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Е. Н. Агапова

ПРАКТИКУМ ПО ПРОФЕССИОНАЛЬНО-ОРИЕНТИРОВАННОМУ ПЕРЕВОДУ ДЛЯ СТУДЕНТОВ-ФИЗИКОВ

Рекомендовано Ученым советом Государственного образовательного учреждения высшего профессионального образования «Оренбургский государственный университет» в качестве учебного пособия для студентов, обучающихся по программам высшего профессионального образования по естественнонаучным и инженерно-техническим специальностям

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В учебном пособии приведены аутентичные тексты на английском языке по физике, задания к текстам для обучения переводу, профессиональная лексика для изучения и закрепления, список употребляемых в технической литературе сокращений.

Данное пособие рассчитано на 110 аудиторных часов и предназначено для студентов специальностей физического факультета, изучающих английский язык. Оно также может использоваться и для студентов других естественнонаучных и технических специальностей в качестве дополнительной литературы. Цель пособия – формирование познавательной самостоятельности студентов в процессе профессионально-направленного обучения английскому языку.

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Содержание

Введение

Вступая в 21 век, необходимо четко представлять, какими должны быть высшее профессиональное образование и специалисты, выпускаемые высшей школой. Требования к подготовке специалиста исходят из общеэкономических и общественных целей государства.

Специалист сегодня – это человек с широкими общими и специальными знаниями, способный быстро реагировать на изменения в технике и науке; ему нужны базовые знания, проблемное, аналитическое мышление, социально-психологическая компетентность, интеллектуальная культура.

Необходимость идти в ногу со временем определяет такие задачи для будущего специалиста как умение читать и понимать литературу на иностранном языке, поддерживать профессиональное общение с зарубежными коллегами, представлять свои идеи для многоязычной аудитории.

Возросшее значение владения иностранным языком как инструментом будущей профессиональной деятельности предъявляет новые требования к преподаванию английского языка студентам неязыковых ВУЗов, делая акцент на профессионально-ориентированный подход. Это и определило содержание и структуру данного учебного материала.

Тексты практикума собраны из различных разделов физики и не только позволяют ознакомиться с ее историей как науки, учеными, внесшими значительный вклад для ее развития, и последними достижениями, но и служат богатым источником как узкопрофильной, так и общетехнической лексики, конструкций и оборотов, используемых в технической литературе.

Не отменяя значимости работы с научно-техническим текстом, все-таки не следует сводить все профессионально-ориентированное обучение английскому языку только к переводу, забывая о его главной задаче: формирование языковой личности, использующей иностранный язык для общения в реальных ситуациях с представителями других культур. С этой целью в пособии даны разнообразные языковые и речевые упражнения, развивающие коммуникативные навыки.

Поскольку конечной целью современного образования является воспитание личности, способной к саморазвитию, то упражнениям, способствующим формированию у студентов такого качества как познавательная самостоятельность в данном практикуме уделяется особое внимание.

Познавательная самостоятельность определяется мотивами, установками, целями конкретной личности и является одним из главных источников активности, придающих деятельности направленность, силу и субъектную значимость.

Таким образом, одной из задач представляемого пособия является задача воспитания личности, способной к самостоятельности, самоконтролю и обладающей высоко развитыми умениями познавательной деятельности, готовой творчески решать проблемы, порождаемые неуклонным развитием производства и научного знания.

Отсюда следует еще одна особенность практикума, состоящая в том, что некоторые задания побуждают обучаемых к использованию дополнительных современных источников получения и представления информации, информационных технологий, таких как, например, Интернет и мультимедийный класс для проведения презентаций.

Учебное пособие по профессионально-ориентированному переводу предназначено для студентов 1, 2 и 5 курсов специальностей физического факультета, но также может быть использовано и для студентов других естественнонаучных и технических специальностей в качестве дополнительной литературы.

Практикум состоит из четырех разделов: раздел об истории физики как науки; раздел, содержащий тексты из различных разделов физики; раздел с дополнительными текстами и раздел, включающий термины и сокращения из текстов. Через каждые 3 - 5 параграфов дается лексика по всему пройденному материалу и обобщающие упражнения.

Учебный материал рассчитан на 110 аудиторных часов. Цель пособия – формирование познавательной самостоятельности студентов в процессе профессионально-направленного обучения английскому языку.

1 Section I The History of Physics

1.1 Text Why Study Physics, Physical Science, and Astronomy?

1.1.1 Read the text, translate it and answer the questions: What does physics study as a science? What period of future physicist's life is major for his or her occupational choice?

Physics is the basis of science and technology. The laws of physics describe the behavior of matter and energy and help us to understand the physical world. On the smallest scale, physicists study quarks, nuclei, atoms, and other basic constituents of matter. They also study the mechanical, electromagnetic, and thermal properties of solids, liquids, gases, and plasmas. On the grand scale, physicists and astronomers study stars and galaxies, and apply physical principles to questions about the nature of the universe.

For example, in the United States more than 50,000 physicists work in industry, educational institutions, state and federal government, and nonprofit research centers. Some of them perform basic research in physics, while others apply their knowledge to solve human problems in such areas as energy sources, environmental protection, medicine, transportation, communication, meteorology, geology, and defense.

These researchers are supported by those who teach science and engineering, providing students with the problem-solving and laboratory skills necessary for challenging the future. Physical science teachers are educated to work in the elementary and middle schools where school children receive their first in-depth exposure to science and technology. Their work is crucial because the attitudes toward science instilled at this level generally persist for a lifetime. Physics teachers are trained to instruct in the high school or community college, and many physicists are employed as college professors. Besides educating future physics researchers, physics teachers provide the knowledge of physics that is required for such fields as medicine, engineering, technical writing, and environmental science [3, http://www.phy.cmich.edu/Overview/overview.shtml].

1.1.2 Read the text again. Summarize it and add personal information: Why have you chosen your speciality? Where do physicists usually work in your country?

1.2 Text The History of Physics

1.2.1 Read the text, translate it and name important milestones in the history of physics.

The most advanced science at present and the one, which seems to give the most light on the structure of the world, is physics. It is useful to have some idea of not only what the up-to-date development of physics is but also how we came to think in that way and how the whole of modern physics is connected with its history. In fact, the history of this science begins with Galileo, but in order to understand his work it will be well to see what was thought before his time.

The scholastics, whose ideas were derived from Aristotle, thought that there were different laws for celestial and terrestrial bodies, and also for living and dead matter. There were four elements: earth, water, air and fire, of which earth and water were heavy, while air and fire were light. Earth and water had a natural downward motion, air and fire upward motion. There was no idea of one set of laws for all kinds of matter; there was no science of changes in the movements of bodies.

Galileo – and in a lesser degree Descartes – introduced the fundamental concepts and principles which were enough for physics until the present century. They showed that the laws of motion are the same for all kinds of dead matter and probably for living matter also.

Galileo introduced the two principles that made mathematical physics possible: the law of inertia and the parallelogram law. The law of inertia, now familiar as Newton's first law of motion made it possible to calculate the motions of matter by means of the laws of dynamics alone.

Technically the principle of inertia meant that causal laws of physics should be stated in terms of acceleration, i.e. a change of velocity in amount or direction or both which was found in Newton's law of gravitation. From the law of inertia it followed that the causal laws of dynamics must be differential equations of the second order, though this form of statement could not be made until Newton and Leibniz had developed the infinitesimal calculus. Most of what students do on the mathematical side of physics may be found in Newton's *Principia*. The basic idea of dynamics, the equations of motion, the ideas of momentum, of inertia, of mass and acceleration were applied by Newton to large bodies like the Earth and the Moon to explain the structure and the motion of the universe. From Newton to the end of the 19th century, the progress of physics involved no basically new principles. The first revolutionary novelty was Planck's introduction of the quantum constant h to explain the structure and behaviour of atoms in the year 1900. Another departure from Newtonian principles followed in 1905, when Einstein published his special theory of relativity. Ten years later he published his general theory of relativity which was primarily a geometrical theory of gravitation showing that the universe is expending.

In fact, when modern science was growing up from the time of Galileo to the time of Newton, all the sciences were very much joined together. A single man could do absolutely first-class research in pure mathematics, in physics, in camistry and even in biology. Towards the end of that time the sciences were beginning to separate and after that they continued to separate more and more.

Just at this moment we can see a great convergence of all sciences. Physics is increasingly penetrating all the other parts of science and this is evident in the names of the new hybrid subjects. We have long had physical chemistry; now we have chemical physics, which is different not so much in the propotion of physics and chemistry, but in its central interest of extending the range of physics. A biologist cannot do without knowledge of modern physics, while a physicist must know something of biology, as he may find a great deal of his work will be concerned with biophysics. The mathematical aspect of physics is also becoming much more evident especially now that we are having a growing symbiosis between physics and mathimatics in computational physics.

Our job in physics is to see things simply, to understand a great many complicated phenomena in a unified way, in terms of a few simple principles. You cannot predict what will happen in future, but you have to be ready to meet it [1, C. 186-187].

1.2.2 Find key sentences in the text and retell it.

1.2.3 Scan the text from Wikipedia about Physics History and answer: What facts weren't mentioned in the previous text?

The History of Physics (From Wikipedia, the free encyclopedia)

Physics is the science of matter and its behaviour and motion. It is one of the oldest scientific disciplines. The first written work of physics with that title was Aristotle's *Physics*.

Elements of what became physics were drawn primarily from the fields of astronomy, optics, and mechanics, which were methodologically united through the study of geometry. These disciplines began in Antiquity with the Babylonians and with Hellenistic writers such as Archimedes and Ptolemy, then passed on to the Arabic-speaking world where they were critiqued and developed into a more physical and experimental tradition by scientists such as Ibn al-Haytham and Abū Rayhān Bīrūnī, before eventually passing on to Western Europe where they were studied by scholars such as Roger Bacon and Witelo. They were thought of as technical in character and many philosophers generally did not perceive their descriptive content as representing a philosophically significant knowledge of the natural world. Similar mathematical traditions also existed in ancient Chinese and Indian sciences.

Meanwhile, philosophy, including what was called “physics”, focused on explanatory (rather than descriptive) schemes developed around the Aristotelian idea of the four types of “causes”. According to Aristotelian and, later, Scholastic physics, things moved in the way that they did because it was part of their essential nature to do so. Celestial objects were thought to move in circles, because perfect circular motion was considered an innate property of objects that existed in the uncorrupted realm of the celestial spheres. The theory of impetus, led to the concepts of inertia and momentum, also belonged to this philosophical tradition, and was developed by medieval philosophers such as John Philoponus, Avicenna and Jean Buridan. The physical traditions in ancient China and India were also largely philosophical.

In the philosophical tradition of “physics”, motions below the lunar sphere were seen as imperfect, and thus could not be expected to exhibit consistent motion. More idealized motion in the “sublunary” realm could only be achieved through artifice, and prior to the 17th century, many philosophers did not view artificial experiments as a valid means of learning about the natural world. Instead, physical explanations in the sublunary realm revolved around tendencies. Stones contained the element earth, and earthy objects tended to move in a straight line toward the center of the universe (which the earth was supposed to be situated around) unless otherwise prevented from doing so. Other physical explanations, which would not later be considered within the bounds of physics, followed similar reasoning. For instance, people tended to think, because people were, by their essential nature, thinking animals [10, http://en.wikipedia.org/wiki/History_of_physics].

1.2.4 Look through the text and find the English equivalents for the following Russian phrases and word-combinations:

древнегреческие писатели; многие философы в общем не воспринимали; природное свойство; которые существовали в неискаженной сфере; теория движущей силы.

1.3 Revision texts 1.1 - 1.2

1.3.1 Match words and word-combinations with their translation:

computation physics	движение вниз
celestial body	правило параллелограмма
lunar sphere	ядра
hybrid subjects	дифференциальное уравнение
infinitesimal calculus	гравитация
parallelogram law	кварки (фундаментальные частицы)
upward motion	живая материя
medieval philosopher	расширять(ся)
explanatory scheme	скорость
quantum constant	ученый
gravitation	причинный закон
quarks	вычислительная физика
innate property	элементы вещества
convergence	схема описания
differential equation	схоластика
downward motion	ускорение
descriptive scheme	объединенные предметы
dead matter	инерция
to expend	движение вверх
causal law	исчисление бесконечно малых
nuclei	схождение в одной точке, сближение, конвергенция
scholar	средневековый философ
acceleration	земное тело
constituents of matter	лунная сфера
velocity	природное свойство

terrestrial body	теория движущей силы
scholastics (scholasticism)	схема объяснения
inertia	неживая материя
living matter	квантовая постоянная
theory of impetus	небесное тело

1.3.2 Find the sentences with these words and word-combinations in texts 1.1 – 1.2 and translate them.

1.3.3 Prepare the words and word-combinations for a dictation.

1.3.4 Translate the following text into English. You may use vocabulary notes below it.

Античная физика

В античные времена, модель явлений природы часто заменяли религиозные мифы (“молния есть гнев богов”).

Средств для проверки теорий в древности было крайне мало, даже если речь шла о земных каждодневных явлениях. Единственная физическая величина, которую умели тогда достаточно точно измерять — длина; позже к ней добавился угол. Эталоном времени служили сутки, которые в Древнем Египте делили не на 24 часа, а на 12 дневных и 12 ночных. Но даже когда установили привычные нам единицы времени, из-за отсутствия точных часов большинство физических экспериментов было просто невозможно провести. Поэтому естественно, что вместо научных школ возникали полурелигиозные учения.

Преобладала геоцентрическая система мира, хотя пифагорейцы развивали и пироцентрическую, в которой звёзды, Солнце, Луна и шесть планет обращаются вокруг Центрального Огня. Чтобы всего получилось священное число небесных сфер (десять), шестой планетой объявили Противоземлю.

Впрочем, отдельные пифагорейцы (Аристарх Самосский и др.) создали гелиоцентрическую систему. У пифагорейцев возникло впервые и понятие эфира как всеобщего заполнителя пустоты.

Первую формулировку закона сохранения материи предложил Эмпедокл в V веке до н. э.:

Ничто не может произойти из ничего, и никак не может то, что есть, уничтожиться.

Позже аналогичный тезис высказывали Демокрит, Аристотель и другие.

Термин “Физика” возник как название одного из сочинений Аристотеля. Предметом этой науки, по мнению автора, было выяснение первопричин явлений.

Такой подход долго (фактически до Ньютона) отдавал приоритет метафизическим фантазиям перед опытным исследованием. В частности, Аристотель и его последователи утверждали, что движение тела поддерживается приложенной к нему силой, и при её отсутствии тело остановится (по Ньютону, тело сохраняет свою скорость, а действующая сила меняет её значение и/или направление).

Некоторые античные школы предложили учение об атомах как первооснову материи. Эпикур даже полагал, что свобода воли человека вызвана тем, что движение атомов подвержено случайным смещениям.

Кроме математики, эллины успешно развивали оптику.

Тем не менее, в оптике древних были и грубые ошибки. Например, угол преломления считался пропорциональным углу падения (эту ошибку разделял даже Кеплер). Гипотезы о природе света и цветности были многочисленны и довольно нелепы [10, http://en.wikipedia.org/wiki/History_of_physics].

Vocabulary notes:

Геоцентрическая система (модель мира) - geocentric model;

пифагорейцы – Pythagoreans;

пироцентрическая модель - pyrocentric model;

Противоземля - Anti-earth;
Аристарх Самосский – Aristarkh Samossky;
гелиоцентрическая система – heliocentric model;
Эмпедокл – Empidocle;
Демокрит – Democritis;
Аристотель – Aristotle;
Ньютон – Newton;
Эпикур – Epicur;
Эллины – Hellenes;
Кеплер – Kepler.

1.3.5 Read texts 1.1 – 1.2, 1.3.4 again, find the unknown words in the dictionary and prepare the presentation of your report on “The History of Physics”. You may use Internet to add some information.

1.4 Text Emergence of Experimental Method and Physical Optics

1.4.1 Read the text and answer the questions: What is your attitude to Ibn al-Haytham? Have you read any of his books? Do you like them?

The use of experiments in the sense of empirical procedures in geometrical optics dates back to second century Roman Egypt, where Ptolemy carried out several early such experiments on reflection, refraction and binocular vision. Due to his Platonic methodological paradigm of “saving the appearances”, however, he discarded or rationalized any empirical data that did not support his theories, as the idea of experiment did not hold any importance in Antiquity. The incorrect emission theory of vision thus continued to dominate optics through to the 10th century.

Figure 1 - Ibn al-Haytham (965-1039)

The turn of the second millennium saw the emergence of experimental physics with the development of an experimental method emphasizing the role of experimentation as a form of proof in scientific inquiry, and the development of physical optics where the mathematical discipline of geometrical optics was successfully unified with the philosophical field of physics. The Iraqi physicist, Ibn al-Haytham (Alhazen), is considered a central figure in this shift in physics from a philosophical activity to an experimental and mathematical one, and the shift in optics from a mathematical discipline to a physical and experimental one. Due to his positivist approach, his *Doubts Concerning Ptolemy* insisted on scientific demonstration and criticized Ptolemy's confirmation bias and conjectural undemonstrated theories. His *Book of Optics* (1021) was the earliest successful attempt at unifying a mathematical discipline (geometrical optics) with the philosophical field of physics, to create the modern science of physical optics. An important part of this was the intromission theory of vision, which in order to prove, he developed an experimental method to test his hypothesis. He conducted various experiments to prove his intromission theory and other hypotheses on light and vision. The *Book of Optics* established experimentation as the norm of proof in optics, and gave optics a physico-mathematical conception at a much earlier date than the other mathematical disciplines. His *On the Light of the Moon* also attempted to combine mathematical astronomy with physics, a field now known as astrophysics, to formulate several astronomical hypotheses which he proved through experimentation [10, http://en.wikipedia.org/wiki/History_of_physics].

1.4.2 Note to text 1.4.1:

- Ibn al-Haytham - Ибн ал-Хайсам.

1.5 Text Galileo Galilei and the rise of physico-mathematics

1.5.1 Read the text and answer: What is Galileo famous for? Reread the third and the fourth abstracts of text 1.2.1 and make a list of Galileo's contributions to science using the information from both the texts.

In the 17th century, natural philosophers began to mount a sustained attack on the Scholastic philosophical program, and supposed that mathematical descriptive schemes adopted from such fields as mechanics and astronomy could actually yield universally valid characterizations of motion. The Tuscan mathematician Galileo Galilei was the central figure in the shift to this perspective.

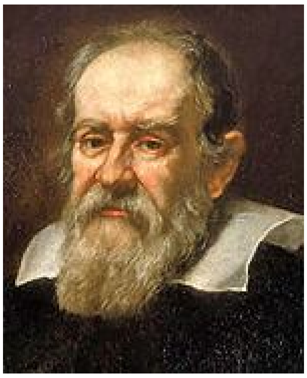


Figure 2 - Galileo Galilei (1564-1642)

As a mathematician, Galileo's role in the university culture of his era was subordinated to the three major topics of study: law, medicine, and theology (which was closely allied to philosophy). Galileo, however, felt that the descriptive content of the technical disciplines warranted philosophical interest, particularly because mathematical analysis of astronomical observations—notably the radical analysis offered by astronomer Nicolaus Copernicus concerning the relative motions of the sun, earth, moon, and planets—indicated that philosophers' statements about the nature of the universe could be shown to be in error. Galileo also performed mechanical experiments, and insisted that motion itself—regardless of whether that motion was natural or artificial—had universally consistent characteristics that could be described mathematically.

Galileo used his 1609 telescopic discovery of the moons of Jupiter, as published in his *Sidereus Nuncius* in 1610, to procure a position in the Medici court with the dual title of mathematician and philosopher. As a court philosopher, he was expected to engage in debates with philosophers in the Aristotelian tradition, and received a large audience for his own publications, such as *The Assayer* and *Discourses and Mathematical Demonstrations Concerning Two New Sciences*, which was published abroad after he was placed under house arrest for his publication of *Dialogue Concerning the Two Chief World Systems* in 1632.

Galileo's interest in the mechanical experimentation and mathematical description in motion established a new natural philosophical tradition focused on experimentation. This tradition, combining with the non-mathematical emphasis on the collection of "experimental histories" by philosophical reformists such as William Gilbert and Francis Bacon, drew a significant following in the years leading up to and following Galileo's death, including Evangelista Torricelli and the participants in the Accademia del Cimento in Italy; Marin Mersenne and Blaise Pascal in France; Christiaan Huygens in the Netherlands; and Robert Hooke and Robert Boyle in England [10, http://en.wikipedia.org/wiki/History_of_physics].

1.5.2 Retell the text using the list of Galileo's contributions.

1. 6 Text The Cartesian Philosophy of Motion

1.6.1 Read the text, traslate it and answer the questions: What was the role of René Descartes in the development of science? What is he notable by?

Figure 3 - René Descartes (1596-1650)

The French philosopher René Descartes was well-connected to, and influential within, the experimental philosophy networks. Descartes had a more ambitious agenda, however, which was geared toward replacing the Scholastic philosophical tradition altogether. Questioning the reality interpreted through the senses, Descartes sought to reestablish philosophical explanatory schemes by reducing all perceived phenomena to being attributable to the motion of an invisible sea of “corpuscles”. (Notably, he reserved human thought and God from his scheme, holding these to be separate from the physical universe). In proposing this philosophical framework, Descartes supposed that different kinds of motion, such as that of planets versus that of terrestrial objects, were not fundamentally different, but were merely different manifestations of an endless chain of corpuscular motions obeying universal principles. Particularly influential were his explanation for circular astronomical motions in terms of the vortex motion of corpuscles in space (Descartes argued, in accord with the beliefs, if not the methods, of the Scholastics, that a vacuum could not exist), and his explanation of gravity in terms of corpuscles pushing objects downward.

Descartes, like Galileo, was convinced of the importance of mathematical explanation, and he and his followers were key figures in the development of mathematics and geometry in the 17th century. Cartesian mathematical descriptions of motion held that all mathematical formulations had to be justifiable in terms of direct physical action, a position held by Huygens and the German philosopher Gottfried Leibniz, who, while following in the Cartesian tradition, developed his own philosophical alternative to Scholasticism, which he outlined in his 1714 work, *The Monadology* [10, http://en.wikipedia.org/wiki/History_of_physics].

1. 7 Text Newtonian Motion versus Cartesian Motion

1.7.1 Before reading the text aswer the question: What do you know about Newton? Now read it and say: What new facts have you learnt?

In the late 17th and early 18th centuries, the Cartesian mechanical tradition was challenged by another philosophical tradition established by the Cambridge University mathematician Isaac Newton. Where Descartes held that all motions should be explained with respect to the immediate force exerted by corpuscles, Newton chose to describe universal motion with reference to a set of fundamental mathematical principles: his three laws of motion and the law of gravitation, which he introduced in his 1687 work *Mathematical Principles of Natural Philosophy*.

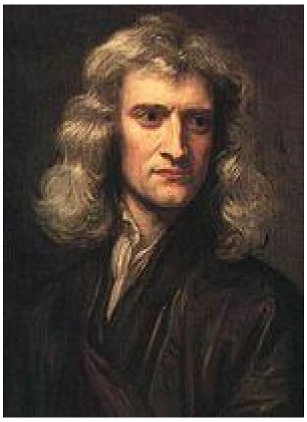


Figure 4 - Sir Isaac Newton, (1643-1727)

Using these principles, Newton removed the idea that objects followed paths determined by natural shapes (such as Kepler's idea that planets moved naturally in ellipses), and instead demonstrated that not only regularly observed paths, but all the future motions of any body could be deduced mathematically based on knowledge of their existing motion, their mass, and the forces acting upon them. However, observed celestial motions did not precisely conform to a Newtonian treatment, and Newton, who was also deeply interested in theology, imagined that God intervened to ensure the continued stability of the solar system.

Figure 5 - Gottfried Leibniz, (1646-1716)

Newton's principles (but not his mathematical treatments) proved controversial with Continental philosophers, who found his lack of metaphysical explanation for movement and gravitation philosophically unacceptable. Beginning around 1700, a bitter rift opened between the Continental and British philosophical traditions, which were stoked by heated, ongoing, and viciously personal disputes between the followers of Newton and Leibniz concerning priority over the analytical techniques of calculus, which each had developed independently. Initially, the Cartesian and Leibnizian traditions prevailed on the Continent (leading to the dominance of the Leibnizian calculus notation everywhere except Britain). Newton himself remained privately disturbed at the lack of a philosophical understanding of gravitation, while insisting in his writings that none was necessary to infer its reality. As the 18th century progressed, Continental natural philosophers increasingly accepted the Newtonians' willingness to forgo ontological metaphysical explanations for mathematically described motions [10, http://en.wikipedia.org/wiki/History_of_physics].

1.7.2 Find key sentences in the text and retell it. You may use Internet to get supplementary information.

1.8 Revision texts 1.4 - 1.7

1.8.1 Match words and word-combinations with their translation:

refraction	бинокулярное зрение
immediate force	эмпирический метод
scientific inquiry (investigation)	решение, трактовка
corpuscular motion	доказательство
universe	гипотетический, предположительный
positivist approach	естественная (присущая) форма
justifiable	экспериментальная физика
solar system	богословие
intromission theory	вихревое движение
metaphysical explanation	сила, действующая непосредственно
empirical procedure	геометрическая оптика
to deduce mathematically	математическая астрономия
Tuscan mathematician	мир, вселенная, космос
natural shape	отражение
to discard	склонность к утверждениям (как правило, неподтвержденным)
geometrical optics	преломление, рефракция
natural philosopher	позитивистский подход

theology	теория эмиссии
proof	корпускулярное движение
mathematical astronomy	теория интромиссии (впуска, вхождения)
vortex motion	научное исследование, изучение
to obey	метафизическое объяснение
binocular vision	состоятельный
treatment	философская структура, система взглядов
experimental physics	этрусский математик (математик-тосканец)
conjectural	отказываться (от прежних взглядов)
reflection	выводить математически
philosophical framework	натурфилософ, естествоиспытатель
confirmation bias	солнечная система
emission theory	подчиняться

1.8.2 Find the sentences with these words and word-combinations in texts 1.4 – 1.7 and translate them.

1.8.3 Prepare the words and word-combinations for a dictation.

1.8.4 Translate the following texts into English. You may use vocabulary notes below them.

Ибн ал-Хайсам. Пытаясь доказать пятый постулат Евклида, хоть и ошибочно, Ибн ал-Хайсам впервые рассмотрел четырёхугольник, у которого три внутренних угла — прямые. Он сформулировал три возможных варианта для четвёртого угла: острый, прямой, тупой. Обсуждение этих трёх гипотез многократно возникало в более поздних исследованиях.

Ибн ал-Хайсаму принадлежит большое количество сочинений, повлиявших на развитие математической науки, и фундаментальный труд по оптике в 7 томах.

В области физиологической оптики он дал описание строения глаза и выдвинул собственную теорию, согласно которой зрительный образ получается при помощи лучей, которые испускаются видимыми телами и попадают в глаз. Он же дал правильное представление бинокулярного зрения. Наконец, он высказал предположение о конечности скорости света.

Ибн ал-Хайсаму принадлежит также ряд сочинений по астрономии [8, http://ieeexplore.ieee.org/Xplore/Ibn_al_Haytham].

Vocabulary notes:

пятый постулат Евклида – Euclidean fifth postulate;
внутренний угол - concluded angle;
прямой угол - right angle;
острый угол - sharp angle;
тупой угол - obtuse angle;
бинокулярное зрение - binocular vision.

Декарт. Физические исследования Декарта относятся главным образом к механике, оптике и строению Вселенной.

Декарт ввёл понятие “силы” (меры) движения (количества движения), подразумевая под ним произведение “величины” тела (массы) на абсолютное значение его скорости. Французский ученый сформулировал также закон сохранения движения (количества движения), однако не учитывал, что количество движения является векторной величиной.

Он исследовал законы удара, впервые чётко сформулировал закон инерции (1644).

Декарт первый математически вывел закон преломления света на границе двух различных сред. Точная формулировка этого закона позволила усовершенствовать оптические приборы, которые тогда стали играть огромную роль в астрономии и навигации (а вскоре и в микроскопии).

Философия Декарта была дуалистической.

Главным вкладом Декарта в философию стало классическое построение философии рационализма как универсального метода познания.

Исходной точкой рассуждений Декарта является “сомнение во всём” [8, http://ieeexplore.ieee.org/Xplore/Rene_Descartes].

Vocabulary notes:

преломление света – light refraction;
различные среды – different media;
дуалистический – dualistic;
рационализм - rationalism.

1.9 Text Rational Mechanics in the 18th Century

1.9.1 Read the text, translate it and name the main steps of the mechanics development in the 18th century.

Figure 6 - Leonhard Euler, (1707-1783)

The mathematical analytical traditions established by Newton and Leibniz flourished during the 18th century as more mathematicians learned calculus and elaborated upon its initial formulation. The application of mathematical analysis to problems of motion was known as rational mechanics, or mixed mathematics (and was later termed classical mechanics). This work primarily revolved around celestial mechanics, although other applications were also developed, such as the Swiss mathematician Daniel Bernoulli's treatment of fluid dynamics, which he introduced in his 1738 work *Hydrodynamica*.

Rational mechanics dealt primarily with the development of elaborate mathematical treatments of observed motions, using Newtonian principles as a basis, and emphasized improving the tractability of complex calculations and developing of legitimate means of analytical approximation. A representative contemporary textbook was published by Johann Baptiste Horvath. By the end of the century analytical treatments were rigorous enough to verify the stability of the solar system solely on the basis of Newton's laws without reference to divine intervention—even as deterministic treatments of systems as simple as the three body problem in gravitation remained intractable.

British work, carried on by mathematicians such as Brook Taylor and Colin Maclaurin, fell behind Continental developments as the century progressed. Meanwhile, work flourished at scientific academies on the Continent, led by such mathematicians as Daniel Bernoulli, Leonhard Euler, Joseph-Louis Lagrange, Pierre-Simon Laplace, and Adrien-Marie Legendre. At the end of the century, the members of the French Academy of Sciences had attained clear dominance in the field [10, http://en.wikipedia.org/wiki/History_of_physics].

1.10 Text Physical Experimentation in the 18th and early 19th Centuries

1.10.1 Read the text, translate it and choose the best ending to the sentences:

a) Newton's book Opticks…

- showed him to be a prominent experimenter;

- led to new important discoveries;

b) In the 18th century the experiments in different feilds of science…

- were not clearly understood;
- were rather mixed to each other;

c) Soon the experimentation tradition…

- led to the development of new kinds of research laboratories;
- caused some new types of apparatus and instruments to appear;

d) In the early years of the 19th century analytical methods of rational mechanics began to be applied to experimental phenomena…

- mostly due to Joseph Fourier;
- thanks to Thomas Young and Michael Faraday.

At the same time, the experimental tradition established by Galileo and his followers persisted. The Royal Society and the French Academy of Sciences were major centers for the performance and reporting of experimental work, and Newton was himself an influential experimenter, particularly in the field of optics, where he was recognized for his prism experiments dividing white light into its constituent spectrum of colors, as published in his 1704 book *Opticks* (which also advocated a particulate interpretation of light). Experiments in mechanics, optics, magnetism, static electricity, chemistry, and physiology were not clearly distinguished from each other during the 18th century, but significant differences in explanatory schemes and, thus, experiment design were emerging. Chemical experimenters, for instance, defied attempts to enforce a scheme of abstract Newtonian forces onto chemical affiliations, and instead focused on the isolation and classification of chemical substances and reactions.

Nevertheless, the separate fields remained tied together, most clearly through the theories of weightless “imponderable fluids", such as heat (“caloric”), electricity, and phlogiston (which was rapidly overthrown as a concept following Lavoisier’s identification of oxygen gas late in the century). Assuming that these concepts were real fluids, their flow could be traced through a mechanical apparatus or chemical reactions. This tradition of experimentation led to the development of new kinds of experimental apparatus, such as the Leyden Jar and the Voltaic Pile; and new kinds of measuring instruments, such as the calorimeter, and improved versions of old ones, such as the thermometer. Experiments also produced new concepts, such as the University of Glasgow experimenter Joseph Black's notion of latent heat and Philadelphia intellectual Benjamin Franklin's characterization of electrical fluid as flowing between places of excess and deficit (a concept later reinterpreted in terms of positive and negative charges).

While it was recognized early in the 18th century that finding absolute theories of electrostatic and magnetic force akin to Newton's principles of motion would be an important achievement, none were forthcoming.

This impossibility only slowly disappeared as experimental practice became more widespread and more refined in the early years of the 19th century in places such as the newly-established Royal Institution in London, where John Dalton argued for an atomistic interpretation of chemistry, Thomas Young argued for the interpretation of light as a wave, and Michael Faraday established the phenomenon of electromagnetic induction.

Figure 6 - Michael Faraday (1791-1867) delivering the 1856 Christmas Lecture at the Royal Institution

Meanwhile, the analytical methods of rational mechanics began to be applied to experimental phenomena, most influentially with the French mathematician Joseph Fourier's analytical treatment of the flow of heat, as published in 1822 [10, http://en.wikipedia.org/wiki/History_of_physics].

1.11 Text Thermodynamics, Statistical Mechanics, and Electromagnetic Theory

1.11.1 Read the text, translate it and find one extra step in the list of main steps below the text.

The establishment of a mathematical physics of energy between the 1850s and the 1870s expanded substantially on the physics of prior eras and challenged traditional ideas about how the physical world worked. While Pierre-Simon Laplace's work on celestial mechanics solidified a deterministically mechanistic view of objects obeying fundamental and totally reversible laws, the study of energy and particularly the flow of heat, threw this view of the universe into question.

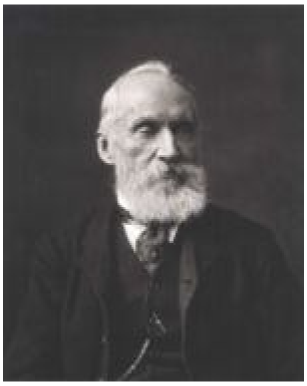


Figure 7 - William Thomson (1824-1907), later Lord Kelvin

Drawing upon the engineering theory of Lazare and Sadi Carnot, and Émile Clapeyron; the experimentation of James Prescott Joule on the interchangeability of mechanical, chemical, thermal, and electrical forms of work; and his own Cambridge mathematical tripos training in mathematical analysis; the Glasgow physicist William Thomson and his circle of associates established a new mathematical physics relating to the exchange of different forms of energy and energy overall conservation (what is still accepted as the "first law of thermodynamics"). Their work was soon allied with the theories of similar but less-known work by the German physician Julius Robert von Mayer and physicist and physiologist Hermann von Helmholtz on the conservation of forces.

Figure 8 - Ludwig Boltzmann (1844-1906)

Taking his mathematical cues from the heat flow work of Joseph Fourier (and his own religious and geological convictions), Thomson believed that the dissipation of energy with time (what is accepted as the “second law of thermodynamics”) represented a fundamental principle of physics, which was expounded in Thomson and Peter Guthrie Tait’s influential work *Treatise on Natural Philosophy*. However, other interpretations of what Thomson called thermodynamics were established through the work of the German physicist Rudolf Clausius. His statistical mechanics, which was elaborated upon by Ludwig Boltzmann and the British physicist James Clerk Maxwell, held that energy (including heat) was a measure of the speed of particles. Interrelating the statistical likelihood of certain states of organization of these particles with the energy of those states, Clausius reinterpreted the dissipation of energy to be the statistical tendency of molecular configurations to pass toward increasingly likely, increasingly disorganized states (coining the term “entropy” to describe the disorganization of a state). The statistical versus absolute interpretations of the second law of thermodynamics set up a dispute that would last for several decades (producing arguments such as “Maxwell's demon”), and that would not be held to be definitively resolved until the behavior of atoms was firmly established in the early 20th century.

Meanwhile, the new physics of energy transformed the analysis of electromagnetic phenomena, particularly through the introduction of the concept of the field and the publication of Maxwell's 1873 *Treatise on Electricity and Magnetism*, which also drew upon theoretical work by German theoreticians such as Carl Friedrich Gauss and Wilhelm Weber. The encapsulation of heat in particulate motion, and the addition of electromagnetic forces to Newtonian dynamics established an enormously robust theoretical underpinning to physical observations. The prediction that light represented a transmission of energy in wave form through a "luminiferous ether", and the seeming confirmation of that prediction with Helmholtz student Heinrich Hertz's 1888 detection of electromagnetic radiation, was a major triumph for physical theory and raised the possibility that even more fundamental theories based on the field could soon be developed. Research on the transmission of electromagnetic waves began soon after, with the experiments conducted by physicists such as Nikola Tesla, Jagadish Chandra Bose and Guglielmo Marconi during the 1890s leading to the invention of radio [10, http://en.wikipedia.org/wiki/History_of_physics].

Main steps of the physical science and mechanics development in the second half of the 19th century:

1. The new study of energy throws the deterministically mechanistic view of the universe into question.
2. A new mathematical physics relating to the exchange of different forms of energy and energy's overall conservation is introduced.
3. The second law of thermodynamics and other interpretations appeare.
4. The new physics of energy transformed the analysis of electromagnetic phenomena.
5. The prediction that light represents a transmission of energy in wave form and some other scientific events raise the possibility that even more fundamental theories based on the field could be developed.

6. After the publication of Maxwell’s 1873 *Treatise on Electricity and Magnetism* a new self-propelled vehicle is built.

7. The research on the transmission of electromagnetic waves during the 1890s leads to the invention of radio.

1.11.2 Look through the text and find the English equivalents for the following Russian phrases and word-combinations:

детерминистически механистическое понимание; полностью обратимые законы; полное сохранение энергии; работа, посвященная тепловому потоку; единица измерения скорости частиц; устанвливая статистическую вероятность; чрезвычайно прочное теоретическое обоснование; передача электоромагнитных волн.

1.12 Revision texts 1.9 - 1.11

1.12.1 Match words and word-combinations with their translation:

calorimeter	электромагнитная индукция
application	флогистон
Voltaic Pile	аналитическая аппроксимация (округление, приближение)
rational mechanics	течение, поток
weightless	термодинамика
Leyden Jar	определение природы света, как состоящего из частиц
magnetism	калориметр
fluid dynamics	сложные вычисления
entropy	статическое электричество
to elaborate upon	применение
chemical affiliation	трактовка

oxygen	призма
analytical approximation	исходная формулировка
phlogiston	гидродинамика
flow	лейденская банка
electromagnetic induction	взаимозаменяемость
thermodynamics	полное сохранение энергии
positive charge	химия
prism	невесомый
latent heat	рациональная механика
complex calculations	отрицательный заряд
particulate interpretation of light	кислород
aluminiferous ether	избыток, излишек
spectrum of color	физиология
interchangeability	гальваническая батарея
initial formulation	светоносный, люминесцентный эфир
negative charge	химическое присоединение
tractability	скрытая, латентная теплота
chemistry	энтропия
chemical substance	детально разрабатывать, обдумывать
dissipation of energy	положительный заряд
static electricity	спектр цвета
physiology	рассеивание энергии
excess	химическое вещество
energy overall conservation	магнетизм

1.12.2 Find the sentences with these words and word-combinations in texts 1.9 - 1.11 and translate them.

1.12.3 Prepare the words and word-combinations for a dictation.

1.13 Text The Emergence of a New Physics circa 1900

1.13.1 Read the text, translate it and answer the questions: What important discovery was made before the beginning of the 20th century? On what property of matter was physical research focused in 30s of the 20th century? Who introduced the term "radioactivity"? What theories did Albert Einstein and other physicists introduce?

Figure 9 - Marie Sklodowska Curie (1867-1934)

The triumph of Maxwell's theories was undermined by inadequacies that had already begun to appear. The Michelson-Morley experiment failed to detect a shift in the speed of light, which would have been expected as the earth moved at different angles with respect to the ether. The possibility explored by Hendrik Lorentz, that the ether could compress matter, thereby rendering it undetectable, presented problems of its own as a compressed electron (detected in 1897 by British experimentalist J. J. Thomson) would prove unstable. Meanwhile, other experimenters began to detect unexpected forms of radiation: Wilhelm Röntgen caused a sensation with his discovery of x-rays in 1895; in 1896 Henri Becquerel discovered that certain kinds of matter emit radiation on their own account. Marie and Pierre Curie coined the term "radioactivity" to describe this property of matter, and isolated the radioactive elements radium and polonium.

Ernest Rutherford and Frederick Soddy identified two of Becquerel's forms of radiation with electrons and the element helium. In 1911 Rutherford established that the bulk of mass in atoms are concentrated in positively-charged nuclei with orbiting electrons, which was a theoretically unstable configuration. Studies of radiation and radioactive decay continued to be a preeminent focus for physical and chemical research through the 1930s, when the discovery of nuclear fission opened the way to the practical exploitation of what came to be called "atomic" energy.

Figure 10 - Albert Einstein (1879-1955)

Radical new physical theories also began to emerge in this same period. In 1905 Albert Einstein, then a Bern patent clerk, argued that the speed of light was a constant in all inertial reference frames and that electromagnetic laws should remain valid independent of reference frame—assertions which rendered the ether "superfluous" to physical theory, and that held that observations of time and length varied relative to how the observer was moving with respect to the object being measured (what came to be called the "special theory of relativity"). It also followed that mass and energy were interchangeable quantities according to the equation $E=mc^2$. In another paper published the same year, Einstein asserted that electromagnetic radiation was transmitted in discrete quantities ("quanta"), according to a constant that the theoretical physicist Max Planck had posited in 1900 to arrive at an accurate theory for the distribution of blackbody radiation—an assumption that explained the strange properties of the photoelectric effect. The Danish physicist Niels Bohr used this same constant in 1913 to explain the stability of Rutherford's atom as well as the frequencies of light emitted by hydrogen gas [10, http://en.wikipedia.org/wiki/History_of_physics].

1.13.2 Match Russian word-combinations with their English variants:

открытие рентгеновских лучей	arrive at an accurate theory
ядерное деление	speed of light
дискретная величина	reference frame
прийти к точной теории	with respect to
система отсчета	discovery of x-rays
скорость света	nuclear fission
по отношению к	discrete quantity

1.14 Text The Radical Years: General Relativity and Quantum Mechanics

1.14.1 Read the text, translate it and name the main steps of the mechanics development in the first half of the 20th century.

The gradual acceptance of Einstein's theories of relativity and the quantized nature of light transmission, and of Niels Bohr's model of the atom created as many problems as they solved, leading to a full-scale effort to reestablish physics on new fundamental principles. Expanding relativity to cases of accelerating reference frames (the "general theory of relativity") in the 1910s, Einstein posited an equivalence between the inertial force of acceleration and the force of gravity, leading to the conclusion that space is curved and finite in size, and the prediction of such phenomena as gravitational lensing and the distortion of time in gravitational fields.

Figure 11 - Niels Bohr (1885-1962)

The quantized theory of the atom gave way to a full-scale quantum mechanics in the 1920s. The quantum theory (which previously relied in the "correspondence" at large scales between the quantized world of the atom and the continuities of the "classical" world) was accepted when the Compton Effect established that light carries momentum and can scatter off particles, and when Louis de Broglie asserted that matter can be seen as behaving as a wave in much the same way as electromagnetic waves behave like particles (wave-particle duality). New principles of a "quantum" rather than a "classical" mechanics, formulated in matrix form by Werner Heisenberg, Max Born, and Pascual Jordan in 1925, were based on the probabilistic relationship between discrete "states" and denied the possibility of causality. Erwin Schrödinger established an equivalent theory based on waves in 1926; but Heisenberg's 1927 "uncertainty principle" (indicating the impossibility of precisely and simultaneously measuring position and momentum) and the "Copenhagen interpretation" of quantum mechanics (named after Bohr's home city) continued to deny the possibility of fundamental causality, though opponents such as Einstein would assert that "God does not play dice with the universe". Also in the 1920s, Satyendra Nath Bose's work on photons and quantum mechanics provided the foundation for Bose-Einstein statistics, the theory of the Bose-Einstein condensate, and the discovery of the boson [10, http://en.wikipedia.org/wiki/History_of_physics].

1.15 Revision texts 1.13 - 1.1

1.15.1 Match words and word-combinations with their translation:

unstable configuration	наблюдатель, эксперт
radioactivity	угол
quantum theory	фотоэлектронная эмиссия (эффект активно-электрический)
assertion	гравитационная фокусировка
interchangeable quantities	избыточный, излишний
to scatter off particles	распад, разложение
to measure	ядерное деление
theory of relativity	искажение времени
matrix form	двойственность, дуализм
angle	явления
gravitational lensing	радиоактивность
to deny	измерять, мерить
photoelectric effect	излучение черного тела
superfluous	утверждение
boson	теория относительности
hydrogen gas	неустойчивая (нестабильная) конфигурация
to emerge	причинная связь, обусловленность
inertial force	отрицать, отвергать
nuclear fission	рассеивать частицы
distortion of time	сжатый электрон
decay	квантовая теория
light transmission	испускать излучение
phenomena	матричная форма (уравнения)
observer	взаимозаменяемые

	(взаимозаместимые) величины
duality	возникать, появляться
compressed electron	икс-лучи, рентгеновские лучи
x-rays	бозон, бозе-частица
blackbody radiation	газ водорода
causality	передача (пропускание) света
emit radiation	инерционная сила, сила инерции

1.15.2 Find the sentences with these words and word-combinations in texts 1.13 - 1.14 and translate them.

1.15.3 Prepare the words and word-combinations for a dictation.

1.16 Text Constructing a New Fundamental Physics

1.16.1 Read the text, translate it and write one sentence with the main idea for every of six paragraphs.

1. As the philosophically inclined continued to debate the fundamental nature of the universe, quantum theories continued to be produced, beginning with Paul Dirac's formulation of a relativistic quantum theory in 1927.

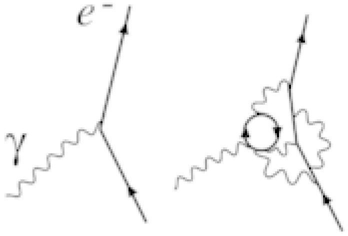


Figure 12 - A "Feynman diagram" of a renormalized vertex in quantum electrodynamics.

However, attempts to quantize electromagnetic theory entirely were stymied throughout the 1930s by theoretical formulations yielding infinite energies. This situation was not considered adequately resolved until after World War II ended, when Julian Schwinger, Richard Feynman, and Sin-Itiro Tomonaga independently posited the technique of "renormalization", which allowed for an establishment of a robust quantum electrodynamics (Q.E.D.).

2. Meanwhile, new theories of fundamental particles proliferated with the rise of the idea of the quantization of fields through "exchange forces" regulated by an exchange of short-lived "virtual" particles, which were allowed to exist according to the laws governing the uncertainties inherent in the quantum world. Notably, Hideki Yukawa proposed that the positive charges of the nucleus were kept together courtesy of a powerful but short-range force mediated by a particle intermediate in mass between the size of an electron and a proton. This particle, called the "pion", was identified in 1947, but it was part of a slew of particle discoveries beginning with the neutron, the "positron" (a positively-charged "antimatter" version of the electron), and the "muon" (a heavier relative to the electron) in the 1930s, and continuing after the war with a wide variety of other particles detected in various kinds of apparatus: cloud chambers, nuclear emulsions, bubble chambers, and coincidence counters. At first these particles were found primarily by the ionized trails left by cosmic rays, but were increasingly produced in newer and more powerful particle accelerators.

3. Thousands of particles explode from the collision point of two relativistic (100 GeV per ion) gold ions in the STAR detector of the Relativistic Heavy Ion Collider; an experiment done in order to investigate the properties of a quark gluon plasma such as the one thought to exist in the ultrahot first few microseconds after the big bang.

4. The interaction of these particles by "scattering" and "decay" provided a key to new fundamental quantum theories. Murray Gell-Mann and Yuval Ne'eman brought some order to these new particles by classifying them according to certain qualities, beginning with what Gell-Mann referred to as the "Eightfold Way", but proceeding into several different "octets" and "decuplets" which could predict new

particles, most famously the Ω^-, which was detected at Brookhaven National Laboratory in 1964, and which gave rise to the "quark" model of hadron composition.

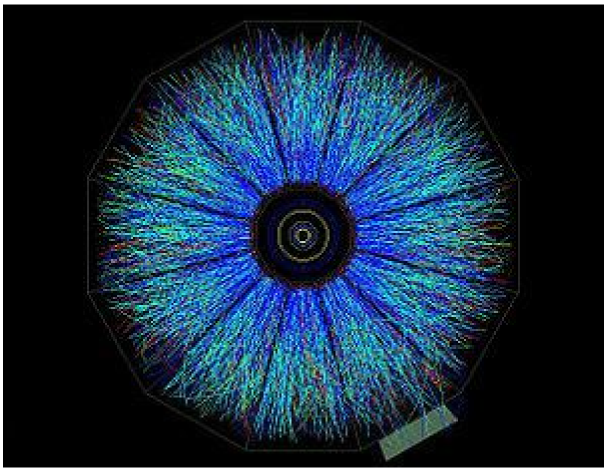


Figure 13 - Theories of fundamental particles

While the quark model at first seemed inadequate to describe strong nuclear forces, allowing the temporary rise of competing theories such as the S-Matrix, the establishment of quantum chromodynamics in the 1970s finalized a set of fundamental and exchange particles, which allowed for the establishment of a "standard model" based on the mathematics of gauge invariance, which successfully described all forces except for gravity, and which remains generally accepted within the domain to which it is designed to be applied.

5. The "standard model" groups the electroweak interaction theory and quantum chromodynamics into a structure denoted by the gauge group $SU(3)\times SU(2)\times U(1)$. The formulation of the unification of the electromagnetic and weak interactions in the standard model is due to Abdus Salam, Steven Weinberg and, subsequently, Sheldon Glashow. After the discovery, made at CERN, of the existence of neutral weak currents, mediated by the Z boson foreseen in the standard model, the physicists Salam, Glashow and Weinberg received the 1979 Nobel Prize in Physics for their electroweak theory.

6. While accelerators have confirmed most aspects of the standard model by detecting expected particle interactions at various collision energies, no theory

reconciling the general theory of relativity with the standard model has yet been found, although “string theory” has provided one promising avenue forward. Since the 1970s, fundamental particle physics has provided insights into early universe cosmology, particularly the “big bang” theory proposed as a consequence of Einstein’s general theory. However, starting from the 1990s, astronomical observations have also provided new challenges, such as the need for new explanations of galactic stability (the problem of dark matter), and accelerating expansion of the universe (the problem of dark energy) [10, http://en.wikipedia.org/wiki/History_of_physics].

1.17 Text Modern Physics and Physical Sciences

1.17.1 Read the text, translate it and answer the questions: What does the term *Modern physics* mean? With what scientific fields is physics allied nowadays?

With increased accessibility to and elaboration upon advanced analytical techniques in the 19th century, physics was defined as much, if not more, by those techniques than by the search for universal principles of motion and energy, and the fundamental nature of matter. Fields such as acoustics, geophysics, astrophysics, aerodynamics, plasma physics, low-temperature physics, and solid-state physics joined optics, fluid dynamics, electromagnetism, and mechanics as areas of physical research. In the 20th century, physics also became closely allied with such fields as electrical, aerospace, and materials engineering, and physicists began to work in government and industrial laboratories as much as in academic settings. Following World War II, the population of physicists increased dramatically, and came to be centered on the United States, while, in more recent decades, physics has become a more international pursuit than at any time in its previous history.

The term "modern physics" refers to the post-Newtonian conception of physics. The term implies that classical descriptions of phenomena are lacking, and that an accurate, "modern", description of reality requires theories to incorporate elements of quantum mechanics or Einsteinian relativity, or both. In general, the term is used to refer to any branch of physics either developed in the early 20th century and onwards, or branches greatly influenced by early 20th century physics.

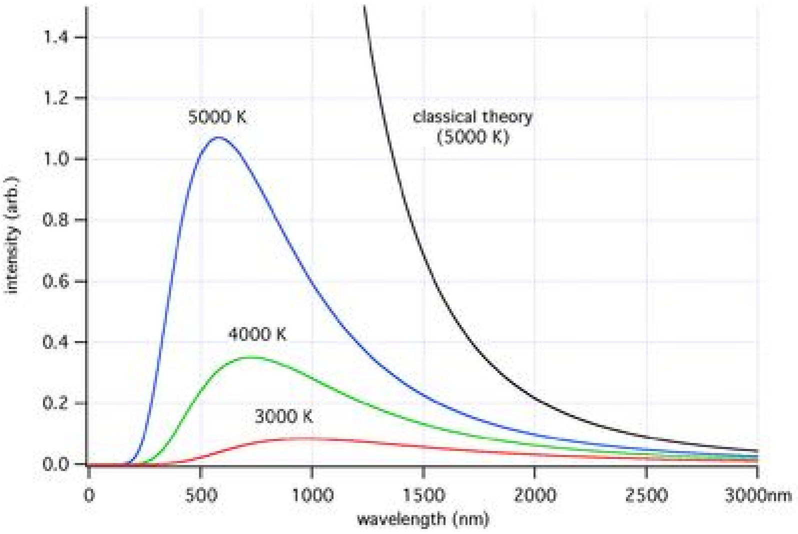


Figure 14 - Classical physics failed to explain black body radiation. The quantum description is said to be *modern physics*

The term "modern physics", taken literally, means of course, the sum total of knowledge under the head of present-day physics. In this sense, the physics of 1890 is still modern; very few statements made in a good physics text of 1890 would need to be deleted today as untrue. The principle changes required would be in a few generalizations, perhaps, to which exceptions have since been discovered, and in certain speculative theories, such as that concerning the ether, which any good physicist of 1890 would have recognized to be open to possible doubt.

On the other hand, since 1890, there have been enormous advances in physics, and some of these advances have brought into question, or have directly contradicted, certain theories that had seemed to be strongly supported by the experimental evidence.

For example, few, if any physicists in 1890 questioned the wave theory of light. Its triumphs over the old corpuscular theory seemed to be final and complete, particularly after the brilliant experiments of Hertz, in 1887, which demonstrated, beyond doubt, the fundamental soundness of Maxwell's electromagnetic theory of light. And yet, by an irony of fate which makes the story of modern physics full of the most interesting and dramatic situations, these very experiments of Hertz brought to light a new phenomenon—the photoelectric effect—which played an important part in establishing the quantum theory. The latter theory, in many of its aspects, is diametrically opposite to the wave theory of light; indeed, the reconciliation of these two theories, each based on incontrovertible evidence, was one of the great problems of the first quarter of the twentieth century [10, http://en.wikipedia.org/wiki/History_of_physics].

1.18 Revision texts 1.16 - 1.17

1.18.1 Match words and word-combinations with their translation:

virtual particle	слабое электронное взаимодействие
solid-state physics	калибровочная инвариантность
exist	физика низких температур
particle accelerator	изображать, описывать
unification	мюон, мюонный
dark energy	хромодинамика (теория взаимодействий кварков)
collision point	прямо противоположно, диаметрально противоположный
gluon	конденсационная камера
short-lived particle	темная энергия

to describe	состав адрона
electroweak interaction	объединение, придание единообразия, унификация
muon	сила с малым радиусом действия
gauge invariance	нейтрон, нейтронный
coincidence counter	короткоживущая частица
chromodynamics	глюон (переносчик взаимодействия между кварками)
pion	позитрон
ionized trail	пузырьковая камера
diametrically opposite	космические лучи
positron	пион
hadron composition	ускоритель частиц
cosmic rays	точка столкновения (частиц)
cloud chamber	виртуальная частица
short-range force	счетчик совпадений
bubble chamber	существовать, иметься в природе
neutron	ионизированный след, “дорожка”
low-temperature physics	физика твердого тела

1.18.2 Find the sentences with these words and word-combinations in texts 1.16 - 1.17 and translate them.

1.18.3 Prepare the words and word-combinations for a dictation.

1.19 Consolidation

1.19.1 Read the following physical notions and try to remember when and by whom they were introduced:

laws of motion, theory of relativity, inertia, law of gravitation, experimental physics, rational mechanics, electromagnetic induction, radioactivity, wave nature of light transmission, thermodynamics, entropy, x-rays, quantized nature of light transmission.

1.19.2 Read three texts in Russian, choose one of them and translate from Russian into English.

Галилео Галилей. Галилей по праву считается основателем не только экспериментальной, но — в значительной мере — и теоретической физики. В своём научном методе он сочетал эксперимент с его рациональным осмыслением и обобщением, и лично дал впечатляющие примеры таких исследований. Иногда из-за недостатка научных данных Галилей ошибался, но в подавляющем большинстве случаев его метод приводил к цели.

До Галилея научные методы мало отличались от теологических и ответы на научные вопросы по-прежнему искали в книгах древних авторитетов. Научная революция в физике началась с Галилея.

В отношении философии природы Галилей был убеждённым рационалистом. Он считал, что законы природы постижимы для человеческого разума.

Галилей считается одним из основателей механицизма.

Для проектирования эксперимента в качестве основы теоретической модели Галилей считал математику, выводы которой он рассматривал как самое достоверное знание: книга природы написана на языке математики.

Опыт Галилей рассматривал не как простое наблюдение, а как осмысленный и продуманный вопрос, заданный природе. Полученный же от природы ответ должен подвергнуться анализу.

Галилей изучал инерцию и свободное падение тел. В частности, он заметил, что ускорение свободного падения не зависит от веса тела, таким образом, опровергнув первое утверждение Аристотеля.

В своей последней книге Галилей сформулировал правильные законы падения.

Галилей опроверг и второй из приведённых законов Аристотеля, сформулировав первый закон механики (закон инерции): при отсутствии внешних сил тело либо покоится, либо равномерно движется. Само понятие “движение по инерции” впервые введено Галилеем, и первый закон механики по справедливости носит его имя.

Галилей является одним из основоположников принципа относительности в классической механике, который также был позже назван в его честь.

Эти открытия Галилея, кроме всего прочего, позволили ему опровергнуть многие доводы противников гелиоцентрической системы мира, утверждавших, что вращение Земли заметно сказалось бы на явлениях, происходящих на её поверхности.

Галилей опубликовал исследование колебаний маятника.

Многие рассуждения Галилея представляют собой наброски физических законов, открытых намного позднее.

В статике Галилей ввёл фундаментальное понятие момента силы.

В 1609 году Галилей самостоятельно построил свой первый телескоп с выпуклым объективом и вогнутым окуляром.

Первые телескопические наблюдения небесных тел Галилей провёл 7 января 1610 года. Галилей опроверг один из доводов противников гелиоцентризма: Земля не может вращаться вокруг Солнца, поскольку вокруг неё самой вращается Луна.

Галилей открыл также солнечные пятна и сделал еще много открытий для развития астрономии.

Галилей изобрёл гидростатические весы для определения удельного веса твёрдых тел, первый термометр, ещё без шкалы, пропорциональный циркуль, используемый в чертёжном деле, микроскоп, с его помощью Галилей изучал насекомых.

Ученый разработал теорию множеств, занимался также оптикой, акустикой, теорией цвета и магнетизма, гидростатикой, сопротивлением материалов, проблемами фортификации. Провёл эксперимент по измерению скорости света и первым опытным путём измерил плотность воздуха ближе к истинному значению [10, http://en.wikipedia.org/wiki/Galileo_Galilei].

Vocabulary notes:

теологический – theological;
убеждённый рационалист - staunch rationalist;
первое утверждение - first statement;
выпуклый объектив - convex objective;
вогнутый окуляр - concave ocular;
гелиоцентризм - heliocentrism.

Майкл Фа́радей — английский физик, химик, основоположник учения об электромагнитном поле, член Лондонского королевского общества (1824).

Майкл родился 22 сентября 1791 года в семье кузнеца из лондонского предместья.

Скромные доходы семьи не позволили Майклу окончить даже среднюю школу, с тринадцати лет он начал работать как поставщик книг и газет, а затем в возрасте 14 лет пошёл работать в книжную лавку, где обучался и переплётному ремеслу. Семь лет работы в мастерской стали для юноши и годами напряженного самообразования. Он с упоением читал все переплетаемые им научные труды по физике и химии, а также статьи из “Британской энциклопедии”, повторял в устроенной им домашней лаборатории эксперименты, описанные в книгах, на самодельных электростатических приборах. Важным этапом в жизни Фарадея стали занятия в Городском философском обществе, где Майкл по вечерам слушал научно-популярные лекции по физике и астрономии и участвовал в диспутах.

В 1813 знаменитый физик и химик, первооткрыватель многих химических элементов Дэви пригласил Фарадея на место лаборанта в химической лаборатории Королевского института, где тот проработал много лет.

В 1816 Фарадей начал читать публичный курс лекций по физике и химии в Обществе для самообразования. В этом же году появляется и его первая печатная работа. В 1820 Фарадей провёл несколько опытов по выплавке сталей, содержащих никель. Эта работа считается открытием нержавеющей стали, которое не заинтересовало в то время металлургов. В 1821 он опубликовал две значительные научные работы (о вращениях тока вокруг магнита и магнита вокруг тока и о сжижении хлора).

В период до 1821 Фарадей опубликовал около 40 научных работ, главным образом по химии. В 1824 ему первому удалось получить хлор в жидком состоянии, а в 1825 г он впервые синтезирует гексахлоран — вещество, на основе которого в XX веке изготовлялись различные инсектициды.

Постепенно его экспериментальные исследования всё более переключались в область электромагнетизма. После открытия в 1820 Х.Эрстедом магнитного действия электрического тока Фарадея увлекла проблема связи между электричеством и магнетизмом.

Фарадей экспериментально открыл явление электромагнитной индукции — возникновение электрического тока в проводнике, движущемся в магнитном поле. Фарадей также дал математическое описание этого явления, лежащего в основе современного электромашиностроения.

В 1832 г. Фарадей открывает электрохимические законы, которые ложатся в основу нового раздела науки — электрохимии.

Майкл Фарадей был верующим христианином и продолжал верить даже после того, как узнал о работах Дарвина [10, http://en.wikipedia.org/wiki/Michael_Faraday].

Vocabulary notes:

переплётное ремесло – bookbinding;
гексахлоран - hexachloran;
инсектицид - insecticide;
электрохимия – electrochemistry;
верующий христианин - Faithful Christian.

Мария Склодовская-Кюри — известный физик и химик польского происхождения. Она была дважды лауреатом Нобелевской премии по физике и химии. Кюри основала институты в Париже и в Варшаве, вместе с мужем занималась исследованием радиоактивности и открыла элементы радий и полоний.

Мария Склодовская стала первой в истории Сорбонны женщиной-преподавателем. В Сорбонне она встретила Пьера Кюри, также преподавателя, за которого позже вышла замуж. Вместе они занялись исследованием аномальных лучей (рентгеновских), которые испускали соли урана.

В 1910 г. ей удалось выделить чистый металлический радий. Таким образом, было доказано, что радий является самостоятельным химическим элементом.

В конце 1910 г. кандидатура Склодовской-Кюри по настоянию ряда французских ученых была выдвинута на выборах во Французскую Академию Наук, но в результате жестокой полемики между сторонниками и противниками, её кандидатура была отвергнута на выборах только потому, что она была женщиной.

Незадолго до начала Первой мировой войны Парижский университет и Пастеровский институт учредили Радиевый институт для исследований радиоактивности. Склодовская-Кюри была назначена директором отделения фундаментальных исследований и медицинского применения радиоактивности. Сразу после начала активных боевых действий на фронтах Первой мировой войны Мария Склодовская Кюри принялась закупать на личные средства, оставшиеся от Нобелевской премии, рентгеновские переносные аппараты для просвечивания раненых. Во время войны она обучала военных медиков применению радиологии, например, обнаружению с помощью рентгеновских лучей шрапнели в теле раненого.

В последние годы своей жизни она продолжала преподавать в Радиевом институте, где руководила работами студентов и активно способствовала применению радиологии в медицине. Она написала биографию Пьера Кюри, которая была опубликована в 1923 г.

Вследствие многолетней работы Кюри с радием ее здоровье стало заметно ухудшаться.

Мария Склодовская-Кюри скончалась в 1934 г. от лейкемии. Смерть её является трагическим уроком — работая с радиоактивными веществами, она не предпринимала никаких мер предосторожности и даже носила на груди ампулу с радием как талисман.

Помимо двух Нобелевских премий, Склодовская-Кюри была удостоена тремя медалями. Она была членом 85 научных обществ всего мира, получила 20 почетных степеней [10, http://en.wikipedia.org/wiki/Marie_Sklodowska_Curie].

Vocabulary notes:

Мария Склодовская-Кюри — Marie Skłodowska Curie;
радий – radium;
полоний – polonium;
Сорбонна – The Sorbonne (La Sorbonne);
Парижский университет - The University of Paris;
Пастеровский институт - The Pasteur Institute;
шрапнель - shrapnel;
лейкемия – leucaemia;
талисман – talisman

1.19.3 Play a game who will be the first to guess your secret person. Choose one famous figure in physics, write about him/her according to the plan below (don't name him or her!), and read to your partner, then listen to his/her reading. You should try to guess your each other's secret persons; you may ask additional questions to each other.

Plan

1. The time, when he/she was born.
2. The field of physics, he/she was interested in.
3. His/her attitude to religion, philosophical conceptions, world outlook and so on.
4. His/her contributions in physics.
5. The result of his/her activity and his/her followers.

1.19.4 Discuss your favourite scientists with your partner. Use the constructions below:

- As for me, the most important figure in physics is…
- To my mind, the greatest discovery was…
- I suppose … (Ibn al-Haytham, Galileo, Descartes, Newton, Einstein, etc.) made a great deal to…
- In my opinion, it was a real break-through to…
- I'm afraid without this figure we wouldn't …
- I believe him/her to be the greatest …(physicist/chemist/engineer, etc.).
- It was not until…then …
- It was … (Ibn al-Haytham, Galileo, Descartes, Newton, Einstein, etc.) who … (invented/introduced, etc.).

1.19.5 Translate the following constructions and word-combinations:

- On the grand scale / on the smallest scale;
- in the sense of empirical procedures;
- to date back;
- regardless of;
- leading up to;
- in terms of;
- with respect to;
- with reference to;
- to become more widespread;
- to throw something into question;
- on someone / something account;
- relative to;
- in order to

1.19.6 Look for examples with them in texts 1.1 – 1.17.

1.19.7 Make your own sentences with these constructions and word-combinations.

1.19.8 Look through all the texts of Section I and prepare the presentation of your report on The Important Figures in the History of Physics (use a projector in the multimedia class). You may use Internet to add some information.

2 Section II Physics

2.1 Texts Elements of Physics

2.1.1 Read the Introduction into the course of physics, answer the questions: What is physics as a science? What aspects does it include?

What is Physics. — Physics is a broad science that deals primarily with phenomena involving the transformation of matter and energy. Its object is to determine exact relations between physical phenomena so that the sequence of events can be clearly understood and definitely predicted. The boundaries between physics and chemistry are not very definite. Sharp distinctions between these sciences are inaccurate and unnecessary. There are certain aspects of nature, however, that are primarily the legitimate field of physics. For convenience, they may be grouped under seven headings: mechanics, sound, heat, electricity and magnetism, light and spectroscopy, atomic and nuclear physics and astrophysics. In addition to these seven fields of physics, another field known as biophysics is rapidly developing. These different fields are not distinct but merge into each other. In all cases physics deals primarily with phenomena that can be accurately described in terms of matter and energy. Hence, the basic concepts in all physical phenomena are the concepts of matter and energy. It becomes of first importance in physics therefore, to determine accurately the characteristics of both matter and energy, the laws that govern their transformations, and the fundamental relations that exist between them [2, C.39].

2.1.2 Read the text Measurements and Units and explain: What are derived units? and What is radian?

Measurements and Units

Systems of Units. — Some measurements are fundamental and seem to refer to concepts that cannot be further analyzed. There are three of these basic concepts:

time, space, and mass. The units used to measure them are called fundamental units. There are other magnitudes that cannot be thought of without connecting them with two or more of these fundamental units more than once. Units of this kind that involve more than one fundamental unit, or one fundamental unit more than once, are called derived units. Units of speed, units of volume, units of area, units of acceleration, etc., are derived units.

Units of Time.—For many scientific purposes the second is chosen as the unit of time. It is defined as the 1/86,400 part of the mean solar day. The *minute*, which is equivalent to 60 sec, and the hour, which is equal to 60 min, are also used as units of time.

Measurement of Angles.—Degrees, minutes, and seconds are the familiar units in which angles are measured. A degree is the angle subtended at the center of a circle by an arc equal to one three hundred sixtieth part of the circumference of the circle. A minute is one sixtieth of a degree and a second is one sixtieth of a minute. There are, therefore, 360 deg in a circle, 60 min in a degree, and 60 sec in a minute.

The angular unit ordinarily used in physics is called a radian.

The two systems of units commonly employed are the decimal metric system devised by the French and the more familiar English system [2, C. 39-40].

2.1.3 Look through texts 2.1.1 - 2.1.2 and find the English equivalents for the following Russian phrases and word-combinations:

истинная область изучения физики; взаимопроникающие области; производные единицы; единицы ускорения; обычно применяемые единицы; десятичная метрическая система.

2.1.4 Look through the text in Russian and retell it in English.

Физика (от др.-греч. природа) — это область естествознания, наука, изучающая наиболее общие и фундаментальные закономерности, определяющие структуру и эволюцию материального мира. Законы физики лежат в основе всего естествознания.

Термин “физика” впервые появился в сочинениях одного из величайших мыслителей древности — Аристотеля, жившего в IV веке до нашей эры. Первоначально термины “физика” и “философия” были синонимичны, поскольку обе дисциплины пытаются объяснить законы функционирования Вселенной. Однако в результате научной революции XVI века физика выделилась в отдельное научное направление.

В русский язык слово “физика” было введено Михаилом Васильевичем Ломоносовым, когда он издал первый в России учебник физики в переводе с немецкого языка. Первый отечественный учебник под названием “Краткое начертание физики” был написан первым русским академиком Страховым.

В современном мире значение физики чрезвычайно велико. Всё то, чем отличается современное общество от общества прошлых веков, появилось в результате применения на практике физических открытий. Так, исследования в области электромагнетизма привели к появлению телефонов, открытия в термодинамике позволили создать автомобиль, развитие электроники привело к появлению компьютеров.

Физическое понимание процессов, происходящих в природе, постоянно развивается. Большинство новых открытий вскоре получают применение в технике и промышленности. Однако новые исследования постоянно поднимают новые загадки и обнаруживают явления, для объяснения которых требуются новые физические теории. Несмотря на огромный объём накопленных знаний, современная физика ещё очень далека от того, чтобы объяснить все явления природы.

Общенаучные основы физических методов разрабатываются в теории познания и методологии науки.

Физика — это наука о природе в самом общем смысле. Она изучает вещество (материю) и энергию, а также фундаментальные взаимодействия природы, управляющие движением материи.

Некоторые закономерности являются общими для всех материальных систем, например, сохранение энергии, — называют физическими законами. Физику иногда называют “фундаментальной наукой”, поскольку другие естественные науки (биология, геология, химия и др.) описывают только некоторый класс материальных систем, подчиняющихся законам физики.

Например, химия изучает атомы, образованные из них вещества и превращения одного вещества в другое. Химические же свойства вещества однозначно определяются физическими свойствами атомов и молекул, описываемыми в таких разделах физики, как термодинамика, электромагнетизм и квантовая физика.

Физика тесно связана с математикой: математика предоставляет аппарат, с помощью которого физические законы могут быть точно сформулированы. Физические теории почти всегда формулируются в виде математических выражений, причём используются более сложные разделы математики, чем обычно в других науках. И наоборот, развитие многих областей математики стимулировалось потребностями физических теорий.

Хотя физика имеет дело с разнообразными системами, некоторые физические теории применимы в больших областях физики. Такие теории считаются в целом верными при дополнительных ограничениях. Например, классическая механика верна, если размеры исследуемых объектов намного больше размеров атомов, скорости существенно меньше скорости света, и гравитационные силы малы. Эти теории всё ещё активно исследуются; например, такой аспект классической механики, как теория хаоса был открыт только в XX веке. Они составляют основу для всех физических исследований [10, http://en.wikipedia.org/wiki/Physics].

2.2 Texts Measurements and Weights

2.2.1 Read the texts and explain what the difference is between the British Imperial System and the U.S. one.

The British Imperial System

The British system of weights and measures has evolved from units having many origins, many of the units having been introduced into Britain at the time of the Roman conquest.

The basic units of the British imperial system are the Yard, the Pound, and the Gallon.

The British imperial yard is defined (Weights and Measures Act, 1878) as the distance, at 62.00°F., between two fine lines engraved on gold studs sunk in a specified bronze bar known as "№ 1 standard yard." This bar was cast in 1845.

The British imperial pound is defined as the mass (the weight in vacuo) of a cylinder of pure platinum about 1.35 in. high and 1.15 in. diameter. This is the only pound legal for use in Great Britain and is sometimes called the avoirdupois pound.

The British imperial gallon is the volume of 10 lb. avoirdupois of pure water as weighed in air against brass weights, the temperature of the air and the water being 62 °F., and the barometric pressure 30 in. of mercury. This legal definition is incomplete; for instance it does not state the density of the brass weights, but in official comparisons this density is taken as 8.143 g. per cm".

The multiples and submultiples of the British yard are similar to the corresponding units of the U.S. customary system. It is subdivided into 3 feet of 12 inches each. Five and a half yards (16 1/2 ft.) make a rod, pole, or perch. 40 rods make a furlong; and 8 furlongs (5,280 ft.) make a statute mile. Units of area and volume are simply the squares and cubes, respectively, of the units of length, except for the insertion of the acre which consists of 43,560 square feet.

The British pound is subdivided into16 ounces, or 256 drams, or 7,000 grains. Fourteen pounds equal 1 stone, 2 stones = 1 quarter (28 pounds), 8 stones =1 hundredweight (cwt) = 112 pounds, and 20 hundredweight = 1 ton = 2,240 pounds. This ton (i. e. of 2,240 pounds) is called gross ton or long ton to distinguish it from the net ton or short ton which is equal to 2,000 pounds.

The British gallon, as defined above, is by calculation equivalent to 277.42 cubic inches. It is used as a unit of capacity, both liquid and dry.

The British gallon is divided into 4 quarts, or 8 pints, or 32 gills, or 160 fluid ounces (the U.S. gallon being divided into 128 fluid ounces, the result is that the British fluid ounce is smaller than the U.S. fluid ounce, whereas the other British units of capacity are larger than the corresponding U.S. units). Two gallons make a peck, 8 gallons make a bushel, and 8 bushels make a quarter.

The U.S. Customary System

The weights and measures in common use in the American colonies at the time of the American Revolution were all of English origin and were the same as those then used in Great Britain.

The following units are still in use in the United States: (a) the yard of 35 inches, (b) the avoirdupois pound of 7,000 grains, (c) the gallon of 231 cubic inches, and (d) the winchester bushel (or simply bushel) of 2,150.42 cubic inches.

In 1893, after receipt of the metric standards, it was decided that a more stable basis for the system of customary weights and measures in the United States would be obtained by defining the yard in terms of the metre and the pound in terms of the kilogram using the U.S. prototype metre and the U.S. prototype kilogram, respectively, with their certified corrections as the primary standards of length and mass in this country. This is the present basis of the units.

The U.S. yard is defined as 3.600/3.937 metre and the U.S. pound as 0.4535924277 kilogram.

For industrial purposes, in the conversion of inches to millimetres and millimetres to inches, a relation between the inch and the millimetre has been adopted by the American Standard Association (1933) and by similar organizations in other countries.

This relation is

1 inch = 25.4 millimetres (exactly)

whereas the relation 1 U.S. yard = 3.600/3.937 = metre gives

1 inch = 25.4000508 millimetres.

It is to be noted that although the mass of a body, often defined as the quantity of matter in a body, remains constant everywhere and under all conditions as long as no portion of the body is taken away and no matter added to it, its weight, being a force equal to the product of mass of the body by the acceleration of gravity, varies with the locality in which it is measured [2, C. 40 - 41].

2.2.2 Read the text about the metric system and answer which sentences below it are true and which are false.

The Metric System. The metric system is the international decimal system of weights and measures based on the metre and kilogram.

The metre, the unit of length, is defined in terms of the bar of platinum-indium known as the international prototype metre at the International Bureau.

This is a line standard of length made with a cross section known as the Tresca section, selected because of its great rigidity for a given weight, and having microscopic lines engraved on the plane of its neutral axis.

The composition of the alloy is 90% platinum, 10% iridium. The distance between the central and one of the group of lines at each end when the bar, being subjected to normal atmospheric pressure, is supported on two rollers at least 1 centimetre in diameter placed symmetrically 572 mm. apart and the bar is at temperature of 0 °C. is defined as one metre.

It was shown by Albert Abraham Michelson that a standard of lengths could be replaced by reference to the measurement of wave length of light. In 1927 the Seventh General (International) Conference on Weights and Measures adopted provisionally a supplementary definition of the metre in terms of the wave length of light. According to this definition the relation for red cadmium light waves under specified conditions of temperature, pressure and humidity is 1 metre =

1,553,164.13 wave lengths. The kilogram is the mass of a definite platinum-iridium standard, the international prototype kilogram, kept at the International Bureau of Weights and Measures. The composition of this cylinder, which has a height approximately equal to its diameter, is the same as that of the prototype metre, namely, 90% platinum and 10% iridium.

The litre is defined as the volume of a kilogram of pure water at the temperature of its maximum density and under standard pressure [2, C. 42 - 43].

False or true?

1. The weights and measures of the metric system are based on the metre and kilometer.
2. The platinum-indium alloy consists of 90% platinum and 10% iridium.
3. In the 30s of the 20th century the explanation of the metre with the help of the wave length of light was adopted.
4. One litre may be defined as the volume of a kilogram of any liquid at the temperature of its maximum density and under standard pressure.

2.2.3 Read the text, translate it and choose the right form from brackets.

Effects of Temperature and Pressure and Gravity. Because the dimensions of any standard change with temperature, it is … ***(necessary, necessarily)*** to state the temperature at which standards of length, area, volume, or capacity are to be used, or, if used at any other than standard temperature, then the coefficient of expansion must be stated. The standard temperatures most often used are: 0 °C. (32 °F.), the standard temperature for the prototypes of the metric system, also used for some secondary metric standards and for some measurements; 20 °C. (68 °F.), the internationally adopted standard temperature which is being … ***(increasing, increasingly)*** used for weights and measures work; 16.67 °C. (62 °F.), the official temperature used in connection with the British imperial system; 4 °C. (39.20 °F.), the temperature of maximum density of water, used in density and volumetric work in which water is … ***(direct, directly)*** or … ***(indirect, indirectly)*** involved; 25 °C. (41 °F.), a standard temperature … ***(used, using)*** in some work in physical chemistry; and 15.56 °C. (60 °F.), the standard temperature … ***(used, using)*** in the petroleum industry for density and volume work.

Changes in … ***(atmospheric, atmospherically)*** pressure have very little effect on length standards, a change in pressure from 710 to 790 mm. causing a change in length of about 0.00005 mm. in the case of the prototype metre. Changes in … ***(atmospheric, atmospherically)*** pressure are usually disregarded in measurements of length.

Any change in air pressure, as well as changes in the temperature and humidity of the air is, however, of importance in any comparison of masses because these are factors … ***(affected, affecting)*** the buoyant effect of the air.

Any definitions of weights which involve comparisons of the weights of bodies having different densities are incomplete unless the atmospheric conditions are specified together with the densities of material employed. In the United States most commercial weights are verified on the basis of apparent mass in air against brass standards of density 8.4 g./cm.^{3} at 0 °C., no correction being made for the buoyant effect of the air, the values for the brass standards being their true mass or weight in vacuo.

When weighing on an equal arm balance, if the body being weighed does not have the same density as the weights, a correction must be made.

The standard air pressure usually … ***(used, using)*** in weights and measures work is 760 mm. mercury, at 20 °C., mercury having a specified density of 13.5951 g. per cm.^{3}, with gravity 980.665 cm./sec.^{2}

Since a spring balance indicates weight and not mass, a constant mass suspended from a spring balance will produce different readings when measurements are made in a series of places having sufficient changes in the force of gravity, the indicated weights varying … ***(direct, directly)*** with the force of gravity, other conditions being equal. An equal arm balance likewise really compares weights rather than masses, but on the assumption that the two pans of the balance are acted upon by the same force of gravity, the result is an … ***(indirect, indirectly)*** comparison of masses. If other conditions remained constant, a balance would everywhere give the same balance between the same two bodies, no matter how the force of gravity varied from place to place — provided always as above, the assumption is justified that the force of gravity is the same on the two pans of the balance [2, C. 43 - 44].

2.2.4 Try to explain your choice grammatically.

2.2.5 Read the text and explain what the difference is between the Scalar and Vector Quantities.

Scalar and Vector Quantities

Scalar Quantity. — There are many quantities, such as mass, time, area, volume, etc., that have only magnitude. They do not involve any idea of direction and are completely known when their magnitudes are specified. Such quantities obey the ordinary laws of addition, subtraction, multiplication, and division. A field has an area of 10 acres. To it is added another field containing 3 acres. The combined fields now have an area of 13 acres. A block of wood weighs 8 lb. A piece weighing 3 lb. is cut off. The remainder weighs 5 lb. These are illustrations of the addition and subtraction of scalar quantities. A Scalar quantity is a quantity that has magnitude only.

Vector Quantity. — Quantities such as force, weight, displacement and velocity which have both magnitude and direction are known as vector quantities. They require knowledge of both magnitude and direction for their complete description. They cannot be added, subtracted, multiplied, or divided according to the ordinary methods of arithmetic, but must be added, subtracted, multiplied, or divided vectorially. For example, a force of 8 lb. directed east and a force of 6 lb. directed north are equal to a force of 10 lb. in a direction north of east. A vector quantity is a quantity that has both magnitude and direction.

A vector quantity can be represented by means of a straight line. The length of the line represents the magnitude of the vector. The direction of the line represents the direction of the vector, and an arrowhead on the line shows the sense in which the vector is to be taken. A line 2 in. long pointing directly east may represent a force of 20 lb. acting toward the east.

If a body moves from one position to another, it is said to have had a displacement. For example, a body is moved from position A to position B and then from B to C. It has experienced two displacements, and these two displacements are equivalent to a single displacement from A to C, In each case the length of the line represents the magnitude of the displacement, the direction of the line represents the direction of the displacement, and the arrowhead on the line shows the sense in which the displacement took place. Since displacements have both magnitude and direction, they are vector quantities [2, C. 44 - 45].

2.3 Revision texts 2.1 - 2.2

2.3.1 Match words and word-combinations with their translation:

legitimate	нейтральная ось
multiplication	приближенно равный
avoirdupois pound	погружаться, сливаться, проникать
multiple	десятичная метрическая система
derived unit	точные отношения
circumference	плотность
great rigidity	делить, подразделять
scalar / vector quantity	обоснованный, оправданный
volume	плавучий эффект

humidity	вычитание
mercury	солнечные (астрономические) сутки
density	коэффициент расширения
addition	чистый, беспримесный
magnitude	полный делитель; величина, делящаяся без остатка
assumption	кратное число
fluid ounce	сплав
decimal metric system	окружность
to merge	фунт “эвердьюпойс”, фунт британской системы массы (0,453 кг)
subdivide	законный, истинный, настоящий
submultiple	умножение
Tresca (cross) section	производная единица
buoyant effect	как для жидких веществ, так и нет
solar day	поперечное сечение (сечение Треска)
subtraction	величина
division	ртуть
pure	основание, предположение
alloy	кубический дюйм
coefficient of expansion	деление
exact relations	скалярная / векторная величина
cubic inch	тонкая линия
approximately equal	влажность
justified	огромная ригидность (твердость, упругость)
neutral axis	сложение
both liquid and dry	жидкая унция (мера жидкостей; в Великобритании = 28,4 см3, в США =

	29,57 см3)
fine line	емкость, объем

2.3.2 Find the sentences with these words and word-combinations in texts 2.1 - 2.2 and translate them.

2.3.3 Prepare the words and word-combinations for a dictation.

2.4 Texts Statics

2.4.1 Read and translate the text about Forces, choose one or two main sentences for every of six chapters.

Forces

1. Nature of a Force. — The word force is a general term for any push or pull. A force is always exerted on a body by another body, or on a part of a body by another part. Though a force is really an action of one body on another, it is customary and convenient to speak of the force itself as acting on the body to which it is applied.

A force may act through contact like the pressures of a crankshaft on its bearings, or it may act from a distance like gravitational or magnetic attraction. It may act on or be distributed over a considerable area of contact like the thrust of earth against a retaining wall, or it may act on so small an area as to be practically concentrated at a point like the pressure of a locomotive wheel on a rail.

But whether exerted through contact or from a distance, whether distributed or concentrated, a force is always exerted on something by something.

The gravitational force exerted on a body by the earth acts toward the earth's center; it is a distributed force, acting on all the particles that make up the body, but for many purposes it is convenient and correct to regard it as concentrated force acting at a point called the center of gravity of the body.

The gravitational attraction or earth pull on a body is commonly called the weight of the body.

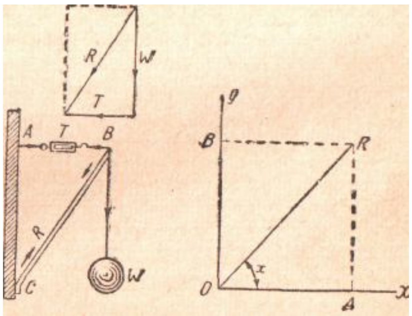
2. Description and Representation of a Force. — Your earliest ideas about forces were based on your own experience with forces exerted by or on yourself. For example, when moving a heavy body you realize that the force you applied had 1) magnitude, according to how hard you pushed or pulled, 2) direction, according to whether you pushed or pulled up, down, to the right, or to the left, 3) place of application, according to where you grasped the body. These three attributes - magnitude, direction, and place of application — serve to describe a force and are called the elements or characteristics of a force.

The line of action of a concentrated force, or a force so considered, is a line of indefinite length, parallel to the direction of the force, and containing its point of application.

In other words it is the line along which the force acts.

3. Composition and Resolution of Forces. — A force is an action exerted by one body on another that tends to change the state of motion of the body acted upon. To specify a force, it is necessary to know its direction, magnitude, and sense. Hence, forces are vector quantities. They must be added, subtracted, multiplied, and divided vectorially. The ordinary arithmetical rules of addition, subtraction, multiplication, and division, which are valid for scalar quantities, cannot be used except in special cases. Forces like other vector quantities can be represented by straight lines. The length of the line represents the magnitude of the force. The direction of the line represents the direction, in which the force acts, and the head of an arrow on the line shows whether the force acts up or down, to the right or to the left, east or west, etc.

4. Resultant. — If a force acts on a body that is free to move, the body moves in the direction of the force. When two forces are applied in opposite directions, the body moves in the direction of the greater force. The force tending to displace the body in this case is the difference between the two forces. When the forces act in the same direction, the effective force is the sum of the two forces. This effective, or equivalent, force is known as the resultant of the forces. In the case of two oppositely directed forces acting at the same point this resultant is found by taking the difference between the applied forces, and its direction is the direction of the greater force. When the forces act in the same direction, the resultant is found by adding the applied forces.



a **b**

Figure 15 (a) - Forces acting on a simple crane;
(b) - Rectangular components of a force

In Figure 15 (a) a simple crane illustrates the composition of two forces. Let the top of the beam *BC* be connected by means of a cord to the wall at *A*, in such a way that when the beam is in equilibrium the cord *AB* is at right angles to the wall. A spring balance inserted in this cord indicates the tension in it. A weight *W* is hung from *B*. Under the action of those two forces, the beam exerts a thrust that is just enough to overcome their combined action. This thrust is equal in magnitude and opposite in direction to the resultant of these two forces. To obtain the force diagram, lay off on a vertical line a distance which represents the weight *W*, and at right angles to this line lay off a second line which represents the magnitude and direction of the tension *T* in the cord *AB*. Now, draw the rectangle of which *T* and *W* are the two sides. The diagonal of this rectangle represents the resultant of the horizontal and vertical forces and is equal to the force exerted on the beam.

5. Resolution of Forces. — It has been seen that two forces can be combined into a single force. On the other hand, a single force may be broken up into two or more forces to which it is equivalent. When one force is given, it is possible to find two other forces which when applied simultaneously will produce the same effect as the single force. This process of splitting up a single force into two or more parts is known as the resolution of forces, and the parts into which the force is split up are called the components of the force.

6. Rectangular Components of a Force. — Most frequently the force is resolved in such a way that the components are at right angles to each other. In Figure 15 (b) *OR* represents a given force, and the components are desired along *OX* and *OY*, two directions which are at right angles to each other. By completing the rectangle *OARB*, the magnitudes of the components are found to be *O A* and *OB*. The relation between the components and the original forces is given by the trigonometric formulas

$OA = OR \cos x$

$OB = AR = OR \sin x$

The forces acting on a body may neutralize each other in such a way that there is no tendency for the body to change either its motion of translation or its motion of rotation. The body is then said to be in equilibrium under the action of the applied forces. If the body is at rest, it will remain at rest, and if it is in uniform motion — either motion of translation or motion of rotation — it will continue to move with uniform motion [2, C. 45 - 47].

2.4.2 Retell the text using your sentences.

2.4.3 Read and translate the text, give brief definitions to torque, equilibrium, gravity center and stability of a body.

Equilibrium of Forces

1. Torque. — The tendency of a force to produce rotation depends on the magnitude of the force and on the perpendicular distance between the line of action of the force and the axis about which the rotation takes place. It is proportional to the magnitude of the force and also to the distance between the line of action of the force and the axis of rotation. It is convenient to define torque, or moment of force, as the product of the force and the perpendicular distance between the line of action of the force and the axis of rotation.

Torque = force X distance from axis

2. Conditions of Equilibrium. — In order to make a body in equilibrium under the action of any number of forces, two conditions must be satisfied:

1. The sum of the forces acting on the body in any direction must be equal to zero. When this condition is satisfied, the body will have no tendency to change its motion of translation, since there is no net force acting on it.

2. In order that the body may have no tendency to change its motion of rotation, the sum of the moments of force tending to produce clockwise rotation about any axis must be equal to the sum of the moments of force tending to produce counterclockwise rotation about that same axis. When this second condition is fulfilled, there is no net torque acting on the body, and its motion of rotation will not change with time, i. e., if the body is already at rest, it will not start into rotation; and, if it is already in rotation, its rate of rotation will not change.

3. Center of Gravity. — Every particle of a body possesses weight, so that the pull of the earth on the body is made up of a large number of forces directed toward the center of the earth.

Suppose that there are two particles of mass, m and M, at A and B, respectively, and that these particles are connected by a light rod. These particles are attracted to the earth with forces that are nearly parallel to each other. If a point C in the rod is so chosen that

$$m \text{ X } AC = M \text{ X } BC$$

then the moments of force tending to turn the rod clockwise are just equal to the moments tending to turn it counterclockwise. If the rod is turned into some other position, the forces will no longer be perpendicular to the rod, but the moments of force about C will still balance each other. Hence, it is possible to regard the two masses as concentrated at C, since the action of gravity on these two masses concentrated at C is the same as its action when the masses are at the ends of the rod. A point at which it is possible to assume the masses concentrated without changing the action of gravity on them is called the center of gravity of the masses.

Whatever the shape and size of the body, it is always possible to find one point at which a force equal and opposite to the weight of the body can be applied so that the body will remain at rest.

About this point the body has no tendency to rotate under the action of gravity, and at this point we may consider all the mass of the body to be concentrated. If the body is balanced on a knife edge, this point will lie directly above the knife edge. The center of gravity need not necessarily lie in the substance of the body. Thus the center of gravity of a uniform ring lies outside the material of the ring - at its center.

4. Types of Equilibrium. — The equilibrium of a body may be stable, unstable, or neutral. When a body returns to its original position after being slightly disturbed, the equilibrium is said to be stable. A cone standing on its base is an illustration of this type of equilibrium. When a cone on its base is raised slightly from the table on which it rests, it returns to its original position on being released. It is in stable equilibrium. If, however, the cone rests on its vertex and is then slightly displaced, it tends to fall into a new position rather than return to its original position. In this case the cone is in unstable equilibrium. Any body which tends to get as far as possible from its original position when disturbed is in unstable equilibrium. A sphere resting on a horizontal table when slightly displaced tends neither to return to its former position nor to go still farther away from it, but it remains in any position in which it finds itself. Such a body is in neutral equilibrium.

5. Stability of a Body. — The position of the center of gravity is of much importance in determining the stability of a body. The lower the center of gravity, the greater the stability of the body and the more difficult it is to overturn. A body becomes unstable as soon as the vertical line through the center of gravity falls outside its base. The body which must be displaced the greater amount in order to make the vertical through its center of gravity fall outside the base is the more stable [2, C. 48 - 49].

2.4.4 Play a game with your partner, where one person is the examiner in physics and the other one is examinee, who has to tell him/her about the equilibrium of forces.

2.5 Texts Kinematics

2.5.1 Read the text and answer: What is motion, plane motion, rotation, plane of rotation, center of rotation, S-coordinate, uniform motion, nonuniform motion, angular displacement?

Motion. — The commonest phenomena which we observe are those involving the movement of objects from one point to another. Walking, riding, flying, dancing, climbing and sailing are all familiar examples of motion.

Motion is the continuous change in position of an object or a particle. The line along which a moving particle travels is called the path of the particle or path of the motion. If the path is a straight line the motion is rectilinear; if it is a curved line the motion is curvilinear.

Plane Motion is motion in which each point of the moving body remains at a constant distance from a fixed plane. Each point of the body moves in a plane, and that plane in which the center of gravity of the body moves is called the plane of the motion.

The wheels of a locomotive running on a straight track have plane motion, as has also a book which is slid about in any way on the top of a table. A translation may or may not be a plane motion; a rotation about a fixed axis is always a plane motion.

A rotation is such a motion of a rigid body that one line of the body or of an extension of the body remains fixed. The fixed line is the axis of rotation. The motion of the flywheel of a stationary engine is rotation, and the axis of rotation is the axis of the shaft on which the wheel is mounted; the motion of an ordinary clock pendulum is a rotation, and the axis of rotation is the horizontal line through the point of support and perpendicular to the pendulum. Obviously all particles of a rotating body except those on the axis describe circles or circular arcs whose centers are in the axis and whose planes are perpendicular to the axis. The plane in which the center of gravity of the body moves is the plane of rotation and the intersection of the axis of rotation and this plane is the center of rotation. All particles of the body on any line parallel to the axis move alike, hence the motion of the projection of the line on the plane of rotation represents the motion of all these particles. And the motion of the body itself is represented by the motion of the projection of the body on the plane of rotation.

Position; Displacement. — The position, at any instant, of a particle that has rectilinear motion is conveniently specified by its distance from a chosen fixed origin in the path. We call this distance the S-coordinate and customarily denote it by S. To indicate which side of the origin the moving particle is on, S is given a sign. Either direction along the path may be taken as positive and the other as negative. We assume for convenience that rectilinear motions are horizontal, and we take direction to the right as positive. The displacement of a particle for any given interval of time is the increment in its S-coordinate; it is equal to the distance between the initial and final positions of the particle, and is positive when the final position is to the right of the initial position.

If the direction of the motion does not change during a given interval of time, the displacement of the particle for that interval is equal to the distance it travels. But if the motion is reversed during the interval the distance travelled is greater than the displacement. If a particle moves so that it undergoes equal displacement in all equal intervals of time it has uniform motion; if it moves in any other way it has nonuniform motion.

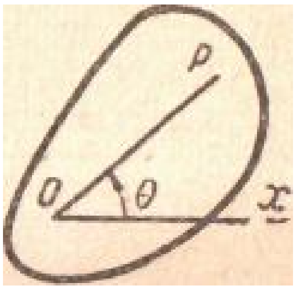


Figure 16 - Angular displacement

Angular Displacement. - By angular displacement of a rotating body during any time interval is meant the angle described during that interval by any line parallel to the plane of rotation. Obviously all such lines turn through equal angles in the same interval; it is convenient, for purposes of illustration, to select a line that cuts the axis. Let the irregular outline (Figure 16) represent a rotating body, the plane of rotation being the plane of the paper and the center of rotation being *O*. Line *OP* is a line in the body perpendicular to the axis of rotation, and Θ is the angle between *OP* and any fixed line of reference *OX*, also perpendicular to the axis of rotation. As customarily, Θ is regarded as positive when measured counterclockwise from *OX* to *OP*. If $\Theta 1$ and $\Theta 2$ denote initial and final values of Θ for any time interval, then the angular displacement for that interval is $\Theta = \Theta 2 - \Theta 1$ [2, C. 50 - 51].

2.5.2 Read and translate the text and choose the best summary below.

Forces and Motions

Types of Motion. — The motions of bodies may be divided into three classes: (1) translation, (2) rotation, and (3) vibration or oscillation. A body is said to have a motion of translation when it moves on continuously in the same direction. A ball thrown from the hand and an automobile running on a straight road are illustrations of motions of translation. If a body instead of travelling forward turns on fixed axis, it has a motion of rotation. Thus the flywheel of a stationary engine turns continuously around its axis without ever moving forward. Any point on the wheel returns again and again to its original position. This is a motion of rotation. The drive wheels of a locomotive are moving forward and are at the same time rotating. Therefore they have two motions, one of rotation and the other of translation. Some bodies reverse their motions from time to time and return at regular intervals to their original positions. Such bodies are said to have a motion of vibration or oscillation. The pendulum of an ordinary clock swings back and forth at regular intervals, so that the same motion is repeated again and again. The bob of the pendulum has a motion of vibration [2, C. 51].

Summary variants:

- Translation is a motion with the continuous changing of the direction, while rotating means circling and oscillation represents a periodic motion.
- Translation is a continuous forward motion, while rotating means swinging back and forth and oscillation represents a motion with some intervals.
- Translation is a forward motion in a straight line, while rotating means revolving on the axis and oscillation represents reversing motion with some periodicity.

2.5.3 Read the text, translate it and find out what sentences to the text are false.

Speed and Velocity

Speed. — The speed of a body is defined to be the rate at which the body is passing through space or the space passed over in unit time. It is determined by dividing the space over which a body has passed by the time required to pass over that space. It is a scalar quantity and has magnitude only.

Speed = space per unit time = distance / time

Velocity. — The velocity of a body has a directional quality in addition to its magnitude. Velocity is a vector quantity in contrast to speed, which is a scalar quantity. The magnitude of the velocity is the same as the numerical value of the speed. In giving the velocity of a body the direction of motion must also be specified. If it is stated that an automobile is running 30 mph the information is not sufficient to locate the machine. In addition to stating the speed of the machine, it is necessary to give the direction in which the machine is moving and the point from which it starts. Directed speed, which is called velocity, is therefore a vector quantity. The velocity of a body may change either by changing the numerical value of the speed or by changing the direction of motion. A body that is moving in a circular path with uniform speed continually changes its direction. Its velocity is therefore variable. The magnitude of the velocity = space passed over per unit time = distance : time.

Addition of Velocities. — Suppose that a railroad train is running east at 10 mph and that a man walks forward on the train at the rate of 4 mph. The man has a forward velocity because of the motion of the train and also a forward motion because of his walking. His forward velocity with respect to the earth is the sum of these two velocities, or 14 mph. Now suppose that he walks backward on the train at the rate of 4 mph. Again he has two velocities, 10 mph forward and 4 mph backward. His net velocity with respect to the earth is the difference between his forward and his backward velocity or 6 mph forward. In this case the two velocities lie along the same line and the resultant velocity is equal to the algebraic sum of the separate velocities. When the separate velocities lie along different lines, they must be added with proper regard for the directions of motion.

As an illustration of the composition of velocities that are at right angles to each other, consider the case of a man rowing a boat across a stream. The man has a velocity across the stream owing to his rowing. If the man rows at right angle to the direction in which the water flows, conditions are as represented in Figure 17a. The effect of the combined velocities is that the boat is carried across the stream and at the same time is carried down the stream. The speed at which the boat actually moves and the direction of its motion are found by constructing a rectangle so that one side represents the speed and direction of motion of the boat due to the rowing, and the other side the speed and direction of motion of the boat due to the stream alone. The actual direction of motion and speed of the boat is given by the diagonal of this rectangle.

Resolution of Velocities. — As in the case of displacements, forces and other vector quantities, it is often convenient to replace a velocity by its components at right angles to each other. This process is called the resolution of velocities. Let *OB*, Figure 17b represent the magnitude and direction of a velocity V.

Velosity of stream

a

$V_x = V\cos\Theta$

b

Figure 17 a - Addition of velocities at right angles to each other;

b- Rectangular components of a velocity

This velocity can be resolved into two components that are at right angles to each other. If the velocity V makes an angle θ with the x axis, its component Vx in the direction of the x axis is

$$OA = Vx = V \cos \theta$$

and its component in the direction of the y axis is

$$OC = Vy = V \sin \theta$$ [2, C. 52 - 53].

Sentences to the text:

1. Being a scalar quantity, speed doesn’t include the direction.
2. Velosity is the synonym of speed and equals distance divided by time.
3. When you count your velocity you should take gravity into consideration.
4. To get the right velocity of the object, his/her net velocity we should add all velocities with respect to the directions of motion.
5. Resolution of velocity means resolving it into its components at right angles to each other.

2.5.4 Read and translate the text. Think out a headline.

We know the velocity of a particle to be continuously changing if this particle has nonuniform motion; in each successive time interval the particle acquires or takes on some increment of velocity. The time rate at which the velocity changes is the acceleration of particle. This rate has magnitude, according to how much velocity is being taken on per unit of time, and direction, according to the direction of the velocity that is being taken on. The magnitude of acceleration is expressed in units of velocity per unit of time, as miles per hour per minute (mi/hr/min) or feet per second per second (ft/sec/sec or ft/sec).

The direction of the acceleration is conveniently indicated by sign, plus when to the right, minus when to the left.

If the velocity changes uniformly (equal velocity increments in all equal intervals of time), then the acceleration is constant and may be computed by dividing the velocity-increment for any interval of time by the interval. That is $a = \Delta v:\Delta t$ (1) where Δv denotes the velocity increment for the interval Δt.

If the velocity does not change uniformly, then the acceleration is not constant but changes continuously, and Eq. 1 does not, in general, give the acceleration at any particular instant but gives only average acceleration for the interval Δt.

That is, $\alpha_\alpha = \Delta v:\Delta t$ (2) where α_α denotes average acceleration. The acceleration at a particular instant is the limit of the average acceleration for an interval that includes the instant *in question* (in question - рассматриваемый; in question - зд. является определением) as the interval is taken smaller and smaller.

This limit is dv/dt; that is $\alpha = dv:dt$ (3). If we substitute for v its value ds/dt, Eq, 3 becomes $\alpha = \mathrm{ds}/dt$.

The above equations indicate that α_α and α are positive or negative according to the sign of Δv or dv, and this is consistent with the rule for the sign of acceleration given above. It should be particularly noted that the sign of the acceleration does not depend merely on whether the speed is increasing or decreasing.

If a particle is moving to the right and going faster and faster it has positive acceleration, but it also has positive acceleration when moving to the left and going slower and slower. In both cases positive velocity is being taken on and the direction of the acceleration is to the right. The magnitude of the acceleration, without regard to sign, represents the rate of change of speed [2, C. 53 - 54].

2.5.5 Look through the text and find the English equivalents for the following Russian phrases and word-combinations:

в каждый последующий интервал времени; за единицу времени; изменяется равномерно; постоянно изменяется; означает среднее ускорение; уравнения выше; в обоих случаях.

2.5.6 Read and translate the text, give brief definitions to angular velocity, angular acceleration, rotary inertia and explain Newton’s second law for rotary motions.

Rotary Motions

Angular Velocity. — Let one end of a line *OA* of Figure 18 be fixed, and then let the line revolve in a plane about this fixed end. The rate at which the line rotates is called its angular velocity which is usually expressed in radians per second. If the rate of rotation of the line is constant, the angular velocity is constant and is equal to the angle through which the line turns in unit time. The angular velocity may also be measured in revolutions per second or per minute. Angular velocity like linear velocity is a vector quantity. It can be represented by drawing a line of suitable length in the direction of the axis about which the rotation takes place.

Angular Acceleration. — The rate at which the angular velocity changes is called the angular acceleration. It is the increase or decrease in angular velocity per unit of time. It is related to the angular velocity in the same way in which the linear acceleration is related to linear velocity. In an angular acceleration as in linear acceleration it is necessary to specify two units of time. One of these units gives the unit of time in which the angular velocity is measured, and the other gives the unit of time used to measure the change in the angular velocity. Ordinarily, the same unit of time is used in both cases.

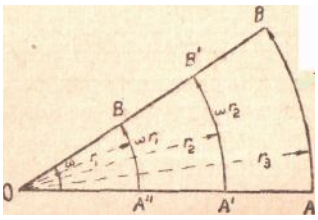


Figure 18 - Relation between angular velocity and linear velocity. Angular velocity times radius gives linear velocity

Relation of Torque to Angular Acceleration. — In order to produce linear acceleration, it is necessary to apply a force to the body, and the greater the force the greater the acceleration. To produce angular acceleration, it is necessary to apply a torque to the body. The greater the torque, the greater is the angular acceleration that is produced. For a particular body rotating about a fixed axis, it is found that the angular acceleration is proportional to the torque that produces it. This factor of proportionality by which the angular acceleration must be multiplied in order to give the torque is a measure of the opposition of the body to being set in rotation. It is analogous to the mass of a body, which is a measure of the opposition of a body to being set in translation. The relation between the torque and the angular acceleration can be expressed by the equation

$$T = IA$$

where A = the angular acceleration in radians per second per second; T = the torque (force in poundals and distance in feet, or force in dynes and distance in centimeters); I = the factor of proportionality called the rotary inertia.

This relation is known as Newton's second law for rotary motions. It states that the angular acceleration is proportional to the torque.

Rotary Inertia. — Experiment has shown that the opposition of a body to being set in translation is proportional to the mass of the body and does not depend on anything else. It is found, however, that the opposition which a body offers to being set in rotation, or accelerated, about a fixed axis depends not only on the mass but also on the way in which this mass is distributed about the axis. This opposition which is called the rotary inertia, or the moment of inertia, is proportional to the mass and to the square of the distance of the mass from the axis of rotation. For this reason, when it is desired to make the rotary inertia of a flywheel of given mass as large as possible, the mass of the wheel is concentrated in the rim. When the mass is concentrated near the axis, the tendency of the wheel to continue in motion, or its resistance to being set in motion, is much less. In order to calculate the rotary inertia, multiply each element of mass by the square of its distance from the axis of rotation, and then add together all these products [2, C. 54 - 55].

2.5.7 Read the text, translate it and answer the questions: In what way can we find the acceleration when acting force is variable? What is SHM? What is periodic motion? What is oscillatory motion? What is the period of the motion?

Harmonic Motion

Now we are to study the motion of a body when the resultant force on it is not constant, but varies during the motion. Naturally, there are an infinite number of ways in which a force may vary and hence no general expression can be given for the motion of a body when acted on by a variable force, except that the acceleration at each instant must equal the force at that instant divided by the mass of the body. There is, however, one particular mode of variation which is met with in practice so frequently that it is worth while to develop formulas for this special case. The force referred to is an elastic restoring force, brought into play whenever a body is distorted from its normal shape. When released, the body will be found to vibrate about its equilibrium position.

The example of this sort of motion is given below.

Suppose that a flat strip of steel is clamped vertically in a vice and a small mass is attached to its upper end as in Figure 19.

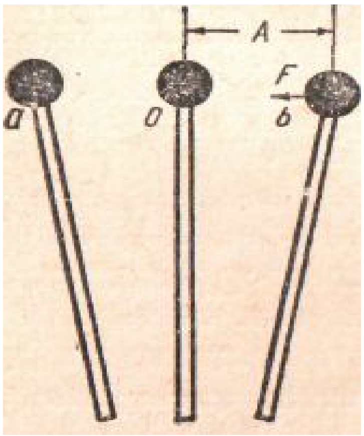


Figure 19 - A flat strip of steel

We shall assume that the strip is sufficiently long and the displacement sufficiently small so that the motion is essentially along a straight line. The mass of the strip itself is negligible.

Let the top of the strip be pulled to the right a distance A as in Figure 19 and released. The attached mass is then acted on by a restoring force exerted by the steel strip and directed toward the equilibrium position O. It therefore accelerates in the direction of this force, and moves on toward the center with increasing speed. The rate of increase (i. e. the acceleration) is not constant, however, since the accelerating force becomes smaller as the body approaches the center.

When the body reaches the center the restoring force has decreased to zero, but because of the velocity which has been acquired, the body overshoots the equilibrium position and continues to move toward the left.

As soon as the equilibrium position is passed the restoring force again comes into play directed now toward the right. The body therefore decelerates and it will therefore be brought to rest at some point to the left of O, and repeat its motion in the opposite direction.

Both experiment and theory show that the motion will be confined to a range $\pm A$ on either side of the equilibrium position, each to-and-fro movement taking place in the same length of time.

Were there no loss of energy by friction the motion would continue indefinitely once it had been started. This type of motion, under the influence of an elastic restoring force and in the absence of all friction, is called simple harmonic motion, often abbreviated SHM.

Any sort of motion which repeats itself in equal intervals of time is called periodic, and if the motion is back and forth over the same path it is also called oscillatory.

A complete vibration or oscillation means one round trip, say from α to b and back to α.

The periodic time, or simply the period of the motion, represented by T, is the time required for one complete vibration.

The frequency, *f*, is the number of complete vibrations per unit time.

Evidently the frequency is the reciprocal of the period or

$$T = 1:f$$

The displacement, *x*, at any instant, is the distance away from the equilibrium position or center of the path at that instant.

The amplitude, *A*, is the maximum displacement. The total range of the motion is therefore 2 *A* [2, С. 56 - 57].

2.5.8 Notes to text 2.5.7:

- to bring into play - привести в действие;
- to come into play – начать действовать;
- to bring to rest – остановить;
- the body overshoots the equilibrium position - тело переходит за пределы положения равновесия.

2.6 Revision texts 2.4 - 2.5

2.6.1 Match words and word-combinations with their translation:

curvilinear	вращение по часовой стрелке
motion of translation	разлагать на составляющие
to substitute	прямоугольник
oscillation	преодолевать
to distribute	оказывать давление, влиять
to overturn	твердое тело
resultant	незначительный
increment	скреплять, зажимать
net force	обратная величина
forward	назад

to overshoot	вращающий момент
tension	земное притяжение
cone	обод
rectilinear	пружина
to-and-fro movement	прямолинейный
clockwise rotation	вибрация, качание, колебание
to resolve into components	перекрещивание, пересечение
rigid body	конус
reciprocal	вперед
thrust	поступательное движение
to pass over	опрокидывать, переворачивать
to clamp	равнодействующая (результирующая) сила
spring	маховик, маховое колесо
revolution	результант, векторная сумма
backward	заменять, замещать
rectangle	увеличение
torque	проскакивать, отклоняться
negligible	напряжение, натяжение
earth pull	разложение сил
rim	возвратно-поступательное движение
counterclockwise rotation	распределять
resolution of forces	оборот
to exert	криволинейный
flywheel	сила тяги, толчок
intersection	вращение против часовой стрелки

2.6.2 Find the sentences with these words and word-combinations in texts 2.4 - 2.5 and translate them.

2.6.3 Prepare the words and word-combinations for a dictation.

2.6.4 Translate from Russian into English.

Статика представляет собой тот отдел механики, в котором рассматриваются условия равновесия сил, приложенных к телу. При равновесии сил требуется, чтобы ни одна точка тела не имела ускорения. Если рассматриваемое тело есть свободная материальная точка, то для равновесия приложенных к ней сил необходимо, чтобы их геометрическая сумма или равнодействующая была равна нулю. Если материальная точка не может сходить с гладкой поверхности, то, при положениях равновесия, геометрическая сумма приложенных к ней сил должна быть равна и прямо противоположна реакции поверхности, а так как реакция гладкой поверхности направлена по нормали, то и геометрическая сумма приложенных к точке сил должна быть направлена по нормали. В этом состоит условие равновесия сил, приложенных к материальной точке, остающейся на гладкой поверхности [10, http://en.wikipedia.org/wiki/Statics].

Кинематика – это раздел физики, изучающий состояние движения независимо от вызывающих его сил, и составляющий часть общей науки о движении - механики.

Цель ее состоит в изучении геометрических свойств движения, скоростей и ускорений: для достижения этой цели пользуются анализом и геометрией. Кинематику называют геометрией четырех измерений, так как она имеет дело с тремя координатами пространства и еще с четвертым переменным, представляющим собой время. Скорости представляются первыми производными от координаты по времени, ускорение - вторыми производными и еще, кроме того, рассматриваются производные от координат по времени высших порядков, называемые ускорениями высших порядков. С аналитической точки зрения, вся кинематика сводится к изучению соотношений, существующих между этими величинами. В последнее время появилось стремление к ее изучению чисто геометрическими способами [10, http://en.wikipedia.org/wiki/Kinematics].

2.7 Texts Dynamics

2.7.1 Before reading the text answer the question: What do you know about three laws of motion? Now read it and say: what new facts have you learnt?

Laws of Motion

Thus far we have studied the laws of motion, without asking, “What is it that causes a body to move?” We know that a force is needed in order to change the motion of a body, that is, in order to accelerate it or decelerate it, or to change its direction. In the absence of a force, a body will either remain at rest, or continue to move with constant speed in a straight line. These conclusions are summed up in three statements known as laws of motion.

The First Law. — The statement of the first law of motion is as follows: A body at rest remains at rest and a body in motion remains in motion at a constant speed in a straight line, unless acted upon by an external force.

Thus the first law involves the idea of motion and the idea of force. It explains what is to be understood by force: it is that which tends to change the state of rest of a body, or of uniform motion in a straight line. The first law, however, tells us more than this. It tells us that if a body is kept free from the action of forces, it will remain in its state of rest or of uniform motion in a straight line. Thus the normal state for a body to be in is one of rest or of uniform motion in a straight line, i. e. motion with uniform velocity; it is only the presence of force which can alter this normal state. The property by virtue of which a body tends to remain in either of the natural states, and to resist being accelerated, is called inertia. In this sense, inertia is an absolute quality possessed in equal degree by all bodies, because all bodies are completely inert.

The Second Law. — The second law deals with the change in motion of a body when force is applied to it.

This law is stated as follows:

Rate of change of motion of a body is proportional to the applied force and is in the direction in which the force acts.

The expression change of motion requires explanation. By motion is here meant quantity of motion or momentum. It is defined as the product of the velocity and a quantity called the mass of the body.

Using the word momentum, the second law may also be stated as follows: Rate of change in momentum of a body is proportional to the applied force and is in the direction in which the force acts.

The Third Law may be stated as follows.

To every action there is always an equal and opposite reaction. It is a matter of common observation that a body *A* cannot exert force on a second body *B* without *B* at the same time exerting force on *A*. Thus all forces occur in pairs, which may conveniently be spoken of as action and reaction. The third law of motion tells us that the two forces which constitute such a pair are equal in magnitude and opposite in direction.

For example, when we stretch a rubber band, holding one end in each hand, you must pull as hard with your left hand as you do with your right [2, C. 57 - 58].

2.7.2 Find the main sentences in the text and retell it. You may use Internet to get supplementary information.

2.7.3 Read the texts about Work and Power, translate them and find one wrong statement in the list of the main statements below the texts.

Work

Work is done by a force when the point of application of the force moves so that the force has a component along the path of the point of application. This component we call the working component of the force and the length of the path of the point of application we call the distance through which the force acts. If the working component is constant, the amount of work done is equal to the product of the magnitude of the working component and the distance through which the force acts. When the working component acts in the direction of the motion, the work of the force is positive; when the working component acts oppositely to the direction of motion, the work of the force is negative. Forces which do positive work are sometimes called efforts; those which do negative work, resistances.

We denote work by W.

Since it is the product of two scalar quantities, work is a scalar quantity. It can be expressed in any units of force and distance.

In the discussion above we have spoken of work as being done by a force but, since the force which does work must be exerted by some body on some other body, it is also correct to say that the work is done by one body on the other body. Thus a spring does the work of closing a door and the work is done on the door, etc. The amount of work done in any given case is usually determined by separately calculating the work done by each of the forces that act, and so we usually speak of the work done by a force rather than of the work done by a body.

Gravitational Units of Work. — Since work is measured by the product of the force times the distance through which it acts, in order to measure work it is necessary to measure two quantities — force and distance. In the English system, the force is measured in terms of a unit of force that is equal to the pull of gravity of a mass of 1 lb, and the distance is measured in feet. In this system the unit of work is called the foot-pound.

One foot-pound of work is defined as the work that is done when a force equal to the weight of 1 lb acts through a distance of 1 ft.

For example, 1 ft-lb of work is done when a mass of 1 lb is raised a distance of 1 ft at constant speed against the action of gravity.

In the metric system the unit of work may be chosen as the gram-centimeter or kilogram-meter.

One gram-centimeter of work is defined as the amount of work that is done when a force equal to the weight of 1 g acts through a distance of 1 cm, and the kilogram-meter is defined as the work which is done when a force equal to the weight of 1 kg acts through a distance of 1 m.

The gram-centimeter is the amount of work done when a mass of 1 g is lifted a vertical distance of 1 cm at constant speed against the action of gravity.

The Erg. — The gravitational units of work, like the gravitational units of force which enter into them, depend on the place on the surface of the earth at which they are used. For this reason an absolute unit of work, the erg, is frequently used. An erg of work is the work done when a force of 1 dyne acts through a distance of 1 cm. Since the weight of 1 g is equivalent to 980 dynes, a gram-centimeter of work is equivalent to 980 ergs; i. e., when a mass of 1 g is lifted a distance of 1 cm against the force of gravity, 980 ergs of work are done [2, C. 58 - 60].

Power

In defining work as the force multiplied by the distance through which it acts, it is to be observed that the element of time does not enter. The same work is done in lifting a mass of 300 lb a distance of 100 ft whether the work is done in a day or in a minute. The same work is done whether the mass is carried in a single load or in two or more loads. The amount of work done is measured by the end result, and it does not in any way depend upon the time to do the work. In the consideration of a machine it is necessary to know more than the total amount of work that the machine can do. It is desirable to know the rate at which the machine works. The time rate of doing work is called power. Hence

Power = work : time = force x distance : time = F x s : t = work, per unit of time

Since $s : t = v$

Power = force x velocity = Fv

Horsepower. — The English unit of power is called the horsepower. A horsepower denotes the ability of a machine to do 33,000 ft-lb of work in 1 min or 550 ft-lb in 1 sec [2, C. 60 - 61].

Main statements:

1. Working component is such a constituent of force and its direction determines whether the work of the force is positive or negative.
2. Work is a vector quantity and can be expressed in the units of force and distance.
3. In the English system they designate the unit of work as the foot-pound, while in the metric system it can be named as the gram-centimeter.
4. The erg is an absolute unit of work.
5. To find the machine amount of work we should know the rate of its doing work.
6. Horsepower is the English unit for the time rate of doing work.

2.7.4 Look through texts 2.7.1, 2.7.3 and find the English equivalents for the following Russian phrases and word-combinations:

закон формулируется следующим образом; обычно наблюдается; десятичная система мер; сила измеряется на основе (в единицах); гравитационная единица работы; конечный результат; действует в одном направлении с движением; желательно знать; абсолютная единица работы; произведение силы умноженной на расстояние.

2.7.5 Read the article about Energy, translate it and give the definitions to energy, potential energy and kinetic energy. Explain how to measure the

kinetic energy and how to measure the potential energy. When should we use Newton's second law of motion? State the law of the conservation of energy.

Energy

Definitions. — When the state or condition of a body is such that it can do work, the body is said to possess energy. It is customary to distinguish several kinds of energy. Thus a body may have kinetic energy by virtue of its motion, potential energy by virtue of its position in a field of force or by virtue of its state of internal stress, thermal energy by virtue of its temperature, chemical energy by virtue of its chemical composition. The amount of energy, of any given kind, that a body possesses at a given instant is the amount of positive work the body can do in changing from the condition it is in at that instant to some other condition taken as standard. Thus we may reckon the kinetic energy of a rotating flywheel to be the work the flywheel can do in coming to rest relative to the earth, and the potential energy of a stretched spring to be the work the spring can do in contracting to its normal length.

Energy is measured in the same units as work and, like work, is a scalar quantity.

Potential energy is the energy a body possesses by virtue of its position or configuration relative to some standard position, or configuration, and is measured by the amount of work required to get it into its position, or configuration, or by the amount of work it can perform in returning to its original position, or configuration, with neglect or omission of any dissipated work.

Kinetic energy is the energy a body possesses by virtue of its velocity relative to a reference frame and is measured by the work done upon it to get it into its present motion, or numerically by the work that must be performed upon it to bring it to rest, or, finally, by the work it can do in being brought to rest, with neglect or omission of dissipated work.

In the definitions for potential and kinetic energy there is a catch that should be pointed out. Suppose a block rests upon an inclined plane. Its potential energy is usually expressed as Mgh, and if the block returns to the foot of the plane, it might be supposed that the block would perform an amount of work Mgh. But this need not be the case. Suppose that the block slides down the plane at an indefinitely slow speed under the action of its weight, the normal traction of the plane, and the tangential reaction of the plane. It is clear that the tangential reaction of the plane does work upon the block to the extent of $-Mgh$ but the block does no work at all.

Similarly a compressed spring could be released to its natural length without its performing any work. It is for this reason that the definition reads with neglect of dissipated work. Thus it could be supposed that the block would slide frictionlessly down the plane and then compress a spring at the foot of the plane and, if the process were entirely frictionless, the work performed upon the spring would be equal to Mgh.

With regard to kinetic energy, consider the following. The reference is a heavy vehicle, such as a truck, and the body is a light automobile. Suppose that the truck is at rest and that the automobile has a speed of 30 mi/hr down the road. The energy of the automobile is the work done upon it to get it under way, with neglect of dissipated work, and is of course $1/2\ mv^2$. Its kinetic energy relative to the truck may be destroyed in two ways: (1) stop the automobile or (2) speed up the truck to 30 mi/hr. But the works (not including frictional work) required to do these are by no means equal, in fact they are $1/2\ mv^2$ and $1/2\ Mv^2$.

The definition, therefore, must speak specifically of the work performed by the body or upon the body.

How to Measure the Potential Energy. — The measure of the potential energy which a lifted body, such as a pile driver, has because of its position is equal to the work which has been spent in lifting the body. If the height in feet through which the body has been lifted is h and its weight in pounds is P, then the potential energy of the lifted body is

$$\text{Potential energy} = Ph \text{ ft.-lbs.}$$

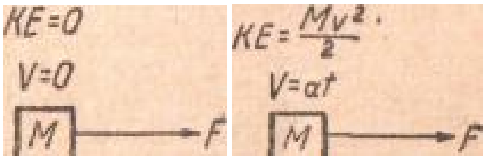
How to Measure the Kinetic Energy. — To find the kinetic energy which a body possesses by virtue of its motion, consider the work which must be done on it in order to give it a certain speed. When the body is stopped, it will give up an amount of energy that is equal to the work done in starting it. By definition, this latter is its kinetic energy.

From Newton's second law of motion, the force necessary to make a body move with an acceleration α is

$$F=M\alpha$$

where force is in dynes or poundals, mass in grams or pounds and acceleration in centimeters per second per second or feet per second per second.

Let s (Fig. 20) be the distance in centimeters or feet through which the body moves.



$s=\frac{1}{2}\alpha t^2$

Figure 20 - Kinetic energy equals the work to produce the change of velocity = $Mv^2/2$

Then the work done on the body in this distance is

$$\text{Work} = Fs = M\alpha s \text{ ergs or foot-poundals.}$$

If the body starts from rest, its velocity in centimeters per second or feet per second at the end of t sec is

$$v = \alpha t$$

where α is the acceleration in centimeters per second per second or in feet per second per second. The space passed over is equal to the average velocity times the time. Hence

$$s = \frac{O + v}{2} t = \frac{1}{2} vt$$

and since $v = \alpha t$ and $t = v/\alpha$, we have by substitution

$$s = \frac{1v^2}{2\alpha},$$

$$v^2 = 2\,\alpha s,$$

$$\alpha s = \frac{v^2}{2}$$

Substituting this value of αs in the expression for the work done on the body

$$\text{Work} = Fs = \frac{Mv^2}{2} \text{ ergs or foot-poundals.}$$

This expression gives the work necessary to cause a mass M to acquire a velocity v. This work does not depend on the distance covered or on the acceleration. It is determined solely by the mass of the body and its speed. If a retarding force is applied to this body so that it is brought to rest, the moving body will do work against this retarding force. When the body has come to rest, the amount of work that has been done will be just equal to the work done in starting the body. According to the law of conservation of energy, the energy spent in starting the body must be just equal to that derived from the body when it is stopped. Hence

$$\text{Kinetic energy} = \frac{Mv^2,}{2} \text{ ergs or foot-poundals.}$$

If the body has an initial velocity u and an initial kinetic energy $\frac{1}{2} Mu^2$, the gain in kinetic energy is the work done on the body by the accelerating force.

Conservation of Energy. — Energy is defined as the ability to do work. It occurs in many forms. The work required to stretch a spring is stored up as energy in the spring. The work necessary to compress a gas may be stored up as heat in the gas. The study of the various forms in which energy may occur and of the transformation of one kind of energy into another has led to the statement of a very important principle known as the conservation of energy. This principle may be stated as follows: In any body, or system of bodies, which is not receiving or giving up energy, the total amount of energy is unchanged. This principle states that energy can never be created or destroyed. It can be transformed from one form into another, but the total amount in the end is unchanged. For example, a bullet leaves the muzzle of the gun with kinetic energy that it received because of the work done on it by the expanding gases. As it passes through the air, it loses some of this kinetic energy because of the heat developed by the friction in the air. When it strikes the target, sound waves are sent out that carry away some of the energy. There may also be a flash of light, which uses up some energy. Heat will be developed in the target, and fragments of the bullet may carry away some of the energy. If all these energies are added together, they will be found to be just equal to the energy with which the bullet left the muzzle of the gun.

Prior to the modern views concerning matter and energy, it was customary to make a similar statement concerning the conservation of matter. Now matter is regarded as a form of energy. It can be transformed into energy and conversely energy can be transformed into matter. When the sun emits radiation, its mass decreases because of the decrease of energy due to radiation. The law of conservation of energy must therefore be extended to include transformations of both mass and energy. Experiments in nuclear physics have established the validity of this principle. Hence, the principle of the conservation of energy and the principle of the conservation of matter combine to form a single principle requiring the conservation of both matter and energy. The proportionality between mass and energy derived from the principle of relativity is given by the equation

$$E = c^2m$$

where E is the energy in ergs; m is the change of mass in grams; c is the velocity of light in centimeters per second that equals $3x10^{10}$ cm per sec [2, C. 60 - 64].

2.7.6 Look through text 2.7.5 and find the English equivalents for the following Russian phrases and word-combinations:

но это не обязательно так; в силу его положения; в силу его движения; никоим образом; чтобы привести его в движение; пренебрегая какой бы то ни было потерянной работой; что касается кинетической энергии; есть одно обстоятельство (или один момент), которое следует отметить; на самом деле; до современных представлений; вследствие излучения.

2.7.7 Look through the text once again and summarize it. Can you remember any scientists interested in the phenomena of energy? Find supplementary information about them from Section I and prepare the presentation of your report on "Energy" (use a projector in the multimedia class). You may use Internet to add some information.

2.7.8 Read the text, translate and answer what sentences below it are true and what are false.

Friction

Nature of Friction. — When a heavy block of wood is pushed along the top of a table, a certain resistance is encountered. By making the surface of the table and the surface of the block very smooth, the amount of this resistance can be much decreased. No matter what the nature of the surfaces that are moving over each other, there is always some resistance, or opposition, to the motion. This resistance, the amount of which depends in part on the characteristics of the rubbing surfaces, is called friction. It always opposes the motion, whatever its direction. It never tends to push the body either forward or backward. It merely tends to stop the motion or to make it more difficult to move the body. It is more difficult to start the body than it is to keep it in uniform motion when once started. There are for this reason two kinds of friction, kinetic friction and static friction. The former is the force to keep the body moving with uniform speed. The latter is the force to start the body from rest. Kinetic friction is less than static friction.

Sliding friction means the force of opposition offered to the sliding of one surface over another. The force is due to the minute irregularities of one surface engaging in those of the other. A simple example of the resistance which a body encounters is when it slides or tends to slide over another.

Friction between two bodies is called static friction if slipping does not occur and kinetic friction if slipping does occur. The amount or magnitude of static friction between two bodies depends on the degree of the tendency to slip. Static friction is a passive force, which comes into action only to prevent a slipping that other forces tend to cause, and which is, in any given case, only so large as may be necessary to prevent that slipping. It increases as the tendency to slip increases, having its greatest value when slipping impends. Likewise, the inclination of the total reaction to the normal pressure increases as the tendency to slip increases, having its greatest value when slipping impends.

Limiting friction is a name sometimes given to the friction of impending slip. We denote it by F_0 because it is a maximum value. The coefficient of static friction for two surfaces is the ratio of the limiting friction to the corresponding normal pressure. We denote it by μ, then $F_0 = \mu N$.

The angle of friction for two surfaces is the angle between the directions of the normal pressure and the total reaction when slipping impends. We denote it by φ; then, since R may be looked on as the resultant of F_0 and N, $\tan \varphi = F_0/N$ and so $\mu = \tan \varphi$.

Laws of Friction. - The laws which determine the amount of friction between the dry surfaces of solids are as follows:

1. The friction between two sliding surfaces is nearly independent of the velocity.
2. If the force perpendicular to the surface remains the same, the friction does not depend on the area of the rubbing surfaces. This statement is only approximately true.
3. The force of friction is proportional to the total force pressing one surface against another.

4. The force of friction is greater at the start than after motion has begun.

Rolling Friction, the opposition offered to the rolling of one body on another, is in general very much smaller than sliding friction. For this reason the sliding friction force exerted on a shaft rotating in bearings can be reduced by installing ball or roller bearings which replace sliding friction by rolling friction. However, the sliding friction of a well lubricated shaft is already so small that there is no great gain in efficiency on mounting it in roller bearings. The chief reason for the use of such bearings in machinery is to reduce wear and to simplify lubrication problems [2, C. 64 - 66].

True or false?

1. We can reduce friction by using table and block with smooth surfaces.
2. There are three types of friction: potential friction, kinetic friction and static friction.
3. Static friction tends to prevent a slipping.
4. The friction of impending slip is denoted by $F_{0.}$
5. The force of friction is equal to the total force pressing one surface against another.
6. The sliding friction force decreases because of the replacing of sliding friction by rolling friction.

2.7.9 Read the text and answer the questions: Why does every machine waste energy? What is the efficiency of machine? What is the simplest form of machine? What is the actual mechanical advantage? What is the principle of the pulley operation? jackscrew operation?

Simple Machines

Efficiency of Machines. — Every machine wastes energy because of friction. Consequently, the work put into the machine is always more than that obtained from it. This loss decreases the efficiency of the machine. The efficiency of a machine is defined to be the ratio of the work done by the machine to the work done on the machine. It is therefore the output of the machine divided by the input.

$$\text{Efficiency} = \frac{\text{work done}}{\text{energy supplied}} = \frac{\text{output energy}}{\text{input energy}}$$

Levers. — A lever is a very simple form of machine.

The simplest kind of lever is one in which the arms are of equal length. The scale beam on a pair of ordinary balances is such a lever. In this case equal forces, or weights, at the ends of the lever just balance each other. Usually the distances of the forces from the point at which the lever is supported are not equal, and for equilibrium in such cases the forces must also be unequal. The larger force, at a smaller distance from the fulcrum, then has the same tendency to tip the lever as does the smaller force at a greater distance.

Law of the Lever. — Any lever is balanced when the sum of the moments of force tending to produce rotation clockwise is equal to the sum of the moments of force tending to produce rotation counterclockwise. If only one force is applied and one force overcome, this law may be stated as follows: A lever is balanced when

Weight x weight arm = force x force arm.

This law states that when a lever is balanced under the action of two forces, the forces applied to the lever are inversely proportional to their distances from the fulcrum.

Mechanical Advantage. — In all simple machines like levers a certain advantage is obtained by the use of the machine. This advantage does not consist in an increase or in a decrease of the work performed by the machine. Neglecting friction, the work done on the machine must always be the same as the work done by the machine. This law follows from the law of the conservation of energy. However, by means of a suitable lever or other machine it is possible to exert a large force by the application of a small force. The large force will net through a small distance, and the small force through a large distance, so that the work done in the two cases will be the same.

The ratio of the resistance, or the force, overcome to the applied force is called the actual mechanical advantage. Because of friction the actual mechanical advantage is always less than the ideal, or theoretical, mechanical advantage.

The Pulley. — A pulley consists of a wheel with a grooved rim, called a sheave, which is free to move about an axle which is mounted in a frame called a block. A flexible rope or cord passes over the groove in the rim of the wheel. To the ends of this rope are applied the weight and the force that overcomes this weight. In the case of a simple fixed pulley, equal forces or weights applied to the ends of the rope just balance each other. Neglecting friction, the tension in the rope is everywhere the same and the mechanical advantage of the pulley is unity. Therefore there is no advantage in such a pulley except that it is sometimes more convenient to pull down on the rope than it is to lift the weight directly.

When the pulley is movable and the weight is attached to it, it is evident that the weight is supported by two parts of the cord. Therefore it is necessary for each part to exert a pull equal to only one-half of the weight. If the weight is lifted, it moves only one-half as far as the free end of the cord to which F is applied. By applying the principle of work to this simple machine, it is seen that if the weight W is lifted α ft and the force F moves b ft, then

$$W \times \alpha = F \times b,$$

$$\frac{W}{F} = \frac{b}{\alpha} = 2 = \text{the mechanical advantage}$$

The Jackscrew. — When large forces must be exerted, a jackscrew is often used (Figure 21). The pitch of such a screw is the distance between successive threads. Let p be the pitch of the screw, W the weight to be lifted, F the force applied to the lever arm, and r the length of the lever arm. In one complete turn of the screw, the output is the weight lifted times the distance through which it is lifted.

$$W \times p$$

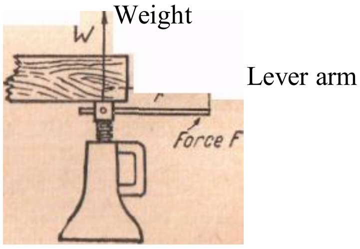


Figure 21 - The jackscrew combines the principle of the lever and that of the inclined plane

The input is the force applied times the distance through which it acts.

$$F \times 2\pi r$$

By the principle of work

$$W \times p = 2\pi rF,$$

$$\frac{W}{F} = \frac{2\pi r}{p} = \text{the mechanical advantage.}$$

Hence, the mechanical advantage is equal to the circumference traced out by the end of the lever in one complete revolution divided by the pitch of the screw. The mechanical advantage may be made large by making the pitch of the screw small or by making the lever arm long [2, C. 66 - 68].

2.7.10 Look through texts 2.7.8 - 2.7.9 and find the English equivalents for the following Russian phrases and word-combinations:

независимо от характера поверхностей; сила, которая выводит тело из состояния покоя; сила, которая заставляет тело двигаться с равномерной скоростью; сила, которая начинает действовать; перед тем, как должно наступить скольжение; закон сохранения энергии; вследствие трения; может свободно вращаться вокруг оси; в один полный оборот винта.

2.8 Revision texts 2.7

2.8.1 Match words and word-combinations with their translation:

conclusion	сваебойная машина
chemical composition	подобно, так же
tangential reaction	наклон
erg	потеря
sheave, pulley	футо-фунт
omission	потерянная работа (рассеиваемая)
inclined plane	точка опоры (рычага)
unity	касательная реакция
to sum up	подстановка, замещение
gun muzzle	эрг
jackscrew	борозда, выемка, паз
to alter	дуло ружья
retarding force	пропуск, упущение
circumference	ролик, шкив
dissipated work	точка приложения силы
inclination	естественное притяжение
internal stress	поверхность трения
likewise	заключение
fulcrum	химический состав
pile driver	замедляющая сила, тормозная сила
loss	наклонная плоскость
pitch	окружность
lever	подсчитывать
point of application	внутреннее напряжение
substitution	шаг (резьбы винта)
to reckon	единство, сплоченность

normal traction	винтовой домкрат
groove	вага, рычаг
foot-pound	видоизменять
rubbing surface	резюмировать, подводить итог

2.8.2 Find the sentences with these words and word-combinations in texts 2.7 and translate them.

2.8.3 Prepare the words and word-combinations for a dictation.

2.9 Texts Gases

2.9.1 Read the text, translate it and answer: What is the main distinction of gases from liquids and solids?

What Gases Are

The behaviour of a gas is easily enough understood if we remember what it is. A gas is a very scattered assembly of molecules moving as fast as bullets but not getting very far before they collide with each other. Each molecule has a good big free space round it: in fact, a molecule of a gas has about a thousand times as much elbow-room as a molecule of a liquid or a solid. Well, anyone can see that if this is a true picture of a gas, it must be very light, because it is made up of very few molecules. Picture a swarm of midges in which each midge was about two inches from the next and you will have a fair notion of the amount of elbow-room in a gas. It follows from that a gas will flow very easily, for the molecules will not get in each other's way, nor will they greatly attract or repel each other. For the latter reason, it should be easy to compress a gas: a solid or liquid is almost incompressible because the repulsions of the electrical charges of which its atoms are made up are far stronger than any forces we can apply. In the case of a gas, the molecules are much too far from each other to repel each other. Of course, the idea of a gas as a swarm of busy molecules is not much more than a hundred years old. Gases are so unlike any other kind of matter that many centuries elapsed before people made up their minds that they were matter at all.

One of the reasons why people before the eighteenth century knew hardly anything about gases was that they are difficult to handle. You can put a solid in a basket or a basin, you can pour a liquid into a jug, but a gas has to be handled in a special way. Suppose you have a bottle full of it. As soon as you uncork it, the gas molecules begin to spread into the air and the air molecules into the gas [2, C. 69].

2.9.2 Have you ever bought gases? Are you sure? Read the text, translate it and, however, say what gases you happened to buy and for what purposes.

The Ways of Storing Gases

On the industrial scale, there are three favourite ways of storing gases. First, they are stored in gasometers over water, or under a sliding piston or diaphragm.

Secondly, gases are stored in cylinders under pressures as high as 1,800 lbs. per square inch. This squeezes a lot of gas into a little space.

Thirdly, some gases can be made into liquids by compressing them, and these are sold in strong glass syphons or iron cylinders. When the valve at the top of the syphon is opened, the liquid evaporates and the gas rushes out. One gas, acetylene, explodes when it is strongly compressed, so it is dissolved under moderate pressure in a liquid called acetone, just as carbon dioxide is dissolved under pressure in water to make soda-water. When the cylinder of acetylene dissolved in acetone is opened, the acetylene comes bubbling out like the carbon dioxide from soda-water. To prevent the acetone from being spilt, it is soaked up in porous material.

The selling of gas is now a big industry, and at least eighteen different kinds can be bought.

The great chemical works usually make their gases and use them on the spot. Oxygen is sold to engineers for welding with the oxyacetylene blowpipe, and to doctors for sustaining pneumonia patients. Nitrogen, which does not burn, is sold for filling electric lamps and some other purposes. Hydrogen is sold for filling balloons and for various chemical purposes. Chlorine — the green poison-gas — is sold for bleaching and for making various chemicals. Carbon dioxide is sold in cylinders for making fizzy drinks and soda-water, which are simply still drinks or water into which this gas has been forced under pressure. Ethylene and ethyl chloride are used as anaesthetics. Acetylene is used for lighting. Liquefied ammonia (not the solution in water you buy at the chemist's) is used for refrigerators, and so is liquefied sulphur dioxide. Argon — obtained from air — is sold for filling electric light bulbs, and neon, a gas of which the air contains only one part in 55,000, is extracted from it and is used to fill those brilliant neon tubes which make the modern street so gay at night. So there are at least thirteen familiar gases you can buy, packed in cylinders or "siphons".

One more gas is familiar to us all, the coal-gas, which is supplied to houses. This is a mixture of half-a-dozen gases. It is mostly hydrogen and methane — the gas which causes explosions in coal mines — but it also contains the poisonous carbon monoxide and small amounts of several other gases [2, C. 69 - 70].

2.9.3 Read the text, translate it and answer: What unique features distinguish gases?

Compressed and Liquefied Gases

Nearly all the machines or inventions that employ air use it for its compressibility. Pneumatic tyres, air-guns, pneumatic drills, chisels and riveters all make use of the fact that pressure makes air contract and that when the pressure is released, it expands once more. Air behaves like a perfect spring.

Air and all other gases are very compressible and if the pressures are not too enormous they are all equally compressible. It may seem odd that gases as different as oxygen, hydrogen, chlorine, and steam are all equally compressible, but the reason is not difficult to understand.

It follows first from the fact that all molecules have the same average energy at any given temperature; in other words, any molecule, at, say, 10 °C, whether of oxygen or hydrogen or chlorine, on the average hits just as hard as any other. The light swift molecules of hydrogen on an average hit just as hard as the slow heavy ones of chlorine. Secondly, it follows from the interesting fact that the same volume of any gas contains the same number of molecules. In actual fact, a gallon of oxygen, hydrogen or any other gas at 0 °C contains 1.23x10 (123,000,000,000,000,000,000,000) molecules.

Very well, then, every gas contains (under the same conditions) just as many molecules as any other and every kind of molecule on the average hits just as hard as every other kind, and it is the blow of these molecules that are the pressure of a gas [2, C. 70 - 71].

2.9.4 Look through texts 2.9.1 - 2.9.3 and find the English equivalents for the following Russian phrases and word-combinations:

Совокупность очень рассеянных молекул; в тысячу раз больше простора, чем молекула жидкости; это следует из того, что; по последней причине; люди пришли к пониманию того, что; для различных химических целей; изобретения, которые работают (используют) на воздухе; заставляют воздух сжиматься; расширяется снова; другими словами.

2.9.5 Read the text, translate it and answer the questions: For what purposes are gases liquefied? How can we make gases liquefy? What is the regenerative cooling?

Liquefaction of Gases

Now suppose you put enough pressure on a gas to halve its volume — to make a pint of it into half a pint. The half-pint has as many molecules in it as the pint had. There are twice as many molecules in the gas, so it hits twice as many blows on a given area as it did when it was a pint. Accordingly, it is thrusting on its container twice as hard and it has twice the pressure.

If pressure is put upon any gas the molecules are crowded by the pressure towards each other, and when they get very near to each other they get within the range of each other's attraction. If the gas is one like carbon dioxide or sulphur dioxide, the crowded molecules may pull on each other so strongly that they hang together and the gas becomes a liquid. It is thus possible to turn many gases into liquids simply by compressing them. Ammonia, carbon dioxide, sulphur dioxide, chlorine and some other gases can easily be turned into liquid in this way. Any gas in fact can be turned into a liquid by compressing it — as long as it is not too hot. The jostling of the molecules, which we call heat, prevents the molecules clinging together and making a liquid; the attraction of the molecules pulls them together and causes them to make a liquid.

If there is a strong attraction, as with ammonia or carbon dioxide, pressure will liquefy the gas even if fairly warm; but gases like oxygen or hydrogen can only be liquefied by pressure if their molecules are calmed down by a great deal of cooling. So, if we try to see what happens if we compress a gas to the greatest extent possible, we find that it starts by halving its volume each time we double the pressure. Then we begin to find it more than halves its volume when we double the pressure on account of the molecules attracting each other. Then either the gas collapses into a liquid, or, if it is too hot to do this, increase of pressure drives the molecules still nearer and makes the volume smaller. Now the molecules get so close that they repel each other, and as their outer rings of electrons get nearer the repulsion between them gets huge and the gas becomes more and more difficult to compress and finally is incompressible as a liquid or a solid. The liquefying of gases is an important industry. A gas takes up several hundred times as much room as it does in the form of a liquid and so if we want to send it by train or ship it, it is best to send it as a liquid. Chlorine gas — the green-poison-gas — is used for many quite beneficent purposes such as bleaching, making dyes, medicines, etc. A ton of chlorine as gas would have a volume of 422 cubic yards. It would take about forty railway trucks to hold it.

If chlorine is compressed, it collapses to a greenish liquid, which is run into closed steel boilers mounted on railway wheels. A ton of chlorine as liquid occupies only one cubic yard. The chlorine under the pressure of some seven atmospheres (105 lbs. per 1 square inch) in the boiler remains liquid permanently. If the boiler were to be smashed up in a railway accident the effects would not be quite as disastrous as might be expected, for the evaporation of the liquid would cool it intensely and the gas would be but slowly evolved.

Gases like oxygen and hydrogen will remain liquid only at very low temperatures (— 150 °C to — 250 °C) and so it is almost as difficult to keep them liquid at ordinary temperatures as it would be to keep water liquid if the world were red-hot! Accordingly, we transport oxygen and hydrogen compressed in cylinders to 120 times the pressure of the air. If the cylinder holds 1 cubic foot, we can accordingly pack 120 cubic feet of gas into it. Higher pressures would be too dangerous.

Regenerative Cooling, — Air, oxygen and such other gases as cannot be liquefied by simply compressing them at ordinary temperatures are now easily liquefied on the large scale by what is called “regenerative cooling”.

To liquefy air, we want a temperature of — 185 °C, compared to which the North Pole is a hot-house. Now cooling is just the slowing up of molecules: to liquefy air we want to slow up its molecules. How shall we do this? Well, if you want to slow up a stream of water you can make it push a water-wheel round; if you want to slow a horse, let it pull a cart; if you want to slow a molecule, let it do some work and so part with some of its energy. The method finally adopted is this. First compress your air and let it cool down to room temperature. Then make your cold compressed air push the piston of an air engine round. The piston is speeded up only by slowing the molecules down; in other words by cooling them. The air which comes out of the engine is at about — 50 °C. But this is not nearly cold enough; and this is where the clever trick comes in — we use this cold air to cool the compressed air before it reaches the engine. Our next lot of air reaches the cylinder at, say, — 40 °C, and by pushing the piston slows down its own molecules and comes out at, say, - 90 ºC. This very cold air cools the incoming air still more, so that ever colder air goes on coming into the cylinder and air much colder still leaves it, until quite soon — 180 °C is reached and the air liquefies. Liquid air boils at about — 185 °C, and therefore boiling liquid air is a very good means for making things extremely cold [2, C. 71 - 73].

2.9.6 Read the text, translate it and choose the right form from brackets.

Expansion of Gases

Just as we can cool a gas by ***(make, making)*** it do work, so we can heat it by ***(do, doing)*** work upon it. Suppose, instead of letting the gas push the piston we ***(apply, applying)*** power to the piston and make it push the gas. This speeds up its molecules and makes it hot. It follows, then, that if we ***(compress, compressing)*** a gas it becomes hotter. The ***(better, best)*** example of this is seen in a bicycle pump, which becomes very ***(warm, warmest)*** when a tyre is inflated. Yon might think this was due to the friction of the piston, but if you try working the pump without a tyre, you will find it does not heat up ***(noticeable, noticeably)***.

The expansion of a compressed gas is used in driving steam-engines, petrol-engines, hot-air-engines, etc.

Gases expand very ***(larger, largely)*** when they are heated. We saw that a cubic foot of steel expanded by 5 cubic inches when heated from 0 °C to 78 °C, while a cubic foot of alcohol expanded 150 cubic inches over the same range. A cubic foot of air when heated from 0 °C to 78 °C expands by no less than 493 cubic inches. An interesting thing is that all gases expand to exactly the same extent when heated under the same conditions, which is by no means true for liquid or solids. When a liquid or solid is heated and expands there are two forces at work. The molecules are speeded up and so tend to swing in ***(bigger, biggest)*** orbits or to get further from each other. This effect is the same for all solids or liquids. But the attraction of the molecules opposes this effect; consequently substances whose molecules attract each other ***(strong, strongly)*** will expand little and vice versa. But the molecules of gases are too far from each other to attract each other appreciably, so the effect of heating them is simply to increase the speed and energy of the molecules and make them bounce off each other ***(hard, harder)*** and so fly farther apart. As the same rise of temperature means the same increase of energy, all gases expand ***(equal, equally)***.

The expansion of gases is very large, but it is not very useful for measuring temperatures because they expand and contract not only when the temperature alters but also when the air pressure alters. The expansion of a gas is sometimes used to measure rather high or very ***(low, lower)*** temperatures and also for very accurate work. An air thermometer is rather a difficult affair to handle, and it is used only in the laboratory [2, C. 73].

2.9.7 Try to explain your choice grammatically.

2.9.8 Read the text. Find the definitions of Brownian motion and specific heat of a gas. Summarize the text into 8 main sentences.

Kinetic Theory of Gases

Brownian Motions. — The simplest and most direct evidence for the existence of molecules was first noted by an English botanist by the name of Brown. With a microscope he observed very fine particles held in suspension in water and noted that these fine particles are constantly in motion. The smaller the particles the more freely do they move. The motion of these particles is caused by the incessant bombardment of the molecules of the water or other liquid in which they are suspended. This bombardment of the water molecules is not the same on the different sides of the particles. Hence they are driven hither and thither. An approximate picture of the behavior of such small particles is obtained by projecting on a screen the shadows of finely divided glass particles that are set in motion by rapidly boiling mercury.

Perrin and others who have made careful studies of these motions have found that the distribution of these particles, their velocities, and their mean free paths are precisely what should be expected from the kinetic theory of gases. From these observations it is possible to determine the number of molecules in 1 cu cm of a gas under standard conditions. The fact that the number of molecules per cubic centimeter in a gas as determined in this way is in good agreement with the number derived from the methods involving the kinetic theory of gases shows that the motion of these particles obeys the same general laws as the motion of molecules.

Basic Assumptions. — To explain the physical properties of gases, three basic assumptions are necessary:

1. The molecules of a gas are extremely small, perfectly elastic spheres. This assumption implies that when molecules of gas collide with other molecules or with the walls of the containing vessel, the total kinetic energy of the molecules is not diminished in any way.

2. The molecules move with changing velocities through the space occupied by the gas. Between collisions, their paths are straight lines. This assumption implies that the forces acting on the molecules are negligible except at collision.

3. The time occupied in a collision between two molecules or in a collision of a molecule with the wall is small compared with the time between collisions. This assumption implies that a collision is nearly instantaneous.

Specific Heats of Gases. — The specific heat of a gas depends on whether the gas is heated at constant volume or at constant pressure. These two specific heats are known as specific heat at constant pressure and specific heat at constant volume.

Specific Heat at Constant Volume.—When heat is supplied to a gas in which the volume is kept constant, the pressure increases, and all the energy which is supplied to the gas is used to increase the kinetic energy of the molecules. There is no external work done by the gas. When the temperature of 1 g of the gas is raised through l°C, the gas will absorb C_v units of heat, and this quantity of heat is its specific heat at constant volume.

Specific Heat at Constant Pressure. — In heating a gas 1 °C, at constant pressure the heat required to increase the speed of the molecules will be the same as it was in case the gas was heated an equal amount at constant volume. In addition to this heat, it is necessary to supply a certain amount of heat to do external work while the gas is expanding. For example, if the gas is expanding in a cylinder closed by a moving piston, the molecules after colliding with the piston will rebound with less energy than that with which they reached the piston. Additional energy must be supplied to make up this decrease. Consequently, the specific heat at constant pressure must exceed the specific heat at constant volume by an amount which is just equal to the thermal equivalent of the work which is done when unit mass of gas is heated through 1 °C at constant pressure.

The ratio of the specific heat of a gas at constant pressure C_p to the specific heat at constant volume C_v is

$$k = \frac{C_p}{C_v} \begin{cases} = 1.41 \text{ for air} \\ = 1.66 \text{ for mercury vapor} \end{cases}$$

[2, C. 74 - 75].

2.9.9 Read the text “Properties of Gases”, translate it and choose the best ending to the sentences:

a) Study of air properties…

- is of great importance because of its components: oxygen and nitrogen;
- has the same value for gases study as that of water properties for liquids study;

b) We can find the weight of the air removed from the sphere…

- by using an air pump and the stopcock and counting the difference between two weights before and after pumping out the air;
- by using an air pump at the temperature of melting ice and counting the difference between two weights at different temperatures;

c) Due to the compressibility of gases…

- it is not so difficult to change the volume of the air-filled object;
- the volume of the air-filled object increases very little;

d) According to Boyle's law the volume of the mass of gas …

- depends on the pressure exerted on it;
- is proportional to the pressure exerted on it.

Properties of Gases

Composition of the Air. - Just as water is the most widely distributed and most important of liquids, so the air is the most important and intimate of gases. It consists for the most part of two elements that are mixed together but not chemically combined. These elements are oxygen and nitrogen. In spite of the fact that there is no chemical union between them, the composition of the air is extraordinarily constant. Up to a height of 7 miles it always contains about 21 parts of oxygen to 79 parts of nitrogen. Besides oxygen and nitrogen, the air contains small parts of other gases, the most important of which are water vapor and carbon dioxide.

Weight of Air. - To an ordinary observer the air seems to have no weight and to offer little resistance to bodies moving through it. Yet smoke rises through the air and small balloons ascend out of sight. This is because the air is denser than the gas with which the balloon is filled. The heavier air crowds the lighter gas upward as a piece of wood is forced to the surface of the water because it is lighter than water.

If a hollow glass sphere provided with a stopcock is weighed when the stopcock is open and then connected to an air pump by which as much of the air as possible is removed from the sphere, and if now the stopcock is closed and the sphere weighed a second time, it is found that the second weight is less than the first. The difference between these two weights is the weight of the air removed from the sphere. If the volume of the sphere is known and if it is almost completely exhausted, a fair approximation to the density of the air can be obtained by this method. A liter (1,000 cu. cm.) of air at the temperature of melting ice and under standard conditions of pressure weighs 1.293 g.

Compressibility of Gases. - If an attempt is made to decrease the volume of a liquid by the application of pressure, it is found that it is necessary to apply an enormous pressure in order to get appreciable changes in volume. The behavior of gases in this respect is quite different. It is easy to compress the body of air so that it occupies only one-third or one-tenth of its original volume. As soon as this pressure is removed, the air or other gas springs back to its original volume. The tires of automobiles are ordinarily filled with air. As more and more air is forced into the tire, the volume of the tire increases very little; but the air taken from the outside is forced to occupy much less volume than it originally occupied. As the air is forced into the tire, the pressure it exerts is more and more increased.

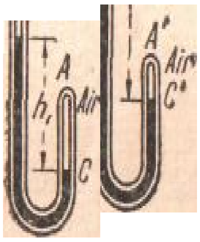


Figure 22 - Boyle's law: pressure times volume is constant

Boyle's Law. Relation between Pressure and Volume of a Gas. - The relation between the volume of any mass of gas and the pressure exerted by the gas upon the walls of the containing vessel was investigated by Robert Boyle and is known as Boyle's law. This law states that at constant temperature the volume of a given mass of gas is inversely proportional to the pressure to which it is subjected. Thus, if V_1 and P_1 denote the original volume and pressure and V_2 and P_2 denote the final volume and pressure,

$$P_1V_1 = P_2V_2 = \text{constant}$$

or for a constant temperature the product of the pressure and the volume is a constant. By pouring mercury into the open end of the tube (Figure 22), the pressure on the air in AC is increased and its volume decreased. Since the density is inversely proportional to the volume, this law states that at constant temperature the density of a gas is proportional to the pressure.

$$\frac{P_1}{P_2} = \frac{d_1}{d_2}$$

For high pressures and low temperatures this law is only an approximation. Gases that can be liquefied by the application of pressure do not obey this law near the temperature and pressure at which they begin to liquefy [10, http://en.wikipedia.org/wiki/Gas].

2.9.10 Look through texts 2.9.5 - 2.9.9 and find the English equivalents for the following Russian phrases and word-combinations:

оказывает давление на свой контейнер в два раза сильнее; обращать многие газы в жидкости; сжимать газ до максимально возможного предела; легко сжижаются широко применяемым способом посредством; другими словами; и вот тут-то и заключается вся хитрость; когда нагреваются в тех же самых условиях; полностью соответствует; наиболее важный и хорошо известный; не смотря на факт, что; вплоть до; поднимаются, теряясь из виду; как только это давление устраняется; по мере того, как всё больше воздуха нагнетается в шину.

2.9.11 Play a game with your partner, where one person is the examiner in physics and the other one is examinee, who has to tell him/her all about gasses (use the information from texts 2.9).

2. 10 Texts Liquids

2.10.1 Read the text, translate it and answer which sentences below are true and which are false.

Liquids at Rest

Characteristics of Liquids. — The molecules of a liquid at rest are displaced by the slightest force, and for this reason a liquid has no shape of its own but takes the shape of the containing vessel. Hence, liquids yield to a continued application of force that tends to deform them or to change their shape in any way. They, however, manifest wide differences in their readiness to yield to distorting forces. Water, alcohol and ether are very mobile liquids, which yield readily to forces tending to change their shape. Glycerin is less mobile, and tar is still less so.

There is no sharp line of separation between liquids and solids. In warm weather, paraffin candles yield under their own weight and bend double. Although shoemaker's wax will break readily when cold, it behaves like a very viscous liquid at higher temperatures. All liquids offer large resistance to forces tending to change their volume. For example, it requires a pressure of 1,500 lb per sq in, to cause the volume of water to change 0.5 per cent.

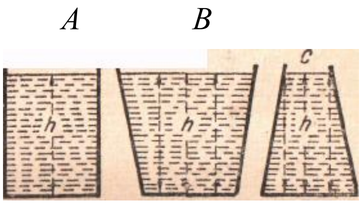


Figure 23 - Pressure independent of shape of the vessel

Pressure in Vessels of Different Shape.—Where a vessel has vertical sides, the pressure on the bottom is equal to the height of the liquid times its density. If the sides of the vessel flare out (Figure 23), might be expected that the force on each square centimeter of the bottom in case *B* would be greater than in case *A* because there is more water in *B*. The pressure in each case is the same. The extra water above the slanting sides is held up by the sides and does not press on the bottom. If the area of the base is the same in case *A* and case *B*, the total downward force on the base in the two cases is the same. When the vessel is conical as in case *C*, the total force on the base is the same as in the preceding case. The pressure on the area directly under the top is the same as in the other cases. The slanting walls press down with a force which, when added to the weight of the liquid, makes the force on each square centimeter of the base in case *C* equal to the force on each square centimeter of the base in case *A* or in case *B*.

Liquids in Communicating Vessels. — It is a matter of common experience that liquids seek their own level in communicating vessels. If tubes of various sizes are connected, liquid poured into one of these tubes will come to the same level in all the tubes. This result is to be expected from the fact that the pressure in a liquid depends on the depth below free surface. If points in the interior of the liquid are at the same level, the pressure at these points must be the same, or the liquid would flow from one point to another until the pressure was equalized.

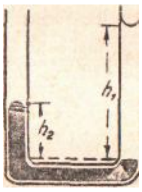


Figure 24 - Density of nonmiscible liquids by balanced columns

Liquids in Communicating Tubes. — Let two liquids that do not react chemically be placed in a bent tube (Figure 24). When the liquids are at rest, the less dense liquid stands at a height h_1 above the junction of the two liquids. The pressure exerted by this column of lighter liquid is just balanced by the weight of the column of heavier liquid that stands above the junction of the liquids. Let d_1 be the density of the lighter liquid, d_2 the density of the heavier liquid, h_1 the height of the lighter liquid above the junction, and h_2 the height of the heavier liquid. Then

$$h_1 \text{ x } d_1 = h_2 \text{ x } d_2 ,$$

$$\frac{h_1}{h_2} = \frac{d_1}{d_2}$$

Hence, the heights of the two liquids above their surface of separation are inversely proportional to the densities of the liquids.

In case the liquids react chemically, the bent tube is inverted and the ends are placed in cups containing the liquids (Figure 25) whose densities will be denoted by d_1 and d_2. The air from the upper part of the bent tube is partly removed and the stopcock closed. The pressure above both liquids inside the tube is the same, and the atmospheric pressure on the liquids in the open vessels is the same. The difference between the pressure inside the tube and the atmospheric pressure is in each case balanced by the rise of the liquid in the tube. These differences in pressure are the same and

$$h_1 \times d_1 = h_2 \times d_2 ,$$

$$\frac{h_1}{h_2} = \frac{d_1}{d_2}$$

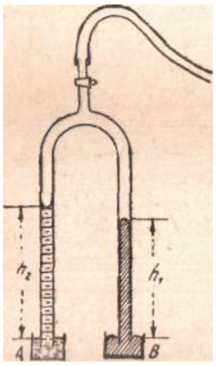


Figure 25 - Densities of miscible liquids.

The heights of the liquids vary inversely as the densities

Example. If one of the beakers in Figure 25 contains sulfuric acid and the other contains water, and if the height of the column of water is 40 cm when the height of the column of acid is 30 cm, find the density of the sulfuric acid.

$$\frac{\text{Density of acid}}{\text{Density of water}} = \frac{\text{height of water}}{\text{height of acid}} ,$$

$$\frac{d_2}{d_1} = \frac{h_1}{h_2} = \frac{40}{30} ,$$

$d_2 = 1.33$ g per cu cm density of acid

A Hydraulic Press. - A hydraulic press consists of a strong cylinder (Figure 26) in which works a cylindrical piston *C*. By means of a small pump *D* oil is forced into the large cylinder through a check valve K, which prevents its return.

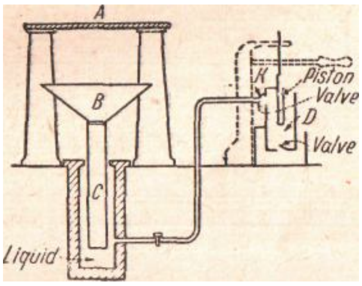


Figure 26 - The hydraulic press produces large forces. Pressure is transmitted uniformly throughout the liquid

In consequence of Pascal's principle, whatever pressure is communicated to the liquid by the pump is transmitted undiminished to the walls of the containing cylinder and the piston *C*. If the large piston *C* has 100 times the area of the small piston *D*, the force exerted on *C* will be 100 times that applied to *D*, and on the downward stroke of the small piston the large piston *C* will be moved only one hundredth the distance through which the small piston moved. If the oil is incompressible, the work done on the large piston is just equal to that done on the small piston, i.e., the input of the machine is just equal to the output. In order to increase the pressure exerted on the piston *C* still further, the small piston is ordinarily forced down by means of a lever. Hydraulic presses are used in baling paper, cotton, etc., in punching holes through steel plates, and extracting oil from seeds. By means of them, a small force operating through a large distance produces a large force operating through a small distance [2, C. 77 - 79].

True or false?

1. The shape of the containing vessel depends on the kind of the liquid and its shape.
2. Liquids always resist changing their volume.

3. To find the pressure on the bottom of the vessel with vertical sides we should multiply height of the liquid by its density.
4. The depth below free surface determines the pressure in a liquid.
5. The heights of two liquids above their surface of separation are proportional to the densities of the liquids.
6. The relation of heights of the liquids in communicating tubes is proportional to the relation of their densities.
7. The check valve in a hydraulic press is used to pump oil into the large cylinder.
8. Thanks to the fact that hydraulic presses help to convert a large force into a small one they are widely used for extracting oil from seeds.

2.10.2 Read the text, translate it and name the main points of the Archimedes' Principle. Finish the following statement:

A body immersed in a fluid would displace the fluid of equal ...

Archimedes' Principle

Buoyancy of Liquids. — It is a matter of common experience that bodies are lighter in water than they are in air. A fresh egg will sink in pure water but will float in water to which a considerable quantity of salt has been added. A piece of iron sinks in water but floats in mercury. This is because the density of the mercury is greater than that of the iron. When a diver lifts a stone under water and brings it to the surface, he finds that the stone is heavier above the surface. In the case of lighter bodies, such as wood or cork, this lifting effect may be sufficient to keep parts of the body above water.

This resultant upward pressure of a liquid on a wholly or partly immersed body is called buoyancy. It is a force acting vertically upward and counterbalancing in whole or in part the weight of the body. A body may float (Figure 27) by being buoyed by more than one liquid at the same time.

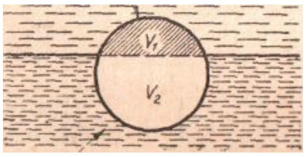


Figure 27 - A sphere floating in two liquids of different densities

That point through which the force of buoyancy acts is the center of buoyancy. This point lies at the center of gravity of the displaced liquid. The buoyant force of all the displaced liquid might be replaced by a single force acting through the center of buoyancy without altering the behavior of the body.

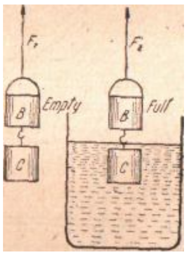


Figure 28 - Test of Archimedes' principle

Suspend from one arm of a balance (Figure 28) a hollow cylindrical cup and a piece of brass which has been nicely turned in the form of a cylinder so that it will just fit the cavity inside the cup. Now counterbalance the weight of the cup and cylinder by adding the necessary weights to another pan of the balance. When a vessel of water is brought up in such a way that the cylinder *C* is completely immersed, it is observed that the side of the balance carrying the cylinder rises, showing that the water is pushing up on the cylinder. If water is now poured into the cup until it is just filled, the equilibrium of the balance is restored. Since the weight of a volume of water equal to that displaced by the cylinder is sufficient to compensate for the lifting effect of the water on the cylinder, it is evident that the cylinder is lifted up by a force equal to the weight of the displaced water. If the experiment is repeated with kerosene or some other liquid instead of water, the same result will always be obtained. The loss in the weight of the immersed body is equal to the weight of the volume of liquid displaced by it.

This analysis and the preceding experiment makes it possible to formulate Archimedes' principle which states that the loss of weight of a body immersed in a fluid is equal to the weight of the displaced fluid, or a body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by it.

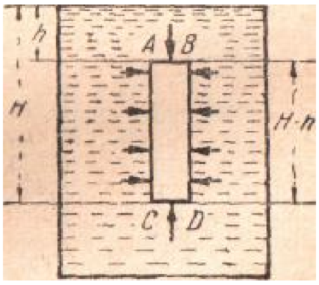


Figure 29 Upward forces on the submerged body equal weight of the displaced liquid

Experimental Demonstration of Archimedes' Principle. — If a rectangular block *ABCD* (Figure 29) is immersed in a vessel of liquid, the pressures on the vertical sides are equal and in opposite directions. These forces will not therefore tend to move the block in the liquid. Upon the upper face of the block, there is a downward force equal to the weight of the column of liquid having this face as a base and having a height *h*. On the lower face, there is an upward force equal to the weight of a column of liquid which has an area equal to the area of the lower base and a height *H* equal to the depth of this face below the surface of the liquid. The upward force exceeds the downward force by the weight of a column of liquid having a base equal to the area of the cross section of the block and a height equal to the height of the block. The volume of this column is just equal to the volume of the liquid displaced by the immersed block, and the weight of this column is equal to the weight of the displaced liquid. The same sort of reasoning will hold for a body of any shape in any liquid. Hence, a body immersed in a liquid is lighter by the weight of the volume of liquid that it has displaced.

Density and Specific Gravity. — In order to determine the density of a body, it is necessary to determine its mass and its volume. The density is then found by dividing the mass by the volume. The mass of the body is easily determined by weighing, but it is sometimes difficult to find the volume, especially when the body has an irregular shape. In such cases, the volume may be determined by an application of Archimedes' principle. Since the body displaces a volume of water equal to its own volume and since each cubic centimeter of water weighs 1 g, the loss of weight in water is numerically equal to the volume of the immersed body.

The numerical value of the density of a body depends on the units which the mass and the volume are measured. In the cgs system, the density is the number of grams per cubic centimeter. In the British system, it is the number of pounds per cubic foot.

The specific gravity of a body is the ratio of its density to the density of water at 4 °C. Since in the cgs system a gram is defined to be the weight of a cubic centimeter of water at 4 °C, the numerical values of the density and the specific gravity in this system are the same. In the British system, however, they are very different.

Density of Solids Heavier than Water. — When a body is heavier than an equal volume of water and is insoluble in water, its volume can be determined by finding its loss in weight when weighed in water. This loss of weight is equal to the weight of the water displaced, and if this loss of weight is expressed in grams, it is numerically equal to the volume of the body in cubic centimeters. By dividing the mass of the body by this volume, the density is obtained.

Density of Solids Lighter than Water. — If the body is lighter than water but insoluble, its volume may still be determined by this method by fastening to the body a sinker large enough to force it below the surface of the water. In this case (Figure 30), the combined weight of the body and the sinker is first determined when the sinker is immersed in water and the body is above the surface of the water.

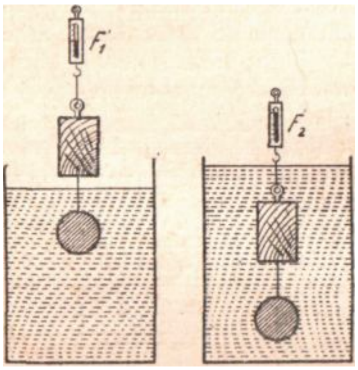


Figure 30 Densities of floating bodies determined by weighing them inside and outside a liquid

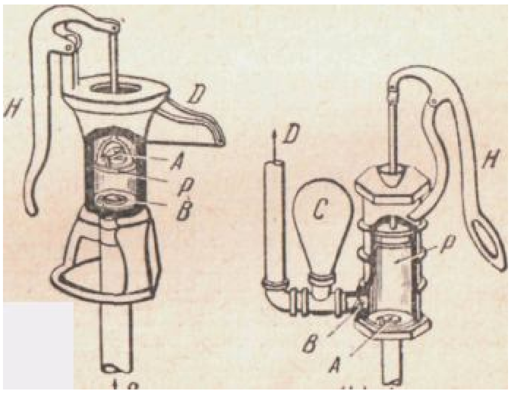
The body is then also submerged and the combined weight redetermined. The change in weight is due to the buoyant force of the water on the body and equal to the weight of the water displaced by the body. It therefore gives the volume of the body in cubic centimeters. The density is then determined as in the preceding case [8, http://ieeexplore.ieee.org/Xplore/ Browse/Journals/Education/IEEE_Transactions].

2.10.3 Read the text, translate it and answer the questions: For what purposes is lift pump used and what's its construction? What's the force pump principle of operation? What type of pump is called a single-acting pump and what is a double-acting one?

Fluids in Motion

Lift Pump. — Water for household or farm purposes is usually lifted out of moderately deep wells by a lift pump. This pump (Figure 31a) consists of a cylinder that is connected to a pipe *S*. The lower end of the pipe *S* is immersed in the water in the well. At the bottom of the cylinder there is a valve *B* that opens upward. A plunger *P* which contains a valve *A* opening upward is moved up and down in the cylinder by means of a pump handle. The valve B in the cylinder prevents any water above it from passing downward. As the handle is forced downward, the plunger is raised with the valve *A* closed. The water above the plunger is thus raised and flows out of the spout. The upward stroke of the piston reduces the pressure in the space below the plunger. The reduction of the pressure in this space allows the pressure of the air on the water in the well to force more water up the pipe *S*, through the valve *B*, into the cylinder. When the piston makes its next downward stroke, the valve *B* closes, and the water above the valve is trapped in the cylinder. During the downward stroke the valve *A* in the piston opens and the water flows above the piston. The upward stroke is again repeated and the water flows out of the spout as before. In order that the pump may operate, the valve *B* must not be more than 30 ft above the surface of the water in the well.

Force Pump. — In the force pump (Figure 31b) the suction pipe *S* with its valve *A* is just like this portion of the lift pump. An outlet pipe with a valve *B* is connected to the lower part of the cylinder. As the piston moves downward, the water in the cylinder is forced through the valve *B* into the delivery pipe *D*. Raising the piston allows the valve *A* to open and water to be forced through it by the atmospheric pressure on the water in the well. On the downward stroke of the piston, this valve closes and the valve in the delivery pipe opens.



↑*S* ↑*S*

Figure 31 a - A lift pump; b - A force pump

In order to obtain a steady stream of water from the pump, an air cushion *C* is provided. On the downward stroke of the piston, the air in this chamber is compressed by the water flowing into it from the delivery pipe. While the piston is making its upward stroke, the compressed air in this chamber expands and forces water through the delivery pipe. That results in this way a more or less steady stream of water through the delivery pipe. The compressed air in this chamber tends to prevent the jars and shocks that would accompany the starting and stopping of the water if it flowed only on the downward stroke of the piston.

Measuring Pumps. — Pumps are often used in measuring the volumes of liquids, especially in the sale of gasoline. The ordinary piston pump can be used for this purpose, if means are provided for defining the length of the stroke and ensuring that each stroke of the piston will discharge the same volume of liquid. This requires that the valves be tight and the piston close fitting so as to prevent leakage or slippage of the liquid past the valves or the piston. Such pumps may discharge either on the upstroke or they may discharge on both the upward and downward strokes. In the former case, they are said to be single-acting pumps and in the latter case they are known as double-acting pumps [2, C. 82 - 83].

2.10.4 Look through texts 2.10 and find the English equivalents for the following Russian phrases and word-combinations:

1.500 фунтов на квадратный дюйм; высота жидкости, умноженная на ее плотность; как показывает общая практика (опыт); посредством малого насоса; площадь в сто раз больше площади малого поршня; одна сотая расстояния; для того, чтобы увеличить давление; целиком или полностью погруженное тело; для того, чтобы определить плотность тела; заставить его (тело) опуститься ниже; вплоть до; для того, чтобы достигнуть постоянного потока; таким образом; в первом случае; в последнем случае.

2.11 Revision texts 2.9 - 2.10

2.11.1 Match words and word-combinations with their translation:

subjected	обратно пропорциональный
insoluble	соударение, столкновение
elbow-room	взвесь, суспензия

lower face	сжимать, сдавливать
to bounce off	заметно, значительно
approximation	основание, предположение
clinging	наклонные стороны
to diminish	отталкивание
to exhaust	сообщающиеся сосуды
cavity	внешняя работа
compressibility	скольжение, проскальзывание
upper face	нижняя грань
suspension	отскакивать рикошетом от чего-либо
inversely propotional	впадина, полость
fizzy drink	слипание
slanting sides	приближение, округление
assumption	свободное пространство
communicating vessels	откачивать, создавать вакуум
repulsion	убывать, уменьшаться
external work	газированный напиток
ratio	снижать скорость, замедлять
to squeeze	надолго, постоянно
noticeably	плавучесть
communicating tubes	увеличивать скорость, ускорять
jostling	мензурка, химический стакан
to yield to	утечка, просачивание
flare out	верхняя грань
permanently	подвергнутый
leakage	нерастворимый
buoyancy	сжимаемость
diaphragm	коэффициент, соотношение
slippage	расходиться раструбом

to slow up	сообщающиеся трубки
beaker	уступать
to speed up	диафрагма, перегородка

2.11.2 Find the sentences with these words and word-combinations in texts 2.9 - 2.10 and translate them.

2.11.3 Prepare the words and word-combinations for a dictation.

2.11.4 Translate from Russian into English.

Жидкости

Жидкость — одно из агрегатных состояний вещества. Основным свойством жидкости, отличающим её от других агрегатных состояний, является способность неограниченно менять форму, практически сохраняя при этом объём.

Жидкое состояние обычно считают промежуточным между твёрдым телом и газом: газ не сохраняет ни объём, ни форму, а твёрдое тело сохраняет и то, и другое.

Форма жидких тел может полностью или отчасти определяться тем, что их поверхность ведёт себя как упругая мембрана. Так, вода может собираться в капли. Но жидкость способна течь даже под своей неподвижной поверхностью, и это тоже означает несохранение формы (внутренних частей жидкого тела).

Молекулы жидкости не имеют определённого положения, но в то же время им недоступна полная свобода перемещений. Между ними существует притяжение, достаточно сильное, чтобы удержать их на близком расстоянии.

Вещество в жидком состоянии существует в определённом интервале температур, ниже которого переходит в твердое состояние (происходит кристаллизация либо превращение в твердотельное аморфное состояние —

стекло), выше — в газообразное (происходит испарение). Границы этого интервала зависят от давления.

Как правило, вещество в жидком состоянии имеет только одну модификацию. (Наиболее важные исключения — это квантовые жидкости и жидкие кристаллы.) Поэтому в большинстве случаев жидкость является не только агрегатным состоянием, но и термодинамической фазой (жидкая фаза).

Все жидкости принято делить на чистые жидкости и смеси. Некоторые смеси жидкостей имеют большое значение для жизни: кровь, морская вода и др. Жидкости могут выполнять функцию растворителей.

Основным свойством жидкостей является текучесть. Если к участку жидкости, находящейся в равновесии, приложить внешнюю силу, то возникает поток частиц жидкости в том направлении, в котором эта сила приложена: жидкость течёт.

В отличие от пластичных твёрдых тел, жидкость не имеет предела текучести: достаточно приложить сколь угодно малую внешнюю силу, чтобы жидкость потекла.

Одним из характерных свойств жидкости является то, что она имеет определённый объём (при неизменных внешних условиях). Жидкость чрезвычайно трудно сжать механически, поскольку, в отличие от газа, между молекулами очень мало свободного пространства. Давление, производимое на жидкость, заключенную в сосуд, передаётся без изменения в каждую точку объёма этой жидкости. Эта особенность, наряду с очень малой сжимаемостью, используется в гидравлических машинах.

Жидкости обычно увеличивают объём (расширяются) при нагревании и уменьшают объём (сжимаются) при охлаждении. Впрочем, встречаются и исключения, например, вода сжимается при нагревании, при нормальном давлении и температуре от 0 °C до приблизительно 4 °C.

Кроме того, жидкости (как и газы) характеризуются вязкостью.

Из-за сохранения объёма жидкость способна образовывать свободную поверхность. Такая поверхность является поверхностью раздела фаз данного вещества: по одну сторону находится жидкая фаза, по другую — газообразная (пар), и, возможно, другие газы, например, воздух.

Испарение – постепенный переход вещества из жидкости в газообразную фазу (пар).

При тепловом движении некоторые молекулы покидают жидкость через её поверхность и переходят в пар. Вместе с тем, часть молекул переходит обратно из пара в жидкость. Если из жидкости уходит больше молекул, чем приходит, то имеет место испарение.

Конденсация – обратный процесс, переход вещества из газообразного состояния в жидкое. При этом в жидкость переходит из пара больше молекул, чем в пар из жидкости.

Испарение и конденсация – неравновесные процессы, они происходят до тех пор, пока не установится локальное равновесие (если установится).

Кипение — процесс парообразования внутри жидкости. При достаточно высокой температуре давление пара становится выше давления внутри жидкости, и там начинают образовываться пузырьки пара, которые (в условиях земного притяжения) всплывают наверх [10, http://en.wikipedia.org/wiki/Liquid].

Vocabulary notes:

квантовые жидкости - quantum liquid;
жидкие кристаллы - liquid crystals;
термодинамическая фаза - thermodynamic phase;

2.12 Texts Heat

2.12.1 Read the text, translate it and give the definition to heat.

Nature of Heat

Heat has much to do with molecular motion; and from the fact that it is able to melt ice, vaporize water and cause bodies to expand, we may well suspect that it is at least closely related to some form of energy. There are many simple experiments which may be performed to support this inference:

1. Try rubbing the face of a button or a coin rapidly against a piece of cloth or wood for a minute or more. It becomes hot.
2. Rapidly bend a rather stiff piece of iron wire back and forth about ten times and then feel the place where the bending was produced. It becomes very warm.
3. Give the end of a nail or a piece of lead a dozen blows with a hammer and then try to detect the heat produced.

These are only a few of the many ways in which heat may be generated at the expense of the work done by the person who performs the experiment. That is, energy is given up by the person and heat appears. A moving train or automobile loses its kinetic energy when the brakes are applied; but an examination of the brakes and wheels will show that energy has been converted into heat.

On the other hand, heat is constantly used in engines for hauling trains, running machinery, and performing work in many other ways. Therefore, the conclusion is that the heat energy is a form of energy [2, C. 84].

2.12.2 Read and translate the text, answer the questions below it.

Heat Is a Form of Energy

The statement that heat is a form of energy raises the question: What form of energy is heat? In mechanics we classify energy as either kinetic or potential. To which of these classes does heat belong?

Let us consider some of the ways in which heat is produced from mechanical energy. The molecules forming a nail are, we believe, in motion. When the head of the nail is struck by a hammer, the top layers of molecules receive the first impulse and move with greater speed, that is, their kinetic energy is increased; but, owing to the frequency of collisions between molecules, the motions are entirely at random, and the particles dash around in all possible directions. Part of the increase of kinetic energy is handed on by impact to the next layers, and so on. Much the same thing happens when the body is rubbed by another. This suggests that heat is kinetic energy of the particles of a body.

But we have seen that there are forces between the particles of a body, as shown by the properties of cohesion, elasticity, etc., and, when work is done against forces of attraction or repulsion, potential energy is produced. Hence changes in the potential energy of the particles of a body must accompany changes in their kinetic energy. Potential might not, it is true, affect the sense of touch in the same way as kinetic energy would, but, since we cannot separate it from the kinetic energy of the particles, we must let it go into the same account and consider it as part of what we call heat. Gases consist of particles which exert such feeble forces on one another, except at impact, that the potential energy is usually negligible. For this reason we shall see that gases play a particularly important part in the study of heat.

Let us now consider what we mean by “particles”. We know all bodies to consist of molecules, and these of atoms, and further that the atoms contain electrons, and that these are also free electrons temporarily separated from atoms and molecules. Moreover, in many bodies molecules are probably united in aggregates forming larger particles. All these various particles receive kinetic and potential energy when a body is heated, and, without distinguishing between them in any way, we may say that their total increase of kinetic and potential energy constitutes the increase of heat.

We must, however, distinguish the motions of a body as a whole, or its “mass-motions” from the “random motions” of the particles. In the former all the particles move in the same way (as in translation) or in some regular way (as in rotation), and, as we have seen, the energy of this motion can be calculated. It is the energy of the motion of the particles in random directions that constitutes heat. A gas or liquid flowing at a high speed in a pipe does not possess more heat because of its mass-motion, though by impact of the particles on the surface of the pipe part of this motion may be turned into the random motion that constitutes heat. Similarly a current of electricity in a wire consists of a stream of electrons in the wire, but this also does not constitute heat, although it may give rise to heat. For the same reason, wave motions of the particles in a body do not constitute heat.

With these explanations we may regard heat as the kinetic energy of the irregular motions of the particles of a body and the potential energy associated with it.

Note. It should be mentioned that the author of mechanical theory of heat is a great Russian scientist M.V. Lomonosov.

Before M.V. Lomonosov's time there existed a so called caloric theory which is in its essence a reactionary theory of heat. Even more than a century after M.V. Lomonosov's death the conception of heat in the form of caloric theory was being spread everywhere.

Only in the last quarter of the 19th century Lomonosov's point of view considering heat as the result of the motion of molecules was revived.

Temperature. - The most familiar temperature is that of the human body. Objects are said to be warm, hot, cool, or cold compared with this temperature. This is not a very reliable or accurate standard. Therefore it is necessary to look for some more accurate method of estimating temperatures. For this purpose at ordinary temperatures it is customary to use a thermometer, which depends for its operation on the fact that a liquid like mercury expands when its temperature is increased.

Mercury Thermometer. - The most common type of thermometer for ordinary use is the mercury-in-glass thermometer. It consists of a small glass bulb to which is sealed a glass tube with a very small bore. The bulb and part of the tube are filled with mercury. The residual air above the mercury in the tube is carefully removed so that the space above the mercury is empty. The glass tube is then sealed off. In order to use this bulb with its fine tube for a thermometer, it is necessary to have on the stem a scale divided into equal divisions called degrees.

Fixed Points. - The two fixed points that are ordinarily chosen for a thermometer are the melting point of ice and the boiling point of water under atmospheric pressure.

To determine the first of these fixed points, the bulb of the thermometer is surrounded with finely divided ice or snow. This melting ice or snow keeps the same temperature while melting. After the mercury in the bulb has reached the same temperature as the ice or snow, the height of the mercury in the stem of the thermometer does not change. The point at which the mercury stands is now taken and used as one of the fixed points on the thermometer. On the centigrade scale, this point is called 0, while on the ordinary Fahrenheit scale it is arbitrarily called 32. The bulb and as much as possible of the stem of the thermometer are now placed in steam rising from water boiling at standard atmospheric pressure. The mercury expands and assumes a new position in the stem. This position, which does not change after the temperature of the thermometer has reached the temperature of the steam, is marked on the scale and used as a second fixed point for the thermometer. On the centigrade scale this point is called 100, and on the Fahrenheit scale it is called 212.

Comparison of Centigrade and Fahrenheit Thermometers. - Consider the thermometer. On one side is a centigrade thermometer and on the other is a Fahrenheit thermometer. The freezing point on the centigrade scale is 0 °C and that on the Fahrenheit is taken as 32 °F. The boiling point on the centigrade scale is 100 °C and that on the Fahrenheit is 212 °F. Hence, 100 divisions, or degrees, on the centigrade scale correspond to 180 on the Fahrenheit scale, and 1 °F on the Fahrenheit scale equals five ninths of 1 °C on the centigrade.

To change from the Fahrenheit to the centigrade scale, first find how many degrees above or below the freezing point of water the temperature is on the Fahrenheit scale, and then take five ninths of this; the result will be the reading on the centigrade scale. In other words, subtract 32 from the reading on the Fahrenheit scale and take five ninths of the remainder.

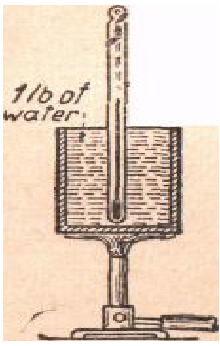
$$\text{Reading on centigrade} = \frac{5}{9}\ (\text{reading on Fahrenheit}) - 32\ ^{\circ}\ \text{F.}$$

$$\text{Reading on Fahrenheit} = \frac{9}{5}\ (\text{reading on centigrade}) + 32\ ^{\circ}\text{C.}$$

Unit of Heat. - Although heat is a form of energy and may be measured in the units in which energy is measured, it is convenient to use a unit that is based on the effect of heat in raising the temperature of a substance. In looking for a substance to use as a standard, it is natural to choose water because of the ease with which it is obtained. Since it always takes the same amount of energy to raise the temperature of 1 g of water 15 °C to 16 °C, it is possible to define an arbitrary unit in which to measure other quantities of heat. Here the choice of the unit is largely a matter of convenience. In this respect, however, it does not differ from the unit of length or the unit of mass which is also chosen arbitrarily.

Calorie. - The unit of heat in the cgs system is called calorie. It is defined as the quantity of heat or energy which is necessary to raise the temperature of 1 g of water from 15 °C to 16 °C on the centigrade scale. Because of the fact that the heat required to raise the temperature of 1 g of water 1°C is not the same at all temperatures, it is necessary to state the temperature at which the calorie is defined.

The British Thermal Unit. - In the English system of units, the unit of heat is known as the British thermal unit (Btu). It is defined as the quantity of heat required to raise the temperature of 1 lb of water from 59 °F to 60 °F on the Fahrenheit scale (Figure 21). This is a much larger unit of heat than the calorie. Here, as in the case of the calorie it is necessary to state the temperature, for the amount of heat required to raise 1 lb of water 1 °F varies with the temperature.



59° to 60°F

Figure 32 - One British thermal unit is the quantity of heat required to raise the temperature of 1 Ib of water 1°F

Specific Heat. - So far we have been dealing with a single substance, viz., water. The amount of heat required to raise the temperature of 1 g of another substance 1 °C may be compared with the amount of heat required to raise the temperature of 1 g of water from 15 °C to 16 °C. Such a comparison gives a definition of what is called the specific heat of the substance. The specific heat of a substance is numerically equal to the number of calories required to raise the temperature of 1 g of the substance 1 °C, or, what amounts to the same thing, the number of British thermal units required to raise the temperature of 1 lb of the substance 1 °F.

Let Q denote the quantity of heat added to a mass of M g, let t and t' be the initial and final temperatures, and let S be the specific heat of the body. Then

$$Q = SM(t - t')$$

Heat of Combustion. - The heat of combustion is the heat liberated by burning unit mass or unit volume of a fuel, such as coal or gas. To find it, the fuel is placed in a crucible *C* inside a bell jar, which is closed so that the products of combustion cannot escape except through the openings at the base of the jar. The bell jar is placed inside a vessel, the mass of which is known, and this vessel is then filled with a known weight of water. The temperature of the water is determined, and then a supply of oxygen is admitted through the opening at the top of the bell jar until all the fuel has been burned. The products of combustion bubble up through the water. When the combustion is complete, the temperature of the water is again observed. From these data the heat of combustion of the fuel can be found.

$$\text{Heat of combustion} = \frac{\text{mass of water x temperature change x sp ht}}{\text{mass of fuel}}$$

where sp ht = specific heat

In this expression for the heat of combustion, it is assumed that the water equivalent of the calorimeter is so small that it can be neglected in comparison with that of the water in the calorimeter. In case this is not true, the water equivalent of the calorimeter must be added to that of the water in the calorimeter [2, C. 84 - 88].

Questions to the text "Heat Is a Form of Energy":

1. What type of energy is heat: kinetic or potential?
2. Why do gases play an important part in the study of heat?
3. Who was the author of mechanical theory of heat?
4. Regarding what standard is temperature usually estimated?
5. What is the principle of mercury thermometer operation?
6. What is the difference between Centigrade and Fahrenheit Thermometers?
7. What unit is more convenient to measure heat?
8. What is calorie?
9. What is the British thermal unit?
10. What is the specific heat of a substance?
11. How can we find the heat of combustion?

2.12.3 Read the text, translate it and answer which sentences below are true and which are false.

Fusion

The Melting Point. - If a vessel of ice or snow is heated, the temperature at first rises until it is 0 °C and then remains stationary until all the ice is melted. After all the ice has been melted, the temperature of the water begins to rise. That temperature at which the solid changes into a liquid without a change of temperature is called the melting point. For ice this temperature is 0 °C or 32 °F. At the melting point, the addition of heat simply serves to hasten the melting process without any change of temperature.

If a pail of water is placed in a freezing mixture of ice and snow, the temperature of the water decreases until ice begins to be formed in the pail. After this temperature has been reached, the temperature of the water in the pail remains the same until all the water has become ice. That temperature at which the liquid changes into the solid state is its freezing point. This temperature is ordinarily the same as the temperature at which the solid melts. For crystalline substances, such as ice or copper, the freezing point or the melting point is sharply defined. For substances that are not crystalline, such as wax or glass, the substance gradually softens in passing from the solid to the liquid state. Such substances do not have a definite melting point. In the cases of certain fats, the melting point is not the same as the freezing point. For example, butter melts between 28 °C and 32 °C and solidifies between 20 °C and 23 °C.

Heat of Fusion. - In order to cause a solid like ice to change into a liquid, it is necessary to supply a given quantity of heat to each gram or each pound of it. The heat of fusion of a substance is defined to be the number of calories necessary to convert 1 g at the melting point into liquid at the same temperature. It may also be defined as the number of Btu that must be supplied to change 1 lb of the solid to liquid without a change of temperature. To change 1 g of ice to water at 0 °C requires 80 cal, and to convert 1 lb of ice to water at 32 °F requires 144 Btu.

Effect of Pressure on the Melting Point. - Since an increase of pressure tends to cause a body to contract, the melting point of ice, which contracts on melting, is lowered by the application of pressure. Careful experiments show that this lowering is 0.0075 °C for an increase of 1 atm of pressure. If, on the other hand, a substance expands upon melting, its melting point will be raised by the application of pressure.

The effect of pressure on the melting point of ice may be shown by taking a piece of ice which is about 1.5 ft long and 6 in. square, and hanging over it a loop of wire from which a weight of 35 or 40 lb is supported. The pressure of the wire on the ice lowers the melting point of the ice, so that it is in a condition to melt as soon as the necessary heat is supplied. In order to melt each gram, it is necessary to supply 80 cal to it. This heat is taken from the water above the wire, causing it to freeze again. This process continues, until the wire cuts its way through the block of ice, leaving the block as solid as it was at the beginning of the experiment.

Boiling Point of Water. - Fill a flask half full of water, and insert a thermometer in one of the holes in the stopper. In the other hole insert a short glass tube through which the steam may escape. Heat the flask over a flame until the water boils. By reading the thermometer from time to time, it will be found that no matter how rapidly the heat is applied, the temperature does not rise above 100 °C. It will be noticed that at a certain temperature bubbles forming at the bottom of the flask rise to the surface, growing in size as they rise. That temperature at which the bubbles begin to reach the surface of any given liquid is called the boiling point or the boiling temperature. The boiling point can be defined as the temperature at which the pressure of the saturated vapor of the liquid is equal to the pressure of the atmosphere on the surface of the liquid.

Effect of Pressure on the Boiling Point. - Since the boiling point of a liquid is the temperature at which the vapor pressure of the liquid is the same as the outside pressure on it, it follows at once that when the outside pressure is changed, the boiling point will also change. This is easily understood if we recall that ordinarily the pressure of the atmosphere is 14.7 lb to the square inch. If this pressure is decreased, it will not be necessary to raise the temperature so high in order to allow the bubbles to form. When the pressure is raised, it will be necessary to raise the temperature still higher in order to produce bubbles. The bubbles will form only when the pressure of the vapor in the bubble is equal to the pressure on the surface of the liquid.

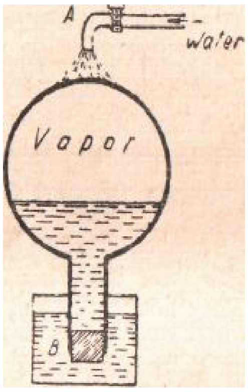


Figure 33 - The boiling point is lowered by the reduction of the pressure above the liquid

The Influence of pressure on the boiling point can be shown by filling a flask (Figure 33) half full of water and boiling it vigorously for some time to remove the air from above the water. Insert a rubber stopper in the flask, rendering the flask airtight. Remove the flask immediately from the flame. Invert the flask, and pour cold water on the bottom. This cold water will cause some of the vapor in the flask to condense, and the pressure on the hot water in the flask will be reduced sufficiently to allow the water to begin boiling again [2, C. 89 - 91].

True or false?

1. Different substances have different melting points.
2. Freezing point is such a temperature that, for example, is required to turn water into ice.
3. To find the heat of fusion of a substance we should find the number of calories necessary to convert 1 g at the melting point into solid at the same temperature.
4. We can change the melting point of a substance with the help of pressure.
5. The pressure of the saturated vapor at boiling point is greater then the pressure of the atmosphere on the surface of the liquid.
6. The boiling point does not depend on the outside pressure.

2.12.4 Read the text, translate it and give the definitions to convection and conduction.

Transfer of Heat

Convection. – The simplest way in which heat may be transferred from one place to another is by the motion of the heated substance. Such a transfer is known as convection. It is caused by the change in density that takes place when the substance is heated. For example, when a gas or a liquid is heated, it expands and becomes lighter than the cold gas or liquid. When water is heated in a vessel on a stove, the liquid in the bottom of the vessel is hotter than that on the top. The density at the bottom is less than that near the top. The cool liquid sinks down and forces the warmer liquid to a higher level. The currents of water thus set up in the liquid are known as convection currents.

Conduction. - When a metal rod is held in the fire, the heat travels along the rod and after a time the rod becomes too hot to hold. In this process the vibrations of the molecules are handed on from molecule to molecule. The layer of molecules in contact with the fire is heated first and thus made to vibrate more rapidly. This layer hands the motion on to the adjacent layer, because each layer is bound to the adjacent layer by certain cohesive forces. It is thus impossible for the molecules in one layer to vibrate without setting the molecules in the neighboring layers in vibration. As this process goes on, the entire medium is heated after a time. When heat, as in this case, is transferred from one part of the body to another without any progressive motion of the parts of the substance, the heat is said to be transferred by conduction. The conductivity differs widely according to the nature of the substance. Steam pipes are covered to reduce heat losses [2, C. 91].

2.12.5 Read the text Heat and Work, translate it and choose the best ending to the sentences:

a) By supplying heat to a gasoline engine we transform…

- heat into a work;
- work into a heat;

b) While transforming heat into work and inversely work into heat…

- an enormous energy can be created;
- energy remains the same;

c) Due to the second law of thermodynamics heat always flows…

- from higher to lower temperatures;
- from higher place to the lower one;

d) The slide valve is used in steam engines.…

- to prevent heating;
- to cut off the supply of steam;

e) The gasoline engine is.….

- the most sophisticated type of engine;
- the commonest type of engine;

f) The vertical axis and the horizontal axis in the diagram of gas work represent.….

- pressure and volume;
- pressure and temperature;

g) The diagrams representing the work done by a gas expanding at constant pressure and at variable pressure…

- are similar;
- do not differ;

h) To find the useful work done in one complete cycle it is required…

- to subtract negative work from the positive work;
- to subtract positive work from the negative work.

Heat and Work

Transformation of Heat into Work. - The heat engines that play such a large part in modern life depend on the transformation of heat into work. The heated steam in the cylinder of a steam engine does work in pushing the piston back. This work is available for driving the machinery connected to the engine. A gasoline engine can drive an automobile or a tractor only when it is supplied constantly with heat from the exploding gasoline in the cylinders. In these cases, heat is transformed into work.

First Law of Thermodynamics. - The first law of thermodynamics is a special case of the law of conservation of energy. It is implied in the definition of the mechanical equivalent of heat and may be expressed by the equation

$$W=JH,$$

where W = the work measured in work units;

H = heat measured in heat units;

J = the mechanical equivalent of heat.

More specifically, the law states that when any mechanical change occurs in an isolated system, the energy of the system remains constant. Heat may be transformed into work or work into heat, but the total energy of the system remains unchanged. In other words, the first law of thermodynamics states that in the transformation of work into other forms of energy or in the transformation of one form of energy into other forms of energy, no energy is ever created or destroyed. The energy before and after the transformation is always the same. This law in its general form can not be proved by experiment but conclusions based on it have always been confirmed by experiment.

Second Law of Thermodynamics. - The second law of thermodynamics states the conditions under which heat may be transferred from one body to another. It is in effect a statement of the fact that heat naturally flows from a place of higher to one of lower temperature but never in the reverse direction. An analogue may make the meaning clearer. Water may flow from a higher to a lower level with the performance of work. Heat may flow from a higher to a lower temperature with the performance of work. To make water flow from a lower to a higher level requires external work to be done on it. To cause heat to flow from a lower to a higher temperature also requires the performance of external work. The natural tendency of heat to flow from a higher to a lower temperature makes it possible for a heat engine to transform heat into work. On the contrary, a mechanical refrigerating machine must transfer heat from a colder to a hotter body. Work must be done on such a machine to make this transfer. The following is one form of statement of the law:

It is impossible for any kind of a machine working in a cycle to transfer heat from a lower to a higher temperature unless external work is done on it. A similar statement of the water analogy would be: It is impossible for a pump working in a cycle to transfer water from a lower to a higher level unless external work is done on it. The law cannot be proved by direct experiment. It is a generalization based on the fact that in all human experience no contradictions of the law have been found. It merely states that heat of itself can flow only from higher to lower temperatures and no exceptions to this rule are known.

Steam Engine. — In a steam engine (Figure 34) a closely fitting piston moves in a cylinder that is connected to the steam chest by means of two pipes, which are provided with valves, serving alternately as inlet and exhaust for the steam. As the piston moves forward, steam enters through *A* and the used steam is forced out through *B*.

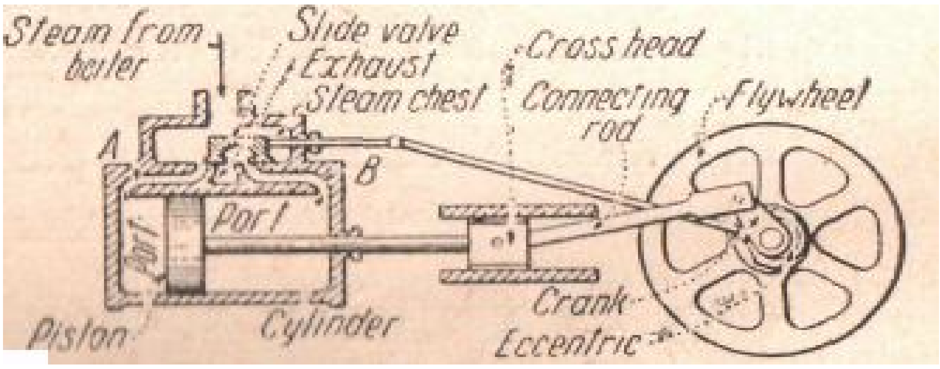


**Figure 34 - Steam engine cylinder and plane slide valve.
A case of transformation of heat into work**

When the piston moves in the opposite direction, steam enters the cylinder *B* and used steam is forced out at *A*. With this simple arrangement, the steam would leave the cylinder on exhaust at a temperature nearly as high as that at which it entered it. A considerable quantity of heat would thus be carried to the condenser or the outside air and lost so far as useful work is concerned. In order to prevent this waste as far as possible, an automatic cutoff is provided. When the piston has moved through about one fourth of its stroke, this slide valve automatically cuts off the supply of steam.

After this cutting off of the steam from the steam chest the steam that has already entered the cylinder expands and pushes the piston forward, through the remainder of the stroke. During this expansion, the piston is doing work, the pressure of the steam is being reduced, and the temperature of the steam is lowered. The heat contained in the steam is thus converted into useful work.

When the piston has reached the end of this stroke, the slide valve opens *A* and connects *B* to the steam chest. Live steam is now again admitted to the cylinder behind the piston and it pushes the piston toward the left. The dead steam in front of the piston is forced through *A*. When, as before, the piston has made about one fourth of its stroke, the slide valve closes *B*, and the steam behind the piston expands until the piston has reached the end of its stroke. The cycle is then repeated.

The pressure of the steam in the boiler is regulated by means of a pop valve, which allows the steam to escape when the pressure exceeds a certain value.

Gas Engine. - Gas engines and gasoline engines operate on the same principle. In each case the energy is derived from the explosion of a mixture of air and gas or gasoline vapor. The gasoline engine is now the commonest type of engine. It is used to drive motorcars, motorboats, tractors, etc.

Work Done by a Gas Expanding at Constant Pressure. - Let a volume of gas be enclosed behind a piston which is airtight and which moves without friction. Let the pressure acting on the piston be denoted by p and the area of the piston by S. The total force acting on the piston pushing it backward is

$$F=pS$$

If, now, the gas in the cylinder is heated, it may be allowed to expand without any change in its pressure, and the piston moves back through a distance x. Work done on piston = force X distance = $p \times S \times x$

Now $S \times x$ = increase of volume of the gas during expansion.

Hence

$$\text{Work} = p \times \text{change in volume}$$

It is convenient to represent the work done by the gas by plotting the pressure of the gas on the vertical axis and the volume of the gas on the horizontal axis. In this case, the pressure is constant for all volumes. Hence, *AB* represents the relation between the volume and the pressure. If V_1 denotes the original volume and V_2 the final volume, the length of the line *ab* represents the change in volume during expansion. The product of the change in volume and the pressure is represented by the rectangle *ABba*. This area stands for the work done by the gas during its expansion; and since this work is equal to the heat supplied to the gas during expansion, this rectangle also represents the heat taken in by the gas during its expansion.

Work Done by a Gas Expanding at Variable Pressure. - If the gas expands under a variable pressure, the work which it performs may be represented by a diagram similar to that representing the work done by a gas expanding at constant pressure. In this case the line *AB* (Figure 35), instead of being horizontal as in the preceding case, slopes toward the horizontal axis along which the volumes are plotted. Nevertheless, the area under *AB* will represent the work done by the gas as it expands with changing pressure. It is possible to construct a rectangle having the same base as the figure *ABba* and the same area. The height of this rectangle would be the average pressure of the gas during its expansion. If the varying pressure acting on the piston has been replaced by a constant pressure equal to the average pressure, the work done by the gas will remain unchanged. The average pressure may then be defined as the constant pressure by which a varying pressure may be replaced without changing the amount of work done on the piston for the same stroke.

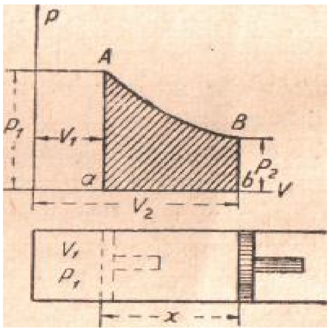


Figure 35 - Work done by a gas at variable pressure equals average pressure times change of volume

Positive and Negative Work. — In the preceding cases the work done on a piston by the expanding gas was discussed. Such work must be considered positive. In order to force the dead steam or the burned gases out of the cylinder, the piston on its return stroke must exert a force and must therefore do work. This is the work done to return the piston to its initial position ready for a new forward stroke. It represents a waste, or loss, that must take place in order to make the working stroke of the piston possible. To distinguish this work from the work done on the piston by the gases in the forward stroke, it is called negative. This work done on the gases by the piston must be subtracted from the work done on the piston by the gases in order to obtain the useful work done by the piston in one complete cycle [2, C. 93 - 97].

2.12.6 Look through the text and answer the questions: For what purpose should we know work efficiency? How can we calculate it?

Efficiency

Since heat and work are convertible, the most important thing to know about any device for this purpose is its efficiency, which gives a measure of the amount of heat which can be transformed into work under a given set of conditions. The ratio of the work obtained from the machine to heat put into it is called the efficiency of the machine. Both the heat and the work must be measured in the same units. In finding the efficiency of a burner used to heat a kettle of water, it is necessary to find the amount of gas consumed by the burner and the amount of heat thus developed. It is next necessary to find the amount of heat that gets into the water in the kettle. The ratio obtained by dividing the heat that gets into the water by the heat developed by the burning of the gas is called the efficiency of the burner. The efficiency may be defined as the fraction which tells what portion of the total heat supplied is used for the purpose for which it was intended.

$$\text{Efficiency} = \frac{\text{heat used}}{\text{heat supplied}}$$ [2, C. 97 - 98].

2.12.7 Read the text, translate it and answer the questions: What type of energy: potential or kinetic is more widespread? What is a mechanical energy? What do we call the appliances for energy converting?

Energy Transformation. Varieties of Energy

There are many sources of energy in the world both potential and kinetic. One source consists in water falling from high level such as an upland lake. Another source is wind or moving air. Others are in tides in the sea, also heat from subterranean sources and lastly coal deposits and oil wells yielding mineral oil. But all these sources and stores of energy are not equally useful to mankind. Moreover, some stores of energy such as coal and oil can never be replaced by us when once used up. On the other hand stores of high level water are continually being replaced by rain and wind and tides will not, as far as we know, ever cease to exist.

Hence a very important matter is the conversion of energy from one form to another. The form most required by us is mechanical energy.

We require to rotate shafts in a factory for driving various machines and also for driving the wheels of vehicles of automobiles or locomotives. The energy of water power is very unequally distributed. Some countries such as Norway and Switzerland are rich in it and some such as England are poor.

Appliances for converting energy from one form to another are called engines. Thus a heat engine is a machine for converting heat into mechanical energy by the combustion of coal or oil and a water engine (water turbine) can convert the kinetic energy of falling water into mechanical energy. Another important matter to all such engines and transformation is the question of their efficiency or the ratio of the energy delivered in the desired form to that given to the engine in the available form. Thus, for instance, in the case of a heat engine we give it so much heat by combustion of coal or oil, and we take from it so much mechanical energy in kinetic form rotational or motional and the important question is the ratio of the latter to the former. In most cases it is very small [2, С. 98].

2.12.8 Look through texts 2.12 and find the English equivalents for the following Russian phrases and word-combinations:

теплота тесно связана с молекулярным движением; мы можем вполне подозревать; ударьте по концу гвоздя молотком раз десять (слово dozen -

дюжина в русском переводе заменяется словом десяток или десять в тех случаях, когда не имеется в виду строго определенное число); вследствие частоты столкновений между молекулами; движения совершенно беспорядочны; почти то же самое случается, когда; мы должны также учитывать её (потенциальную энергию); наиболее привычная температура; из-за того факта, что; удельная теплоемкость (теплота) вещества; чтобы найти ее, топливо помещается в; не важно насколько быстро подводится тепло; в нижней части сосуда; на дне; действует утверждение того факта, что теплота; наоборот; для того, чтобы предотвратить; работают по тому же принципу.

2.13 Texts Sound

2.13.1 Read the text, translate it and answer the questions: What is the nature of wave motion? Why do transverse waves have such a name? What examples of transverse waves can you name?

Wave Motion and Sound

Wave Motion. - One of the most important phenomena in nature is the transformation of energy from one point to another by wave motion. This kind of motion is illustrated in many ways. When a stone is dropped into a pool of still water, the surface of the water is covered with circular wavelets which widen out from the central point where the stone fell. The water does not really move outward from the central point, but it rises and then falls again. One can see something alike observing a floating leaf or piece of wood. It does not move forward but return again to its former position. Hence, the water, on which the leaf rests, must have the same kind of upward motion rather than a forward motion.

When one end of a rope is fastened to a rigid wall and the free end moved up and down rapidly, each jerk travels along the rope, each portion of the rope communicating the jerk to the next portion. Each particle to the rope imparts its upward or downward motion to its neighbours. The jerk moves forward, but the particles of the rope move only up and down. Motions of this kind are wave motions. In all these cases it is evident that there is a vibrating center which produces motions in those portions of the medium immediately in contact with it, and that these portions impart their motions to the neighbouring portions.

Transverse Waves. - If part of a stretched string is drawn aside, the tension in the string tends to bring it back to its position of equilibrium. Since the string has inertia, the force that causes the displacement requires time to produce its full effect so that a wave can travel along the string with a definite velocity. Waves of this kind are easily produced in a rope fixed at one end and held in the hand at the other. If the rope is lightly stretched, a jerk imparted to the end *B* travels down the rope as a wave. The more tightly the rope is stretched, the more rapidly the jerk travels down it. If a series of to-and-fro movements is imparted to the end *B* a series of waves travels down the rope. Such waves are known as transverse waves, because the particles of the medium in which the waves travel move perpendicular to the direction of the wave motion. They can be easily represented by plotting the displacements on the vertical axis and the distance from the source in a given direction on the horizontal axis. Light and other forms of electromagnetic waves are excellent illustrations of transverse waves [2, C. 99].

2.13.2 Read the text, translate it and find one wrong statement in the list of the main statements below the text.

Production and Transmission of Sound

Nature of Sound. - The source of sound is always in a state of vibration. As the vibration dies down, the intensity of the sound diminishes. If a ringing bell is touched with the fingers, the sound ceases because the vibrations are stopped by the fingers. When a weight falls to the floor, the weight as well as that part of the floor which is struck is set in vibration, and sound waves are produced. If a stretched guitar string is plucked, it gives a musical note owing to the vibrations set up in it. These vibrations take place too fast for the eye to follow them, and the string seems to be drawn out into a ribbon in the middle. In a vibrating tuning fork the prongs alternately approach and recede from each other. These movements of the prongs can be felt by touching the prongs with the fingers. They produce compressions and rarefactions in the surrounding air that travel forward as sound waves.

Velocity of Sound. - The velocity of sound depends on the density and the elasticity of the medium. The greater the elasticity and the less the density, the greater is the velocity. The relation between the velocity, the density, and the elasticity of the medium is expressed by the formula

$$v = \sqrt{e/p},$$

where v = the velocity of sound;

e = the modulus of elasticity of the medium;

p = the density of medium.

The Intensity of Sound. - When sound waves spread out in every direction from a source of sound, the intensity varies inversely as the square of the distance from the source. In this case, the sound spread out as spheres. The same amount of energy is transmitted across every spherical surface having its center at the source of sound. The larger the surface of these spheres, the smaller the energy that goes through each square centimeter of surface. The surfaces of these spheres increase as the squares of their radii. Hence, the energy that passes through unit area decreases as the squares of the radii increase.

Vibrations of Wires and Strings. - When the center of a stretched string is displaced and then released, the disturbance is handed on from one element of the string to the next and a transverse wave is produced. These waves are reflected at the fixed ends of the string, return to the center of the string where they pass each other, and go on to the ends where they are again reflected. They combine to form stranding waves in the string. When the string is plucked in the middle, the whole string vibrates as one segment. When the string is held lightly at the middle point and plucked at a point midway between the middle and one end, the string vibrates in two segments. In a similar way, the string may be made to vibrate in three, four, etc., segments. The frequency of the sound is increased as the number of segments increases.

If plucked at random, the string may vibrate as a whole and at the same time be vibrating in segments. The note from the string then consists of the fundamental together with one or more overtones. In this case, the stationary wave in the string is the resultant of the fundamental vibration and all the overtones.

Velocity of Transverse Waves in Strings. - The velocity of a transverse wave along a flexible stretched string is constant for a given tension. Whatever the nature of the wave, its velocity of propagation is the same so long as the tension is unchanged [10, http://en.wikipedia.org/wiki/Sound].

Main statements:

1. Sound intensity depends on the vibration frequency of the source.
2. The properties of medium determine the velocity of sound.
3. The larger the distance, the weaker the sound intensity while moving away from the source.
4. The stranding waves in a string produce the transverse waves.
5. The velocity of transverse wave in a string depends on tension.

2.13.3 Look through texts 2.13 and find the English equivalents for the following Russian phrases and word-combinations:

чем более туго веревка натянута, тем быстрее рывок; также, как и та часть пола; скорость звука зависит от плотности; чем больше упругость и меньше плотность, тем больше скорость; обратно пропорционально квадрату расстояния.

2.14 Revision texts 2.12 - 2.13

2.14.1 Match words and word-combinations with their translation:

rarefaction	тигель
heat of fusion	насыщенный пар
generalization	произвольная единица
dash around	отсекать
to force out	отводить в сторону
viz. (videlicet)	ускорять
to-and-fro movement	затухать
crucible	подпочвенный, подземный
jerk	наделять, сообщать
tension	обертон
saturated vapor	мчаться, сновать
airtight	противоречие
inference	когезия, сцепление
hand on	энергично
hasten	теплота плавления
at impact	произвольно
overtone	точка (температура) кипения
adjacent layer	застывать, затвердевать
dead (used) steam	разреженность
boiling point	производить, составлять
arbitrary unit	клониться, иметь наклон
subterranean	напряжение
to cut off	точка (температура) замерзания
elasticity	передавать
vigorously	то есть, а именно
to solidify	выгонять, вытеснять

to impart	рывок
arbitrarily	возвратно-поступательное движение
to constitute	обобщение
contradiction	отработанный пар
freezing point	предположение, гипотеза,
to die down	смежный слой
to draw aside	воздухонепроницаемый
cohesion	при сжатии
to slope	упругость, эластичность

2.14.2 Find the sentences with these words and word-combinations in texts 2.12 - 2.13 and translate them.

2.14.3 Prepare the words and word-combinations for a dictation.

2.14.4 Translate from Russian into English.

Количество теплоты — это энергия, которую получает или теряет тело при теплопередаче. Количество теплоты является одной из основных термодинамических величин. Количество теплоты, полученное системой, зависит от способа, которым она была приведена в текущее состояние [10, http://en.wikipedia.org/wiki/Heat].

Плавление — переход тела из кристаллического твёрдого состояния в жидкое. Плавление происходит с поглощением удельной теплоты плавления.

Способность плавиться относится к физическим свойствам вещества. При нормальном давлении, наибольшей температурой плавления среди металлов обладает вольфрам (3422 °C), среди простых веществ вообще - углерод (по разным данным 3500 — 4500 °C) а среди произвольных веществ — карбид гафния HfC (3890 °C). Можно считать, что самой низкой температурой плавления обладает гелий: при нормальном давлении он остаётся жидким при сколь угодно низких температурах.

Многие вещества при нормальном давлении не имеют жидкой фазы. При нагревании они сразу переходят в газообразное состояние.

У сплавов, как правило, нет определённой температуры плавления. Фиксированной температуры плавления нет также у аморфных тел; они переходят в жидкое состояние постепенно, размягчаясь при повышении температуры [10, http://en.wikipedia.org/wiki/Melting].

Звук — волны, продольно распространяющиеся в среде и создающие в ней механические колебания.

Как и любая волна, звук характеризуется амплитудой и частотой. Считается, что человек слышит звуки в диапазоне частот от 16 Гц до 20 кГц. Звук ниже диапазона слышимости человека называют инфразвуком, выше, до 1 ГГц, — ультразвуком, от 1 ГГц — гиперзвуком.

Звуковые волны могут служить примером колебательного процесса. Всякое колебание связано с нарушением равновесного состояния системы и выражается в отклонении её характеристик от равновесных значений. Для звуковых колебаний такой характеристикой является давление в точке среды, а её отклонение — звуковым давлением.

В жидких и газообразных средах, где отсутствуют значительные колебания плотности, акустические волны имеют продольный характер, то есть направление колебания частиц совпадает с направлением перемещения волны.

В твёрдых телах, помимо продольных деформаций, возникают также упругие деформации сдвига, обусловливающие возбуждение поперечных (сдвиговых) волн; в этом случае частицы совершают колебания перпендикулярно направлению распространения волны. Скорость распространения продольных волн значительно больше скорости распространения сдвиговых волн [10, http://en.wikipedia.org/wiki/Sound].

Vocabulary notes:

карбид гафния - hafnium carbide;
аморфное твердое тело - amorphous solid;
инфразвук – infrasound;
ультразвук – ultrasound;
гиперзвук – hypersound;
сдвиговая волна - shear mode.

3 Section III Supplementary texts

3.1 Texts Optics

3.1.1 Read, translate and retell.

Propagation of Light

Velocity of Light. - Light is a transverse wave motion. It travels through empty space, as well as through such transparent substances as glass, air, and water. Its velocity, which is 186,000 miles per sec, is so great that in 1 sec it would travel more than seven times around the earth at the equator. Light travels from the sun to the earth in a little over 8 min, but it requires 4 years for light to travel from the nearest star to the earth. If the North Star were obliterated, the earth would continue to receive light from it for about 44 years.

Frequency and Wave Length. - The relation between frequency, velocity, and wave length is the same for light waves as it is for sound waves. Waves of yellow light have been found to have a wave length equal to about 0.000059 cm. The wave length of light is often expressed in angstrom units. One angstrom unit = 10^{-8} cm.

Rectilinear Propagation of Light. - Under ordinary circumstances light travels in straight lines and does not appreciably bend around objects. That light travels in straight lines may be shown by placing a candle or other source of light behind a screen having in it a small hole (Figure 36). In front of this screen *AB* are placed two screens *CD* and *OF*, each with a small hole at the center. When these screens are so adjusted that the eye *E* can see the source of light *S* distinctly, it will be found that the straight line joining *S* and *E* passes through the holes in the screens. This shows that light from *S* to *E* comes in a straight line.

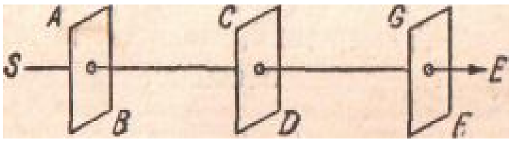


Figure 36 - Rectilinear propagation of light

Sources of Light. - The sun is the chief source of light and heat, but there are many artificial sources. Any body when heated to a sufficient high temperature becomes a source of light.

As the temperature of a body is raised, the body emits invisible radiations. When it becomes red-hot, visible radiations begin to be emitted. The higher the temperature, the greater is the amount of both heat and light waves that are emitted, but the percentage of visible radiations becomes larger and larger as the temperature of the source of radiations is increased. For this reason, the modern tungsten lamp is much more efficient than the old carbon incandescent lamp. Tungsten has a very high melting point, and when it is surrounded by nitrogen or when it is in a vacuum, it can be heated to a high temperature and its efficiency thus made large [2, C. 102 - 103].

3.1.2 Read, translate and retell.

Reflection and Refraction of Light

Laws of Reflection. - When a beam of light, travelling in a homogeneous medium, comes to a second medium, some of the light is reflected. At a polished or silvered surface, nearly all the light is reflected. At the surface of clear glass, only a small part of it is reflected. The greater part of it enters the glass and passes through. In Fig, 37, let *AB* represent the reflecting surface, *MP* the perpendicular or normal to this surface, *OP* the incident ray, and *PN* the reflected ray. The angle *OPM* between the incident ray and the normal to the surface is called the angle of incidence. The angle *MPN* between the reflected ray and the normal to the surface is called the angle of reflection. Reflection at such a surface occurs according to the following two laws:

1. First law of Reflection. The incident ray, the reflected ray, and the normal to the surface lie in the same plane.
2. Second law of Reflection. The angle of incidence is equal to the angle of reflection.

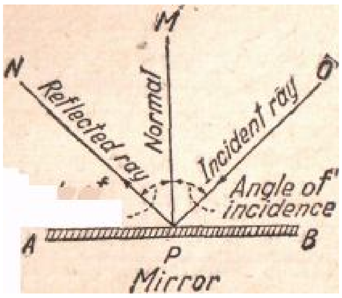


Figure 37 - Reflection of light from a plane mirror. The angle of incidence is equal to the angle of reflection

Refraction. - Experiments have shown that light travels with the greatest speed in a vacuum and that it travels with different speeds in different mediums. When it passes obliquely from one medium to another in which it has a different velocity, there occurs a change in the direction of propagation of the light. This bending of the ray of light when passing from one medium to another is known as refraction.

Refraction can be illustrated by taking a cup which is opaque (Figure 38) and placing a coin on the bottom of it at the point *B*, so that the far edge of the coin can just be seen when the eye is at *E*. If now, without moving the eye, water is poured into the cup, the coin will come completely into view. The ray *BA* as it leaves the water is bent away from the normal *NA*. Other rays are bent in a similar manner, and an image of the coin is formed at *C*, so that the depth of the coin below the surface of the water seems to have been lessened. Here it is seen that rays coming from the water to the air are bent away from the normal. The rays are always bent away from the normal when they enter a medium in which their velocity is greater than it was in the medium from which they came.

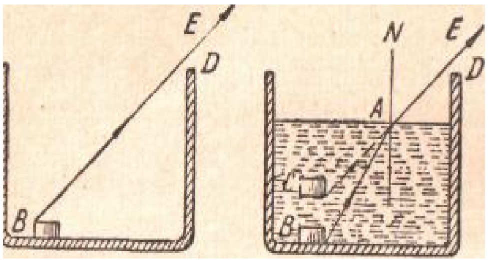


Figure 38 - Refraction of light. The rays bend away from the normal on leaving the water

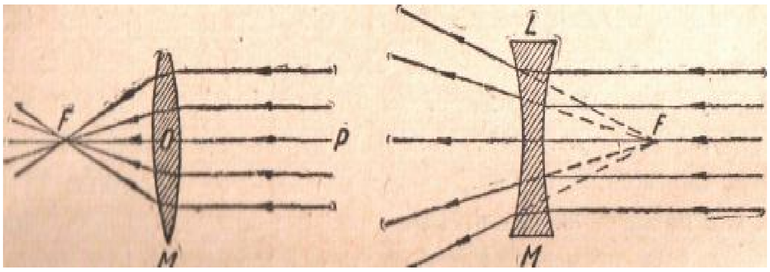
Refraction through a Prism. - A wedge-shaped portion of a refracting medium bounded by two plane surfaces is called a prism. If the medium of which the prism is composed is optically denser than the surrounding medium, a ray of light incident on one of the faces will be bent toward the normal to the face on entering the prism. On emerging from the opposite face, the ray will be going from a denser to a rarer medium and will be bent away from the normal at that face. The angle through which the ray has been deflected in passing through the prism is called the angle of deviation. When the angle at which the ray enters one face is equal to the angle at which it leaves the opposite face, the angle of deviation has its least value and is known as the angle of minimum deviation.

Critical Angle. - When a ray of light passes from a dense medium such as water to a rarer medium such as air, it is bent away from the normal so that the angle of refraction is greater than the angle of incidence. If the angle of incidence is made larger and larger, the angle of refraction will also become larger and larger and will always be greater than the corresponding angle of incidence. When the angle of incidence is increased sufficiently, the angle of refraction becomes 90 deg, and the refracted ray travels along the surface of separation between the two mediums. That angle of incidence for which the angle of refraction is 90 deg is called the critical angle [2, C. 103 - 104].

3.1.3 Read, translate and retell.

Optical Instruments

Lenses. - Lenses are bodies made of transparent material and bounded by faces having a cylindrical or spherical form. Although lenses differ much in form they may be divided into two classes according to the way in which they act on a parallel beam of light. Consider the lens in Figure 39a on which parallel rays are incident. Each ray is bent toward the normal to the surface on entering the lens and away from the normal on emerging from the lens. In this way, the rays above the axis *PO* are bent downward and those below it are bent upward. After leaving the lens, the rays converge to a point F, called the principal focus. Such a lens is a converging lens. If the incident rays are parallel to each other, the incident wave front is a plane perpendicular to the incident rays. When this wave front emerges from the lens, it has been changed to a concave wave front that converges to the focus. When the bounding surfaces of the lens are very convex, the lens converges the rays rapidly. This gives the lens a short focal length.



a b

Fig. 39 a - Principal focus of a converging lens. The incident rays are parallel to the principal axis *POF*; b - Principal focus of a diverging lens

When the bounding surfaces are only convex, the lens has a long focal length. In order that all the rays may come to a point after leaving the lens, the beam of light must be restricted to a narrow bundle near the principal axis of the lens. For an extended beam the outer rays will not pass through the same point as the rays near the axis.

When the surfaces of the lens are concave instead of convex, the lens makes the rays that pass through it more divergent, and for this reason it is known as a diverging lens. In Figure 39b parallel rays are incident on a concave lens. On entering the lens, the rays are bent toward the normal as before, and on leaving they are bent away from the normal. In this case, however, the emerging rays are bent away from the principal axis. They appear on leaving the lens to come from a point *F* behind the lens. When the incident rays are parallel to each other and to the principal axis, this point from which the rays appear to come on leaving the lens is the principal focus. This is only an apparent focus because the light does not really come from it, but the effect on the left-hand side of the lens is the same as if the light actually came from this point behind the lens. This kind of focus from which the light appears to come is a virtual focus. It is to be carefully distinguished from a real focus through which the light actually goes.

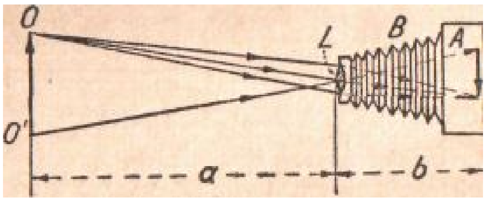


Figure 40 - Photographic camera

If the lens is convex, and the incident rays come from a point source, the incident wave front is spherical, and the emerging wave front is the surface of a sphere with its center at the image. If the lens is concave, the curvature of the wave front is increased in passing through the lens, and the image is behind the lens.

The Photographic Camera. - The simplest application of lenses for optical purposes is in an ordinary photographic camera (Figure 40). A lens or combination of lenses in one end of the camera produces a real image of an external object on the photographic plate or film at the other end of the camera. The distance between the lens and the photographic plate or film can be altered so as to focus the image on the plate. Sometimes the photographic plate is replaced by a ground-glass screen on which the image is cast, and then the lens is moved into such a position that the image is sharply focused on the ground glass. The plate or film is then substituted for the ground glass. The bellows *B* serves to exclude all the light except that which comes from the object. It also makes possible the to-and-fro motion of the lens necessary in the focusing.

To avoid spherical aberration, i.e., the distortion of the image because all the rays do not come to the same focus, and to limit the quantity of light, a diaphragm is placed in front of the lens. This diaphragm restricts the rays to those which pass through the central portion of the lens. The smaller the diameter of the hole in the diaphragm, the better is the definition of the image. On the other hand, the smaller this opening, the less the intensity of the light forming the image on the plate. Where it is desired to have the image as bright as possible, the choice of the size of the opening in the diaphragm becomes a compromise between diminished brightness on the one hand and definition on the other hand.

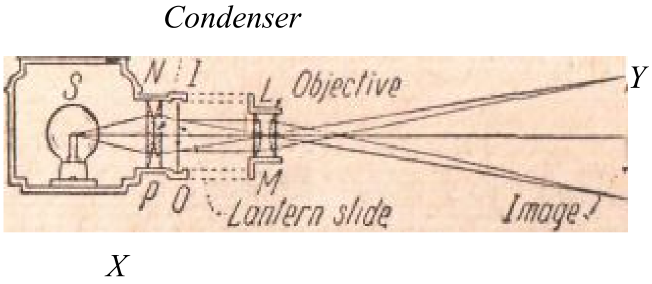


Figure 41 - Projection lantern. It produces real, inverted, and magnified images

Projection Lantern. - The projection lantern, which is used to throw an image of a brilliantly illuminated object on a screen consists of a powerful source of light *S* (Figure 41), a large condensing lens *NP*, and a front or objective, lens *LM*. The condensing lens *NP* collects the light from the source *S* and sends it through the slide *OI*, so that this slide is brilliantly illuminated. The objective *LM* then produces a real image of the slide *OI* on the screen *XY*. Since the slide *OI* is just outside the principal focus of the lens *LM*, the image on the screen is enlarged. This image is also real and inverted. The magnification produced by the lantern is obtained from an application of the law for the magnification of a lens.

Simple Microscope. - When an object is placed slightly nearer to a converging lens than its focus, an eye brought up to the lens sees a virtual, erect, and magnified image *A'B'* (Figure 42). A lens used in this way constitutes a simple microscope. In order to obtain the greatest advantage, the eye should be as near as possible to the lens. In this way, the field of view is made as large as possible, and the distance of the virtual image *A'B'* from the eye for distinct vision is made as large as possible.

In order to find the magnification of a lens used in this way, it is necessary to consider that the apparent size of an object is determined by the angle it subtends at the eye. Now for most distinct vision, an object must be about 10 in. from a normal eye. If an object is placed at a greater distance than this, the image on the retina is smaller and its details are not seen so distinctly. When the object is placed nearer than 10 in., the image on the retina is blurred. When an object is examined with the aid of the magnifying glass, the object is brought nearer to the eye than would be possible for distinct vision without the magnifying glass. In Fig. 42 the angles subtended at the center of the lens by the object *AB* and the image *A'B'* are the same. But *OD* is the distance of distinct vision, and, if the lens were absent, the eye could not see *AB* distinctly until it was removed to *ab*.

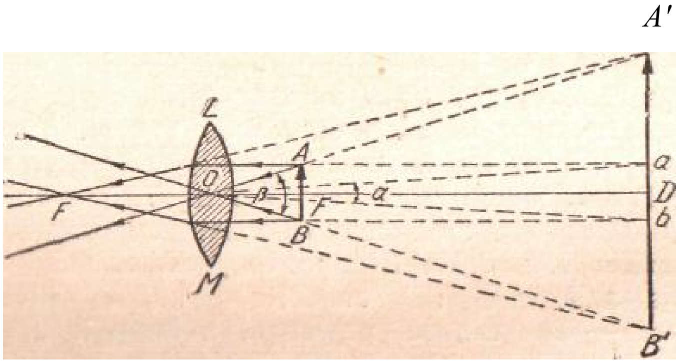


Figure 42 A simple microscope. It produces virtual, magnified, and upright images

Opera or Field Glasses. - The opera glass consists of an objective *LM* which converges the rays toward the point *S* (Figure 43), but before they reach this point they pass through the diverging lens *NP* which replaces the eyepiece of the telescope. In passing through this diverging lens, the rays that were converging on entering it are made to diverge on leaving it. To an eye on the right-hand side of the lens *NP* the rays seem to have come from a point *A'* behind the concave lens *NP*, which thus forms the virtual and erect image *A'B'* of the object from which light was received. Unlike the astronomical telescope, the opera glass gives an erect image. To have the opera glass in focus, the lens *NP* must be so placed with respect to the objective that the rays emerging from the lens *NP* are nearly parallel.

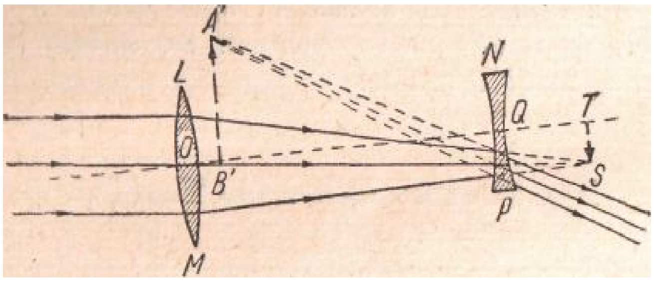


Figure 43 - Opera or field glasses. They produce virtual and upright images

Standards of Illumination. - The intensity of illumination is measured by the amount of light which falls on unit area of a surface. The amount of energy received by unit surface cannot be easily determined in absolute measure. The eye is the most sensitive means of detecting light, but it does not give a quantitative measure of it. By means of the eye it is possible, however, to make an accurate comparison of two intensities of illumination.

To compare sources of illumination, a standard source of illumination is necessary. The choice of these standards is more or less arbitrary. There are a number of such standards in use. The British standard candle is defined to be a candle made of spermaceti, weighing six to the pound and burning at the rate of 120 grains per hr. This standard does not have a sufficiently constant illuminating power to make it of scientific value. Its illuminating power changes with atmospheric conditions and with the conditions under which it is burned.

Candle Power. - The candle power of a lamp is a specification of its illuminating power in terms of some standard candle. For example, the illuminating power of an incandescent lamp may be thirty times that of a standard candle and is then said to be a 30-cp lamp. But the illuminating power of a light varies according to the direction from which it is observed. It becomes necessary, therefore, to measure the average candle power in a given plane. The average illuminating power in the horizontal plane is called the mean horizontal candle power. The mean spherical candle power denotes the average illumination by a source of light from all directions in space.

The Foot-candle. - A Foot-candle is the intensity of illumination upon a surface at a point which is 1 ft distant from a source of 1 candle, the surface being perpendicular to the light rays at that point.

The Lumen. - The unit used to denote quantity or amount of light is the lumen. A lumen is the amount of light falling on a surface that has an area of 1 sq ft when every point of the surface is 1 ft from a point source of light of 1 candle [2, C. 104 - 108].

3.1.4 Note to text 3.1.3:

- a 30-cp lamp - лампа мощностью в 30 свечей (cp - candle power)

3.2 Texts Magnetism and Electricity

3.2.1 Read, translate and retell.

Magnetism

Magnets. - A peculiar mineral (Fe_3O_4) called lodestone was found in early times in the neighborhood of Magnesia in Asia Minor. This mineral has the power of attracting small particles of the same mineral and of setting itself in one particular direction when suspended. When a piece of this lodestone is dipped into iron filings, they adhere to it. It is found that there are two places on each piece of this mineral at which the iron filings adhere in greatest quantities. If such a piece of lodestone is suspended by means of a silk thread, it is found that the line joining the places at which the iron filings adhere in greatest quantities points north and south.

When a steel knitting needle is stroked from one end to the other with a piece of lodestone, using for point of contact one of the points at which the iron filings adhere most freely, the needle acquires the property of attracting iron filings and of setting itself north and south when suspended. Such a needle is called an artificial magnet. There are other ways in which more powerful artificial magnets can be made. The properties of these magnets do not differ in any way from those of the needle, except that they are much more powerful.

Magnetic Poles. - On dipping a magnetized needle into iron filings it is seen that the iron filings adhere most strongly at the ends of the needle. These places at which the tendency of the iron filings to cling to the needle is greatest are called poles. If that end of a suspended needle may be disturbed, it will come to rest with the marked end pointing north. For convenience, it is desirable to call the end of the magnetic needle that points north the north-seeking pole, or *N* pole. The other end is called the south-seeking pole, or the S pole.

Law of Force between Magnetic Poles. - Experiments show the following:

1. Like poles repel each other, but unlike poles attract each other. Thus, two *N* poles repel each other and two *S* poles repel each other, but *N* pole and *S* pole attract each other.

2. The force with which the poles of two magnets attract or repel each other, in a vacuum, is equal to the product of the pole strength divided by the square of the distance between the poles.

Magnetic Field. - The space outside the magnet in which its influence can be detected is called the magnetic field. In the case of powerful magnets this space extends far from the magnet, but in the case of feeble magnets the magnetic field is so weak that it may be considered as confined to a small region near the magnet.

At every point near a magnet or a system of magnets, a free magnetic pole would experience a force tending to drive it in a definite direction. The direction in which a free *N* pole would move is called the direction of the magnetic field and the magnitude of the force on unit pole is known as the intensity of the magnetic field. The intensity of the magnetic field, or the magnetic intensity, is thus defined to be the mechanical force measured in dynes that is exerted on unit pole at a point in free space. The unit of magnetic intensity is called the oersted. If the magnetic field is such that there is a force of 1 dyne on unit pole, the magnetic field or the magnetic intensity at that point is 1 oersted.

Unit Pole. - A unit pole is a pole of such strength that it will repel a similar pole of equal strength with a force of 1 dyne when placed 1 cm away from it in a vacuum. An isolated pole is not a physical possibility, since every magnet must have an equal south pole for every north pole. It is possible to realize approximately the conditions assumed in this definition by supposing that the magnets are very long, so that the influence of the other pole is small. The number of unit poles on the end of a magnet is measured by the number of dynes of force that it will exert on a unit pole 1 cm from it in a vacuum.

The force in air differs little from the force in a vacuum. Hence, the distinction between air and vacuum may be neglected.

Magnetic Lines of Force. - In order to make it easier to understand the way in which the magnetic field changes from point to point, it is convenient to draw certain lines (Figure 44) which by their direction represent the direction of the magnetic field and by their number represent the intensity of the magnetic field.

Such lines are called lines of magnetic force. Such a line of magnetic force is the path along which a perfectly free *N* pole would travel when left alone in the magnetic field. Since such a free *N* pole cannot be obtained in practice, a small compass needle is used to determine the direction of the magnetic field at a point.

When the compass needle comes to rest, its axis points in the direction of the magnetic field at that point.

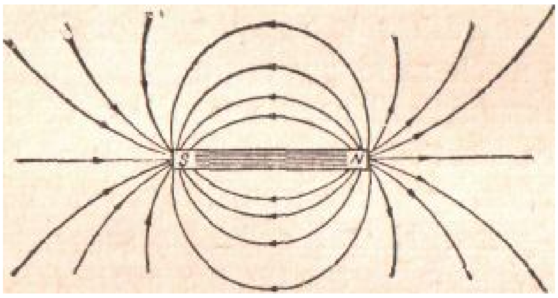


Figure 44 - Magnetic lines of force around a bar magnet

In order to represent the strength of the magnetic field, there is a well-established convention concerning the number of lines of force to be drawn per unit area. The agreement is that the number of lines of force per square centimeter shall be just equal to the number of dynes with which the field would act on a unit pole. For example, a magnetic field equal to 10 oersteds is represented by drawing 10 lines of force per square centimeter.

Molecular Theory of Magnetism. - It is assumed that every substance which is capable of being magnetized consists of a very large number of molecular magnets, probably no larger than the molecules out of which the substances are made. When the substance is unmagnetized, these molecular magnets are not arranged in any particular direction, but are oriented indiscriminately. When the substance is magnetized, a larger number of them are made to point along the axis of the magnet than point in another direction. In the interior of the magnet, the little north poles lie so close to the little south poles that each destroys the influence of the other. At one end of the bar are tree north poles, and at the other end are free south poles. The sum of all these little north poles makes the *N* pole of the magnet, and the sum of all the little south poles makes the *S* pole of the magnet.

Magnetic Induction. - When a bar magnet is placed near a piece of unmagnetized iron, the elementary magnets in the iron tend to arrange themselves so that all the *N* poles point in one direction and all the *S* poles in the opposite direction.

The piece of iron thus becomes a magnet so long as it is in the presence of the permanent bar magnet. South-seeking poles are produced near the north-seeking pole of the bar magnet and north-seeking poles at the other end of the piece of soft iron. This process of magnetization is known as magnetization by induction.

Molecular State of a Magnetized Body. - It is found that when a magnet is broken in two, two complete magnets result, two new poles appearing at the fracture. These poles must have existed in the original magnet, but without producing external effects, since they neutralized each other.

Hence magnetization is a state existing everywhere in a magnet, but manifested only at the poles. On breaking the magnet into still shorter pieces, we still get complete magnets. While the subdivision cannot actually be carried to parts of the size of molecules, there are strong reasons for believing that the molecules (or atoms) of a magnetic substance are magnets.

We can now explain what takes place when a rod of iron is magnetized. The molecular magnets in the unmagnetized rod were like a lot of small magnets thrown into a box, their axes being turned in all directions. In magnetizing the rod we twist the molecular magnets around so that their axes are more or less parallel to the length of the rod, a process that can be imitated by using a glass tube filled with iron filings. The more completely they are lined up in this direction, the stronger is the resulting magnet.

In this position they possess potential energy which they had not before, and this came from the work we had to do to turn them. It is found that there is a limit to the strength to which a rod can be magnetized by using stronger and stronger inducing magnets. All the molecular magnets then agree in direction and the rod is described as saturated.

Hammering, bending, or twisting an iron rod when it is near a magnet increase its magnetization, and they also tend to demagnetize a permanent magnet, owing to the agitation of the molecules that they produce. A permanent magnet can also be demagnetized by heating it to a red heat, since heat is in itself a molecular disturbance and tends to destroy the alinement of the molecules. For the same reason soft iron cannot be magnetized temporarily when it is at a red heat. A long wire of soft iron mounted to swing will cling to the pole of a magnet, but it loses its hold when heated by a Bunsen burner.

When out of the flame it again becomes magnetic and returns to the magnet, and so it continues to vibrate. A similar experiment with a strip of nickel attached to a blackened copper disk (to promote cooling) succeeds when the source of heat is merely an alcohol flame, since nickel loses its magnetic properties at a much lower temperature than iron. The critical temperature is called the Curie point [2, C. 108 - 111].

3.2.2 Read, translate and retell.

The Electron Theory

According to modern theory whole matter is composed of atoms, tiny particles that are the building blocks of the universe. There are many kinds of atoms, one or more for each chemical element. Each atom consists of a nucleus, a small, tightly packed positively charged mass, and a number of larger, lighter, negatively charged particles called electrons, which revolve about the nucleus at tremendous speed. The centripetal force necessary to draw these electrons into their circular or elliptical paths is supplied by the electrical attraction between them and the nucleus. The nucleus consists of a number of protons, each with a single positive charge, and (except for hydrogen) one or more neutrons which have no charge. Thus the positive charge on the nucleus depends upon the number of protons that it contains. This number is called the atomic number of the atom. A neutral atom contains equal numbers of electrons and protons. Each electron carries a single negative charge of the same magnitude as the positive charge of a proton, so that the attraction between the nucleus of an atom and one of the electrons will depend on the number of protons in the nucleus.

An electron has a mass of $9.105X10^{-28}$ gm. Since the mass of a proton or a neutron is about 1.840 times that of an electron, the mass of the atom is concentrated in the nucleus. The chemical properties of the atom are determined by the number of protons in the nucleus.

A solid piece of material consists of inconceivably large number of atoms clinging together. Though these atoms may be vibrating about their normal positions as a result of thermal agitation, their arrangement is not permanently altered by this motion. Also present in solids are numbers of free electrons, so called because they are temporarily detached from atoms. The number and freedom of motion of these electrons determine the properties of the material as a conductor of electricity. A good conductor is a material containing many free electrons whose motion is not greatly impeded by the atoms of which the material is composed.

As a result of the repulsive forces between them, free electrons spread throughout the material, and any concentration of them in any one region of the material will tend to be relieved by a motion of the electrons in all directions away from that region until an equilibrium distribution is again reached.

In the best conductors the outer electrons of the atoms can easily be removed, so that a free electron with an atom often causes an outer electron to leave the atom. When this happens the ejected electron becomes a free electron, moving on, while its place in the atom is taken by another free electron that encounters the atom. An insulator or poor conductor is a substance that contains very few free electrons and whose atoms have no loosely held orbital electrons.

Electrification. - If a piece of sealing wax, hard rubber, or one of many other substances is brought into intimate contact with wool or cat's fur, it acquires the ability to attract light objects such as bits of cork or paper. The process of producing this condition in an object is called electrification, and the object itself is said to be electrified or charged with electricity.

There are two kinds of electrification. If two rubber rods, electrified by being brushed against fur, are brought near each other, they will be found to repel each other. But a glass rod rubbed with silk will attract either of the rubber rods, although two such glass rods will repel each other. The charge on the glass is evidently unlike that on the rubber. These facts suggest that objects that are similarly charged repel each other; bodies with unlike charges attract each other.

The electrification produced in a glass rod by stroking it with silk is arbitrarily called positive electrification, while that produced in the rubber rod by contact with wool is called negative electrification. It is ordinarily assumed that uncharged objects contain equal amounts of positive and negative electricity. When glass and silk are rubbed together, some negative electricity is transferred from the glass to the silk, leaving the glass rod with a net positive charge, and the silk with an equal net negative charge. Similarly, hard rubber receives negative electricity from the wool with which it is in contact, causing the rod to be negatively charged and leaving the wool positive.

Though a similar explanation could be made by assuming a transfer of positive electricity, it has been shown that in solids only negative electricity is transferred [8, http://ieeexplore.ieee.org/Xplore/Browse/Journals/Journal of Applied Physics].

3.2.3 Notes to text 3.2.2:

- the building blocks of the universe - кирпичи мироздания;
- tightly packed – плотная.

3.2.4 Read, translate and retell.

Electrostatics

Two Kinds of Electricity. - If a pith ball is hung from a support by a silk thread, and a rubber rod that has been electrified by stroking it with cat’s fur is brought near it, the pith ball is at first attracted to the rod. If the pith ball is allowed to come in contact with the rod, it is found that the ball is repelled by the rod. When a glass rod which has been rubbed with silk is brought near the same pith ball carrying the charge which is received from the rubber rod, the charged pith ball is attracted by the electrified glass rod. There are then two states of electrification, or, as it’s usually said, two kinds of electricity: that which appears on an ebonite rod when rubbed with cat's fur and that which appears on a glass rod rubbed with silk. These charges differ in one important respect. Charges which are alike repel each other, and charges which are unlike attract each other. That kind of electricity which appears on a glass rod that has been rubbed with silk is called positive electricity and the kind which appears on an ebonite rod rubbed with cat's fur is called negative electricity.

Electric Field of Force. - The region surrounding one or more charged bodies is known as the electrostatic field. It is frequently represented by drawing lines which represent the direction in which the force on a positive charge acts at different points in the neighborhood of the bodies. Such lines are called lines of force. They show the direction in which a positive charge would move if it were placed in the field of force.

The intensity of an electric field is determined by the force that unit positive charge experiences when placed in it. Suppose that A (Figure 45) is a charged sphere having an electrostatic field about it. The intensity of this field at P is the force that would be required to hold unit positive charge in position at P. The force on q units of electricity at P would be q times as great as the force on unit charge. If E denotes the intensity of the electric field at P and q the number of unit charges located at P, then the force F on this charge is

$$F = Eq \text{ dynes}$$

An electrostatic field has an intensity of unity when it exerts a force of 1 dyne on unit charge at that point.

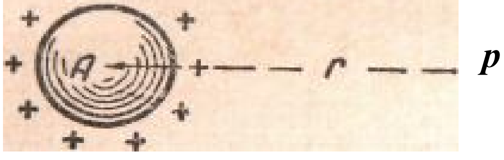


Figure 45 - Definition of intensity of an electric field

Positive and Negative Charges. - The only way to charge a body negatively is to add electrons to it, and the only way to charge it positively is to take electrons away from it, leaving an excess of positive electricity. When the rubber rod was charged negatively by rubbing with cat's fur, some electrons passed from the cat's fur to the rubber rod, leaving the cat's fur charged and the rubber charged negatively. On the other hand, when the glass rod was charged positively by rubbing with silk, some electrons passed from the glass to the silk, leaving the glass rod charged positively and the silk charged negatively.

In the normal condition, the amount of positive electricity in the atom is just equal to the amount of negative electricity on its electrons. One or more of these elections may be detached from the atom, leaving it with an excess of one or more positive charges of electricity. In such a case, the residue that is left after detaching these electrons is what is called a positively charged ion. On the other hand, an atom may gain one or more electrons in excess of its quota. It has on it then one or more negative charges and becomes a negatively charged ion. For example, when hydrochloric acid dissociates to a form 3 hydrogen ions and chlorine ions, the chlorine takes one more electron than its normal quota, thus giving it one negative charge and making it a negatively charged ion. Since the molecule of hydrochloric acid is originally neutral, the hydrogen is left with one less electron than its quota and is thus charged positively and becomes a positive ion.

Conductors and Insulators. — In some cases the forces holding the electrons to the atoms are not very large. They may be detached temporarily and wander about in the vacant space between the atoms. Thus in copper and silver some of the electrons become detached from the atoms and wander about for longer or shorter times in the interstices between the atoms. Under the action of an electric force, these electrons migrate through the metal. Such substances in which there are free electrons which can be made to migrate through the substance under the action of an impressed electric force are called conductors. Metals belong to this class, of bodies.

If the electrons are rigidly bound to the atom so that they do not become free except under the action of very large forces, no free electrons will be found in the vacant spaces between the atoms. If an electric force is applied to such a substance, it cannot cause the electrons to migrate through the substance, and there is no flow of electrons from one part of the substance to the other. If an excess number of electrons be placed on one part of such a substance, they will remain there without wandering to other parts of the body. The most that an impressed electric force can do in such a case is to cause a limited displacement of the electrons within the atom without causing the electrons to migrate from atom to atom. Such substances are called nonconductors, or insulators. To this class of substances belong mica, porcelain, quartz, glass, wood, ebonite, etc.

The Electroscope. — One form of gold-leaf electroscope consists of a metal sphere (Figure 46) which is fastened by means of a metal rod to two thin gold leaves.

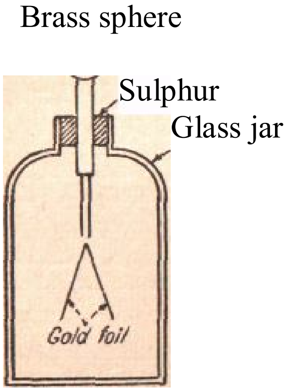


Figure 46 - Cold-leaf electroscope. The leaves are repelled when charged but collapse when the charge escapes

The metal rod passes through a sulphur plug by which it is insulated from the glass jar in which the leaves are mounted. When the brass sphere and the leaves are uncharged, the leaves collapse and hang together. When some electrons are removed from the sphere, leaving the sphere and the leaves charged positively, the leaves diverge because of the repulsion between the like positive charges on them. If part of the positive charge is neutralized by adding some electrons, the gold leaves partly collapse. If all the positive charge is neutralized, the leaves collapse completely. If an excess of electrons is now added to the sphere, electrons will move to the leaves charging them with negative electricity. This causes the leaves to diverge again because of the repulsive forces between the like charges [2, С. 114 - 116].

3.2.5 Note to text 3.2.4:

- in excess of its quota - сверх его доли, т. е. сверх его обычного количества электронов.

3.2.6 Read the text in Russian and translate it from Russian into English.

Теория хаоса

Одной из наиболее интересных и до конца не исследованных теорий классической механики является теория хаоса.

Теория хаоса представляет собой математический аппарат, описывающий поведение некоторых нелинейных динамических систем, подверженных при определённых условиях явлению, известному как хаос. Поведение такой системы кажется случайным, даже если модель, описывающая систему, является детерминированной.

Примерами подобных систем являются атмосфера, турбулентные потоки, биологические популяции, общество и другие социальные системы.

Теория хаоса — это область исследований, связывающая математику, физику и философию.

Она гласит, что сложные системы чрезвычайно зависимы от первоначальных условий и небольшие изменения в окружающей среде ведут к непредсказуемым последствиям.

Первооткрывателями теории считаются французский физик и философ Анри Пуанкаре (доказал теорему о возвращении), советские математики А. Н. Колмогоров и В. И. Арнольд, Мозер, построившие теорию хаоса. Теория вводит понятие аттракторов, устойчивых орбит системы.

Линейные системы никогда не бывают хаотическими. Для того, чтобы динамическая система была хаотической, она должна быть нелинейной. По теореме Пуанкаре–Бендиксона, непрерывная динамическая система на плоскости не может быть хаотической. Среди непрерывных систем хаотическое поведение имеют только неплоские пространственные системы (обязательно наличие не менее трех измерений или неевклидова геометрия). Однако дискретная динамическая система на какой-то стадии может проявить хаотическое поведение даже в одномерном или двумерном пространстве.

Чувствительность к начальным условиям в такой системе означает, что все точки, первоначально близко приближенные между собой, в будущем имеют значительно отличающиеся траектории. Таким образом, произвольно маленькое изменение текущей траектории может привести к значительному изменению в её будущем поведении. Доказано, что последние два свойства фактически подразумевают чувствительность к начальным условиям.

Чувствительность к начальным условиям более известна как “Эффект бабочки”. Термин возник в связи со статьёй “Предсказание: Взмах крыльев бабочки в Бразилии вызовет торнадо в штате Техас”, которую Эдвард Лоренц в 1972 году вручил американской “Ассоциации для продвижения науки” в Вашингтоне. Взмах крыльев бабочки символизирует мелкие изменения в первоначальном состоянии системы, которые вызывают цепочку событий, ведущих к крупномасштабным изменениям. Если бы бабочка не хлопала крыльями, то траектория системы была бы совсем другой.

Несмотря на попытки понять хаос в первой половине двадцатого столетия, теория хаоса как таковая начала формироваться только с середины столетия. Тогда некоторым ученым стало очевидно, что преобладающая в то время линейная теория просто не может объяснить некоторые наблюдаемые эксперименты. Чтобы заранее исключить неточности при изучении — простые “помехи” в теории хаоса считали полноценной составляющей изучаемой системы. Основным катализатором для развития теории хаоса стала электронно-вычислительная машина.

Одним из первых исследователей теории хаоса был также Эдвард Лоренц, интерес которого к хаосу появился случайно, когда он работал над предсказанием погоды в 1961 году. Лоренц обнаружил, что малейшие изменения в первоначальных условиях вызывают большие изменения в результате. Открытию дали имя Лоренца и оно доказало, что Метеорология не может точно предсказать погоду на период более недели. Годом ранее, Бенуа Мандельброт нашел повторяющиеся образцы в каждой группе данных о ценах на хлопок. Он изучал теорию информации и заключил, что Структура помех подобна набору Регента: в любом масштабе пропорция периодов с помехами к периодам без них была константа — значит, ошибки неизбежны и должны быть запланированы. В 1967 он издал работу, где доказывал, что данные о длине береговой линии изменяются в зависимости от масштаба измерительного прибора. Он доказал, что данные измерения объекта всегда относительны и зависят от точки наблюдения. В 1975 году Мандельброт опубликовал работу “Природа фрактальной геометрии”, которая стала классической теорией хаоса. Некоторые биологические системы, такие как система кровообращения и бронхиальная система, подходят под описание фрактальной модели.

В настоящее время теория хаоса продолжает быть очень активной областью исследований, вовлекая много разных дисциплин (математика, топология, физика, биология, метеорология, астрофизика, теория информации, и т.д.).

Теория хаоса применяется во многих научных дисциплинах: математика, биология, информатика, экономика, инженерия, финансы, философия, физика, политика, психология и робототехника.

Одно из самых успешных применений теории хаоса было в экологии, когда динамические системы использовались, чтобы показать зависимость прироста населения от его плотности. В настоящее время теория хаоса также применяется в медицине при изучении эпилепсии для предсказаний приступов. Похожая область физики, названная квантовой теорией хаоса, исследует связь между хаосом и квантовой механикой. Недавно появилась новая область, названная хаосом относительности, чтобы описать системы, которые развиваются по законам общей теории относительности [6, 10: http://en.wikipedia.org/wiki/Theory_of_Chaos].

Vocabulary notes:

детерминированная модель - deterministic model;
турбулентные потоки - turbulent flows;
Анри Пуанкаре - Henri Poincare;
теорема Пуанкаре–Бендиксона - Poincaré-Bendixson theorem;
аттрактор – attractor;
неевклидова геометрия - non-Euclidean geometry;
Эдвард Лоренц – Edward Lorentz;
Бенуа Мандельброт - Benoit Mandelbrot.

4 Section IV Vocabulary and abbreviations

4.1 Vocabulary

A

aberration – искажение, аберрация;
adhere – прилипать, сцеплять(ся);
alter – видоизменять;
angle of deviation - угол девиации, угол отклонения;
angle of incidence - угол падения;
angstrom unit - ангстрем, A;
artificial – искусственный;
Asia Minor - п-ов Малая Азия;

B

bend - сгибать(ся);

blacken – затемнять, чернеть;
blur - размывать, смазать;
brass - латунь, желтая медь;
Bunsen burner - горелка Бунзена;

C

carbon – углерод;
centripetal – центростремительный;
chlorine – хлор, хлористый
cling – цепляться, прилипать, крепко держаться;
curvature – закругление, изгиб;
concave – вогнутый;
converge – сходиться;
critical angle - предельный угол;
Curie point - точка Кюри;

D

deflect – отклонять, преломлять;
detach – отделять, отсоединять;
dissociate – диссоциировать, разъединять;
distortion – деформация, искривление, искажение;
diverge – расходиться, отклоняться;
divergent – расходящийся;

E

Electrification - электризация, наэлектризование;
emerge – возникать;
emit – испускать;
ejected electron – испускаемый электрон;
erect image - прямое (неперевернутое) изображение;

external - внешний, наружный;

F

feeble - немощный, незначительный, ничтожный;
focal length - фокусное расстояние;

H

hammering – вбивание, заколачивание
homogeneous medium - гомогенная среда;

I

impede - мешать, препятствовать, затруднять;
indiscriminately - неразборчиво;
incident ray - падающий луч;
interstice - междоузлие (в кристалической решетке), промежуток;
invert - преобразовывать, переворачивать;
iron filings - железные опилки (стружка);

L

lessen - уменьшать(ся), сокращать(ся);
like charges – одинаковые заряды;
lodestone - магнетит, магнитный железняк;

M

manifest - проявляться, обнаруживаться;
mica – слюда;

N

nitrogen – азот;
normal – перпендикуляр;

O

obliterate – уничтожать;

obliquely - наклонно, наискось;

oersted - эрстед (единица напряженности магнитного поля);

opaque - непрозрачный; непроницаемый;

opposite face - противоположная грань;

outer electron - внешний электрон;

P

poor conductor – слабый проводник;

porcelain - фарфор, фарфоровый;

R

radiation – излучение;

refraction - преломление, рефракция;

retina – сетчатка;

S

spermaceti – спермацет;

sulphur – сера;

T

tungsten - вольфрам, W;

transparent – прозрачный, светопроницаемый;

twisting - закручивание;

U

unconceivably - невообразимо, непостижимо;

V

virtual focus - мнимый фокус;

W

wedge-shaped - клинообразный, клиновидный.

4.2 List of abbreviations from the texts

cgs (centimetre-gram-second) - сантиметр-грамм-секунда (система СГС);
cm (centimeter) - сантиметр, см;
cp (candle power) – мощность свечей;
deg (degree) – градус;
etc. (et cetera) - и так далее;
ft (feet) – фут;
gm (gram) - грамм, г;
hr (hour) – час;
i.e. (id est) - то есть;
in. (inch) – дюйм;
kg (kilogram) - килограмм
lb per sq in (pound per square inch) - фунт на квадратный дюйм;
m (metre) – метр;
mi (mile) – миля;
mi/hr (mile per hour) – миль в час;
min (minutes) – минут;
mph (miles per hour) - миль в час
sec (seconds) – секунд;
sq – (square) – квадрат;
viz. (videlicet) - то есть; а именно (вслух обычно читается namely);
yd (yard) – ярд.

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