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Кафедра английского языка

ASTRONOMY

Учебно-методическое пособие для студентов, обучающихся по специальности «Астрономия - 011501.65»

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Данное пособие предназначено для студентов, обучающихся по специальности «Астрономия», и содержит материалы по специальности, дополняющие основной курс английского языка. Материалы пособия могут быть использованы как для аудиторной, так и для самостоятельной работы студентов.

Предисловие

Настоящее пособие предназначено для занятий со студентами студентов 2 и 3 курсов физического факультета Казанского (Приволжского) федерального университета, по специальности «*Астрономия - 011501.65»*. Пособие разработано с учетом требований государственного стандарта высшего профессионального образования и предназначено для студентов, продолжающих изучение английского языка на базе программы средней школы.

Целью настоящего пособия является углубление и расширение словарного запаса, приобретение учащимися навыков правильного понимания и перевода оригинального текста (научной неадаптированной литературы) по специальности.

Учебно-методическое пособие состоит из 10 уроков, блока научных текстов для самостоятельной работы, приложений, включающих в себя набор фраз и устойчивых выражений, применяемых при реферировании научных статей, источниковедческой базы.

В учебно-методическое пособие включены оригинальные тексты, опубликованные в ведущих зарубежных научных изданиях, сокращенные по мере необходимости. При отборе статей учитывалась их познавательная ценность. Все статьи связаны со специальностью студентов. Тексты снабжены упражнениями по изучению и закреплению лексики.

Все уроки по своей структуре идентичны, даны ясные формулировки заданий, что позволяет достичь искомой цели.

При работе над пособием, мы старались обеспечить участников учебного процесса объемом текстового и лексического материала, набором упражнений, предоставляющим возможность полноценно, эффективно использовать время, отведенное на изучение профессиональных аспектов иностранного языка.

CONTENT

UNIT1

1.1 Practise reading the following words.

a) [ð] – there, **th**ese, wi**th**out, toge**th**er, fur**th**er, wi**th**in, ga**th**er

[ɜ:] – obs**er**ve, s**ear**ch, **ear**th, conc**er**n, occ**ur**, f**ir**st

[i:] - Gr**ee**k, **ea**st, **ea**ch, m**ea**ns, d**ee**p

[ʌ] – c**u**lture, st**u**dy, b**u**t, str**u**cture, S**u**n, **u**nder

б) universe ['juːnɪvɜːs], civilisation [ˌsɪv(ə)laɪ'zeɪʃ(ə)n], ancient ['eɪn(t)ʃ(ə)nt], successful [sək'sesful], cycle ['saɪkl], circumference [sə'kʌmf(ə)r(ə)ns], science ['saɪəns], characterize ['kærəkt(ə)raɪz], mathematician [ˌmæθ(ə)mə'tɪʃ(ə)n], investigate [ɪn'vestɪgeɪt], sophisticate [sə'fɪstɪkeɪt]

c) Democritus [dɪˈmɒkrɪtəs], Anaxagoras [ˌanakˈsagərəs], Aristotle [ˈarɪstɒt(ə)l], Aristarchus [ˌarɪˈstɑːkəs], Eratosthenes [ˌɛrəˈtɒsθəniːz].

1.2 Translate words of the same root into Russian.

To observe – observed – observer – observable – observant – observation – observatory.

To create – creative – creation – creature – creativity – creator.

To exist – existence – existing – existent – existential.

1.3 Fill in the sentences with words from exercise 1.2.

1. Scientists have many theories about how the universe first came into … .
2. Science is the study of … phenomena.
3. The first living … sent into space was a dog named Laika.
4. I was invited to attend their conference as an … .
5. Opportunities … for students to gain sponsorship.
6. The software makes it easy to …colourful graphs.

Active Vocabulary

Word	Pronunciation	Translation
accurate, *adj*.	['ækjərət]	верный, точный правильный; ***syn***. correct, exact, precise, right, true
calculate, *v*.	['kælkjuleɪt]	вычислять; подсчитывать; калькулировать; ***syn.*** compute, count
canopy, *n*.	['kænəpɪ]	балдахин; полог, навес, тент
celestial, *adj*.	[sə'lestɪəl]	божественный, небесный, **syn**. excellent, godlike, divine, heavenly
conclude, *v*.	[kən'kluːd]	(с)делать вывод, подвести итог, принимать решение; ***syn.*** decide
cycle, n.	['saɪkl]	цикл; syn. period, circulation, rotation
daybreak, n.	['deɪbreɪk]	рассвет; syn. dawn
diameter, n.	[daɪ'æmɪtə]	диаметр
dome, n.	[dəum]	купол; верх, верхушка, свод; syn. cupola, big top, head
eclipse, n.	[ɪ'klɪps]	затмение
embark, n.	[ɪm'bɑːk]	грузить, отправиться; начинать, вступать
establish, n.	[ɪs'tæblɪʃ]	учреждать, устанавливать; syn. set up, ascertain
full-fledged, adj.	[ˌful'fleʤd]	полноправный, полноценный; развившийся
gather, v.	['gæðə]	собирать(ся); syn. assemble, collect, accumulate
gaze, v.	[geɪz]	пристально глядеть; вглядываться; уставиться; syn. look
heaven, n.	['hev(ə)n]	небеса, небо, рай; syn. paradise
investigate, v.	[ɪn'vestɪgeɪt]	расследовать, изучать, исследовать; syn. examine
measure, v.	['meʒə]	измерять, мерить; отмерять, отсчитывать

navigate, v.	['nævɪgeɪt]	плавать, вести, управлять, передвигаться, двигаться; syn. sail, guide, get around, move
pattern, *n*.	['pæt(ə)n]	образец, пример, шаблон, система, модель, структура, принцип; ***syn***. prototype, exemplar
predict, *v*.	[prɪ'dɪkt]	предсказывать, пророчить; прогнозировать; ***syn.*** forecast, foretell
scientific, *adj*.	[ˌsaɪən'tɪfɪk]	научный
sophisticated, *adj*.	[sə'fɪstɪkeɪtɪd]	утончённый, умудрённый, сложный, сложно устроенный, современный, передовой; ***syn.*** complex, up-to-date, advanced
stable, *adj*.	['steɪbl]	стойкий, крепкий, прочный, неизменный; ***syn.*** strong, firm, constant
tie, *v*.	[taɪ]	завязывать, привязывать, связывать, скреплять, соединять; ***syn.*** fasten, bind, connect, join

DO YOU KNOW…?

- that Stonehenge’s four rings of stones are aligned with the positions of the Sun at the longest and the shortest days of the year.

- that Anaxagoras was the teacher of some of the most famous men of his time, including the politician Pericles, the playwright Euripedes, and the philosopher Socrates. Despite his prestige, he was eventually banished from Athens for his beliefs, including the idea that the Moon is made of rock and reflects the Sun’s rays.

1.4 Read the text and answer the following questions.

1. How did ancient Egyptians explain what they observed in the sky?
2. What was the easiest way to tell the time of year?
3. What knowledge were necessary to understand the cycles of nature?
4. What did Anaxagoras theorise?

5. Who calculated Earth's circumference?

6. What contribution into astronomy did Aristarchus make?

THE BIRTH OF A SCIENCE

Astronomy may be the oldest science. Precisely how old is difficult to say, since it is impossible to know when the first watchers looked up into the dome of countless stars and wondered at the incredible sights there. One thing is clear, however: the basic practice of astronomy had been well established by the time humans formed the first civilisations.

Since the beginning of human history, people from nearly every culture have gazed into the sky and invented stories to make sense of what they observed. Ancient Egyptians, for example, saw the Sun rise in the east, move across the sky in the day, set in the west, and then appear in the east again at daybreak. They also noted that the sky looked blue, like a great body of water overhead. Their conclusion was that the Sun god, Ra, sailed from east to west each day in a boat of fire. He then disappeared into the underworld until the next morning.

It is likely that even the earliest nomadic people used the patterns of the Sun, Moon, stars, and planets to navigate as they travelled from place to place in search of food. As humans formed stable civilisations, however, measuring time became the most practical use that that ancient sky watchers could make of their observations. The world's earliest known villages based on farming, which formed in Mesopotamia around 7000 BC, could not have grown into successful cities without a knowledge of when to plant, when to expect the rainy season, and when to harvest. The easiest way to tell the time of year is to notice the patterns of the Sun and stars over the course of a long period of time. To understand the cycles of nature requires a primitive understanding of the relationship between Earth and the Sun … in other words, astronomy.

Astronomy (from the Greek *astro,* meaning "star", and *nomos,* meaning "system of law") is the science that studies the stars, planets, and all other celestial bodies. It is concerned with their origins, evolution, physical conditions, movements, distances, and the forces that tie them together. Although astronomy began as simply a means of telling time and location, it soon developed into a full-fledged area of study, characterized by patient observation and detailed record-keeping. As early as 2500 BC in what is now England, work began on Stonehenge, a group of standing stones that are thought to have been aligned to track the movements of the Sun and Moon and to measure eclipses. Around 1300 BC, Chinese astronomers embarked on a long, precise study of eclipses, recording 900 solar eclipses and 600 lunar eclipses over the next 2600 years. In about 700 BC, the Babylonians went one step further by studying their own astronomical records and finding patterns in the appearances of lunar eclipses that helped them to predict when future ones would occur.

The more deeply these early watchers looked onto the canopy of stars, however, the more complex it appeared. It became clear that the myths of the storytellers were not sophisticated enough to explain all the mysteries of the heavens. In the last centuries BC in Greece, a few individual thinkers made names for themselves by developing theories about the structure and workings of the universe. Anaxagoras (500-428 BC) correctly theorized that the Moon shines by the light it receives from the Sun and that lunar eclipses occur when Earth blocks the Sun's light. Democritus (460-370 BC) originated the idea that the Milky Way is not a white cloud but a string of thousands upon thousands of stars. The great philosopher Aristotle (384-322 BC) argued that the circular shadow seen on the Moon during a lunar eclipse was proof that Earth is a sphere, and Eratosthenes (274-194 BC) used geometry to calculate Earth's circumference to within a few percent of its actual size.

Another early watcher who set the stage for the first real scientific investigation of astronomy was a Greek mathematician, Aristarchus of Samos (310-230 BC). By 270 BC, he had developed a way to calculate the diameters of the Sun and Moon and their distances from Earth. From this, he concluded (contrary to what most people assumed at the time) that the Sun was the center of the universe. Aristarchus had correctly described our solar system, but this theory was not accepted during his life – or for1800 years to come.

It would take the work of many other minds over the course of the following centuries to create and then to prove an accurate view of the universe, and scientists today are still wrestling with its secrets. As is often the case in the growth of science, the more information is gathered, the more questions there are to be investigated.

(adopted from the Internet)

1.5 Mark the following sentences True or False.

1. Ancient Egyptians believed that the Sun moved across the sky to during the day and disappeared into the underworld until the next morning.
2. People of the successful cities of Mesopotamia could not do without knowledge of the patterns of the Sun and stars.
3. The Babylonians recorded 600 lunar eclipses.
4. The myths of the storytellers were complicated enough to explain all the mysteries of the heavens.
5. Aristotle was convinced the circular shadow on the Moon to be proof that the Earth is a sphere.
6. Anaxagoras described our solar system in a right way.

1.6 Match words similar in meaning.

1. calculate	a. deduction
2. conclusion	b. firm
3. establish	c. observe
4. incredible	d. observer
5. notice	e. source
6. origin	f. get
7. receive	g. count
8. stable	h. improbable
9. success	i. set up
10. watcher	j. fortune

1.7 Match words opposite in meaning.

1. appear	a. rise
2. celestial	b. disappear
3. clear	c. destroy
4. create	d. untie
5. difficult	e. blurred
6. early	f. ignorance
7. knowledge	g. easy
8. old	h. late
9. set	i. new
10. tie	j. terrestrial

1.8 Match two halves of the statements and translate them into Russian.

1. dome of	a. with secrets
2. stable	b. theories
3. sky	c. the cycles of nature
4. to understand	d. investigation
5. celestial	e. countless stars
6. to track	f. watchers
7. to look onto the	g. the movements of the Sun
8. developing	h. civilization
9. scientific	i. canopy of stars
10. to wrestle	j. bodies

1.9 Complete the text with one word.

No doubt ancient people noticed ... there are about 360 days in a year and that the stellar patterns in the sky are repeated … year. A year is like a circle. Various familiar patterns repeat from year to …: the general nature of the weather, the Sun's way of moving across the …, the lengths of the days, the positions of the stars at sunset. Maybe some guru decided that 360, being close to the … of days in a year, was a natural number … use when dividing up a circle … units for angular measurements. Then people could say that the stars shift in the sky by 1 degree, … or less, every night. Whether this story is true or not doesn't …; different cultures came up … different ideas anyway. The fact is that we are stuck …degrees that represent 1/360 of a circle, whether we … it or not.

1.10 Translate the following sentences into English.

1. Астрономия изучает строение Вселенной, движение, физическую природу, происхождение и эволюцию небесных тел и образованных ими систем.
2. Астрономия исследует также фундаментальные свойства окружающей нас Вселенной.
3. Зачатки астрономии существовали уже тысячи лет назад в Вавилоне, Египте и Китае для целей измерения времени и ориентировки по странам света.
4. Как наука, астрономия основывается, прежде всего, на наблюдениях.
5. В отличие от физиков астрономы лишены возможности ставить эксперименты.
6. Практически всю информацию о небесных телах приносит нам электромагнитное излучение.
7. Объекты астрономического исследования - небесные светила, бывшие еще недавно недосягаемыми, - стали доступны для непосредственного изучения (конечно, лишь ближайшие).

UNIT2

2.1 Practise reading the following words.

a)[**u:**] – l**u**minous, evol**u**tion, incl**u**de, concl**u**de, l**u**nar

[**aɪ**] – pr**i**mary, t**i**dal, sp**i**ral, wh**i**le, m**i**le

[**æ**] – g**a**laxy, coll**a**pse, **a**ngular, m**a**tter, attr**a**ction, regul**a**rity

[**k**] – de**c**ade, a**c**tive, **c**omputational, **c**larify, s**c**ale, gala**c**ti**c**

[**s**] – re**c**ent, advan**ce**, pro**c**ess, for**c**e, tenden**cy**, **c**entrifugal

b) fundamental [ˌfʌndə'ment(ə)l], content ['kɔntent], consequently ['kɔnsɪkwəntlɪ], however [hau'evə], evidence ['evɪd(ə)ns], condensation [ˌkɔnden'seɪʃ(ə)n], decade ['dekeɪd], knowledge ['nɔlɪʤ], bipolar ['baɪ'pəulə], typical ['tɪpɪk(ə)l], multiple ['mʌltɪpl], environment [ɪn'vaɪər(ə)nmənt], characteristic [ˌkærəktə'rɪstɪk].

Active vocabulary

accretion, *n.*	[æ'kriːʃ(ə)n]	разрастание; прирост; приращение, увеличение; ***syn.*** increase, growth
advance, *n.*	[əd'vɑːns]	успех, прогресс, достижение; ***syn.*** improvement, progress
angular, *adj.*	['æŋgjulə]	угловой
attraction, *n.*	[ə'trækʃ(ə)n]	притяжение, тяготение; ***syn.*** gravitation, gravity
binary, *adj.*	['baɪnərɪ]	двойной, сдвоенный; бинарный, двоичный, парный; ***syn.*** double, dual
byproduct, *n.*	['baɪˌprɔdʌkt]	побочный продукт
circumstellar,*adj*	['sɜːkəm 'stelə]	околозвёздный
clarify, *v.*	['klærɪfaɪ]	очищать; прояснить; пролить свет (на что-либо); ***syn.*** explain, explicate, interpret
cluster, *n.*	['klʌstə]	кисть, пучок, гроздь, скопление
collapse, *v.*	[kə'læps]	разрушаться, обваливаться, оседать

collision, *n.*	[kə'lɪʒ(ə)n]	столкновение; ***syn.*** clash
condense, *v.*	[kən'dens]	уплотнять, сгущать; уменьшать объём, сжимать; концентрировать световой поток; ***syn.*** contract, compress, thicken, concentrate
contraction, *n.*	[kən'trækʃ(ə)n]	сжатие, сужение, уменьшение, сокращение, ограничение; ***syn.*** pressure, restriction, limitation, confinement
contribute, *v.*	['kɔntrɪbjuːt]	содействовать, способствовать
core, *n.*	[kɔː]	центр; сердцевина, ядро; ***syn.*** centre
counteract, *v.*	[ˌkaunt(ə)'rækt]	препятствовать, противодействовать, сопротивляться, нейтрализовать; ***syn.*** oppose, object, neutralize
diffuse, *adj.*	[dɪ'fjuːs]	распространённый, рассеянный
dissipation, *n.*	[ˌdɪsɪ'peɪʃ(ə)n]	рассеивание
evidence, *n.*	['evɪd(ə)ns]	ясность, наглядность, очевидность; доказательство, подтверждение; свидетельство; ***syn.*** clearness, proof
interstellar, *adj.*	[ˌɪntə'stelə]	межзвёздный
luminous, *adj.*	['luːmɪnəs]	светящийся, световой; ***syn***. luminescent, fluorescent
merger, *n.*	['mɜːʤə]	поглощение; ***syn.*** absorption
occur, *v.*	[ə'kɜː]	происходить, случаться, совершаться; ***syn.*** happen, befall
overcome, v.	[ˌəuvə'kʌm]	побороть, преодолеть
randomness, *n.*	[ˈrandəmnəs]	случайность; произвольность
spiral, *adj.*	['spaɪər(ə)l]	винтовой, винтообразный, спиральный
tidal, *adj.*	['taɪd(ə)l]	связанный с приливом и отливом; периодический, чередующийся
tracer, *n.*	['treɪsə]	учёный, исследователь

DO YOU KNOW...?

- that our Sun's ratio is more like 70% hydrogen and 29% helium.
- that the color of stars can range from red to white to blue. Red is the coolest color; that's a star with less than 3,500 Kelvin. Stars like our Sun are yellowish white and average around 6,000 Kelvin. The hottest stars are blue, which corresponds to surface temperatures above 12,000 Kelvin. So the temperature and color of a star are connected.
- that the closest star to Earth is Proxima Centauri, located 4.2 light-years away. In other words, it takes light itself more than 4 years to complete the journey from Earth. If you tried to hitch a ride on the fastest spacecraft ever launched from Earth, it would still take you more than 70,000 years to get there from here. Traveling between the stars just isn't feasible right now.

2.2 Read the text and answer the following questions.

1. What are stars in charge of?
2. When did scientists begin to gain understanding of how star formation happens?
3. What forces counteract star formation on galactic scales/ on intermediate sales/ on the small scales?
4. What factor leads to the formation of a binary or multiple systems of stars?
5. What role do magnetic fields play in the star formation?
6. What do the structures of galaxies depend on?
7. What does the evolution of galaxies depend on?

THE PHYSICS OF STAR FORMATION

Stars are the fundamental units of luminous matter of the universe, and they are responsible, directly or indirectly, for most for what we see when we observe it. They also serve as our primary tracers of the structure and evolution of the universe and its contents. Consequently, it is of central importance in astrophysics to understand how stars form and what determines their properties. The generally accepted view that stars form by the gravitational condensation of diffuse matter in space is very old, indeed almost as old as the concept of universal gravitational attraction itself, having been suggested by Newton in 1692. However, it is only in the past half-century that the evidence has become convincing that stars are presently forming by the condensation of diffuse interstellar matter in our Galaxy and others, and it is only in recent decades that we have begun to gain some physical understanding of how this happens. Observations at many wavelengths, especially radio and infrared, have led to great advances in our knowledge of the subject, and the observational study of star formation is now a large and active field of research. Extensive theoretical and computational work has also contributed increasingly to clarifying the physical processes involved.

Star formation occurs as a result of the action of gravity on a wide range of scales, and different mechanisms may be important on different scales, depending on the forces opposing gravity. On galactic scales, the tendency of interstellar matter to condense under gravity into star-forming clouds is counteracted by galactic tidal forces, and star formation can occur only where the gas becomes dense enough for its self-gravity to overcome these tidal forces, for example in spiral arms. On the intermediate scale of star-forming ‘giant molecular clouds’ (GMCs), turbulence and magnetic field may be the most important effects counteracting gravity, and star formation may involve the dissipation of turbulence and magnetic fields. On the small scales of individual pre-stellar cloud cores, thermal pressure becomes the most important force resisting gravity, and it sets a minimum mass that a cloud core must have to collapse under gravity to form stars. After such a cloud core has begun to collapse, the centrifugal force associated with its angular momentum eventually becomes important and may hold its contraction, leading to the formation of a binary or multiple systems of stars. When a very small central region attains stellar density, its collapse is permanently halted by the increase of thermal pressure and an embryonic star or ‘protostar’ forms and continues to grow in mass by accretion. Magnetic fields may play a role in this final stage of star formation, both in mediating star accretion and in launching bipolar jets that typically announce the birth of a new star.

In addition to these effects, interactions between the stars in a forming multiple system or cluster may play an important role in the star formation process. Most, and possibly all, stars form with close companions in binary or multiple systems or clusters, and gravitational interactions between the stars and gas in these systems may cause the redistribution of angular momentum that is necessary for stars to form. Interactions in dense environments, possibly including direct stellar collisions and mergers, may play a particular important role in the formation of the massive stars. Such processes, instead of generating characteristic properties for forming stars, may be chaotic and create a large dispersion in the properties of stars and stellar systems. Thus, star formation processes, like most natural phenomena, probably involve a combination of regularity and randomness.

Some outcomes of star formation processes that are particularly important to understand include the rate at which the gas in galaxies is turned into stars, and the distribution of masses with which stars are formed. The structures of galaxies depend on the circumstances in which stars form and the rate at which they form, while the evolution of galaxies depends on the spectrum of masses with which they form, since low-mass stars are faint and evolve slowly while massive ones evolve fast and release large amounts of matter and energy that can heat and ionize the interstellar gas, enrich it with heavy elements, and possibly expel some of it into intergalactic space. It is also important to understand the formation of binary systems because many important astrophysical processes, including the formation of various kinds of exotic objects, involve the interactions of stars in binary systems. A further outcome of star formation that is of great interest to understand is the formation of planetary systems, which may often form as byproducts of star formation in disks of leftover circumstellar material.

(adopted from “Reports on Progress in Physics” journal)

2.3 Match words similar in meaning.

1. primary	a. stop
2. recent	b. free
3. occur	c. basic
4. counteract	d. normal
5. associate with	e. modern
6. halt	f. scattering
7. interaction	g. take place
8. release	h. bind
9. natural	i. cooperation
10. dispersion	j. oppose

2.4 Form words opposite in meaning using the following prefixes: un-, im-, ir-, il- .

Responsible, important, necessary, possible, natural, regular, active, logical

2.5 Give English equivalents for the following word combinations.

1. фундаментальные единицы
2. общепринятая точка зрения
3. в последние десятилетия
4. силы, противодействующие гравитации
5. центробежная сила
6. играть важную роль в формировании
7. превращаться в звезды
8. структура галактик зависит от
9. процессы формирования звезд
10. рождение новой звезды

2.6 Give Russian equivalents for the following word combinations.

1. primary tracer
2. at many wavelengths
3. star-forming clouds
4. galactic tidal forces
5. embryonic star
6. to launch bipolar jets
7. a combination of regularity and randomness
8. to evolve slowly/ fast
9. dense environment
10. angular momentum

2.7 Match sentence halves.

1. The problem of star formation	**a**. have been based on realistic evaluation and incorporation of the effects of turbulence.
2. The microphysics of star formation	**b**. deals with the formation of systems of stars, ranging from clusters to galaxies
3. The macrophysics of star formation	**c.** involve gas dynamics.
4. Many of the advances in the theory of star formation .	**d.** can be divided into two broad categories: microphysics and macrophysics
5. Turbulence is in fact important in essentially all branches of astrophysics that	**e.** deals with how individual stars (or binaries) form.

2.8 Ask all possible questions to the sentences from exercise 2.7.

2.9 Complete the text using the words in CAPITALS in the correct form.

Massive star formation has drawn 1) CONSIDER interest for several decades, but the last 10 years have witnessed a strong 2) ACCELERATE of theoretical and observational research in this field. One of the main 3) CONCEPT problems in massive star formation arises from the radiation pressure massive stars exert on the 4) SURROUND dust and gas core. In principle, this radiation pressure could be 5) STRENGTH enough to stop further accretion, which would imply that the standard theory of low-mass star formation had to be adapted to account for the 6) FORM of massive stars.

2.10 Translate the text into English.

Звёзды - горячие светящиеся небесные тела, подобные Солнцу. Звезды различаются по размеру, температуре и яркости. По многих параметрам Солнце - типичная звезда, хотя кажется гораздо ярче и больше всех остальных звезд, поскольку расположено намного ближе к Земле. Хотя звезды рассыпаны по всему небосводу, мы видим их только ночью. Космонавты на орбите видят звезды как цветные немигающие точки.

В настоящее время известно, что звезды - это гигантские природные генераторы энергии, с высокой эффективностью превращающие часть своего вещества в излучение. В последние десятилетия было окончательно установлено, как формируются звезды. Это происходит в тех областях пространства, где собирается достаточно большая масса межзвездного газа, который под действием собственного тяготения сжимается и разогревается до тех пор, пока температура не достигнет критического значения, необходимого для протекания ядерных реакций. Свойства образовавшейся звезды практически полностью определяются массой исходного газового облака.

UNIT3

3.1 Practise reading the following words.

a) [aɪ] – g**ia**nt, s**i**ze, theor**i**ze, l**i**ght, hor**i**zon

[əʊ] – h**o**le, thr**o**w, s**o**da, sl**o**w

[**eɪ] –** sp**a**ce, esc**a**pe, m**ai**nt**ai**n, rem**ai**n, dr**ai**n, str**ai**ght

[dʒ] – gaint, **g**enerate, **g**eneral, bevera**ge**

b) investigate [ɪn'vestɪgeɪt], determine [dɪ'tɜːmɪn], pressure ['preʃə], surrounding [sə'raundɪŋ], approximately [ə'prɔksɪmətlɪ], associate[ə'səusɪeɪt], [-ʃɪeɪt], evidence ['evɪd(ə)ns], constant ['kɔnstənt], anomaly [ə'nɔməlɪ]

c) Einstein [ʌɪnstʌɪn], Schwarzschild [ˈʃvɑːtsˌʃiːlt, ˈʃwɔːtsˌtʃʌɪld], Hawking [hɔːkɪŋ], Cygnus [ˈsɪgnəs], Doppler [ˈdɒplə]

3.2 Translate words of the same root into Russian.

To determine – determined – determination – determining – determinant – determinate

To investigate – investigation – investigative – investigator - investigatory

To apply – application – applicable – applied – applicant - appliance

3.3 Fill in the sentences with words from exercise 3.2.

1. He was one of 30 … for the manager’s job.
2. Social class is a major … of consumer spending patterns.
3. The whole issue is still under … .
4. The offer is only … to bookings for double rooms.
5. I heard a noise and went downstairs ….
6. Investigators are still trying … the cause of the fire.

Active vocabulary

Word	**Pronunciation**	**Translation**
annihilate, *v.*	[ə'naɪəleɪt]	истреблять, уничтожать; отменять, аннулировать, упразднять; ***syn.*** destroy
approximately, *adv.*	[ə'prɔksɪmətlɪ]	приблизительно, близко, около, почти; ***syn.*** about, roughly, almost, nearly
beverage, *n.*	['bevərɪʤ]	напиток; ***syn***. drink
collapse, *v.*	[kə'læps]	разрушаться, обваливаться, оседать
drain, *n.*	[dreɪn]	водосток, труба; канализация
draw, *v.*	[drɔː]	всасывать, втягивать
emit, *v.*	[ɪ'mɪt]	излучать, испускать, выделять
escape, *v.*	[ɪs'keɪp]	бежать, спастись, отделаться; ***syn.*** flee, run away, avoid
expand, *v.*	[ɪk'spænd]	растягиваться, расширяться; ***syn.*** enlarge, swell
explode, *v.*	[ɪk'spləud]	взрывать; ***syn***. burst, bust, erupt
mount, *v.*	[maunt]	подниматься, восходить; ***syn.*** go up, rise
proof, *n.*	[pruːf]	подтверждение, доказательство, проверка, испытание; проба
pull, *n.*	[pul]	влечение, привлекательность, тяга
rough, *adj.*	[rʌf]	грубый, жёсткий, неровный
shrink, *v.*	[ʃrɪŋk]	уменьшаться, сокращаться
spiral, *adj.*	[ˈspʌɪr(ə)l]	спиральный
suck, *v.*	[sʌk]	всасывать, засасывать
swirl, *v.*	[swɜːl]	вращать, кружить в водовороте
vicinity, *n.*	[vɪ'sɪnətɪ]	близость, соседство
virtual, *adj.*	['vɜːʧuəl]	возможный, воображаемый

DO YOU KNOW…?

- that Karl Schwarzschild contracted an illness while in Russia called pemphigus, which is a rare autimmune blistering disease of the skin. For people with this disease the immune system mistakes the cells in the skin as foreign and attacks them causing painful blisters. In Schwarzschild's time there was no known treatment and, after being invalided home in March 1916, he died two months later.

- that Stephen Hawking was diagnosed with ALS, a form of Motor Neurone Disease, shortly after his 21st birthday. In spite of being wheelchair bound and dependent on a computerised voice system for communication he continues to combine family life (he has three children and three grandchildren), and his research into theoretical physics together with an extensive programme of travel and public lectures. He still hopes to make it into space one day.

3.4 Read the text and match paragraphs A-D with gaps 1-5.

BLACK HOLES

A black hole is an (almost invisible) body in space, created most likely from a collapsed red super giant star, that is so dense that neither light nor matter can escape its gravitational pull.

1.	

When a star nears the end of its life it cools off slowly and the outwards pressure grows weaker and weaker as the temperature of the star drops. When the outward pressure from the heat is nearly gone, the inward pressure of gravity still remains and is determined by the size of the star. It is theorized that when a star roughly ten times the size of our Sun nears the end of its life, it shrinks as its own gravity slowly pulls it in, but as it becomes more and more dense the gravity becomes stronger.

2.	

The size of the black hole is determined by the mass of the collapsed star. The critical radius of a non-rotating black hole is called the Schwarzschild radius, named after the German astronomer Karl Schwarzschild (1873-1916) who investigated the problem in 1916 on the basis of Einstein's theory of general relativity. According to general relativity, the gravitation of a black hole bends space and time to such an extent where they are broken down into a dimensionless body of infinite density.

3.	

Black holes can't be seen, as they do not emit any electromagnetic radiation. But they can be detected because of their effects on the surrounding stars.

4.	

Evidence of black holes is mounting, and it is now believed that most galaxies of a large enough size and possibly our own have a black hole at their center.

5.	

C Inside a star there is a constant battle between inward pressure from gravity and outward pressure from heat. If you were to throw an unopened can of soda into a fire, the beverage would expand from the heat and explode. This is the same principle at work when a star is burning; its heat is generating great outward pressure but this constant explosion is matched by gravity that is equally strong, thus a star maintains its shape and size.

E The gravity becomes so intense that not even light can escape it. If you have ever watched water swirling down a drain, then you have a pretty good idea what happens as a black hole pulls things in. As matter and light approach the vicinity of a black hole they are slowly drawn in. If they are not headed straight for the spacial anomaly then they are taken into a violent and unstable orbit around the black hole until finally the orbit falls apart and it is sucked down by the immense gravity.

AThe boundary around the collapsed star having this radius is referred to as the 'event horizon'. Anything, whether it is light or matter passing this boundary, will be forever lost within the black hole with no chance of escape. What happens beyond the event horizon nobody can tell, because all the laws of physics break down and no longer apply. There are many theories but little proof to support them.

D In a binary star system, Cygnus X-1, (where the primary is a normal star of approximately 30 solar masses) due to Doppler shifts from the system it is believed that there is a companion of approximately 10 to 15 solar masses orbiting the primary. There are X-ray emissions from the system usually associated with an 'accretion disk' (a hot, dense disk of gas from the primary star spiraling down into the compact object orbiting the primary). There is evidence indicating that the X-rays are being emitted from the orbiting companion. Due to the mass of the companion object it is thought that it is a black hole.

B It is now known that black holes emit what is called Hawking Radiation through a complex process. Virtual particle pairs are constantly being created near the horizon of the black hole, as they are everywhere. Normally, they are created as a particle-antiparticle pair and they quickly annihilate each other. But near the horizon of a black hole, it's possible for one to fall in before the annihilation can happen, in which case the other one escapes as Hawking radiation.

(adopted from www.astromomytoday.com)

3.5 Match words with their definitions.

battle explosion gravity boundary radiation

1. ………. – the force that causes something to fall to the ground or to be attracted to another;

2. ………. – the real or imaginary line that marks the edge of a state, country etc., or the edge of an area of land that belongs to someone;

3. ………. – to try very hard to achieve something that is difficult or dangerous;

4. ………. – energy in the form of heat or light that is sent out as waves that you can't see;

5. ………. – a loud sound and the energy produced by something such as a bomb bursting into small pieces

3.6 Mark the following sentences True or False.

1. The temperature of the star drops when it nears the end of its life.
2. Approaching the vicinity of a black hole, matter and light are slowly drawn in.
3. Black holes emit electromagnetic radiation.
4. It is believed that possibly our galaxy has a black hole at its centre.
5. Inside a star there is a constant battle between outward pressure from gravity and inward pressure of heat.
6. Near the horizon of a black hole particle-antiparticle pairs are created.
7. Black holes can't be detected as they don't effect on the surrounding stars.

3.7 Find words in the text similar in meaning.

1. huge
2. to evolve
3. to cower
4. evidence
5. to back up
6. permanent
7. to stay
8. to find
9. to examine
10. to ruin

3.8 Match adjectives with suitable nouns.

1. gravitational	a. anomaly
2. collapsed	b. companion
3. constant	c. idea
4. outward/inward	d. pull

5. pretty good	e. hole
6. special	f. star
7. infinite	g. pressure
8. electromagnetic	h. density
9. black	i. explosion
10. orbiting	j. radiation

3.9 Read the text and give a short summary.

Karl Schwarzschild

Karl was the oldest of his parents’ six children, having four younger brothers and one sister. He was part of a larger extended family of relatives, too, who were cultured people with interests mainly in art and music. He attended a Jewish primary school in Frankfurt up to the age of eleven, then he entered the Gymnasium there. It was at this stage that he became interested in astronomy and saved his pocket money to buy himself materials such as lens from which he could construct a telescope.

Schwarzschild studied at the University of Strasbourg during the two years 1891-93 where he learnt a great deal of practical astronomy, then at the University of Munich where he obtained his doctorate.

After the award of his doctorate, Schwarzschild was appointed as an assistant at the Von Kuffner Observatory in Ottakring which is a suburb of Vienna. He took up his appointment in October 1896 and held it until June 1899. While at the Observatory he worked on ways to determine the apparent brightness of stars using photographic plates.

He left the Von Kuffner Observatory in June 1899 and became a Privatdozent at the University of Munich, having submitted his work on measuring stellar magnitudes as his habilitation thesis Beiträge zur photographischen Photometrie der Gestirne. This work led him to make several important discoveries.

From 1901 until 1909 he was extraordinary professor at Göttingen and also director of the Observatory there. In less than a year he had been promoted to Ordinary Professor.

Schwarzschild published on electrodynamics and geometrical optics during his time at Göttingen. He carried out a large survey of stellar magnitudes while at the Göttingen Observatory, publishing Aktinometrie (the first part in 1910, the second in 1912). In 1906 he studied the transport of energy through a star by radiation and published an important paper on radiative equilibrium of the atmosphere of the sun.

In 1913 Schwarzschild was elected to the Berlin Academy.

He wrote two papers on Einstein's relativity theory and one on Planck's quantum theory. Schwarzschild's relativity papers give the first exact solution of Einstein's general gravitational equations, giving an understanding of the geometry of space near a point mass.

The work presented in these two papers formed the basis for a later study of black holes, showing that bodies of sufficiently large mass would have an escape velocity exceeding the speed of light and so could not be seen. However, Schwarzschild himself makes clear that he believes that the theoretical solution is physically meaningless, so making it very clear that he did not believe in the physical reality of black holes.

Since Schwarzschild died at age 42 at the height of his achievements, it is not too surprising that he received relatively few honours in his lifetime. He was, however, elected to the Scientific Society of Göttingen in 1905, the Royal Astronomical Society of London on 11 June 1909, and the German Academy of Sciences in 1913. He did receive posthumous honours too, in particular an observatory, founded in 1960 in Tautenburg as an affiliated Institute of the German Academy of Sciences, was named after him. After the reunification of Germany, the Institute was refounded in 1992 and renamed "Thüringer Landessternwarte 'Karl Schwarzschild' Tautenburg". The German Astronomical Society established a special lectureship in his honour in 1959 and a Karl Schwarzschild Medal.

(adopted from the Internet)

3.10 Ask questions to the underlined words and phrases.

1. Schwarzschild studied at the University of Strasbourg during the two years 1891-93 where he learnt a great deal of practical astronomy.

2. Schwarzschild published on electrodynamics and geometrical optics during his time at Göttingen.

3. In 1913 Schwarzschild was elected to the Berlin Academy.

4. In 2002, astronomers found a missing link between stellar-mass black holes and the supermassive variety in the form of middleweight black holes at the center of some large globular clusters.

5. Schwarzschild's relativity papers give the first exact solution of Einstein's general gravitational equations, giving an understanding of the geometry of space near a point mass.

6. The giant G1 cluster in the Andromeda Galaxy appears to contain a black hole of some 20,000 solar masses.

7. The German Astronomical Society established a special lectureship in his honour in 1959 and a Karl Schwarzschild Medal.

UNIT4

4.1 Practise reading the following words.

a) [eɪ] – l**a**ter, w**a**ve, rel**a**te, indic**a**te, d**a**te, origin**a**te

[**aʊ] –** acc**ou**nt, h**ow**ever, am**ou**nt, f**ou**nded, **ou**t

[ʃ] – emi**ss**ion, specula**ti**on, red**sh**ift, ini**ti**al, observa**ti**on

[ɔ:] – th**ou**ght, s**ou**rce, c**au**ght, l**a**w, m**o**re

b) velocity [vɪ'lɔsətɪ], conclusion [kən'kluːʒ(ə)n], similar ['sɪmɪlə], subsequent ['sʌbsɪkwənt], distance ['dɪst(ə)ns], exhibit [ɪg'zɪbɪt], enormous [ɪ'nɔːməs], luminous ['luːmɪnəs]

4.2 Complete the chart below with the common noun suffixes and mark the stress. There are some spelling changes.

nouns	- ation - ion - ness - ity - ence/ance - sion - ment

noun	verb
communication	co´mmunicate
………………	dis´cuss
………………	´govern
………………	in´vite
………………	de´velop
………………	ex´plain
………………	de´cide
………………	en´joy
………………	´organize
………………	imp´rove
………………	em´ploy

4.3 Fill in the sentences with words from exercise 4.2.

1. The project is under ….. as a possible joint venture between the two space agencies.
2. We finally came to a firm ….. on the matter.
3. There needs to be a change in the ….. of the health service.
4. There have been significant computer ….. during the last decade.
5. There is no convincing ….. of the overall structure of the universe.

Active vocabulary

Word	**Pronunciation**	**Translation**
account for, *v.*	[ə'kaunt]	вычислять
considerable, *adj.*	[kən'sɪd(ə)rəbl]	значительный; важный, заслуживающий внимания, существенный; ***syn.*** important
consume, *v.*	[kən'sjuːm]	истреблять, уничтожать, поглощать
contract, *v.*	[kən'trækt]	сжимать, сокращать; ***syn***. restrict, confine
deem, *v.*	[diːm]	полагать, считать; ***syn***. consider
exhibit, *v.*	[ɪg'zɪbɪt]	показывать, выражать, проявлять; ***syn.*** show
fraction, *n.*	['frækʃ(ə)n]	доля, порция, часть, фракция
frequency, *n.*	['friːkwənsɪ]	частота, частотность
host, *n.*	[həust]	принимающая сторона
nucleus, *n.*, ***pl***. nuclei	['njuːklɪəs] ***pl***.['njuːklɪaɪ]	ядро, центр
power, *v.*	['pauə]	приводить в действие или движение, поддерживать, вдохновлять
recede, *v.*	[rɪ'siːd]	отступать, пятиться; удаляться, ретироваться; ***syn.*** retreat
redshift, *n.*	[redʃɪft]	красное смещение
similar, *adj.*	['sɪmɪlə]	подобный; похожий, сходный
speculation,*n.*	[ˌspekjə'leɪʃ(ə)n]	размышление, обдумывание; ***syn***. reflection,

		thought, contemplation
subsequent, *adj.*	['sʌbsɪkwənt]	более поздний, последующий, следующий
term, *v.*	[tɜːm]	называть, обозначать, давать имя, выражать, показывать

DO YOU KNOW…?

- that Christian Johann Doppler was a 19th century physicist and mathematician.
- that in 1842 Doppler presented his paper "On the Coloured Light of Double Stars and Certain Other Stars of the Heavens," illustrating what has since been called the Doppler Effect. He explained that the perceived change of frequency in light and sound waves was due to the relative motion of the source and the observer. His ideas helped pave the way for the idea that the universe is expanding, and made it possible to follow weather patterns by tracking electromagnetic radio waves.

4.4 Read the text and answer the following questions.

1. What are Quasi-stellar Radio Sources?
2. Why are quasars visible?
3. What feature do quasars have indicating that they are at great distances?
4. What percent of quasars are radio quiet?
5. What are quasars related to?
6. In what cases do quasars turn on and off?

QUASARS

In the 1960s it was observed that certain objects emitting radio waves but thought to be stars had very unusual optical spectra. It was finally realized that the reason the spectra were so unusual is that the lines were Doppler shifted by a very large amount, corresponding to velocities away from us that were significant fractions of the speed of light. The reason that it took some time to come to this conclusion is that, because these objects were thought to be relatively nearby stars, no one had any reason to believe they should be receding from us at such velocities. These objects were named Quasi-stellar Radio Sources (meaning ‘star-like radio sources’) which were soon contracted to quasars. Later, it was found that many similar objects did not emit radio waves. These were termed Quasi-stellar Objects or QSOs. Now, all of these are often termed guasars (only about 1% of the quasars discovered to date have detectable radio emission).

The quasars were deemed to be strange new phenomena, and initially there was considerable speculation that new laws of physics might have to be invented to account for the amount of energy that they produced. However, subsequent research has shown that the quasars are closely related to the active galaxies that have been studied at closer distances.

The quasars have very large redshifts, indicating by the Hubble law that they are at great distances. The fact that they are visible at such distances implies that they emit enormous amounts of energy and are certainly not stars.

Quasars are extremely luminous at all wavelengths and exhibit variability on timescales as little as hours, indicating that their enormous energy output originated in a very compact source. Some quasars emit radio frequency, but most (99%) are radio quiet. Careful observation shows faint jets coming from some quasars.

The quasars are thought to be powered by supermassive rotating black holes at their centers. Because they are the most luminous objects known in the Universe, they are the objects that have been observed at the great distances from us. The most distant are so far away that the light we see coming from them was produced when the Universe was only one tenth of its present age. The present belief is that quasars are actually closely related to active galaxies such as Seyfert Galaxies or BL Lac objects in that they are very active galaxies with bright nuclei powered by enormous rotating black holes. However, because the quasars are at such large distances, it is difficult to see anything other than the bright nucleus of the active galaxy in their case.

The standard theory is that quasars turn on when there is matter to feed their supermassive black hole engines at the center and turn off when there is no longer fuel for the black hole. Recent Hubble Space Telescope observations indicate that quasars can occur in galaxies that are interacting with each other. This suggests the possibility that quasars that have turned off because they have consumed the fuel available in the original galaxy may turn back on if the galaxy hosting the quasar interacts with another galaxy in such a way to make more matter available to the black hole.

(adopted from WEB SYLLABUS Dept. Physics & Astronomy University of Tennessee)

4.5 Mark the following sentences True or False.

1. Quasi-stellar Radio Sources are objects that emit radio waves with unusual optical spectra.
2. Quasars are closely related to the active galaxies.
3. Quasars turn on when there is no longer fuel for the black hole.
4. Faint jets are observed to come from some quasars.
5. Quasars are stars.
6. Quasars cannot occur in galaxies that are interacting with each other.
7. Most quasars emit radio frequency.

4.6. Match words similar in meaning.

1. certain	a. speed
2. correspond	b. happen
3. relatively	c. alike
4. velocity	d. fixed
5. similar	e. modern
6. subsequent	f. comparatively
7. indicate	g. match
8. occur	h. following
9. recent	i. understand
10.realize	j. display

4.7 Match words opposite in meaning.

1. unusual	a. broaden
2. significant	b. unavailable
3. contract	c. absorb
4. detectable	d. be far away
5. active	e. normal
6. available	f. undetectable
7. be nearby	g. dim
8. bright	h. trivial
9. enormous	i. passive
10.emit	j. tiny

4.8 Match two halves of the statements and translate them into Russian.

1. intergalactic	a. radio emission
2. with	b. of matter and energy
3. enigmatic cosmic object	c. medium
4. powerful jet	d. changes in luminosity
5. observable	e. the exception of
6. display	f. of active young galaxies
7. the very centers	g. electromagnetic spectrum
8. strong	h. of high luminosity

4.9 Fill in the sentences with the statements from exercise 4.8.

1. An active galactic nucleus can be associated with ....

2. Some quasars …….. which are rapid in the optical range and even more rapid in the X-rays.

3. Quasars can be detected over the entire …….. including radio, infrared, optical, ultraviolet, X-ray and even gamma rays.

4. A minority of quasars show ……., which originates from jets of matter moving close to the speed of light.

5. This indicates that the ……. has undergone reionization into plasma, and that neutral gas exists only in small clouds.
6. They tend to inhabit ……. and can emit up to a thousand times the energy output of the Milky Way.
7. Any of a class of ……. and strong radio emission observed at extremely great distances.
8. The color of quasars is generally much bluer than that of most stars ……. white dwarf stars.

4.10 Translate the following text into English.

Квазары являются одними из самых ярких объектов во Вселенной — их мощность излучения иногда в десятки и сотни раз превышает суммарную мощность всех звёзд таких галактик, как наша. В первую очередь квазары были опознаны как объекты с большим красным смещением, имеющие электромагнитное излучение (включая радиоволны и видимый свет) и настолько малые угловые размеры, что в течение нескольких лет после открытия их не удавалось отличить от «точечных источников» — звёзд.

Энергия квазаров – это гравитационная энергия, которая выделяется за счет катастрофического сжатия, происходящего в ядре галактики. Квазары сравнивают с маяками Вселенной. Они видны с огромных расстояний, по ним исследуют структуру и эволюцию Вселенной, определяют распределение вещества на луче зрения. Один квазар светится сильнее, чем вся наша Галактика, примерно в 10000 раз. Энергии среднего, ничем не примечательного, квазара хватило бы на то, чтобы снабжать всю Землю электроэнергией в течение нескольких миллиардов лет. А некоторые из квазаров излучают энергии в 60 тыс. раз больше.

UNIT5

5.1 Practise reading the following words.

a) [ɔɪ] – destr**oy**, c**oi**l, spher**oi**dal, sp**oi**lt, enj**oy**

[ɪə] –n**ear**ly, cl**ear**, cl**ear**ly, p**erio**d, atmosph**ere**

[w] – with, **w**ay, out**w**ard, **w**ave, al**w**ays, bet**w**een

[**tʃ**] – **ch**arge, struc**t**ure, su**ch**, ea**ch**, cul**t**ure, vir**t**ual

b) underline the stressed syllable

astronomer, catalog, to classify, classification, constant, intermediate, to object, population, sequence, successive.

c) Messier [ˈmɛsɪə, mɛsje], Andromeda [æn'drɔmɪdə] Dreyer [drīər], Hubble [ˈhʌb(ə)l].

5.2 Translate words of the same root into Russian.

To diffuse – diffusion – diffuser – diffused – diffusing – diffusive – diffusiveness – diffusible – diffuseness.

To modify – modified – modification – modifier – modifying – modifiable – modificated – modificatory – modificating.

To define – definition – definitely – defined – definite – definitive – definitively – definable – definiteness.

5.3 Fill in the sentences with words from exercise 5.2.

1. Fix a … date for the delivery of your computer.
2. The feedback will be used to … the course for the next year.
3. The pollutants … into the soil.
4. I … need a holiday.
5. We’ve made one or two … to the original design.
6. The task will be clearly … by the tutor.

Active vocabulary

Word	**Pronunciation**	**Translation**
axis, *n.; pl*. axes	['æksɪs]	ось, осевая линия
bulge, *n.*	[bʌlʤ]	выпуклость, округлый выступ
cluster, *n.*	['klʌstə]	звёздное скопление
coil, *v.*	[kɔɪl]	свёртывать кольцом, наматывать, обматывать
denote, *v.*	[dɪ'nəut]	отмечать, обозначать, различать, отличать, показывать; указывать, свидетельствовать; ***syn.*** mark, distinguish, indicate
density, *n.*	['densɪtɪ]	густота; плотность, концентрация; ***syn.*** thickness
designation, *n.*	[ˌdezɪg'neɪʃ(ə)n]	знак, обозначение, указание
distinguish, *v.*	[dɪ'stɪŋgwɪʃ]	различать, распознавать; ***syn.*** recognize, differentiate
dwarf, *adj.*	[dwɔːf]	карликовый
ellipticity, *n.*	[ɛlɪpˈtɪsɪti]	овальность, эллиптичность
extend, *v.*	[ɪk'stend]	простираться, тянуться, расширять; ***syn.*** reach, stretch
flat, *adj.*	[flæt]	плоский, ровный
globular, *adj.*	['glɔbjulə]	шаровидный, сферический
halo, *n.*	['heɪləu]	гало, ореол, сияние
isophote, *n.*	[ˈʌɪsə(ʊ)fəʊt]	изофота, кривая равной освещённости
momentum, *n.*	[mə'mentəm]	толчок, импульс, движущая сила
merge, *v.*	[mɜːʤ]	сливаться, соединяться, поглощать
merger, *n.*	['mɜːʤə]	слияние, объединение, поглощение
pinwheel, *n.*	**[**ˈpɪnwiːl]	цевочное колесо
remain, *v.*	[rɪ'meɪn]	оставаться; ***syn.*** stay
semimajor axis	[semi'meɪʤə]	большая полуось

semiminor axis	[semi'maɪnə]	малая полуось
split, *v.*	[splɪt]	раскалывать; расщеплять, трескаться
surround, *v.*	[sə'raund]	окружать; обступать
violent, *adj.*	['vaɪəl(ə)nt]	интенсивный, сильный, резкий

DO YOU KNOW…?

- that the king, Louis XV, famously called Messier "my little comet ferret."

- that Messier was awarded the Cross of the Legion of Honor by Napoleon in 1806

5.4 Read the text and answer the questions about elliptical galaxies.

1. What are elliptical galaxies and how are they subdivided?
2. What is the difference between elliptical galaxies and spiral ones?
3. Where are elliptical galaxies found?
4. What factors influence the size of elliptical galaxies?
5. How many stars can elliptical galaxies have?

THE WORLD OF GALAXIES

The insight that our Milky Way is just one of many galaxies in the Universe is less than 100 years old, despite the fact that many had already been known for a long time. The catalog by Charles Messier (1730 – 1817), for instance, lists 103 diffuse objects. Among them M31, the Andromeda galaxy, is listed as the 31st entry in the Messier catalog. Later this catalog was extended to 110 objects. John Dreyer (1852 – 1926) published the *New General Catalog* (NGC) that contains nearly 8000 objects, most of them galaxies.

Hubble set out his scheme for classifying the galaxies in a 1936 book, *The Realm of the Nebulae.* With later additions and modifications, this system is still used today. Hubble recognized three main types of galaxy: ellipticals, lenticulars, and spirals, with a forth class, the irregulars for galaxies that would not fit into any of the other categories.

Elliptical galaxies (E's) are galaxies that have nearly elliptical isophotes without any clearly defined structure. They are subdivided according to their ellipticity $\epsilon \equiv 1 - b/a$, where *a* and *b* denote the semimajor and the semiminor axes, respectively. They are usually large, containing hundreds of millions to trillions of stars. The biggest galaxies in the Universe are elliptical galaxies. They're the result of many collisions between smaller galaxies, and all these collisions have destroyed the delicate spiral structure that we see in our own galaxy. And they're usually old. Elliptical galaxies look redder than spiral galaxies like the Milky Way. That's because they contain old, red stars and have very low rates of star formation. All of the available gas and dust was already used up in the past, and now all that remains are these old red stars. They also have large populations of globular star clusters. Elliptical galaxies are usually found in the most violent places in the Universe, like at the heart of galaxy clusters and in compact groups of galaxies. In these places, elliptical galaxies have had an accelerated life, with many galaxy mergers and several periods of star formation. These constant mergers and collisions increased their size and used up all the gas available for star formation.

The smallest dwarf elliptical galaxies are no larger than a globular cluster and can contain a mere 10 million stars. The largest elliptical galaxies can have well over 10 trillion stars. The largest known galaxy in the Universe, M87, is an elliptical galaxy.

A spiral galaxy is shaped like a flat disk with a thicker bulge in the center. They are divided into two subclasses: normal spirals (S's) and barred spirals (SB's). In each of these subclasses, a sequence is defined that is ordered according to the brightness ratio of bulge and disk, and that is denoted by *a, ab, b, bc, c, cd*. Objects along this sequence are often referred to as being either an early-type or a late-type; hence, a Sa galaxy is an early-type spiral, and an SBc galaxy is a late-type barred spiral.

Bright spiral arms start from the center and then coil outward like a pinwheel. All spiral galaxies rotate, but very slowly; our own Milky Way completes a single revolution once every 250 million years or so. The spiral arms are actually density waves that move around the disk of the spiral galaxy. As the density wave passes over a region, masses are pulled together, and you get bright pockets of star formation. Then the density wave moves on, and encourages another region to begin star formation.

The central bulge at the center of a spiral galaxy contains older stars, similar to an elliptical galaxy. And at the very center, there's always a supermassive black hole containing millions of times the mass of the Sun.

Spiral galaxies are also surrounded by a vast spheroidal halo of stars. These stars might not have formed in the galaxy, but were stolen through successive mergers with other galaxies. This galactic halo also contains many globular star clusters. Astronomers think that spiral galaxies are slowly built over time through the merger of smaller galaxies. As these tiny galaxies came together, their total momentum set the merged galaxy spinning. This spin flattened out the galaxy and set the spiral arms in motion.

A lenticular galaxy is a type of galaxy which is intermediate between an elliptical galaxy and a spiral galaxy in galaxy morphological classification schemes. Lenticular galaxies are disc galaxies (like spiral galaxies) which have used up or lost their interstellar matter (like elliptical galaxies). Because of their ill-defined spiral arms, if they are inclined face-on it is often difficult to distinguish between them and elliptical galaxies. Although lenticular galaxies do not vary in shape as much as spiral galaxies, they may still be divided into a series of subclasses based on their appearance. Lenticular galaxies may be split into three subclasses based on the presence or absence of a central bar structure. The SA0 designation is used for lenticular galaxies with no apparent bars. The SB0 designation is used for galaxies with a strong bar. The SAB0 designation is an intermediate class that may be referred to as weakly barred.

(adopted from "Extragalactic Astronomy and Cosmology: an Introduction" and the Internet)

5.5 Mark the following sentences True or False.

1. Spiral galaxies resemble elliptical galaxies.
2. The spiral structure is associated with active star-forming regions.
3. The nucleus of a spiral galaxy is typically red in color so this indicates the presence of young and old stars in the nucleus.
4. Astronomers think that spiral galaxies are formed through merging of smaller galaxies.
5. Spiral galaxies are surrounded by stars which were formed in the galaxy.

5.6 Ask questions to the underlined words and phrases about lenticular galaxies.

5.7 Match words with their definitions.

bulge dwarf catalog density star collision ratio cluster

1. ………. – a complete list of things that you can look at, buy, or use, for example in a library or at an art show;
2. ………. – a large ball of burning gas in space that can be seen at night as a point of light in the sky;
3. ………. – an accident in which two or more people or vehicles hit each other while moving in different directions;
4. ………. – a group of things of the same kind that are very close together;
5. ………. – an imaginary creature that looks like a small man;
6. ………. – a relationship between two amounts, represented by a pair of numbers showing how much bigger one amount is than the other;
7. ………. – a curved mass on the surface of something, usually caused by something under or inside it;
8. ………. – the degree to which an area is filled with people or things.

5.8 Complete the text with one word.

Although both stars … galaxies are objects which are held together by the attractive force of …, they differ in many important respects both qualitative and quantitative. One simple observational fact is …, whereas the majority of stars are spherical and depart only slightly from … shape, galaxies exist in many shapes from essentially spherical to … which are highly flattened; some of the latter are spheroidal but … have a much less symmetrical structure. Many … flattened galaxies are observed to rotate rapidly. The great variety in galactic shape indicates that the classification of galaxies may be much more complicated than the … of stars. Another very important … between stars and galaxies is that there … at present no clear evidence that there exist galaxies of significantly different ages; they may almost all have … formed between 10^{10} and 2×10^{10} years ago, with the actual spread of ages being … less than either of these figures.

5.9 Reorder the words to make a sentence.

1. empirical – now – Cosmology – science – mature – by – a – is.
2. universe – must – worldview – a – order – the – we – balanced – have – In – understand – to.
3. but – be – universe – isotropic – homogeneous – can – The – not.
4. forming – are – Galaxies – have – galaxy – probes – as – been – evolution – to – important – regarded – that – actively – stars.
5. other – to – rather – galaxies – Most – appearance – each – similar – are – irregular – in.
6. around – dwarf – have – Way – the – galaxies – found – Astronomers – galaxies – and – Milky – Andromeda.
7. are – distant – Researchers – classifying – way – exploring – galaxies – of – see – what – of – new – we.

5.10 Translate the following sentences into English.

Гершель в XVIII веке открыл и занес в каталоги тысячи наблюдаемых на небе туманных пятен. У многих из них впоследствии была обнаружена спиральная структура.

Американский астроном Хаббл в XX в. получил фотографии туманности в созвездии Андромеды, на которых было видно, что это туманное пятно состоит из множества звезд. Он обнаружил в туманности вспышки новых звезд, рассеянные и шаровые скопления и цефеиды, которые как установил Хаббл, находятся очень далеко за пределами нашей Галактики. Таким образом, спиральная туманность в созвездии Андромеды также находится вне пределов Галактики и уже этим отличается от газовых и пылевых туманностей нашей звездной системы. Зная расстояние до этой туманности и ее угловой диаметр, вычислили его в линейных единицах. Оказалось, спиральная туманность в созвездии Андромеды примерно такая же огромная звездная система, как и наша Галактика. Мы знаем теперь, что до нее 2 миллиона световых лет. В ней есть газовые и пылевые туманности, как и в нашей Галактике. Вследствие того, что галактику в созвездии Андромеды мы видим под некоторым углом к ее оси, она имеет продолговатую форму.

(adopted from http://skywatching.net/astro/vselenn_drgala.php)

UNIT 6

6.1 Practise reading the following words.

a) [θ] – three, **th**irty, bo**th**, **th**ick, **th**ought, **th**eory

[ŋ] – bei**ng**, you**ng**, emergi**ng**, spanni**ng**, drawi**ng**, le**ng**th

[e] - exc**e**ption, **e**vidence, s**e**ction, resp**e**ct, dir**e**ction, eff**e**ct

b) Andromeda [æn'drɔmɪdə], Canis Major [ˌkeɪnɪs ˈmeɪdʒə], Magellanic [ˌmadʒɪˈlanɪk], Sagittarius [ˌsæʤɪ'tɛərɪəs], equator [ɪ'kweɪtə], Scorpius [ˈskɔːpɪəs], Ophiuchus [ɒˈfjuːkəs], Orion [ə'raɪən], Perseus ['pɜːsɪəs]

6.2 Cross out the word with a different sound.

ʌ	p**u**blish str**u**cture cl**u**ster incl**u**de c**u**rrent
æ	g**a**laxy c**a**talog **a**fter h**a**s pl**a**net
k	**c**lose o**cc**upy **c**onspi**c**uous **c**on**c**entrate **c**onsider
əʊ	s**o**lar comp**o**nent pr**o**minent m**o**st kn**o**w
w	**w**ave **w**hole **w**ith **w**ay d**w**arf

Active vocabulary

Word	**Pronunciation**	**Translation**
apparent, *adj.*	[ə'pær(ə)nt]	очевидный, явный; несомненный; видимый, открытый; ***syn.*** evident, obvious, plain
conspicuous, *adj*.	[kən'spɪkjuəs]	видный, заметный, бросающийся в глаза; ***syn.*** plain, noticeable
constellation, *n.*	[ˌkɔnstə'leɪʃ(ə)n]	созвездие
disrupt, *v.*	[dɪs'rʌpt]	разрывать, разрушать, подрывать; разрывать (узы); нарушать

encounter, *n.*	[ɪn'kauntə]	столкновение, стычка; ***syn.*** collision, clash
evidence, *n.*	['evɪd(ə)ns]	доказательство, подтверждение, свидетельство; ***syn.*** testimony, proof
exception, *n.*	[ɪk'sepʃ(ə)n]	исключение, изъятие, невключение; ***syn.*** exclusion, expulsion
hydrogen, *n.*	['haɪdrəʤən]	водород
incorporate, *v.*	[ɪn'kɔːp(ə)reɪt]	соединяться, объединяться; смешиваться, включать в (состав чего-л.); заключать, содержать в себе; ***syn.*** unite, absorb, embody, include
infrared, *adj.*	[ˌɪnfrə'red]	инфракрасный
import, *v.*	[ɪm'pɔːt]	вносить, вводить; привносить; ***syn.*** introduce, bring in
interstellar, *adj.*	[ˌɪntə'stelə]	межзвёздный
nebula, *n.*, *pl.* nebulae, nebulas	['nebjulə] *pl.* ['nebjuliː]	туманность
obscure, *adj.*	[əb'skjuə]	непонятный, неясный, неизвестный, неопределённый, неотчётливый, неясный, смутный
overestimate, *v.*	[ˌəuv(ə)r'estɪmeɪt]	переоценивать, оценивать слишком высоко
perhaps, *adv.*	[pə'hæps]	может быть, возможно, наверно
span, *v.*	[spæn]	измерять, мерить, отмерять, охватывать, распространяться
spectacular, *adj.*	[spek'tækjələ]	впечатляющий, эффектный, волнующий, захватывающий; *syn.* imposing, impressive
supernova, *n.*,	[ˌs(j)uːpə'nəuvə]	сверхновая звезда

pl. supernovae, supernovas	*pl.*[ˌs(j)uːpə'nəuviː]	
transparency, n.	[træn'spær(ə)nsɪ]	прозрачность, ясность, понятность

DO YOU KNOW…?

- that Shapley, Harlow (1885-1972), a United States astronomer. His studies of stars in globular clusters and of Cepheid variable stars led to a new understanding of the structure of the universe. From these studies he determined the size and shape of the Milky Way and placed the solar system far from the galaxy's center. He introduced the theory that the Cepheid variable stars undergo changes in brightness because they pulsate, alternately growing and shrinking in size. He also developed a method of determining the physical properties of eclipsing binaries.
- that the easily recognized "tea pot" shape of Sagittarius was well known in mythology as being represented by the half-man, half-horse – the Centaur. According to some legends, he was the offspring of of Philyra and Saturn. Named Chiron, he turned himself into a horse to hide from his jealous wife and was eventually immortalized in the stars. He is often depicted as an archer as well, with his arrow pointed directly at the red heart of the Scorpion – Antares. Sagittarius may represent the son of Pan, who invented archery and was sent to entertain the Muses who threw a laurel wreath at his feet.

6.3 Read the text and answer the following questions.

1. What does the Milky Way consist of?
2. What is the mass and the diameter of the Milky Way?
3. What kind of galaxy is the Milky Way?
4. What group does it belong to?
5. What are neighbours of the Milky Way?
6. What do spiral arms of the Milky Way contain?

7. What does the bulge component consist of?
8. Where are globular clusters concentrated?
9. What is the “Galactic Equator”?
10. Where is the Solar System situated?

THE MILKY WAY GALAXY

The Milky Way is the galaxy which is the home of our Solar System together with at least 200 billion other stars (more recent estimates have given numbers around 400 billion) and their planets, and thousands of clusters and nebulae, including at least almost all objects of Messier’s catalog which are not galaxies on their own (one might consider two globular clusters as possible exceptions, as probably they are just being, or have recently been, incorporated or imported into our Galaxy from dwarf galaxies which are currently in close encounters with the Milky Way).

As a galaxy, the Milky Way is actually a giant, as its mass is probably between 750 billion and one trillion solar masses, and its diameter is about 100,000 light years. Radio astronomical investigations of the distribution of hydrogen clouds have revealed that the Milky Way is a spiral galaxy of Hubble type Sb or Sc. Therefore, our galaxy has both a pronounced disk component exhibiting a spiral structure, and a prominent nuclear region which is a part of a notable bulge/halo component. It is still not clear if it has a bar structure (so that it would be type Sb) or not but an increasing number of investigations has given some evidence for this.

The Milky Way Galaxy belongs to the Local Group, a smaller group of three large and over thirty small galaxies, and is the second largest (after the Andromeda Galaxy M31) but perhaps the most massive member of this group. M31, at about 2.9 million light years, is the nearest large galaxy, but a number of faint galaxies are much closer: many of the dwarf Local Group members are satellites or companions of the Milky Way. The two closest neighbours have only recently been discovered: the nearest of all, discovered in 2003, is an already almost disrupted dwarf galaxy, the Canis Major Dwarf, and the second - SagDEG. These two dwarfs are currently in close encounters with our galaxy and in sections of their orbits situated well within the volume occupied by our Milky Way. They are followed in distance by the more conspicuous Large and Small Magellanic Cloud, at 179,000 and 210,000 light years, respectively.

The spiral arms of our Milky Way contain interstellar matter, diffuse nebulae, and young stars and open star clusters emerging from this matter. On the other hand, the bulge component consists of old stars and contains the globular star clusters; our galaxy has probably about 200 globulars, of which we know about 150. These globular clusters are strongly concentrated toward the Galactic Center: from their apparent distribution in the sky, Harlow Shapley has concluded that this center of the Milky Way lies at a considerable distance (which he overestimated by factors) in the direction of Sagittarius and not rather close to us, as had been thought previously.

Our Solar System is thus situated within the outer regions of this galaxy, well within the disk and only about 20 light years above the equatorial symmetry plane but about 28,000 light years from the Galactic Center. Therefore, the Milky Way shows up as luminous band spanning all around the sky along this symmetry plane, which is also called the “Galactic Equator”. Its center lies in the direction of the constellation Sagittarius, but very close to the border of both neighbour constellations Scorpius and Ophiuchus. The distance of 28,000 light years has recently (1997) been confirmed by the data of ESA’s astrometric satellite Hipparcos. Other investigations published consequently have disputed this value and propose a smaller value of some 25,000 light years, based on stellar dynamics; a recent investigation (2000) yields roughly 26,000 light years. These data, if of significance, would not immediately effect values for distances of particular objects in the Milky Way or beyond.

The Solar System is situated within a smaller spiral arm, called the Local or Orion Arm, which is merely connection between the inner and outer next more massive arms, the Sagittarius Arm and the Perseus Arm. Similar to other galaxies, there occur supernovae in the Milky Way at irregular intervals of time. If they are not heavily obscured by interstellar matter, they can be, and have been seen as spectacular events from the Earth. Unfortunately, none has yet appeared since the invention of the telescope (the last well observed supernova was studied by J.Kepler in 1604).

In order to obtain a picture of the whole Milky Way as it appears from the Earth, one must either compose a mosaic of many photographs or create a drawing. In the infrared light, the structure of the Milky Way can be better investigated, as the obscuring dust clouds are of better transparency for long wavelength IR than for the visible light. The Cobe satellite has provided an infrared image of the Milky Way's central region. The central region of the Milky Way, as those of many other galaxies, is more densely crowded with stars than the outer region, and contains a massive central object, Sagittarius A*.

(adopted from WEB SYLLABUS Dept. Physics & Astronomy University of Tennessee)

6.4 Mark the following sentences True or False.

1. The Milky Way is a spiral galaxy of Hubble type Sb or Sc.
2. The Andromeda galaxy is the first largest galaxy of the Local Group.
3. Many of the dwarf Local Group members are satellites of the Andromeda galaxy.
4. Canis Major Dwarf is far away from our galaxy.
5. Our galaxy has probably 150 globulars.
6. According to H.Shapley, the Galactic Center lies in the direction of Sagittarius.
7. Our Solar System is situated within the inner regions of the Milky Way galaxy.
8. The Galactic Equator is in close to the border of constellations Scorpius and Ophiuchus.
9. Supernovae appear in the Milky Way at irregular intervals of time.
10. The outer region of the Milky Way is more densely crowded with stars than the central region.

6.5 Match words similar in meaning.

1.include	a. conspicuous
2. on their own	b. offer
3. import	c. merit

4. prominent	d. incorporate
5. occupy	e. abnormal
6. value	f. bring in
7. dispute	g. modern
8. propose	h. by themselves
9. recent	i. debate
10. irregular	j. reside

6.6 Give English equivalents for the following word combinations.

1. в качестве возможных исключений
2. как думали раньше
3. несколько тусклых галактик
4. межзвездная материя
5. возникающие из этой материи
6. в направлении
7. распространяющийся по небу
8. оспаривали это значение

6.7 Give Russian equivalents for the following word combinations.

1. is densely crowded
2. at irregular intervals of time
3. are of better transparency
4. spectacular events
5. in close encounters
6. bar structure
7. are strongly concentrated toward
8. at a considerable distance

6.8 Match sentence halves.

1.The black hole appears to be	**a.** bright, diffuse gaseous objects generally called nebulae.
2.A key distinguishing feature of globular clusters in the Galaxy is	**b.** where star formation is occurring, notably in the spiral arms.
3.Open clusters are highly concentrated along the plane of the Galaxy	**c.** especially along the inner edge of well-defined ones.
4.Stellar associations appear only in regions of the system	**d.** the dynamical center of the Milky Way.
5.The distances of individual stars in a moving group may be determined	**e.** and are found throughout the disk and the inner halo.
6.A conspicuous component of the Galaxy is the collection of large,	**f.** their uniformly old age.
7.Planetary nebulae belong to an intermediate population	**g.** if their radial velocities and proper motions are known and if the exact position of the radiant is determined.
8.The dust clouds are often most conspicuous within the spiral arms,	**h.** and slowly decrease in number outward from its center.

6.9. Ask all possible questions to the sentences from exercise 6.8.

6.10 Translate the following text into English.

Галактика Андромеды (M31, NGC 224) — спиральная галактика типа Sb. Эта ближайшая к Млечному Пути большая галактика расположена в созвездии Андромеды и удалена от нас на расстояние 2,52 млн. световых лет (772 килопарсек).

Галактика Андромеды, как и Млечный Путь, принадлежит к Местной группе, и движется по направлению к Солнцу со скоростью 300 км/с. Астрономы выяснили, что галактика Андромеды и наша Галактика приближаются друг к другу со скоростью 100—140 км/с. Соответственно, столкновение двух галактических систем произойдёт приблизительно через 3-4 млрд. лет. Если это произойдёт, они обе, скорее всего, сольются в одну большую галактику. Не исключено, что при этом наша Солнечная система будет выброшена в межгалактическое пространство мощными гравитационными возмущениями. Разрушение Солнца и планет, вероятнее всего, при этом процессе не произойдёт.

В ядре Андромеды расположена сверхмассивная чёрная дыра, масса которой превышает 140 млн. масс Солнца. Вокруг черной дыры находится скопление более чем из 400 голубых звёзд, сформировавшихся приблизительно 200 миллионов лет назад. Звёзды сгруппированы в диск диаметром всего 1 световой год. В центре диска гнездятся более старые и холодные красные звёзды.

В галактике находится звезда PA-99-N2 — первая, которую открыли за пределами Млечного Пути.

(adopted from http://spaceandyou.ru/node/220447)

UNIT 7

7.1 Practise reading the following words.

a)[eə] – th**ere**, wh**ere**, c**are**ful, p**air**, r**are**, th**eir**, b**are**

[i] - distr**i**bute, shr**i**nk, g**i**ve, v**i**sible, th**i**s, **i**ts, w**i**th**i**n

[ɒ] – c**o**mbat, h**o**t, sh**o**ck, str**o**ng, st**o**p, **o**bject

[f] – enou**gh**, **ph**ase, atmos**ph**ere, o**ff**, **f**ield, lau**gh**

b) carbon ['kɑːb(ə)n], electron [ɪ'lektrɔn], hydrogen ['haɪdrəʤən], isotope ['aɪsətəup], neutron ['njuːtrɔn], nickel ['nɪkl], oxygen ['ɔksɪʤən], photon ['fəutɔn], physicist ['fɪzɪsɪst], radioactive [ˌreɪdɪəu'æktɪv].

7.2 Put the words in the correct column.

<table>
<tr><td colspan="4">Thought some ask set heart couple awful theft half blood horse heavy arm law son head</td></tr>
<tr><td>ɑ:</td><td>ʌ</td><td>e</td><td>ɔ:</td></tr>
</table>

Active vocabulary

Word	**Pronunciation**	**Translation**
blast, *n.*	[blɑːst]	взрыв, ударная волна
cease, *v.*	[siːs]	переставать (делать что-л.), прекращать; ***syn.*** stop
core, *n.*	[kɔː]	центр, сердцевина, ядро; ***syn.*** centre, heart
dense, *adj.*	[dens]	плотный, сжатый, густой, частый, непрозрачный; ***syn.*** thick, opaque
distribute, *v.*	[dɪ'strɪbjuːt]	распределять, раздавать, распространять
envelope, *n.*	['envələup]	оболочка
forge, *v.*	[fɔːʤ]	выдумывать, изобретать, придумывать, постепенно выходить на первое место; возглавлять, лидировать, медленно и

		равномерно продвигаться вперёд
fuse, *v*.	[fjuːz]	объединяться, сливаться, смешиваться, соединяться; ***syn.*** unite, mix
fusion, *n*.	['fjuːʒ(ə)n]	синтез, слияние, интеграция, объединение, слияние, сращивание
halt, *v*.	[hɔːlt]	останавливать, задерживать
liberate, v.	['lɪb(ə)reɪt]	освобождать, избавлять
overcome, *v*.	[ˌəuvə'kʌm]	превозмочь, преодолеть, подавить
propel, *v*.	[prə'pel]	ускорять, двигать, побуждать, стимулировать, толкать; ***syn.*** press, push, move, accelerate
recoil, *v*.	[rɪ'kɔɪl]	отскочить, отпрянуть, отшатнуться
remnant, *n*.	['remnənt]	остаток, следы, остатки
repulsive, *adj*.	[rɪ'pʌlsɪv]	отталкивающий, противный, вызывающий отвращение; **syn.** disgusting, loathsome, revolting
swell, *v*.	[swel]	величиваться, разрастаться, расширяться; ***syn.*** increase
temporary, *adj*.	['temp(ə)r(ə)rɪ]	временный
threshold, *n*.	['θreʃəuld]	порог, ворота, вход, граница
yield, *v*.	[jiːld]	сдаваться, поддаваться

DO YOU KNOW…?

- that supernovae have been recorded as far back as 185 A.D., when Chinese astronomers recorded a short-lived star.

- that the last supernovae to be seen in the Milky Way was Kepler’s Supernova which was first observed in 1604 (also known as Supernova 1604 or Kepler’s Star). Since then no supernova has been indisputably observed in our galaxy, though many outside our galaxy has.

7.3 Read the text and fill it with sentences A-F.

SUPERNOVA

Supernovae (the plural of supernova) are extremely important for understanding our Galaxy. They heat up the interstellar medium, distribute heavy elements throughout the Galaxy, and accelerate cosmic rays.

Stars which are 8 times or more massive than our Sun end their lives in a most spectacular way; they go supernova. A supernova explosion will occur when there is no longer enough fuel for the fusion process in the core of the star to create an outward pressure which combats the inward gravitational pull of the star's great mass. **1**…….. On the inside, the core yields to gravity and begins shrinking. As it shrinks, it grows hotter and denser. A new series of nuclear reactions begin to occur … temporarily halting the collapse of the core… but alas, it is only temporary. When the core contains essentially just iron, it has nothing left to fuse (because of iron's nuclear structure, it does not permit its atoms to fuse into heavier elements). Fusion in the core ceases. **2**…….. The core temperature rises to over 100 billion degrees as the iron atoms are crushed together. The repulsive force between the nuclei overcomes the force of gravity. So the core compresses, but then recoils. The energy of the recoil is transferred to the envelope of the star, which then explodes and produces a shock wave. As the shock encounters material in the star's outer layers, the material is heated, fusing to form new elements and radioactive isotopes. **3**…….. The material that is exploded away from the star is now known as a supernova remnant.

All that remains of the original star is a small, super-dense core composed almost entirely of neutrons – a neutron star. Or, if the original star was very massive indeed (say 15 or more times the mass of our Sun), even the neutrons cannot survive the core collapse… and a black hole forms. The hot material given off by the supernova, the radioactive isotopes, and the free electrons moving in the strong magnetic field of the neutron star… all of these things produce X-rays and gamma rays. **4**……..

Another type of supernova involves the sudden explosion of a white dwarf star in a binary star system. A white dwarf is the endpoint for stars of up about 5 times that of the Sun. The remaining white dwarf has a mass less than 1.4 times the mass of the Sun, and is about the size of the Earth.

A white dwarf star in a binary star system will draw material off its companion star if they are close to each other. **5**……..

Should the in-falling matter from the companion star cause the white dwarf to approach a mass of 1.4 times that of the Sun (a mass called the Chandrasekhar limit after the scientist who discovered it), the pressure at the center will exceed the threshold for the carbon and oxygen nuclei to start to fuse uncontrollably. **6**…….. Nothing is left behind, except whatever elements were left over from the white dwarf or forged in the supernova blast. Among the new elements is radioactive nickel, which liberates huge amounts of energy, including visible light. The evolution of these supernovae tend to all be similar.

(adopted from WEB SYLLABUS Dept. Physics & Astronomy University of Tennessee)

A In less than a second, the star begins the final phase of gravitational collapse.

B This is due to the strong gravitational pull of an object as dense as a white dwarf.

C First, the star will swell into a red supergiant… at least on the outside.

D The shock then propels the matter out into space.

E This results in a thermonuclear detonation of the entire star.

F These high energy photons are used by astrophysicists studying the phenomena of neutron stars and supernovae.

7.4 Read the text again and answer the following questions.

1. What functions do supernovae fulfill?
2. What happens to stars when they end their lives?
3. What case does a supernova explosion happen?
4. What happens in the core of the star during gravitational collapse?
5. How is a supernova remnant formed?

6. What happens if the neutron cannot survive the core collapse?

7. What is the mass and the size of the remaining white dwarf?

8. What causes thermonuclear detonation of the star?

7.5 Mark the following sentences True or False.

1. Supernovae distribute light elements throughout the Galaxy.
2. Massive stars go supernova after completing their lives.
3. It is necessary fuel for the fusion process to create an outward pressure in the core of the star.
4. The core yields to gravity and increases on the inside.
5. When the iron atoms are crushed together, the core temperature of the star rises.
6. Neutron star is a remnant of the original star.

7.6 Match words with their definitions.

hydrogen isotope photon oxygen electron carbon neutron

1……….. - a stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids;

2. ………. - each of two or more forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass but not in chemical properties;

3. ………. - a subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei except those of ordinary hydrogen;

4. ……… - a particle representing a quantum of light or other electromagnetic radiation; it carries energy proportional to the radiation frequency but has zero rest mass;

5. ……… - a non-metal which has two main forms and which also occurs in impure form in charcoal, soot, and coal;

6. ………. - a colourless, odourless, highly flammable gas;

7. ………. - a colourless, odourless reactive gas and the kife-supporting component of the air.

7.7 Match adjectives with suitable nouns.

1. outward	a. detonation
2. inward gravitational	b. field
3. nuclear	c. medium
4. gravitational	d. pressure
5. magnetic	e. element
6. radioactive	f. pull
7. heavy	g. light
8. thermonuclear	h. collapse
9. visible	i. isotope
10. interstellar	j. structure

7.8 Complete the text with one word.

What Causes a Star to Blow up?

Gravity gives the supernova ….. energy. For Type II supernovae, mass flows ….. the core by the continued making of iron ….. nuclear fusion. Once the core has gained so …... mass that it cannot withstand its own weight, the core implodes. This implosion can usually ….. brought to a halt by neutrons, ….. only things in nature that can stop such ….. gravitational collapse. Even neutrons sometimes fail depending ….. the mass of the star's core. When the collapse is abruptly stopped ….. the neutrons, matter bounces off the hard iron core, thus turning the implosion ….. an explosion. For Type Ia supernova, the energy comes ….. the run-away fusion of carbon and oxygen ….. the core of the white dwarf.

7.9 Reorder the words to make a sentence.

1. heavy - suppliers - are - primary - for - the - of – elements - universe - Supernovae – the.

2. cosmological - to - Supernovae - measure - used - as – beacons - light - distances - are.
3. also - release - explosions - X-rays - not - tremendous – radio - amounts - Supernova - and - but - energy - cosmic - only - of - rays.
4. to - A - weeks - supernova - for - several - shines - typically - months – several.
5. characteristics - Supernovas - explosion - their - be - grouped – to - either - observational - may - their - or – according - mechanism.
6. in - Supernovae - other - a - discovered – 150 - galaxies - rate - of - about - per - are - year – at.
7. nature's - Type - supernovae - regarded - as - largest - may thermonuclear - bombs - Ia – be.
8. masses - type - 8 - II - star - supernova - typical - a - somewhat - over - results - from - solar - A.

7.10 Translate the following text into English.

Сверхновые I типа представляют собой термоядерные взрывы звезд – белых карликов, которые приобретают массу выше критической. Звезда с массой в пять солнечных сжигает в своих глубинах водород, а когда ядерное горючие кончается, она превращается в красный гигант. В центре звезды начинается горение гелия, а когда он выгорает, образуется углеродное ядро. Центральная часть звезды представляет собой теперь углеродное ядро, окруженное гелиевой оболочкой. Плотность вещества в нем также велика, как в белом карлике. На поверхности гелиевой оболочки продолжается превращение водорода в гелий, а на границе между гелием и углеродом гелий превращается в углерод. Масса этого ядра, которое по сути представляет собой белый карлик, все время возрастает и когда достигает предела в 1,4 солнечных масс, происходит гравитационный коллапс, который не может предотвратить и горение углерода. Белый карлик меньше чем за минуту превращается в нейтронную звезду. Огромное количество энергии, выделившейся при этом, сносит внешнюю оболочку звезды. *(adopted from http://katastrofa.h12.ru/sstar.htm)*

UNIT8

8.1Practise reading the following words.

a) **[aɪ] –** sk**y**, descr**i**be, h**ei**ght, pr**i**mary, b**y**, modif**y**

[u:] – l**oo**se, concl**u**sive, gr**ou**ping, pr**o**ve, m**o**ve

[ɑ:] – p**ar**ticle, **ar**e, c**ar**bon, M**ar**s, M**ar**tian, st**ar**t

[dʒ] – ori**g**inal, su**gg**est, a**g**e, **g**eolo**g**ical, ori**g**inate

b)chondrite [ˈkɒndrʌɪt], enstatite [ˈɛnstətʌɪt], achondrite [əˈkɒndrʌɪt], pallasite [ˈpaləsʌɪt], olivine [ˈɒlɪviːn, -ʌɪn], sulphur [ˈsʌlfə], phosphorus [ˈfɒsf(ə)rəs], meteor ['miːtɪə], meteorite ['miːtɪ(ə)raɪt]

8.2Translate words of the same root into Russian.

To originate – original – originally – originator – originality – origination.

To perturb – perturbation – perturbed – perturbing – perturbance.

To produce – production – product – produced – productivity – productive – producer – producing.

8.3 Fill in the sentences with words from exercise 8.2.

1. He works in marketing and … development.
2. Professor Adams was the … of the project.
3. My unexpected arrival didn't … him in the least.
4. I'd prefer to read it in the ….
5. They were unable to … any statistics to verify their claims.
6. These shifts and swings in wildlife populations are possibly related to climatic ….

Active vocabulary

Word	**Pronunciation**	**Translation**
coherence, *n.*	[kə(u)'hɪər(ə)ns]	связь, сцепление, логичность, последовательность, обоснованность

collision, *n.*	[kə'lɪʒ(ə)n]	столкновение
decay, *v.*	[dɪ'keɪ]	распадаться, разрушаться, разлагаться; ***syn.*** dilapidation, disintegration
enclose, *v.*	[ɪn'kləuz]	окружать, заключать, вкладывать, помещать
enhance, *v.*	[ɪn'heːns]	увеличивать, усиливать, улучшать; ***syn.*** improve, increase
friction, *n.*	['frɪkʃ(ə)n]	трение
gradual, *adj.*	['grædjuəl]	постепенный, последовательный
grain, *n.*	[greɪn]	зерно, песчинка, мельчайшая частица, крупица
igneous, *adj.*	['ɪgnɪəs]	огненный, пирогенный, вулканического происхождения
incandescence, *n.*	[ˌɪnkæn'des(ə)ns]	накал, накаливание
intersect, *v.*	[ˌɪntə'sekt]	пересекаться, перекрещиваться, скрещиваться
loosely, *adv.*	['luːslɪ]	свободно, неточно, неопределённо
meteoroid, *n.*	[ˈmiːtɪərɔɪd]	метеорное тело
modify, *v.*	['mɔdɪfaɪ]	видоизменять, трансформировать; ***syn.*** change, alter
molten, *adj.*	['məult(ə)n]	расплавленный, источающий тепло, сияние
radiative, *adj.*	['reɪdɪətɪv]	излучающий, испускающий
random, *adj.*	['rændəm]	случайный, произвольный
reshape, *v.*	[ˌriː'ʃeɪp]	придавать новый вид или иную форму, меняться
sample, *v.*	['sɑːmpl]	брать образцы или пробы, определять качество, испытывать, пробовать; ***syn.*** test, taste, try
segregate, *v.*	['segrɪgeɪt]	отделять, выделять; изолировать, обособлять

sporadic, *adj*	[spə'rædɪk]	единичный, отдельный, случайный; ***syn.*** occasional
streak, *n.*	[striːk]	вспышка света
suspect, *v.*	[sə'spekt]	подозревать, думать, полагать; предполагать, допускать
volatile, *adj.*	['vɔlətaɪl]	летучий, непостоянный, изменчивый, неуловимый, переменный
vaporize, *v.*	['veɪp(ə)raɪz]	испарять, распылять

DO YOU KNOW…?

- that NASA scientists found evidence of life on Mars from a meteorite, believed to be from Mars, that was determined to have hydrocarbons which are by-products of dead organisms on Earth, mineral phases determined to be by-products of bacterial activity and microfossils called "carbonate globules" which may be from primitive bacteria.

- that a NASA science team found sugars in two separate meteorites in December 2001. This is significant since it points to evidence that a fundamental building block of life on Earth, sugar, may have come originally from another planet. Previously, researchers discovered other important compounds to life on Earth in meteorites which included amino acids and carboxylic acids.

8.4 Read the text and answer the following questions.

1. What is the term “meteor” used to describe?
2. What is meteoroid?
3. What is the main goal of studying meteorites?
4. What is the difference between stony, iron and stony-iron meteorites?
5. How are stream and sporadic components different?
6. What is the result of the intersection of the Earth’s orbit and a meteor stream?

7. Why do sporadic meteors have a gradual loss of orbital coherence with a meteor shower?

METEOROIDS AND METEORITES

The term meteor comes from the Greek “meteoron”, meaning phenomenon in the sky. It is used to describe the streak of light produced as matter in the solar system falls into Earth's atmosphere creating temporary incandescence resulting from atmospheric friction. This typically occurs at heights of 80 to 110 kilometers (50 to 68 miles) above Earth's surface. The term is also used loosely with the word meteroid referring to the particle itself without relation to the phenomena it produces when entering the Earth's atmosphere. A meteoroid is matter revolving around the sun or any object in interplanetary space that is too small to be called an asteroid or a comet. Even smaller particles are called micrometeoroids or cosmic dust grains, which includes any interstellar material that should happen to enter our solar system. A meteorite is a meteoroid that reaches the surface of the Earth without being completely vaporized.

One of the primary goals of studying meteorites is to determine the history and origin of their parent bodies. Several achondrites sampled from Antarctica since 1981 have conclusively been shown to have originated from the moon based on compositional matches of lunar rocks obtained by the Apollo missions of 1969-1972. Sources of other specific metorites remain unproven, although another set of eight achondrites are suspected to have come from Mars. These meteorites contain atmospheric gases trapped in shock melted minerals which match the composition of the Martian atmosphere as measured by the Viking landers in 1976. All other groups are presumed to have originated on asteroids or comets; the majority of meteorites are believed to be fragments of asteroids.

Meteorites have proven difficult to classify, but the three broadest groupings are stony, stony iron, and iron. Stony meteorites consist of those that are rich in silicon and oxygen with small amounts of iron, magnesium and other elements. Iron meteorites come from the metallic core of a larger parent body such as an asteroid that has melted and separated into pieces. Stony-iron meteorites also come from a larger body, but these meteorites come from the inner crust of those bodies.

The motion of meteoroids can be severely perturbed by the gravitational fields of major planets. Jupiter's gravitational influence is capable of reshaping an asteroid's orbit from the main belt so that it dives into the inner solar system and crosses the orbit of Earth. This is apparently the case of the Apollo and Vesta asteroid fragments.

Particles found in highly correlated orbits are called stream components and those found in random orbits are called sporadic components. It is thought that most meteor streams are formed by the decay of a comet nucleus and consequently are spread around the original orbit of the comet. When Earth's orbit intersects a meteor stream, the meteor rate is increased and a meteor shower results. A meteor shower typically will be active for several days. A particularly intense meteor shower is called a meteor storm. Sporadic meteors are believed to have had a gradual loss of orbital coherence with a meteor shower due to collisions and radiative effects, further enhanced by gravitational influences. There is still some debate concerning sporadic meteors and their relationship with showers.

(adopted from http://www.solarviews.com/eng/meteor.htm)

8.5 Mark the following sentences True or False.

1. Meteor is a streak of light which falls into Earth creating permanent incandescence resulting from atmospheric friction.
2. Meteoroid is too small to be called a comet.
3. Meteor samples from Antarctica have originated from Mars.
4. Most of meteorites are considered to be fragments of asteroids or comets.
5. Stony meteorites come from the inner crust of the parent body.
6. Stony-iron meteorites are rich in silicon, oxygen, iron and other elements.
7. Major planets can perturb the motion of meteoroids.
8. Meteor shower is active for one day only.

8.6 According to the text find words opposite in meaning.

1. rise
2. tight
3. incomplete
4. secondary
5. depart
6. easy
7. join
8. outer
9. orderly
10. decrease

8.7 Match adjectives with suitable nouns

1.volatile	a. meteorites
2. inner	b. system matter
3. thermal	c. properties
4. approximate	d. elements
5. oxidized	e. age
6. different	f. metamorphism
7. solar	g. solar system
8. common	h. elements

8.8 Fill in the text with the statements from exercise 8.7.

The most **1** … are chondrites, which are stony meteorites. Radiometric dating of chondrites has placed them at the age of 4.55 billion years, which is the **2** … of the solar system. They are considered pristine samples of early **3** ..., although in many cases their properties have been modified by **4** … or icy alteration. Some meteoriticists have suggested that the **5** … found in various chondrites suggest the location in which they were formed. Enstatite chondrites contain the most refractory elements and are believed to have formed in the **6** …. Ordinary chondrites, being the most common type containing both volatile and **7** …, are thought to have formed in the inner asteroid belt. Carbonaceous chondrites, which have the highest proportions of **8** … and are the most oxidized, are thought to have originated in even greater solar distances. Each of these classes can be further subdivided into smaller groups with distinct properties.

8.9 Complete the text using the words in CAPITALS in the correct form.

Other meteorite types which have been geologically 1) PROCESS are achondrites, irons and pallasites. Achondrites are also stony meteorites, but they are considered 2) DIFFERENTIATE or reprocessed matter. They are formed by melting and recrystallization on or within meteorite parent bodies; as a result, achondrites have distinct textures and mineralogies 3) INDICATE of igneous processes. Pallasites are stony iron meteorites 4) COMPOSE of olivine enclosed in metal. Iron meteorites are classified into thirteen major groups and consist 5) PRIMARY of iron-nickel alloys with minor amounts of carbon, sulfur, and phosphorus. These meteorites formed when molten metal segregated from less dense silicate material and cooled, 6) SHOW another type of melting behavior within meteorite parent bodies. Thus, meteorites contain evidence of changes that occurred on the parent bodies from which they were removed or broken off, 7) PRESUME by impacts, to be placed in the first of many revolutions.

8.10 Translate the following sentences into English.

1.Падение метеоритов сопровождается мощными звуковыми и световыми явлениями.

2. Метеорное тело, ворвавшись на скорости 15-20 км/сек. в атмосферу Земли, сталкивается с очень сильным сопротивлением воздуха, уже находясь в 100-120 км от Земли.

3. Падение метеоритов происходит очень часто.

4. Большинство метеоритов, попадающих в океаны, моря, пустыни, полярные страны и иные малонаселенные места, остаются не найденными.

5. Пролетая на космической скорости сквозь земную атмосферу, метеориты, как правило, не выдерживают оказываемого на них давления воздуха, и раскалываются на множество частей.

6. На Землю, в таких случаях, падают десятки, а то и сотни тысяч осколков, которые образуют метеоритный дождь.

7. Многие думают, что метеорит падает на Землю раскаленным. Однако это не так.

8. Он может быть теплый или горячий, потому что находится в земной атмосфере только несколько секунд, за которые прогреться не успевает и остается таким же холодным внутри, каким он был, летая в межпланетном пространстве.

UNIT9

9.1Practise reading the following words.

a) **[i:] –** p**ie**ce, sp**ee**d, b**ee**n, str**ea**k, betw**ee**n

[əʊ] – t**o**tal, comp**o**se, th**ough**, n**o**table, appr**oa**ch, **o**ver

[aʊ] – h**ow**ever, **ou**r, enc**ou**nter, d**ow**n, f**ou**nd, sh**ow**er

[ʌ] – ch**u**nk, m**u**ch, st**u**dy, n**u**mber, c**o**me

b) asteroid ['æst(ə)rɔɪd], Ceres ['sɪəriːz], crater ['kreɪtə], diameter [daɪ'æmɪtə], Galileo [ˌgalɪˈleɪəʊ], Saturn ['sætən], silicate ['sɪlɪkeɪt], Jupiter ['ʤuːpɪtə]

9.2Cross out the word with a different sound.

i	ex**i**st v**i**s**i**t s**ee** h**i**t **i**mage
aɪ	l**i**ght des**i**gn s**y**stem classif**y** fl**y**b**y**
ð	**th**en **th**ough **th**ey wi**th**in ear**th**
h	**h**as **h**our **h**owever **h**alf **h**ave
ɪə	th**eo**ry mat**eria**l sc**ie**ntist r**ea**lly h**ere**

Active vocabulary

Word	**Pronunciation**	**Translation**
approach, *n.*	[ə'prəuʧ]	приближение, наступление, подход, подъезд, подступ; ***syn.*** access, avenue, passage
belt, *n.*	[belt]	зона, пояс
chunk, *n.*	[ʧʌŋk]	ломоть, глыба
close-up, *n.*	['kləusʌp]	крупный план, тщательное рассмотрение, изучение
coalesce, *v.*	[kəuə'les]	объединяться, сливаться; ***syn.*** unite
flyby, *n.*	['flaɪbaɪ]	сближение с небесным телом для проведения наблюдений

incinerate, *v.*	[ɪn'sɪn(ə)reɪt]	сжигать, превращать в пепел, испепелять
pebble, *n.*	['pebl]	галька, голыш, булыжник, гравий, неровная, холмистая поверхность
preserve, *v.*	[prɪ'zɜːv]	сохранять, сберегать, хранить; ***syn.*** conserve, guard, protect
resolution, *n.*	[ˌrez(ə)'luːʃ(ə)n]	разрешение, решительность, решимость, твёрдость, решение; ***syn.*** determination, firmness, steadiness
spacecraft, *n.*	['speɪskrɑːft]	космический корабль

DO YOU KNOW…?

- that asteroids and planets share a common birth. The process that helped form the planets is called accretion. During the beginning of the universe when two bodies would collide they would stick together forming a larger body. The planets and asteroids were formed in this manner.

- that an asteroid may have killed the dinosaurs. The Chicxulub impact crater is thought to be 65 million years old. It is also thought to be the source of the climate changes that led to the extinction of all of the dinosaurs. The debris that must have been thrown in the air after an asteroid large enough to create a crater that is over 180 km in diameter is hard to imagine. Those dinosaurs that didn't die right away probably suffered from starvation before their deaths.

9.3 Read the text and answer the following questions.

1. What is an asteroid?
2. Where can asteroids be found?
3. What theory is there about the origin of the asteroids?
4. What per cent of meteorites are composed of silicate?
5. What type of meteorites is the hardest to identify?
6. Why are scientists interested in composition of asteroids?

7. What asteroid was the first to have hi-resolution images?
8. Why was encounter with asteroid 253 Mathilde unique?

ASTEROIDS

Asteroids are rocky and metallic objects that orbit the Sun but are too small to be considered planets. They are known as minor planets. Asteroids range in size from Ceres, which has a diameter of about 1000 km, down to the size of pebbles. Sixteen asteroids have a diameter of 240 km or greater. They have been found inside Earth's orbit to beyond Saturn's orbit. Most, however, are contained within a main belt that exists between the orbits of Mars and Jupiter. Some have orbits that cross Earth's path and some have even hit the Earth in times past. One of the best preserved examples is Barringer Meteor Crater near Winslow, Arizona. Asteroids are material left over from the formation of the solar system. One theory suggests that they are the remains of a planet that was destroyed in a massive collision long ago. More likely, asteroids are material that never coalesced into a planet. In fact, if the estimated total mass of all asteroids was gathered into a single object, the object would be less than 1,500 kilometers (932 miles) across -- less than half the diameter of our Moon.

Much of our understanding about asteroids comes from examining pieces of space debris that fall to the surface of Earth. Asteroids that are on a collision course with Earth are called meteoroids. When a meteoroid strikes our atmosphere at high velocity, friction causes this chunk of space matter to incinerate in a streak of light known as a meteor. If the meteoroid does not burn up completely, what's left strikes Earth's surface and is called a meteorite.

Of all the meteorites examined, 92.8 percent are composed of silicate (stone), and 5.7 percent are composed of iron and nickel; the rest are a mixture of the three materials. Stony meteorites are the hardest to identify since they look very much like terrestrial rocks.

Because asteroids are material from the very early solar system, scientists are interested in their composition. Spacecraft that have flown through the asteroid belt have found that the belt is really quite empty and that asteroids are separated by very large distances. Before 1991 the only information obtained on asteroids was through Earth-based observations. Then on October 1991 asteroid 951 Gaspra was visited by the Galileo spacecraft and became the first asteroid to have hi-resolution images taken of it. Again on August 1993 Galileo made a close encounter with asteroid 243 Ida. This was the second asteroid to be visited by spacecraft. Both Gaspra and Ida are classified as S-type asteroids composed of metal-rich silicates.

On June 27, 1997 the spacecraft NEAR (Near Earth Asteroid Rendezvous) made a high-speed close encounter with asteroid 253 Mathilde. This encounter gave scientists the first close-up look of a carbon rich C-type asteroid. This visit was unique because NEAR was not designed for flyby encounters. NEAR is an orbiter destined for asteroid Eros in January of 1999.

Astronomers have studied a number of asteroids through Earth-based observations. Several notable asteroids are Toutatis, Castalia, Geographos and Vesta. Astronomers studied Toutatis, Geographos and Castalia using Earth-based radar observations during close approaches to the Earth. Vesta was observed by the Hubble Space Telescope.

(http://www.solarviews.com/eng/asteroid.htm)

9.4 Mark the following sentences True or False.

1. Asteroids are considered to be planets.
2. Orbits of some asteroids cross Earth’s path.
3. Scientists’ knowledge of asteroids enrich due to pieces of space debris.
4. 5.7% of asteroids are composed of stone, and 92.8% are composed of iron and nickel.
5. Earth-based observation was the only means of asteroids studying before 1991.
6. Gaspra and Ida are C-type asteroids.

9.5 According to the text find words similar in meaning.

1. to regard
2. to save

3. to offer

4. to ruin

5. to unite

6. to value

7. to comprehend

8. to hit

9. to disconnect

10. to receive

9.5 Match words with their definitions.

Mixture	**remains**	**friction**	**orbit**	**surface**	**encounter debris**	**pebble**

1……….. – small smooth stone found especially on a beach or on the bottom of a river;

2……….. – the curved path travelled by an object which is moving around another much larger object;

3……….. – the pieces of something that are left after it has been destroyed in an accident, explosion etc.;

4……….. – when one surface rubs against another;

5……….. – an occasion when you met someone, or do something with someone you do not know;

6……….. – the parts of something that are left after the rest has been destroyed or has disappeared;

7……….. – the top layer of an area of water or land;

8……….. – a combination of two or more different things, feelings, or types of people

9.7 Match sentence halves.

1.Most asteroids circle the Sun in a wide band	**a.** in terms of both their orbits and their composition
2.In 1801, an Italian astronomer Guiseppe Piazzi	**b.** an asteroid may have created our Moon.
3.Occasionally, asteroids are knocked out of the asteroid belt	**c.** when they collide with one another.
4.A number of the asteroids orbiting in the inner solar system	**d.** between the orbits of Mars and Jupiter.
5.Some scientists believe that	**e.** a left over ring in the solar nebula, basically a ring around the Sun.
6.Most asteroids have surfaces pockmarked with	**f.** gouges, scars, and circular, bowl-like shapes called craters
7.Near-Earth asteroids are more chaotic than their progenitors	**g.** cross paths with Earth's orbit.
8.One theory started the asteroid belt was	**h.** discovered the first asteroid.

9.8 Ask all possible questions to the sentences from exercise 9.7.

9.9 Reorder the words to make a sentence.

1. Italian - Guiseppe - is - astronomer - Piazzi - and – mathematician - priest – an.
2. Piazzi - born - Italy - the - town - of - July - Ponte Valtellina – rural- on - 16 - was - 1746 – in.
3. the - until - Piazzi - at – 1787 - became - Palermo - a - professor - of - University - of - January – Astronomy.
4. training - Piazzi - in - granted - government - by - Paris – to - undergo - was - programs - London - Italian - the - astronomical – and.

5. French - worked - 1787 – 1789 - some - Piazzi - greatest – with - English - and - From - of - astronomers – the.

6. to - discovered - king’s - successfully - he - appointment - 1801 - “Ceres” - “Asteroid Belt” - or - in - the - Prior - January – the.

7. Five - Piazzi’s - the - asteroid - death - was - by - decades - several - Italian - after - astronomers - 1000th – presented.

8. Piazzi’s - “Lunar Crater” - of – named - in - was – contributions - honor.

9.10 Translate the following sentences into English.

1. В Солнечной системе несколько сот тысяч астероидов, многие из которых даже имеют собственные имена.

2. Большинство ученых считает, что многие метеориты являются осколками астероидов, а сами астероиды – остатки некогда существовавших планет.

3. Астероиды часто сталкиваются друг с другом и сходят со своих орбит, то приближаясь, то удаляясь от Солнца.

4. Большая часть астероидов Солнечной системы находится в так называемом поясе астероидов между орбитами Марса и Юпитера.

5. Особую важность представляют астероиды, орбиты которых близко подходят к орбите нашей планеты.

6. По химическому составу астероиды разделяют на три основные группы – С-тип, S-тип и М-тип.

7. Многие астероиды регулярно меняют яркость при вращении.

8. Самые маленькие астероиды вращаются наиболее быстро и очень сильно различаются по форме.

UNIT 10

10.1 Practise reading the following words.

a) **[æ] –** exp**a**nd, h**a**nd, pl**a**net, **a**ccurate, dr**a**g, bl**a**ck, m**a**ss

[ɜ:] – l**ear**n, **ear**liest, c**ir**cular, s**ur**face, f**ir**st, w**ere**

[ʃ] – shaped, mo**ti**on, direc**ti**on, gravita**ti**onal, indistingui**sh**able

[θ] – pa**th**, **th**ousand, ear**th**, leng**th**, **th**roughout, streng**th**

b) ammonia [ə'məunɪə], conglomerate [kən'glɔm(ə)rət], dioxide [daɪ'ɔksaɪd], formaldehyde [fɔː'mældɪhaɪd], methane ['miːθeɪn], monoxide [mə'nɔksaɪd]

10.2 Translate words of the same root into Russian.

To charge – charges – charged – charging – charger – chargeable.

To attract – attractive – attraction – attracted – attractiveness – attractant.

To reflect – reflection – reflective – reflecting – reflector – reflectivity.

10.3 Fill in the sentences with words from exercise 10.2

1. He had time to … on his successes and failures.
2. Advice will be given as a … service.
3. Leftover food … flies.
4. On some level, a student's grades are a … on the teacher.
5. Leave the battery on … all night.
6. The … between them was almost immediate.

Active vocabulary

Word	**Pronunciation**	**Translation**
akin, *adj.*	[ə'kɪn]	родственный, близкий, похожий, сходный, такой же как; ***syn.*** similar
aphelion, *n.*	[æ'fiːlɪən]	афелий *(точка орбиты небесного тела, обращающегося вокруг Солнца, наиболее от*

		него удалённая)
bound, *adj.*	[baund]	связанный
bulge, *v.*	[bʌlʤ]	выдаваться, выпячиваться, оттопыриваться, нависать, раздуваться
coma, *n.*, *pl.* comae	['kəumə], *pl.* ['kəumɪ]	кома *(газовое и пылевое облако, окружающее ядро кометы)*
elongated, *adj.*	['iːlɔŋgeɪtɪd]	вытянутый, удлинённый, продолговатый; ***syn.*** oblong
fluorescent, *adj.*	[flɔː'res(ə)nt]	флуоресцентный
fragile, *adj.*	['fræʤaɪl]	ломкий, хрупкий, слабый; ***syn.*** brittle, friable
glue, *v.*	[gluː]	клеить, приклеивать
obey, *v.*	[ə'beɪ]	подчиняться, слушаться, повиноваться; ***syn.*** comply
perihelion, *n.*	[ˌperɪ'hiːlɪən]	перигелий
solid, *n.*	['sɔlɪd]	твёрдое тело
sublime, *v.*	[sə'blaɪm]	возвышать, возвеличивать; ***syn.*** exalt, elevate
tail, *n.*	[teɪl]	"хвост" кометы
tensile, adj.	['tensaɪl]	растяжимый; эластичный
volatile, *adj.*	['vɔlətaɪl]	летучий, быстро испаряющийся

DO YOU KNOW…?

- that it was once believed that comets were a show of power from the gods. They were also seen by many as a curse, or a warning that something bad was about to happen. Others believe that a comet is the device which angels are carried through heaven.

- that many scientists believe that about 4 billions years ago comets bombarded the Earth also bringing in the process the vast quantities of water into Earth's oceans, and even to Moon.

- that as of May 2009 there are a reported 3,648 known comets.

10.4 Read the text and answer the following questions.

1. What are comets?
2. What is the coma?
3. Why are comets visible?
4. What are comets composed of?
5. Why are comets fragile?
6. Where is the farthest and the closest point of a comet?
7. How is the nucleus of a comet called?
8. What does the nucleus of a comet consist of?

COMETS

Comets are small, fragile, irregularly shaped bodies composed of a mixture of non-volatile grains and frozen gases. They usually follow highly elongated paths around the Sun. Most become visible, even in telescopes, only when they get near enough to the Sun for the Sun's radiation to start subliming the volatile gases, which in turn blow away small bits of the solid material. These materials expand into an enormous escaping atmosphere called the coma, which becomes far bigger than a planet, and they are forced back into long tails of dust and gas by radiation and charged particles flowing from the Sun. Comets are cold bodies, and we see them only because the gases in their comae and tails fluoresce in sunlight (somewhat akin to a fluorescent light) and because of sunlight reflected from the solids. Comets are regular members of the solar system family, gravitationally bound to the Sun. They are generally believed to be made of material, originally in the outer part of the solar system, that didn't get incorporated into the planets -- leftover debris, if you will. It is the very fact that they are thought to be composed of such unchanged primitive material that makes them extremely interesting to scientists who wish to learn about conditions during the earliest period of the solar system.

Comets are very small in size relative to planets. Their average diameters usually range from 750 meters or less to about 20 kilometers. Recently, evidence has been found for much larger distant comets, perhaps having diameters of 300 kilometers or more, but these sizes are still small compared to planets. Planets are usually more or less spherical in shape, usually bulging slightly at the equator. Comets are irregular in shape, with their longest dimension often twice the shortest. The best evidence suggests that comets are very fragile. Their tensile strength (the stress they can take without being pulled apart) appears to be only about 1,000 dynes/cm^2. You could take a big piece of cometary material and simply pull it in two with your bare hands, something like a poorly compacted snowball.

Comets, of course, must obey the same universal laws of motion as do all other bodies. Where the orbits of planets around the Sun are nearly circular, however, the orbits of comets are quite elongated. Nearly 100 known comets have periods (the time it takes them to make one complete trip around the Sun) five to seven Earth years in length. Their farthest point from the Sun (their aphelion) is near Jupiter's orbit, with the closest point (perihelion) being much nearer to Earth. A few comets like Halley have their aphelions beyond Neptune (which is six times as far from the Sun as Jupiter). Other comets come from much farther out yet, and it may take them thousands or even hundreds of thousands of years to make one complete orbit around the Sun. In all cases, if a comet approaches near to Jupiter, it is strongly attracted by the gravitational pull of that giant among planets, and its orbit is perturbed (changed), sometimes radically.

The nucleus of a comet, which is its solid, persisting part, has been called an icy conglomerate, a dirty snowball, and other colorful but even less accurate descriptions. Certainly a comet nucleus contains silicates akin to some ordinary Earth rocks in composition, probably mostly in very small grains and pieces. Perhaps the grains are glued together into larger pieces by the frozen gases. A nucleus appears to include complex carbon compounds and perhaps some free carbon, which make it very black in color. Most notably, at least when young, it contains many frozen gases, the most common being ordinary water. In the low pressure conditions of space, water sublimes, that is, it goes directly from solid to gas -- just like dry ice does on Earth. Water probably makes up 75-80% of the volatile material in most comets. Other common ices are carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), ammonia (NH3), and formaldehyde (H2CO). Volatiles and solids appear to be fairly well mixed throughout the nucleus of a new comet approaching the Sun for the first time. As a comet ages from many trips close to the Sun, there is evidence that it loses most of its ices, or at least those ices anywhere near the nucleus surface, and becomes just a very fragile old rock in appearance, indistinguishable at a distance from an asteroid.

(adopted from http://www.solarviews.com/eng/comet/whatis.htm)

10.5 Mark the following sentences True or False.

1. Most comets are visible when they get close to the Sun.
2. Comets are the objects of interest for scientists who want to know the conditions during the earliest period of the solar system.
3. The orbits of planets are elongated, and the orbits of comets are circular.
4. Halley comet has its aphelion beyond Jupiter.
5. A comet nucleus consists of grains and pieces glued together by the frozen gases.
6. Carbon compounds and free carbon make a nucleus black in colour.
7. Water makes up 65-75% of the volatile material in comets.
8. The nucleus of a new comet has a good mixture of volatiles and solids.

10.6 According to the text find words similar in meaning.

1. unsteady
2. widen
3. huge
4. mirror
5. constitute
6. proof
7. identical

8. showy
9. similar
10. stick

10.7 According to the text find words opposite in meaning.

1. robust
2. discharged
3. irregular
4. closest
5. repulse
6. imprecise
7. old
8. non-volatile
9. exclude
10. simple

10.8 Match two halves of the statements and translate them into Russian.

1. reflected	a. of sunlight
2. easily visible	b. sunlight
3. the composition	c. charged fragments
4. the pressure	d. tail
5. quite difficult	e. Halley
6. electrically	f. to the naked eye
7. Comet	g. to study
8. a dust	h. of the dust and gases

10.9 Fill in the sentences with the statements from exercise 10.8.

1. Radiation pressure, …, forces the dust particles back into a dust tail in the direction opposite to the Sun.

2. A comet's tail can be tens of millions of kilometers in length when seen in the ….

3. The gas molecules are torn apart by solar ultraviolet light, often losing electrons and becoming … or ions.
4. Every comet then really has two tails, … and an ion tail.
5. In 1986, the Giotto spacecraft flew right through … only a few hundred kilometers from the nucleus.
6. Though the coma and tails of a comet may extend for tens of millions of kilometers and become … in Earth's night sky.
7. Because comet nuclei are so small, they are … from Earth.
8. For the first time, actual images of an active nucleus were obtained and … flowing from it was directly measured.

10.10 Translate the following sentences into English.

1. Кометы представляют собой светила незначительной массы по сравнению с масштабом объектов солнечной системы.
2. В каталоги занесено около тысячи наблюдавшихся комет. При открытии комета получает название по фамилии обнаружившего ее ученого.
3. Масса комет крайне мала и нисколько не влияет на движение планет.
4. Чем ближе к Солнцу подходит комета, тем она ярче и тем длиннее ее хвост.
5. Хвост кометы иногда достигает в длину расстояния от Земли до Солнца, а голова кометы — размеров Солнца.
6. Спектр головы и хвоста кометы имеет обычно яркие полосы.
7. В 1910 г. Земля прошла сквозь хвост кометы Галлея. Хотя в хвосте кометы есть угарный газ, он так разрежен, что никакими анализами не удалось обнаружить его примесь в воздухе.
8. Столкновение Земли с ядром кометы крайне маловероятное событие. Если оно и случится, то Земле это ничем не грози

Supplementary reading

The Solar System

There are many popular misconceptions concerning the size and scale of objects in the Solar System. These mostly have to do with a failure to realize the relative radii of planets and the Sun, and the failure to appreciate how large the outer solar system is relative to the inner solar system.

The Sun and the gas giant planets like Jupiter are by far the largest objects in the Solar System. The other planets are small specks on this scale. The masses of the planets are also concentrated in the Gas Giant planets Jupiter, Saturn, Uranus, and Neptune. However, the large mass of these planets comes from their absolute sizes, not their densities. This distribution of masses and densities in the Solar System is a key observation that a theory of the origin of the Solar System must explain. As discovered by Kepler, the planets orbit on ellipses with the Sun at one focus. In addition, the planets all revolve in the same direction on their orbits (direct orbital motion).

Objects executing motion around a point possess a quantity called angular momentum. This is an important physical quantity because all experimental evidence indicates that angular momentum is rigorously conserved in our Universe: it can be transferred, but it cannot be created or destroyed. For the simple case of a small mass executing uniform circular motion around a much larger mass (so that we can neglect the effect of the center of mass) the amount of angular momentum takes a simple form.

The Nebular Hypothesis in its original form was proposed by Kant and Laplace in the 18th century. great cloud of gas and dust (called a nebula) begins to collapse because the gravitational forces that would like to collapse it overcome the forces associated with gas pressure that would like to expand it (the initial collapse might be triggered by a variety of perturbations---a supernova blast wave, density waves in spiral galaxies, etc.). It is unlikely that such a nebula would be created with no angular momentum, so it is probably initially spinning slowly. Because of conservation of angular momentum, the cloud spins faster as it contracts. Because of the competing forces associated with gravity, gas pressure, and rotation, the contracting nebula begins to flatten into a spinning pancake shape with a bulge at the center.

As the nebula collapses further, instabilities in the collapsing, rotating cloud cause local regions to begin to contract gravitationally. These local regions of condensation will become the Sun and the planets, as well as their moons and other debris in the Solar System. While they are still condensing, the incipient Sun and planets are called the protosun and protoplanets, respectively. Because of the original angular momentum and subsequent evolution of the collapsing nebula, this hypothesis provides a natural explanation for some basic facts about the Solar System: the orbits of the planets lie nearly in a plane with the sun at the center (let's neglect the slight eccentricity of the planetary orbits to simplify the discussion), the planets all revolve in the same direction, and the planets mostly rotate in the same direction with rotation axes nearly perpindicular to the orbital plane.

The nebular hypothesis explains many of the basic features of the Solar System, but we still do not understand fully how all the details are accounted for by this hypothesis.

In recent years rather conclusive evidence has accumulated for planets orbiting other stars. This evidence comes from the gravitational perturbations exerted on the star by the unseen companion planet that can be exposed by very accurate measurement of the radial velocity of the star (see the related discussion of detecting unseen companions in binary star systems). These measurements require that variations in the radial velocity of order 10 meters per second be detected relative to a total radial velocity typically of order 10-100 kilometers per second.

The Sun

The Sun is by far the nearest star to us. As such, it is the star that we know the most about. The Sun is clearly mostly hydrogen and helium, with only a trace of heavier elements. This is also true of the Universe as a whole: most of the Universe is hydrogen, with some helium, and the remainder of the elements occur only in trace concentrations. In that sense the composition of the Earth is highly unrepresentative of the rest of the Universe. The element helium is the second most abundant in both the Sun and the Universe, but it is very difficult to find on the Earth. In fact, helium was discovered in the spectrum of the Sun (the name helium derives from helios, which is the Greek name for the Sun). It was postulated that a set of spectral lines observed in the Solar emission spectrum that could not be associated with any known element belonged to a new element (the Sun is too cool to ionize helium appreciably, so absorption lines associated with helium are very weak). Only after this was helium discovered on the Earth and this hypothesis confirmed (helium occurs in certain very deep gas wells on the Earth).

The Sun is enormous compared with other objects in the Solar System. Thus, for example, the radius of the Sun is about 109 times that of the Earth, which implies that the volume of the Sun would hold approximately 1.3 million Earths (since the volume goes as the cube of the radius). However, the average density of the Sun is much smaller than that of the Earth: about 1.4 g/cm3 compared with about 5.5 g/cm3 for the Earth. As we shall see, this is because the composition of the Sun is dominated by the light elements hydrogen and helium (similar to the Gas Giant planets), while that of the terrestrial planets is dominated by heavier metals and their compounds. One way to study the solar interior is through helioseismology. In helioseismology, one attempts to learn about the properties of the Sun by studying the propagation of waves in its body (which, for example, cause small oscillations of the surface that are observable) in a manner similar to geologists learning about the interior of the Earth by studying seismic waves.

The Sun is a ball of gas, so it does not have a well-defined surface. When we speak of the surface of the Sun, we normally mean the photosphere. As we look down into the atmosphere at the surface of the Sun the view becomes more and more opaque. The point where it appears to become completely opaque is called the photosphere. Thus, the photosphere may be thought of as the imaginary surface from which the solar light that we see appears to be emitted. The diameter quoted for the Sun usually refers to the diameter of the photosphere. The photosphere under close observation exhibits a mottled appearance that is called granulation. This is a consequence of heat convection below the photosphere.

Granulation is due to the convection operating below the photosphere. This convection produces columns of rising gas just below the photosphere that are about 700 to 1000 km in diameter. In these columns hot gas rises with a velocity of several kilometers per second (this can be confirmed by Doppler shift measurements). The tops of these columns are the brighter gray-white cells seen in the granulation images. The hot gas then cools at the top of the column and sinks down in the darker regions surrounding each granule. Thus, granulation just represents the tops of convection currents that are transferring heat from below the solar surface to the surface. In that sense, granules are a little like the tops of cumulus clouds in the Earth's atmosphere, which are also associated with convection currents.

The gases of the Sun extend far beyond the photosphere, which may be considered the lowest level of the solar atmosphere. The region immediately above the photosphere is called the chromosphere. The chromosphere is 2000-3000 km thick. It glows faintly relative to the photosphere and can only be seen easily in a total solar eclipse. When it can be seen it is reddish in color (because of strong Balmer H-alpha emission). This color is the origin of its name (chromos meaning ``color").

The faint flow of the chromosphere is due to an emission spectrum from hot, low density gases emitting at discrete wavelengths. The discovery of helium noted earlier was from emission lines seen in the chromosphere during an eclipse in 1868. This new element was only found on the Earth in 1895. The chromosphere contains spikes of gas called spicules that rise through it. Spicules are short-lived phenomena, corresponding to rising jets of gas that move upward at about 30km/sec and last only about 10 minutes.

The extended outer atmosphere of the Sun is called the corona. It has a temperature of millions of degrees, but it is 10 billion times less dense than the atmosphere of the Earth at sea level. The glow of the corona is a million times less bright than that of the photosphere, so it can only be seen when the disk of the Sun is blocked off in a total solar eclipse, or by using a special instrument called a coronagraph (or coronameter) that artificially blocks the disk of the Sun so that it can image the regions surrounding the Sun. The red-orange images superposed on the central disk in the above two figures are corresponding X-ray images taken of the Sun on the same days as the corona images. The dark regions in the X-ray images correspond to coronal holes. The coronal holes also are in evidence in the corona as regions with little bright structure, such as near the north solar pole (top).

It is clear that the corona is very hot because of the electromagnetic radiation that it emits. We observe emission lines from the corona corresponding to very highly ionized atoms (for example, iron atoms in the +16 charge state). Such highly ionized atoms can only be produced at temperatures in the million degree range. The extremely high temperature of the corona is thought to be associated with effects of the solar magnetic field, which can store and transport energy from lower regions of the Sun to the corona.

Sunspots are regions on the solar surface that appear dark because they are cooler than the surrounding photosphere, typically by about 1500 K (thus, they are still at a temperature of about 4500 K, but this is cool compared to the rest of the photosphere). They are only dark in a relative sense; a sunspot removed from the bright background of the Sun would glow quite brightly. The largest sunspots observed have had diameters of about 50,000 km, which makes them large enough to be seen with the naked eye. Sunspots often come in groups with as many as 100 in a group, though sunspot groups with more than about 10 are relatively rare. Sunspots develop and persist for periods ranging from hours to months, and are carried around the surface of the Sun by its rotation.

The most violent events on the surface of the Sun are sudden eruptions called solar flares. Flares typically last a few minutes and can release energies equivalent to millions of hydrogen bombs. Flares become frequent near sunspot maximum, when smaller flares can occur daily and large flares can occur about once a week.

During a flare the material in the flare may be heated to temperatures of 10 million K; matter at these temperatures emits copious amounts of UV and X-Ray, as well as visible light. In addition, flares tend to eject matter, primarily in the form or protons and electrons, into space at velocities that can approach 1000 km/second. These events are called coronal mass ejections, and produce bursts in the solar wind that influence much of the rest of the Solar System, including the Earth. Thus, the observation of a large flare on the surface of the Sun is usually a signal for increased auroras and related activity several days hence when the ejected burst reaches Earth.

The Sun makes itself known throughout much of the Solar System by the influence the solar wind of high-speed charged particles constantly blowing off the Sun. The solar wind may be viewed as an extension of the outer atmosphere of the Sun (the corona) into interplanetary space. The solar wind contains roughly equal number of electrons and protons, along with a few heavier ions, and blows continuously from the surface of the Sun at an average velocity of about 400 km/second. This is a remarkable velocity: particles in the solar wind from the Sun's surface travel at a speed that would allow them to go from Knoxville to Memphis in less than 2 seconds! This wind leads to a mass loss of more than 1 million tons of material per second, which may seem like a large number, but is insignificant relative to the total mass of the Sun. The solar wind escapes primarily through coronal holes, which are found predominantly near the Sun's poles; in the equatorial plane the magnetic field lines of the Sun are more likely to close on themselves, particularly in periods of low solar activity. These closed field lines trap the hot coronal gases, leading to enhanced X-ray emissions from these hotter regions, but suppressing contributions to the solar wind. The solar wind can have a large influence on our planet, particularly in times of the active Sun (near sunspot maximum) when the wind is strong and can contain bursts corresponding to flares and coronal mass ejections from the Sun.

The Planet Mercury

The planet Mercury is very difficult to study from the Earth because it is always so close to the Sun. Even at elongation, it is never more than 28 degrees from the Sun in our sky. It is the second smallest planet (it was believed to be the smallest until the discovery that Pluto is actually much smaller than originally thought), and also the fastest in its orbit since it is the innermost planet. In fact, the name Mercury derives from its speed in moving around its orbit.

Mercury, the innermost planet, is 0.4 A.U. from the Sun on the average. It revolves about the Sun once every 88 days in an orbit that is the most elliptical of any planet except Pluto. The adjacent image shows the November, 1996, locations of the planets in the inner solar system and their orbits.

The orbits of Venus and Earth appear to be circles on this scale, but the orbit of Mercury is clearly not circular. As a result of its highly elliptical path the distance between Mercury and the Sun varies a large amount, from 46 million kilometers at perihelion to 70 million kilometers at aphelion.

Its mass is 5.5% of the Earth's mass, which is 5 times the mass of the Moon (the best determination of the mass came from detailed tracking of the spacecraft Mariner 10). The density is 5.5 g/cc, the same as Earth, and it has a magnetic field that is about 1% of the strength of Earth's field. These facts suggest a differentiated interior with a large iron core, with the weakness of the magnetic field related in some way to the slow rotational period relative to the Earth.

Its rotational period is 59 days, as determined by radar measurements from the Earth using the Doppler effect. The ratio of the rotational period to the orbital period is 2/3, and is an example of more complicated tidal locking than for the Earth-Moon system. The tidal interaction between the Sun and Mercury leads to a 2/3 ratio (instead of 1/1 as for our Moon) because the orbit of the Moon about the Earth is almost a circle, but the orbit of Mercury around the Sun is rather elliptical.

The surface conditions are among the harshest in the Solar System. During the long Mercurian day the temperature rises to about 425 degrees Celsius, hot enough to melt lead and hotter than any planet except Venus. Because there is no substantial atmosphere to retain heat, during the equally long nights, the temperature drops quickly to around -180 degrees Celsius, which is among the coldest found in the

Solar System. This range of -180 Celsius at night to 425 Celsius in the day is the largest surface temperature variation in the Solar System.

Mercury is a planet with a very large iron core and a comparatively thin mantle compared with the Earth. Here are three major types of surface features on Mercury:

1. Smooth plains that resemble Lunar maria.
2. Intercrater plains, which are pocked with small craters and occupy about 70% of the surface that we have examined.
3. Rugged highlands that bear some resemblance to the corresponding regions on the Moon.

There is no evidence for large-scale tectonic motion. It is believed that plate tectonics requires differentiation of the interior, and a large enough volume to trap sufficient radioactive material to heat subsurface layers and produce a plastic consistency below the crustal plates. Mercury is thought to be too small for this to take place, thus explaining the lack of large-scale tectonics.

The Planet Venus

Until the 1960s, Venus was often considered a "twin sister" to the Earth because Venus is the nearest planet to us, and because superficially the two planets seem to share many characteristics.

In earlier times, there was considerable speculation concerning the possibility of life on Venus, sometimes with rather elaborate characteristics. In 1686 a French "man of letters", Bernard de Fontenelle, wrote: “ *I can tell from here . . . what the inhabitants of Venus are like; they resemble the Moors of Granada; a small black people, burned by the sun, full of wit and fire, always in love, writing verse, fond of music, arranging festivals, dances, and tournaments every day*”. (Quoted in National Geographic, June, 1975).

In the last 30 years scientists have learned a great deal about our "sister" planet, and it is now known that almost nothing on Venus is like that on the Earth. Much of the previous misconception can be traced to the difficulty of observing Venus because it is always covered with a thick cloud layer. In the past 3 decades astronomers have learned how to peer through that cloud layer and unlock many of the secrets of this nearby but previously not well known planet.

Venus is the second planet from the Sun, with a nearly circular orbit having an average radius of 0.7 A.U. This gives it an orbital period of 225 days. Venus is peculiar in that its rotation is retrograde (in the opposite sense of the Earth and all other planets except Uranus) and because it is very slow: a day on Venus corresponds to 243 Earth days. At present, we have no solid explanation for why this is so. The most plausible theories invoke the collision of two large masses to form Venus in just such a way to cancel most of the rotation for the two masses. Like Mercury, but unlike the other planets, Venus has no moons.

The radius of Venus is almost exactly that of the Earth. Its average density is 5.2 g/cc, which is slightly less than that of the Earth or Mercury, but suggests a dense iron core and internal structure similar to that of the Earth. Venus has an extremely weak magnetic field, but that may be a consequence of its having such a slow rotational velocity.

Venus is always covered by a thick layer of clouds that make it impossible to see the surface for light in the visible part of the spectrum. Light at radar wavelengths penetrates the cloud deck and allows us to study the surface. A comparison of the motion of the surface with that of the upper clouds indicates that while the surface takes about 8 months to rotate, the clouds rotate all the way around the planet in about 4 days. This indicates that there are very high velocity winds in the upper part of the Venusian atmosphere.

Missions to the surface of Venus (Russian Venera spacecraft) indicate that the cloud deck begins about 50 km above the surface. Spectral analysis of the thick cloud layer surrounding Venus suggests that the clouds are largely composed of sulphuric acid droplets. The cloud layer is rather featureless in visible light, but shows structure in other wavelengths. Different wavelengths of light penetrate the atmosphere to varying degrees and therefore may be used to study different layers of the clouds and atmosphere. A comparison of surface and upper cloud velocities indicates that there are winds in the upper part of the Venusian atmosphere with velocities as large as 300 km/hour. These winds are comparable in speed to jetstreams in the Earth's atmosphere, but extend over much larger regions in the case of Venus. It is not fully understood why these winds have such high velocities. The clouds contain little water vapor, and there is little evidence for water in any form on Venus. It is speculated that the absence of water is because most water that may have initially been on Venus made its way to the upper atmosphere, where it was broken down by sunlight and interactions with cosmic rays and the solar wind into oxygen and hydrogen, which was then lost to interplanetary space.

The atmosphere of Venus is composed of about 96% carbon dioxide, with most of the remainder being nitrogen. The atmosphere appears to be relatively clear until the cloud deck starts about 50 km above the surface. The pressure of the atmosphere is about 90 times that of the Earth at the surface, and the surface temperatures on Venus are around 500 degrees Celsius, exceeding that of Mercury and hot enough to melt soft metals. Calculations indicate that for the temperatures to be so high there must be a mechanism in the Venusian atmosphere that traps solar radiation very effectively.

There are high-velocity winds in the upper atmosphere, but the atmosphere below the cloud deck appears to be relatively stagnant, with only very weak winds blowing at the surface. Convection driven by differential solar heating should give rise to winds of only a few meters per second, so the high velocity upper level winds, and the contrasting stagnation of the lower atmosphere, are not well understood.

The surface of Venus is rather smooth in many places, though not nearly as smooth as originally expected. However, we find evidence for many of the same geological features found on Earth: canyons, volcanoes, lava flows, rift valleys, mountains, craters, and plains. There is substantial evidence for local tectonic activity but the surface appears to be a single crustal plate, with little evidence for large-scale horizontal motion of crustal plates as found on the Earth. Why the two planets differ in this aspect of their geology even though we believe them to have similar interiors is not well understood. The usual explanation is that Venus is a little behind the Earth in geological timescale, and its tectonic activity is just getting started.

The Earth

The Earth is certainly the most familiar planet, though it has only been a few hundred years since we fully realized it was a planet. The Earth is believed to have a solid inner core, made mostly of iron and nickel. This is surrounded by a liquid outer core, also mostly iron and nickel. The diameter of the core is estimated to be 7000 km, compared with a 12,700 km diameter for the entire planet. The crust is only a few tens of kilometers thick. The region between the core and the crust is called the mantle. The upper part of the mantle and the crust together are called the lithosphere. Sitting just below the lithosphere is a region of plastic consistency called the *aesthenosphere.*

Within about 1 billion years of its formation the Earth was melted by heat arising from a combination of sources:

- Gravitational energy left from the formation of the planet,
- Meteor bombardment,
- Decay of radioactive material trapped in the body of the Earth.

While the Earth was molten, gravity acted to concentrate more dense material near the center and less dense material nearer the surface. When the Earth solidified again (except for the liquid outer core) it was left with a layered structure with more dense material like iron and nickel near the center and less dense rocks nearer the surface. As the outer layers cooled and solidified, large cracks developed because of thermal stress, leaving the lithosphere broken up into large blocks or plates.

It is now uniformly agreed that the crustal plates of the Earth are in horizontal motion. This is called continental drift colloquially, and plate tectonics in technically more precise language. We now believe that the surface of the Earth looked very different 200 million years ago from its present appearance. In particular, the continents have changed because they sit on blocks of the lithosphere that are in horizontal motion with respect to each other, and indeed they continue to change because the horizontal motion continues. The following figure illustrates.

The present atmosphere of the Earth is probably not its original atmosphere. Our current atmosphere is what chemists would call an oxidizing atmosphere, while the original atmosphere was what chemists would call a reducing atmosphere. In particular, it probably did not contain oxygen. The original atmosphere may have been similar to the composition of the solar nebula and close to the present composition of the Gas Giant planets, though this depends on the details of how the planets condensed from the solar nebula. That atmosphere was lost to space, and replaced by compounds outgassed from the crust or (in some more recent theories) much of the atmosphere may have come instead from the impacts of comets and other planetesimals rich in volatile materials.

The oxygen so characteristic of our atmosphere was almost all produced by plants (cyanobacteria or, more colloquially, blue-green algae). Thus, the present composition of the atmosphere is 79% nitrogen, 20% oxygen, and 1% other gases.

The Earth is a spinning globe where a point at the equator is travelling at around 1100 km/hour, but a point at the poles is not moved by the rotation. This fact means that projectiles moving across the Earth's surface are subject to Coriolis forces that cause apparent deflection of the motion. Since winds are just molecules of air, they are also subject to Coriolis forces. Winds are basically driven by Solar heating. If solar heating were the only thing influencing the weather, we would then expect the prevailing winds along the Earth's surface to either be from the North or the South, depending on the latitude. However, the Coriolis force deflects these wind flows to the right in the Northern hemisphere and to the left in the Southern hemisphere. For example, between 30 degrees and 60 degrees North latitude the solar convection pattern would produce a prevailing surface wind from the South. However, the Coriolis force deflects this flow to the right and the prevailing winds at these latitudes are more from the West and Southwest. They are called the prevailing Westerlies.

The Earth has a substantial magnetic field, the axis of the magnetic field is tipped with respect to the rotation axis of the Earth. Thus, true north (defined by the direction to the north rotational pole) does not coincide with magnetic north (defined by the direction to the north magnetic pole) and compass directions must be corrected by fixed amounts at given points on the surface of the Earth to yield true directions. A fundamental property of magnetic fields is that they exert forces on moving electrical charges. Thus, a magnetic field can trap charged particles such as electrons and protons as they are forced to execute a spiraling motion back and forth along the field lines.

The solar wind mentioned above is a stream of ionized gases that blows outward from the Sun at about 400 km/second and that varies in intensity with the amount of surface activity on the Sun. The Earth's magnetic field shields it from much of the solar wind.

The imaginary surface at which the solar wind is first deflected is called the bow shock. The corresponding region of space sitting behind the bow shock and surrounding the Earth is termed the magnetosphere; it represents a region of space dominated by the Earth's magnetic field in the sense that it largely prevents the solar wind from entering. However, some high energy charged particles from the solar wind leak into the magnetosphere and are the source of the charged particles trapped in the Van Allen belts.

The Moon

The Moon is the nearest body to us in the Solar System, and as a consequence of the Apollo missions is the only extra-terrestrial object that has yet been explored directly by humans.

The mass of the Moon is about 1/80 that of the Earth, and its diameter is about 1/4 that of the Earth. The orbit of the Moon is very nearly circular (eccentricity ~ 0.05) with a mean separation from the Earth of about 384,000 km, which is about 60 Earth radii. The plane of the orbit is tilted about 5 degrees with respect to the ecliptic plane. The Apollo missions to the Moon left devices that can reflect laser light sent to the moon from the Earth. By timing the roundtrip of such light, it is possible to determine the distance to the Moon at any particular time with an uncertainty of only a few centimeters.

Since the synodic rotational period of the Moon is 29.5 days, Lunar day and Lunar night are each about 15 Earth days long. During the Lunar night the temperature drops to around -113 degrees Celsius, while during the Lunar day the temperature reaches 100 degrees Celsius. The temperature changes are very rapid since there is no atmosphere or surface water to store heat.

The surface of the Moon has two hemispheres with rather asymmetric properties; as a consequence the nature of the Lunar surface that we can see from the Earth is substantially different from the surface that is always hidden from the Earth. The side of the Moon unseen from the Earth is called the far side. One of the discoveries of the first Lunar orbiters is that the far side has a very different appearance than the near side. In particular, there are almost no Maria on the far side, as illustrated in the image shown to the left of a portion of the far side surface. In this figure a number of meteor impact craters are visible.

The amount of cratering is usually an indication of the age of a geological surface: the more craters, the older the surface, because if the surface is young there hasn't been time for many craters to form. Thus, the Earth has a relatively young surface because it has few craters. This is because the Earth is geologically active, with plate tectonics and erosion having obliterated most craters from an earlier epoch. In contrast the surface of the Moon is much older, with much more cratering. Further, different parts of the surface of the Moon exhibit different amounts of cratering and therefore are of different ages: the maria are younger than the highlands, because they have fewer craters.

The oldest surfaces in the Solar System are characterized by maximal cratering density. This means that one cannot increase the density of craters because there are so many craters that, on average, any new crater that is formed by a meteor impact will obliterate a previous crater, leaving the total number unchanged. Some regions of the moon exhibit near maximal cratering density, indicating that they are very old.

The bulk density of the Moon is 3.4 g/cc, which is comparable to that of (volcanic) basaltic lavas on the Earth (however, the bulk density of the Earth is 5.5 g/cc, because of the dense iron/nickel core). The Moon is covered with a gently rolling layer of powdery soil with scattered rocks that is called the regolith; it is made from debris blasted out of the Lunar craters by the meteor impacts that created them. Each well-preserved Lunar crater is surrounded by a sheet of ejected material called the *ejecta blanket.*

A detailed comparison of the properties of Lunar and Earth rock samples has placed very strong constraints on the possible validity of these hypotheses. For example, if the Moon came from material that once made up the Earth, then Lunar and Terrestrial rocks should be much more similar in composition than if the Moon was formed somewhere else and only later was captured by the Earth.

These analyses indicate that the abundances of elements in Lunar and Terrestrial material are sufficiently different to make it unlikely that the Moon formed directly from the Earth. Generally, work over the last 10 years has essentially ruled out the first two explanations and made the third one rather unlikely. At present the fifth hypothesis, that the Moon was formed from a ring of matter ejected by collision of a large object with the Earth, is the favored hypothesis; however, the question is not completely settled and many details remain to the accounted for.

The Planet Mars

Mars, the "Red Planet", is named after the Roman god of war because it commonly appears with a reddish tinge when viewed in our sky. It has always held a fascination for those interested in the possibility of life on other planets.

Mars has a rotational period of 24 hours and 37 minutes, a period for revolution about the sun of 687 days, and a diameter of 6800 km (about half that of Earth). Its average density is 3.9 g/cc, which is considerably less than the 5.2-5.5 g/cc characteristic of Mercury, Venus, and the Earth. This density gives it a mass about 11% of that for Earth. It is most easily observed from Earth when it is at opposition. Even then, it was difficult in the past to observe from Earth because of turbulence in the Martian atmosphere and ours.

There is no evidence on Mars for large-scale plate tectonics as we find on Earth. This is believed to be responsible for the different character of Martian and

Terrestrial volcanoes. On the Earth, as crustal plates move over subsurface chambers of molten rock the lava tends to come to the surface in a line of places, producing strings of volcanoes (for example, volcanic island chains like the Hawaiian Islands). On Mars, with no horizontal motion of crustal plates the same point in the crust sits over subsurface chambers of molten rock and a few very large volcanoes are built. Here is a more extensive discussion of volcanism on Mars.

The Martian surface has some large canyon systems. The largest is Valles Marineris, which extends for about 5000 km, is 500 km wide in the widest portions, and as much as 6km deep. This enormous system of connecting canyons appears to have been formed mostly by local tectonic activity (local motion of surface) rather than by erosion, though as we will discuss below there is some evidence for fluid erosion in portions of it.

There are channels on Mars as much as 1500 km long and 200 km wide that appear to have been cut by running water. Under present atmospheric conditions on Mars (low pressure), water cannot exist as a free liquid on the surface (it must be gas or solid). Thus, evidence for water erosion suggests that the Martian atmosphere may have been denser in the past.

The atmosphere of Mars is thin (about 1/200 of the pressure of the Earth's atmosphere), but this atmosphere supports high velocity seasonal winds that are correlated with solar heating of the surface and that produce dust storms that lead to a lot of surface erosion.

Mars has polar caps that wax and wane with the Martian seasons. These polar caps appear to be partially composed of frozen carbon dioxide ("dry ice") and partially composed of frozen water.

The atmosphere and (probably) the interior of Mars differ substantially from that of the Earth. The atmosphere is much less dense and of different composition, and it is unlikely that the core is molten. The atmosphere has a pressure at the surface that is only 1/200 that of Earth. The primary component of the atmosphere is carbon dioxide (95%), with the remainder mostly nitrogen. Seasonal heating drives strong winds that can reach 100 mph or more, stirring up large dust storms. Clouds form in the atmosphere, but liquid water cannot exist at the ambient pressure and temperature of the Martian surface: water goes directly between solid and vapor phases without becoming liquid.

The density of Mars is about 25% less than that of the Earth, suggesting a proportionally larger concentration of lighter materials relative to the core. It is probably intermediate in composition between the Earth and the Moon. Though Mars is probably at least partially differentiated, there is little evidence for large-scale tectonic motion (but there is smaller scale motion such as that responsible for the Valles Marineris system). The core is thought to be iron sulphide; the absence of any detectable magnetic field even though the rotation period is comparable to that for Earth suggests that the core is probably not liquid.

Mars has two small moons - Phobos and Deimos. Phobos is 27 km long in its longest dimension and Deimos is 15 km long in its longest dimension. Both are cratered and orbit the planet in rather low orbits. Phobos is only about 3000 miles above the Martian surface and orbits in a little over 7 hours (thus it makes more than 3 orbits in a single Martian day). Deimos is a little further out and orbits in about 30 hours. These moons of Mars were not formed in the same way as the Earth's Moon. They are probably fragments of larger objects broken apart in a collision. Such moons may be formed from collisions of objects originally in orbit around the planet, or they might also have been captured gravitationally at some point in the past.

The Planet Jupiter

Jupiter is by far the largest of the planets. It is more than twice as massive as all other planets combined; if it had been only about 100 times more massive at birth (not so much by astronomical standards) it would have become a star instead of a planet. Then the Solar System might be a double star system instead of a single star with a planetary system.

Jupiter has features very different from terrestrial planets. Its composition is more like that of stars, and if it has any solid surface it is hidden deep at its center: Jupiter is apparently almost entirely gas and liquid. It also has an internal energy source and enormous magnetic fields. Finally, the 4 largest moons of Jupiter (the Galilean Moons) are sufficiently interesting in their own right that they are among the most studied objects in the Solar System. We shall devote a separate section to studying their properties.

The planet Jupiter is 5.2 A.U. from the Sun on average, which corresponds to an orbital period of 11.9 Earth years. It is the most massive planet, being 318 times as massive as the Earth, and about 2 1/2 times the mass of all other planets combined.

Jupiter is massive because it has a large diameter (11.2 times that of Earth). Its density is only 1.33 g/cc, which is 1/4 that of Earth, and only slightly more than the 1 g/cc characteristic of water. This very low density compared with the terrestrial planets is because it is composed mostly of hydrogen and helium, in ratios similar to that found in stars (approximately 82% hydrogen and 17% helium by mass).

Furthermore, Jupiter is almost entirely gas and liquid. Therefore, Jupiter and the related planets Saturn, Uranus, and Neptune are sometimes called Gas Giants (these are also called the Jovian Planets, since Jove was another name for Jupiter).

Because Jupiter is not solid its parts do not rotate at exactly the same velocity. However, measurements of the rotation of the magnetic field give a rotation period of 9 hours and 55 minutes. The atmosphere has clouds with a colorful and complex structure. These features are partially associated with the effect of very high velocity winds in the Jovian atmosphere (as much as 900 km/hr).

Jupiter has a very complex atmosphere. It is dominated by colorful bands and turbulent swirls. All that we see is the top of the atmosphere. The light bands are called zones and the darker bands are called belts. The zones tend to be white or yellow, while the belts are often some shade of reddish brown. Temperature measurements by the Pioneer spacecraft (1973) established that the temperature of the dark belts is higher than that of the light zones, implying that the former are lower in the atmosphere. Thus, the belts appear to be regions of descending gas and the zones are regions of rising gas.

The explanation for the color of Jupiter's clouds is still something of a mystery. Although there are compounds in Jupiter's atmosphere that could account for the colors if the atmosphere were warmer, they should not be the colors that are observed at the very cold temperatures in the tops of Jupiter's clouds (about -150 degrees Celsius). It has been suggested that the colors result either from colorful hydrogen compounds welling up from warmer regions, or from colorful compounds associated with trace amounts of elements like sulfur in the atmosphere. Consultation of past observations of Jupiter indicates that the clouds change their colors over time.

The Great Red Spot is a great anti-cyclonic (high pressure) storm akin to a hurricane on Earth, but it is enormous (three Earths would fit within its boundaries) and it has persisted for at least the 400 years that humans have observed it through telescopes. Since it is anti-cyclonic in Jupiter's Southern hemisphere, the rotation is counterclockwise, with a period of about 6 days. The clouds associated with the Spot appear to be about 8 km above neighboring cloud tops. The Coriolis effects that are responsible for cyclones and anti-cyclones on Earth are greatly magnified on Jupiter, which has a rotational frequency about 2 1/2 times that of Earth, but this alone would not account for the persistence and size of the Great Red Spot. There are other features similar to the Great Red Spot on the surface but none are as large as the Great Red Spot. Presumably the persistence of the Great Red Spot is related to the fact that it never comes over land, as in the case of a hurricane on Earth, and that it is driven by Jupiter's internal heat source. Computer simulations suggest that such large disturbances may be stable on Jupiter, and that stronger disturbances tend to absorb weaker ones, which may explain the size of the Great Red Spot.

Most of the interior of Jupiter is liquid (primarily hydrogen and about 10% helium). The central temperatures are thought to lie in the 13,000-35,000 degree Celsius range, and the central pressure is about 100 million Earth atmospheres. We infer indirectly that the small core is rocky. The inner layers of highly compressed hydrogen are in a state that has never been produced on the Earth. Normally, hydrogen does not conduct heat or electricity very well, which are defining characteristics for a metal. Thus, under normal conditions hydrogen is not a metal. Under the extreme pressure found deep inside Jupiter, theory suggests that the electrons are released from the hydrogen molecules and are free to move about the interior. This causes hydrogen to behave as a metal: it becomes conducting for both heat and electricity.

Jupiter radiates 1.6 times a much energy as falls on it from the Sun. Thus, Jupiter has an internal heat source. It is thought that much of this heat is residual heat left over from the original collapse of the primordial nebula to form the Solar System, but some may come from slow contraction. This internal heat source is presumably responsible for driving the complex weather pattern in its atmosphere, unlike the Earth where the primary heat source driving the weather is the Sun.

Jupiter has a large, complex, and intense magnetic field that is thought to arise from electrical currents in the rapidly spinning metallic hydrogen interior. The Earth has a strong magnetic field, but Jupiter's magnetic field at the tops of its clouds is 10 times stronger than that of the Earth. Further, the Jovian magnetic field has much higher complexity than that of the Earth, with some aspects of Jupiter's fields having no Earthly counterpart. The intensity and complexity relative to the magnetic field of the Earth is presumably related in some way to the more rapid rotation and larger metallic interior for Jupiter.

Jupiter has 16 moons. By far the largest and best known are the 4 Galilean Moons, so named because they were discovered by Galileo. Indeed, the 4 Galilean moons are not difficult to see from Earth with even small telescopes. The Galilean satellites are all named after objects of mythological Jupiter's wide-ranging fancies.
Finally, it even has a faint ring.

The Planet Saturn

Saturn, the second most massive planet, and the most distant planet known to the ancients, is one of the most beautiful sites in the Solar System. The most striking feature of Saturn is the spectacular ring system. Although this feature is no longer unique, since we now know that all the Gas Giant planets have rings, the rings of Saturn are much more elaborate than those of any of the other planets. Saturn shares many features with its even larger Gas Giant neighbor Jupiter, but has various unique features in its own right.

Saturn is the second most massive planet, and also the second largest in size. It is a Gas Giant planet with a rotational period of 10-11 hours (depending on latitude), and an orbital period of 29.5 years. The rapid rotation flattens Saturn at the poles by about 10%, making it the most oblate planet. Its composition is similar to that of Jupiter, being composed mostly of hydrogen and helium. Like Jupiter, it is mostly liquid, with a small rocky core expected, but not directly observed, and like Jupiter, it has an internal heat source (it radiates more energy than it receives).

Saturn has the lowest density of any planet, 0.7 g/cc, which is less than that of water. Saturn is of such low density that it would float in a (gigantic) bathtub. The interior is probably similar to Jupiter, with metallic hydrogen responsible for the strong magnetic field of Saturn. The concentration of helium relative to hydrogen is somewhat less than for Jupiter. This is thought to be due to the colder temperature of Saturn.

The surface of Saturn bears many similarities with the surface of Jupiter, but the color contrast is generally less. This is thought to be due to Saturn being colder than Jupiter (further from the Sun), so it has different chemical reactions in its atmosphere, leading to different coloration.

There are large anticyclonic cells on the surface, apparently driven by the planet's internal heat source, but none are as large as the Great Red Spot on Jupiter, and they are not as abundant as on Jupiter.

There are extremely high velocity winds in the atmosphere of Saturn. Unlike the case for Jupiter, the variations in wind speeds are not strongly correlated with the positions of the belts and bands. The wind speeds in the atmosphere of Saturn have been measured to be as high as 1800 km/hr, which is about 4 times the highest speeds in the atmosphere of Jupiter.

Like Jupiter, Saturn is largely liquid. The slightly higher concentration of helium relative to hydrogen in the atmosphere is thought to be be due to the colder temperature of Saturn. Under these colder conditions, liquid helium does not dissolve in liquid hydrogen and drops of helium sink to the center, depleting the outer regions in helium. Speculation on Saturn's internal heat source is similar to that for Jupiter.

The magnetic field of Saturn is similar to that of Jupiter, but weaker. Electrical currents in liquid metallic hydrogen deep in the interior are assumed to be the cause of the magnetic field. Unlike the case for Jupiter, the magnetic field traps charged particles in "Van Allen belts" rather than in sheets, and there appear to be fewer trapped charged particles than is the case for Jupiter.

The ring system of Saturn is divided into 5 major components: the G, F, A, B, and C rings, listed from outside to inside (but in reality, these major divisions are subdivided into thousands of individual ringlets). The F and G rings are thin and difficult to see, while the A, B, and C rings are broad and easily visible. The large gap between the A ring and the B ring is called the Cassini division. Three bright ring features are seen: the F Ring, the Cassini Division, and the C Ring (moving from the outer rings to the inner). The low concentration of material in these rings allows light from the Sun to shine through them. The A and B rings are much denser, which limits the amount of light that penetrates through them. Instead, they are faintly visible because they reflect light from Saturn's disk.

The current known number of Saturn's satellites is 19. The largest moon of Saturn is Titan. It has an atmosphere which has several layers of haze. It has a pressure at the surface of 1.6 times that of Earth, and is made up primarily of nitrogen, with about a 1% concentration of methane. The temperature on the surface is very cold, about -180 degrees Celsius. The atmosphere is extremely opaque because of thick smog that appears to result from sunlight interacting with hydrocarbons, much as smog forms on the Earth. The clouds are probably composed of liquid nitrogen and methane drops, and it is speculated that Titan may be covered with hydrocarbon lakes or oceans (specifically, methane and ethane). Although many of the organic chemicals thought to have been the precursors to life on Earth are present on Titan, it appears to be too cold for life as we know it to have evolved there.

Saturn's other moons have icy surfaces that are very cold so that ice is as rigid as rock and craters form from meteor impacts. The mean densities of these moons are 1.0 to 1.5 g/cc, implying that they are probably mostly ice, though they may have some rocky constituents. Most of Saturn's satellites (as for those of Jupiter) are tidally locked and keep the same face turned toward the planet as they orbit.

The Planet Uranus

The planet Uranus, the first planet discovered in modern times. It was found accidentally by William Herschel while he was searching the sky with a telescope in 1781. It had actually been seen many times before but dismissed as a star.

Uranus is largely hydrogen and helium, but (like Neptune) contains higher proportions of heavy elements than Jupiter or Saturn, and is covered with clouds.

Uranus is the 3rd of the Gas Giant planets, and the first planet discovered in "modern" times (1781). It is barely visible from the Earth without a telescope, which explains why it was not known as a planet to the ancients, and why it had been observed various times after the telescope had been invented without the observers realizing that it was a planet and not a star. Documented sitings go back to at least 1690 when Flamsteed catalogued it as a star.

The density is about 1.2 g/cc, implying that it is mostly hydrogen and helium. The mass is about 15 times that of the Earth, which makes it the 4th most massive planet. But its radius of about 4 times that of the Earth makes it the 3rd largest planet, since Neptune has a smaller radius but larger mass (because Neptune's density is higher). The rotation axis is unusual in that it lies only 8 degrees out of the plane of the orbit. Thus, at times the rings and the orbits of the moons appear like a "bulls-eye" when viewed from the Earth. The average rotational period is a little over 17 hours, and its orbital period is 84 years, at a mean separation of 19.2 A. U. from the Sun.

The rings are less extensive than those of Saturn, and may be rock rather than ice. There are 5 large moons and 10 small ones.

Uranus has a relatively featureless appearance at visible wavelengths. Even from Voyager 2 at a distance of 80,000 km there were few distinguishable features. This is believed to be due to Uranus being further from the Sun than Jupiter and Saturn, which means its temperature is lower (only 58 degrees Kelvin in the upper atmosphere). This decreases the likelihood of chemical reactions making the colorful compounds that give the surface features on Jupiter and Saturn. In addition, the upper atmosphere is thought to have a high-level petrochemical haze that obscures features lower in the atmosphere.

The blue color is because of methane gas in the atmosphere, which absorbs red and orange light strongly, leaving more blue light to be scattered to the observer. The clouds are thought to be mostly methane ice, with a temperature at the cloud tops of about -221 degrees Celsius.

Uranus had a magnetic field that is about 50 times stronger than that of the Earth and is tilted about 60 degrees with respect to the rotation axis. As a result, the magnetic field moves like a corkscrew as Uranus rotates. One hypothesis for this behavior of the magnetic field is that it originates in a thin conducting shell outside the core of the planet rather than deep in the core as for the Earth or Jupiter. The pressure would not be high enough for the relevant conducting material to be metallic hydrogen. A mixture of water, methane, and ammonia under sufficient pressure could provide the requisite electrical conductor.

The magnetosphere contains belts of charged particles similar to those of the Earth. The rings and most of the moons orbit within the magnetosphere and thus are protected from the Solar wind.

The rings of Uranus were discovered from the Earth in 1977 when Uranus occulted (passed in front of) a star and it was noticed that there were dips in the brightness of the star before and after it passed behind the body of Uranus. This data suggested that Uranus was surrounded by at least 5 rings. Most of the rings are not quite circular, and most are not exactly in the plane of the equator. The rings vary in brightness with angle around the moon, apparently because they vary in width with angle. The rings are very narrow (some only a few kilometers across) and no material can be detected in the regions between the rings. It is speculated that this stability of the narrow rings may be due to small "shepherding satellites.

The Planet Neptune

Neptune is like Uranus in many ways, but has its own unique features. Because of Pluto's highly elliptical orbit, it is currently the most distant planet from the Sun, at a separation of about 30 Astronomical Units.

Neptune has been particularly challenging to study from the ground because its disk is small and badly blurred by the Earth's atmosphere at that distance. In spite of this, ground-based astronomers had learned a great deal about this planet since its position was first predicted by Adams and Leverrier in 1845.

Neptune is currently the most distant planet from the Sun, with an orbital radius of 30 Astronomical Units and an orbital period of 165 years. Its diameter is about four times that of the Earth, which makes it the 4th largest planet. It is slightly smaller than Uranus, but its density is 1.6 g/cc (compared with 1.2 g/cc for Uranus), which makes it the 3rd most massive planet. The relatively low density indicates large concentrations of hydrogen and helium, but Uranus and Neptune both have much larger concentrations of heavier elements than Jupiter and Saturn. As for all the gas giant planets, models suggest rocky cores of maybe 15 Earth masses, but there is no direct confirmation of this.

The bluish color of Uranus, because of methane in the atmosphere, which absorbs red light, leaving the light scattered from Neptune preferentially enhanced at blue wavelengths. The period of rotation is about 16 hours, comparable to that of Uranus and much slower than for Jupiter and Saturn. The temperatures at the cloud tops are about -216 degrees Celsius, slightly warmer than for Uranus. Neptune, like Jupiter and Saturn but unlike Uranus, has an internal heat source and produces 2.7 times more heat than it absorbs.

The interior is presumed to contain a rocky core with an icy mantle topped by a deep layer of liquid hydrogen. Like Uranus, the field is tipped with respect to the axis of rotation and offset from the center (the tilt is 50 degrees for Neptune, compared with 60 degrees for Uranus). However, the field is somewhat weaker than for Uranus. As for Uranus, it is speculated that this magnetic field may originate in a conducting shell not far below the clouds, rather than deep in the interior as for Jupiter or the

Earth. In that case, the conducting material would not be metallic hydrogen, as for Jupiter, or iron and nickel, as for the Earth. As noted earlier for Uranus, a mixture of water, methane, and ammonia under the right pressure could be responsible.

Neptune's rings were first detected in star occultation experiments from Earth in 1983. Neptune has two large moons that are easily seen from Earth, Triton and Nereid. Triton is comparable in size with our own moon, and has a thin atmosphere, mostly of nitrogen. The polar ice cap in this image is probably mostly nitrogen ice. Triton orbits Neptune with retrograde motion, which probably means that it is a captured object. The six newly-discovered moons orbit with direct motion nearly in the equatorial plane. Most are closer to Neptune than its rings. Because this lies inside the Roche limit, these moons could not have formed by accretion in their present location. They must have formed elsewhere before coming to their present orbits, though we are not certain where.

The Planet Pluto

Pluto, which was discovered in 1930, is but a dot of light in even the largest Earth-based telescopes. Pluto is 2/3 the size of Earth's moon but 1,200 times farther away, which makes viewing surface detail as difficult as trying to read the printing on a golf ball located thirty-three miles away.

Pluto is on a highly elliptical orbit at an average separation of almost 40 A. U. from the Sun, with an orbital period of 248 years. Since the planet was only discovered in 1930, we have observed only a portion of its orbit so far. Further, the orbit is tilted by about 17 degrees relative to the plane of the ecliptic, much more than for any other planet. Its equatorial radius of 1150 km is only 20% of that of the Earth, and its mass is only 0.0025 that of the Earth. Thus, it is by far the smallest planet, either in mass or diameter. Its period of rotation appears to be almost 6 1/2 days.

This, and other peculiar aspects of Pluto's orbit, have led to some speculation that Pluto is not really a planet but instead an escaped moon of one of the gas giant planets, most likely Neptune. Its composition, as inferred from its density of 2.1 g/cc, is largely ices. Thus, Pluto is more similar in structure to moons of the gas giant planets than it is to the terrestrial planets. However, other details may favor an origin of Pluto independent of Neptune, so this is an open question at present.

The surface of Pluto is resolved for the first time in these NASA Hubble Space Telescope pictures, taken with the European Space Agency's (ESA) Faint Object Camera (FOC) in 1994. These images, which were made in blue light, show that Pluto has large-scale contrast than any planet except Earth. Pluto isn't large enough to retain much of an atmosphere, but it has a thin one that appears to be mostly nitrogen with some methane.

In 1978, careful Earth-based observation indicated that the image of Pluto had a slight bulge. This was interpreted as evidence for a previously unknown moon, named Charon. With the presence of a moon, it was now possible to determine the mass of Pluto to much better precision than before because of the gravitational interaction between the moon and planet. This caused a drastic decrease in the previously assumed value for the mass of Pluto (previously the mass had been assumed to be as large as 10-100% of that of the Earth).

Appendices

Appendix 1

Phrases for summary and rendering

1. The text/ article tells of ...
2. The text/ article shows ...
3. At the beginning the author describes /depicts/ touches upon/ explains/ introduces/ mentions/ characterizes/ points out/ generalizes/ reveals/ exposes
4. The text/ article begins (opens) with a (the) description of introduction of/ the mention of/ the analysis of a summary of/ the characterization of/ (author's) opinion of
5. Then/ after that/ further/ further on/ next the author passes on to/ goes on from ... to/ goes on to say that/ gives a detailed analysis/ description, etc. of
6. In conclusion the author depicts, etc.
7. The author concludes with a/ the description of/ his recollections of/ the generalization of/ the characterization of/ (his) opinion of …
8. To finish with, the author …

Appendix 2

Linking words

Beginning

First(ly)

First of all

For a start

In the first place

Initially

To begin/start with

Let us begin/start by

First and foremost

First and most importantly

Going further

Second(ly)/third(ly)

In the second place

Subsequently

Simultaneously

And then

Next

Formerly/previously

Adding information

And

In addition

As well as

Also

Too

Furthermore

Moreover

Besides

Above all

Along with

Additionally

Besides

Further

Not only . . . but also . . .

Not to mention

One could also say

What is more

Sequencing ideas

The former, … the latter

Firstly, secondly, finally

The first point is

The following

Giving a reason

Due to / due to the fact that

Owing to / owing to the fact that

Because

Because of

Since

As

Well, you see

The (main/basic) reason is that

Let me explain. You see

But the point is

I think … is right for the following reasons …

Giving a result

Therefore

So

Consequently

This means that

As a result

Comparison/Contrast

Although / even though

Nevertheless

In theory…

in practice…

Both… and …

Analogously

Equally

Likewise

Just like

Similarly

Correspondingly

In the same way

In the same manner

By the same token

Alternatively

But/ However

Conversely/ On the contrary

Despite / despite the fact that

In spite of / in spite of the fact that

Differing from/ In contrast\Instead

In comparison

In reality

On the one hand/ On the other hand

Notwithstanding/ Nonetheless/ Nevertheless

Still/ Yet

Unlike

Whereas/ While

Emphasis

Indeed/truly

In fact/actually

Notably

Particularly/specifically Especially/mainly

Admittedly

Of course /certainly/surely

No doubt

Obviously

Needless to say

As a matter of fact

For this reason

Clarification

In other words

That is

Namely

That is to say

To put in another way,

One example of this is

For example/for instance

Such as

Frequently

As an illustration

To demonstrate

To illustrate

Transitions

Accordingly

As a consequence

For this/that reason

Hence

In that case

On account of this

Therefore

Thus

Summarising

In short

In brief

In summary

To summarise

To conclude

In conclusion

Eventually

In the end (I'd like to say that)

Weighing up all pros and cons

To crown it all

Concluding

Summing up/to sum up

To conclude/in summary

Finally

In short/in brief

On the whole

Ultimately

Last/lastly

Last of all

Last but not the least

Personal or other people's opinion

In my opinion/In my view/To my mind

To my way of thinking

Personally I believe that/ I think that…

It strikes me that

I feel very strongly that

I'm inclined to believe that

It seems to me that

As far as I am concerned

It's popularly believed that

People often claim that

It is often alleged that

Some people argue that

A lot of people think/believe that

As I see it

From my point of view

If I'm not mistaken

To my way of thinking

I'll say straightforwardly

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26. www.britannica.com
27. http://spaceandyou.ru/node/220447
28. www.universetoday.com/23445/sagittarius
29. www.solarviews.com/eng/meteor.htm
30. www.solarviews.com/eng/comet.htm
31. http://www.ehow.com
32. http://cometasite.ru