove your point of view. Work in pairs. Use the following phrases.

USEFUL EXPRESSIONS TO EXPRESS YOUR OPINION
In my opinion, ...
To my mind, ...
As far as I am concerned, ...
Speaking personally, ...

From my point of view, ...
As for me, ...
My view / opinion / belief / impression / conviction is that ...
I would say that ...
It seems to me that ...
I am of the opinion that ...
I have no doubt that ...
I am sure / I am certain that ...
I think / consider / find / feel / believe / suppose / presume / assume that ..
It goes without saying that ...

USEFUL WORDS TO EXPRESS YOUR AGREEMENT

I agree with you / him ...
I share your view.
I (really) think so.
You are (quite / absolutely) right that …
I have come to the same conclusion
I hold the same opinion.
We are of one mind / of the same mind on that question.

USEFUL WORDS TO EXPRESS YOUR DISAGREEMENT

I don't agree.
I disagree.
I don't think so.
You are / he is wrong.
I think otherwise.
I don't think that's quite right.
I don't agree with you (with what you say).
I am afraid that is not quite true.
I take a different view.
I don't share his / her / your view.
Not at all!
Nonsense!

EXERCISE 11

Read and translate the sentences, pay attention to the emphatic construction 'It is (was) … that'.

1. It was the Greek mathematician Euclid who wrote the book 'Optics'.
2. It was Max Planck who worked out the quantum theory.
3. It was a Dutch eyeglass maker named Hans Lippershey who made the earliest written record of a refracting telescope.
4. It was in Italy where the first wearable eyeglasses were invented.
5. It was Einstein who recognized the existence of stimulated emission.
6. It was only in 1969 that the operation of semiconductor laser became possible at room temperature.

7. It was Keppler who invented the form of the refracting telescope.
8. It was a ruby crystal that was used in the first lasers.
9. It was I who received the promotion.
10. It is the awful weather that drives him crazy.
11. It was after my first accident that I started driving more carefully.
12. It is the hacker who cracks computer codes to penetrate into other people's private information.

EXERCISE 12
Read the texts. Choose the correct answer (A, B, C) for each gap.

I. Believe it or not, sunglasses are not a twentieth century 1._____. The Inuit people used materials from their 2._____ to fashion protective eyewear to cut down on the sun's glare many years before. They needed to 3._____ themselves from the blinding glare called 'snow blindness', which 4._____ when light reflects off snow. Items used to make these sunglasses were driftwood, deer's hooves, and whalebone.

	A	B	C
1	discovery	invention	research
2	environment	nature	evolution
3	provide	protect	prove
4	obscure	offers	occurs

II. The Ancient Greek mathematician, physicist, engineer, inventor, and astronomer Archimedes used 1._____ acting collectively as a parabolic reflector 2._____ ships attacking Syracuse. The device, called the 'heat ray' was used to focus sun rays onto 3._____ ships, causing them to catch fire. It 4._____ that Archimedes used copper or bronze shields as mirrors to reflect sunlight onto the boat.

	A	B	C
1	mirrors	miracles	myriads
2	burnt	burn	to burn
3	approaching	approach	approached
4	suggested	was suggested	suggest

III. In fact, it was a Dutch eyeglass maker named Hans Lippershey who made the earliest 1._____ record of a refracting telescope. But he 2._____ to receive the patent. There is a story that he took the idea of a telescope from the children playing with lenses at his shop. The children observed that when they 3._____ two lenses, remote objects appeared to be larger and clearer. According to the story, Lippershey tried it himself and realized the 4._____ possibilities. He then placed a tube between the lenses to make a three-power telescope.

	A	B	C
1	written	writing	write
2	fooled	fulfilled	failed
3	looked through	looked for	looked after
4	amazed	amazing	amazement

EXERCISE 13
Arrange the following words into pairs of synonyms.

1. improvement	a) processing
2. sight	b) eyeglasses
3. speed	c) vision
4. technology	d) velocity
5. to enlarge	e) to discover
6. to invent	f) perfection
7. to update	g) to use
8. spectacles	h) to perform
9. to change	i) to design
10. to develop	j) to magnify
11. to employ	k) to replace
12. to carry out	l) to innovate

EXERCISE 14
Choose the correct tense form of the verbs and translate the sentences.

1. British-Hungarian scientist Dennis Gabor *was developing / developed* the theory of holography while he *was working / worked* to improve the resolution of an electron microscope.
2. The great German mathematician and physicist Carl Friedrich Gauss *was publishing / published* his classical book on optics in 1841.
3. Dr. Stephen A. Benton *was inventing / invented* white-light transmission holography while he *was researching / researched* holographic television at Polaroid Research laboratories.
4. There is a legend that Sir Isaac Newton, the great scientist and thinker, *was discovering / discovered* one of the fundamental laws of mechanics when he *was sitting / sat* under an apple-tree.
5. The union of electromagnetic theory with optics *was beginning / began* when Maxwell *was finding / found* that his equations for the electromagnetic field (1873) described waves travelling at the velocity of light.
6. About 1609 Galileo Galilei *was learning / learned* of the invention of the telescope by Hans Lippershey and one year later he *was announcing / announced* the telescopic observations of the moon and planets.
7. A lens *is / were* a piece of glass, plastic or other transparent material curved on one or both sides.

8. Lenses *are refracting / refract* the light rays from an object forming an image.
9. The walls of the house *absorb* / *absorbing* heat day after day.
10. Electromagnetic waves *travelled / travel* in all directions through the Universe.

EXERCISE 15

Listen to the audio / watch the video Einstein's miracle year (by Larry Lagerstrom on http://ed.ted.com/lessons/einstein-s-miracle-year-larry-lagerstrom) and do the quiz.

As the year 1905 began, Albert Einstein faced life as a 'failed' academic. Yet within the next twelve months, he would publish four extraordinary papers, each on a different topic, that were destined to radically transform our understanding of the universe. Larry Lagerstrom details these four groundbreaking papers.

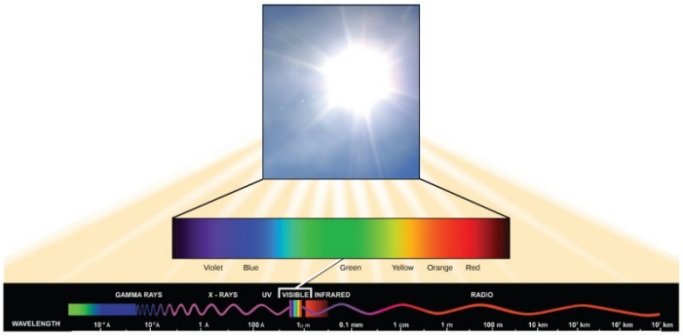
1. Einstein's first 'miracle year' paper, in March 1905, put forth a surprising idea. He proposed that:
    A. Light was an electromagnetic wave
    B. Light could be a particle
    C. Light waves could explain the mysterious photoelectric effect
    D. The photoelectric effect proved that the speed of light was constant
2. Einstein's second 'miracle year' paper, in May 1905, showed that _____ could explain the so-called 'Brownian motion' behavior of small particles randomly moving around in a liquid.
    A. Invisible atoms
    B. Biological effects
    C. Magnetic forces
    D. Electric forces
3. Einstein's third 'miracle year' paper, in June 1905, introduced his special theory of relativity. The key concept of relativity is that:
    A. Everything is relative and thus there is no absolute truth
    B. The speed of light is relative (depends on the observer)
    C. The speed of light is constant while time and space are relative to the observer
    D. The nature of light is relative – it can be both a wave and a particle
4. Einstein's fourth 'miracle year' paper, in September 1905, expanded on the results of the relativity paper and thereby concluded that:
    A. Mass and energy are equivalent
    B. Mass is relative to gravity
    C. Light is a form of energy, and therefore has mass.
    D. Gravity can be measured by the bending of starlight

5. Surprisingly, Einstein's miracle year did not make him famous. That only happened later when:
    A. The atomic bomb was developed during the Second World War
    B. A photograph of him playfully sticking out his tongue went viral
    C. He was forced to leave Germany when Hitler came to power
    D. His ‘general theory of relativity’ was confirmed by a measurement of the bending of starlight during a solar eclipse
6. Which of Einstein’s four ‘miracle year’ papers do you find most interesting and why?
7. Quotations attributed to Einstein appear all over the place. Though a good number are actually fake, he did have a way with words and left us many profound sayings. The quotations below are authentic Einstein (in translation from German). Which ones resonate with you the most, and why? Explain your point of view in writing.
    A. ‘The important thing is not to stop questioning. Curiosity has its own reason for existing.’
    B. ‘One should not pursue goals that are easily achieved. One must develop an instinct for what one can just barely achieve through one’s greatest efforts.’
    C. ‘Try to become not a person of success, but try rather to become a person of value.’

EXERCISE 16
Do the project on one of the topics.

1. Dwell on the main stages of the development in the field of optics.
2. Prepare a report about a person who has used light, color, or optical instruments to change the world.

UNIT 2
WHAT IS LIGHT?



EXERCISE 1

Make nouns from the following words according to the model and translate them.

a) *e.g. verb + -al: to arrive –arrival*

To approve, to deny, to propose, to refuse, to dismiss, to remove, to survive.

b) e.g. *verb + -ance / -ence: to attend –attendance*

To accept, to prefer, to insure, to refer, to exist, to insist, to appear, to endure, to maintain, to resist, to differ.

c) *e.g. adjective + ty / cy = noun: accurate – accuracy*

Efficient, capable, resistive, possible, monochromatic, frequent, intensive, democratic, vacant, consistent, excellent, elegant.

EXERCISE 2

Make adverbs from the following adjectives according to the model and translate them.

e.g. adjective + - ly: total – totally

General, simultaneous, sequential, rapid, real, virtual, actual, moderate, entire, great, classical, hard, near, recent, traditional, rotational, effective, automatic, usual, wide, frequent, easy.

EXERCISE 3

Make up singular-plural pairs.

Phenomenon, spectra, bacterium, woman, criterion, foot, child, formula, man, datum, index, spectrum, radius, indices, person, phenomena, bacteria, data, people, radii, criteria, women, children, feet, formulae, men.

EXERCISE 4

Guess the riddle. Prove in what way the underlined words are related to the answer.

It can be both **visible** and **invisible**. It can be **short** and **long**. It is **electromagnetic radiation**, a kind of **energy** at the same time. It can be **dangerous**, but it also can be very **helpful**. It is one of the most interesting phenomena in the world. What is it?

EXERCISE 5
Match the words with their Ukrainian equivalents and learn them.

1. matter	a) рух
2. on the atomic level	b) залежати від
3. to emit	c) швидкість
4. motion	d) частка, частинка, корпускула
5. particle	e) виділяти, випромінювати
6. nucleus	f) різниця
7. excess	g) ядро
8. velocity	h) надлишок
9. radiation	i) матерія
10. frequency	j) поширюватися
11. to propagate	k) на атомному рівні
12. to exhibit	l) експеримент з подвійною щілиною
13. amount	m) джерело
14. to depend on	n) заломлення
15. to appear	o) частота
16. source	p) заряджений
17. stream	q) квантова теорія
18. charged	r) кількість
19. difference	s) хвильова теорія
20. reflection	t) випромінювання
21. refraction	u) відбивання
22. the wave theory	v) з'являтися, виявлятися
23. the corpuscular theory	w) корпускулярна теорія
24. the quantum theory	x) потік
25. the double-slit experiment	y) корпускулярно-хвильовий дуалізм
26. wave-particle duality	z) показувати, виявляти

EXERCISE 6
Read and translate the text.

Nature of Light

To understand the nature of light and how it is created, it is necessary to study matter at its atomic level. Atoms are the building blocks of matter, and the motion of one of their constituents, the electron, leads to the emission of light in most sources. Electrons are negatively charged particles which orbit the nucleus

of an atom. Each electron has a natural orbit, but if given extra energy, it becomes energized, or excited. It moves into an orbit further away from the nucleus. When the excited electron drops from a high energy orbit to a lower energy one, excess amount of energy appears. This energy can't just disappear, so it is emitted as a photon of light. The photon has a frequency, or color, that exactly matches the distance the electron falls. Its energy depends on the difference in energy between the two orbits of the electron.

EXERCISE 7

On the bases of the information from the text 'Nature of Light' and the Figure 1 given below be ready to explain how light appears. While speaking try to use as many linking words as possible:

In general / first / next / also / as a result / therefore / that is / usually / in particular / then / that is how

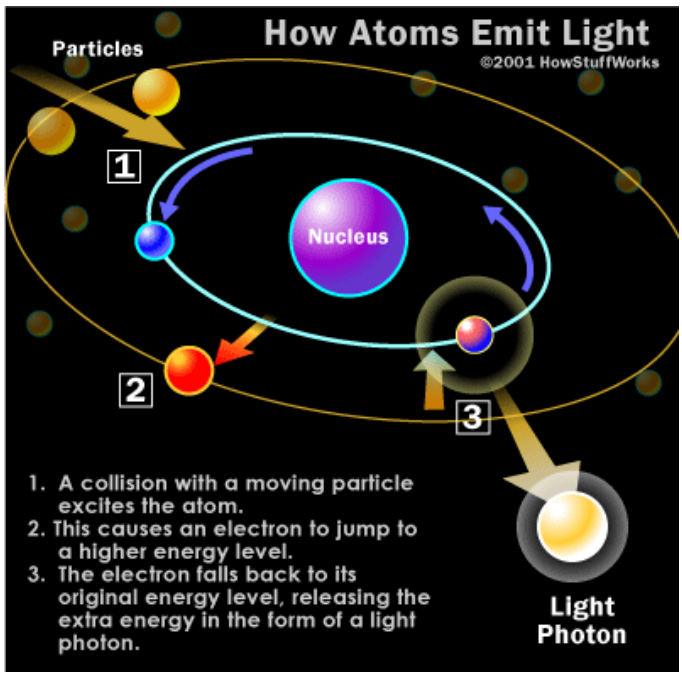


Figure 1

EXERCISE 8

Read and translate the text.

Theories of Light

Since the ancient times there have been attempts to explain the nature of light scientifically. The first theories about light came from the ancient Greeks. They basically described light as a ray – a straight line moving from one point to another.

Arab scholars took these ideas and honed them even further, developing what is now known as geometrical optics – applying geometrical methods to the optics of lenses, mirrors and prisms.

In 1690 Dutch mathematician and astronomer Christiaan Huygens

(1629–1695) worked out the first wave theory of light. He proposed that light was emitted in all directions as a series of waves in a medium. But at those times this theory did not gain recognition among scientists.

French philosopher, astronomer and mathematician Pierre Gassendi (1592–1655) set the corpuscular theory of light, stating that light is made up of small discrete particles called 'corpuscles' (little particles) which travel in a straight line with a finite velocity. It was largely developed by Sir Isaac Newton who believed that light was shot out from a source as a stream of particles, and this view was accepted for over a hundred years. But the corpuscular theory failed to adequately explain the diffraction, interference and polarization of light and it was abandoned in favour of Huygens' wave theory.

In 1801 Thomas Young performed the double-slit experiment thus experimentally proving the wave theory of light.

In the 1860s, Scottish physicist James Clerk Maxwell formulated the theory of electromagnetism. He described light as a very special kind of wave – one composed of electric and magnetic fields. Because light has both electric and magnetic fields, it's also referred to as electromagnetic radiation.

The quantum theory put forward by Max Planck in 1900 combined the wave theory and the particle theory, and showed that light can sometimes behave like a particle and sometimes like a wave. Max Planck proposed the existence of a light quantum, a finite packet of energy which depends on the frequency and velocity of the radiation.

Albert Einstein advanced Planck's theory in 1905 when he studied the photoelectric effect. Einstein suggested that light is composed of tiny particles called photons and each photon has energy. Thus light has dual nature and can be defined as a collection of one or more photons propagating through space as electromagnetic waves. This theory has been named wave-particle duality.

Light can exhibit both a wave nature and a particle nature at the same time. Light waves are also called electromagnetic waves because they are made up of both electric and magnetic fields. Light is part of the electromagnetic spectrum; the spectrum is the collection of all waves, which include visible light, microwaves, radio waves (AM, FM, SW), X-rays, and gamma rays.

EXERCISE 9

Answer the question in writing, be ready to discuss them.

1. What are the most popular theories of light?
2. How did the ancient Greeks describe light?
3. What is the essence of the wave theory of light proposed by Christiaan Huygens?
4. What are corpuscles? What does the corpuscular theory state?
5. Why did the corpuscular theory fail?
6. What did Thomas Young's double-slit experiment prove?
7. Why light can be referred to electromagnetic radiation?

8. What is the essence of the quantum theory?
9. Why light is considered to have dual nature?
10. What is light?

EXERCISE 10

Complete the following sentences.

1. The first light theories described light as _____.
2. Geometrical optics is _____.
3. The wave theory of light states that _____.
4. The corpuscular theory of light states that _____.
5. The wave theory of light was proved by _____.
6. The theory of electromagnetism states that _____.
7. The quantum theory combined _____ and showed _____.
8. The wave–particle duality states that _____.

EXERCISE 11

Translate the sentences into English.

1. Світло має двоїсту корпускулярно-хвильову природу та демонструє одночасно і хвильові й корпускулярні властивості.
2. Світло поширюється в просторі зі скінченною швидкістю.
3. Евклід висунув теорію про прямолінійне поширення світла, відкрив закони відбивання і заломлення світла.
4. Хоча погляди стародавніх мислителів ґрунтувалися не на дослідах, а на спостереженнях за явищами природи, вони мали досить великий вплив на наукові дослідження більш пізніх часів.
5. У 1666 році Ньютон відкрив явище дисперсії світла.
6. Ньютон вважав, що світло – це потік особливих найдрібніших частинок, що випромінюються тілами, які світяться.
7. Гюйгенс і Гук розуміли світло як сукупність пружніх хвиль, що поширюються в особливому просторі, який називається ефір.
8. Гюйгенсу вдалося науково обґрунтувати такі явища як заломлення, відбивання та подвійне заломлення променів, проте він не зміг довести теорію кольорів, прямолінійне поширення світла і явище поляризації світла.
9. Німецький фізик Планк у 1900 році висунув гіпотезу про квантову природу випромінювання.
10. Хвильова оптика – розділ фізики, що вивчає оптичні явища, у яких виявляється хвильова природа світла. До них належить інтерференція, дифракція, поляризація.

EXERCISE 12

Listen to the audio / watch the video: 'Is light a particle or a wave?' (by Colm Kelleher on *http://ed.ted.com/lessons/is-light-a-particle-or-a-wave-colm-kelleher)* and do the quiz.

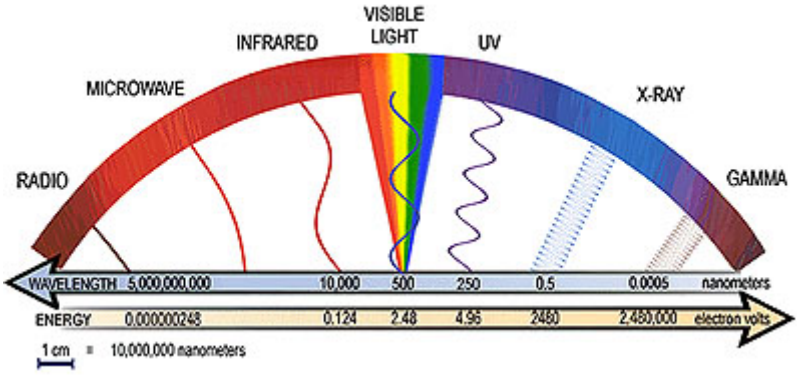
Can we accurately describe light as exclusively a wave or just a particle? Are the two mutually exclusive? Colm Kelleher discusses wave-particle duality and its relationship to how we see light and, therefore, color.

1. Who were the first to think scientifically about what light is?
    A. Greeks
    B. Romans
    C. Native Americans
    D. Chinese
2. Who hypothesized that light was not perceived by tiny probes released from the eyes, but rather by sensing the light emitted by objects outside of the body?
    A. Aristotle
    B. Plato
    C. Alhazen
    D. Aristophanes
3. All objects emit their own light.
    A. True
    B. False
4. Is light a particle or a wave?
    A. Particle
    B. Wave
    C. Neither
    D. Both
5. What are interference patterns?
    A. A complicated football strategy
    B. A popular print from which you can make dresses
    C. The complicated undulations that happen when two wave patterns occupy the same space
    D. The complicated undulations that happens when two wave patterns do not occupy the same space
6. Colm says, ‘Even geniuses sometimes get things wrong.’ What other major scientific principles did scientists get wrong for centuries and centuries? When were these principles correctly proven?
7. Explain why light is both a wave and a particle. Give one example why is behaves like a wave and then why it behaves like a particle.

EXERCISE 13
Do the project on one of the topics.

1. The development of light theories.
2. How light is emitted.

UNIT 3
THE ELECTROMAGNETIC SPECTRUM



EXERCISE 1

Read and translate the words paying attention to the meaning of the Latin and Greek prefixes.

Latin prefix	Basic meaning	Example words
co-	together	coauthor, coedit, coexist
contra-	against	contradiction, contrast
de-	away; remove	deactivate, defrost, decompress, deplane, delete
dis-	not	disbelief, discomfort, discredit, disrepair, disrespect
ex-	out; former	exclude, extend, ex-champion
inter-	between	international, interface, intersection, intercellular
non-	not	nonessential, nonmetallic, nonresident, nonstop
post-	after	postscript, postdate, postwar, postgraduate
pre-	before	pre-arrange, preamble, pre-establish, prepay
re-	again	rearrange, rebuild, remake, reread, rewrite
semi-	half	semicircle, semiconductor, semiautomatic, semifinal
sub-	under	submarine, subway, substandard
trans-	across	transatlantic, transpolar, transportation
ultra-	beyond	ultrasonic, ultramodern, ultra-short, ultraviolet

Greek prefix	Basic meaning	Example words
a-, an-	without	achromatic, amoral, atypical, asymetric
ant(i)-	opposite	anticrime, antipollution, antibiotic, antipode
auto-	self	autobiography, automatic, autopilot
bi-	two	binoculars, binary, biathlon
bio-	life, living organism	biology, biophysics, biotechnology, biography
geo-	Earth	geography, geomagnetism, geophysics, geopolitics
hyper-	excessive	hyperactive, hypercritical, hypersensitive
micro-	small	microcosm, microorganism, microscope
mono-	one, single	monochrome, monosyllable, monoxide
neo-	new, recent	neologism, neoconservatism, neoclassical
pan-	all	panorama, panchromatic, pandemic
therm(o)	heat	thermal, thermometer, thermostat

EXERCISE 2

Read and translate the sentences, paying attention to the words with Latin and Greek prefixes.

1. We have only one planet, and we must learn to coexist on it.
2. Just as a triangle is half of a square, a semicircle is half of a circle.
3. The pipes are manufactured from sheet steel that has undergone a 100% automated ultrasonic testing.
4. Ruby is the fastest transatlantic cable that there is.
5. Bidirectional satellite Internet communication is perfect solution for those who prefer high quality and good service.
6. It is not difficult to find many of the features of ‘hyperactivity’ in modern social life.
7. The construction of transducer consists of two bipolar transistors, active inductance and gaseous sensing device.
8. The technical result of the invention consists in providing a completely fibre laser with an ultrashort pulse length.
9. At the beginning of 2009 Nova Company passed a resolution to reconstruct the telephone network.
10. The prepayment for the first 7 nights will not be refunded.

EXERCISE 3
Read the following figures, dates, numerals, etc.

1. 19; 90; 45; 700; 506; 268; 40 93l; 1 175; 254 786; 1 567 382
2. 1984; 1700; 1961; from 1954 to 1960; since 1812; 2005; 2019
3. 1/2; 1/3; 1/4; 3/7; 5/17; 2.58; 13.567; 0.005;
4. 90%; 65%; 1 cm; 36 m; 140 km/h; 25°C; -14^{o}C.

EXERCISE 4
Match the words with their Ukrainian equivalents and learn them.

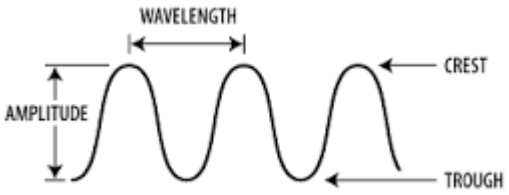
1. electromagnetic waves	a) випромінення
2. radiation	b) поглинати
3. to radiate	c) електромагнітні хвилі
4. to move	d) а також
5. motion	e) випромінювати
6. as well as	f) рух
7. source	g) виявляти
8. to detect	h) рухати
9. solid state physics	i) отримувати
10. to carry	j) довжина хвилі
11. to receive	k) нести
12. to absorb	l) співвідношення, коефіцієнт
13. absorption	m) гребінь хвилі
14. angle	n) джерело
15. direction	o) відбуватися, траплятися
16. frequency	p) діапазон
17. wavelength	q) поглинання
18. wave crest	r) кут
19. wave trough	s) напрямок
20. to measure	t) частота
21. to respond	u) западина хвилі
22. range	v) фізика твердого тіла
23. ratio	w) вимірювати
24. to occur	x) відповідати, реагувати

EXERCISE 5
Scan the text and find answers to the questions:

1. How are electromagnetic waves produced?
2. Why are they called electromagnetic radiation?
3. What do electromagnetic waves carry?
4. Can the objects receive the electromagnetic waves?
5. What speed do the electromagnetic waves travel at?
6. What characteristics do electromagnetic waves have?

7. How can we define the amplitude of a wave?
8. How can we define a wavelength?
9. What is the range of the electromagnetic waves frequencies?
10. What is the ratio of frequency to the wavelength?
11. If a wave has a higher frequency, it has more energy, doesn't it?
12. What are the three basic units of electromagnetic radiation?

Electromagnetic Waves: Basic Properties



Electromagnetic waves consist of oscillating electrical and magnetic fields, acting perpendicular to each other. Electromagnetic waves are produced by the motion of electrically charged particles. These waves are also called 'electromagnetic radiation' because they are radiated from the electrically charged particles. They travel through empty space as well as through air and other substances. As you know, electromagnetic waves carry energy in all directions through the universe. All objects receive, absorb, and radiate the waves which can be pictured as electric and magnetic fields vibrating at right angles to each other and also to the direction in which the wave is travelling. An electromagnetic wave transports its energy through a vacuum at a speed of 300 000 km per second (a speed of light).

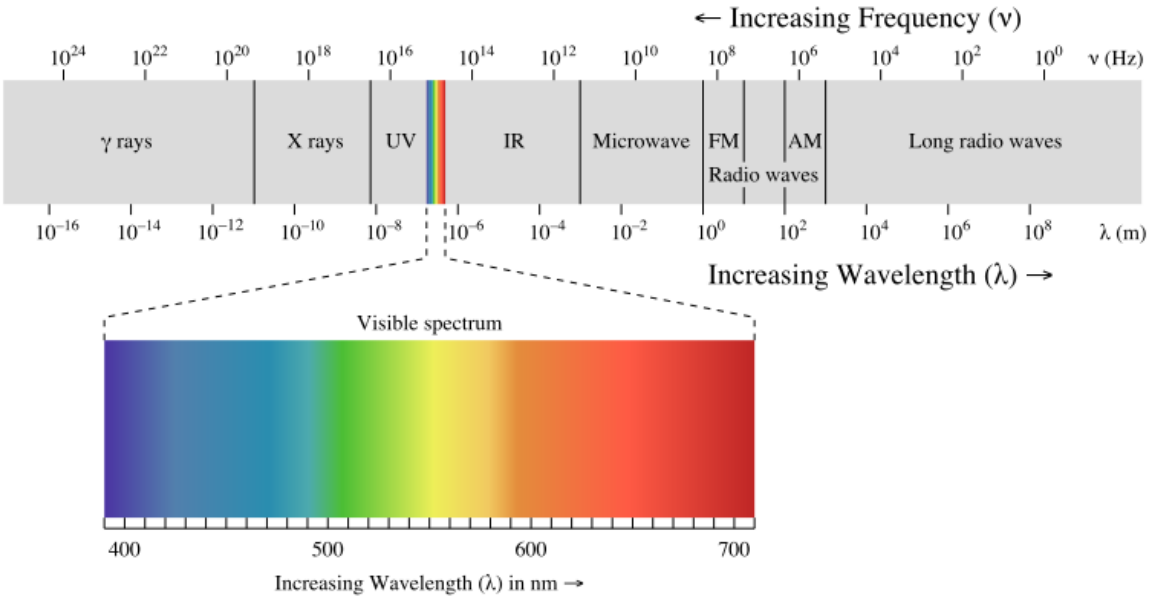
A wave has a trough (lowest point) and a crest (highest point). The vertical distance between the tip of a crest and the wave's central axis is known as its amplitude. This is the property associated with the brightness, or intensity, of the wave. The horizontal distance between two consecutive troughs or crests is known as the wavelength of the wave. Electromagnetic waves show a continuous range of frequencies and wavelengths. The frequency of a wave is the number of times a wave crest occurs each second. It is measured in hertz (Hz). Wavelength and frequency are inversely proportional: that is, the shorter the wavelength, the higher the frequency, and vice versa. Besides, if a wave has a higher frequency, it has more energy. And, if a wave has a smaller frequency, it has less energy. The range of wavelengths for electromagnetic waves – from the very long to the very short – is called the electromagnetic spectrum

So, electromagnetic radiation can be expressed in terms of energy, wavelength, or frequency. Frequency is measured in cycles per second, or Hertz. Wavelength is measured in meters. Energy is measured in electron volts. Each of these three quantities for describing EM radiation are related to each other in a precise mathematical way.

EXERCISE 6

The electromagnetic spectrum covers a wide range of wavelengths and photon energies. Study the picture and see if you can find answers to these questions:

1. How many regions is the electromagnetic spectrum divided?
2. What kind of electromagnetic radiation has the shortest wavelength? The longest?
3. What are the wavelengths of visible light spectrum?
4. What colour has the shortest (the longest) wavelength?



EXERCISE 7

Match electromagnetic waves with their characteristics and applications.

Radio waves	a) They are extremely high frequency radio waves with wavelengths of a couple of centimeters. They cause water and fat molecules to vibrate, which makes the substances hot. So, we can use them to cook many types of food. Mobile phones, radars and Wi-Fi also use them.
Microwaves	b) They are emitted by the Sun and are the reason skin tans and burns. They can be used to kill microbes. The ozone layer in the Earth's atmosphere screens us from its negative effects.
Infrared waves	c) They are very high frequency waves, and carry a lot of energy. They will pass through most substances, including the body and this makes them useful in medicine and industry to see inside things.

Visible waves	d) Naturally occurring waves are generated by lightning, or by astronomical objects like stars, the artificial ones are produced by transmitters and received by receivers and used mainly for communication and broadcasting. They are the longest usable waves, having a wavelength of 1 mile (1.5 kilometer) or more.
Ultraviolet waves	e) They are dangerous rays given off by stars, and by some radioactive substances. They pass through most materials, and are quite difficult to stop – you need lead or concrete in order to block them out. They can kill living cells and they are used to kill cancer cells. They have the shortest wavelength in the electromagnetic spectrum of about 1/10,000,000 centimeter.
X-rays	f) They are the deep red rays just below visible red light in the electromagnetic spectrum. They're given off by hot objects like stars, lamps, flames, radiators and you can feel them as warmth on your skin. They are also used in remote controls for consumer electronics.
Gamma rays	g) They are the radiation you can see with your eyes. Their wavelengths are in the range of 1/1000 centimeter. We use it to see things!

EXERCISE 8

Describe each type of the electromagnetic waves. Be sure to mention its wavelength, size, source, frequency and energy. Follow the example.

e.g. Microwaves are a type of electromagnetic radiation. Microwaves have frequencies ranging from about 1 billion cycles per second, or 1 gigahertz (GHz), up to about 300 gigahertz and wavelengths of about 30 centimeters (12 inches) to 1 millimeter (0.04 inches), They have a range of applications, including communications, radar and consumer electronics.

EXERCISE 9

Arrange the following verbs into pairs of synonyms.

1) to fabricate	a) to traverse
2) to coat	b) to look
3) to cross	c) to cover
4) to want	d) to produce
5) to peer	e) to desire

EXERCISE 10

Arrange the following nouns into pairs of synonyms.

1) increase	a) scope
2) adjustment	b) velocity
3) purpose	c) enlargement
4) range	d) change
5) speed	e) goal

EXERCISE 11

Read and translate the text. Fill in the gaps with proper words. Listen to the audio 'Definition of the Visible Spectrum' and check your answers.

Definition of the Visible Spectrum

cells	X-rays	propagated	frequency	bulbs	radio	perceptible

You see the visible spectrum every day and probably don't even realize it. This is because we commonly refer to the visible spectrum as light, or visible light. Nearly all of us see some form of light every day.

Electromagnetic waves are grouped according to _____. The electromagnetic spectrum is the range of frequencies over which electromagnetic radiation can be _____. It includes all groups of electromagnetic waves. The lowest frequencies are associated with _____ waves. Microwaves have a higher frequency, and then infrared waves, light, ultraviolet radiation, _____, and gamma rays in sequence. The visible spectrum is one group of electromagnetic waves in the electromagnetic spectrum.

Visible light is a very narrow band of frequencies of electromagnetic waves that are _____ by the human eye. The eye contains specialized _____ called rods and cones that are sensitive to the visible spectrum. As mentioned previously, most of us see visible light every day. For example, the sun produces visible light. Incandescent light _____, fluorescent, and neon lights are other examples of visible light that we may see on a regular basis. Visible light is probably the most important of all electromagnetic waves for most of us.

EXERCISE 12

Read the texts. Choose the correct answer (A, B, C) for each gap.

I. Characteristics of Electromagnetic Waves

Electromagnetic waves are transverse waves, similar to water waves in the ocean or the waves seen on a guitar string. All waves have amplitude, wavelength, velocity and frequency.

The amplitude of electromagnetic waves 1. _____ to its intensity or brightness (as in the case of visible light). With visible light, the brightness is usually 2. _____ in lumens. With other wavelengths the intensity of the radiation, which is power per unit area or watts per square meter is used. The square of the amplitude of a wave is the intensity.

The wavelengths of electromagnetic waves go from extremely long to extremely short and everything in between. The wavelengths 3. _____ how matter responds to the electromagnetic wave, and those characteristics determine the name we give that particular group of wavelengths.

The velocity of electromagnetic waves in a vacuum is 4. _____ 186,000 miles per second or 300,000 kilometers per second, the same as the speed of light. When these waves pass through matter, they slow down slightly, 5. _____ their wavelength.

The frequency of any waveform 6. _____ the velocity divided by the wavelength. The units of measurement are in cycles per second or Hertz.

by Ron Kurtus (revised 15 February 2016)

	A	B	C
1	reminds	relates	repeats
2	memorised	murdered	measured
3	demand	determine	devote
4	approximately	approach	approve
5	in case of	in order to	according to
6	evens	equals	events

II. Sources of Electromagnetic Radiation

Electromagnetic radiation 1. _____ from all matter with a temperature above absolute zero. Temperature is the measure of the average energy of 2. _____ atoms and that vibration causes them to give off electromagnetic radiation. As the temperature increases, more radiation and shorter wavelengths of electromagnetic radiation are emitted.

Microwaves, radio, and television waves are emitted from electronic devices. They 3. _____ when sparks and alternating current cause vibrations at the appropriate frequencies.

Visible light is emitted from matter 4. _____ than about 700 degrees Celsius. This matter 5. _____ to be incandescent. The sun, a fire, and the ordinary light bulb are incandescent sources of light.

As the element in an electric stove gets warm, it gives off infrared radiation, and then when it gets hotter than 700 degrees, it starts to glow. Visible light 6. _____ from the hot element.

By 7. _____ high-energy electrons into other particles, such as atoms in a metal, X-rays are created.

Gamma rays are emitted from nuclear reactions, atomic bombs, and explosions on the Sun and other stars.

by Ron Kurtus (revised 15 February 2016)

	A	B	C
1	is emit	emitted	is emitted
2	vibrating	vibrated	vibrate
3	appearing	appear	appears
4	hottest	hot	hotter
5	is said	say	said
6	is emitted	is being emitted	emitted
7	smash	smashing	having smashing

EXERCISE 13

Listen to the audio / watch the video "Light waves, visible and invisible" (by Lucianne Walkowicz on *http://ed.ted.com/lessons/light-waves-visible-and-invisible-lucianne-walkowicz)* **and do the quiz based on it.**

Each kind of light has a unique wavelength, but human eyes can only perceive a tiny slice of the full spectrum – the very narrow range from red to violet. Microwaves, radio waves, x-rays and more are hiding, invisible, just beyond our perception. Lucianne Walkowicz shows us the waves we can't see.

1. Which is not a form of light?
    A. Radio waves
    B. X-rays
    C. Microwaves
    D. Pigment
2. Light is _____ that behaves like a wave and a particle.
    A. Electromagnetic radiation
    B. Gamma radiation
    C. Unfiltered radiation
    D. Air
3. The only thing that makes one kind of light different from another is its _____.
    A. Frequency
    B. Color
    C. Wavelength
    D. Temperature
4. The universe displays _____.
    A. Only visible colors
    B. The full spectrum of light
    C. Only reds and green light
    D. None of the above
5. What are the functions of both rods and cones in your eyes?

6. Explain the differences in wavelength and frequency.

EXERCISE 14

Project. Research a specific type of electromagnetic wave. Your task is to provide:

— **the characteristics.** Describe the characteristics of your particular type of electromagnetic wave (wavelength, frequency, energy).

— **key facts.** List at least 2 key facts about your wave type (something you found interesting, or something that makes your wave type unique from any of the others, etc.).

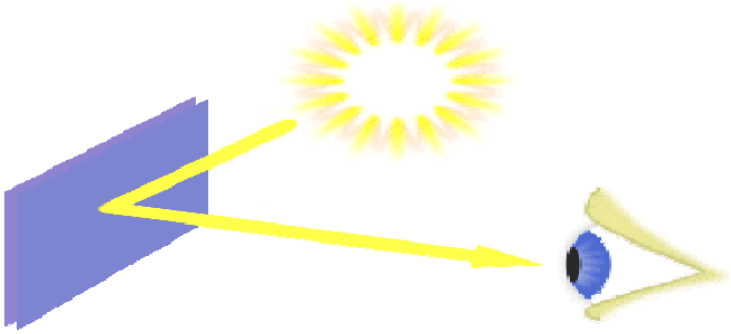
— **where it is found.** Where is your wave type found? (Where does it come from?)

— **examples of uses.** List at least 2 uses of your wave type.

— **dangers of the type of wave.** List at least one danger of your wave type.

Present your findings to the rest of the class. While presenting, your task is to 'prove' that the particular wave you researched is the best and most useful type. You are going to need to be persuasive in your presentation.

UNIT 4
LIGHT BEHAVIOUR



EXERCISE 1

Make adjectives from the following words according to the model and translate them.

a) *e.g. noun / verb + -ive = adjective: effect – effective*

Act, excess, success, to create, to attract, to prevent, to select, to destruct, to invent, to protect.

b) e.g. noun + less = adjective: hope - hopeless

Use, harm, help, shape, color, meaning, power, friend, home, worth, rest.

c) e.g. noun + ic = adjective: metal - metalic

Athlete, artist, base, history, science, ion, electron, atom, photon.

d) e.g. verb + -able / -ible = adjective: to compare - comparable

To operate, to change, to solve, to reason, to vary, to convert, to note, to use, to extend, to control, to recognize, to break, to read, to tune, to achieve, to adjust, to value, to repeat, to afford, to count, to notice.

EXERCISE 2

Match the words with their Ukrainian equivalents and learn them.

1.	to scatter	a) межа, кордон
2.	the index of refraction	b) поширення
3.	to overlap	c) відходити, відскакувати
4.	to absorb	d) падаючий промінь
5.	incident ray	e) перешкода
6.	refracted ray	f) дзеркальне відбивання
7.	angle of incidence	g) кут падіння
8.	boundary	h) напівпрозорий
9.	deflection	i) стик, місце з'єднання, межа
10.	propagation	j) пунктирна лінія
11.	interface	k) відхилення
12.	to bounce	l) розсіяне (дифузне) відбивання
13.	to spread	m) коефіцієнт заломлення

14.	obstacle	n) прозорий
15.	diffuse reflection	o) розсіювати
16.	specular reflection	p) непрозорий
17.	dashed line	q) поширювати
18.	equal to	r) перекривати, заходити один на одне
19.	normal line	s) заломлений промінь
20.	transparent	t) поглинати
21.	opaque	u) менш густе (розріджене) середовище
22.	translucent	v) дорівнювати
23.	dense medium	w) передавати
24.	rare medium	x) густе середовище
25.	to transmit	y) перпендикулярна лінія

EXERCISE 3
Read, translate and memorise the word chains.

1. to transmit, transmission, transmitted, transmitting, transmitter;
2. to reflect, reflection, reflected, reflecting, reflector;
3. to refract, refraction, refracted, refracting, refractor;
4. to absorb, absorption, absorbed, absorbing, absorber;
5. to polarize, polarization, polarized, polarizing, polarizer;
6. to diffract, diffraction, diffracted, diffracting, diffractor;
7. to scatter, scattering, scattered, scatterer;
8. to interfere, interference, interfered, interfering, interferer;
9. to propagate, propagation, propagating, propagative, propagator.

EXERCISE 4
Arrange the following adjectives into pairs of antonyms.

1) narrow	a) liquid
2) quiet	b) pulsed
3) light	c) simple
4) solid	d) noisy
5) continuous	e) low
6) complicated	f) wide
7) high	g) dark

EXERCISE 5
Arrange the following nouns into pairs of antonyms.

1) difference	a) increase
2) emission	b) relaxation
3) decrease	c) similarity
4) development	d) element
5) excitation	e) absorption
6) compound	f) stagnation

EXERCISE 6

Read and translate the text. Say:

- what happens with light rays when they encounter objects;
- what happens to the light that is not transmitted or reflected;
- what happens when light waves superimpose on one another;
- which types of behavior are typical of light waves.

Light waves across the electromagnetic spectrum behave in similar ways. Transmission, absorption and reflection account for all the light energy when light strikes an object. In the course of transmission, light may be scattered, refracted or polarized. It can also be polarized by reflection. The light that is not transmitted or reflected is absorbed and its energy contributes to the heat energy of the molecules of the absorbing material. When light waves overlap, we observe interference. Thus, light behavior includes transmission, absorption, reflection, refraction, scattering, diffraction, interference and polarization.

EXERCISE 7

Match the terms with the descriptions.

1. Reflection	a) is when light waves move all the way through a material without being absorbed.
2. Refraction	b) is the way in which the energy of a photon is taken up by matter, typically the electrons of an atom. Thus, the electromagnetic energy is transformed into internal energy
3. Diffraction	c) is a general physical process where some forms of radiation, such as light, sound, or moving particles, are forced to deviate from a straight trajectory by one or more paths due to non-uniformities in the medium through which they pass.
4. Interference	d) the deflection of a light ray from a straight path when it passes from one medium (such as air) into another (such as glass) in which there are differences in the propagation medium and velocity changes.
5. Scattering	e) is when waves, whether physical or electromagnetic, bounce from a surface back toward the source; the return of light or sound waves from a surface.
6. Transmission	f) a modification which light undergoes especially in passing by the edges of opaque bodies or through narrow openings and in which the rays appear to be deflected; the spreading of waves around obstacles.
7. Absorption	g) is a phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude.

EXERCISE 8

Read and translate the text. Fill in the gaps with the proper words and word combinations. Listen to the audio U4 and check if you were right.

Law of Reflection. Specular and Diffuse Reflection

emit, reflected ray, bounces off, angle, law of reflection, specular reflection, measured, uneven, incident ray, diffuse reflection, smooth

Our surroundings – the sky, trees, people, and our image in the mirror –are made visible to us by reflection, where light 1._____ the surface of the object and this light reaches our vision. Most of these objects do not 2._____ light, but we can see them because light is reflected off of these objects.

Let us consider a ray of light hitting the surface, which is called the 3._____. The incident ray comes in at an 4._____, which is called the angle of incidence. The ray of light that bounces off the surface is called the 5._____, and the angle at which the reflected ray bounces off the surface is called the angle of reflection.

According to the 6._____, the angle of incidence is equal to the angle of reflection. Here, we see an illustration of the law of reflection, where the vertical dashed line is normal (perpendicular) to the surface. The angles of incidence and reflection are 7._____ relative to the dashed line.

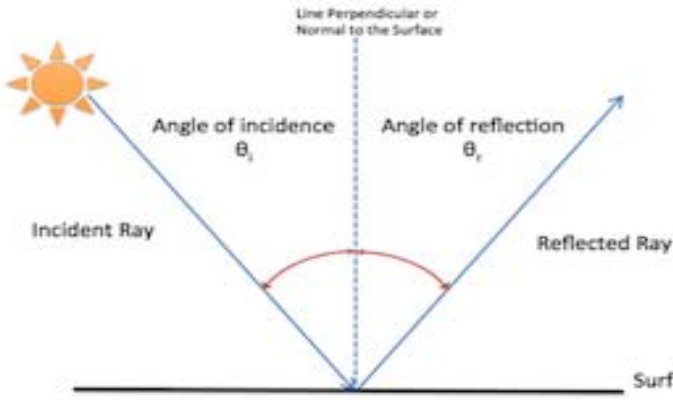


Figure 1: Law of reflection - the angle of incidence, θ_i is equal to the angle of reflection, θ_r.

We can, therefore, say that the law of reflection states that the angle of incidence (theta-i) is equal to the angle of reflection (theta-r). ($\theta_i = \theta_r$)

Reflection occurs on both smooth and uneven surfaces. If multiple incident rays parallel to each other reach a 8._____ surface, such as still water, the reflected rays are all bounced off at the same angle. This results in a clear image known as 9._____ on the surface. Some examples of objects that give off specular reflections are plane mirrors, smooth glass windows, and clear, still water.

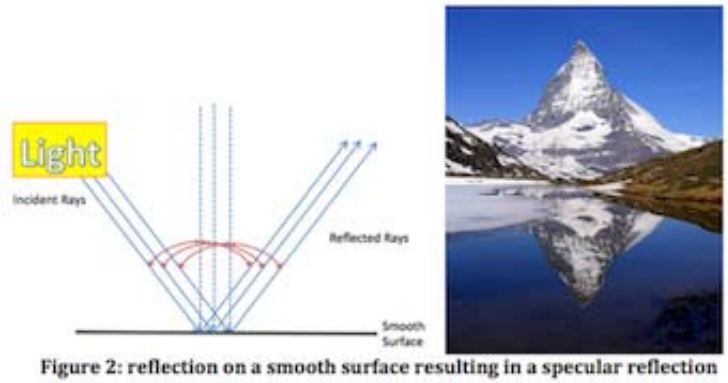


Figure 2: reflection on a smooth surface resulting in a specular reflection

When reflection occurs on 10._____ surfaces, the law of reflection is still observed, with multiple incident rays bouncing off at multiple reflected rays due to the texture of the surface. Light is diffused and a 11._____ occurs. Some examples of objects that give off diffuse reflections are textured glass and a rough asphalt road.

Figure 3: A diffuse reflection results from light reflected on rough/uneven surface

EXERCISE 9

Reread the text and answer the questions.

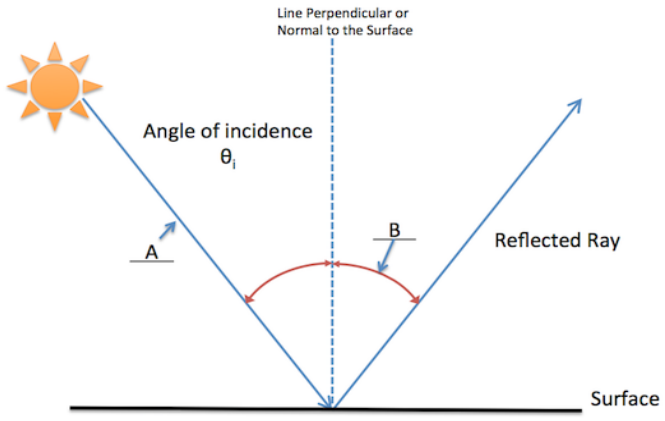
1. Why can we see the objects surrounding us?
2. What is the difference between the incident ray and the reflected ray?
3. When does specular reflection occur?
4. Can we observe specular reflection if light rays are reflected from textured glass?
5. Why do some surfaces not show specular reflection?
6. Is the law of reflection observed when reflection occurs on rough surfaces?
7. Which objects give off diffuse reflection?
8. What does the law of reflection state?

EXERCISE 10

Study the illustrations and do the tasks. Use the given phrases to prove your answer.

To my mind, ...
It seems to me ....
I am sure that ....
It is definitely ....
My point of view is that ....

What do the letters A and B stand for in the illustration that shows the law of reflection?



1. A – angle of reflection
   B – incident angle
2. A – incident angle
   B – angle of reflection
3. A – incident ray
   B – angle of reflection
4. A – reflected ray
   B – angle of reflection

EXERCISE 11

Insert prepositions *in, into, of, on, at, off, through* where it is necessary.

1. Electromagnetic waves carry energy _____ all directions through the universe.
2. Its speed _____ air is almost the same as its speed _____ space.
3. The two phenomena based _____ straight light propagation are reflection and refraction.
4. In reflection, the waves bounce _____ the surface. On the contrary, in refraction, the waves pass _____ the surface, that changes their speed and direction.
5. When light strikes a mirror _____ an angle, it is reflected _____ the same angle.
6. Incident and reflected rays are _____ opposite sides _____ the normal.
7. When a beam _____ light enters a plane glass perpendicular to the surface, it slows down.
8. The index of refraction depends _____ the wavelength.
9. Dispersion of light occurs when white light is separated _____ its different constituent colors because of refraction and Snell's law.
10. White light only appears white because it is composed _____ every color on the visible spectrum.
11. Such an image is formed _____ a microscope or a telescope and can be seen by looking _____ the eyepiece.

EXERCISE 12
Unscramble the words.

1. When light is transmitted, it can be refracted, polarized, or ***srecatedt***.
2. A copy of an object formed by reflected or refracted light waves is known as an ***giame***.
3. When parallel light waves strike a rough, uneven surface and reflect in many different directions, ***fdsifue*** reflection occurs.
4. Light bends, or ***freatrcs***, when it passes at an angle from one type of medium into another.
5. When light strikes a new medium, it can be ***lrefetcde***, ***asbobred*** or ***trnmatsited***.

EXERCISE 13
Match each term to its definition.

transparent	a) Light cannot shine through such materials at all. In fact, they absorb the light that shines on them. A little of the light is reflected back, though.
opaque	b) Such materials allow light to pass through, but prevent the light from forming images. The object scatters the light when it enters. When the light is scattered, the image loses its sharpness. So, light can shine through but such materials aren't really clear.
translucent	c) Such materials allow light to pass through without being scattered; that is they transmit light.

EXERCISE 14
Read and translate the text. Explain in your own words:

– under what conditions we can observe refraction;

– what causes the speed of the light ray change when it enters a different medium;

– what the index of refraction shows;

– formulate the index of refraction;

– formulate the laws of refraction.

Refraction

Refraction is the change in direction of propagation of light waves due to the change in the transmission medium. Simply stated, refraction occurs when light waves change direction as they pass from one medium to another. The speed of the light ray changes when it enters a different medium. In most cases the direction of the light also changes. We say the light bends. Depending on the new medium the light will travel faster or slower. It is the different densities that cause the ray to slow down or speed up and then cause it to bend. For instance,

light rays slow down about 25% when passing through water and 35% when passing through glass. If the light travels slower, this medium is called the denser medium. If the light ray travels faster, the medium is called the rarer medium. When light enters a denser medium the ray bends toward the normal – when light enters a rarer medium it is bent away from the normal.

In order to measure how light will behave in different substances, scientists use the index of refraction. The refractive index of a substance is the ratio of the speed of light in space (or in air) to its speed in the substance. This ratio is always greater than one.

The equation for the index of refraction is: **n = c/v** where **n** is the index of refraction, **c** is the speed of light in a vacuum, and **v** is the speed of light in the substance. As an example, let us take the index of refraction for water which is 1.33. This means that the speed of light in a vacuum is 1.33 times faster than the speed of light in water.

Scientists have figured out the laws of refraction. It has been proved that incident and refracted rays lie in the same plane. When a ray of light passes at an angle into a denser medium, it is bent towards the normal, hence the angle of refraction is smaller than the angle of incidence.

EXERCISE 15

Use these words to complete the sentences about light:

absorb	**focus**	**prism**	**refraction**	**slower**	**transmit**

Transparent materials like glass _____ light. When light passes through glass, it changes direction at the surface. This is called _____. The light travels _____ in the glass. A lens uses refraction to _____ light at a focal point. When white light passes through a _____ it splits into a spectrum. Opaque materials like cardboard _____ light.

EXERCISE 16

Listen to the audio / watch the first half of the video What is a Prism? - Definition & Refraction (by *Richard Cardenas on http://study.com/academy/lesson/what-is-a-prism-definition-refraction-quiz.html*) and fill in the gaps with the words you hear.

What Is a Prism?

white	transparent	spreads	rainbows	surfaces	applications
angle	emerge	prisms			

Have you ever wondered why there are 1. _____? Did you ever see a prism work and wonder why a prism seems to create rainbows? Well, in this lesson you'll learn about 2. _____, how they work, why they work, and what 3. _____ they may have to everyday phenomena.

A prism is an object made up of a 4._____ material like glass or plastic that has at least two flat 5. _____ that form an acute 6. _____ (less than 90 degrees). 7. _____ light is comprised of all the colors of the rainbow. When white light is passed through a prism, the colors of the rainbow 8. _____ from the prism much like in the figure here (see video). We'll learn more about why a prism 9._____ white light out into the colors of the rainbow.

Definition of Refraction

refraction	medium	bent	wave	occur

Have you ever noticed that people standing in a pool always look shorter than they really are or that a spoon in a glass of water seems to be 10. _____? The reason why these phenomena 11. _____ is because of the concept of 12. _____, which is simply the bending of a light 13. _____. In order to further understand what refraction is and why it occurs, we need to look at what happens to light when is goes from one 14. _____ to another (like from air to water or a vacuum to air).

Index of Refraction

diamond	speed	denser	vacuum	fastest changes
property	formula	slows	index of refraction	

The 15. _____ of light in a vacuum is denoted by the letter *c* and has a value of 300,000,000 meters per second (m/s). When light goes from a 16. _____ to another medium, light 17. _____ down. How much it slows down is dependent on something called the 18. _____, which is denoted by the letter *n*. The index of refraction is a 19. _____ of a material (or medium). When light goes into a 20. _____ medium, it slows down more. The denser the material, the slower light will travel through that medium. The speed of light in a material, denoted by *v*, 21. _____ according to the following 22. _____:

$$v_n = \frac{c}{n} = \frac{3.0 \times 10^8 \frac{m}{s}}{n}$$

The table here is a sampling of different materials and their corresponding index of refraction:

Medium	Index of Refraction
Vacuum	1.00
Air	1.0003
Water	1.33

Flint Glass	1.66
Diamond	2.42

Based on the index of refraction, the speed of light is 23. _____ in a vacuum and slowest in 24. _____. The reason why light slows down is because it bends as it goes from one medium to another. The figure here (see video) illustrates an incident light beam entering water (red light ray) and refracting as it goes from air to water (blue light ray).

EXERCISE 17
Think and explain:

— why it's better to wear lighter colors (such as white and pale yellow) during the summer and better to wear darker colors (like black and charcoal gray) in the winter.
— what happens when light passes through a prism. What other common object refracts light?
— if color is nothing more than wavelengths of light, why do you think people vary so differently in their color preferences? Why is my favorite color blue when yours can be red or green? Is there such a thing as the philosophy of color?

EXERCISE 18
Translate the sentences into English.

1. В однорідному прозорому середовищі світло поширюється прямолінійно.
2. Частина світла може пройти крізь тіло, якщо це тіло прозоре, частина поглинеться, а частина відіб'ється від тіла.
3. Ми бачимо предмети завдяки тому, що вони відбивають світло і ці відбиті промені потрапляють нам в очі.
4. Згідно із законом відбивання святла, кут падіння дорівнює куту відбивання.
5. Якщо світло відбивається від шорсткої поверхні, то таке відбивання називають розсіяним (дифузним). У цьому випадку відбиті промені поширюються в різних напрямках.
6. Біла поверхня тіла відбиває світлові промені, а чорна поверхня поглинає практично все світло, що падає на неї.
7. Предмет буде абсолютно невидимим, якщо розсіювання світлових променів дорівнює нулю.
8. Найкращі відбивачі світла – дзеркала: вони можуть відбивати до 95% падаючого світла.

EXERCISE 19
Choose the correct answer.

1. What is the nature of light?
    A. Light is the form of electromagnetic wave.
    B. Light is a magnetic field.
    C. Light is an electric field.
    D. Light is a stream of molecules.
2. What happens with the light that is not transmitted or reflected?
    A. It is polarized.
    B. It is refracted.
    C. It is scattered.
    D. It is absorbed.
3. At what angles does the light leave an object in diffuse reflection?
    A. The light leaves an object in diffuse reflection at the same angle as it strikes an object.
    B. The light leaves an object in diffuse reflection so that incident and reflected rays are on opposite sides of the normal.
    C. The light leaves an object in diffuse reflection at many different angles.
    D. When the light leaves an object in diffuse reflection angle of reflection equals to angle of the incidence.
4. When a light ray crosses the boundary between two different materials what doesit change?
    A. It changes its speed.
    B. It changes its direction.
    C. It changes its wavelength and frequency.
    D. It changes its wavelength, speed and direction.
5. How many laws of reflection do you know?
    A. 3 laws
    B. 2 laws
    C. 1 law
    D. 4 laws

UNIT 5
OPTICAL INSTRUMENTS

EXERCISE 1

Read and translate the words and word-combinations, pay attention to the word-building components.

1. to converge, convergence, convergent, converging;
2. to refract, refraction, refractor, refracted, refracting, refractive index;
3. to coat, coating, coated;
4. to split, splitting, splitted, splitter, beam splitter;
5. to diffuse, diffusion, diffusing, diffused, diffuser;
6. to reflect, reflaction, reflactor, reflected, reflecting, law of reflection;
7. to require, requiring, required, requirement;
8. to measure, measuring, measured, measurement;
9. to perform, performing, performed, performance;
10. to diverge, divergence, divergent;
11. to magnify, magnifying, magnified, magnifier, magnifying glass;
12. to produce, producing, produced, producer, production.

EXERCISE 2

Arrange the following words into pairs of synonyms.

1) viewer	a) mechanism
2) aid	b) glasses
3) increase	c) quantity
4) fall	d) eyepiece
5) device	e) incidence
6) amount	f) looking glass
7) spectacles	g) aberration
8) mirror	h) help
9) distortion	i) enlargement

EXERCISE 3
Arrange the following words into pairs of antonyms.

1) negative	a) large
2) light	b) base
3) top	c) less
4) small	d) shade
5) diverge	e) thick
6) more	f) positive
7) thin	g) converge

EXERCISE 4
Match the words with their Ukrainian equivalents and learn them.

1. to converge	a) поверхня
2. to diverge	b) довжина хвилі
3. diverging lens	c) увігнута лінза
4. converging lens	d) кривизна, викривлення
5. concave lense	e) плаский
6. convex lense	f) форма
7. compound lens	g) кут падіння
8. medium	h) складна лінза (об'єктив)
9. curvature	i) розсіювальна лінза
10. interface	j) середовище
11. shape	k) вісь
12. wavelength	l) одночасний
13. negligible	m) фокусна відстань
14. surface	n) збільшене зображення
15. planar	o) зір, бачення
16. an angle of incidence	p) незначний, не вартий уваги
17. simultaneous	q) опукла лінза
18. enlarged image	r) розділяти, розщеплювати
19. vision	s) розходитися
20. to split	t) діоптрія
21. axis	u) меніск
22. focal length	v) стик; межа
23. diopter	w) зводити в одну точку, збирати
24. meniscus	x) збиральна лінза

EXERCISE 5
Read, translate and memorise the given words and word combinations.

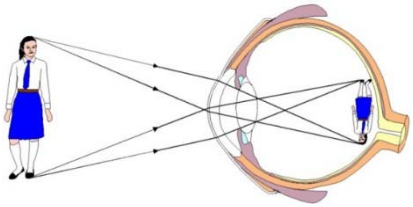
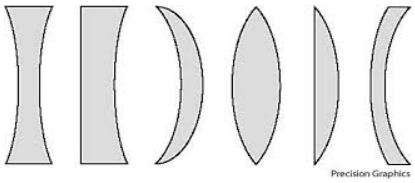
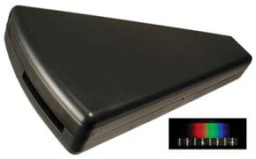
To bend, to alter, to change, to separate, to reflect, to scatter, to need, spectrum, a power source, a lense, direction, an application, a filter, a surface, concave, convex, a mirror, a concave mirror, a plate, imaging, microscopy,

interferometry, a prism, transparent glass, a substrate, a splitter, a beam, a diffuser, an eyepiece, testing, far-off objects, measuring, a focal point, a focal length, a screen

EXERCISE 6
Answer the questions.

1. What optical instruments do you know?
2. What is common for all optical instruments?
3. What optical instruments have you ever tried to use?

EXERCISE 7
Match an optical instrument to a picture.

magnifying glass microscope glasses camera binoculars telescope projector lenses eye spectroscope	
1. 	2. 
3. 	4. 
5. 	6. 
7. 	8. 
9. 	10. 

EXERCISE 8
Read the statements and guess what optical instrument mentioned in the previous exercise is described.

1. It is a transparent optical device used to converge or diverge transmitted light and to form images.

2. This optical instrument projects an enlarged image onto a screen.
3. It consists of a frame that holds a pair of lenses for correcting defective vision.
4. It splits light into its component colors.
5. It is a lens that lets the observer see a larger image of the object being observed.
6. These optical devices allow a user to record an image of an object, either on photo paper or digitally.
7. These optical instruments are designed for simultaneous use by both eyes.
8. It aids in observation of remote objects by collecting electromagnetic radiation, such as visible light.

EXERCISE 9

Read the text, substitute the Ukrainian words with their English equivalents.

Optical components are items that are used to **вигинати**, **розділити**, **розсіювати**, **відбивати** or otherwise **змінювати** or refocus light wavelengths. This may include changing the **спектр** of the light, transforming a light pattern into an electric one (image), or simply altering the **напрямок** or path. These items generally function without an outside **джерело енергії**, although they may be part of a larger system that does **потребує** a power source. Typical components within this family include **лінзи**, **фільтри**, **розщеплювачі променя світла**, **дзеркала**, **розсіювачі**, **пластини**, **призми** and **вікна**.

Optical components are integrated into a limitless number of **застосування**, such as **мікроскопія**, **обробка зображень**, or interferometry, for industries ranging from the life sciences to **тестування** and **вимірювання**. Optical components are often designed using specific substrates or anti-reflection **покриття** to optimize **продуктивність** in ultraviolet, **видимих**, or infrared **довжинах хвиль**.

EXERCISE 10

Read and translate the text.

The Types of Lenses

The role played by optical instruments in the advent of the contemporary age is seldom taken into account. However, their role was really great for the development of the modern science. For example, the invention of the telescope has changed our understanding of the universe. The microscope also performed a similar revolutionary function in biology and medicine, opening immense horizons for them. Before the appearance of the camera, the descriptions of the world were produced by artists only. The camera introduced a more accurate way of observing the world.

These short considerations make it possible to understand how great the role played by optical instruments was in the formation of the world we know. These instruments are perfectly suitable to the modern and objective way of observing reality, but how do they work? Understanding the properties of lenses is fundamental to becoming familiar with these instruments in order to use them with confidence.

A lens is a curved piece of transparent material (usually glass or plastic) designed to refract light rays in a specific way and to form an image. There are a variety of lenses types. They differ from one another in terms of their shape and the materials from which they are made.

One way to classify lenses is by how they bend light. The two main lenses types are converging lenses and diverging lenses.

A converging lens is a lens that converges rays of light that are travelling parallel to its principal axis (see Fig.1). It converges them to a point called the focus (focal point). The distance between the middle of the lens and the focus is called the focal length, known as *f*. Converging lenses can be identified by their shape – they are relatively thick across their middle and thin at their upper and lower edges.

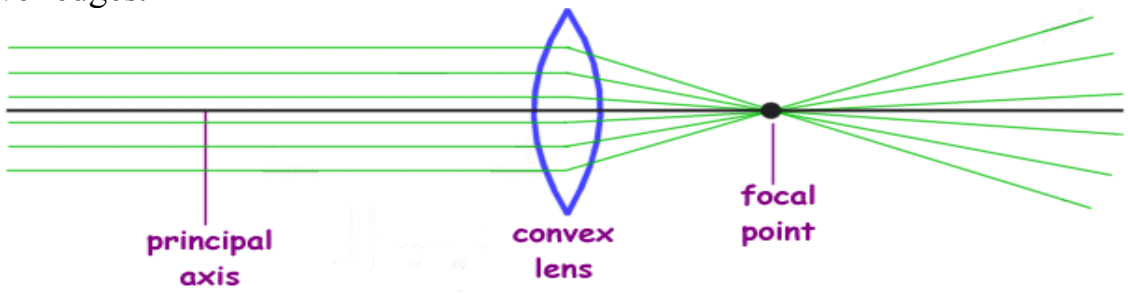


Fig.1

A diverging lens is a lens that diverges rays of light that are traveling parallel to its principal axis (see Fig.2). Diverging lenses can also be identified by their shape – they are relatively thin across their middle and thick at their upper and lower edges.

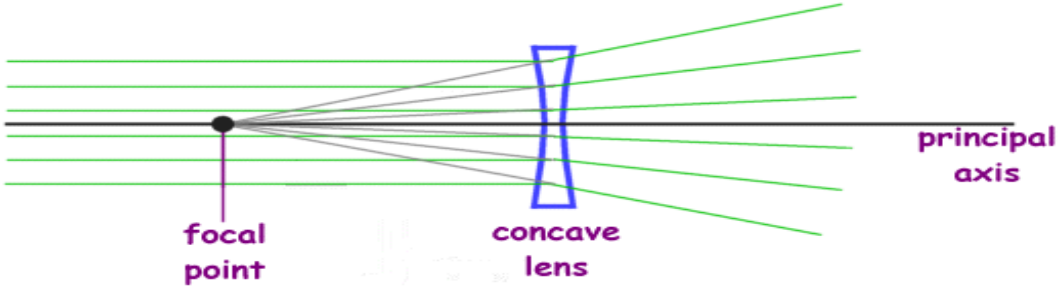


Fig.2

An important property of a lens is its power. The power of a lens is its ability to focus parallel light rays to a short distance. It is measured in diopter and is given by the formula D=1/f, where D is the power in diopters and f is the focal length in meters.

Another way of lenses classification is based on the curve of the glass on each side of the lens. As a result of such classification we have convex, concave, plano and meniscus lenses.

A convex lens is one where the center of the lens is thicker than the edges. A concave lens has the center which is thinner than its edges. A plano lens is a flat lens. It can have one side flat and another one concave or convex. A meniscus lens is the one where one side is concave and one side is convex.

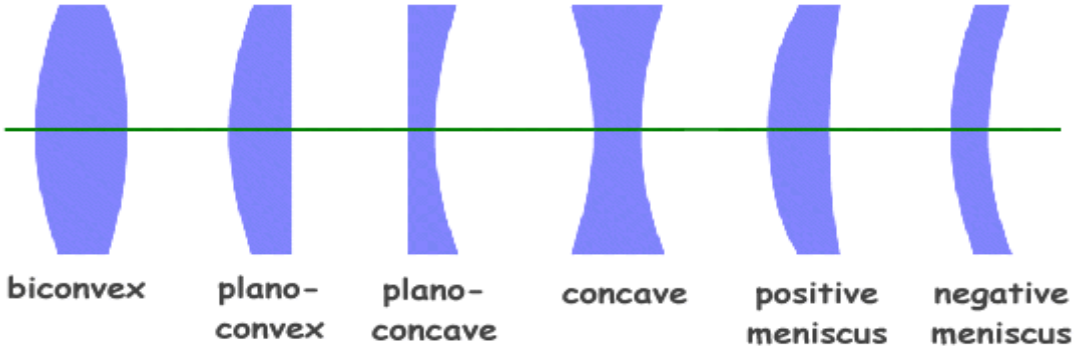
There are also combinations of several lenses types. For instance, a biconvex lens is a lens in which both sides are convex. Biconvex lenses are converging lenses.

Plano-convex lenses have one convex side, the other side is plano. Plano-convex lenses are also converging lenses.

When both sides are concave we speak about biconcave lenses. Biconcave lenses are diverging lenses.

When we have one concave side and another plano side we mean plano-concave lenses. Plano-concave lenses are diverging lenses.

A converging lens where one side is concave and the other side is convex is called positive meniscus. And a diverging lens where one side is concave and the other one is convex is called negative meniscus lense.



(Read more at:
http://www.ducksters.com/science/physics/lenses_and_light.php)

EXERCISE 11
Answer the questions in writing.

1. Have optical instruments played an important role for the development of humanity? Prove it giving the examples of your own.
2. Why is it necessary to know the properties of lenses?
3. What is a lens? How does it look like? What material can it be made from?
4. What is the principle of work of a converging lens?
5. What is the difference between the focal point and the focal length?
6. What is the principle of work of a diverging lens?
7. How is the power of a lens defined? What unit is it measured in?
8. How do convex lenses look like?

9. How do concave lenses look like?
10. What are the main lenses types? What is the difference between them?

EXERCISE 12

Remember the meaning of the terms that you have found in the texts. Match the terms with their definitions.

focus	a) is a piece of glass or glass-like substance with one or both sides curved for use in spectacles, cameras, telescopes and other optical instruments.
focal point	b) is a solid figure with similar equal and parallel ends which are parallelograms, body of this form made of glass breaks up white light into the colours of the rainbow.
lens	c) is a meeting point of rays of light.
prism	d) is scattering of waves in back of a solid object after they strike it.
diffraction	e) the point where waves of light or sound that are moving towards each other meet

EXERCISE 13

Listen to the audio / watch the video: What light can teach us about the universe (by Pete Edwards) on https://ed.ted.com/lessons/what-light-can-teach-us-about-the-universe-pete-edwards#watch and do the quiz.

1. How many pieces of information about the objects in our universe are carried by their light?
    A. 6
    B. 3
    C. 5
    D. 0
2. The effect where sound waves generated by an approaching object are ‘compressed’, while those from a receding object are ‘stretched’, is named after which scientist?
    A. Edwin Hubble
    B. Henrietta Leavitt
    C. Christian Doppler
    D. Marie Curie
3. What did Edwin Hubble notice about the light from distant galaxies?
    A. The colours in their spectra were red shifted
    B. The colours in their spectra were not as bright
    C. The colours in their spectra were blue shifted
    D. The colours in their spectra disappeared
4. One of the Big Bang Theory’s most important predictions is that the early universe consisted of just two gases. Which ones?

A. Hydrogen and Oxygen
B. Hydrogen and Helium
C. Nitrogen and Helium
D. Neon and Nitrogen

5. We currently believe about two thirds of our universe consists of Dark Energy, which is slowly tearing it apart. Which observations provided the first evidence for Dark Energy?
   A. Distant galaxies were closer than expected
   B. Distant galaxies were fuzzier than expected
   C. Distant galaxies were greener than expected
   D. Distant galaxies were further away than expected

EXERCISE 14

Put the verbs in brackets into the correct tense and voice.

1. A lens *(to be)* a piece of glass, plastic or other transparent material curved on one or both sides.
2. Lenses *(to refract)* the light rays from an object forming an image.
3. The walls of the house *(to absorb)* heat day after day.
4. Electromagnetic waves *(to travel)* in all directions through the Universe.
5. Spectacles *(to invent)* in Northern Italy in the second half of the 13th century.
6. A lens *(to be)* biconvex if both surfaces *(to be)* convex.
7. Lenses *(not to form)* perfect images, and a lens always *(to introduce)* some degree of distortion or aberration that makes the image an imperfect replica of the object.
8. Modern lenses *(to employ)* different techniques to dramatically reduce spherical aberration.
9. In the past, most of those microscopes *(to make)* of inferior quality materials, *(to have)* minimal optical quality and *(to be)* likely to break quickly.
10. The microscope *(to improve)* and *(to refine)* continuously throughout its history, that is practically since the 17th century.

EXERCISE 15

Read and translate the sentences into Ukrainian.

1. The projection lens is to be especially corrected for curvature of field and distortion.
2. The purpose of the condenser is to concentrate the light coming from the mirror to a point approximately 1.25 mm above the surface of its top lens.
3. The magnifying power of microscopes is being increased from year to year.
4. Some stars that look white to the naked eye can be seen in their true colour when viewed with a telescope.

5. It is common knowledge that looking at the Sun can cause permanent damage to your eyes.
6. Everything in this article refers to a light microscope, that is a microscope that includes a built-in light source.
7. Total magnification is achieved by multiplying the power of the objective lens by that of the eyepiece lens
8. A simple lens consists of a single piece of transparent material, while a compound lens consists of several simple lenses, usually arranged along a common axis.
9. A lens can focus light to form an image, unlike a prism, which refracts light without focusing.
10. With the invention of the telescope and microscope there was a great deal of experimentation with lens shapes in the 17th and early 18th centuries trying to correct chromatic errors seen in lenses.
11. Convex-concave (meniscus) lenses can be either positive or negative, depending on the relative curvatures of the two surfaces.
12. Several types of aberration affect image quality, including spherical aberration, comatic (coma) aberration, and chromatic aberration.
13. Spherical aberration is an optical problem that occurs when all incoming light rays end up focusing at different points after passing through a spherical surface.
14. Optical coma aberration is regarded as the worst among aberrations due to the asymmetry of the image that it causes.
15. Chromatic aberration is a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, or when wavelengths of color are focused at different positions in the focal plane. As a result, the image can look blurred or noticeable colored edges (red, green, blue, yellow, purple) can appear around objects, especially in high-contrast situations.

EXERCISE 16

Project. Prepare a presentation about one of the optical instruments (a microscope, a telescope, glasses, etc.) Be sure to mention:

— The brief history of its origin;
— Its general look;
— Its principle of work;
— Its sphere of usage.

UNIT 6
OPTOELECTRONIC DEVICES & THEIR APPLICATIONS

EXERCISE 1
Read, translate and memorise the terms.

Photonics, quantum, photodiode, phototransistor, photomultiplier, photoresistor, photoconductivity, photoconductive camera tube, photoemissivity, photoemissive camera tube, photoelectric, photovoltaic, photovoltaic cells, photoluminescence, semiconductor, optoisolator, optocoupler, sensor, emitter, stimulated emission, laser, light-emitting diode, laser diode, solar cell, optical fiber communication.

EXERCISE 2
Arrange the following words into pairs of synonyms.

1) to emerge	a) to take place
2) rate	b) to propagate
3) to spread	c) speed
4) to occur	d) quality
5) property	e) to alter
6) to change	f) to appear

EXERCISE 3
Read the given collocations and find their Ukrainian equivalents.

I. a) high energy level, ordinary light source, stimulated emission, unstable atoms, energy state, wholly coherent light, incandescent lamp, resulting beam, powerful energy, electromagnetic avalanche;

b) components are in step with each other, to excite molecules, to reach high temperature;

II. a) лампа розжарення, нестабільні атоми, енергетичний стан, високий енергетичний рівень, потужна енергія, звичайне джерело світла, електромагнітна лавина, вимушене випромінення, повністю когерентне світло, отриманий пучок світла;

b) збуджувати молекули, досягати високої температури, компоненти співпадають за фазою.

EXERCISE 4
Read and translate the following chemical elements.

Germanium (Ge), silicon (Si), phosphorous (P), boron (B), aluminum (Al), arsenic (As), gallium (Ga), zinc (Zn), lithium (Li), beryllium (Be), nitrogen (N), fluorine (F), neon (Ne), sodium (Na), magnesium (Mg), sulphur (S), argon (Ar), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), selenium (Se), krypton (Kr), yttrium (Y), indium (In), xenon (Xe), neodymium (Nd), terbium (Tb), erbium (Er), tellurium (Te)

EXERCISE 5
Read and translate the text. Find answers to the folloing qiestions.

— What chemical elements are often used in electronics and optoelectronics?
— Where is gallium applied?
— What elements are so soft that can be cut with a knife?
— What element is used for making LCD screens?
— What is a metalloid?
— What element is a byproduct of the refinement of copper?
— What is erbium used for?

Rare-earth and other chemical elements play an important role in the photonics industry, routinely used in semiconductor, PV, and photodetector devices and to power solid-state and fiber lasers. While many of these elements are abundant, some are experiencing volatile supply and processing issues.

Germanium (Ge), indium (In), gallium (Ga), and arsenic (As) are widely used in semiconductor, photovoltaic thin-film, and photodetector devices, while yttrium (Y) and ytterbium (Yb) power solid-state and fiber lasers. Let's characterize some of them.

Gallium is a soft and silvery metal with a melting point just above room temperature. Nearly all gallium used in industry today goes towards building computer chips and electronics. It is used in doping semiconductors and in blue-light LEDs. Gallium is a byproduct of the production of aluminum and zinc, both are mined all over the world.

Indium is a super soft (it's easily cut with a knife) shiny metal with numerous applications in computers and electronics. It is used in making LCD screens, computer chips, LEDs and solar panels. Indium is mostly derived as a byproduct of zinc production and can be found all over the world.

Tellurium is a rare and brittle metalloid (an element with attributes of both metals and non-metals) with applications in solar panels and computer chips. Tellurium, in the compound cadmium telluride, is a major component of high-efficiency solar panels. In addition, it's used in making semiconductors and rewritable optical media (CDs, DVDs, and Blu-Ray). Tellurium is produced as a byproduct of the refinement of copper.

Erbium is used to color lasers, in nuclear power plant technology, and as a doping agent in fiber optic amplifiers. One form of erbium is utilized for its pink color in glass and photographic filters. Erbium is present in ores all over the world.

EXERCISE 6
Match the words with their Ukrainian equivalents and learn them.

1. solid-state devices	a) твердотільні прилади
2. IR (infrared) emitter	b) застосування
3. application	c) система підрахунку
4. counting systems	d) охоронна система
5. twilight switches	e) виявляти
6. house security systems	f) сутінковий вимикач
7. to detect	g) p-n перехід
8. electronic circuit	h) генерувати струм
9. p-n junction	i) перетворювач
10. to generate current	j) електронна схема
11. to illuminate	k) інфрачервоний випромінювач
12. potential difference	l) домішка
13. impurity	m) область збіднення
14. doping	n) фотопровідний
15. movement	o) прилад із зарядовим зв'язком
16. electrons and holes	p) легування
17. depletion layer	q) різниця потенціалів
18. equilibrium	r) рух
19. transducer	s) взаємодія
20. charge-coupled device (CCD)	t) оптопара (оптрон)
21. optocoupler	u) фотогальванічний
22. interaction	v) рівновага
23. photovoltaic	w) електрони і дірки
24. photoconductive	x) освітлювати

EXERCISE 7
Listen to the audio 'Optoelectronics' and complete the sentences.

1. Optoelectronics is the study and application of electronic devices that _____, _____ and _____ _____.
2. Light often includes invisible forms of radiation such as _____, _____, _____ and _____, in addition to _____ _____.
3. Optoelectronic devices are electrical-to-optical or optical-to-electrical _____.
4. Electro-optics is a wider branch of physics that deals with all interactions between _____ and _____ fields.

5. Optoelectronics is based on the quantum mechanical effects of light on electronic materials, especially _____, sometimes in the presence of _____ _____.
6. Photoelectric or photovoltaic effect, used in: _____, _____, _____, _____, integrated _____ _____ elements.
7. Photoconductivity, used in: _____, _____ _____ tubes _____-_____ imaging devices.
8. Stimulated emission, used in: injection _____ _____, quantum _____ _____.
9. Important applications of optoelectronics include: _____, _____ _____ communications.

EXERCISE 8
Read and translate the text.

The p-n Junction as a Voltage Source

The controlled diffusion of impurities into such materials as germanium and silicon produces semiconductors. The process of introducing impurities into a pure semiconductor material is known as 'doping.' Phosphorous, arsenic, boron, and aluminium are some of the materials used as impurities for doping. Doping creates a *p-n* junction.

A *p-n* junction is a boundary between two types of semiconductor materials, *p*-type and *n*-type, inside a single crystal of semiconductor. The '*p*' (positive) side contains an excess of holes, while the '*n*' (negative) side contains an excess of electrons in the outer shells of the electrically neutral atoms there. This allows electrical current to pass through the junction only in one direction.

Within the *p-n* junction there is movement of electrons and holes (*refer Fig. 1*). From the *n* region electrons diffuse across the junction into the *p* region and combine with the holes present in *p*-type material.

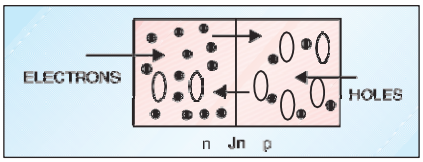


Fig. 1: Diffusion of electrons and holes across the n-p junction

Similarly, some of the holes present in the *p*-type material move across the junction to the *n* region and combine with the electrons present in the *n* region. The process continues and creates a region on either side of the junction with no free charges. This region is known as 'depletion layer' (*refer Fig. 2*).

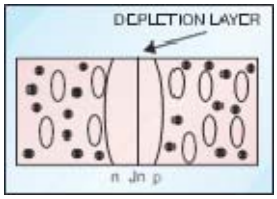


Fig. 2: Depletion layer with no charges on either side of the junction.

In fact, *p-n* junctions are elementary 'building blocks' of semiconductor electronic devices such as diodes, transistors, solar cells, LEDs,

and integrated circuits; they are the active sites where the electronic action of the device takes place.

EXERCISE 9
Answer the questions.

1. How are semiconductors produced?
2. What is doping?
3. What materials are commonly used as impurities for doping?
4. What is a *p*-*n* junction?
5. What is depletion layer?

EXERCISE 10
Read and translate the text.

Optoelectronic Devices and their Application

Optoelectronics is a branch of electronics that combines electronics and optics. Optoelectronic devices and components are those electronic devices that operate on both light and electrical currents. They find varied applications in telecommunications, military services, medical field, and automatic control systems. Such devices include those that emit light (LEDs and light bulbs), channel light (fiber optic cables), detect light (photodiodes and photoresistors), or are controlled by light (optoisolators and phototransistors). Let's discuss some of them

Photoresistors detect variations in the light intensities and activate or deactivate electronic circuits. They are nothing more than light-controlled variable resistors, also known as light dependent resistors (LDRs). Typically, when a photoresistor is placed in the dark its resistance is very high (in the megaohms). In contrast, when a photoresistor is illuminated, its resistance drops dramatically. Depending on the intensity of the light shining on it, the resistance may be as low as hundreds of ohms. Photoresistors are used in light-sensitive switching devices, in counting systems, twilight switches, house security systems, etc.

A photodiode is a kind of light detector, which involves the conversion of light into voltage or current, based on the mode of operation of the device. A photodiode is constructed using a very thin *n*-type semiconductor together with a thicker *p*-type semiconductor. The *n* side has an abundance of electrons and is considered the cathode while the *p* side has an abundance of holes and is considered the anode. When a photon (i.e., light) of sufficient energy strikes the diode, it creates an electron-hole pair. The holes move toward the anode while the electrons move toward the cathode, thus creating a light-induced current (i.e., a photocurrent). Photodiodes find application in cameras, medical devices, optical communication devices, position sensors, bar code scanners, etc.

Photoelectric transducers generate electric current when exposed to light. A photovoltaic cell consists of many p-n junctions connected in series. One of the junctions is very thin, so light can easily pass through it. When light passes, charge carriers such as holes and electrons are produced proportional to the incident light. Photovoltaic cells are used in various applications to generate electricity where mains power is not available. Examples include solar cells and solar batteries. Large arrays of solar cells are combined togrther into solar panels to produce large voltage.

Phototransistors are light-sensitive transistors. They are ideal photodetectors and can be used in a host of different applications.They employ the principle of photodiodes, but the amplifying action of the transistor makes these devices more sensitive. The phototransistor can be used in a variety of circuits and in a number of ways including security systems, counting systems, optoisolators. Being a low cost device the phototransistor is widely used in electronic circuits and it is also easy to incorporate.

There is a broad rande of other types of optoelectronic devices. Infrared (IR) diodes are photodiodes that emit a beam of infrared light. They are used in TV remotes, remote switching burglar alarms, etc. Light-emitting diodes (LEDs) are two-lead semiconductor devices that are similar to normal diodes except that they emit light that can be visible, infrared, or ultraviolet. A laser diode is a semiconductor laser device that is very similar, in both form and operation, to a light-emitting diode (LED). A range of small laser diodes is used in laser pointers and bar-code scanners. However, the most common laser diodes can be found in CD-ROMs and DVD-ROMS. Visible laser diodes are found in barcode and UPC (Universal Product Code) scanners (like the ones used in grocery stores), laser pointers, and positioning devices found in X-ray machines and CT and MRI scanners. Optical fiber is used in conjunction with optoelectronic devices in order to transmit information via modulated light.

EXERCISE 11

Complete the sentences.

1. Optoelectronic devices operate on _____.
2. Photoresistors are also known as _____.
3. Photoresistors detect _____ activate or deactivate _____.
4. Photoresistors are used in _____.
5. A photodiode involves _____.
6. Photodiodes are applied in _____.
7. A photovoltaic cell generates _____.
8. Phototransistors are light-sensitive transistors and are _____.
9. Emitting a beam of infrared light, infrared (IR) diodes are used in _____.
10. Light-emitting diodes (LEDs) emit _____.
11. Laser diodes are used in _____.
12. Optical fiber transmits _____.

EXERCISE 12

Translate the sentences paying attention to the words in italics.

1. Nowadays the most commonly-used optical transmitters *are* semiconductor devices such as light-emitting diodes (LEDs) and laser diodes.
2. The difference between LEDs and laser diodes *is* that LEDs *produce* incoherent light while laser diodes *produce* coherent light.
3. Engineers always look at current limitations *in order to* improve fiberoptic communication.
4. Internet protocol data traffic *was increasing* exponentially, at a faster rate than integrated circuit complexity *had increased* under Moore's Law.
5. After a period of research starting from 1975, the first commercial fiber-optic communications system *was developed*.
6. The information transmitted *is* typically digital information generated by computers, telephone systems, and cable television companies.
7. German-born American physicist Albert Einstein's equation E=mc2 *predicted* that energy *could be converted* to matter.
8. Recent advances in fiber and optical communication technology *have reduced* signal degradation so far that regeneration of the optical signal *is* only *needed* over distances of hundreds of kilometers.
9. The main characteristics *to be refined* have always been the resolution and the elimination of aberrations.
10. Phototransistors are duo diodes *having* two junctions in the same device *separated* by a wide base region, thus *forming* an n-p-n junction.

EXERCISE 13

Translate the sentences paying attention to the Absolute Participial Construction.

1. The working day being over, the public transport was overcrowded.
2. All the problems having being solved, they stopped discussion.
3. The experiments having been made, everyone is interested in the results.
4. Our lab being equipped with different new instruments, the students can do their practical workd there.
5. Radioactivity having been discovered, scientists made great progress in atomic physics.
6. The Curies discovered radioactive elements radium and polonium, the latter being named after M. Curie's native country Poland.
7. An electron leaving the surface, the metal becomes positively charged.
8. The cathode heated, the electrons leave the surface and move to the anode.
9. The cell being charged, a certain quantity of electricity is passed through it.

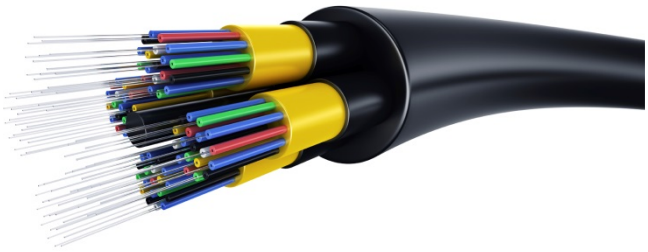
10. The scanning electron microscope employs either two, three or four electronoptical lenses, all performing the same function.
11. Atoms being held together by electromagnetic forces, their electromagnetic properties can be accurately predicted.

EXERCISE 14

Project. Prepare a presentation about one of the optoelectronic devices (a photodiode, a phototransistor, a photocell, etc.) Be sure to mention:

— Its general look;
— Its principle of work;
— Its sphere of usage.

UNIT 7
OPTICAL FIBER AND OPTICAL FIBER TRANSMISSION



EXERCISE 1
Choose the proper English equivalents to the Ukrainian words.

Випромінення – radiate, radiation, radiative, radiated;
проводити – conductive, conduct, conductance;
приймач – receive, receiver, receiving;
забезпечувати – provide, provider, providing;
початковий – original, origin, originally;
передача – transmitter, transmit, transmitting, transmission;
підсилення – amplification, amplify, amplifier, amplified;
вимірювання – measure, measurement, measuring;
потужний – power, powered, powerless, powerful;
штучний – art, artificial, artificially;
випромінювати – emit, emission, emitter, emitted.

EXERCISE 2
Arrange the following verbs into pairs of synonyms.

1) to operate	a) to allow
2) to change	b) to bend
3) to invent	c) to influence
4) to curve	d) to alter
5) to effect	e) to enlarge
6) to permit	f) to devise
7) to widen	g) to work

EXERCISE 3
Arrange the following nouns into pairs of synonyms.

1) viewer	a) enlargement
2) aid	b) mechanism
3) increase	c) incident
4) fall	d) observer
5) amount	e) help
6) source	f) quantity
7) device	g) origin

EXERCISE 4

Match the words with their Ukrainian equivalents and learn them.

1. fiber-optic cable	a) оболонка
2. core	b) повне внутрішнє відбиття
3. cladding	c) оптоволоконний кабель
4. total internal reflection	d) багатомодовий
5. single-mode	e) волога
6. multi-mode	f) оточувати
7. to surround	g) серцевина
8. to protect	h) передавати
9. moisture	i) напруження
10. to damage	j) захищати
11. communication	k) пошкодження
12. application	l) зв'язок
13. to transmit	m) одномодовий
14. pure	n) застосування
15. quantity	o) кількість
16. pressure	p) чистий
17. strain	q) тиск
18. to measure	r) вимірювати
19. intrusion detection security system	s) обладнання
	t) пропускна здатність
20. equipment	u) дані
21. bandwidth	v) завади
22. data	w) вразливий
23. susceptible	x) система виявлення вторгнень
24. interference	
25. fragile	y) крихкий

EXERCISE 5

Read the collocations and translate them paying attention to Participle II as an attribute.

A described mechanism, a broken heart, a written confirmation, focused beams, the money got yesterday, the books read by him last week, the questions discussed at the meeting, a list of the goods sold yesterday, a powerful short pulse beam of light produced by a laser, single-mode fibers wrapped together into a huge bundle, a very fast laser-activated switches, trained personnel, curved glass lenses, stimulated emission techniques.

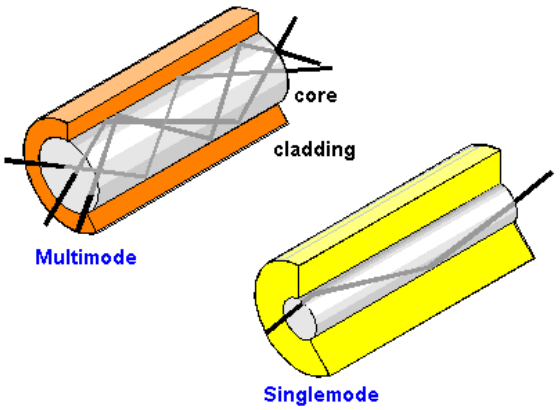
EXERCISE 6

Read and translate the text, match the questions (A-F) to the paragraphs (1-6).

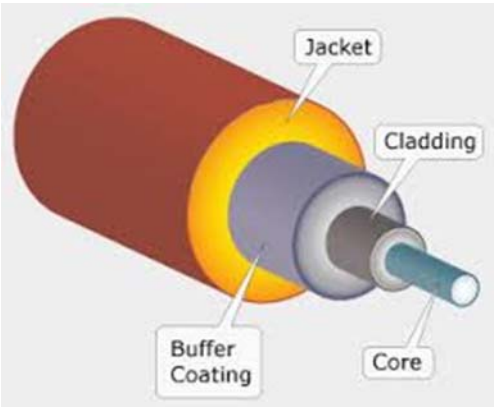
A. What is fiber optics?

B. What parts does a single optical fiber consist of?
C. How does fiber optics work?
D. What are the types of optical fibers?
E. What advantages and disadvantages does an optical fiber have?
F. Where are optical fibers used?

1. The light in a fiber-optic cable travels through the core by constantly bouncing from the cladding (mirror-lined walls). This is called total internal reflection. Because the cladding does not absorb any light from the core, the light wave can travel great distances.
2. Optical fibers carry light signals down them in what are called modes. A mode is simply the path that a light beam follows down the fiber. The simplest type of optical fiber is called single-mode. It has a very thin core about 5-10 microns in diameter. In a single-mode fiber, all signals travel straight down the middle without bouncing off the edges. Cable TV, Internet, and telephone signals are generally carried by single-mode fibers, wrapped together into a huge bundle. Cables like this can send information over 100 km. Another type of fiber-optic cable is called multi-mode. Each optical fiber in a multi-mode cable is about 10 times bigger than one in a single-mode cable. This means light beams can travel through the core by following a variety of different paths – in other words, in different multiple modes. Multi-mode cables can send information only over relatively short distances and are mainly used for data transmission. Computer networks are usually linked together with them.



3. The main part of the cable is called the core. It is a thin glass center of the fiber where the light travels. The optic core is the light carrying element at the center of the optical fiber. It is commonly made from a combination of silica and germanium. The core is surrounded with the cladding. The cladding's job is to keep the light signals inside the core. It reflects the light back into the core. It can do this because it is made of a different type of glass than the core and it has a lower refractive index. It is found that even when the cladding has a slightly higher refractive index, the light passing down the core undergoes total



internal reflection, and it is thereby contained within the core of the optical fibre. Hundreds or thousands of these optical fibers are arranged in bundles in optical cables. The bundles are protected by the cable's outer covering. A buffer material shields the core and cladding from damage. A strength material surrounds the buffer, preventing stretch problems when the fiber cable is being pulled. The outer jacket made of plastic is added to protect the fiber from damage and moisture.

4. Optical fibers have many applications. They are used for transmitting telephone signals, Internet communication, and cable television signals. Optical fibers can be used as sensors to measure strain, temperature, pressure and other quantities. Common use for fiber optic sensors includes intrusion detection security systems. They have found a broad application in medical and military equipment. They can also be used for illumination.
5. Fiber optics has several advantages over traditional metal communications lines:
   — Fiber optic cables have a much greater bandwidth than metal cables. This means that they can carry more data.
   — Fiber optic cables are less susceptible to interference than metal cables.
   — It has low levels of signal attenuation.
   — Fiber optic cables are much thinner, lighter and more flexible than metal wires.
   — Data can be transmitted in a digital form (the natural form for computer data) rather than in analogue.
6. The main disadvantage of fiber optics is that the cables are expensive to install. In addition, they are more fragile than wire and are difficult to space.

(Based on *http://www.explainthatstuff.com/fiberoptics.html*)

EXERCISE 7
Reread the text and answer the questions in writing.

1. What is optical fiber?
2. What is optical fiber used for?
3. How does the optical fiber look like?
4. What is the structure of an optical fiber?
5. What are the functions of a core and a cladding?
6. Why can the light wave travel great distances within the fiber?
7. What is a mode?
8. What is the difference between a single-mode fiber and a multi-mode fiber?
9. Describe the sphere of application of a single-mode fiber and a multi-mode fiber.
10. Where is optical fiber applied?

11. What are advantages of optical fiber over traditional metal communications lines?
12. What are the drawbacks of optical fiber?

EXERCISE 8

Read and translate the sentences, choose the appropriate tense form.

1. It is apparent that fiber optics steadily *is replacing* / *replace* copper wire as an appropriate means of communication signal transmission.
2. He said that fiber optics *is using / uses* light pulses to transmit information.
3. The students were told that today more than 80 percent of the world's long-distance traffic *is carried* / *was carried* over optical fiber cables.
4. The Danish astronomer Olaf Roemer calculated that the light *is travelling / travels* a distance equal to the diameter of the Earth's orbit around the Sun for about 22 minutes.
5. The use of fiber optics in telecommunications and wide area networking *is / has been* common for many years.
6. Fiber's ability to carry the light signal, with very low losses, *is based* / *bases* on some fundamental physics associated with the refraction and reflection of light.
7. Optical fibers *are manufactured / manufactured* in three main types: multi-mode step-index, multi-mode graded-index, and single-mode.
8. Single-mode fibers *offer / are offered* much lower attenuation than multi-mode fibers.
9. Optical fibers *exhibit / are exhibited* some attenuation due to absorption and scattering.
10. Optical fibers *allow* / *are allowing* data signals to propagate through them by ensuring that the light signal enters the fiber at an angle greater than the critical angle of the interface between two types of glass.

EXERCISE 9

Read and translate the text, write out and memorise the underlined terms.

Facts about Fiber

Optical fiber is central to the successful operation of a wide variety of high-speed communications applications, from local area networks (LANs) to metropolitan area networks. Each of these applications has unique technical requirements, for which a specific optical fiber has been developed to provide optimized performance and high value.

Every optical fiber has the same two basic elements: a core and a cladding. The core is the inner, **light-guiding section**; the cladding surrounds the core. Because the refractive index of the core is higher than that of the cladding, the **index mismatch** causes **total internal reflection** at the **interface** – light that

enters the core at an angle reflects off the core/cladding boundary and propagates down the length of the fiber. Over distance, the signal experiences some **attenuation**. Nevertheless, all optical fibers combine **low signal loss** with very high bandwidth and are lightweight, small, have high **tensile strength**, and are **immune** from electromagnetic interference.

Modes in multiples

There are two main designs for communication-type optical fiber: multimode fiber and singlemode fiber. Each is the size of a human hair, with identical **outer** diameters of 125 µm. The important difference is in the size of each fiber's core. The core of singlemode fiber is 7 to 10 µm in diameter, while the core diameter of a multimode fiber is much larger, generally 50 µm or 62.5 µm. Core size is critical to how a fiber transmits data.

Light propagates down the fiber core in a stable path known as a mode. Multimode fiber supports hundreds of modes in the core, each of which is a different length. If we **launch** a single **pulse** of light into a fiber, the light will **excite** multiple modes, entering at various angles to bounce off the **core/cladding interface**. In other words, the light in each mode will travel a different distance depending on the modal path, so the light in some modes will arrive at the far end of the fiber later than others. The pulse will be spread out in time, a phenomenon known as **modal dispersion**.

{ PRIVATE "TYPE=PICT;ALT=Figure 1" } Multimode fiber can be optimized to reduce modal dispersion using a **graded refractive index** profile in which the refractive index of the core glass decreases slowly as a function of the radial distance from the center of the fiber. The lower the index of refraction, the faster light travels; therefore, light travels slower at the center and faster toward the core-clad interface. If this graded index profile were perfect, all modes would arrive at the receiver simultaneously. In practice, modal dispersion can be minimized but not **eliminated**, and it is the principal **bandwidth-limiting factor** in multimode fiber.

Nevertheless, with more than sufficient bandwidth for current and future applications, multimode fiber is ideal for the LAN environment. Moreover, its large core enables the use of inexpensive light sources such as **light-emitting diodes** or **vertical-cavity surface-emitting lasers** (VCSELs). These sources, combined with new laser-optimized multimode fibers, provide the means to cost-effectively transmit data at high speeds over distances required by LANs.

Staying single

In singlemode fiber, the core is so narrow that it only supports one mode, eliminating modal dispersion effects. Singlemode fiber works very well for long-distance communication because it can **transmit signals** quite far before signal strength **diminishes** to the point at which **amplification** is required. In telephony applications, for example, amplifiers typically are placed at intervals of 80 km or more.

The primary **bandwidth-limiting effect** for singlemode fiber is **chromatic dispersion**, the spectral spreading of an optical pulse. Light at shorter wavelengths travels down a fiber more rapidly than light at longer wavelengths. Because all laser sources have some finite spectral bandwidth, an optical pulse spreads as it propagates down the fiber, undergoing chromatic dispersion.

EXERCISE 10
Read the sentences, translate the terms given in Ukrainian.

1. *Оптоволокно* is central to the successful operation of a wide variety of highspeed communications systems.
2. Every *оптоволокно* has the same two basic elements: a *серцевину* and a *оболонку*.
3. Over distance the signal experiences some *затухання*.
4. All *оптоволокна* combine low *втрату сигналу* with very high *пропусконою здатністю.*
5. All *оптоволокна* are lightweight, small, have high *межу міцності на розрив,* and are *невразливі* from electromagnetic interference.
6. *Розмір серцевини* is critical to how a *волокно передає дані*.
7. *Світло поширюється* down the *серцевина волокна* in a stable path known as a mode.
8. If we *запустимо* a single *пучок світла* into a *волокно*, the *світло* will *збудить* multiple modes entering at various angles to bounce off the core/cladding *межа*.
9. If multiple *пучки запустити* into the *волокно* and they all suffer *модова дисперсія*.
10. The lower the *коефіцієнт заломлення*, the faster *світло* travels.
11. If the *градієнтний показник заломлення* were perfect, all modes would arrive at the *отримувач* simultaneously.
12. In practice, *модова дисперсія* can be minimized but not eliminated, and it is the principal *фактор, що обмежує пропускну здатність* in multimode fiber.
13. *Багатомодове волокно* is ideal for the *систем локального зв'язку*.

EXERCISE 11
Read and translate the sentences, pay attention to the Passive Voice.

1. Optical fibers can be either glass or plastic tubing capable of transmitting light, which is then converted into sound, speech or information.
2. The glass core of optical fiber is made of silica and is purified to minimise the loss of signal.
3. Light can be transmitted over long distances by being reflected inward thousands of times with no loss.
4. Optical fibers are used in some medical instruments to transmit images of the inside of the human body.

5. Fibers have also been developed to carry high-power laser beams for cutting and drilling.
6. Optical fiber was technologically advanced in 1970 by Corning Glass Works, with attenuation low enough for communication purposes (about 20dB/km), and at the same time GaAs semiconductor lasers were developed that were compact and therefore suitable for transmitting light through fiber optic cables for long distances.
7. Long-range communication systems are being successfully used worldwide nowadays.
8. Particular attention had been paid to the means of improving the properties of semiconductors.
9. The transmitter section of the telephone is equipped with a special microphone and an amplifier to enlarge the voice of the speaker.
10. Electric signals are amplified with the help of a semiconductor device.
11. The student was asked if pure germamiune could be employed as a semiconductor material.
12. When light is introduced into the end of an optical fiber, any ray of light that hits the end of the fiber at an angle greater than the critical angle will propagate through the fiber.

EXERCISE 12
Choose the correct form of the verb.

1. The new department of laser and optical engineering just _____.
    A. has opened
    B. has been opened
    C. opened
2. Wavelengths of visible light _____ in meters or in nanometers (nm), which are one-billionth of a meter.
    A. can measure
    B. can be measured
    C. be measured
3. The distance light travels in one second _____ since 1983.
    A. having known
    B. have known
    C. has been known
4. Accurate measurements of the speed of light _____ by scientists because they were looking for the medium that light traveled in.
    A. were made
    B. is made
    C. to be made
5. An ammeter _____ to the circuit in series.
    A. should be connected
    B. should connect
    C. should be connecting

6. Fabrication of photodiodes _____ of at the last lecture.
    A. is spoken
    B. was spoken
    C. spoke

EXERCISE 13
Fill in the gaps with the following prepositions.

in	for	of	by	on	with	without

1. _____1880 Alexander Graham Bell and his assistant Charles Sumner Tainter created a very early precursor to fiber-optic communications, the Photophone, at Bell's newly established Volta Laboratory _____ Washington, D.C.
2. Since 2000, the prices _____ fiber-optic communications have dropped considerably.
3. Fiber-optic communication is a method _____ transmitting information from one place to another _____ sending pulses of light through an optical fiber.
4. The device allowed for the transmission of sound _____ a beam of light.
5. The Photophone's first practical use came _____ military communication systems many decades later.
6. Fiber Optics is a branch of optics dealing _____ the transmission of light through hair-thin, transparent fibers.
7. A basic fiber-optic system consists _____ a transmitting device which generates the light signal, an optical-fiber cable which carries the light, and a receiver which accepts the transmitted light signal and converts it to an electrical signal.
8. Newly developed optical fiber amplifiers, for example, can directly amplify optical signals _____ first converting them to an electrical signal, speeding up transmission and lowering power.

EXERCISE 14
Listen to the audio / watch the video (by Mocomi Kids on *https://www.youtube.com/watch?v=o5t6evogJbg* and answer the questions in writing.

1. What is the speed of light?
2. Has fiber optic technology reduced or increased the time in which information can be sent and received?
3. What are the properties of optical fibers?
4. Why are strands of optical fibers arranged in bundles?
5. How many parts is a fiber-optic cable made of?
6. Name the parts of a fiber-optic cable.

7. What is a special property fiber optic cables exhibit?
8. What device id responsible for converting an electrical digital signal into a light signal?
9. What is the function of the optical re-generator?
10. What device decodes a signal into a binary digital format?
11. Where are optical fibers used?

EXERCISE 15

Project. Prepare a report about fiber-optic cables. Be sure to mention:

— their construction;

— principal of their work;

— field of their application.

UNIT 8
OPTOELECTRONIC COMMUNICATION SYSTEMS

EXERCISE 1

Read and translate the words and word-combinations, pay attention to the word-building components.

1. Transmit, transmitted, transmitting, transmission, transmissible, transmitter.
2. Organize, organization, organizer, organizing, organizational, organized.
3. Improve, improving, improvement, improved.
4. Complete, completed, completely, completing, completion, completeness, incomplete.
5. Pure, purification, purify, impure, impurity, purifiers.
6. Reread, rewrite, redo, remake, reorient, reorganise, remove, reconvert, regenerate.
7. Post-graduate, post-war, post-impressionism, postscript, postindustrial, postdate.
8. Prepay, pretest, preview, preapprove, pre-war, pre-establish, pre-determine.

EXERCISE 2

Arrange the following collocations into pairs of synonyms.

1. in the same manner	a) thanks to
2. in addition to	b) it's important
3. in terms of	c) besides
4. owing to	d) is substituted
5. it's worth	e) similarly
6. is completely replaced	f) from a viewpoint
7. in a variety of	g) despite
8. moreover	h) although
9. though	i) furthermore
10. in spite of	j) in a great number

EXERCISE 3

Choose the right conjunction.

1. We enjoyed the meal *because of / although / so that* the wonderful cooking.
2. I'm going to have a dessert *although / so that / in spite of* being on a diet.
3. Keep an eye on the sauce *because of / though / so that* it doesn't burn.
4. I'm really hungry *because / though / so that* I had a big breakfast.
5. I never eat vegetables *because of / even though / for* I know they're healthy.
6. It was an excellent meal *despite / even though / so that* the unfriendly waiters.
7. We were put in a room overlooking the main road, *so / although / yet* we had asked for a room at the back of the hotel.
8. There was a long queue for taxis. *Because / However / Also*, we didn't have to wait very long to get one.
9. We were disappointed because the art gallery was closed and the museum *as well / also / although.*
10. Apart from the cathedral, I could *also / as well / too* see the river from my hotel room.
11. There are very few hotels. However / Though / Besides, we were lucky and we found a room.

EXERCISE 4

Match Ukrainian words and word combinations with their English equivalents.

1. coaxial cable	a) дріт
2. wire	b) поверхня
3. critical value	c) приймач
4. data rate	d) критичне занчення
5. duct	e) швидкість передавання данних
6. surface	f) канал
7. intercom	g) коаксіальний кабель
8. receiver	h) лінія електропередачі
9. transmitter	i) пропускна здатність
10. transmission medium	j) іскра
11. power line	k) цифровий
12. spark	l) перевищувати
13. total internal reflection	m)обробляти
14. digital	n) повне внутрішнє відбиття
15. bandwidth	o) перетворювати
16. to process	p) початковий
17. to tunnel	q) передавач
18. to exceed	r) захищати

19. to shield	s) домофон
20. to prevent	t) прокладати
21. to convert	u) хвилевід
22. waveguide	v) завада, перешкода
23. interference	w)запобігати
24. original	x) середовище передавання

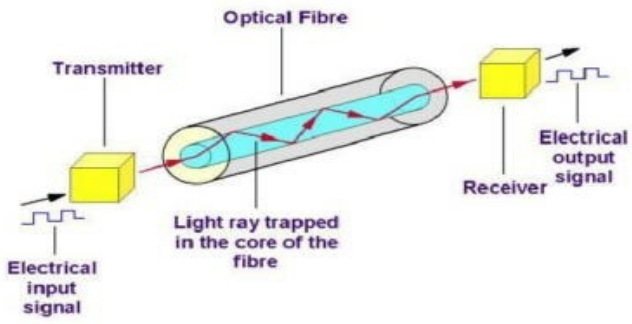
EXERCISE 5
Translate the word-combinations into Ukrainian.

Buffer material, carrier of information, communication signal transmission, travel via optical fiber, extremely reflective surface, analog signal, digital signal, digital encryption, serial data transmission, transmission medium, light pulse, optic chain, coded light pulses, to exceed critical value, pure silica, refractive index, to tunnel into the fiber-optic medium, the angle of incidence, to shield from damage, to reach the destination, to convert to an electrical signal, low-loss glass fiber optic cable.

EXERCISE 6
Read and translate the text. Find answers to the following questions.

1. Where are fiber optic systems used?
2. What is the difference between fiber optic system and copper wire system?
3. What are the three main components of a fiber optic system?
4. How does a fiber optic system work?
5. What is the purpose of an optical transmitter and how does it work?
6. What makes possible the transmission of information down fiber lines?
7. What is the purpose of an optical receiver and how does it work?
8. Why should photonic signal be regenerated periodically?

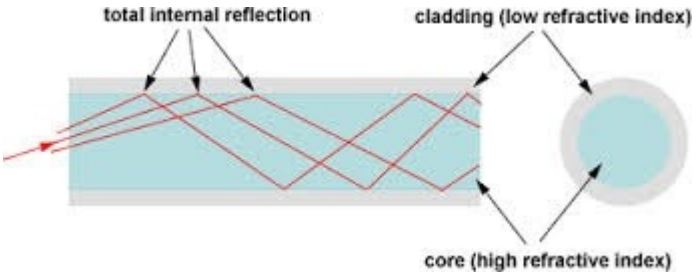
Fiber Optic Systems



Light has always been considered an excellent carrier of information. In recent years it has become apparent that fiber optics are steadily replacing copper wire for communication signal transmission. Fiber optic systems are currently used very extensively. Virtually any type of signal can travel via optical fiber. For example: analog video and audio, digital signal, digital encryption, serial and parallel data transmission, intercom, etc. The fiber has an almost unlimited bandwidth.

A fiber-optic system generally consists of three main components: a transmitter, a transmission medium (an optical fiber) and a receiver. Its principal of work is similar to the copper wire system that fiber optics is replacing. The difference is that fiber optics uses light pulses to transmit information down fiber lines instead of using electronic pulses to transmit information down copper lines. Looking at the three main components in the fiber optic chain will give a better understanding of how the system works.

At the head end of the chain is a transmitter. The transmitter is the light source. A light-emitting diode (LED) or an injection-laser diode (ILD) can be used for generating the light pulses. The transmitter converts the electrical analog or digital signal into a corresponding optical signal. Using a lens, the light pulses are tunneled into the fiber-optic medium. The fiber optic cable acts as a waveguide for the optical signal. The cable can be a single strand of specially manufactured glass or multiple strands bundled together. Light pulses move easily down the fiber-optic cable because of a principle known as total internal reflection. This principle of total internal reflection states that when the angle of incidence exceeds a critical value, light cannot get out of the glass; instead, the light bounces back in. Due to this principle, it is possible to transmit information down fiber lines in the form of light pulses.



Once the light pulses reach their destination they are channeled into the optical receiver. The receiver is a photodetector. Its basic purpose is to detect the received light incident on it and to convert it to an electrical signal containing the information at the transmitting end. In other words the coded light pulse information is translated back into its original state as coded electronic information. The electronic information is then ready for input into electronic communication devices such as a computer, telephone or TV.

As a photonic signal travels through a fiber optic strand, it attenuates and begins to lose its shape. If it is not regenerated periodically, the signal will not be recognizable at the receiving end. So, regenerators are added into fiber optic transmission system. These regenerators can either be optical-electrical-optical devices, usually found in terrestrial systems, or all-optical systems found in undersea lightwave systems.

EXERCISE 7

Insert the following prepositions into the sentences.

in	of	by	on	with	into

1. Light scattering depends _____ the wavelength of the light being scattered.

2. The scattering of light _____ glass fiber is caused _____ molecular level irregularities _____ the glass structure.
3. In fibers, the cladding is usually coated _____ a tough resin buffer layer, which may be further surrounded _____ a jacket layer, usually glass.
4. The main component _____ an optical receiver is a photo detector, which converts light _____ electricity using the photoelectric effect.

EXERCISE 8

Read and translate the sentences. Choose the correct degree of comparison.

1. In vibrational excitation the atoms of the molecule vibrate in relation to each other. This kind of excitation requires *(less, the least)* energy than electronic excitation.
2. It must be remembered that the normal eye is far *(more, the most)* sensitive to the visible spectrum than *(more, the most)* delicate bolometers.
3. A bolometer is a *(highly, more highly)* sensitive instrument used for detecting heat or electromagnetic radiation.
4. Although optical fibers are hair-thin, they have the capacity for *(greater, the greatest)* bandwidth than traditional cables.
5. Fiber optic cables require *(the least, less)* insulation and jacketing than copper cable.
6. In general, fiber optic cable is *(more, the most)* expensive than copper cable due to its high performance and capacity.
7. The optical fibre is more efficient than coax cable as it has *(higher, the highest)* noise immunity.
8. Coaxial cable can be *(easily, more easily)* installed whereas installation of optical cable requires extra effort and care.
9. The optical fibre is lightweight and has a small diameter while a coaxial cable is *(heavier, the heaviest)* and has a large diameter.

EXERCISE 9

Read and translate the text, choose the correct form of the verb.

In 1880 Alexander Graham Bell and Sumner Tainter _____ *(invented / was invented)* the 'Photophone' at the Volta Laboratory in Washington, D.C., to transmit voice signals over an optical beam. It _____ *(was / were)* an advanced form of telecommunications, but _____ *(was subject / was subjected)* to atmospheric interferences and impractical until the secure transport of light that would be offered by fiber-optical systems.

In the late 19th and early 20th centuries, light _____ *(guided / was guided)* through bent glass rods to illuminate body cavities. Jun-ichi Nishizawa, a Japanese scientist at Tohoku University also _____ *(proposed / was*

proposed) the use of optical fibers for communications in 1963. He _____ *(stated / was stated)* these ideas in his book published in 2004 in India. Nishizawa _____ *(invented / was invented)* other technologies that _____ *(contributed / were contributed)* to the development of optical fiber communications, such as the graded-index optical fiber as a channel for transmitting light from semiconductor lasers.

Charles K. Kao and George A. Hockham of the British company Standard Telephones and Cables (STC) _____ *(was / were)* the first to promote the idea that the attenuation in optical fibers could be reduced below 20 decibels per kilometer (dB/km), making fibers a practical communication medium. They _____ *(proposed / were proposed)* that the attenuation in fibers available at the time _____ *(caused / was caused)* by impurities that could be removed, rather than by fundamental physical effects such as scattering. They correctly and systematically _____ *(theorized / were theorized)* the light-loss properties for optical fiber, and _____ *(pointed out / were pointed out)* the right material to use for such fibers – silica glass with high purity. This discovery _____ *(earned / was earned)* Kao the Nobel Prize in Physics in 2009.

EXERCISE 10

Put the verbs in brackets in the required tense form and translate the sentences into Ukrainian.

1. Light waves from the Sun _____ *(to produce)* a very large number of photons.
2. Scientists _____ (to learn) through experimentation that light _____ *(to behave)* like a particle at times and like a wave at other times.
3. In the late 1990s through 2000 research companies such as KMI and RHK _____ *(to predict)* massive increases in demand for communications bandwidth due to increased use of the Internet.
4. Since 1990 optical-amplification systems _____ *(to become)* commercially available, the telecommunication industry _____ *(to lay)* a vast network of intercity and transoceanic fiber communication lines.
5. In 1900 the German physicist Max Planck _____ *(to discover)* that light energy _____ *(to carry)* by photons.
6. Modern fiber-optic communication systems generally _____ *(to include)* several components, each _____ *(to perform)* some certain functions. An optical transmitter _____ *(to convert)* an electrical signal into an optical signal to send into the optical fiber. A cable containing bundles of multiple optical fibers _____ *(to route)* through underground conduits and buildings. Multiple kinds of amplifiers and an optical receiver _____ *(to recover)* the signal as an electrical signal.

7. The main component of an optical receiver _____ *(to be)* a photodetector, which _____ *(to convert)* light into electricity using the photoelectric effect.
8. Human eyes _____ *(to respond)* best to green light at 550 nm, which _____ *(to be)* also approximately the brightest color in sunlight at Earth's surface.
9. An optical fiber _____ *(to consist)* of a core, cladding, and a buffer, in which the cladding _____ *(to guide)* the light along the core by using the method of total internal reflection.
10. First developed in the 1970s, fiber-optic communication systems _____ *(to revolutionize)* the telecommunications industry and _____ *(to play)* a major role in the advent of the Information Age since then.
11. The core and the cladding _____ usually _____ *(to make)* of high-quality silica glass, although they can both _____ *(to make)* of plastic as well.
12. Connecting two optical fibers is _____ *(to do)* by fusion splicing or mechanical splicing and requires special skills and interconnection technology.
13. For use in optical communications, semiconductor optical transmitters must _____ *(to design)* to be compact, efficient and reliable while operating in an optimal wavelength range and directly modulated at high frequencies.

EXERCISE 11
Read and translate the text.

Today's low-loss glass fiber optic cable offers almost unlimited bandwidth and unique advantages over all previously developed transmission media. The basic point-to-point fiber optic transmission system consists of three basic elements: the optical transmitter, the fiber optic cable and the optical receiver.

The optical transmitter converts an electrical analog or digital signal into an optical signal. The source of the optical signal can be either a light emitting diode, or a solid-state laser diode. The most popular wavelengths for optical transmitters are 850, 1300, or 1550 nanometers.

The fiber optic cable consists of one or more glass fibers, which act as waveguides for the optical signal. Fiber optic cable is similar to electrical cable in its construction, but provides special protection for the optical fiber within. For systems requiring transmission over distances of many kilometers, or where two or more fiber optic cables must be joined together, an optical splice is commonly used.

The optical receiver converts the optical signal back into electrical signal. Fiber optic transmission systems – a fiber optic transmitter and receiver, connected by fiber optic cable – offer a wide range of benefits not offered by traditional copper wire or coaxial cable. These include:

— The ability to carry much more information and deliver it with greater fidelity than either copper wire or coaxial cable.
— Fiber optic cable can support much higher data rates, and at greater distances, than coaxial cable, making it ideal for transmission of digital data.
— The fiber is totally immune to virtually all kinds of interference.
— As the basic fiber is made of glass, it will not corrode and is unaffected by most chemicals.
— Since the only carrier in the fiber is light, there is no possibility of a spark from a broken fiber. So, there is no fire hazard, and no danger of electrical shock to personnel repairing broken fibers.
— Fiber optic cables are virtually unaffected by outdoor atmospheric conditions, allowing them to be lashed directly to telephone poles or existing electrical cables.
— A fiber optic cable, even one that contains many fibers, is usually much smaller and lighter in weight than a wire or coaxial cable with similar information carrying capacity. It is easier to handle and install, and uses less duct space.
— Fiber optic cable is ideal for secure communications systems because it is very difficult to damage but very easy to monitor. In addition, there is absolutely no electrical radiation from a fiber.

EXERCISE 12
Answer the following questions.

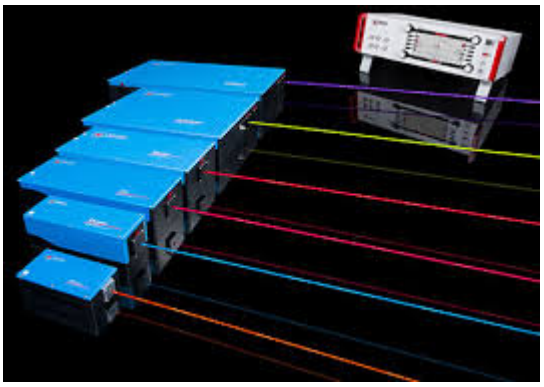
1. What components does the basic point-to-point optic transmission system consist of?
2. What function has an optical transmitter?
3. What kinds of cables are used in fiber optics?
4. What is a fiber optic system?
5. What are the advantages of fiber optic systems?

EXERCISE 13
Translate the sentences into English.

1. Оптоволокно складається з серцевини, оболонки та кожуха (жакета).
2. Коефіцієнт заломлення оболонки нижчий, ніж коефіцієнт заломлення серцевини.
3. Оптоволоконна система передавання інформації складається з трьох основних компонентів: передавача, оптоволокна та приймача.
4. Передавач приймає закодований електричний сигнал і перетворює його в імпульси світла.
5. Світлодіод або лазерний діод використовується для створення імпульсів світла.

6. Основна функція оптичного приймача – перетворити світловий сигнал в електричний сигнал.
7. Оптоволоконний кабель має величезну пропускну здатність.
8. Оптоволоконний кабель складається з оптичних волокон, які виконують функцію хвилевода.
9. Оптоволоконний кабель може передати більше інформації, ніж мідний дріт чи коаксіальний кабель.
10. Сигнал, переданий через оптоволоконний кабель, має низький рівень загасання.

UNIT 9
LASERS



EXERCISE 1

Read and translate the words and word-combinations, pay attention to the word-building components.

1. Application, apply, misapply, applying, appliance, applicable.
2. Transform, transformer, transforming, transformed, transformation.
3. Improve, improving, improved, improvements.
4. Add, added, adding, addition, additional.
5. Connect, connecting, connector, connection, connected, interconnection.
6. Measure, measurement, measuring, measured, measurable, immeasurable.
7. Amplify, amplified, amplifying, amplifier, amplification.
8. Determine, determined, determining, determination.
9. Strength, strengthing, strengthened, strong.
10. Radiate, radiating, radiated, radiator, radiation.
11. Emit, emitting, emitting, emitter, emission.
12. Absorb, absorbing, absorbed, absorber, absorband, absorbtion.

EXERCISE 2

Arrange the following nouns into pairs of synonyms.

1) application	a) combustion
2) burning	b) resonator
3) burst	c) flash
4) cavity	d) production
5) junction	e) interface
6) mirror	f) use
7) purity	g) pureness
8) generation	h) reflector

EXERCISE3

Read the given collocations and find their Ukrainian equivalents.

a) to make use of microwave amplifier, to study molecular structure of a material, to make the process more easy, to determine quantitative characteristics, to construct an operable laser, to select the relevant optical frequency, to determine a distance by means of a radar, to propose a new concept, to use molecular beams in microwave spectroscopy, high frequency coherent radiation;

b) обрати потрібну оптичну частоту, визначити кількісні характеристики, використовувати молекулярний пучок в мікрохвильовій спектроскопії, створити лазер готовий до роботи, використати мікрохвильові підсилювачі, запропонувати нову концепцію, високочастотне когерентне випромінення, вивчати молекулярну структуру матеріалу, зробити процес більш легким, визначити відстань за допомогою радару.

EXERCISE 4

Match the words with their Ukrainian equivalents and learn them.

1. amplification	a) збуджений
2. light bulb	b) лазерне середовище
3. artificial	c) підсилення
4. laser medium	d) розповсюдження, поширення
5. pump source	e) лампочка
6. excited	f) рідкий
7. population inversion	g) джерело накачки
8. propagation	h) твердий
9. solid	i) випромінення
10. liquid	j) штучний
11. solidstate	k) оптичний резонатор
12. partially	l) частково
13. optical cavity	m) фарба, фарбник
14. semiconductor	n) вивільняти, випускати
15. dye	o) напівпровідник
16. to occur	p) лазер на склі з домішками неодиму
17. frequency	q) частота
18. radiation	r) діодний напівпровідниковий лазер
19. narrow	s) посилатися на, стосуватися
20. to refer	t) відбуватися, траплятися
21. to release	u) вузький
22. semiconductor junction laser	v) твердотілий w) безперервна хвиля
23. continuous wave	x) інверсія заселеності (енергетичних рівнів)
24. neodymium-doped glass laser	

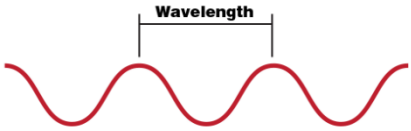
EXERCISE 5

Read and translate the text. Find the answers to the following questions.

1. What is the meaning of the word LASER?
2. Does laser light exist in nature?
3. What is the wavelength?
4. What kind of light does laser produce?
5. Why does laser produce narrow light beams?
6. How is laser applied in engineering?
7. How do doctors apply lasers?
8. What is a spectrometer and what it is used for?
9. Why have lasers found a great application in the sphere of communication?
10. How are lasers applied in space?

What is a LASER?

The letters in the word LASER stand for Light Amplification by Stimulated Emission of Radiation. Lasers are devices that amplify light and produce beams of light which are very intensive, directional and pure in colour. A laser is an unusual light source. It is quite different from a light bulb or a flash light.



Light travels in waves, and the distance between the peaks of a wave is called the wavelength. Each color of light has a different wavelength. For example, blue light has a shorter wavelength than red light. Sunlight as well as the typical light from a lightbulb is made up of light with many different wavelengths. Our eyes see this mixture of wavelengths as white light. But a laser is different, it does not occur in nature. It has been created artificially. Lasers produce a narrow monochromatic beam of light. It contains one specific wavelength of light (one specific color). The laser's light waves travel together with their peaks all lined up, or in phase. The light released is coherent. This is why laser beams are very narrow, very bright, and can be focused into a very tiny spot.

The laser light is very directional. It stays focused and does not spread out much (like a flashlight would). That is why laser beams can travel very long distances without losing signal strength. They are ideal for communications in space. Laser light can carry much information because of its high frequency.

EXERCISE 6

Reread the text and write down the adjectives that describe the main properties of the laser light. Build your own sentences according to the example.

Laser light is intense. Laser light is .....

EXERCISE 7
Read and translate the text about the laser development.

A Story of Invention: the Laser

The laser was the result of not one individual's efforts, but the combination of many leading optics and photonics scientists and engineers over the course of history.

The laser's history can be traced back to 1900, when Max Plank published his work on the law of radiation, which explained the relationship between energy and the frequency of radiation, essentially saying that energy could be emitted or absorbed only in discrete chunks. His theory marked a turning point in physics and inspired Albert Einstein, who in 1905 released a paper on the photoelectric effect which stated that light also delivers its energy in chunks, called photons. Taking these ideas further, in 1917 Einstein published the paper 'On the Quantum Theory of Radiation'. He described the theory of stimulated emission, establishing the principle in accordance with which lasers work. Einstein theorized that, besides absorbing and emitting light spontaneously, electrons could be stimulated to emit light of a particular wavelength. It took over 30 years for scientists to prove his theory correct.

In 1953, an American physicist Charles Townes developed a maser. The maser is an acronym for 'microwave amplification by stimulated emission of radiation'. It is a device that produces coherent electromagnetic waves through amplification by stimulated emission. Within a short time, the maser was in use as an amplifier in microwave communication systems. The maser was the forerunner of the laser. The laser works by the same principle as the maser, but produces higher frequency coherent radiation at visible wavelengths. The devices known as masers and lasers serve as amplifiers and generators of radiation. Their common characteristic is that they make use of the conversion of atomic or molecular energy to electromagnetic radiation by means of the process known as stimulated emission of radiation. When the wavelength of the emitted radiation is in the vicinity of 1 cm we speak of microwave amplifiers or masers.

In 1959 Columbia University graduate student Gordon Gould proposed that stimulated emission could be used to amplify light. He described an optical resonator that could create a narrow beam of coherent light, and called it a laser for "Light Amplification by Stimulated Emission of Radiation".

In 1960 Theodore Maiman built the first working prototype of a laser at Hughes Research Laboratories in Malibu, California. This laser used synthetic ruby as the active medium and emitted a deep red beam of light with a wavelength of 694.3 nm. The first application for the ruby laser was for military range finders and is still used commercially for drilling holes in diamond because of its high peak power. Following the invention of the ruby laser, many other materials were found that could be used as the basis of laser action. Thus different types of lasers have been developed.

Early in 1961 the first continuously operating laser was announced by Ali Javan and his coworkers at Bell Laboratories. This laser was the first to use a gas, a mixture of helium and neon, for the light emitting material. At the same years scientists from American Optical Company made the first neodymium-doped glass laser. In 1962 scientists at General Electric and International Business Machines (IBM) almost simultaneously demonstrated the first semiconductor junction laser. In 1962 Basov and Oraevskii proposed that rapid cooling could produce population inversions in molecular systems. And in 1966, the first gasdymamic laser was successfully operated at the Avco Everett Research Laboratory. The 1970s years became the time of discovery of a free electron laser.

The laser was a remarkable technical breakthrough, that found application in many spheres of industry. Alongside with the transistor and the computer the laser is often defined as a key invention of the mid-20th century.

EXERCISE 8

Match the scientific developments with their creators and the year of their creation.

1990	Albert Einstein	developed a maser
1905	Charles Townes	proposed that stimulated emission could be used to amplify light
1917	Theodore Maiman	published the law of radiation
1953	Max Plank	developed the photoelectric effect
1959	Albert Einstein	built the first working laser
1960	Gordon Gould	described the theory of stimulated emission

EXERCISE 9

Choose the correct item.

1. When the wavelength of the emitted radiation is about 1 cm we speak of _____.
   A. lasers
   B. masers
   C. magnifiers.
2. It was _____ who announced the construction and operation of a maser.
   A. Townes
   B. Schawlow
   C. Basov
3. The achievement of _____ opened the laser period.
   A. the gas laser
   B. the ruby laser
   C. the dye lasers
4. It was proposed that _____ could produce population inversion in molecular systems.

A. slow cooling
B. rapid heating
C. rapid cooling

5. The _____ years became the time of discovery of a free electron laser.

A. 1960s
B. 1970s
C. 1980s

EXERCISE 10

Listen to the audio 'How does a Laser Work' and fill in the gaps. Read and translate the text.

A laser beam is basically (1)_____ similar to light that a light bulb emits. There are three big differences. The light bulb emits several (2)_____ but the laser has only one wavelength meaning it is (3)_____. The light bulb radiates in all directions whereas the beam of the laser is directed. The laser light is (4)_____ so the wave trains are much longer than those from a light bulb. But what does laser mean?

Anyway laser is an acronym for light (5)_____ by stimulated emission of radiation. Sounds complicated at first but actually it is not. A laser consists of a laser (6)_____ for example a gas and energy source (7)_____ and two (8)_____ one of which is partially transmissive. The laser medium consists of particles that are in their basic state. The pump feeds (9)_____ into the particles and they rise to a higher energy level. If any of these particles then falls back into their basic state energy is released in the form of a photon also called light (10)_____. If this photon hits another excited particle then it's forced back into the basic state policing another photon. This is referred to as stimulated (11)_____. If these photons hit other excited particles then further photons are released and so on. A sort of photon avalanche is triggered. Energy is repeatedly (12)_____ into the laser medium stimulating the particles so that they can release more photons. The mirrors (13)_____ the photons thereby increasing the number of photons further and further. A directional (14)_____ is formed. This beam can (15)_____ the laser through the partially transmissive mirror and is directed onto the material where it engraves marks or cuts the desired motif.

EXERCISE 11

Read the given collocations and find their Ukrainian equivalents.

a) conventional light sources, gas-dynamic laser, worldwide recognition, light emitting material, free electron laser, molecular systems, arc lamp, semiconductor laser, narrow spectral regions, flash lamp, quantum electronics, monochromatic radiation, cavity dimensions, high-resolution microwave spectrometer, optical frequency range, pink ruby medium;

b) світловипромінювальний матеріал, молекулярні системи, діапазон оптичних частот, газодинамічний лазер, лазер на вільних електронах, напівпровідниковий лазер, світове визнання, монохроматичне випромінення, спектрометр з високою пропускною здатністю, дугова лампа, імпульсна лампа, лазерне активне середовище на рожевому рубіні, вузькі спектральні ділянки (випромінення), розміри резонатора, звичайні (загальноприйняті) джерела світла, квантова електроніка.

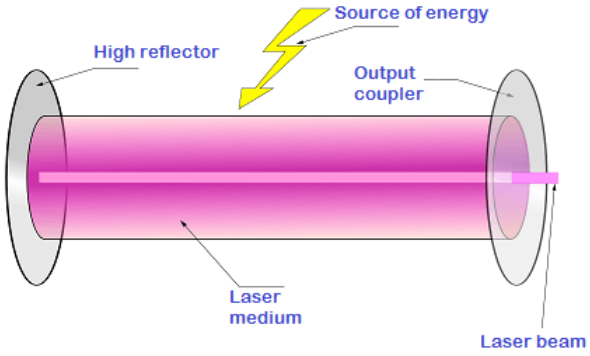
EXERCISE 12

Read and translate the text about laser construction.

Laser Construction

Every LASER consists of three basic components:

1. Lasing material (active medium);
2. Energy source (a pump source);
3. Optical resonator.



Pump Source

The pump source or energy source is the part of a laser system that provides energy to the laser medium. To get laser emission, first we need to produce population inversion. Population inversion is the process of achieving greater number of electrons in higher energy state as compared to the lower energy state.

There are different kinds of pumping system: optical (the sun, flash lamps, continuous arc lamps or tungsten-filament lamps, diode or other lasers), electrical (gas discharge tubes, electric current in semi-conductors) or chemical. The type of energy source used is mostly depends on the laser medium.

Laser Medium

The laser medium is a medium where spontaneous and stimulated emission of radiation takes place. It is here where light amplification is achieved. This medium is composed of atoms, molecules, ions or electrons whose energy levels are used to increase the power of a light wave during its propagation. The physical principle involved is called stimulated emission. The laser medium will determine the characteristics of the laser light emitted. The laser medium can be solid, liquid, or gaseous.

Optical Resonator

The laser medium is surrounded by two parallel mirrors which provide feedback of the light. One mirror is fully reflective (100 % reflective) whereas another one is partially reflective (<100 % reflective). These two mirrors form an optical resonator. The optical resonator is also known as an optical cavity or a resonating cavity.

The light generated within the laser medium will bounce back and forth between the two mirrors. It is reflected many hundreds of times between the mirrors before it escapes through the partially reflecting mirror. The light escaped from the partially reflecting mirror is produced by the stimulated emission process.

EXERCISE 13
Match laser components with their functions.

Lasing material	a) Consists of reflectors to act as the feedback mechanism for light amplification
Pump source	b) Is usually in the form of a crystal, gas, semiconductor or dye and is responsible for creation of stimulated emission of radiation
Optical cavity	c) Adds energy to the lasing material, e.g. flash lamp, electrical current to cause electron collisions, radiation from a laser, etc.

EXERCISE 14
Read and translate the sentences.

1. Recently solid state lasers have been developed using insulating crystals.
2. Scientists are successfully developing quantum generators called lasers.
3. There are no lasers today that have not been used for material processing operations.
4. Electrons collide with many ions passing through the metal.
5. Functioning as a generator the laser is used as a source of coherent light.
6. This substance has always been chosen for the purpose of using it as light-amplifying substance.
7. Energy barriers confine injected holes and electrons within the active layer.
8. The raising temperature increases the movement of the electrons.
9. The behaviour of the laser light beam has been influenced by a variety of circumstances.
10. When an atom absorbs energy, its energy level increases.

EXERCISE 15
Translate the sentences into English.

1. Лазер – пристрій для генерування або підсилення монохроматичного світла.
2. Лазер створює вузький пучок світла, що здатний поширюватися на великі відстані без розсіювання.
3. Лазерний промінь може переносити велику кількість інформації, набагато більше, ніж радіохвилі.

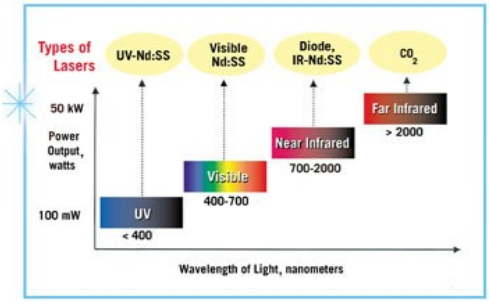
4. Лазери мають широкий спектр використання; вони використовуються для зв’язку, різання, створювання отворів, зварювання, у медичних і біологічних дослідженнях, у хірургії, а також у військовій сфері.
5. Головний елемент лазера – активне середовище, для утворення якого використовують різні методи «накачування», такі як вплив світла, електричний розряд у газах, хімічні реакції та ін.
6. Активне середовище розташоване між дзеркалами, які утворюють оптичний резонатор.
7. Усі лазери складаються з трьох основних частин: активного середовища, системи накачування та оптичного резонатора.
8. Оптичний резонатор може бути відсутнім, якщо лазер працює в режимі підсилювача.
9. Розрізняють твердотільні, газові й рідинні лазери.
10. Рубіновий лазер працює в імпульсному режимі.

EXERCISE 16

Project. Be ready to speak about lasers. Be sure to mention:

— **The brief history of its development;**
— **Its basic construction;**
— **Principle of its work;**
— **Its application.**

UNIT 10
TYPES OF LASERS AND THEIR APPLICATIONS



EXERCISE 1
Read and translate the words, state their part of speech.

1. Power, powerful, powerfully, powerless, empower, empowered.
2. General, generally, generalize, generalization, generality, general-purpose.
3. Vary, various, variously, varying, variety, variance, variable.
4. Practical, practically, practice, practitioner, practise, practised, practicable, practicability.

EXERCISE 2
Arrange the following nouns into pairs of synonyms.

1) development	a) reversal
2) emission	b) exploration
3) inversion	c) difference
4) mixture	d) achievement
5) recognition	e) radiation
6) research	f) compound
7) variety	g) acknowlegement

EXERCISE 3
Arrange the following verbs into pairs of synonyms.

1) to achieve	a) to turn into
2) to amplify	b) to incite
3) to convert	c) to increase
4) to cool	d) to attain
5) to demonstrate	e) to show
6) to stimulate	f) to freeze

EXERCISE 4
Read and translate word combinations, translate them into Ukrainian.

To retrieve information, to melt materials, delicate surgery, precise eyes operations, to drill super hard materials, to cut complex shapes, to carry TV signal, spot welding, surfacing techniques, a bar code scanner, to treat damaged tissue.

EXERCISE 5
Match the examples of laser application with the field of their usage.

Laser Applications

Communications	a) Lasers are ideal for recording and retrieving information.
Computing and IT	b) Laser beams can heat, melt, or vaporize materials in a very precise ways.
Engineering and manufacture	c) They are used to make parts for computers and other electronics.
Medicine	d) They are used for carrying TV and Internet signals.
Instrumentation	e) They can be applied in delicate surgeries such as precise eyes operations.
Arts	f) They can be used for drilling super hard materials, cutting complex shapes, for spot welding and for surfacing techniques.
	g) Laser beams can be focused on a small area.
	h) We also find them in laser printers, bar code scanners, and DVD players.
	i) Lasers can provide fantastic displays of light. Shows and concerts are often accompanied by laser displays.
	j) Lasers have also been used in instruments that map the surfaces of planets, moons, and asteroids.
	k) Laser beams can treat damaged tissue in a fraction of a second without harming healthy tissue.
	l) Lasers are used in spectrometers that analyze what things are made of.

EXERCISE 6
Read and translate chemical elements.

Aluminum, sapphire, helium, neon, nitrogen, hydrogen, neodymium, yttrium, garnet, corundum, argon, ion, carbon, carbon dioxide, carbon monoxide, cerium (Ce), erbium (Eu), terbium (Tb), ethyl alcohol, methyl alcohol, exalite, coumarin, rhodamine, pyrromethene, pyridine, fluorescein, pyridine, styryl, gallium arsenide, hydrogen fluoride, deuterium fluoride, neodymium-doped glass (Nd:glass), ytterbium-doped glass (Yb:glass).

EXERCISE 7
Read and translate some common laser types.

Helium neon (HeNe) lasers, argon ion lasers, carbon dioxide lasers (CO2 lasers), carbon monoxide lasers (CO lasers), excimer lasers, nitrogen lasers,

hydrogen lasers, chemical oxygen iodine laser (COIL), all gas-phase iodine laser (AGIL), the hydrogen fluoride (HF), deuterium fluoride (DF) lasers, neodymium-doped yttrium aluminum garnet (Nd:YAG).

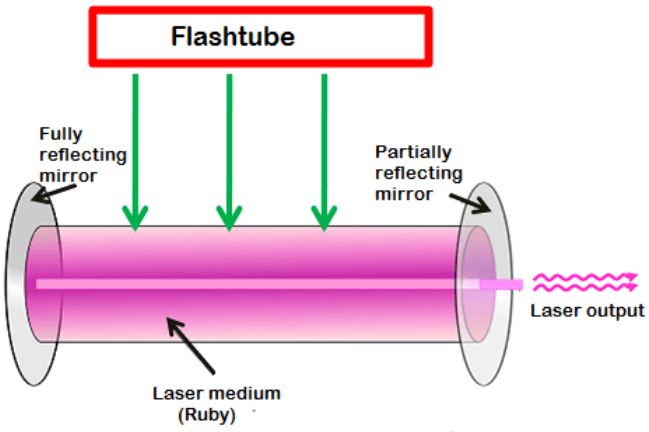
EXERCISE 8
Match the words with their Ukrainian equivalents and learn them.

1. active species	a) перехідний елемент
2. arc lamp	b) об'єднаний
3. associative	c) екзотермічна хімічна реакція
4. combustion reaction	d) імпульсна лампа
5. exothermal chemical reaction	e) рентгенівські промені
6. flash tube	f) дугова лампа
7. in a pulsed manner	g) з'єднання, перехід
8. junction	h) лампа з розрядом в парах металів
9. metal-vapour lamp	i) активні частки
10. retinal treatment	j) розчинник
11. transition element	k) в імпульсному режимі
12. tunable dye laser	l) налаштовуваний лазер на фарбнику
13. X-rays	m) рубіновий стрижень
14. doping	n) реакція згорання
15. impurity	o) лікування сітківки
16. rare earth elements	p) підсилювальне середовище
17. glass tube	q) розчиняти
18. solvent	r) рідкісноземельні елементи
19. to dissolve	s) легування
20. ruby rod	t) домішка
21. gain medium	

EXERCISE 9
Read and translate the text.

Types of Lasers

According to the laser medium used, lasers are generally classified into solid-state, gas, semiconductor, liquid, chemical lasers and others.



Solid-State Lasers

A solid-state laser is a laser that uses solid as a laser medium. In these lasers, glass or crystalline materials are used. Ions are

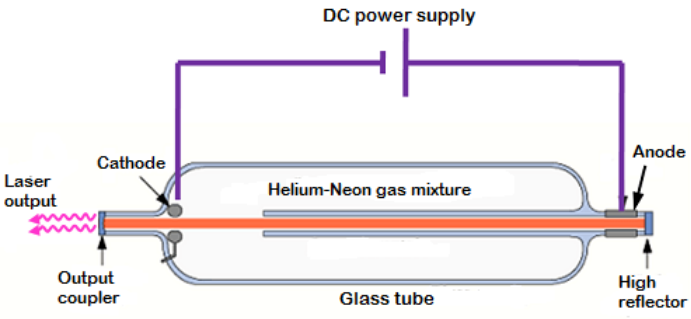
introduced as impurities into host material which can be a glass or crystalline. The process of adding impurities to the substance is called doping. Rare earth elements such as cerium (Ce), erbium (Eu), terbium (Tb), etc. are most commonly used as dopants.

Materials such as sapphire, neodymium-doped yttrium aluminum garnet (Nd:YAG), neodymium-doped glass (Nd:glass) and ytterbium-doped glass are used as host materials for laser medium. Out of these, neodymium-doped yttrium aluminum garnet (Nd:YAG) is most commonly used.

The first solid-state laser was a ruby laser. It is still used in some applications. In this laser, a ruby crystal is used as a laser medium.

Gas Lasers

A gas laser is a laser in which an electric current is discharged through a gas inside the laser medium to produce laser light. In gas lasers, the laser medium is in the gaseous state.



Gas lasers are used in applications that require laser light with very high quality beam and long coherence lengths. In gas laser, the laser medium is made up of the mixture of gases. This mixture is packed up into a glass tube. The glass tube filled with the mixture of gases acts as an active medium or laser medium.

A gas laser is the first laser that works on the principle of converting electrical energy into light energy. It produces a laser light beam in the infrared region of the spectrum at 1.15 μm.

Gas lasers are of different types: they are, helium neon (HeNe) lasers, argon ion lasers, carbon dioxide lasers (CO_2 lasers), carbon monoxide lasers (CO lasers), excimer lasers, nitrogen lasers, hydrogen lasers, etc. The type of gas used to construct the laser medium can determine the lasers wavelength or efficiency.

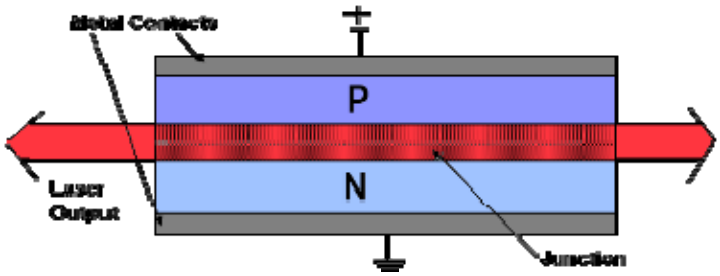
Liquid Lasers (Dye Lasers)

The liquid lasers are those in which the active medium consists of solutions of certain organic dye compounds in liquid solvents such as ethyl alcohol, methyl alcohol, or water. Many different dyes are nowadays available, and in total they can cover huge wavelength regions. Some of them are exalite, coumarin, rhodamine, pyrromethene, pyridine, fluorescein, pyridine, styryl. Due to wide range of emission wavelengths, wide spectral coverage, and the possibility of generating very short pulses, organic dye lasers have found a broad application in various fields. In particular, these lasers are widely used in scientific reseach. Other applications include the biometrical field (e.g., retinal

treatment or photodynamic therapy) and applications in the field of laser photochemistry.

Semiconductor Lasers

These lasers are very cheap, compact size and consume low power. They are also called semiconductor diodes. They usually consist of a junction between layers of semiconductors with different electrical conducting properties. In semiconductor lasers, a p-n junction of a semiconductor diode forms the active medium. Electrical energy is used as the pump source. So, semiconductor lasers emit visible or infrared light when an electric current passes through them. The emission occurs at the interface of p-n junction between two regions doped with different materials. The p-n junction which acts as a laser medium, generates stimulated emission and provides lasing action. Gallium arsenide is the semiconductor most commonly used. The semiconductor laser can be pulsed at varying rate and pulse widths. Therefore, this laser is a natural transmitter of digital data.



Chemical Lasers

Chemical lasers are devices that are powered by a chemical reaction. Chemical lasers usually involve a chemical reaction between gaseous elements, and often involve exothermal chemical reaction. Chemical lasers can reach continuous wave output with power reaching to megawatt levels. They provide an interesting example of direct conversion of chemical energy into electromagnetic energy. They are potentially able to provide either large output power (in CW operation) or large output energy (in pulsed operation). Common examples of chemical lasers are the chemical oxygen iodine laser (COIL), all gas-phase iodine laser (AGIL), the hydrogen fluoride (HF) and deuterium fluoride (DF) lasers, all operating in the mid-infrared region. Chemical lasers are widely used in industry, especially for cutting and drilling. But the most important area of these lasers seems to be for high-power military applications.

EXERCISE 10

Reread the text, find English equivalents to the Ukrainian word-combinations.

Твердотільний лазер, додавання домішок, рідкісноземельні елементи, електричний стум, газоподібний стан, скляна колба, перетворення електричної енергії у світлову, лазерний промінь світла, інфрачервона ділянка спектру, вуглекислотний лазер, лазер на фтористому водні, азотний лазер, лазер на барвниках, вимушене випромінювання, джерело накачки, легований різними матеріалами, довжина хвилі, лазерний промінь,

EXERCISE 11
Answer the following questions.

1. What types of lasers were mentioned in the text?
2. What substances are used as host materials for laser medium in solid-state lasers?
3. What principal does a gas laser work on?
4. What are the most common types of gas laser media?
5. What may act as solvents in solutions of organic dye compounds in liquid lasers?
6. Where are liquid lasers used?
7. What is the structure of a semiconductor laser?
8. What role does electrical current play in semiconductor diodes?
9. What powers chemical laser?
10. What is the most important area of chemical lasers application?

EXERCISE 12
Complete the sentences.

1. The most common solid laser media are _____.
2. Gas lasers are pumped by _____.
3. The active medium of the liquid lasers consists of _____ .
4. Chemical lasers are able to provide _____.

EXERCISE 13
Listen to the audio / watch the video 'Ruby Laser' and complete the sentences. Translate them into Ukrainian.

1. The laser medium can be a _____, _____, _____ or _____.
2. The most important types of lasers are _____, _____, _____, _____ and _____ lasers.
3. In ruby laser the lasing material is a _____.
4. A ruby laser consists of a _____, a _____and two _____.
5. One of the mirrors is partially _____.
6. The ruby rod is the _____ _____ and the flash tube _____ the medium.
7. The flash tube _____ and _____ light into the ruby rod.
8. The light _____ atoms in the ruby.
9. Some of these atoms emit _____.
10. Most of these photons _____ in a direction parallel to the axis of the ruby rod and they _____ back and forth from the mirrors.
11. As they pass through the crystal they _____ emission in other atoms.
12. These photons come out through the partially silvered mirror as a _____ single phase and colonnaded laser.

EXERCISE 14
Read and translate the text, fill in the gaps with the suitable word.

The Ruby Laser

This type of laser was the first 1. _____ to operate (T.H. Maiman, June 1960) and still continues to be used. Ruby, which 2. _____ for hundreds of years as a naturally occurring precious stone, is a crystal of corundum in which some of the Al3+ ions 3. _____ by Cr3+ ions.

Ruby lasers, once very popular, are now less widely used, since they 4. _____ by competitors, such as Nd:YAG or Nd:glass lasers. But they are, however, still commonly used for a number of scientific and technical applications where the shorter wavelength of ruby compared to Nd:YAG 5. _____ a considerable advantage (such as pulsed holography, where Nd:YAG 6. _____ owing to the lack of response of the photographic films at the longer wavelength of the Nd:YAG laser). Ruby lasers 7. _____ extensively in the past for military rangefinders, an application in which this laser is now completely replaced by Nd:YAG or Nd:glass lasers.

	A	B	C
1	to make	to be made	to made
2	has known	have been known	has been known
3	is replaced	are replaced	replaced
4	have been replaced	have replaced	replaced
5	is representing	is represented	represents
6	cannot be used	cannot used	cannot use
7	are used	were used	used

Neodymium Lasers

Neodymium lasers are the most popular type of solid-state laser. The laser medium is commonly called YAG (yttrium aluminum garnet). Nd:YAG lasers can 1. _____ either cw (continuous wave) or pulsed.

Nd:YAG lasers are widely used in a variety of 2. _____, among which we mention (1) ranging (most military laser rangefinders and target designators now use

Nd:YAG lasers); (2) scientific applications (Q-switched lasers); (3) material 3. _____ (cutting, drilling, and welding etc.); (4) medical applications (photocoagulation).

From an engineering viewpoint, i.e., 4. _____ pumping configurations and rod dimensions, the most commonly used Nd:glass lasers do not 5. _____ greatly from those used for Nd:YAG lasers. Nd:glass lasers are often used in applications where pulsed laser of low repetition rate is 6. _____. This is the case for some military rangefinders and for some scientific Nd:glass lasers. A

very important application of Nd:glass is as laser 7. _____ in the very high energy systems used in laser-driven fusion experiments.

	A	B	C
1	operand	operate	operation
2	applications	apprentices	appreciation
3	procession	processing	process
4	in terms of	however	though
5	differed	differ	difference
6	repeated	revised	required
7	amplifiers	amplification	amplify

EXERCISE 15
Read the text, translate the words given in Ukrainian.

Helium-Neon Lasers

The He-Ne laser is certainly *найважливіший* of the noble gas lasers. One of the most characteristic *особливостей* of the He-Ne laser is that the output power does not *зростає* monotonically with discharge current but *досягає* a maximum and thereafter *зменшується*. For this reason commercially available He-Ne lasers are provided with a *джерело живлення* designed to give only the optimum current.

He-Ne lasers oscillating on the red transition are widely used for many *застосувань* where a low-power *видимий промінь* is needed (e. g., alignment, character reading, metrology, holography, video disk memories).

Copper vapor lasers are used for many *наукових* applications and for some *промислових* applications (such as high-speed photography). Gold vapor lasers *використовуються* increasingly for photodynamic therapy of tumors.

Excimer Lasers

An excimer laser is a *потужний* kind of laser which nearly always *працює* in the ultraviolet (UV) spectral region and *створює* nanosecond pulses. The excimer *підсилювальне середовище* is a *суміш газів*, typically containing a *благородний газ* (e.g. argon, krypton, or xenon) and a halogen (e.g. fluorine or chlorine), apart from helium and/or neon as buffer gas. An excimer gain medium *is pumped* with short (nanosecond) current pulses in a high-voltage electric discharge (or sometimes with an electron beam), which *створює* so-called excimers (excited dimers) – molecules which represent a bound state of their constituents only in the excited electronic state, but not in the electronic ground state. As excimer lasers use molecules as the gain medium, they can also be called molecular lasers. The short *довжини хвиль* in the ultraviolet spectral region make possible a number of *застосувань*:

— the generation of very fine patterns with photolithographic methods (*microlithography*), for example in semiconductor chip *виробництві;*

— *обробка матеріалів* with laser ablation, *використовуючи* the very short absorption lengths of the order of a few micrometers in many materials;
— *хірургія ока*, particularly for vision correction;
— *накачування* other lasers, e.g. certain dye lasers.

EXERCISE 16

Read the sentences and translate them into Ukrainian pating attention to the topical vocabulary.

1. It is because the FELs (free electron lasers) are so large and expensive that their application is practically limited by the frequency ranges unavailable for conventional lasers.
2. Processing materials with lasers is largely based on two main laser types: the Nd: YAG laser and CO2 laser.
3. Special attention has been recently paid to the research of suitability of the excimer laser for surgical operations.
4. A decision to use laser for eye surgery has been followed by a process of selecting the particular kind of laser best suited for this aim.
5. A solid laser uses a crystal, glass or seшiconductor as its light-amplifying substance.
6. The most common industrial uses of laser beams are in drilling, cutting, welding, joining, facing and other material processing operations.
7. A copper vapor laser makes use of copper vapors as a lasing medium and emits yellow and green laser light at 578.2 and 510.6nm of the electromagnetic spectrum, respectively.
8. Lasers made using pure metal vapor produced from elemental copper are difficult to produce because of the high temperature required to form vapor. Hence, compounds like copper chloride, copper iodide, and copper bromide are used, as they form vapors at low temperatures.
9. Polymethine dyes provide laser oscillation in the red or near infrared region.
10. Chemical lasers provide an interesting example of direct conversion of chemical energy into electromagnetic energy.
11. It is because the FELs are so large and expensive, that their application is practically limited by the frequency ranges unavaible for conventional lasers.

EXERCISE 17

Read and translate the sentences paying attention to the infinitive constructions.

1. The free-electron laser is said to operate in the Raman regime.
2. An electron beam is supposed to move at a speed close to the speed of light.
3. In a FEL an electron beam is known to pass through the magnetic field.

4. The question of efficiency is believed to be the most important issue for a FEL.
5. Demonstrations of FEL operation are reported to have been made on several devices around the world.
6. Free electron lasers are known to be inherently large and expensive machines.
7. Because of low values of electron energy, free electron lasers were found to oscillate in the millimeter wave region.
8. Interest in the FEL applications is likely to be the strongest in the frequency ranges where more conventional lasers are not available.
9. The potential high power capability of a FEL is sure to be used in military applications.
10. Free electron lasers are unlikely to be widely used due to their limited efficiency.
11. Injected along the periodic structure, the electrons seem to acquire a wiggly motion.
12. The resulting electron acceleration seems to produce a longitudinal emission of radiation.

EXERCISE 18
Translate the text from Ukrainian into English.

Основне джерело лазерного випромінювання – оптичний квантовий генератор (лазер). Лазери є генераторами електромагнітних хвиль оптичного діапазону, у яких використовується вимушене електромагнітне випромінювання молекул активної речовини, що приводиться в збуджений стан джерелом накачування. Типи лазерів розрізняються видом активної речовини та у спосіб накачування.

У твердотілих лазерах як активну речовина використовуються кристали рубіна, іттриєво-алюмінієвий гранат (АІГ) або скло, активоване неодимом (Nd) або ербієм. Для збудження активної речовини застосовують імпульсні ксенонові лампи.

У газових лазерах активною речовиною є газ або суміш газів, які приводяться в збуджений стан газовим розрядом. У напівпровідникових лазерах активною речовиною є напівпровідниковий кристал. Накачування лазера здійснюється електричним струмом, що проходить через кристал. У рідинних лазерах як активну речовину використовують, зазвичай, органічні барвники. Збудження активної речовини здійснюється або когерентним випромінюванням іншого лазера, або некогерентним випромінюванням імпульсних ламп.

EXERCISE 19

Project. Prepare a report about one type of laser (a dye laser, a FEL, etc.). Be sure to mention:

— The peculiarities of its construction;

— Its active medium;

— Its properties;

— The field of its usage.

Acronyms and Abbreviations

ACR: Attenuation to Crosstalk Ratio
Al: Aluminium
AM: Amplitude Modulation
APD: Avalanche PhotoDiode
APF: All Plastic Fiber
As: Arsenide
ATM: Asynchronous Transfer Mode
BBC: British Broadcasting Company
BER: Bit Error Rate
bit: Binary digit
CAD: Computer Aided Design
CATV: Community Antenna Television (or cable TV)
CPU: Central Processor Unit
CSMA: Carrier Sense Multiple Access
CSMA/CD: Carrier Sense Multiple Access with Collision Detection
CSP: Channelled Substrate Planer (LASER)
DARPA: US Defense Advanced Research Projects Agency
dB: Decibel
dB(mu): Optical power referenced to 1 microwatt
dB/km: Decibels per 97ilometer
dBm: Optical power referenced to 1 milliwatt
dBr: Decibels relative to a known power level
DC: Direct Current
DFB: Distributed FeedBack
DOT: Department of Transport
DSB: Digital Signal Processing
DSF: Dispersion Shifted Fiber
DTI: Department of Trade and Industry
DWDM: Dense Wavelength Division Multiplex(ing)
EDFA: Erbium-Doped Fiber Amplifier
EDTFA: Erbium-Doped Tellurite Fiber Amplifier
EFTA: European Free Trade Association
EIA: Environmental Impact Assessment
EIA: Electronic Industries Association
ELED: Edge Light Emitting Diode
ELFEXT: Equal Level Far End Cross Talk
EMC: ElectroMagnetic Compatibility
EMD: Equilibrium Mode Distribution
EMI: Electromagnetic Interference
EU: European Union

FDDI: Fiber Distributed Data Interface
FDM: Frequency Division Multiplex(ing)
FEXT: Far End Cross Talk
FIA: Fiber Industry Association
FITL: Fiber In The Loop
FLOD: Full Length Outside Deposition
FM: Frequency Modulation
FO: Fiber Optic
FOA: Fiber Optic Amplifier
FOTP: Fiber Optic Test Procedure
FOTS: Fiber Optic Transmission System
FPLD: Fabry-Perot Laser Diode
FTTB: Fiber To The Building
FTTC: Fiber To The Curb
FTTH: Fiber To The Home
FWHM: Full Width Half Maximum
FXC: Fiber switch Cross Connect
Ga: Gallium
Gbit: Gigabit
GI: Graded Index
GIPFOC: Graded Index Plastic Fiber Optic Cable
GOF: Glass Optical Fiber
IDF: Intermediate Distribution Frame
IDP: Integrated Detector/Amplifier
ILD: Index guided Laser Diode
ILD: Injection Laser Diode
In: Indium
IR: Infrared
ISDN: Integrated Services Digital Network
ISO: International Standards Organization
kg: Kilogram
km: Kilometre
km/s: Kilometres per second
LAN: Local Area Network
LASER: Light Amplification by Stimulated Emission/Radiation
lb: Pound (weight, UK)
LD: Laser Diode
LED: Light Emitting Diode
LLDPE: Linear Low Density PolyEthylene jacketing
LLIDS: Local Light Injection and Detection System
LPE: Liquid Phase Epitaxy

LSFH: Low Smoke Halogen Free
m: Metre
mA: MilliAmpere
MAN: Metropolitan Area Network
MBE: Molecular Beam Epitaxy
MBPS: (see Fiber distributed data interface network in the Glossary)
MCRW: Metal-Clad Ridge Waveguide (laser)
MDF: Main Distribution Frame
MEMS: Micro ElectroMechanical Systems
MHz: MegaHertz
mm: Millimetre
MMF: Multimode Fiber optic cable
MOCVD: Metal Organic Chemical Vapour Deposition
Modem: Modulator/demodulator
MOVPE: Metal Organic Vapour Phase Epitaxy
MRI: Magnetic Resonance Imaging
mW: MilliWatt
NA: Numerical Aperture
NEXT: Near End Crosstalk
NIR: Near Infrared
NIU: Network Interface Unit
NLO: Non-Linear Optics
nm: Nanometre
NTSC: National Television System Committee
OSI: Open Standards Interconnect
OTDR: Optical Time Domain Reflectometer
P: Phosphorous
PAL: Phase Alternation Line (European TV format)
PCB: Printed Circuit Board
PCM: Pulse Code Modulation
PCS: Plastic Clad Silica
PD: Potential Difference
PD: Photodiode
PDFFA: Praseodymium-Doped Fluoride Fiber Amplifier
PE: Polyethylene. This is a type of plastic material used to make cable jacketing
PET: Position Emission Tomography
PF: Perfluorinated
PIN: Positive Intrinsic Negative photodiode
PIN-FET: PIN-Field Effect Transistor
PIN-PD: PIN-Photodiode

PMMA: Polymethylmethacrylate
POF: Plastic Optical Fiber
POFA: Plastic Optical Fiber Amplifier
PSTN: Public Switched Telephone Networks
PTFE: Polytetrafluoroethylene (Teflon)
PTT: Postal Telegraph and Telephone
PUR: Polyurethane
PVC: Polyvinyl Chloride
R&D: Research and Development
RF: Radio Frequency
RI: Reflective Index
RX: Receiver
SC: A connector type, primarily used with single-mode fiber optic cables
ScTP: Screened Twisted Pair
SDM: Space Domain Multiplexing
Si: Silicon
SIPFOC: Step Index Plastic Fiber Optic Cable
SLB: System Loss Budget
SNR, S/N: Signal to Noise Ratio. Usually expressed in dB
SOA: Semiconductor Optical Amplifier
SONET: Synchronous Optical Network
STL: Standard Telecommunications Laboratories
TDM: Time Division Multiplex(ing)
TIA: Transimpedence Amplifier
TIR: Total Internal Reflection
TX: Transmitter
UK: United Kingdom
US: United States
UTP: Unshielded Twisted Pair
UV: Ultraviolet
VCSEL: Vertical Cavity Surface Emitting Laser
VCSL: Vertical Cavity Semiconductor Laser
W: Watt
WAN: Wide Area Network
WDM: Wavelength Division Multiplex(ing)
WIC: Wavelength Independent Coupler

Glossary

A	
aberration	аберація, спотворення
absorb	поглинати
absorption	поглинання
accuracy	точність
action	дія, вплив,
achromat, achromatic lens, appliqué	ахромат
amplifier	підсилювач
angle	кут
application	застосування
approach	підхід, метод
area	ділянка, зона
array	матриця, гратка
attenuation	згасання
B	
base	база, підкладинка
beam	промінь, пучок
bend	відхиляти, вигинати
bifocals	біфокальні (окуляри)
boundary	межа, контур
brightness	яскравість, освітленість
C	
capability	можливість, здатність
cardinal points	кардинальні точки
carrier	носій
CCD	прилад із зарядовим зв’язком
cell	елемент, комірка
channel	канал
charge	заряд
chip	кристал, інтегральна схема
circuit	ланцюг, контур, схема
collimator	коліматор
compare	порівнювати
compression	стиснення
concave	увігнутий
converge	сходитися (в одній точці)
convergence	конвергенція, сходження
converging lens	збиральна лінза

conversion	перетворення
converter	перетворювач
convex	опуклий
correction	виправлення
correlator	корелятор
counter	лічильник
current	струм
curvature	вигин, кривизна
D	
damp	вносити затухання, ослаблювати
dasar	оптичний атенюатор
dashed line	пунктирна лінія
data storage	збереження даних
decompose	розкладати
definition	чіткість (зображення)
deflection	відхилення
defocus	дефокусувати
degree	степінь
density	щільність, густина
design	проектування, розроблення
detection	реєстрація (випромінювання)
detector **optical detector**	детектор, сенсор фотоелектричний сенсор
deviation	відхилення
device	прилад, пристрій
diffract	заломлювати, відхиляти
diffraction	дифракція
diffusion	розсіювання (світла)
digital	цифровий
diode **laser** **light-emitting** **optical** **photoemissive**	діод лазерний діод світлодіод оптрон, оптопара фотоелемент
discrimination	розпізнавання, роздільна здатність
dispersion	дисперсія
display	дисплей, пристрій відображення, індикатор
distortion	спотворення
distribution	розподіл
disturbance	завада, збурення
diverge	розходитися

divergence	дивергенція, розходження
diverging lense	розсіювальна лінза
division	розподіл
double-slit experiment	експеримент з подвійною щілиною
E	
echo	відбитий сигнал
edge	край, межа
effect	ефект, вплив, явище
emerald	ізумруд
emission	емісія, випромінювання
emissivity	коефіцієнт випромінювання
employ	використовувати
engineering	техніка, технологія
equation	рівняння
expansion	розширювання
eyepiece	окуляр
F	
field **electromagnetic**	поле електромагнітне
film	плівка
filter	фільтр
flicker	мерехтіти, мерехтіння
flow	потік
fluorescence	флуоресценція
flux	потік, щільність потоку
focal **focal length** **focal point**	фокальний фокальна відстань фокальна точка
focus	фокус
force	сила
frame	система відліку, кадр
frequency	частота
G	
gain	коефіцієнт підсилення
gate	логічний елемент
glass	скло, скляна оптика
grating	гратка, дифракційна гратка
guide	хвилевід, світловід

H	
hologram	голограма
I	
identification	ідентифікація, розпізнавання
illuminance	освітлюваність
illuminant	джерело світла
illumination	освітлення
image	зображення
imaging	формування зображення
immersion	імерсія
impedance	опір
incident	падаючий
incidence **angle of incidence**	падіння кут падіння
infrared	інфрачервоний
intelligence	інтелект
intensity	інтенсивність, сила світла
interface	межа, стик; взаємодія
interfere	перешкоджати
interference	інтерференція
interferometry	інтерферометрія
intermittence	затримка
J	
junction **pn-junction**	з'єднання, перехід pn-перехід
L	
ladar, lidar	лазерний локатор
lambda	довжина хвилі
laser	лазер
lasing	лазерна локація
layer	шар, плівка
LED (light emitting diode)	світлодіод
lens **biconvex** **concave** **converging** **diverging** **meniscus** **plano-concave** **plano-convex**	лінза двоопукла лінза увігнута лінза збиральна лінза розсіювальна лінза меніск лінза плоско-увігнута лінза плоско-опукла лінза

level	рівень
liquid crystal displays	рідинно-кристалічні дисплеї
light	світло, світлове випромінювання
link	лінія зв'язку, канал зв'язку, ділянка
loss	втрата
luminescence	люмінесценція
M	
magnification	збільшення, посилення
magnify **magnifying glass**	збільшувати збільшувальне скло, лупа
matrix	матриця
matter	матерія
medium **dense medium** **rare medium**	середовище густе середовище менш густе (розріджене) середовище
measurement	вимірювання
memory	пам'ять
mirror	дзеркало, відбивач
mixing	змішування
N	
nanoelectronics	наноелектроніка
network	мережа, схема
noise	шум
nonuniformity	нерівномірність
normal line	перпендикулярна лінія
nucleus	ядро
O	
objective, object glass	об'єктив
obstacle	перепона, перешкода, завада
opaque	непрозорий, світлонепроникний
optical axis	оптична вісь
optical communication systems	системи оптичного зв'язку
operation	робота, режим
overlap	перекривати, накладати
oscillation	коливання
P	
package	блок, вузол, модуль
particle	частка, частинка

pattern	зображення, структура
photocell	фотоелемент
photodiode	фотодіод
photoelectric effect	фотоелектричний ефект
photon	фотон
photoresistor	фоторезистор
photosensor	фотоелемент
phototransistor	фототранзистор
pipe	хвилевід, магістраль
plate	пластина, плита
point	точка, контакт
polarization	поляризація
power **power source** **three power instrument**	сила, потужність, енергія джерело живлення інструмент із трикратним збільшенням
propagate	поширювати(ся)
propagation	поширення
pulse	імпульс
Q	
quality	якість
quantity	величина, кількість
quantization	квантування
quantum	квант
quartz	кварц
R	
radiance	енергетична яскравість
radiation **electromagnetic** **ultraviolet**	випромінювання, радіація електромагнітне випромінювання ультрафіолетове випромінювання
range	діапазон
rate	швидкість, частота, інтенсивність (відмов)
ratio	співвідношення, відношення
ray **incident ray** **refracted ray**	промінь, пучок промінь, що падає заломлений промінь
real-time	у реальному масштабі часу
receiver	приймальний пристрій
receptor	приймач
recognition	розпізнавання, ідентифікація

recording	запис, реєстрація
recovery	відновлення, повернення
reduction	зменшення, послаблення
reference	еталон, взірець
reflect	відбивати
reflection **diffuse reflection** **specular reflection** **the law of reflection**	відбивання розсіяне (дифузне) відбивання дзеркальне відбивання закон відбивання
reflectivity	коефіцієнт відбиття
reflector	відбивач, дзеркало
refract	заломлювати
refraction	рефракція, заломлення
refringence	заломлення
region	ділянка, зона
registration	реєстрація
rejection	ослаблення, відбиття, режекція
relation	відношення, зв'язок
relay	трансляція, передача (сигналів)
reliability	надійність
repair	ремонт, відновлення
reradiation	перевипромінювання, розсіювання
research	дослідження
resistance	опір, резистор
resolution	роздільна здатність
retrieval **retrieval systems**	пошук (інформації) системи коригування
return	відбивання (відбивати)
rotation	обернення, поворот
route	шлях, траса
S	
safety	безпека
sample	взірець, відлік
sampling	дискретизація
saturation	насичення
scale	масштаб, шкала; змінювати масштаб
scan, scanning **point-by-point scanning**	сканування; сканувати сканування по точках
scatter	розсіювання; розсіювати
screen	екран
search	пошук; шукати
selection	селекція, вибір

semiconductor	напівпровідник
sensation	відчуття, сприйняття
sense	розпізнавання, зчитування, знак
sensitivity	чутливість
sensor	сенсор, детектор
separation	розділення
sequence	послідовність
sequential	послідовний
set	набір, множина, пристрій, апарат
sheet	шар, діаграма, графік, таблиця
sigh	знак, символ, ознака,
simulation	моделювання, імітація
solid-state	твірдотільна
source	джерело
space	простір, ділянка, зона
spatial	просторовий
speckle	спекл-структура
spectacles	окуляри
spectroscope	спектроскоп
spectroscopy	спектроскопія
spectrum **visible**	спектр видимий
speed	швидкість, швидкодія
split	розщеплення, розбиття
splitter	світлоподільний елемент
spot	пляма, ділянка, точка
stage	стадія, етап, каскад
standard	еталон, взірцева міра
state	стан, положення
storage	пам’ять; запам’ятовувати
stream	потік
strength	інтенсивність, сила
substrate	основа, підложка
surface	поверхня
T	
technology	техніка, технологія
test	випробування; випробувати
theory **the corpuscle theory** **the quantum theory** **the wave theory of light**	теорія корпускулярна теорія світла квантова теорія хвильова теорія світла
trace	слід; спостерігати

transducer	перетворювач
transfer	передача, передавати
transform	перетворення
translucent	напівпрозорий
transparency	транспарант, прозорість
transparent	прозорий
U	
unit	одиниця (фізичної) величини, елемент, прилад, апарат, блок, вузол, модуль
V	
value	(числове) значення
velocity **relative velocity**	швидкість відносна швидкість
vertex **vertex of a refracting surface**	вершина, вузол (схеми, графа) вершина заломленої поверхні
vessel	посудина, ємність
vision	зір, бачення
video	відеосигнал
visible	видимий
voltage	напруга
W	
wave **wave crest** **wave trough** **waveform** **waveguide** **wavelength** **wave-particle duality**	хвиля гребінь хвилі западина хвилі форма хвилі хвилевід довжина хвилі корпускулярно-хвильовий дуалізм
X	
x-ray	рентгенівський промінь
Z	
zone	зона, ділянка

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Медведєва Світлана Олександрівна,
Присяжна Олеся Дмитрівна,
Тульчак Людмила Володимирівна

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Видавець та виготовлювач
Вінницький національний технічний університет,
інформаційний редакційно-видавничий центр.
ВНТУ, ГНК, к. 114.
Хмельницьке шосе, 95,
м. Вінниця, 21021.
Тел. (0432) 65-18-06.
press.vntu.edu.ua;
E-mail: kivc.vntu@gmail.com.

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