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ОДЕСЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ  
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КАФЕДРА ІНОЗЕМНИХ МОВ ПРОФЕСІЙНОГО СПРЯМУВАННЯ

**ENGLISH FOR STUDENTS OF PHYSICS AND  
ASTRONOMY**

**(PART 3. ASTRONOMY)**

МЕТОДИЧНІ ВКАЗІВКИ

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

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E56 до практичних занять та самостійної роботи з навчальної  
дисципліни «Іноземна мова (за професійним спрямуванням)»  
для здобувачів першого (бакалаврського) рівня вищої освіти  
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Методичні вказівки до практичних та самостійних занять укладено відповідно до робочої програми навчальної дисципліни «Іноземна мова (за професійним спрямуванням)», яка є обов'язковою дисципліною для здобувачів першого (бакалаврського) рівня вищої освіти спеціальності 104 «Фізика та астрономія. Методичні вказівки містять тексти за спеціальністю, списки слів та термінів, вправи для виконання практичних завдань, теми для обговорювання.

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## ВСТУП

Методичні вказівки «ENGLISH FOR STUDENTS OF PHYSICS AND ASTRONOMY. (PART 3. ASTRONOMY)» розроблені до практичних занять та самостійної роботи з навчальної дисципліни «Іноземна мова (за професійним спрямуванням)» для здобувачів першого (бакалаврського) рівня вищої освіти денної форми навчання спеціальності 104 «Фізика та астрономія».

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

Методичні вказівки складаються з 9 розділів, в кожному є автентичний текст за спеціальністю, питання до тексту, перелік термінів для удосконалення фахової лексики, лексичні вправи та вправи на переклад, а також завдання спрямовані на вдосконалення навичок пошуку інформації в Інтернеті, її відбору і критичного оцінювання.

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

## **Unit 1.**

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

#### **The Birth of Modern Astronomy**

Astronomy is defined as the study of the objects that lie beyond our planet Earth and the processes by which these objects interact with one another. We will see, though, that it is much more. It is also humanity's attempt to organize what we learn into a clear history of the universe, from the instant of its birth in the Big Bang to the present moment. In considering the history of the universe, we will see again and again that the cosmos evolves; it changes in profound ways over long periods of time. For example, the universe made the carbon, the calcium, and the oxygen necessary to construct something as interesting and complicated as you. Today, many billions of years later, the universe has evolved into a more hospitable place for life. Tracing the evolutionary processes that continue to shape the universe is one of the most important (and satisfying) parts of modern astronomy.

The ultimate judge in science is always what nature itself reveals based on observations, experiments, models, and testing. Science is not merely a body of knowledge, but a method by which we attempt to understand nature and how it behaves. This method begins with many observations over a period of time. From the trends found through observations, scientists can model the particular phenomena we want to understand. Such models are always approximations of nature, subject to further testing. As a concrete astronomical example, ancient astronomers constructed a model (partly from observations and partly from philosophical beliefs) that Earth was the center of the universe and everything moved around it in circular orbits. At first, our available observations of the Sun, Moon, and planets did fit this model; however, after further observations, the model had to be updated by adding circle after circle to represent the movements of the planets around Earth at the center. As the centuries passed and improved instruments were developed for keeping track of objects in the sky, the old model (even with a huge number of circles) could no longer explain all the observed facts, a new model, with the Sun at the center, fit the experimental evidence better. After a period of philosophical struggle, it became accepted as our view of the universe.

Astronomy made no major advances in medieval Europe. The birth and expansion of Islam after the seventh century led to a flowering of Arabic and Jewish cultures that preserved, translated, and added to many of the astronomical ideas of the Greeks. Many of the names of the brightest stars, for example, are today taken from the Arabic, as are such astronomical terms as "zenith." As European culture began to

emerge from its long, dark age, trading with Arab countries led to a rediscovery of ancient texts such as *Almagest* and to a reawakening of interest in astronomical questions. This time of rebirth (in French, “*renaissance*”) in astronomy was embodied in the work of Copernicus.

Nicolaus Copernicus introduced the heliocentric cosmology to Renaissance Europe in his book *De Revolutionibus Orbium Coelestium* (On the Revolution of Celestial Orbs), published in 1543, the year of his death. Copernicus wanted to develop an improved theory from which to calculate planetary positions, but in doing so, he was himself not free of all traditional prejudices. Although he retained the Aristotelian idea of uniform circular motion, Copernicus suggested that Earth is a planet and that the planets all circle about the Sun, dethroning Earth from its position at the center of the universe.

Many of the modern scientific concepts of observation, experimentation, and the testing of hypotheses through careful quantitative measurements were pioneered by a man who lived nearly a century after Copernicus. Galileo Galilei, a contemporary of Shakespeare, was born in Pisa. Like Copernicus, he began training for a medical career, but he had little interest in the subject and later switched to mathematics. He held faculty positions at the University of Pisa and the University of Padua, and eventually became mathematician to the Grand Duke of Tuscany in Florence. Galileo was the father of both modern experimental physics and telescopic astronomy. He studied the acceleration of moving objects and, in 1610, began telescopic observations, discovering the nature of the Milky Way, the large-scale features of the Moon, the phases of Venus, and four moons of Jupiter. Although he was accused of heresy for his support of heliocentric cosmology, Galileo is credited with observations and brilliant writings that convinced most of his scientific contemporaries of the reality of the Copernican theory.

The new ideas of Copernicus and Galileo began a revolution in our conception of the cosmos. It eventually became evident that the universe is a vast place and that Earth’s role in it is relatively unimportant. The idea that Earth moves around the Sun like the other planets raised the possibility that they might be worlds themselves, perhaps even supporting life. As Earth was demoted from its position at the center of the universe, so, too, was humanity. The universe, despite what we may wish, does not revolve around us. Most of us take these things for granted today, but four centuries ago such concepts were frightening and heretical for some, immensely stimulating for others. The pioneers of the Renaissance started the European world along the path toward science and technology that we still tread today. For them, nature was rational

and ultimately knowable, and experiments and observations provided the means to reveal its secrets.

*(From <https://openstax.org/details/books/astronomy>)*

## Vocabulary

the Big Bang	великий вибух
to evolve [ɪˈvɒlv]	розвиватися
profound [prəˈfaʊnd]	глибокий
carbon [ˈkɑːbən]	вуглець
ultimate [ˈʌl.tɪ.mət]	остаточний
observation [ˌɒb.zəˈveɪ.ʃən]	спостереження
medieval [ˌmed.iː.vəl]	середньовічний
expansion [ɪkˈspæn.ʃən]	розширення
to emerge [ɪˈmɜːdʒ]	виникати
heliocentric [ˌhiː.li.əʊˈsen.trɪk]	геліоцентричний
prejudice [ˈpreɪdʒ.ə.dɪs]	упередження
celestial orb [sɪˈles.ti.əl ɔːb]	небесна куля
circular [ˈsɜː.kjə.lər]	круговий
to dethrone [diˈθrəʊn]	скинути з престолу
universe [ˈjuː.nɪ.vɜːs]	Всесвіт
quantitative [ˈkwɒn.tɪ.tə.tɪv]	кількісний
heresy [ˈher.ə.si]	єресь
contemporary [kənˈtem.pər.ər.i]	сучасний
vast [vɑːst]	величезний
to demote [diˈməʊt]	понижувати в посаді
immensely [ɪˈmens.li]	надзвичайно

to tread [tred]

ступати

to reveal [ri'vi:l]

виявляти

### **Exercise 1. Answer the following questions**

1. How is Astronomy defined? 2. Why is it also a humanity's concept? 3. What will we see again and again in considering the history of the universe? 4. What did the Universe make? 5. Has the Universe evolved into a more hospitable place for life? 6. What is the ultimate judge in science? 7. What is science? 8. How can scientists model the particular phenomena we want to understand? 9. What did ancient astronomers construct? 10. Why did the model have to be updated? 11. What was the new model that fit the experimental evidence better? 12. Did Astronomy make major advances in medieval Europe? 13. Where are many of the names of the brightest stars taken from? Why? 14. Was the rebirth of Astronomy embodied in the works of Copernicus? 15. What did Nicolaus Copernicus introduce? 16. What did he want to develop? 17. Was Nicolaus Copernicus free of all traditional prejudices? 18. What did Copernicus suggest? 19. What can you say about Galileo Galilei? 20. When did Galileo Galilei begin telescopic observations? 21. What was Galileo Galilei accused of? Why? 22. What did the new ideas of Copernicus and Galileo do? 23. Does the Universe revolve around us? 24. What did the pioneers of the Renaissance do? 25. What provided the means to reveal the secrets of the Universe?

### **Exercise 2. Find English equivalents in the text**

бути визначеними як, лежати за межами, взаємодіяти один з одним, чітка історія Всесвіту, глибоко змінюватися, еволюціонувати, формувати Всесвіт, базуватися на спостереженнях, експериментах, моделях і випробуваннях; протягом певного періоду часу, моделювати конкретні явища, рухатися навколо них по кругових орбітах, середньовічна Європа, розквіт культур, повторне відкриття стародавніх текстів, представити геліоцентричну космологію, обчислити положення планет, сучасні наукові концепції, перейти до математики, обіймати посади викладача, експериментальна фізика, телескопічна астрономія, великомасштабні особливості, бути звинуваченим, прискорення рухомих об'єктів, природа Чумацького Шляху, наукові сучасники, заслуговувати, стати очевидним, бути пониженим у посаді, сприймати речі як належне, страшні та еретичні, надавати засоби, розкривати таємниці.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. Astronomy is a science	a) is always the same, regardless of the relative motion of the source and the receiver.
2. It is not certain who first conceived of the idea of combining two or more pieces of glass	b) noting and predicting the positions of the Sun, Moon, and planets, originally for calendrical and astrological purposes and later for navigational uses and scientific interest.
3. Until the invention of the telescope and the discovery of the laws of motion and gravity in the 17th century, astronomy was primarily concerned with	c) to produce an instrument that enlarged images of distant objects, making them appear nearer.
4. A key theoretical development for 20th-century astronomy and cosmology	d) that encompasses the study of all extraterrestrial objects and phenomena.
5. The theory of relativity grew out of contradictions	e) were made in 1608 by the Dutch spectacle maker Hans Lippershey (1570–1619).
6. Einstein assumed, first, that all uniformly moving reference frames are equally valid for doing physics and, second, that the speed of light	f) with a three-power magnification ( $3\times$ ), which made distant objects appear three times nearer and larger.
7. The first such “spy glasses” (now called telescopes) that attracted much notice	g) between electromagnetic theory (worked out by Scottish physicist James Clerk Maxwell in the 1860s) and what people thought they knew about relativity of motion.
8. Galileo heard of the discovery and, without ever having seen an assembled telescope, constructed one of his own	h) was the development of the theory of relativity, from 1905 to 1915, which eventually led to an explanation of the origin of the universe.
9. With his telescope, Galileo was able	i) so that we see different parts of its daylight side at different times. noting and predicting the positions of the Sun, Moon, and planets, originally for calendrical and astrological purposes

	and later for navigational uses and scientific interest.
10. Within a few months, he had found that Venus goes through phases like the Moon, showing that it must revolve about the Sun,	j) could belong to the realm of celestial bodies.
11. Galileo also observed the Moon and saw craters, mountain ranges, valleys, and flat, dark areas	k) to carry out the test of the Copernican theory, based on the phases of Venus.
12. These discoveries showed that the Moon might be not so dissimilar to Earth—suggesting that Earth, too,	l) that he thought might be water.

#### Exercise 4. Translate the following sentences into English

1. Астрономія — одна з найстаріших наук, яка виникла з практичних потреб людства.

2. Особливо великого розвитку досягла астрономія у Стародавній Греції.

3. Народження сучасної астрономії пов'язують з відмовою від геоцентричної системи світу Птолемея (II століття) і заміною її геліоцентричною системою Миколая Коперника (середина XVI століття), з початком досліджень небесних тіл за допомогою телескопа (Галілео Галілей, початок XVII століття) і відкриттям закону всесвітнього тяжіння (Ісаак Ньютон, кінець XVII століття).

4. Відкриття інших галактик стало поштовхом для розвитку позагалактичної астрономії. Дослідження спектрів галактик дало змогу Едвіну Хаббл 1929 року виявити явище «розбігання галактик», яке згодом здобуло пояснення на основі загального розширення Всесвіту.

5. У XX столітті астрономія поділилася на дві основні галузі: спостережну і теоретичну. Спостережна астрономія зосереджена на спостереженнях небесних тіл, які потім аналізують за допомогою основних законів фізики.

6. Теоретична астрономія зорієнтована на розробку моделей (аналітичних чи комп'ютерних) для опису астрономічних об'єктів і явищ.

7. Ці дві гілки доповнюють одна одну: теоретична астрономія шукає пояснення результатам спостережень, а спостережну астрономію застосовують для підтвердження теоретичних висновків і гіпотез.

8. Науково-технічна революція XX століття мала надзвичайно великий вплив на розвиток астрономії в цілому та особливо астрофізики.

9. Створення оптичних і радіотелескопів з високою роздільною здатністю, застосування ракет і штучних супутників Землі для позаатмосферних

астрономічних спостережень призвели до відкриття нових видів космічних тіл: радіогалактик, квазарів, пульсарів, джерел рентгенівського випромінювання тощо.

10. Були розроблені основи теорії еволюції зір і космогонії Сонячної системи. Найбільшим досягненням астрофізики XX століття стала релятивістська космологія — теорія еволюції Всесвіту в цілому.

*(From [https:// my-astronomy.ucoz.ua/index/astronomija\\_jak\\_nauka](https://my-astronomy.ucoz.ua/index/astronomija_jak_nauka))*

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

Diamond, one of the hardest and most lustrous materials on Earth, is formed under extreme pressure and heat deep beneath the surface of the planet. But it turns out that diamonds are not exclusive to our own planet and may be found throughout the Solar System, Galaxy and beyond. Scientists have proposed that diamonds may be formed in the atmospheres of both Uranus and Neptune. Astronomers have discovered the presence of hydrocarbons in both atmospheres and, under the right conditions, they become the building blocks of diamonds.

*(From <https://www.rmg.co.uk/stories/topics/15-awe-inspiring-astronomy-discoveries>)*

### **Speaking**

- Speak about the birth of Astronomy.
- Speak about awe-inspiring astronomy discoveries.
- Speak about Galileo Galilei, Copernicus, Newton.

### **Unit 2.**

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

##### **Laws of Planetary Motion**

At about the time that Galileo was beginning his experiments with falling bodies, the efforts of two other scientists dramatically advanced our understanding of the motions of the planets.



[https://www.researchgate.net/figure/Tycho-Brahe-1546-1601\\_fig1\\_241470218](https://www.researchgate.net/figure/Tycho-Brahe-1546-1601_fig1_241470218)



<https://www.nmspacemuseum.org/>

inductee/johannes-kepler/

These two astronomers were the observer Tycho Brahe and the mathematician Johannes Kepler. Together, they placed the speculations of Copernicus on a sound mathematical basis and paved the way for the work of Isaac Newton in the next century.

Three years after the publication of Copernicus' *De Revolutionibus*, Tycho Brahe was born to a family of Danish nobility. He developed an early interest in astronomy and, as a young man, made significant astronomical observations. Among these was a careful study of what we now know was an exploding star that flared up to great brilliance in the night sky.

His growing reputation gained him the patronage of the Danish King Frederick II, and at the age of 30, Brahe was able to establish a fine astronomical observatory on the North Sea island of Hven. Brahe was the last and greatest of the pre-telescopic observers in Europe.

At Hven, Brahe made a continuous record of the positions of the Sun, Moon, and planets for almost 20 years. His extensive and precise observations enabled him to note that the positions of the planets varied from those given in published tables, which were based on the work of Ptolemy. These data were extremely valuable, but Brahe didn't have the ability to analyze them and develop a better model than what Ptolemy had published. He was further inhibited because he was an extravagant and cantankerous fellow, and he accumulated enemies among government officials. When his patron, Frederick II, died in 1597, Brahe lost his political base and decided to leave Denmark. He took up residence in Prague, where he became court astronomer to Emperor Rudolf of Bohemia. There, in the year before his death, Brahe found a most able young mathematician, Johannes Kepler, to assist him in analyzing his extensive planetary data.

Johannes Kepler was born into a poor family in the German province of Württemberg and lived much of his life amid the turmoil of the Thirty Years' War. He attended university at Tübingen and studied for a theological career. There, he learned the principles of the Copernican system and became converted to the heliocentric hypothesis. Eventually, Kepler went to Prague to serve as an assistant to Brahe, who set him to work trying to find a satisfactory theory of planetary motion—one that was compatible with the long series of observations made at Hven. Brahe was reluctant to provide Kepler with much material at any one time for fear that Kepler would discover the secrets of the universal motion by himself, thereby robbing Brahe of some of the glory. Only after Brahe's death in 1601 did Kepler get full possession of the priceless records. Their study occupied most of Kepler's time for more than 20 years. Through his analysis of the motions of the planets, Kepler developed a series of principles, now known as Kepler's three laws, which described the behavior of planets based on their paths through space. The first two laws of planetary motion were published in 1609 in *The New Astronomy*. Their discovery was a profound step in the development of modern science.

### **The First Two Laws of Planetary Motion**

The path of an object through space is called its orbit. Kepler initially assumed that the orbits of planets were circles, but doing so did not allow him to find orbits that were consistent with Brahe's observations. Working with the data for Mars, he eventually discovered that the orbit of that planet had the shape of a somewhat flattened circle, or ellipse. Next to the circle, the ellipse is the simplest kind of closed curve, belonging to a family of curves known as conic sections.

Kepler's second law deals with the speed with which each planet moves along its ellipse, also known as its orbital speed.

If a planet moves in a circular orbit, the elastic line is always stretched the same amount and the planet moves at a constant speed around its orbit. But, as Kepler discovered, in most orbits that speed of a planet orbiting its star (or moon orbiting its planet) tends to vary because the orbit is elliptical.

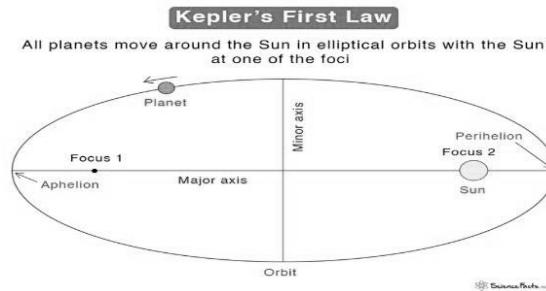
### **Kepler's Third Law**

Kepler's first two laws of planetary motion describe the shape of a planet's orbit and allow us to calculate the speed of its motion at any point in the orbit. Kepler was pleased to have discovered such fundamental rules, but they did not satisfy his quest to fully understand planetary motions. He wanted to know why the orbits of the planets were spaced as they are and to find a mathematical pattern in their movements—a "harmony of the spheres" as he called it. For many years he worked to discover

mathematical relationships governing planetary spacing and the time each planet took to go around the Sun.

Kepler's three laws of planetary motion can be summarized as follows:

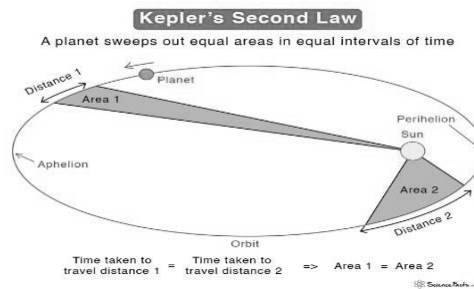
**Kepler's first law:** Each planet moves around the Sun in an orbit that is an ellipse, with the Sun at one focus of the ellipse. ‘



**Fig.1. Kepler's first law**

<https://www.sciencefacts.net/keplers-first-law.html>

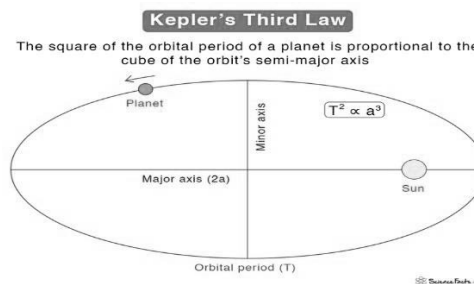
• **Kepler's second law:** The straight line joining a planet and the Sun sweeps out equal areas in space in equal intervals of time.



**Fig.2. Kepler's second law**

<https://www.sciencefacts.net/keplers-second-law.html>

**Kepler's third law:** The square of a planet's orbital period is directly proportional to the cube of the semi major axis of its orbit.



**Fig.3. Kepler's third law**

<https://www.sciencefacts.net/wp-content/uploads/2022/04/Keplers-Third-Law.jpg>

(From <https://openstax.org/details/books/astronomy>)

## Vocabulary

observer	спостерігач
speculation [ˌspek.jəˈleɪ.ʃən]	спекуляції
nobility [nəʊˈbɪl.ə.ti] [nəˈbɪl.ə.ti]	дворянство
flare up	спалахувати
brilliance ['brɪl.jəns]	блиск
patronage ['pæt.rən.ɪdʒ] ['peɪ.trən.ɪdʒ]	патронат
to inhibit [ɪnˈhɪb.ɪt]	гальмувати
cantankerous [ˌkænˈtæŋ.kərə.əs]	сварливий
turmoil ['tɜː.mɔɪl]	сму́та
theological [ˌθiː.əˈlɒdʒ.ɪ.kəl]	теологічний
reluctant [rɪˈlʌk.tənt]	неохоче
curve [kɜːv]	крива
conic ['kɒn.ɪk]	конічний
ellipse [iˈlɪps]	еліпс
quest [kwest]	квест

### Exercise 1. Answer the following questions

1. What dramatically advanced our understanding of the motions of the planets?  
2. Who were these two astronomers? 3. When was Tycho Brahe born? 4. What was he interested in? 5. Why was Brahe able to establish a fine astronomical observatory on the North Sea island of Hven? 6. What did Brahe make? 7. Did Brahe have the ability to analyze his valuable data? 8. Why did Brahe decide to leave Denmark? 9. Who did he meet in Prague? 10. What can you tell about Johannes Kepler? 11. Why did Kepler go to Prague? 12. Why was Brahe reluctant to provide Kepler with much material at any one time? 13. When did Kepler get possession of the priceless records? 14. How long did Kepler study them? 15. What did Kepler develop? 16. When were the first two laws of planetary motion published? 17. What is called object's orbit? 18. What did Kepler initially assume? 19. What does Kepler's second law deal with? 20. Did

Kepler's first two laws of planetary motion satisfy his quest to fully understand planetary motions? 21. What did he want to know? 22. What is Kepler's third law?

**Exercise 2. Find English equivalents in the text**

падіння тіл, рух планет, міцна математична основа, прокласти шлях для, розвинути ранній інтерес до астрономії, зробити значні астрономічні спостереження, ретельне дослідження, зірка, що вибухає; заснувати чудову астрономічну обсерваторію, здійснювати безперервний запис положення Сонця, Місяця та планет; опубліковані таблиці, засновані на роботі, надзвичайно цінні дані, оселитися, найздібніший молодий математик, допомогти йому в аналізі його обширних планетних даних, лихоліття війни, навчатися для теологічної кар'єри, вивчати принципи системи Коперника, служити помічником, знайти задовільну теорію руху планет, позбавити частини слави, отримати повне володіння безцінними записами, розробити серію принципів, глибокий крок, бути узгодженим із, сплющене коло, рухатися по круговій орбіті, обчислювати швидкість його руху, знаходити математичну закономірність, узагальнювати як, описувати (змітати) рівні площі в просторі, за рівні проміжки часу, бути пропорційним до.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. Tycho Brahe's accurate observations of planetary positions	a) provided the data used by Johannes Kepler to derive his three fundamental laws of planetary motion.
2. Kepler's laws describe	b) the behavior of planets in their orbits.
3. Kepler himself never numbered these laws	c) or specially distinguished them from his other discoveries.
4. A radius vector joining any planet to the Sun	d) sweeps out equal areas in equal lengths of time.
5. The squares of the sidereal periods (P) of the planets	e) are directly proportional to the cubes of their mean distances (d) from the Sun.
6. Kepler's first law means	f) that planets move around the Sun in elliptical orbits.

7. Knowledge of these laws, especially the second (the law of areas), proved crucial to Sir Isaac Newton in 1684–85,	g) when he formulated his famous law of gravitation between Earth and the Moon and between the Sun and the planets, postulated by him to have validity for all objects anywhere in the universe.
8. The usefulness of Kepler’s laws extends to the motions of natural and artificial satellites,	h) as well as to stellar systems and extrasolar planets.
9. It may be noted that Kepler’s laws apply not only to gravitational but also	i) to all other inverse-square-law forces and, if due allowance is made for relativistic and quantum effects, to the electromagnetic forces within the atom.
10. Sun is a star around which	j) Earth and the other components of the solar system revolve.
11. The Sun is classified as a G2 V star, with G2 standing for the second hottest stars of the yellow G class—of surface temperature about 5,800 kelvins (K)—	k) and the V representing a main sequence, or dwarf, star, the typical star for this temperature class.
12. Planet, (from Greek planētes, “wanderers”),	l) broadly, any relatively large natural body that revolves in an orbit around the Sun or around some other star and that is not radiating energy from internal nuclear fusion reactions.

#### Exercise 4. Translate the following sentences into English

1. Йоганн Кеплер визначив, що Марс рухається навколо Сонця по еліпсу, а потім було доведено, що й інші планети теж мають еліптичні орбіти.

2. Перший закон Кеплера. Всі планети обертаються навколо Сонця по еліпсах, а Сонце розташоване в одному з фокусів цих еліпсів.

3. Орбіта Землі має маленький ексцентриситет  $e = 0,017$  і майже не відрізняється від кола, тому відстань між Землею та Сонцем змінюється в невеликих межах від  $r_{\min} = 0,983$  а. о. в перигелії до  $r_{\max} = 1,017$  а. о. в афелії.

4. Орбіта Марса має більший ексцентриситет, а саме 0,093, тому відстань між Землею та Марсом під час протистояння може бути різною — від 100 млн км до 56 млн км.

5. Супутники планет теж рухаються по еліптичних орбітах, причому у фокусі кожної орбіти розміщений центр відповідної планети.

6. Другий закон Кеплера. Радіус-вектор планети за однакові проміжки часу описує рівні площі.

7. Головний наслідок другого закону Кеплера полягає в тому, що під час руху планети по орбіті з часом змінюється не тільки відстань планети від Сонця, але і її лінійна та кутова швидкості.

8. Другий закон Кеплера фактично визначає відомий фізичний закон збереження енергії: сума кінетичної та потенціальної енергії в замкненій системі є величиною сталою.

9. Кінетична енергія визначається швидкістю планети, а потенціальна — відстанню між планетою та Сонцем, тому при наближенні до Сонця швидкість планети зростає.

10. Третій закон Кеплера. Квадрати сидеричних періодів обертання планет навколо Сонця відносяться як куби великих півосей їхніх орбіт.

*(From <https://subjectum.eu/textbook/astronomy>)*

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

Kepler's Laws have been used to discover exoplanets.

By observing the motion of stars and studying changes in their brightness, astronomers have been able to apply Kepler's Laws to detect and characterize planets orbiting stars outside our solar system. This has led to the discovery of thousands of exoplanets.

*(<https://facts.net/science/physics/15-astounding-facts-about-keplers-laws-of-planetary-motion/>)*

**Speaking**

- Speak about Laws of Planetary motion.
- Speak about Tycho Brahe.
- Speak about Johann Kepler.
- Speak about how Kepler's work inspired future generations of astronomers and scientists.

## Unit 3.

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

#### Earth and Sky

In order to create an accurate map, a mapmaker needs a way to uniquely and simply identify the location of all the major features on the map, such as cities or natural landmarks. Similarly, astronomical mapmakers need a way to uniquely and simply identify the location of stars, galaxies, and other celestial objects. On Earth maps, we divide the surface of Earth into a grid, and each location on that grid can easily be found using its latitude and longitude coordinate. Astronomers have a similar system for objects on the sky. Learning about these can help us understand the apparent motion of objects in the sky from various places on Earth.



**Fig. 1. Latitude and Longitude of Washington, DC.**

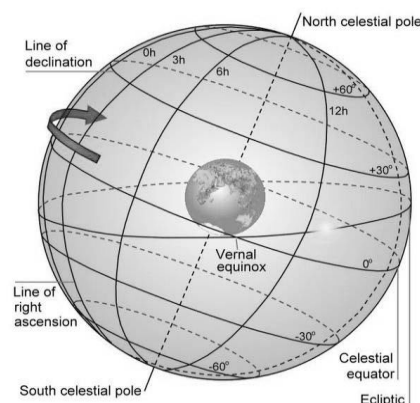
*(<https://www.collegesidekick.com/study-guides/astronomy/earth-and-sky>)*

Earth's axis of rotation defines the locations of its North and South Poles and of its equator, halfway between. Two other directions are also defined by Earth's motions: east is the direction toward which Earth rotates, and west is its opposite. At almost any point on Earth, the four directions—north, south, east, and west—are well defined, despite the fact that our planet is round rather than flat. The only exceptions are exactly at the North and South Poles, where the directions east and west are ambiguous (because points exactly at the poles do not turn). We can use these ideas to define a system of coordinates attached to our planet. Such a system, like the layout of streets and avenues in Manhattan or Salt Lake City, helps us find where we are or want to go. Coordinates on a sphere, however, are a little more complicated than those on a flat surface. We must define circles on the sphere that play the same role as the rectangular grid that you see on city maps. A great circle is any circle on the surface of a sphere whose center is at the center of the sphere. For example, Earth's equator is a great circle

on Earth's surface, halfway between the North and South Poles. We can also imagine a series of great circles that pass through both the North and South Poles. Each of these circles is called a meridian; they are each perpendicular to the equator, crossing it at right angles. Any point on the surface of Earth will have a meridian passing through it. The meridian specifies the east-west location, or longitude, of the place. By international agreement (and it took many meetings for the world's countries to agree), longitude is defined as the number of degrees of arc along the equator between your meridian and the one passing through Greenwich, England, which has been designated as the Prime Meridian. The longitude of the Prime Meridian is defined as  $0^\circ$ .

Why Greenwich, you might ask? Every country wanted  $0^\circ$  longitude to pass through its own capital. Greenwich, the site of the old Royal Observatory, was selected because it was between continental Europe and the United States, and because it was the site for much of the development of the method to measure longitude at sea. Longitudes are measured either to the east or to the west of the Greenwich meridian from  $0^\circ$  to  $180^\circ$ . As an example, the longitude of the clock-house benchmark of the U.S. Naval Observatory in Washington, DC, is  $77.066^\circ$  W.

Places in the Sky Positions in the sky are measured in a way that is very similar to the way we measure positions on the surface of Earth. Instead of latitude and longitude, however, astronomers use coordinates called declination and right ascension. To denote positions of objects in the sky, it is often convenient to make use of the fictitious celestial sphere. The sky appears to rotate about points above the North and South Poles of Earth—points in the sky called the north celestial pole and the south celestial pole.



**Fig.2. Celestial poles**

<https://www.quora.com/>

Halfway between the celestial poles, and thus  $90^\circ$  from each pole, is the celestial equator, a great circle on the celestial sphere that is in the same plane as Earth's equator. We can use these markers in the sky to set up a system of celestial coordinates. Declination on the celestial sphere is measured the same way that latitude is measured

on the sphere of Earth: from the celestial equator toward the north (positive) or south (negative). So Polaris, the star near the north celestial pole, has a declination of almost  $+90^\circ$ . Right ascension (RA) is like longitude, except that instead of Greenwich, the arbitrarily chosen point where we start counting is the vernal equinox, a point in the sky where the ecliptic (the Sun's path) crosses the celestial equator. RA can be expressed either in units of angle (degrees) or in units of time. This is because the celestial sphere appears to turn around Earth once a day as our planet turns on its axis. Thus the  $360^\circ$  of RA that it takes to go once around the celestial sphere can just as well be set equal to 24 hours. Then each  $15^\circ$  of arc is equal to 1 hour of time. For example, the approximate celestial coordinates of the bright star Capella are RA  $5\text{h} = 75^\circ$  and declination  $+50^\circ$ . One way to visualize these circles in the sky is to imagine Earth as a transparent sphere with the terrestrial coordinates (latitude and longitude) painted on it with dark paint. Imagine the celestial sphere around us as a giant ball, painted white on the inside. Then imagine yourself at the center of Earth, with a bright light bulb in the middle, looking out through its transparent surface to the sky. The terrestrial poles, equator, and meridians will be projected as dark shadows on the celestial sphere, giving us the system of coordinates in the sky.

(From <https://openstax.org/details/books/astronomy>)

## Vocabulary

accurate [ˈæk.jə.rət]	точні
mapmaker	картограф
uniquely [ju:ˈni:k.li]	однозначно
landmark [ˈlænd.mɑ:k]	орієнтир
grid	сітка
latitude	широта
UK [ˈlæt.ɪ.tʃu:d] US [ˈlæt.ə.tu:d]	
longitude [ˈlɒŋ.gɪ.tʃu:d] [ˈlɒn.dʒɪ.tʃu:d]	довгота
apparent [əˈpær.ənt]	очевидний
ambiguous [æmˈbɪɡ.ju.əs]	неоднозначний
rectangular [rekˈtæŋ.gjə.lər]	прямокутний
clock-house	прохідна
benchmark [ˈbentʃ.mɑ:k]	орієнтир

declination [ˌdek.lɪˈneɪ.ʃən]	схилення
right ascension [raɪt əˈsen.ʃən]	пряме сходження
fictitious [fɪkˈtɪʃ.əs]	фіктивний
vernal equinox [ˈvɜː.nəl ˈek.wɪ.nɒks]	весняне рівнодення
ecliptic [ɪˈkliptɪk]	екліптика

### Exercise 1. Answer the following questions

1. What does a mapmaker need in order to create an accurate map? 2. What do astronomical mapmakers need? 3. What do we divide the surface of Earth into? 4. What do astronomers have? 5. What does Earth's axis of rotation define? 6. Are the four directions well defined? 7. What are the only exceptions? 8. What does a system of coordinate help us do? 9. Are coordinates on sphere a little more complicated? 10. What is a great circle? 11. What is called a meridian? 12. What does the meridian specify? 13. How is the longitude defined? 14. How is the longitude of the prime meridian defined? 15. Why was Greenwich selected? 16. How are longitudes measured? 17. How are places in the sky positions measured? 18. What coordinates do astronomers use? 19. Why is it often convenient to make use of the fictitious celestial sphere? 20. Where does the sky appear to rotate about? 21. Where is the celestial equator? 22. How is the declination on the celestial sphere measured? 23. What declination does Polaris have? 24. What is right ascension? 25. How can RA be expressed? 26. How can one visualize these circles in the sky?

### Exercise 2. Find English equivalents in the text

створити точну карту, визначити розташування всіх основних об'єктів на карті, природні орієнтири, визначити розташування зірок, галактик та інших небесних об'єктів; координати широти та довготи, мати подібну систему, видимий рух об'єктів, різні місця на Землі, вісь обертання Землі, визначити систему координат, схема вулиць і проспектів, визначити кола на сфері, прямокутна сітка, у центрі сфери, пройти через обидва Північний і Південний полюси, перпендикулярні до екватора, міжнародна угода, метод вимірювання довготи на морі, використання фіктивної небесної сфери, небесні полюси, встановлення системи небесних координат, можна виразити в одиниці кута (градуси) або в одиниці часу, візуалізувати ці кола на небі.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. The basic unit of astronomical time is the day—either the solar day (reckoned by the Sun)	a) have nearly the same angular size (about $1/2^\circ$ ).
2. Apparent solar time is based on the position of the Sun in the sky, and mean solar time	b) is based on the average value of a solar day during the year.
3. By international agreement, we define 24 time zones around the world,	c) or the sidereal day (reckoned by the stars).
4. The convention of the International Date Line is necessary	d) to reconcile times on different parts of Earth.
5. The fundamental problem of the calendar is	e) to reconcile the incommensurable lengths of the day, month, and year.
6. Most modern calendars, beginning with the Roman (Julian) calendar of the first century BCE, neglect the problem of the month	f) to coexist with the older lunar calendars' system of months.
7. Today, most of the world has adopted the Gregorian calendar established in 1582 while finding ways	g) only during the night; other phases are visible during the day as well.
8. The Moon's monthly cycle of phases results from the changing angle of its illumination by the Sun. The full moon is visible in the sky	h) and concentrate on achieving the correct number of days in a year by using such conventions as the leap year.
9. Because its period of revolution is the same as its period of rotation,	i) when the Moon moves between the Sun and Earth, casting its shadow on a part of Earth's surface.
10. The Sun and Moon	j) each with its own standard time.
11. A solar eclipse occurs	k) the Moon always keeps the same face toward Earth.

#### **Exercise 4. Translate the following sentences into English**

1. У першому наближенні Земля має форму кулі.
2. Але насправді через обертання вона дещо сплюснута біля полюсів й опукла біля екватора.
3. Тому зазвичай форму Землі подають як еліпсоїд обертання — еліпс, що обертається навколо малої осі.
4. Маса Землі відносно невелика – приблизно в 318 разів менша, ніж маса Юпітера, найбільшої планети в Сонячній системі.
5. Водяна пара й почасти вуглекислий газ затримують у нижніх шарах атмосфери значну кількість тепла, яке випромінює Земля.
6. Кратери, найпоширеніший елемент місячного рельєфу, утворені внаслідок падіння метеоритів.
7. Поверхню Місяця вкриває шар пухкої речовини – реголіт, що структурою й хімічним складом близький до земних вулканічних порід.
8. Місяць лежить найближче до Землі, тому він став першим небесним тілом, до якого спрямували космічні апарати (1958).
9. Нашу планетну систему схематично можна уявити так: в її центрі міститься Сонце, навколо якого обертаються вісім планет.
10. Завдяки гравітаційній взаємодії Сонце утримує всі тіла планетної системи, що обертаються навколо нього.

*(From [https://lib.iitta.gov.u/713280/1/18-24\\_Astronomy\\_Workbook\\_P-7.pdf](https://lib.iitta.gov.u/713280/1/18-24_Astronomy_Workbook_P-7.pdf))*

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

The name Earth is at least 1,000 years old. All of the planets, except for Earth, were named after Greek and Roman gods and goddesses. However, the name Earth is a Germanic word, which simply means “the ground.”

- If the Sun were as tall as a typical front door, Earth would be the size of a nickel.
- Earth is a rocky planet with a solid and dynamic surface of mountains, canyons, plains and more. Most of our planet is covered in water.
- Earth's atmosphere is 78 percent nitrogen, 21 percent oxygen and 1 percent other ingredients—the perfect balance to breathe and live.

*(<https://science.nasa.gov/earth/facts>)*

## Speaking

- Speak about Earth and Sky.
- Speak about the system of coordinates of our planet.
- Speak about Gregorian calendar and its accuracy.

### Unit 4.

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

### The Seasons

One of the fundamental facts of life at Earth's midlatitudes is that there are significant variations in the heat we receive from the Sun during the course of the year. We thus divide the year into seasons, each with its different amount of sunlight. The difference between seasons gets more pronounced the farther north or south from the equator we travel, and the seasons in the Southern Hemisphere are the opposite of what we find on the northern half of Earth. With these observed facts in mind, let us ask what causes the seasons. Many people have believed that the seasons were the result of the changing distance between Earth and the Sun. This sounds reasonable at first: it should be colder when Earth is farther from the Sun. But the facts don't bear out this hypothesis. Although Earth's orbit around the Sun is an ellipse, its distance from the Sun varies by only about 3%. That's not enough to cause significant variations in the Sun's heating. To make matters worse for people in North America who hold this hypothesis, Earth is actually closest to the Sun in January, when the Northern Hemisphere is in the middle of winter. And if distance were the governing factor, why would the two hemispheres have opposite seasons? As we shall show, the seasons are actually caused by the  $23.5^\circ$  tilt of Earth's axis.

Note that our axis continues to point the same direction in the sky throughout the year. As Earth travels around the Sun, in June the Northern Hemisphere "leans into" the Sun and is more directly illuminated. In December, the situation is reversed: the Southern Hemisphere leans into the Sun, and the Northern Hemisphere leans away. In September and March, Earth leans "sideways"—neither into the Sun nor away from it—so the two hemispheres are equally favored with sunshine.

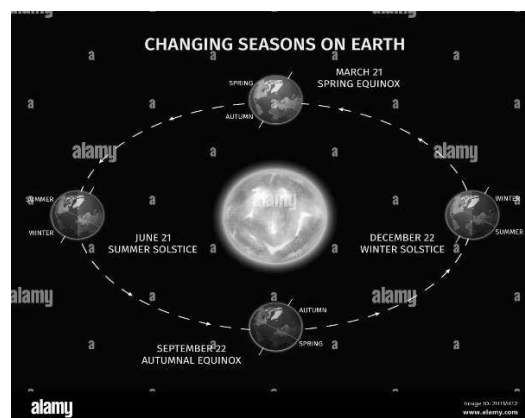
How does the Sun's favoring one hemisphere translate into making it warmer for us down on the surface of Earth? There are two effects we need to consider. When we lean into the Sun, sunlight hits us at a more direct angle and is more effective at

heating Earth's surface. You can get a similar effect by shining a flashlight onto a wall. If you shine the flashlight straight on, you get an intense spot of light on the wall. But if you hold the flashlight at an angle (if the wall "leans out" of the beam), then the spot of light is more spread out. Like the straight-on light, the sunlight in June is more direct and intense in the Northern Hemisphere, and hence more effective at heating.

The second effect has to do with the length of time the Sun spends above the horizon. Even if you've never thought about astronomy before, we're sure you have observed that the hours of daylight increase in summer and decrease in winter. Let's see why this happens.

An equivalent way to look at our path around the Sun each year is to pretend that the Sun moves around Earth (on a circle called the ecliptic). Because Earth's axis is tilted, the ecliptic is tilted by about  $23.5^\circ$  relative to the celestial equator. As a result, where we see the Sun in the sky changes as the year wears on. In June, the Sun is north of the celestial equator and spends more time with those who live in the Northern Hemisphere. It rises high in the sky and is above the horizon in the United States for as long as 15 hours. Thus, the Sun not only heats us with more direct rays, but it also has more time to do it each day.

The Northern Hemisphere's gain is the Southern Hemisphere's loss. There the June Sun is low in the sky, meaning fewer daylight hours. In Chile, for example, June is a colder, darker time of year. In December, when the Sun is south of the celestial equator, the situation is reversed.



**Fig. 1. Changing seasons on Earth**

*(<https://www.alamy.com/stock-photo/earth-orbit-sun-seasons.html?sortBy=relevant>)*

Many early cultures scheduled special events around the summer solstice to celebrate the longest days and thank their gods for making the weather warm. This required people to keep track of the lengths of the days and the northward trek of the Sun in order to know the right day for the "party." Now it is the Arctic Circle that has the 24-hour night and the Antarctic Circle that has the midnight Sun. At latitude  $23^\circ$  S,

called the Tropic of Capricorn, the Sun passes through the zenith at noon. Days are longer in the Southern Hemisphere and shorter in the north. In the United States and Southern Europe, there may be only 9 or 10 hours of sunshine during the day. It is winter in the Northern Hemisphere and summer in the Southern Hemisphere.

Many cultures that developed some distance north of the equator have a celebration around December 21 to help people deal with the depressing lack of sunlight and the often dangerously cold temperatures. Originally, this was often a time for huddling with family and friends, for sharing the reserves of food and drink, and for rituals asking the gods to return the light and heat and turn the cycle of the seasons around. Many cultures constructed elaborate devices for anticipating when the shortest day of the year was coming. Stonehenge in England, built long before the invention of writing, is probably one such device.



**Picture 2. Stonehenge**

*([https:// www.istockphoto.com/uk/search/2/image-film?phrase=stonehenge](https://www.istockphoto.com/uk/search/2/image-film?phrase=stonehenge))*

In our own time, we continue the winter solstice tradition with various holiday celebrations around that December date. Halfway between the solstices, on about March 21 and September 21, the Sun is on the celestial equator. From Earth, it appears above our planet's equator and favors neither hemisphere. Every place on Earth then receives roughly 12 hours of sunshine and 12 hours of night. The points where the Sun crosses the celestial equator are called the vernal (spring) and autumnal (fall) equinoxes.

*(From [https:// openstax.org/ details/books/ astronomy](https://openstax.org/details/books/astronomy))*

## **Vocabulary**

hypothesis [haɪ'pɒθ.ə.sɪs]

гіпотеза

tilt [tɪlt]

нахил

to lean into	нахилятися
to illuminate [ɪ'luː.mɪ.neɪt]	висвітлювати
flashlight ['flæʃ.laɪt]	ліхтарик
horizon [hə'raɪ.zən]	горизонт
gain [geɪn]	посилення
solstice ['sɒl.stɪs]	сонцестояння
to huddle ['hʌd.əl]	збиратися разом
elaborate [ɪ'læb.ər.ət]	майстерно зроблений, ретельно вироблений
to anticipate [æn'tɪs.ɪ.peɪt]	передбачити
hemisphere ['hem.ɪ.sfiə]	півкулі
vernal ['vɜː.nəl]	весняний
autumnal [ɔ:'tʌm.nəl]	осінній
equinox UK /'ek.wɪ.nɒks/ US /'ek.wə.nɑːks/	рівнодення

### Exercise 1. Answer the following questions

1. What is one of the fundamental facts of life at Earth's midlatitudes? 2. Do we divide the year into seasons? 3. What causes seasons? 4. What have some people believed? 5. Why would two hemispheres have the opposite seasons? 6. Where does the Northern Hemisphere lean into in June? 7. When does the Earth lean "sideways"? 8. What two effects do we need to consider? 9. What happens when you hold a flashlight at an angle? 10. What does the second effect have to do with? 11. Why is the ecliptic tilted? 12. Where is the Sun in June? 13. When is the Sun low in the sky? 14. What did many early cultures do? 15. Where does the Sun pass through the zenith at noon? 16. Why do people in many cultures have a celebration around December, 21? 17. What can you say about elaborate devices for anticipating the shortest day of the year? 18. Stonehenge in England is probably one such device, isn't it? 19. Do we continue the winter solstice tradition with various holiday celebrations around that December date? 20. What are the points where the Sun crosses the celestial equator?

## Exercise 2. Find English equivalents in the text

один із фундаментальних фактів життя, протягом року, різна кількість сонячного світла, результат зміни відстані між Землею та Сонцем, спричиняти значні зміни в нагріванні Сонця, погіршувати ситуацію, керуючий фактор, нахил земної осі, протягом року, під більш прямим кутом, відносно небесного екватора, у Північній півкулі, втрата південної півкулі, літнє сонцестояння, відстежувати тривалість днів, тропік Козерога, впоратися з гнітючою нестачею сонячного світла, час для спілкування з родиною та друзями, задовго до винайдення писемності, небесний екватор, весняне та осіннє рівнодення.

## Exercise 3. Match up the half of the sentence on the left with its ending on the right

1. The seasonal effects	a) for a few minutes longer than 12 hours, and below the horizon for fewer than 12 hours.
2. As we travel north or south, the seasons	b) our weather involves the air and water covering Earth's surface, and these large reservoirs do not heat up instantaneously.
3. At the North Pole, all celestial objects that are north of the celestial equator	c) followed by 6 months of darkness.
4. The Sun is north of the celestial equator from about March 21 to September 21,	d) to see a little way "over the horizon."
5. Each year there are 6 months of sunshine at each pole,	e) and evening twilight extends until the Sun sinks more than 18° below the horizon.
6. In reality, however, the atmosphere has the curious effect of allowing us	f) so at the North Pole, the Sun rises when it reaches the vernal equinox and sets when it reaches the autumnal equinox.
7. This effect is a result of refraction, the bending of light	g) are always above the horizon and, as Earth turns, circle around parallel to it.

8. Because of this atmospheric refraction (and the fact that the Sun is not a point of light but a disk),	h) passing through air or water.
9. In addition, the atmosphere scatters light and	i) the Sun appears to rise earlier and to set later than it would if no atmosphere were present.
10. Astronomers define morning twilight as beginning when the Sun is 18° below the horizon,	j) provides some twilight illumination even when the Sun is below the horizon.
11. At the equinoxes, for example, the Sun appears to be above the horizon	k) are different at different latitudes on Earth.
12. The hottest months in the Northern Hemisphere are July and August. This is because	l) become more pronounced, until we reach extreme cases in the Arctic and Antarctic.

#### Exercise 4. Translate the following sentences into English

1. Рік – одиниця часу, за яку Земля здійснює повний оберт навколо Сонця по еліптичній траєкторії.

2. Рік триває 365 днів 5 год 48 хв 46 с.

3. Траєкторія руху Землі навколо Сонця не є ідеально круговою, тому кількість сонячної енергії, яка досягає планети, змінюється протягом року, що призводить до явища змін пір року.

4. А разом з особливостями форми Землі та явищем нахилу планети до площини обертання це явище призводить до виникнення широтної поясності (залежність клімату від географічної широти).

5. Також річний рух Землі призводить до зміни полуденної висоти Сонця над горизонтом протягом року.

6. Форма Землі – геоїд (куля, приплюснута на полюсах).

7. Земна вісь нахилена до площини орбіти під кутом 66°33'.

8. Саме нахил призводить до зміни кількості світла, одержуваного тією чи іншою півкулею протягом року, оскільки одна півкуля планети більше освітлюється, ніж інша.

9. Як наслідок, на більшій частині планети відбувається зміна клімату протягом року.

10. Час, коли одна з півкуль найбільше обернена до Сонця, називається сонцестоянням.

(From [https://geography.ed-era.com/nauka\\_geografiya/ruh\\_zemli\\_u\\_kosmos/rychnyu\\_ruh\\_zemli](https://geography.ed-era.com/nauka_geografiya/ruh_zemli_u_kosmos/rychnyu_ruh_zemli))

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

Seasonal changes influence animal behavior, migration patterns, and reproduction cycles. Many animals, for example, hibernate in the winter to preserve energy, while others move to warmer climates.

Some animals, such as deer, mate in the fall to prepare for breeding in the spring. The shifting of the seasons can also affect animal food sources, threatening their existence.

(<https://www.havefunwithhistory.com/facts-about-the-seasons/>)

### **Speaking**

- Speak about seasons.
- Speak about seasonal festivities and rituals.
- Speak about how seasons have an impact on our lives.

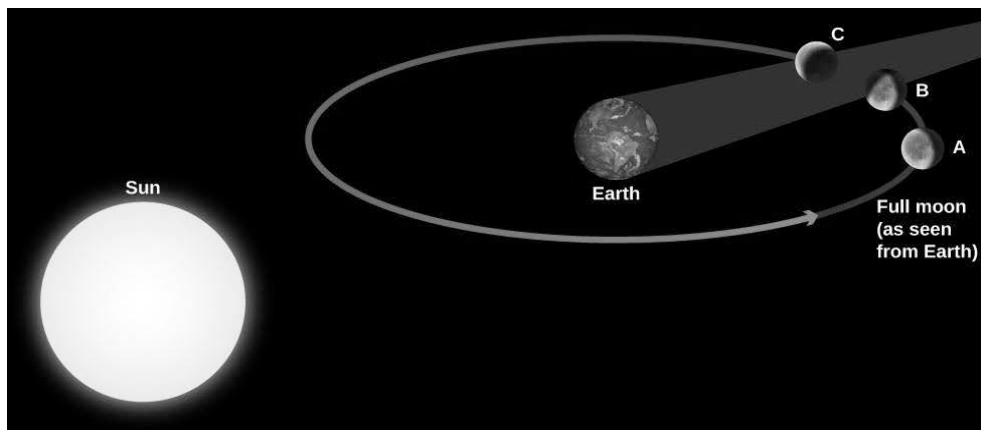
## **Unit 5.**

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

#### **Eclipses of the Sun and Moon**

One of the coincidences of living on Earth at the present time is that the two most prominent astronomical objects, the Sun and the Moon, have nearly the same apparent size in the sky. Although the Sun is about 400 times larger in diameter than the Moon, it is also about 400 times farther away, so both the Sun and the Moon have the same angular size—about  $1\frac{1}{2}^{\circ}$ . As a result, the Moon, as seen from Earth, can appear to cover the Sun, producing one of the most impressive events in nature. Any solid object in the solar system casts a shadow by blocking the light of the Sun from a region behind it. This shadow in space becomes apparent whenever another object moves into it. In general, an eclipse occurs whenever any part of either Earth or the Moon enters the shadow of the other. When the Moon's shadow strikes Earth, people within that shadow see the Sun at least partially covered by the Moon; that is, they witness a solar eclipse. When the Moon passes into the shadow of Earth, people on the

night side of Earth see the Moon darken in what is called a lunar eclipse. Let's look at how these happen in more detail.



**Figure 1. Geometry of a Lunar Eclipse.**

**(The Moon is shown moving through the different parts of Earth's shadow during a total lunar eclipse. Note that the distance the Moon moves in its orbit during the eclipse has been exaggerated here for clarity).**

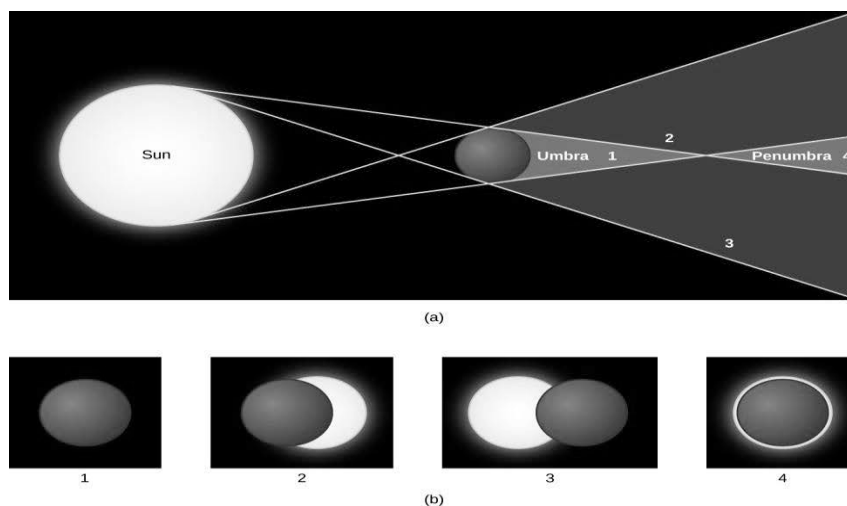
*(<https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/>)*

The shadows of Earth and the Moon consist of two parts: a cone where the shadow is darkest, called the umbra, and a lighter, more diffuse region of darkness called the penumbra. As you can imagine, the most spectacular eclipses occur when an object enters the umbra.

If the path of the Moon in the sky were identical to the path of the Sun (the ecliptic), we might expect to see an eclipse of the Sun and the Moon each month—whenever the Moon got in front of the Sun or into the shadow of Earth. However, as we mentioned, the Moon's orbit is tilted relative to the plane of Earth's orbit about the Sun by about  $5^\circ$  (imagine two hula hoops with a common center, but tilted a bit). As a result, during most months, the Moon is sufficiently above or below the ecliptic plane to avoid an eclipse. But when the two paths cross (twice a year), it is then "eclipse season" and eclipses are possible.

The apparent or angular sizes of both the Sun and Moon vary slightly from time to time as their distances from Earth vary. Much of the time, the Moon looks slightly smaller than the Sun and cannot cover it completely, even if the two are perfectly aligned. In this type of "annular eclipse," there is a ring of light around the dark sphere of the Moon. However, if an eclipse of the Sun occurs when the Moon is somewhat nearer than its average distance, the Moon can completely hide the Sun, producing a total solar eclipse. Another way to say it is that a total eclipse of the Sun occurs at those times when the umbra of the Moon's shadow reaches the surface of Earth.

If the Sun and Moon are properly aligned, then the Moon's darkest shadow intersects the ground at a small point on Earth's surface. Anyone on Earth within the small area covered by the tip of the Moon's shadow will, for a few minutes, be unable to see the Sun and will witness a total eclipse. At the same time, observers on a larger area of Earth's surface who are in the penumbra will see only a part of the Sun eclipsed by the Moon: we call this a partial solar eclipse. Between Earth's rotation and the motion of the Moon in its orbit, the tip of the Moon's shadow sweeps eastward at about 1500 kilometers per hour along a thin band across the surface of Earth. The thin zone across Earth within which a total solar eclipse is visible (weather permitting) is called the eclipse path. Within a region about 3000 kilometers on either side of the eclipse path, a partial solar eclipse is visible. It does not take long for the Moon's shadow to sweep past a given point on Earth. The duration of totality may be only a brief instant; it can never exceed about 7 minutes.

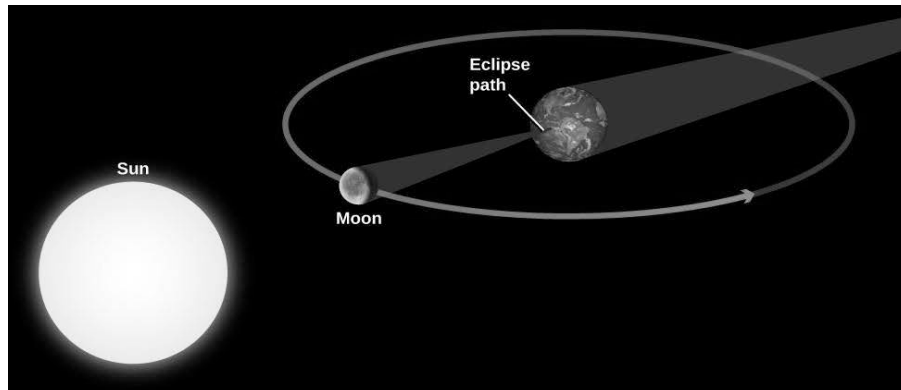


**Figure 2. Solar Eclipse.** (a) The shadow cast by a spherical body (the Moon, for example) is shown. Notice the dark umbra and the lighter penumbra. Four points in the shadow are labeled with numbers. In (b) you see what the Sun and Moon would look like in the sky at the four labeled points. At position 1, you see a total eclipse. At positions 2 and 3, the eclipse is partial. At position 4, the Moon is farther away and thus cannot cover the Sun completely; a ring of light thus shows around the Sun, creating what is called an “annular” eclipse.

[\(https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/\)](https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/)

What can you see if you are lucky enough to catch a total eclipse? A solar eclipse starts when the Moon just begins to silhouette itself against the edge of the Sun's disk. A partial phase follows, during which more and more of the Sun is covered by the Moon. About an hour after the eclipse begins, the Sun becomes completely hidden behind the Moon. In the few minutes immediately before this period of totality begins,

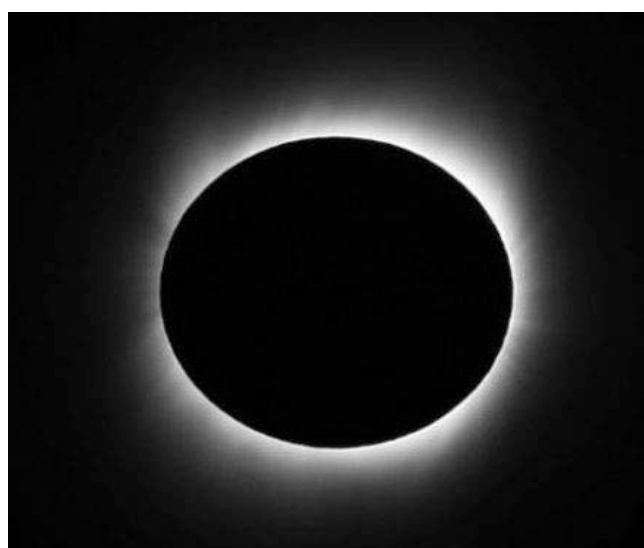
the sky noticeably darkens, some flowers close up, and chickens may go to roost. As an eerie twilight suddenly descends during the day, other animals (and people) may get disoriented. During totality, the sky is dark enough that planets become visible in the sky, and usually the brighter stars do as well. As the bright disk of the Sun becomes entirely hidden behind the Moon, the Sun's remarkable corona flashes.



**Figure 3. Geometry of a Total Solar Eclipse. The Sun is drawn at lower left and the Earth at upper right. Surrounding the Earth is a blue circle for the Moon's orbit, with the Moon drawn at a point directly between the Sun and Earth. The Earth's shadow is a dark grey cone extending from the night side of Earth toward the upper right, away from the Sun. The Moon's shadow is a dark grey cone extending from the night side of the Moon away from the Sun to a point on Earth's surface labeled**

*(<https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/>)*

The total phase of the eclipse ends, as abruptly as it began, when the Moon begins to uncover the Sun. Gradually, the partial phases of the eclipse repeat themselves, in reverse order, until the Moon has completely uncovered the Sun.



**Figure 3. The Sun's Corona. The corona (thin outer atmosphere) of the Sun is visible during a total solar eclipse. (It looks more extensive in photographs than it would to the unaided eye.) (credit: modification of work by Lutfar Rahman Nirjhar)**

*(<https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/>)*

We should make one important safety point here: while the few minutes of the total eclipse are safe to look at, if any part of the Sun is uncovered, you must protect your eyes with safe eclipse glasses or by projecting an image of the Sun (instead of looking at it directly).

*(From <https://openstax.org/details/books/astronomy>)*

## **Vocabulary**

apparent [ə'pær.ənt]	очевидний
a lunar eclipse ['lu:.nər ɪ'klɪps]	місячне затемнення
a cone [kəʊn]	конус
umbra ['ʌm.brə]	тінь
diffuse [dɪ'fju:z]	дифузний
penumbra [pɪ'nʌm.brə]	півтінь
plane [pleɪn]	площина
hula hoop ['hu:.lə, hu:p]	обруч
to vary ['veə.ri]	варіювати
aligned [ə'laɪnd]	вирівняні
to intersect [ɪn.tə'sekt]	перетинатися
eclipse path [ɪ'klɪps pɑ:θ]	шлях затемнення
instant ['ɪn.stənt]	миттєвий
to exceed [ɪk'si:d]	перевищувати
spectacular [spek'tæk.jə.lər]	видовищний
to brag about [bræg ə'baʊt]	хвалитися
to silhouette [ɪsɪl.u'et]	вимальовуватися (на тлі чого-небудь)
edge [edʒ]	край

totality [təʊ'tæl.ə.ti]	повне затемнення, фаза повного затемнення
to roost [ru:st]	сідати на сідал
eerie twilight ['iə.ri 'twaɪ.laɪt]	моторошні сутінки
to descend [dɪ'send]	спускатися
corona [kə'rəʊ.nə] plural	сонячна корона
coronae uk [-ni:]	
to flash flæʃ]	блимати

### Exercise 1. Answer the following questions

1. What do the Sun and the Moon have? 2. Why can the Moon be seen from Earth? 3. What does any solid object in the solar system do? 4. When does this shadow in space become apparent? 5. When can people see the Sun at least partially covered by the Moon? 6. What is called “a lunar eclipse”? 7. What does the shadow of Earth and the Moon consist of? 8. When do the most spectacular eclipses occur? 9. How is the Moon’s orbit tilted relative to the plane of Earth’s orbit? 10. What is the result of it? 11. What happens when the two paths cross? 12. Why does the Moon look slightly smaller than the Sun? 13. When can the Moon completely hide the Sun? 14. When does the total eclipse of the Sun occur? 15. When does the Moon’s darkest shadow intersect the ground at a small point on Earth’s surface? 16. What do we call a partial solar eclipse? 17. What does the tip of the Moon’s shadow do? 18. What is called the eclipse path? 19. Where is a partial solar eclipse visible? 20. What is the duration of totality? 21. When does the solar eclipse start? 22. What happens during the period of totality? 23. When does the Sun’s remarkable corona flash? 24. When does the total phase of eclipse end? 25. What is one important safety point here?

### Exercise 2. Find English equivalents in the text

два найвидатніших астрономічних об’єкта, мати однаковий видимий розмір, мати однаковий кутовий розмір, закривати Сонце, спостерігати сонячне затемнення, місячне затемнення, розсіяна область темряви, бачити затемнення Сонця та Місяця щомісяця, уникнути затемнення, повністю охопити, досягти поверхні Землі, бути правильно вирівняним, часткове сонячне затемнення, обертання Землі, рух Місяця по його орбіті, перевищити, зловити повне

затемнення, вимагують бути проти краю диска Сонця, стати повністю схованим, закінчитися раптово, відкрити Сонце, безпечні окуляри.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. The corona is the Sun's outer atmosphere, consisting of sparse gases	a) so at the Moon's distance (an average of 384,000 kilometers), it could cover about four full moons.
2. Only when the brilliant glare from the Sun's visible disk is blotted out by the Moon during a total eclipse	b) lunar eclipses are observed far more frequently from a given place on Earth than are solar eclipses.
3. A lunar eclipse occurs	c) its umbra is larger, so that lunar eclipses last longer than solar eclipses.
4. Earth's dark shadow is about 1.4 million kilometers long,	d) making the darkening even more dramatic.
5. Because a lunar eclipse can be seen (weather permitting) from the entire night side of Earth,	e) when the Moon enters the shadow of Earth.
6. But because Earth is larger than the Moon,	f) the pearly white corona is visible.
7. The Moon is opposite the Sun, which means the Moon will be in full phase before the eclipse,	g) and the sequence of events is reversed.
8. About 20 minutes before the Moon reaches the dark shadow,	h) how closely the Moon's path approaches the axis of the shadow.
9. As the Moon begins to dip into the shadow,	i) each partial phase consumes at least 1 hour, and totality can last as long as 1 hour and 40 minutes.
10. After totality, the Moon moves out of the shadow	j) that extend for millions of miles in all directions from the apparent surface of the Sun.
11. The total duration of the eclipse depends on	k) it dims somewhat as Earth partly blocks the sunlight.
12. For an eclipse where the Moon goes through the center of Earth's shadow,	l) the curved shape of Earth's shadow upon it soon becomes apparent.

#### **Exercise 4. Translate the following sentences into English**

1. Повне затемнення відбувається, якщо Місяць потрапляє у тінь Землі повністю, сонячне проміння упродовж певного часу взагалі не потрапляє безпосередньо до його поверхні.

2. Під час такого затемнення поверхня Місяця стає темно-червоною, але Місяць не зникає повністю.

3. темно-червоне забарвлення зумовлене слабким світлом, яке розсіюється крізь атмосферу Землі.

4. Природа цього явища подібна до природи заграви, завдяки якій небо є червоним деякий час після заходу і до сходу Сонця.

5. Для оцінки яскравості Місяця під час затемнення використовується шкала Данжона.

6. Часткове затемнення настає, коли у тінь потрапляє лише частина Місяця.

7. При такому типі затемнення, навіть в максимальній фазі, частина Місяця лишається в півтіні, і освітлюється прямими сонячними променями.

8. Якщо Місяць заходить тільки до напівтіні Землі, затемнення називають півтіньовим.

9. Такі затемнення малопомітні й їх фіксують лише за допомогою приладів.

10. Тривалість повного затемнення Місяця може бути різною, найбільше — 1 година 40 хвилин.

*(From [https://uk.wikipedia.org/wiki/Місячне\\_затемнення](https://uk.wikipedia.org/wiki/Місячне_затемнення))*

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

- A solar eclipse occurs when the Sun, the Moon, and Earth are aligned, or in syzygy.

- A solar eclipse only happens at New Moon.

- Eclipse totalities are different lengths.

*(<https://www.astronomy.com/observing/25-facts-you-should-know-about-the-total-solar-eclipse-on-april-8-2024/>)*

#### **Speaking**

- **Speak about the Sun and the Moon eclipses.**

- **Speak about myths of eclipses.**

- **Speak about types of solar eclipses.**

## Unit 6.

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

#### The Behavior of Light

Coded into the light and other kinds of radiation that reach us from objects in the universe is a wide range of information about what those objects are like and how they work. If we can decipher this code and read the messages it contains, we can learn an enormous amount about the cosmos without ever having to leave Earth or its immediate environment. The visible light and other radiation we receive from the stars and planets is generated by processes at the atomic level—by changes in the way the parts of an atom interact and move. Thus, to appreciate how light is generated, we must explore how atoms work. There is a bit of irony in the fact that in order to understand some of the largest structures in the universe, we must become acquainted with some of the smallest. Notice that we have twice used the phrase “light and other radiation.” One of the key ideas is that visible light is not unique; it is merely the most familiar example of a much larger family of radiation that can carry information to us. In everyday language, “radiation” is often used to describe certain kinds of energetic subatomic particles released by radioactive materials in our environment. (An example is the kind of radiation used to treat some cancers.) But this is not what we mean when we use the word “radiation” in an astronomy text. Radiation, as used in this book, is a general term for waves (including light waves) that radiate outward from a source. Newton’s theory



of gravity accounts for the motions of planets as well as objects on Earth. Application of this theory to a variety of problems dominated the work of scientists for nearly two centuries. In the nineteenth century, many physicists turned to the study of electricity and magnetism, which are intimately connected with the production of light. The scientist who played a role in this field comparable to Newton’s role in the study of gravity was physicist James Clerk Maxwell, born and educated in Scotland (Figure 1).

**Fig.1. James Clerk Maxwell (1831–1879)**

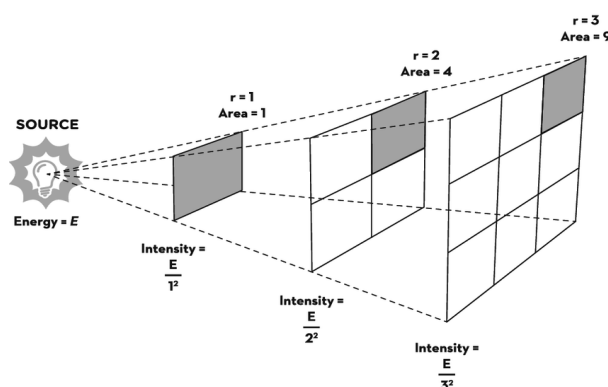
*(<https://www.researchgate.net/figure/Portrait-of-James-Clerk-Maxwell->)*

Inspired by a number of ingenious experiments that showed an intimate relationship between electricity and magnetism, Maxwell developed a theory that describes both electricity and magnetism with only a small number of elegant

equations. It is this theory that gives us important insights into the nature and behavior of light.

James Clerk Maxwell showed that whenever charged particles change their motion, as they do in every atom and molecule, they give off waves of energy. Light is one form of this electromagnetic radiation. The wavelength of light determines the color of visible radiation. Wavelength ( $\lambda$ ) is related to frequency ( $f$ ) and the speed of light ( $c$ ) by the equation  $c = \lambda f$ . Electromagnetic radiation sometimes behaves like waves, but at other times, it behaves as if it were a particle—a little packet of energy, called a photon. The apparent brightness of a source of electromagnetic energy decreases with increasing distance from that source in proportion to the square of the distance—a relationship known as the inverse square law.

## Inverse Square Law



**Fig.2. Visual propagation of light following the inverse square law**

[https://www.researchgate.net/figure/Visual-propagation-of-light-following-the-inverse-square-law\\_fig2\\_320926645](https://www.researchgate.net/figure/Visual-propagation-of-light-following-the-inverse-square-law_fig2_320926645)

The electromagnetic spectrum consists of gamma rays, X-rays, ultraviolet radiation, visible light, infrared, and radio radiation. Many of these wavelengths cannot penetrate the layers of Earth's atmosphere and must be observed from space, whereas others—such as visible light, FM radio and TV—can penetrate to Earth's surface. The emission of electromagnetic radiation is intimately connected to the temperature of the source. The higher the temperature of an idealized emitter of electromagnetic radiation, the shorter is the wavelength at which the maximum amount of radiation is emitted. The mathematical equation describing this relationship is known as Wien's law:  $\lambda_{\text{max}} = (3 \times 10^6) / T$ . The total power emitted per square meter increases with increasing temperature. The relationship between emitted energy flux and temperature is known as the Stefan-Boltzmann law:  $F = \sigma T^4$ .

**Spectroscopy in Astronomy.** A spectrometer is a device that forms a spectrum, often utilizing the phenomenon of dispersion. The light from an astronomical source can consist of a continuous spectrum, an emission (bright line) spectrum, or an

absorption (dark line) spectrum. Because each element leaves its spectral signature in the pattern of lines we observe, spectral analyses reveal the composition of the Sun and stars.

When electrons move from a higher energy level to a lower one, photons are emitted, and an emission line can be seen in the spectrum. Absorption lines are seen when electrons absorb photons and move to higher energy levels. Since each atom has its own characteristic set of energy levels, each is associated with a unique pattern of spectral lines. This allows astronomers to determine what elements are present in the stars and in the clouds of gas and dust among the stars. An atom in its lowest energy level is in the ground state. If an electron is in an orbit other than the least energetic one possible, the atom is said to be excited. If an atom has lost one or more electrons, it is called an ion and is said to be ionized. The spectra of different ions look different and can tell astronomers about the temperatures of the sources they are observing.

If an atom is moving toward us when an electron changes orbits and produces a spectral line, we see that line shifted slightly toward the blue of its normal wavelength in a spectrum. If the atom is moving away, we see the line shifted toward the red. This shift is known as the Doppler effect and can be used to measure the radial velocities of distant objects.

*(From <https://openstax.org/details/books/astronomy>)*

## Vocabulary

to decipher [dɪ'saɪ.fər]	розшифрувати
to become acquainted [brɪ'kʌm ə'kwem.tɪd]	ознайомитись
unique [ju:'ni:k]	унікальний
outward ['aʊt.wəd]	назовні
to account for	відноситися до
ingenious [ɪn'dʒi:.ni.əs]	геніальний
flux [flʌks]	потік
dispersion [dɪ'spɜ:.ʃən]	дисперсія
radical ['ræd.ɪ.kəl]	радикальний

### **Exercise 1. Answer the following questions**

1. How is the visible light and other radiation we receive from the stars and planets generated? 2. Is the visible light unique? 3. How is the word “radiation” used in everyday language? 4. Does it have the same meaning in an astronomy text? 5. What does Newton’s theory of gravity account for? 6. When did many physicists turn to the study of electricity and magnetism? 7. Who played a role in this field comparable to Newton’s role in the study of gravity? 8. What did Maxwell develop? 9. What does Maxwell’s theory give us? 10. What did James Clerk Maxwell show? 11. What is light? 12. What does the wavelength of light determine? 13. How does electromagnetic radiation behave? 14. What is a relationship known as the inverse square law? 15. What does electromagnetic spectrum consist of? 16. How can many of these wavelengths be observed? 17. What is intimately connected to the temperature of the source? 18. What is known as Wien’s law? 19. What is the relationship between emitted energy flux and temperature? 20. What is a spectrometer? 21. What can the light from an astronomical source consist of? 22. What do spectral analyses reveal? 23. When are photons emitted? 24. What is associated with a unique pattern of spectral lines? 25. What does the spectral analysis allow astronomers to determine? 26. When is an atom said to be excited? 27. What is called an ion? 28. What can the spectra of different ions tell astronomers? 29. When is the line shifted slightly toward the blue of its normal wavelength in a spectrum? 30. What can Doppler effect be used to measure?

### **Exercise 2. Find English equivalents in the text**

широкий спектр інформації, безпосереднє оточення, як генерується світло, найбільші структури у Всесвіті, описати певні види енергетичних субатомних частинок, пояснення теорії гравітації, різноманітні проблеми, вивчення гравітації, розробити теорію, лише з невеликою кількістю елегантних рівнянь, важливі відомостей про природу та поведінку світла, випромінювання хвиль енергії, визначення кольору видимого випромінювання, закон обернених квадратів, проникнення в шари земної атмосфери, використовувати явище дисперсії, виявити склад Сонця та зірок, перейти до вищих енергетичних рівнів, унікальний малюнок спектральних ліній, у хмарах газу та пилу серед зірок, бути іонізованим, спектри різних іонів, трохи зміщувати, вимірювати радіальні швидкості віддалених об’єктів.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. Light is	a) beginning in the 1600s, of a practical science of optics and optical instrument design.
2. The speed of light in a vacuum is	b) with electromagnetic radiation of a certain range of wavelengths visible to the human eye.
3. A rainbow is formed	c) electromagnetic radiation that can be detected by the human eye.
4. Light from the Sun warms the Earth, drives global weather patterns, and	d) and temporal information.
5. In physics colour is associated specifically	e) a fundamental physical constant, and the currently accepted value is 299,792,458 metres per second, or about 186,282 miles per second.
6. Light transmits spatial	f) initiates the life-sustaining process of photosynthesis; about 1022 joules of solar radiant energy reach Earth each day.
7. In most everyday circumstances, the properties of light	g) when sunlight is refracted by spherical water droplets in the atmosphere; two refractions and one reflection, combined with the chromatic dispersion of water, produce the primary arcs of colour.
8. At that level a quantum theory is needed	h) can be derived from the theory of classical electromagnetism, in which light is described as coupled electric and magnetic fields propagating through space as a traveling wave.
9. A detailed understanding of the nature of light was not needed for the development,	i) the apparent frequency of sound waves from an approaching source is greater than the frequency emitted by the source and that the apparent frequency of a receding source is lower.

10. The basic element in geometrical optics is	j) to explain the characteristics of light and to explain the interactions of light with atoms and molecules.
11. Through his careful investigation of the refraction of white light as it passed through a glass prism, Newton was famously credited with	k) the light ray, a hypothetical construct that indicates the direction of the propagation of light at any point in space.
12. In 1842 Austrian physicist Christian Doppler established that	l) the discovery that white light consists of a spectrum of colours.

#### Exercise 4. Translate the following sentences into English

1. Всі джерела світла випромінюють безколірові пучки променів, які людина називає світлом.

2. Світло – це електромагнітні хвилі видимого спектру. У видимий діапазон входять електромагнітні хвилі що сприймаються людським оком, це вкладається в інтервал частот  $7,5 \times 10^{14}$  –  $4 \times 10^{14}$  Гц і довжину хвилі від 390 до 750 нанометрів.

3. У фізиці термін «світло» охоплює ще інфрачервоні та ультрафіолетові області спектру.

4. У XVII столітті виникає перша наукова теорія, яка пояснює, як розкладається світло на кольоровий спектр. Ця теорія актуальна і до сьогодні. Її розробником був І. Ньютон (1642-1726) – один з найвидатніших фізиків і математиків епохи Просвітництва.

5. Розглянувши спектр сонячного променю, можна у ньому розрізнити сім кольорів, які плавно переходять один у другий: червоний, оранжевий, жовтий, зелений, блакитний, синій і фіолетовий.

6. Було встановлено що кольори спектру завжди знаходяться у певній послідовності.

7. Світловий потік – це частина потоку променів, яка сприймається людиною як світло і характеризується потужністю світлового випромінювання.

8. Сила світла – це щільність світлового потоку і просторі.

9. Освітленість – це щільність світла на поверхні об'єкта.

10. Яскравість – це відношення сили світла до площі поверхні.

(From <https://suzirya.org/2020/14/philosophy/480>)

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

- The Greek philosopher was not completely wrong. Like all living things, humans are bioluminescent: We glow. We are brightest during the afternoon, around our lips and cheeks. The cause may be chemical reactions involving molecular fragments known as free radicals.

- Bioluminescence is the largest source of light in the oceans; 90 percent of all creatures who live below about 1,500 feet are luminous.

- World War II aviators used to spot ships by the bioluminescence in their wakes. In 1954 Jim Lovell (later the pilot of Apollo 13) used this trick to find his darkened aircraft carrier.

*(<https://www.discovermagazine.com/the-sciences/20-things-you-didnt-know-about-light>)*

### **Speaking**

- Speak about the behavior of light.
- Speak about the radiation and spectra.
- Speak about spectroscopy in astronomy.

## **Unit 7.**

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

#### **Telescopes**

There are three basic components of a modern system for measuring radiation from astronomical sources. First, there is a telescope, which serves as a “bucket” for collecting visible light (or radiation at other wavelengths).

Just as you can catch more rain with a garbage can than with a coffee cup, large telescopes gather much more light than your eye can. Second, there is an instrument attached to the telescope that sorts the incoming radiation by wavelength. Sometimes the sorting is fairly crude. For example, we might simply want to separate blue light from red light so that we can determine the temperature of a star. But at other times, we want to see individual spectral lines to determine what an object is made of, or to measure its speed. Third, we need some type of detector, a device that senses the

radiation in the wavelength regions we have chosen and permanently records the observations.

The history of the development of astronomical telescopes is about how new technologies have been applied to improve the efficiency of these three basic components: the telescopes, the wavelength-sorting device, and the detectors. Let's first look at the development of the telescope. Many ancient cultures built special sites for observing the sky (Figure 1).

At these ancient observatories, they could measure the positions of celestial objects, mostly to keep track of time and date. Many of these ancient observatories had religious and ritual functions as well. The eye was the only device available to gather light, all of the colors in the light were observed at once, and the only permanent record of the observations was made by human beings writing down or sketching what they saw.



**Fig.1. Machu Picchu is a fifteenth century Incan site located in Peru.**

*(<https://unsplash.com/s/photos/machu-picchu>)*

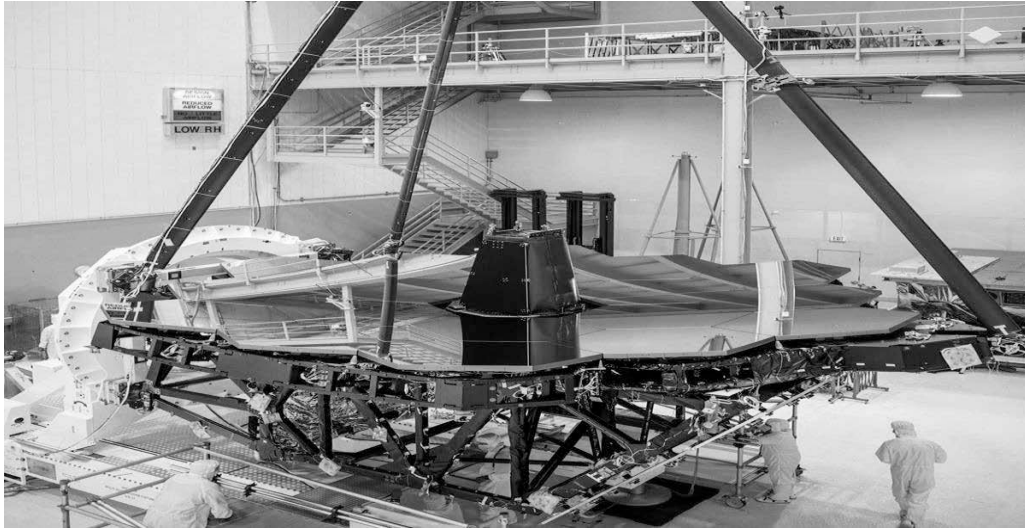
While Hans Lippershey, Zaccharias Janssen, and Jacob Metius are all credited with the invention of the telescope around 1608—applying for patents within weeks of each other—it was Galileo who, in 1610, used this simple tube with lenses (which he called a spyglass) to observe the sky and gather more light than his eyes alone could. Even his small telescope—used over many nights—revolutionized ideas about the nature of the planets and the position of Earth.

Telescopes have come a long way since Galileo's time. Now they tend to be huge devices; the most expensive cost hundreds of millions to billions of dollars. The reason astronomers keep building bigger and bigger telescopes is that celestial objects—such as planets, stars, and galaxies—send much more light to Earth than any

human eye (with its tiny opening) can catch, and bigger telescopes can detect fainter objects. The most important functions of a telescope are (1) to collect the faint light from an astronomical source and (2) to focus all the light into a point or an image. Most objects of interest to astronomers are extremely faint: the more light we can collect, the better we can study such objects. Telescopes that collect visible radiation use a lens or mirror to gather the light. Other types of telescopes may use collecting devices that look very different from the lenses and mirrors with which we are familiar, but they serve the same function. In all types of telescopes, the light-gathering ability is determined by the area of the device acting as the light-gathering “bucket.” Since most telescopes have mirrors or lenses, we can compare their light-gathering power by comparing the apertures, or diameters, of the opening through which light travels or reflects. The amount of light a telescope can collect increases with the size of the aperture. A telescope with a mirror that is 4 meters in diameter can collect 16 times as much light as a telescope that is 1 meter in diameter. (The diameter is squared because the area of a circle equals  $\pi d^2 / 4$ , where  $d$  is the diameter of the circle.)

After the telescope forms an image, we need some way to detect and record it so that we can measure, reproduce, and analyze the image in various ways. Before the nineteenth century, astronomers simply viewed images with their eyes and wrote descriptions of what they saw. This was very inefficient and did not lead to a very reliable long-term record; you know from crime shows on television that eyewitness accounts are often inaccurate. In the nineteenth century, the use of photography became widespread. In those days, photographs were a chemical record of an image on a specially treated glass plate. Today, the image is generally detected with sensors similar to those in digital cameras, recorded electronically, and stored in computers. This permanent record can then be used for detailed and quantitative studies. Professional astronomers rarely look through the large telescopes that they use for their research.

Astronomers and engineers are working on the technologies that will allow us to explore even more distant parts of the universe and to see them more clearly (Fig.2). These powerful new instruments will enable astronomers to tackle many important astronomical problems. For example, they should be able to tell us when, where, and how often planets form around other stars.



**Fig.2. Webb's telescope structure fully deployed in the clean room at NASA Goddard. Credit: NASA, Chris Gunn.**

*(<https://webbtelescope.org/news/milestones/mission-timeline#:~:text=Construction%20on%20Webb%20began%20in,testing%20to%20meet%20required%20specifications>)*

They should even be able to provide us images and spectra of such planets and thus, perhaps, give us the first real evidence (from the chemistry of these planets' atmospheres) that life exists elsewhere.

*(From <https://openstax.org/details/books/astronomy>)*

## Vocabulary

to measure ['meʒ.ər]	вимірювати
bucket ['bʌk.ɪt]	відро
garbage ['gɑː.bɪdʒ]	сміття
crude [kruːd]	непродуманий
to be credited with	відносити до чийось досягнень
a spyglass ['spaɪ.glɑːs]	підзорна труба
fainter [feɪntə]	слабкіше
aperture ['æp.ə.tʃər]	діафрагма
inaccurate [ɪn'æk.jə.rət]	неточно
quantitative ['kwɒn.tɪ.tə.tɪv]	кількісний
to tackle ['tæk.əl]	вирішувати
evidence ['ev.ɪ.dəns]	докази

### Exercise 1. Answer the following questions

1. What are three basic components of a modern system for measuring radiation from astronomical sources? 2. What is the history of the development of astronomical telescopes about? 3. What have many ancient cultures done? 4. What could they do in the ancient observatories? 5. Did many of these ancient observatories have religious and ritual functions as well? 6. How were observations made at that time? 7. Who is credited with the invention of the telescope? 8. What did Galileo do? 9. Have telescopes come a long way since Galileo's time? 10. Why do astronomers keep building bigger and bigger telescopes? 11. What are the most important function of a telescope? 12. What do telescopes use? 13. What determines the light-gathering ability in telescopes? 14. Does the amount of light a telescope can collect increase with the size of the aperture? 15. What happens after the telescope form an image? 16. How did early astronomers analyzed the images? 17. In the nineteenth century photographs were a chemical record of an image on a specially treated glass plate, weren't they? 18. How is the image detected today? 19. What are astronomers and engineers working on? 20. What will these powerful instruments enable astronomers to tackle?

### Exercise 2. Find English equivalents in the text

вимірювати випромінювання від астрономічних джерел, збирати видиме світло, інструмент, прикріплений до телескопа; сортувати вхідне випромінювання за довжиною хвилі, бути досить грубим, визначати температуру зірки, постійно записувати спостереження, покращувати ефективність, стародавні культури, спостерігати за небом, вимірювати положення небесних об'єктів, виконувати релігійні і ритуальні функції, малювання, приписують винайдення телескопа, використання простої труби з лінзами, спостерігати за небом, мільярди доларів, можуть виявляти слабкіші об'єкти, збирати видиме випромінювання, виконувати ті самі функції, розмір апертури, вимірювати, відтворювати та аналізувати зображення різними способами; дуже надійний довгостроковий запис, хімічний запис зображення, можна використовувати для детальних і кількісних досліджень, вирішення багатьох важливих астрономічних проблем, отримати зображення і спектри таких планет.

### Exercise 3. Match up the half of the sentence on the left with its ending on the right

1. A telescope collects the faint light from astronomical sources	a) clear weather, dark skies, low water vapor, and excellent atmospheric seeing (low atmospheric turbulence).
2. Light is then directed to a detector,	b) by turbulence in Earth's atmosphere.

3. The light-gathering power of a telescope is determined	c) a radio antenna (often a large, curved dish) connected to a receiver.
4. The site for an astronomical observatory must be carefully chosen for	d) by the diameter of its aperture, or opening—that is, by the area of its largest or primary lens or mirror.
5. The resolution of a visible-light or infrared telescope is degraded	e) and brings it to a focus, where an instrument can sort the light according to wavelength.
6. Visible-light detectors include the	f) are the premier X-ray and gamma-ray observatories, respectively.
7. A spectrometer disperses the light into a spectrum	g) human eye, photographic film, and charge-coupled devices (CCDs).
8. A radio telescope is basically	h) to be recorded for detailed analysis.
9. Infrared observations are made with telescopes aboard aircraft and in space,	i) as well as from ground-based facilities on dry mountain peaks.
10. The largest-aperture telescope in space is the Hubble Space telescope (HST), the most significant infrared telescope is Spitzer, and Chandra and Fermi	j) and a new generation of visible-light/infrared telescopes with apertures of 24.5 to 39 meters in diameter.
11. The James Webb Space Telescope, a 6-meter successor to Hubble	k) where a permanent record is made.
12. Astronomers are building the LSST to observe with an unprecedented field of view	l) was scheduled for launch in 2018.

#### Exercise 4. Translate the following sentences into English

1. Два основних тренди сучасної астрономії полягають у дослідженні екзопланет і віддалених галактик.

2. У другому випадку необхідні справді великі телескопи.

3. Від джерел світла, розташованих дуже далеко, до нас долітає надзвичайно мало фотонів, тому вони мають більш тьмянний вигляд, ніж небесні тіла порівнюваної світності, розташовані ближче.

4. Щоб їх зареєструвати, необхідно довго накопичувати слабе світло, що йде від них.

5. До того ж поверхня, яка його “ловить”, повинна мати якомога більшу площу.

6. Hubble вже надав нам деякі цікаві відомості про це: саме йому належать зображення найвіддаленіших відомих галактик.

7. Знаходити найбільш ранні галактики складно ще й тому, що вони віддалені від нас на колосальну відстань і до того ж за розмірами набагато менші навіть за карликові системи в наших найближчих околицях.

8. Для їхнього виявлення необхідні інструменти нового покоління, які вже отримали назву “надзвичайно великих телескопів”: їхньої потужності повинно вистачити, щоб вивчити більш ранню епоху еволюції Всесвіту – коли найперші галактичні структури тільки починали формуватися.

9. Не так важливо отримати зображення найвіддаленіших галактик, як побачити різницю між ними – саме за такими відмінностями можна відстежити, коли в них починаються процеси формування зірок, коли самі галактики починають взаємодіяти між собою тощо.

10. Для цього необхідно порівняти спектри різних галактик і їхніх частин.

*(<http://www.streetastronomy.com.ua/articles/teleskopy-novogo-pokolinnya-yakoyu-bude-astronomiya-majbutnogo.html>)*

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

- Almost all modern scientific telescopes are networked to the internet, enabling astronomers to easily access their data and control them remotely.

- Telescopes can be separated in several categories, most notably type of its mount and electromagnetic spectrum it is observing (Optical, Radio, X-Ray, Gamma-ray and high-energy particle telescopes).

- Scientific telescopes are not always solitary instruments. They can be built as large arrays of telescopes that collect visible light or radio signals over large distances. The most famous telescope observatory of that type is Very Large Array (VLA) in New Mexico. It has 27 antennae with dish diameters of 25m.

*(<http://www.historyoftelescope.com/telescope-facts/interesting-facts-about-telescopes/>)*

### **Speaking**

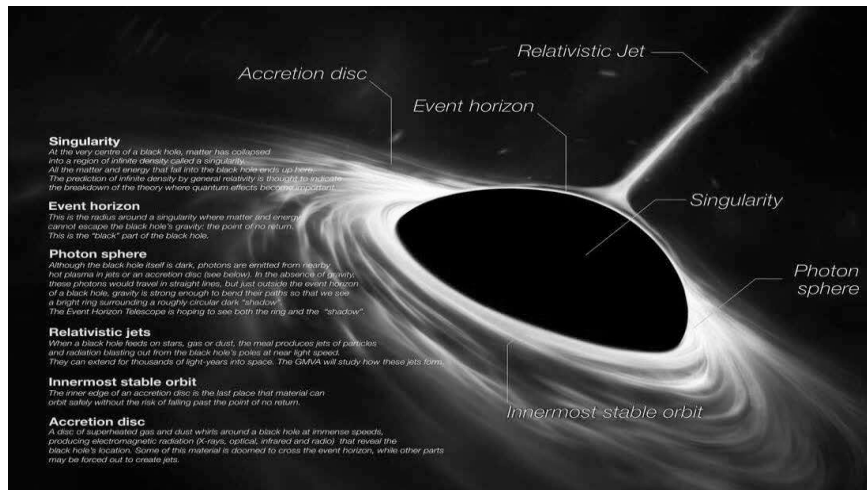
- Speak about the history of the development of telescopes.
- Speak about types of telescopes.
- Speak about modern telescopes.

## Unit 8.

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

#### Black Holes and Curved Spacetime

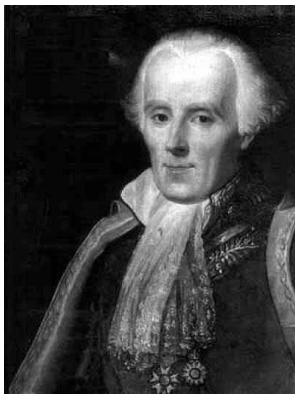
Let's begin with a thought experiment. We want to know what speeds are required to escape from the gravitational pull of different objects. A rocket must be launched from the surface of Earth at a very high speed if it is to escape the pull of Earth's gravity. In fact, any object—rocket, ball, astronomy book—that is thrown into the air with a velocity less than 11 kilometers per second will soon fall back to Earth's surface. Only those objects launched with a speed greater than this escape velocity can get away from Earth. The escape velocity from the surface of the Sun is higher yet—618 kilometers per second. Now imagine that we begin to compress the Sun, forcing it to shrink in diameter. Recall that the pull of gravity depends on both the mass that is pulling you and your distance from the center of gravity of that mass. If the Sun is compressed, its mass will remain the same, but the distance between a point on the Sun's surface and the center will get smaller and smaller. Thus, as we compress the star, the pull of gravity for an object on the shrinking surface will get stronger and stronger. When the shrinking Sun reaches the diameter of a neutron star (about 20 kilometers), the velocity required to escape its gravitational pull will be about half the speed of light. Suppose we continue to compress the Sun to a smaller and smaller diameter. (We saw this can't happen to a star like our Sun in the real world because of electron degeneracy, i.e., the mutual repulsion between tightly packed electrons; this is just a quick "thought experiment" to get our bearings). Ultimately, as the Sun shrinks, the escape velocity near the surface would exceed the speed of light. If the speed you need to get away is faster than the fastest possible speed in the universe, then nothing, not even light, is able to escape. An object with such large escape velocity emits no light, and anything that falls into it can never return. In modern terminology, we call an object from which light cannot escape a black hole, a name popularized by the American scientist John Wheeler starting in the late 1960s (Figure 1).



**Fig. 1. This artist's impression depicts a rapidly spinning supermassive black hole surrounded by a thin disc of rotating material, the leftovers of a Sun-like star.**

*ESO, ESA/Hubble, M. Kornmesser/N. Bartmann*

<https://www.npr.org/2023/04/13/1169469591/goodbye-fuzzy-donut-the-famous-first-black-hole-photo-gets-sharpened-up>



**Fig. 2. John Michel**

**(1724-1793)**

<https://ar.inspiredpencil.com/pictures-2023/john-mitchell-black-holes>

The idea that such objects might exist is, however, not a new one. Cambridge professor and amateur astronomer John Michell wrote a paper in 1783 about the possibility that stars with escape velocities exceeding that of light might exist. And in 1796, the French mathematician Pierre-Simon, marquis de Laplace, made similar calculations using Newton's theory of gravity; he called the resulting objects "dark bodies."

While these early calculations provided strong hints that something strange should be expected if very massive objects collapse under their own gravity, we really need general relativity theory to give an adequate description of what happens in such a situation.

General relativity tells us that gravity is really a curvature of spacetime. As gravity increases (as in the collapsing Sun of our thought experiment), the curvature gets larger and larger. Eventually, if the Sun could shrink down to a diameter of about 6 kilometers, only light beams sent out perpendicular to the surface would escape. All others would fall back onto the star. If the Sun could then shrink just a little more, even that one remaining light beam would no longer be able to escape collapsing star is a black hole in this view, because the very concept of "out" has no geometrical meaning.

The star has become trapped in its own little pocket of spacetime, from which there is no escape. The star's geometry cuts off communication with the rest of the universe at precisely the moment when, in our earlier picture, the escape velocity becomes equal to the speed of light. The size of the star at this moment defines a surface that we call the event horizon. It's a wonderfully descriptive name: just as objects that sink below our horizon cannot be seen on Earth, so anything happening inside the event horizon can no longer interact with the rest of the universe.



**Fig.2. Karl Schwarzschild**  
(1873-1916)

<https://mathshistory.st-andrews.ac.uk/Biographies/Schwarzschild/pictdisplay/>

Events inside the event horizon can never again affect events outside it. The characteristics of an event horizon were first worked out by astronomer and mathematician Karl Schwarzschild (Figure 2). A member of the German army in World War I, he died in 1916 of an illness he contracted while doing artillery shell calculations on the Russian front. His paper on the theory of event horizons was among the last things he finished as he was dying; it was the first exact solution to Einstein's equations of general relativity. The radius of the event horizon is called the Schwarzschild radius in his memory.

The event horizon is the boundary of the black hole; calculations show that it does not get smaller once the whole star has collapsed inside it. It is the region that separates the things trapped inside it from the rest of the universe. Anything coming from the outside is also trapped once it comes inside the event horizon. The horizon's size turns out to depend only on the mass inside it. If the Sun, with its mass of  $1 M_{\text{Sun}}$ , were to become a black hole (fortunately, it can't—this is just a thought experiment), the Schwarzschild radius would be about 3 kilometers; thus, the entire black hole would be about one-third the size of a neutron star of that same mass. Feed the black hole some mass, and the horizon will grow—but not very much.

Doubling the mass will make the black hole 6 kilometers in radius, still very tiny on the cosmic scale. The event horizons of more massive black holes have larger radii. For example, if a globular cluster of 100,000 stars (solar masses) could collapse to a black hole, it would be 300,000 kilometers in radius, a little less than half the radius of the Sun. If the entire Galaxy could collapse to a black hole, it would be only about 10<sup>12</sup> kilometers in radius—about a tenth of a light year. Smaller masses have

correspondingly smaller horizons: for Earth to become a black hole, it would have to be compressed to a radius of only 1 centimeter—less than the size of a grape. A typical asteroid, if crushed to a small enough size to be a black hole, would have the dimensions of an atomic nucleus.

General relativity predicts that the rearrangement of matter in space should produce gravitational waves. The existence of such waves was first confirmed in observations of a pulsar in orbit around another neutron star whose orbits were spiraling closer and losing energy in the form of gravitational waves. In 2015, LIGO found gravitational waves directly by detecting the signal produced by the merger of two stellar-mass black holes, opening a new window on the universe.

*(From <https://openstax.org/details/books/astronomy>)*

## Vocabulary

to shrink /ʃrɪŋk/	скорочуватися
a neuron /'njʊə.rən/	нейрон
degeneracy /dɪ'dʒen.ər.ə.si/	виродження
repulsion /rɪ'pʌl.ʃən/	відштовхування
to get our bearings /'beə.rɪŋz/	зорієнтуватися
to exceed /ɪk'si:d/	перевищувати
a leftover /'left.əʊ.vər/	залишки
marquis /'mɑ:.kwɪs/	маркіз
a light beam	світловий промінь
precisely /prɪ'saɪs.li/	точно
shell	оболонка
scale	масштаб
a globular cluster /'glɒb.jə.lər 'klʌs.tər/	кульове скупчення
LIGO (Laser Interferometer Gravitational-Wave Observatory)	лазерно-інтерферометрична гравітаційно-хвильова обсерваторія
merger /'mɜ:.dʒər/	злиття
curvature /'kɜ:.və.tʃər/	викривлення

## **Exercise 1. Answer the following questions**

1. What speed must a rocket be launched from the surface of Earth if it is to escape the pull of Earth's gravity? 2. What speed should any object have to escape the pull of gravity? 3. What is the escape velocity from the surface of the Sun? 4. What will happen if the Sun is compressed? 5. When will the velocity required to escape its gravitational pull be about half the speed of light? 6. What is electron degeneracy? 7. When would the escape velocity near the surface exceed the speed of light? 8. When isn't light able to escape? 9. What do we call such an object in modern terminology? 10. Who was this name popularized by? 11. What did John Michel write? 12. Who made similar calculations using Newton's theory of gravity? 13. Do we really need general relativity theory to give an adequate description of what happens in such a situation? 14. What does general relativity tell us? 15. What happens as gravity increases? 16. What would happen if the Sun could shrink down to a diameter of about 6 kilometers? 17. When does the star's geometry cut off communication? 18. What does the size of the star at this moment define? 19. Events inside the event horizon can never again affect events outside it, can't they? 20. Who were the characteristics of an event horizon first worked out? 21. What is called the Schwarzschild radius? 22. What is the event horizon? 23. The horizon's size turns out to depend only on the mass inside it, doesn't it? 24. Will doubling the mass make the black hole 6 kilometers in radius? 25. Do smaller masses have correspondingly smaller horizons? 26. When could a typical asteroid be a black hole? 27. What does general relativity predict? 28. When was the existence of such waves first confirmed? 29. What did LIGO find in 2015?

## **Exercise 2. Find English equivalents in the text**

уявний експеримент, уникнути впливу гравітації різних об'єктів, уникнути впливу сили тяжіння Землі, зменшитися в діаметрі, відстань від центру ваги цієї маси, досягти діаметра нейтронної зірки, взаємне відштовхування між щільно упакованими електронами, перевищити швидкість світла, уникнути чорної діри, дати адекватний опис, викривлення простору-часу, один промінь світла, що залишився; власна маленька кишеня простору-часу, решта Всесвіту, горизонт подій, дивовижна описова назва, перше точне рішення рівнянь загальної теорії відносності Ейнштейна, межа чорної діри, решти Всесвіту, стати чорною дірою, дуже крихтітна в космічному масштабі, кульове скупчення із 100 000 зірок, руйнуватися до чорної діри, мати розміри атомного ядра, перегрупування матерії в просторі, створювати гравітаційні хвилі, шляхом виявлення сигналу, нове вікно у Всесвіті.

**Exercise 3. Match up the half of the sentence on the left with its ending on the right**

1. Black Holes Theory suggests that stars with stellar cores more massive than three times the mass of the Sun at the time they exhaust their nuclear fuel	a) a point of infinite density and zero volume.
2. The surface surrounding a black hole, where the escape velocity equals the speed of light,	b) nothing sticks out of a black hole to give us clues about what kind of star produced it or what material has fallen inside.
3. Nothing, not even light,	c) we would pass through the event horizon.
4. At its center, each black hole is thought to have a singularity,	d) will collapse to become black holes.
5. Matter falling into a black hole appears, as viewed by an outside observer,	e) indicate that the mass of its invisible companion is greater than $3M_{\text{Sun}}$ .
6. However, if we were riding on the infalling matter,	f) can escape through the event horizon from the black hole.
7. As we approach the singularity,	g) is called the event horizon, and the radius of the surface is called the Schwarzschild radius.
8. The best evidence of stellar-mass black holes comes from binary star systems in which (1) one star of the pair is not visible, (2) the flickering X-ray emission is characteristic of an accretion disk around a compact object, and (3) the orbit and characteristics of the visible star	h) are found in the centers of large galaxies.
9. Black holes with masses of millions to billions of solar masses	i) its mass, its spin (rotation), and whether it has any electrical charge.

10. Physicists like to say “black holes have no hair,” meaning that	j) that black holes go about sucking things up with their gravity.
11. The only information a black hole can reveal about itself is	k) the tidal forces would tear our bodies apart even before we reach the singularity.
12. Much of the modern folklore about black holes is misleading. One idea you may have heard is	l) to freeze in position at the event horizon.

#### Exercise 4. Translate the following sentences into English

1. Чорна діра — це об'єкт, гравітація якого настільки сильна, що жодна з частинок не може його покинути.
2. Одностороння межа у просторі-часі навколо чорної діри, яку не здатне перетнути навіть світло, називається горизонтом подій.
3. Вважається, що всередині чорної діри існує сингулярність — нескінченно стиснута область, у якій гравітаційне поле стає нескінченним, а неперервна геометрія простору-часу зникає.
4. Жодний з відомих нам законів фізики у цій точці не буде діяти.
5. Чорні діри — розповсюджені об'єкти у астрофізиці та мають широкий спектр мас.
6. Найменші з них — чорні діри зоряної маси, які утворюються внаслідок гравітаційного колапсу масивної зірки.
7. Їхня маса лежить у діапазоні від 5 до 10 сонячних мас.
8. Надмасивні чорні діри з масами від одного мільйона сонячних існують у центрах майже усіх великих галактик.
9. У центрі Чумацького Шляху також є така діра, вона називається Стрілець А\*, її маса еквівалентна приблизно 4 мільйонам сонячних.
10. Механізм формування таких об'єктів лишається загадкою для вчених. Вважається, що надмасивні чорні діри з'являються на світ одночасно з галактиками, у яких вони формуються.

*(<https://nauka.ua/card/shcho-take-chorna-dira>)*

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

- If you fell into a black hole, you would never escape.
- If you got really close to a black hole, anything that passes too close, from a wandering star to a photon of light, or even a human, gets captured. Scientists call this point of no return around a black hole the event horizon. The closest known black hole to Earth is believed to be 1,000 light-years away, so don't fret — we are not getting sucked in.

*(<https://new.nsf.gov/science-matters/5-black-hole-facts-blow-your-mind>)*

**Speaking**

- Speak about Black Holes.
- Speak about a Black Hole Myth.
- Speak about Space time and Gravity.

**Unit 9.**

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

**Life in the Universe**

As we have learned more about the universe, we have naturally wondered whether there might be other forms of life out there. The ancient question, “Are we alone in the universe?” connects us to generations of humans before us. While in the past, this question was in the realm of philosophy or science fiction, today we have the means to seek an answer through scientific inquiry. In this lesson, we will consider how life began on Earth, whether the same processes could have led to life on other worlds, and how we might seek evidence of life elsewhere. This is the science of astrobiology. The search for life on other planets is not the same as the search for intelligent life, which (if it exists) is surely much rarer. Learning more about the origin, evolution, and properties of life on Earth aids us in searching for evidence of all kinds of life beyond that on our planet.

The universe was born in the Big Bang about 14 billion years ago. After the initial hot, dense fireball of creation cooled sufficiently for atoms to exist, all matter consisted of hydrogen and helium (with a very small amount of lithium). As the universe aged, processes within stars created the other elements, including those that

make up Earth (such as iron, silicon, magnesium, and oxygen) and those required for life as we know it, such as carbon, oxygen, and nitrogen. These and other elements combined in space to produce a wide variety of compounds that form the basis of life on Earth. In particular, life on Earth is based on the presence of a key unit known as an organic molecule, a molecule that contains carbon. Especially important are the hydrocarbons, chemical compounds made up entirely of hydrogen and carbon, which serve as the basis for our biological chemistry, or biochemistry. While we do not understand the details of how life on Earth began, it is clear that to make creatures like us possible, events like the ones we described must have occurred, resulting in what is called the chemical evolution of the universe.

What Made Earth Hospitable to Life? About 5 billion years ago, a cloud of gas and dust in this cosmic neighborhood began to collapse under its own weight. Out of this cloud formed the Sun and its planets, together with all the smaller bodies, such as comets, that also orbit the Sun (Figure 1). The third planet from the Sun, as it cooled, eventually allowed the formation of large quantities of liquid water on its surface.

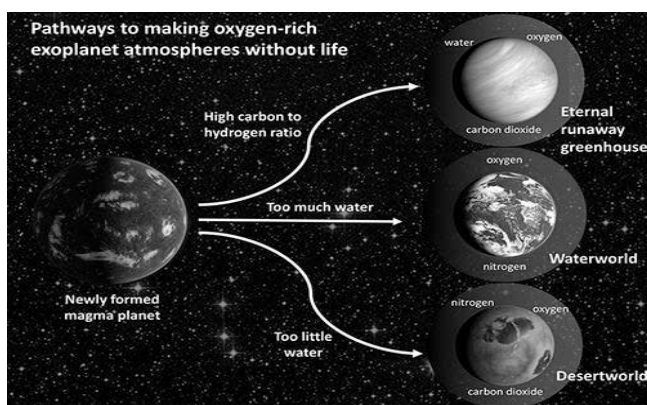


**Fig.1. Comet Hyakutake. Comet impacts can deliver both water and a variety of interesting chemicals, including some organic chemicals, to Earth.**

*(<https://www.mreclipse.com/Comets/Hyakutake/HY96-211w.JPG>)*

The chemical variety and moderate conditions on Earth eventually led to the formation of molecules that could make copies of themselves (reproduce), which is essential for beginning life. Over the billions of years of Earth history, life evolved and became more complex. The course of evolution was punctuated by occasional planet wide changes caused by collisions with some of the smaller bodies that did not make it into the Sun or one of its accompanying worlds. Mammals may owe their domination of Earth's surface to just such a collision 65 million years ago, which led to the extinction of the dinosaurs (along with the majority of other living things). The details of such mass extinctions are currently the focus of a great deal of scientific interest.

Through many twisting turns, the course of evolution on Earth produced a creature with self-



**Fig.2. Pathways to making oxygen-rich exoplanet atmospheres without life.**

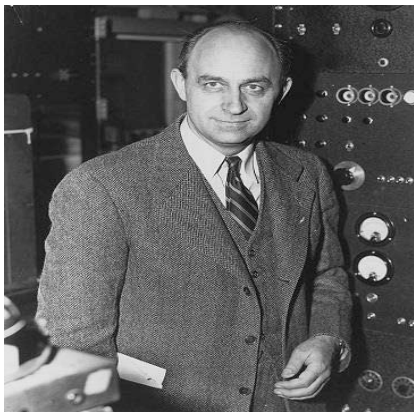
*(Illustration by J. Krissansen-Totton).*  
<https://news.ucsc.edu/2021/04/exoplanet-atmospheres.html>

consciousness, able to ask questions about its own origins and place in the cosmos. Like most of Earth, this creature is composed of atoms that were forged in earlier generations of stars—in this case, assembled into both its body and brain. We might say that through the thoughts of human beings, the matter in the universe can become aware of itself.

Think about those atoms in your body for a minute. They are merely on loan to you from the lending library of atoms that make up our local corner of the universe. Atoms of many kinds circulate through your body and then leave it—with each breath you inhale and exhale and the food you eat and excrete. Even the atoms that take up more permanent residence in your tissues will not be part of you much longer than you are alive. Ultimately, you will return your atoms to the vast reservoir of Earth, where they will be incorporated into other structures and even other living things in the millennia to come. This picture of cosmic evolution, of our descent from the stars, has been obtained through the efforts of scientists in many fields over many decades. Some of its details are still tentative and incomplete, but we feel reasonably confident in its broad outlines. It is remarkable how much we have been able to learn in the short time we have had the instruments to probe the physical nature of the universe.

Our study of astronomy has taught us that we have always been wrong in the past whenever we have claimed that Earth is somehow unique. Galileo, using the newly invented technology of the telescope, showed us that Earth is not the center of the solar system, but merely one of a number of objects orbiting the Sun. Our study of the stars has demonstrated that the Sun itself is a rather undistinguished star, halfway through its long main sequence stage like so many billions of others. There seems nothing special about our position in the Milky Way Galaxy either, and nothing surprising about our Galaxy's position in either its own group or its supercluster. The discovery of planets around other stars confirms our idea that the formation of planets is a natural consequence of the formation of stars. We have identified thousands of exoplanets—

planets orbiting around other stars, from huge ones orbiting close to their stars (informally called “hot Jupiters”) down to planets smaller than Earth. A steady stream of exoplanet discoveries is leading to the conclusion that earthlike planets occur frequently—enough that there are likely many billions of “exo-Earths” in our own Milky Way Galaxy alone. From a planetary perspective, smaller planets are not unique. Philosophers of science sometimes call the idea that there is nothing special about our place in the universe the Copernican principle. Given all of the above, most scientists would be surprised if life were limited to our planet and had started nowhere else. There are billions of stars in our Galaxy old enough for life to have developed on a planet around them, and there are billions of other galaxies as well. Astronomers and biologists have long conjectured that a series of events similar to those on the early Earth probably led to living organisms on many planets around other stars, and possibly even on other planets in our solar system, such as Mars. If the Copernican principle is applied to life, then biology may be rather common among planets.



**Fig.3. Enrico Fermi, an Italian American physicist (1901-1954)**

*(<https://study.com/academy/lesson/enrico-fermi-biography-inventions-contributions.html>)*

Taken to its logical limit, the Copernican principle also suggests that intelligent life like us might be common. Intelligence like ours has some very special properties, including an ability to make progress through the application of technology. Organic life around other (older) stars may have started a billion years earlier than we did on Earth, so they may have had a lot more time to develop advanced technology such as sending information, probes, or even life-

forms between stars. Faced with such a prospect, physicist Enrico Fermi asked a question several decades ago that is now called the Fermi paradox: where are they?

If life and intelligence are common and have such tremendous capacity for growth, why is there not a network of galactic civilizations whose presence extends even into a “latecomer” planetary system like ours? Several solutions have been suggested to the Fermi paradox. Perhaps life is common but intelligence (or at least technological civilization) is rare. Perhaps such a network will come about in the future but has not yet had the time to develop. Maybe there are invisible streams of data flowing past us all the time that we are not advanced enough or sensitive enough to detect. Maybe advanced species make it a practice not to interfere with immature,

developing consciousness such as our own. Or perhaps civilizations that reach a certain level of technology then self-destruct, meaning there are no other civilizations now existing in our Galaxy. We do not yet know whether any advanced life is out there and, if it is, why we are not aware of it.

Whether or not we ultimately turn out to be the only intelligent species in our part of the Galaxy, our exploration of the cosmos will surely continue. An important part of that exploration will still be the search for biomarkers from inhabited planets that have not produced technological creatures that send out radio signals. After all, creatures like butterflies and dolphins may never build radio antennas, but we are happy to share our planet with them and would be delighted to find their counterparts on other worlds. Whether or not life exists elsewhere is just one of the unsolved problems in astronomy. A humble acknowledgment of how much we have left to learn about the universe is one of the fundamental hallmarks of science. This should not, however, prevent us from feeling exhilarated about how much we have already managed to discover, and feeling curious about what else we might find out in the years to come. Our progress report on the ideas of astronomy ends here, but we hope that your interest in the universe does not. We hope you will keep up with developments in astronomy through media and online, or by going to an occasional public lecture by a local scientist. Who, after all, can even guess all the amazing things that future research projects will reveal about both the universe and our connection with it?

*(From <https://openstax.org/details/books/astronomy>)*

## Vocabulary

realm [reɪlm]	сфера
dense [dens]	щільний
creature ['kri:tʃə]	істота
to punctuate ['pʌŋk.tʃu:.eɪt]	переривати
collision [kə'liʒ.ən]	зіткнення
extinction [ɪk'stɪŋk.ʃən]	вимирання
a dinosaur ['daɪ.nə.sɔ:r]	динозавр
self-consciousness [ˌself'kɒn.ʃəs.nəs]	самосвідомість
to forge [fɔ:dʒ]	кувати
to inhale [ɪn'heɪl]	вдихнути

to excrete [ɪk'skri:t]	виділяти
tissue ['tɪʃ.u:] ['tɪs.ju:]	тканина
descent [dɪ'sent]	спуск
tentative ['ten.tə.tɪv]	нездійснений, пробний
to probe [prəʊb]	зондувати
undistinguished [ˌʌn.dɪ'stɪŋ.gwɪʃt]	невизначний
exoplanet ['ek.səʊ.plæn.ɪt]	екзопланета
to conjecture [kən'dʒek.tʃər]	здогадуватися
fortunate ['fɔ:.tʃən.ət]	пощастило
exceedingly [ɪk'si:.dɪŋ.li]	надзвичайно
immature [ˌɪm.ə'tʃʊər]	незрілі
consciousness ['kɒn.ʃəs.nəs]	свідомість
a counterpart ['kaʊn.tə.pa:t]	відповідник; щось добре, що поєднується з іншим; особа, яка займає аналогічну посаду
hallmark ['hɔ:l.mɑ:k]	відмітний знак
exhilarated [ɪg'zɪl.ə.reɪ.tɪd]	збуджений

### Exercise 1. Answer the following questions

1. What is the ancient question that connects us to generations of humans before us? 2. What kind of a question was that in the past? 3. What will we consider in this lesson? 4. What aids us in searching for evidence of all kinds of life beyond that on our planet? 5. When was the Universe born? 6. What did all matter consist of? 7. What created the other elements? 8. What is life on Earth based on? 9. What made earth hospitable to life? 10. What led to the formation of molecules that could make copies of themselves? 11. How was the course of evolution punctuated? 12. What is currently the focus of a great deal of scientific interest? 13. What did the course of evolution produce? 14. How can the matter in the universe become aware of itself? 15. How do atoms of many kinds circulate through your body and then leave it? 16. Is it remarkable how much we have been able to learn in the short time? 17. What has our study of

astronomy has taught us? Give examples. 18. What are exoplanets? 19. What is the discovery of exoplanets leading us to? 20. What is the Copernican principle? 21. What question did Enrico Fermi ask? 22. How many solutions have been suggested to Fermi paradox? 23. Is the search for biomarkers from inhabited planets still an important part of our exploration of the cosmos? 24. What is one of the unsolved problems in astronomy? 25. What is a humble acknowledgment? 26. Do you feel curious about what else we might find out in the years to come?

### Exercise 2. Find English equivalents in the text

інші форми життя, бути у Всесвіті, наукова фантастика, шукати відповідь через науковий запит, шукати докази існування життя деінде, астробіологія, Великий вибух, створювати інші елементи, виробляти різноманітні сполуки, біохімія, створювати такі істоти, як ми; хімічна еволюція Всесвіту, хімічна різноманітність і помірні умови на Землі, спричинені зіткненнями з, вимирання динозаврів, бути зібраним у, циркулювати крізь ваше тіло, у наступні тисячоліття, відчувати себе достатньо впевнено, центр сонячної системи, досить непомітний зірка, природний наслідок утворення зірок, траплятися часто, застосовуватися до життя, досить поширене, розумне життя, мати деякі дуже особливі властивості, розвивати передові технології, невидимі потоки даних, надсилати радіосигнали, відчувати натхнення, скромне визнання, періодичні публічні лекції, майбутні дослідницькі проекти.

### Exercise 3. Match up the half of the sentence on the left with its ending on the right

1. Life on Earth is based on the presence of a key unit known as	a) that if life could develop on Earth, it should be able to develop in other places as well.
2. Our solar system formed about 5 billion years ago	b) after the end of heavy bombardment, if not sooner.
3. Life is made up of	c) from a cloud of gas and dust enriched by several generations of heavier element production in stars.
4. The Copernican principle, which suggests that there is nothing special about our place in the universe, implies	d) chemical combinations of these elements made by stars.
5. The Fermi paradox asks why,	e) an organic molecule, a molecule that contains carbon, especially complex hydrocarbons.

6. The study of life in the universe, including its origin on Earth,	f) if life is common, more advanced life-forms have not contacted us.
7. Life as we know it requires water, certain elemental raw materials (carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur), energy,	g) has served to make many scientists optimistic about the chances that life could exist elsewhere.
8. Carbon-based (or organic) molecules are abundant in space	h) and an environment in which the complex chemistry of life is stable.
9. Life appears to have spread around our planet within 400 million years	i) there is no evidence that any of these are related to extraterrestrial visits.
10. The actual origin of life—the processes leading from chemistry to biology—	j) and may also have been produced by processes on Earth.
11. This proliferation of life into so many environmental niches, so relatively soon after our planet became habitable,	k) is not completely understood.
12. Despite many UFO reports and tremendous media publicity,	l) is called astrobiology.

#### Exercise 4. Translate the following sentences into English

1. Життя – це високоорганізований стан речовини, здатний до самовідтворення за допомогою певним чином кодованих молекул і до обміну з навколишнім середовищем речовиною, енергією та інформацією.

2. Життя на Землі ґрунтується на сполуках вуглецю, розчинником для яких слугує вода. Керуючись процесами само відтворення нуклеїнової кислоти – ДНК, які за величезного розмаїття усього живого використовують для програмування індивідуального розвитку організмів однаково „мову” – один і той же генетичний код.

3. Земля знаходиться від Сонця на дуже зручній відстані – 149 600 000 км.

4. Саме на цій відстані середня температура така, що дозволяє воді знаходитись у рідкому стані.

5. До цього треба додати важливість планет-гігантів у Сонячній системі. Їх наявність сприяє стабілізації орбіти Землі.

6. Юпітер як наймасивніша планета притягує до себе метеорити, які могли б повністю зруйнувати Землю.

7. Дослідження показують, що більшість зір у нашій Галактиці входять до складу кратних систем. Це свідчить про те, що у більшості випадків протозоряна

хмара, в якій іде формування зорі, розбивається на фрагменти так, що утворюється одразу кілька об'єктів.

8. Побачити планети біля інших зір дуже важко, бо їхня яскравість набагато менша, ніж яскравість основного світила.

9. Розенталь вважає, що всю структуру Всесвіту та його історію визначають чотири фундаментальні взаємодії – гравітаційна, електромагнітна, сильна і слабка, а також співвідношення:

- між масою електрона і протона
- між масою нейтрона і протона
- розмірністю фізичного простору.

10. Ще 1934 р. австрійський вчений К. Гедель сформулював теорему про неповноту наших знань, яка проголошує: „жодна система не може бути пізнаною до кінця зсередини – поза зв'язком її з іншими системами вищого порядку”. Це означає, що не можна вичерпно описати світ, у якому живе людина, не вийшовши за його межі.

*([https://my-astronomy.ucoz.ua/index/zhittja\\_u\\_vsesviti/0-13](https://my-astronomy.ucoz.ua/index/zhittja_u_vsesviti/0-13))*

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

- There are more stars in the universe than grains of sand on all the beaches on Earth. That's at least a billion trillion!
- The universe has no centre and is constantly expanding (getting bigger) every second – making it impossible to reach the edge.
- The Earth is about 4.5 billion years old – but that's only a third of the age of the universe – which is 13.5 billion years old!
- The Earth is tiny in comparison with the rest of the universe – it could fit into the sun 1.3 million times. How small does that make you feel?

*(<https://www.natgeokids.com/uk/discover/science/space/universe-facts/>)*

### **Speaking**

- Speak about life in the Universe.
- Speak about Astrobiology.
- Speak about life beyond our planet.

## INFORMATION RESOURCES

1. <https://openstax.org/details/books/astronomy>
2. [https://my-astronomy.ucoz.ua/index/astronomija\\_jak\\_nauka](https://my-astronomy.ucoz.ua/index/astronomija_jak_nauka)
3. <https://www.rmg.co.uk/stories/topics/15-awe-inspiring-astronomy-discoveries>
4. [https://www.researchgate.net/figure/Tycho-Brahe-1546-1601\\_fig1\\_241470218](https://www.researchgate.net/figure/Tycho-Brahe-1546-1601_fig1_241470218)
5. <https://www.sciencefacts.net/keplers-first-law.html>
6. <https://www.nmspacemuseum.org/>
7. <https://www.sciencefacts.net/keplers-second-law.html>
8. <https://www.sciencefacts.net/wp-content/uploads/2022/04/Keplers-Third-Law.jpg>
9. <https://subjectum.eu/textbook/astronomy>
10. <https://facts.net/science/physics/15-astounding-facts-about-keplers-laws-of-planetary-motion/>
11. <https://www.collegesidekick.com/study-guides/astronomy/earth-and-sky>
12. <https://www.quora.com/>
13. [https://lib.iitta.gov.u/713280/1/18-24\\_Astronomy\\_Workbook\\_P-7.pdf](https://lib.iitta.gov.u/713280/1/18-24_Astronomy_Workbook_P-7.pdf)
14. <https://science.nasa.gov/earth/facts>
15. <https://www.alamy.com/stock-photo/earth-orbit-sun-seasons.html?sortBy=relevant>
16. <https://www.istockphoto.com/uk/search/2/image-film?phrase=stonehenge>
17. [https://geography.ed-era.com/nauka\\_geografiya\\_ruh\\_zemli\\_u\\_kosmos\\_rychnyu\\_ruh\\_zemli](https://geography.ed-era.com/nauka_geografiya_ruh_zemli_u_kosmos_rychnyu_ruh_zemli)
18. <https://www.havefunwithhistory.com/facts-about-the-seasons/>
19. <https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon>
20. <https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/>
21. <https://courses.lumenlearning.com/suny-astronomy/chapter/eclipses-of-the-sun-and-moon/>
22. [https://uk.wikipedia.org/wiki/Місячне\\_затемнення](https://uk.wikipedia.org/wiki/Місячне_затемнення)
23. <https://www.astronomy.com/observing/25-facts-you-should-know-about-the-total-solar-eclipse-on-april-8-2024/>
24. <https://www.researchgate.net/figure/Portrait-of-James-Clerk-Maxwell->
25. [https://www.researchgate.net/figure/Visual-propagation-of-light-following-the-inverse-square-law\\_fig2\\_320926645](https://www.researchgate.net/figure/Visual-propagation-of-light-following-the-inverse-square-law_fig2_320926645)
26. <https://suzirya.org/2020/14/philosophy/480>
27. <https://www.discovermagazine.com/the-sciences/20-things-you-didnt-know-about-light>

28. <https://unsplash.com/s/photos/machu-picchu>
29. <https://webbtelescope.org/news/milestones/mission-timeline#:~:text=Construction%20on%20Webb%20began%20in,testing%20to%20meet%20required%20specifications>
30. <http://www.streetastronomy.com.ua/articles/teleskopy-novogo-pokolinnya-yakoyu-bude-astronomiya-majbutnogo.html>
31. <http://www.historyoftelescope.com/telescope-facts/interesting-facts-about-telescopes/>
32. <https://www.npr.org/2023/04/13/1169469591/goodbye-fuzzy-donut-the-famous-first-black-hole-photo-gets-sharpened-up>
33. <https://ar.inspiredpencil.com/pictures-2023/john-mitchell-black-holes>
34. <https://mathshistory.st-andrews.ac.uk/Biographies/Schwarzschild/pictdisplay/>
35. (<https://nauka.ua/card/shcho-take-chorna-dira>
36. <https://new.nsf.gov/science-matters/5-black-hole-facts-blow-your-mind>
37. <https://www.mreclipse.com/Comets/Hyakutake/HY96-211w.JPG>
38. <https://news.ucsc.edu/2021/04/exoplanet-atmospheres.html>
39. <https://study.com/academy/lesson/enrico-fermi-biography-inventions-contributions.html>
40. [https://my-astronomy.ucoz.ua/index/zhittja\\_u\\_vsesviti/0-1](https://my-astronomy.ucoz.ua/index/zhittja_u_vsesviti/0-1)
41. <https://www.natgeokids.com/uk/discover/science/space/universe-facts/>

*Навчальне видання*

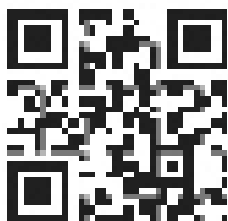
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(PART 3. ASTRONOMY)**

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