Міністерство освіти і науки України
Вінницький національний технічний університет

Potupeiko L.M.

FROM THE HISTORY OF ELECTRONICS

Затверджено Вченою радою Вінницького національного технічного університету як навчальний посібник з англійської мови для студентів старших курсів спеціальностей, пов'язаних з електронікою. Протокол №2 від 30 вересня 2004р.

Вінниця, ВНТУ 2005

УДК 802.0(075)

П 64

Рецензенти:

С.М.Злепко, доктор технічних наук, професор

С.Г.Носик, кандидат філологічних наук, доцент

В.С.Осадчук, доктор технічних наук, професор

І.С.Степанова, кандидат філологічних наук, доцент

Рекомендовано до видання Вченою радою Вінницького національного технічного університету Міністерства освіти і науки України.

Потупейко Л.М.

П 64 From the History of Electronics. Навчальний посібник з англійської мови. - Вінниця: ВНТУ,2005.-160с.

Посібник базується на неадаптованих текстах з журналів "Spectrum", "Electronics World + Wireless World" та Інтернету і призначений для студентів старших курсів, що вивчають електроніку.

Перший та другий розділи посібника розраховані на аудиторну роботу і складаються з 16 уроків, кожен з яких містить текст та декілька вправ. Передтекстові граматичні вправи – це низка окремих речень, підібраних з вищезгаданих джерел для повторення матеріалу, що вивчався на молодших курсах. Лексичні вправи слугують як для повторення словотворення, так і для введення нових слів, котрі зустрічаються у тексті даного уроку. Післятекстові вправи призначені для розвитку навичок мовлення.

Третій розділ складається з текстів для домашнього читання і присвячений непересічним людям та відкриттям у галузі електроніки. Після кожного тексту пропонується декілька тем для обговорення в аудиторії задля закріплення матеріалу.

Оскільки тексти та усі речення до вправ взяті як з англійських, так і з американських джерел, в них збережені пунктуація та орфографія, притаманні кожній з цих країн. Основні відмінності британської та американської орфографії надані у Додатку 2, а Додаток 1 містить усі абревіатури, що зустрічаються у посібнику.

УДК 802.0 (075)

Contents

Appendices

PART 1

FROM THE HISTORY OF ELECTRONICS

LESSON 1

Exercise 1

Translate the following words paying attention to suffixes.

Electron, electrical, electrically, electricity, electrify, electronic, electronics; ninth, nineteen, ninetieth, ninety; transmit, transmitted, transmitting, transmission, transmissible, transmitter; organize, organization, organizer, organizing, organizational, organized; improve, improving, improvement, improved; part, party, parted, partition, partly, particular, particularly, particularity; serve, server, servant, served, service, serviceable.

Exercise 2

Translate the following sentences paying attention to tenses.

1.IBM,Siemens and Toshiba have developed a fully-functional 256Mbyte dynamic ram chip. 2. For the manufacturers and developers a faster chip means improved overall system performance. 3. Toshiba and Siemens have been collaborating in various semiconductor areas. 4. Analogue microphones produce an output proportional to incident sound pressure, which is converted to digital form. 5. The robots tend to get confused if they receive signals from more than four other robots at once. 6. Automobile engineers have long been searching for a simple technique to enable continuous monitoring of combustion parameters inside an engine. 7. But what technology your next-generation optical-disk player will use is still being worked out. 8. Microsoft and Intel want to standardize key software and semiconductor hardware for mobile phones, much as they made the Windows operating system and Pentium processors the norm for PCs. 9.Carmakers are spending more on silicon these days, as electronics and software spread throughout motor vehicles.

10.Technology is evolving so rapidly that any standard may prove merely temporary. 11.One application to which energy storage is of great importance is on the International Space Station. 12. Basically, there is no difference between single-chip microcomputers and microcontrollers. 13. Eight-bit microcomputers represent for many applications a sensible compromise in terms of performance and on-chip circuit utilisation. 14. The device does not incorporate analogue interfaces, but does have a flexible and powerful instruction set. 15. Engineers have been shortening the delay for several years, by simply reducing the line's so-called time constant, which is equivalent to the product of its resistance and capacitance.

Exercise 3

Match the English phrases with their Ukrainian translations.

1. incandescent lamp	1. НВЧ прилад
2. oscillation valve	2. радіопередача
3. wireless transmission	3. твердотільні компоненти
4. proceedings of the IRE	4. лампа розжарення
5. microwave device	5. нотатки IPE
6. travelling-wave tube	6. генераторна лампа
7. solid-state components	7. лампа біжної (прямої) хвилі

Exercise 4

Pay attention to the translation of the following phrases from the text.

1.to trace its own origins back to the 1930s - віднайти власні джерела в 1930х роках;

2. particularly noteworthy among them was...- серед них на особливу увагу заслуговувала...;

3. in response to consumer demands - як реакція на споживчий попит;

4. the lion's share - левина частка;

5. the flood gates burst - греблю прорвало.

The Electron Tube Legacy

Electron devices have played a central role in electrical engineering almost since the birth of the profession near the end of the nineteenth century. Indeed, the first article published in the initial 1884 volume of the *Transactions of the American Institute of Electrical Engineers* (AIEE) was "Notes on Phenomena in Incandescent Lamps", by Edwin Houston. Over a decade before the discovery of the electron he discussed the Edison effect, a curious trickle of current through the lamps, that was to become the physical basis of electron tubes. Working for the Marconi Company in 1905, British physicist John Ambrose Fleming employed this effect in his "oscillation valve", which served as a detector of wireless transmissions.

In America, Lee de Forest and Reginald Fessenden soon adapted this valve to function as an amplifier in radio transmitters by inserting a third electrode to serve as a modulating grid. With the much improved physical understanding of electrons achieved by 1912, scientists developed high-power electron tubes, which were being used a few years later for transcontinental and transatlantic radio and telephone communications.

In parallel with these developments, a professional organization emerged devoted to the interests of electrical engineers specializing in radio applications. Formed from the union of two smaller societies, the Institute of Radio Engineers (IRE) held its first official meeting in 1912. The following year, it established offices in New York City and began publishing its widely read journal, the Proceedings of the IRE. For the next fifty years, the AIEE and IRE served as dual representatives of the electrical engineering profession in America - at a time when radio and television broadcasting grew into major industries and electronics became an integral part of modern life.

Beginning in the 1920s, many companies started manufacturing a great variety of electron tubes for a steadily growing list of applications. At the heart of all this economic activity was the manipulation of streams of electrons flowing from cathode to anode in myriads of different configurations. In fact, the word "electronics" itself emerged during the 1920s to describe the new technology.

The Electron Devices Society can trace its own origins back to the 1930s, when the Technical Committee on Electronics co-ordinated IRE activities in the field. In 1938 it sponsored the first Conference on Electron Tubes. The meeting was so successful that two more Electron Tube Conferences were held the following year. Attendance grew to over a hundred.

Wartime secrecy prevented further Electron Tube Conferences until the 1946 meeting, when microwave devices developed during World War II were the focus of attention . Particularly noteworthy among them was the travelling-wave tube invented by Rudolf Kompfner and dramatically improved by John Pierce. Travelling-wave tubes headed the list of topics at the 1947 Syracuse meeting, while magnetrons and klystrons received top attention at the 1948 Cornell meeting.

The microwave tubes and crystal rectifiers used in radar systems had helped the Allies win World War II. Now these and other electron devices found their way into the commercial market. The post-war decade witnessed great changes occurring in the field of electrical engineering, partly in response to consumer demands. Electronics technology was growing rapidly: television, FM radio, computers, solid-state components and military applications. Electronics began attracting the lion's share of electrical engineering students, offering them good jobs in industry and science.

Solid-state electron devices were also beginning to attract major attention. The vastly improved understanding of semiconductor physics and technology, particularly involving germanium and silicon, that had emerged from the wartime programs resulted in several new devices during post-war years. The flood gates burst in 1948 after the invention of the transistor by John Bardeen, Walter Brattain and William Shockley.

Exercise 5

Answer the following questions.

1. When was the first article on electron tubes published?
2. What was it about?
3. What is the physical basis of electron tubes?
4. In what way was the tube used by Lee de Forest and Fessenden?
5. Who developed high-power electron tubes and when did it happen?
6. What is IRE?
7. When did it begin publishing its journal?
8. For how long did the AIEE and IRE serve as representatives of electrical engineering profession in America?
9. What became an integral part of modern life?
10. When did the word "electronics" began to represent the new technology?
11. When was the first Conference on Electron Tubes held?
12. Was it successful?
13. Why wasn't the next Conference held until 1946?

14. What was the theme of it?
15. What topics were discussed at the next two Conferences?
16. Where were electron devices used during World War II?
17. Why did electronics attract many students in the post-war decade?
18. What influenced the development of solid-state devices?
19. Who invented the transistor?
20. When did it happen?

LESSON 2

Exercise 1

Translate the following words paying attention to suffixes.

Complete, completed, completely, completing, completion, completeness, incomplete; follow, following, follower, followed by; operate, operation, operative, operating, operator, operatively, operated; flow, flowing, flown; success, succeed, successful, successive, successively, succession; pure, purification, purify, impure, impurity, purifiers; refract, refracted, refraction, refractive, refracting.

Exercise2

Translate the following sentences paying attention to adjectives and adverbs.

1. Today's technology has given us simplification, better performance and lower cost. 2. Automation is more available and efficiency has increased overall by a factor of two. 3. Microsoft and Intel foresee a far larger demand for these new data-enabled wireless devices than for computers. 4. Interestingly, while the latest microprocessors offer higher processing rates than most users need, semiconductor fabrication facilities now offer circuit design teams more transistors than they need. 5. This discovery process works better when products are introduced faster and more frequently. 6. It can power the load for twice as long as a chemical battery without recharging. 7. Though at the moment it is more expensive to communicate with light than with electric current, the day is coming when only optical technologies will be able to keep up with the demands of ever-more-powerful microprocessors. 8. At low frequencies the series resistance and shunt capacitance of a circuit board dominate its behaviour,

determining the rise and the fall times and thereby limiting its data rate. 9. The larger the amplitude, the more positive the dc component is. 10. The solar-energy-powered system was, in fact, designed for just such manoeuvres and is ten times more efficient than conventional chemical one. 11.Now chip designers no longer have to plot out lines and spaces for the transistors and interconnections. 12. The shorter a product life cycle, the greater the pressure on the SoC (system on a chip) design process. 13.XP4 laptop 3D graphics processor can generate a billion pixels per second at less than 3W, more than twice the pixels per watt of competitors that use twice as many transistors. 14.The narrower the wire, the longer it takes a signal to propagate along it. 15.The low power consumption can also do away with the need for fans, allowing notebook makers to design slimmer, lighter notebooks.

Exercise 3

Match the following English words with their Ukrainian translations.

1. to fight one's way	1. надчистий
2. solid-state kin	2. транзистор дифузійний
3. zone refining	3. транзистор стоплений площинний
4. junction device	4. споріднені твердотільні прилади
5. alloy-junction transistor	5. торувати собі шлях
6. high-fidelity (Hi – Fi)	6. очистка зони
7. ultrahigh-purity	7. висока якість
8. diffused-base transistor	8. площинний прилад

Exercise 4

Mind the translations of the following English phrases.

1. to fight a loosing battle - вести програшний бій;
2. to pursue different approaches - розробляти інші підходи;
3. rumors circulated that Shockley was about ... -
поширювалися чутки, що Шоклі збирався...;
4. to receive a strong affirmation in late 1956 -
отримати сильне заохочення наприкінці 1956;
5. to argue well for - беззаперечно свідчити на користь;
6. no matter what the cost - за будь-яку ціну.

From Tubes to Transistors

Although electron tubes almost completely dominated the marketplace for electronic devices as the 1950s began, ten years later they were fighting a losing battle with solid-state devices. This was the decade in which transistors fought their way into consumer electronics, computers and other circuitry, starting with hearing aids in 1953 and the famous transistor radio the following year. Shockley's invention of the junction transistor led this invasion, capturing nearly every market in their path. The only applications left were high-fidelity audio electronics, television and microwave systems, which operated at high power or high frequencies that transistors could not (yet) attain.

With the begining of the Cold War between the United States and Soviet Union, government support for the development of advanced electronics - especially solid-state devices and microwave tubes - was not hard to obtain. This was a decade in which the principal theme was the steady process innovations. Rapid improvements in materials science and manufacturing techniques - as well as novel structural approaches - continually expanded the operating characteristics of transistors and their solid-state kin. Development of zone refining at Bell Labs gave researchers and engineers ultrahigh-purity germanium and silicon to work with. Gordon Teal demonstrated how to grow large crystals of both semiconductors, ensuring the necessary materials uniformity that would result in controllable, predictable behavior of the electrons flowing through them. He adapted this technique to grow junction transistors that found ready applications in portable radios and military electronics.

Others were pursuing different approaches. John Saby at General Electric developed the alloy-junction transistor, which proved easier to manufacture than grown-junction devices. Smaller companies were producing dozens of alloy-junction transistors by mid-decade. Robert Noyce was attempting to push their performance levels to higher frequencies when Shockley came by in early 1956 to recruit the bright young physicist for a company devoted exclusively to silicon semiconductors that he was about to establish.

In mid-1955 rapid changes were occurring in the field of solid-state devices. At the June Solid-State Device Research Conference held in Philadelphia, Bell Labs researchers revealed that they had just succeeded in making transistors using diffusion techniques to incorporate impurities into the germanium and silicon. The operating frequencies of the diffused-base transistors made with this technique soon exceeded 100 MHz - making them competitive with electron tubes in the FM radio range. What's more, Bell Labs had succeeded in extending zone-refining purification techniques to silicon, a far more refractory element than germanium. It was only a year earlier that a Texas Instruments team led by Willis Adcock and Gordon Teal had fabricated the first successful silicon transistor to reach the market. Diffusion and silicon were truly the hits and rumors circulated that Shockley was about to leave Bell Labs and set up a California semiconductor company concentrating on these technologies.

With the deepening Cold War and the urgent needs it created for advanced electronic systems, electron device developers found strong support among the U.S. armed services for their advanced research activities. Silicon transistors had much smaller leakage currents than germanium transistors and more uniform operating characteristics over large temperature ranges. Military purchasing agents, who soon preferred silicon over germanium, were willing to pay as much as a hundred dollars for a single transistor. The eager market for these and other electron devices helped to build a solid foundation under the young semiconductor industry.

Its intellectual roots also received a strong affirmation in late 1956 with the announcement that Bardeen, Brattain and Shockley would receive the Nobel Prize in physics for their invention of the transistor. The three men headed for Stockholm in December to accept their awards from the Swedish king. This was not the last time that a Nobel prize was given for the invention of an electron device.

As the decade came to an end, major developments in science, technology and world affairs augured well for the future of research on electron devices. The October 1957 launch of Sputnik redoubled military interest in and support for the field, while President Eisenhower established the National Aeronautics and Space Administration (NASA) to pursue civilian R&D in space. Photovoltaic cells and transistors made by Bell Labs and Texas Instruments powered radio transmitters in the U.S. Vanguard and Explorer satellites sent up in response to the Soviet challenge. The new field of satellite communications required highly efficient microwave tubes, especially traveling-wave tubes; their electronic circuits absolutely demanded use of ultralight semiconductor devices, no matter what the cost.

Meanwhile, Jack Kilby at Texas Instruments and Robert Noyce at Fairchild Semiconductor Company in California invented the integrated circuit. Over the next few decades, this revolutionary breakthrough would promote radical reductions in the size and weight of electronic circuitry. Along with other advances in computers and communications, the integrated circuit would open up an era we now refer to as the Information Age.

Exercise 5

Answer the questions.

1. When were electron tubes mainly substituted by transistors?

2. In what devices were they primarily used?
3. Why did designers continue to apply electron tubes in television and microwave systems?
4. What influenced the operating characteristics of solid-state devices?
5. What technique resulted in junction transistor?
6. Who developed alloy-junction transistor?
7. When was this invention widely used ?
8. How were the operation frequencies of transistors raised over 100MHz?
9. What company was the first to produce commercial silicon transistors?
10. What are the advantages of silicon transistors over germanium ones?
11. What was the initial price of a silicon transistor ?
12. Who received the Nobel Prize for the invention of the transistor?
13. When and where did it happened?
14. How did the US react to the launch of the first Sputnik by the USSR?
15. What technical innovations were used in first American satellites?
16. What did satellite communications require?
17. Where was the integrated circuit invented?

LESSON 3

Exercise 1

Translate the following words paying attention to affixes.

Ultralight, uniformity, uniform, exclusively, exclude, exclusive, include, coming, income, overcome, needless, needed, needs, needful, counterparts, parted, parting, possibility, impossible, possibly, promotion, promoter, promoting, useful, misuse, uselessly, substrate, submarine, subordination, another, others, pieces, apiece, post-graduate, post-war, post-impressionism, semiconductor, semifinal, semicircular, semiaxis, co-ordination, co-operation, co-existence, co-produce, cosponsored, collaborate, unpredictable, predicted, predictive, midday, midland, mid-week, midyears mid-decade, reorient, reorganise, redo, rewrite, transatlantic, transcontinental, myself, ourselves, itself, pre-war, preview, predetermined, pre-establish, pre-amp, prepay, misfortune, misfortunately, misunderstand.

Exercise 2

Translate the following sentences paying attention to modal verbs and their equivalents.

1. The standards should be applicable to all direct-to-home satellite and cable transmission and should include conditional access. 2. At high amplitude and frequency, magnetisation from one half-cycle may not be removed from the record head sufficiently quickly. 3. Apart from the production standard, transmission standards also need to be specified. 4. The system can achieve a 43dB improvement in signal to noise ratio over the equivalent standard recording. 5. It should be possible to come to an earlier agreement if discussions with the other parties could produce an acceptable compromise. 6. This type of device can handle binary-coded decimal data one decimal digit at a time, but information involving more than one decimal digit must be processed in a digit serial manner. 7. If the system knows exactly what type of device has been connected, it can automatically adjust its input or output parameters accordingly an even load the relevant program for processing. 8. Electromagnetic fields can physically move, reorient, or even alter molecules or ions - or their distributions - in a body. 9. In another seven cases there was some evidence to suggest that a low level of noise may have been present. 10. If car makers were to make full use of the system's potential, this simple approach could be used to supply information on everything from misfiring to pre-spark ignition. 11. In time even well designed coaxial signal distribution system can need maintenance. 12. They are to work out their public-private partnership in accordance with the revenues expected from the future. 13. Typically the user will have to connect a computer to the broadband modem. 14.Contrary to some reports earlier this year, Galileo - a six-satellite global positioning system is not to be cancelled. 15. A physics effect called extraordinary magnetoresistance (EMR) may be used to create computer disk drives that can store and access at least 40 times as much data as today's disk drives can.

Exercise 3

Match the Ukrainian translations to the following English words.

1. ballistic missile	1. польовий транзистор
2. thrust	2. стимулювати, підганяти

3. pn junction	3. у прямому ефірі
4. substrate	4. світловипромінювальний діод
5. actual yield	5. металоксид напівпровідник транзистор
6. light-emitting diode	6. реактивна сила
7. vapour deposition	7. корисне навантаження
8. field-effect transistor	8. p-n перехід
9. metal-oxide semiconductor transistor	9. балістична крилата ракета
10. to spur	10. фактичний вихід, результат
11. live on television	11. основа, нижній шар, підкладка
12. payload	12. нанесення шарів паровим методом

Exercise 4

Mind the translation of the following phrases.

1. to scrimp on the weight of payloads - зменшувати вагу корисного навантаження ракет;
2. to place a huge premium on - надзвичайно заохочувати;
3. to take the genius of... to envision - потребувати генія... щоб уявити;
4. to add fuel to the burning fire - підлити оливи до палаючого полум'я;
5. to pioneer the technique - першим запровадити технологію;
6. to passivate from affecting - унеможливити вплив;
7. to prove superior to ...- виявитись кращим за...

The Decade of Integration

In terms of both circuit geometries and the organisations devoted to the electrical engineering profession, the 1960s was truly the "decade of integration." Fairchild and Texas Instruments made the first commercially available integrated circuits in 1961; these miniature electronic circuits on a single chip of silicon found ready applications in ballistic-missile and portable electronic systems for military purposes. At about the same time, the IRE and AIEE merged into a single organisation, the Institute of Electrical and Electronic Engineers (IEEE), in 1963, the year after the IRE celebrated its 50th (and last) anniversary. Both of these sweeping changes have fundamentally altered the practice of electrical engineering in the USA and throughout the world.

After the Soviet Union managed to put the first man, Yuri Gagarin, in orbit, the United States responded quickly with the flight of Alan Shepard in May 1961. President John F. Kennedy then committed the nation to land a man on the Moon by the end of the decade. Because the existing American rockets had much less thrust than their Soviet counterparts, U.S. engineers had to scrimp everywhere possible on the weight of their payloads, which placed a huge premium on solid-state components and integrated circuitry. The high cost of these devices was of little concern when the nation was spending $20 billion to reach the Moon first.

The idea of integrated circuitry had been in the air since the mid-1950s, with the U.S. armed forces promoting three different approaches to miniaturization. Various techniques that could make miniature circuits possible, such as diffusion technology, planar processing, and photolithography, had been developed by the end of the decade. But it took the genius of two men, first Kilby in July 1958 and Noyce the following January, to envision how these techniques could be employed to fabricate an electronic device that their companies would be able to manufacture reliably and in quantity.

Still, it required another two years of development before integrated circuits were ready for market. There were significant problems of materials processing and engineering that had to be solved, such as exactly how to isolate individual circuit elements on a chip by introducing additional pn junctions into the silicon substrate. The actual yields of successful circuits at first were abysmally low - only fractions of a percent. And the "market" for the devices was extremely limited at first. About the only customers willing to pay over a hundred dollars apiece for these integrated circuits were the armed services.

In October 1964, the IEEE agreed to begin publishing a new professional journal devoted to quantum electronics - just before the Royal Swedish Academy announced that Charles Townes was to share the Nobel Prize in physics for his research on masers and lasers. The new publication, named the IEEE Journal of Quantum Electronics, was cosponsored by the Electron Devices Group and the Group on Microwave Theory and Techniques.

Quantum devices were increasingly discussed in technical papers presented at conferences. The development of semiconductor lasers and light-emitting diodes in the 1960s added fuel to this rapidly burning fire. Special sessions were typically devoted to electron tubes, solid-state devices, energy-conversion devices, integrated circuits, and quantum devices. And a new area of professional specialization also began to emerge in this decade - imaging displays and sensors.

The annual device research conferences, one devoted to solid-state devices and another to electron tubes and other devices, continued their separate existence until 1969.One such memorable gathering was the 1960 Solid-State Device Research Conference at the Carnegie Institute in Pittsburgh, at which Bell Labs researchers revealed important new results. Led by Ian Ross, one group had pioneered the techniques to grow very thin germanium and silicon layers "epitaxially" by chemical vapour deposition. This process allowed them to fabricate layers of semiconductor material that were just microns thick and to control precisely the electrical properties of each layer.

Another group led by John Atalla and Dawon Kahng revealed the first practical, successful field-effect transistor, known as the metal-oxide semiconductor (MOS or MOSFET) transistor. By carefully growing an oxide layer on the silicon surface, they managed to passivate the frustrating "surface-state" electrons that had previously blocked external electric fields from affecting the behaviour of electrons within the underlying material; they then deposited an aluminium lead atop the oxide layer to introduce the fields. By the end of the 1960s, these MOS transistors were replacing junction transistors in electronic circuits, especially for lower-power applications.

Two years later, at the Solid-State Device Research Conference held at the University of New Hampshire, researchers from MIT Lincoln Laboratory revealed surprisingly high efficiencies, over 85 percent, for conversion of electricity to light in gallium arsenide pn junction diodes. This discovery spurred intense work on GaAs semiconductor lasers by groups at MIT, General Electric and IBM.

As the decade of integration ended, integrated circuits and light-emitting diodes were finding their way increasingly into commercial applications, such as computers and pocket calculators. By then, MOS transistors had proved superior to junction transistors in many applications and the component densities on microchips continued to grow exponentially.

And electron devices played a crucial role in landing the first man on the Moon. With their computers based on integrated circuits and their communications systems relying on traveling-wave tubes, Apollo 11 and its lunar module reached this destination in July 1969. Thanks to these marvellous electron devices, millions watched Neil Armstrong live on television as he stepped onto its surface, uttering the soon-famous words, "One small step for man, one giant step for mankind."

Exercise 5

Answer the questions to the text.

1. What is an integrated circuit?
2. How did the U.S. react to the first manned flight of a Soviet spaceship?

3. What was the main problem of the U.S. rockets?
4. What technologies aimed at ultimate decrease of the component size had been developed by the end of the decade?
5. Who proved to be able to employ these techniques for actual mass production of an electronic device?
6. When did integrated circuits become available in the market?
7. Were they perfect?
8. Why were the armed forces the only customers of the companies producing ICs?
9. Who became the Nobel Prize winner in the field of Electronics in 1964 ?
10. What electronic devices were being developed in 1960s ?
11. What new technique was pioneered by Bell Labs researchers?
12. What were its advantages?
13. What is MOSFET?
14. For what applications were MOS transistors replacing junction transistors at the end of 1960s ?
15. In what commercial applications were light-emitting diodes first used?
16. What was the role of electron devices in the U.S. space achievements?

LESSON 4

Exercise 1

Translate the following words paying attention to word-building affixes.

Power, powerful, powered, powers, power-plant, powerless; application, apply, misapply, applying, appliance, applicable; possibility, impossible, possibly; rely, reliable, reliability, reliance, reliably, unreliable; additional, add, adding, addition, added; strength, strengthen, strong, strengthening, strongly; science, scientific, scientists; instant, instantly, instantaneous; contain, contained, container, containing, containment, content; seen, seeing, foresee; exponent, exponential, exponentially.

Exercise 2

Translate the sentences paying special attention to noun groups.

1. The dynamic random access memory chip - less than half an inch in size - is the culmination of two and half year's research by leading scientists. 2.The smaller size and faster speed of the device will be required by the memory-hungry systems of the future such as high-definition digital video, multimedia PCs and telecommunication systems. 3. The device uses cmos process technology and is designed to support any proposed Joint Electron Device Engineering Council standard for 256Mbyte DRAMs. 4. IBM, Siemens and Toshiba are partners in 64Mbyte d-ram development, and a joint venture between IBM Japan and Toshiba manufactures advanced colour flat panel computer displays. 5. Video-on-demand (vod) developer Online Media says it is involved in research which could lead to personalised point-to-point satellite communications services delivering 2Mbit/s channels to the home. 6. The company is using Olivetti's satellite hardware joint venture with Hughes to adapt spot beam technology for interactive tv services. 7. According to Online Media chief executive Malcolm Bird, the cable TV companies' window of opportunity for interactive tv is between three and five years. 8. Quad Designs, a Viewlogic Systems subsidiary, has introduced an electromagnetic interference analysis tool that includes a three-dimensional simulation engine. 8. System-on-a-chip (SoC) products are modular designs constructed from reusable intellectual property (IP) blocks that perform specific functions. 9. Last year Japan's two largest mobile phone makers, Matsushita and NEC, entered into an alliance, while Ericsson formed a joint venture with Sony. 10. So, in February, at the annual world congress on the Global System for Mobile (GSM) Communication world congress in Cannes, France, Microsoft and Intel announced they were joining forces to design a new cellphone.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. charge-coupled device (CCD)	1. дисплей на рідких кристалах
2. major emphasis	2. динамічна оперативна пам'ять
3. via networks	3. цифровий дисплей
4. numeric display	4. інтеграція дуже високого рівня
5. liquid-crystal display (LCD)	5. докорінно нове
6. very large-scale integration (VLSI)	6. пристрій з зарядовим зв'язком (ПЗЗ)
7.dynamic random-access memory (DRAM)	7. основний наголос
8. brash new	8. через мережі

Exercise 4

Mind the translation of the following expressions from the text.

1. it was ... that - саме...;
2. the sobriquet “Silicon Valley” was coined to describe... -

   була створена назва «Силіконова Долина» для характеристики… ;
3. relentless exponential climb - неухильне експоненційне зростання ;
4. one could foresee - можна було передбачити;
5. to seize upon - захопитися.

New Light on Electron Devices

As the 1970s began, there was strong and growing interest among electrical engineers and materials scientists in the new field of opto-electronics. It arose largely in response to the invention of the semiconductor laser during the previous decade. Devices that emit, convert or detect light became a focus of extensive activity among members of the Electron Devices Group. Visual electronic displays were another; the charge-coupled device, or CCD, revealed at IEEE meetings in 1970, was an instantaneous sensation. Devices that generate and absorb electromagnetic radiation had, of course, been used since the beginning of the century, but the major emphasis was now on the visible and infrared portions of the spectrum. The promise of broadband communications via networks of glass fibers soon became a potent force driving research and development efforts.

Solid-state integrated circuits, then becoming widely known as microchips, was another area of major activity, as component densities continued to follow the exponential growth curve enunciated by Moore in the mid-1960s. It was in fact the planar techniques used in the manufacture of MOS field-effect transistors that had made CCDs possible. In 1970 Marcian Hoff, working at the Intel Corporation, invented the microprocessor - in effect, a complete computer on a single chip of silicon. This was also the year that the sobriquet "Silicon Valley" was coined to describe California's Santa Clara Valley, which had become the global epicenter of the semiconductor industry. And in that very same year President Nixon awarded Jack Kilby the National Medal of Science for his pioneering work on integrated circuits.

Hand-held pocket calculators also emerged in the early 1970s, based upon a single microprocessor and a semiconductor memory chip. They created a rapidly growing demand for numeric displays that was satisfied by light-emitting diodes and organic liquid-crystal displays - electron devices that had been invented and developed during the previous decade. Some calculators were even powered by silicon photovoltaic cells; this was one of the first successful commercial applications of these semiconductor devices, which had been introduced in 1954.

The component densities of microchips, in the dawning era of very large-scale integration (VLSI), continued their relentless exponential climb. Introduced at the beginning of the decade, dynamic random-access memory (DRAM) chips by 1979 contained over 100,000 transistors and offered 64Kbits of memory. But one could still foresee a day in the not-distant-future when there would be millions of transistors on a single microchip.

Unwilling to wait that long, however, computer hobbyists had already seized upon the Altair 8800 microcomputer, whose architecture was built around an Intel 8bit microprocessor. Two of them - Steve Jobs and Steve Wozniak - had even founded their own brash new microcomputer company, the Apple Computer Company, in a Silicon Valley garage. That very same September of 1977 the company began selling the Apple II personal computer. The world would never be the same again.

Exercise 5

Answer the following questions .

1. What devices caused great interest to opto-electronics?
2. Why did scientists and engineers become interested in visible and infra-red portions of the spectrum?
3. How were solid-state integrated circuits called in 1970s ?
4. What made CCDs possible?
5. Who introduced microprocessor?
6. What does the name “ Silicon Valley” mean?
7. When and why did Jack Kilby receive the National Medal of Science?
8. What devices invented in previous decades were used in pocket calculators?
9. How had DRAM chips changed by the end of the decade?
10. Where was the Apple Computer Company founded?
11. When did it start selling its first personal computer?

LESSON 5

Exercise 1

Translate the following words paying attention to word-building affixes.

Event, eventful, eventuate, eventual, eventuality, eventually; compete, competition, competitor, competitive, competitioner, competitively; deep, deepen, deeply, deepness, depth, deepening; widely, wide, widen, nationwide, widening, widespread; share, sharing, shareholder, share-out, shared; connect, connecting, connector, connection, connected, interconnection; dense, density, densely, densimeter; face, faced, facing, facial, interface, interfacing; transform, transformer, transforming, transformed, transformation.

Exercise 2

Translate the following sentences paying attention to infinitives.

1. Among the first to benefit from the new laser will be astronomers. 2.Certain GaAs layers throughout the active regions are doped to give them a positive dielectric constant. 3. What little radiation such lasers produced tended to be absorbed by the semiconductor materials. 4. For a solid-state laser to produce light, electrons in the laser material must be forced to release protons by dropping from one energy level to the next. 5. To produce light of a specific frequency the electron jump within the material must match the energy of the protons. 6. Microsoft and Intel hope to use their marketing experience and computer expertise to get big money from the emerging market for broadband mobile phones. 7. Spadd (smart passive damping devices) was developed to protect satellites from vibration during launch. 8. As every computer user knows, software is far more likely than hardware to fail. 9. In order to develop a modular product architecture with standardized interfaces among subsystems, it is necessary to waste some of the functionality that is theoretically possible. 10.The specification seeks to standardise output range - likely to be 0.5V to 4.5V - and the supply voltage, probably at 5V. 11. The 256 Mbyte d-ram project seems to be not the only area in which the three companies are willing to co-operate to share cost and expertise. 12. It turned out to be possible to measure a reflection coefficient of 0.06 to an accuracy of about 10 %. 13. Two diodes are considered to have been selected in a pair if their forward resistances coincide in three points (in the three sub-bands) to within 5%. 14. No-one working in the field expects molecular devices to be fabricated by processes like vapour deposition or etching. 15. So far, most candidate molecules tend to be unstable or difficult to interface. 16. This causes the rising edges of a sine wave signal to be expanded, while the falling edges are compressed. 17. But who will win remains to be seen.

Exercise 3

Match Ukrainian translations to the following English phrases .

1. oil embargo	1. судова постанова
2. to corner the consumer market	2. відповідна галузь
3. judicial decree	3. субмікронні масштаби
4. long-distance telephone carrier	4. заборона на імпорт нафти з країни
5. “Baby Bell”	5. захопити споживчий ринок
6. respective domain	6. філія компанії “Белл”
7. submicron scales	7. відбуватися
8. to be underway	8.оператор міжміського телефонного зв’язку

Exercise 4

Pay attention to translation of the following phrases.

1. to be on the ropes - відчувати обмеження;
2. to challenge the hegemony that the two behemots had once enjoyed - претендувати на провідне становище, що колись належало двом гігантам;
3. to champion the goal - прагнути до мети;
4. to be on much better footings - знаходитись у значно кращому становищі.

Focus on Manufacturing

There was deep and widening concern about the economic health of the United States as the 1980s began. Oil embargoes of the previous decade had ignited two energy crises. Heavy industries such as steel and automaking had responded while their European and Japanese competitors grabbed market share. And the U.S. electronics industry was on the ropes, too, while such giants as SONY and Panasonic cornered the consumer market.

There were widespread fears that even the U.S. computer industry was in trouble. Japanese electronics firms had begun to dominate the market for memory chips and were expected to target microprocessors next. So great were the fears of foreign competition in the semiconductor industry that the Reagan Administration eventually took the unprecedented step of partially funding a consortium of U.S. chipmakers - including such heavyweights as IBM, Intel, Motorola and Texas Instruments - to do cooperative R&D on microchip manufacturing technologies. With Noyce at the helm, SEMATECH began operations in Austin, Texas, in July 1988.

Two other events of major significance for the electron-device field occurred during the early 1980s. In 1981 IBM began manufacturing and selling its personal computer, based on an open architecture that other firms were free to copy. And in 1984, the nationwide AT&T communications system was broken up by a judicial decree into a long-distance telephone carrier plus regional "Baby Bells." The competition stimulated by these events was to have a profound impact on the computer and telecommunications industries - with many small electronics companies successfully challenging the hegemony that the two behemoths had once enjoyed in their respective domains.

The principal goal of microchip manufacturing in Europe, Japan and the United States was to make the component parts of integrated circuits - transistors, capacitors and their interconnections - ever smaller and to pack them ever more densely on the chip surface. Such unrelenting miniaturization helps ensure that microchips offer ever-increasing computational power and do their appointed tasks at ever-greater speeds. As the 1980s began, semiconductor industry leaders championed the goal of very large-scale integration, in which the microchip features would have to become as small as a micron, or a millionth of a meter. By the mid-1980s, VLSI pioneers were beginning to breack this barrier and work toward the submicron scale.

Tremendous changes were then underway in world affairs, especially in Eastern Europe, where a decade of unrest that had begun with the Solidarity movement in Poland ended with the fall of the Berlin Wall in November 1989. With the long Cold War finally drawing to its close, major transformations were also occurring in the United States, which under President George Bush was beginning to shift resources out of the military-industrial complex and into the civilian economy. More and more, a U.S. company's success or failure would be determined by its performance in the commercial marketplace. Computer and telecommunications firms had responded aggressively to the competitive stimuli that were introduced during the 1980s and were now on much better footings as the decade ended. In particular, the U.S. microelectronics industry was back in excellent condition and growing steadily as the 1990s began.

Exercise 5

Answer the following questions.

1. What was the main concern of the U.S. at the beginning of 1980s?
2. Why was the American electronics industry considered to be in trouble?

3. What firms dominated the memory chip market?

4. How did the U.S. Government react to growing foreign competition?

5. What is SEMATECH ?

6. What events stimulated competition among American computer and telecommunication companies?

7. Why is miniaturization the main aim of microchip industry?

8. What were the achievements of VLSI designers in 1980s?

9. What political events allowed the U.S. to invest much more in civilian economy?

10. How can you describe American microelectronics industry of the beginning of 1990s?

LESSON 6

Exercise 1

Translate the following words paying attention to word-building affixes.

Rejoin, joining, joint, joined, occurred, occurring, occurrence, improve, improving, improved, improvements, relentless, relent, relenting, approach, approachable, approaching, globe, global, globalise, globally, measure, measurement, measuring, measured, measurable, immeasurable, behave, behaviour, misbehave, impress, impression, impressive, impressively, impressionism, owe, own, owing, owner, owed, exist, existing, existed, existence.

Exercise 2.

Translate the following sentences paying attention to participles

1. Having sold over 100 million handsets, Ericsson has plenty to offer. 2.The problem is that Celeron microprocessor is a one-size-fits-all proposition, its architecture being more modular than that of the Pentium products it is displacing. 3. With product life cycles approaching a year or less, some microprocessors currently spend a good part of their lives being manufactured. 4.The system helps identify and manage requirements throughout the product’s

life cycle, the goal being to understand what the customer wants and ensuring that the particular product meets those requirements. 5. Standards have always been a means of increasing reliability while decreasing cost and shortening time to market. 6. The active region developed by the group consists of seven-layer structure of GaAs separated by aluminum gallium arsenide repeated many times. 7. Now, scientists having been encouraged to continue researching molecular electronics phenomena, their work is expected to lead to a new golden age for electronics. 8. Ionic current flowing through the plug is then measured as a voltage appearing across a resistor. 9.The instrument described is an experimental cable tester used under real conditions when installing and maintaining private cable tv networks. 10.Two 741 op-amps are used as logarithmic amplifiers, the type having moderate thermal drift. 11. The enhanced version of Intel's Speed-Step technology, included the processor, saves power by stepping the operating voltage and frequency up and down, matching the demands of the application running on the processor. 12. Three of the world's top 10 chipmakers are now European, compared to just one a decade ago, according to IC Insights Inc., a market research group. 13. According to our sources, the capacitors made from the formula become unstable when charged, generating hydrogen gas, bursting and letting the electrolyte leak onto the circuit board. 14. Having been forced to face up to reality years ago, Europe's chipmakers have come through 2001-02 better than most and now appear well positioned to capture a good part of the global semiconductor market, which is expected to grow 15 – 20 percent. 15. Signals traveling through fiber comprise a carrier wave and a modulation signal, two different wavelengths traveling at different speeds.

Exercise 3

Match Ukrainian translations to the following English phrases .

1. dramatic thaw	1. наукова фантастика
2. large part due to the impact	2. транзистор з одним електроном
3. strategic alliances	3. заводи з виготовлення напівпровідників
4. semiconductor foundries	4. неухильний розвиток
5. science fiction	5. великою мірою завдяки впливу
6. single-electron transistor	6. широкосмуговий супутниковий зв'язок
7.broadband satellite communication	7. різке потепління
8. voice-and-data	8. стратегічна спілка
9. relentless progress	9. голос та дані

Exercise 4

Pay attention to translation of the following phrases.

1. collapsed after a bungled August coup- розпався після недолугого серпневого заколоту;
2. at the throbbing heart of this expansion - у самому серці цього розширення;
3. prodded these technologies onward - просували ці технології вперед;
4. one increasingly began to encounter the terms - все частіше почали зустрічатись терміни;
5. no longer seemed so far-fetched - більше не здавалися такими віддаленими.

Toward a Global Society

Spurred by a dramatic thaw in international relations, the world became a much closer and more intimate place during the 1990s. The Cold War stumbled to a dramatic end in 1991, when the Soviet Union collapsed after a bungled August coup. Germany was reunited after more than three decades of division, while China and Eastern Europe hastened to rejoin the world economy. Trade relations warmed as tariffs fell in many parts of the world.

At the throbbing heart of this expansion was a great boom in the computer, semiconductor and telecommunications industries that occurred in large part due to the impact of the Internet and World Wide Web upon business and everyday life. Improvements in computers and communications relied heavily upon advances in electron devices, and increasingly upon improved electro-optical devices. Market pressures for smaller, faster and better devices prodded these technologies onward. The miniaturization of microchip components continued its relentless march toward submicron dimensions - leading to microprocessors having millions of transistors and memory chips approaching gigabit storage capacities by the century's close. In part due to increasingly high costs, multinational microchip manufacturers began to form strategic alliances to develop products and technologies jointly. Semiconductor foundries also emerged, mainly in the Asia-Pacific region, providing manufacturing services to chip-design firms as well as established chipmakers. The semiconductor industry itself became increasingly globalized.

During the 1990s, one increasingly began to encounter the terms "nanoscale" and "nanotechnology," as it became possible to envision producing device features - and perhaps even entire electron devices - that could be measured in tens of nanometers. Prior to this decade, such possibilities had been largely regarded as science fiction. But after the discovery of spherical carbon-60 molecules and cylindrical carbon nanotubes, as well as the development by various research groups of single-electron transistors, these ideas no longer seemed so far-fetched. Features were beginning to approach the size where the quantum-mechanical behavior of electrons could not be ignored any more.

As the third millennium began, the impact of electron devices upon modern life was impressive indeed. During the previous decade, the world had effectively become much smaller and faster paced, due in large part to light-speed voice-and-data communications over global networks of copper and glass, which owed their very existence to electron and electro-optical devices. Broadband satellite and wireless communications relied heavily on these devices, too. And the march of miniaturization continued toward device features at and even below the 100 nanometer scale - much smaller than the wavelength of visible light. As the number of components on microchips continued to double every 18 months it seemed inevitable that this relentless progress would continue for at least another decade.

Exercise 5

Answer the following questions.

1. What political events happened at the beginning of 1990s?
2. How did those changes influence the world economy and industry?
3. What was the basis for the development of electronic devices?
4. Why did microchip manufacturers begin to unite?
5. Where did major semiconductor producers develop the most rapidly?
6. What new terms appeared in 1990s?
7. Had the devices of 1990s been considered real in previous decades?
8. What discoveries made the ideas of nanotechnology real and close?
9. How did electronic devices influence the world at the end of the second millenium?
10. What was the tendency about chips?

LESSON 7

Exercise 1

Translate the following words paying attention to word-building affixes.

Provided, provision, providing, provider, reflect, reflector, reflecting, reflective, reflection, reflected, non-reflected, contribute, contributor, contributing, contributory, contributions, converse, conversely, conversion, convertible, convertibility, reconvert, recognise, recognition, recognising, unrecognised, illustration, illustrate, illustrating, illustrious, conclude, concluding, concluded, conclusion, conclusive, inconclusive, fabricate, fabricated, fabrication, explicit, explicitly, confine, confining, confined, confinement, perform, performed, performing, performance, inform, informing, information, invent, inventive, invented, invention, innovations, innovative, innovate, innovator.

Exercise 2

Translate the following sentences paying attention to gerunds.

1. In a DRAM, data is stored by charging the capacitor in a memory cell. 2. Typical off-line error-recovery techniques include: attempting to read the data on a second disk revolution; reading the data by positioning the read/write head slightly off track. 3. The wireless industry has lots of experience in responding to customer demands. 4. Local-area networks establish communication links by limiting the distance between transmitter and receiver. 5. The mesh architecture helps keep signal strength up by replacing single long radio links with multiple short ones. 6. The subscriber units are roof-mounted, but have no need for careful antenna siting and aiming. 7. The company makes money not by manufacturing the devices, but by developing enabling technologies and licensing them to other companies. 8. The discs will be capable of storing as much as 270 minutes of compressed digital video. 9. The company has an open-minded approach to research, but it is concentrating on solving problems in electroluminescence. 10.So, scanning a laser beam over the structure generates a series of pulses. 11.The technique depends on combining two separate methods for reading and storing data – a multilayer method that allows data to be stored and read in three dimensions in the disk and wavelength multiplexing. 12. Using the set of three identical Varicaps gives a 1.8:1 tuning ratio in all three sub-bands. 13. Mode-switching affects the current flowing in the output devices, but the output voltage is controlled by the global feedback loop, and

switching is completely silent in operation. 14. The mode is switchable while the amplifier is handling audio, allowing some interesting A/B listening tests. 15.Tuning of the second detector is carried out in the same way, but the signal is fed to the directional coupler output.

Exercise 3

Match Ukrainian translations to the following English phrases .

1. via satellite	1. вуглецеві нанотрубки
2. cellular phones	2. великі масиви
3. to churn away	3. від джерела до стоку
4. semiconductor heterostructures	4. через супутник
5. nanoscale devices	5. наноелектромеханічні системи
6. are trapped around a single point	6. кремнієвий маятник
7. level of atmospheric pollutants	7. поєднати гетероструктури
8. nanoelectromechanical systems	8. обмежені рухом навколо однієї точки
9. from source to drain	9. стільникові телефони
10. silicon pendulum	10. межі електронних приладів
11. to mate heterostructures	11. виконувати
12. the electron-device frontiers	12. молекули на основі вуглецю
13. large arrays	13. нанорозмірні прилади
14. carbon nanotubes	14. рівень забруднювачів атмосфери
15. custom-designed	15. напівпровідникові гетероструктури
16. carbon-based molecules	16. сконструйовані на замовлення

Exercise 4

Pay attention to translation of the following phrases.

1. to the accompaniment of trumpet fanfares -

   під гучний акомпанемент фанфар;
2. only halfway through - лише на півдорозі;
3. were still yielding penetrating insights -

   все ще приносили глибинне усвідомлення сутності;

4. microchips sporting billions of transistors - мікрочіпи, що могли похвалитися мільярдами транзисторів;
5. in the wake of this epochal device - як наслідок цього епохального приладу;
6. shows little sign of letting up - виявляє мало ознак до зменшення.

Into the Third Millennium

The initial years of the third millennium provided an excellent opportunity for reflection upon the impact that electron devices have had on the world over the past century - and upon the contributions of the individuals and institutions that invented and developed them. Telephone and wireless communications were in their infancy a century ago, and electronic computation did not even exist. Today, thanks in large part to electron devices, people can witness via satellite events on the far side of the globe at almost the moment of occurrence. They can converse over cellular phones from a rapidly growing variety of locations throughout the world. And they can afford to purchase computers whose microprocessors churn away at over a billion cycles per second.

The crowning recognition of achievement in electron devices came when the Royal Swedish Academy of Sciences announced that Jack Kilby, Zhores Alferov and Herbert Kroemer had won the Nobel Prize in physics. Kilby was honored "for his part in the invention of the integrated circuit," while Alferov and Kroemer were recognised "for developing semiconductor heterostructures used in high-speed- and opto-electronics." (Although he clearly deserved to, Robert Noyce could not share in this prize, since he had died in 1990.) Reflecting the increasingly global nature of the discipline, a Texas electrical engineer born in Kansas, a German-born California physicist and a Russian physicist from St. Petersburg would share science's most prestigious prize.

On December 10, 2000 Kilby, Kroemer and Alferov marched onto the stage of Stockholm's Concert Hall to the accompaniment of trumpet fanfares as Bardeen, Brattain and Shockley had done over four decades earlier, walking before two phalanxes of previous Nobel laureates. With an audience of over half a billion watching on television screens across Europe and around the world, lord Claeson, Chairman of the Nobel physics committee, said, “ Few have had such a beneficial impact on mankind as yours." Following that, the three men accepted their gold medals from the King of Sweden, joining such illustrious figures as Albert Einstein, Enrico Fermi and James Watson in the Pantheon of science. It had been a very good year for electron devices.

"The advanced materials and tools of microelectronics are being used for studies in nanoscience and of quantum effects," Claeson had noted in concluding his speech. He confidently predicted that "there will be continued development, as we may be only halfway through the information technology revolution." The events of that year and the next were already beginning to prove him right. The scientific and technological breakthroughs that these three men and others had achieved were still yielding penetrating insights and potentially revolutionary electron devices.

Existing techniques are actively being applied to the fabrication of nanoscale devices such as quantum corrals, wells, wires and dots - in which electrons move in only one or two dimensions, or are trapped around a single point. The explicitly quantum behavior imposed by such a close confinement promises important new applications. The quantum cascade laser developed by Bell Labs is just one example of nanotechnology already being put to practical use, such as measuring the levels of atmospheric pollutants.

Other researchers have managed to fabricate nanoelectromechanical systems (NEMS) in silicon. One such device is an electromechanical transistor developed by University of Munich scientists, in which a single electron shuttles from source to drain upon a silicon pendulum vibrating at frequencies up to 100 MHz. And in June 2001, researchers at Intel announced the fabrication of silicon-based transistors with features measuring only 20 nanometers across. With such ultramicroscopic electron devices, companies can envision one day manufacturing silicon microchips sporting billions of transistors. That very same summer, Motorola scientists announced that they had developed a revolutionary way to mate heterostructures made of gallium arsenide and other III-V compounds with silicon microstructures. This advance promises a whole new generation of microchips that can offer both computational and opto-electronic functions.

Still other scientists and engineers are pushing the electron-device frontiers into domains where they no longer rely on silicon. In April 2001 IBM researchers announced having fabricated large arrays of transistors made from carbon nanotubes. The following August, the same group reported the successful operation of a logic circuit built solely out of such nanoscale components. Meanwhile, Hewlett-Packard scientists have been developing custom-designed carbon-based molecules that can serve as on-off switches. Such "molecular electronics" devices may offer dramatic increases in the performance of the electronic circuits of the future.

The "information technology revolution" spawned by the 1947 invention of the transistor clearly has a long way to go before it runs its full course. The flood of striking innovations that have occurred over the past fifty years, in the wake of this epochal electron device, still shows little sign of letting up.

Exercise 5

Answer the following questions to the text.

1. What impact have electronic devices had on the world over the twentieth century?
2. How fast do modern microprocessors work?
3. Who received the Nobel Prize for the invention of the integrated circuit?
4. What are the most famous developments of Alferov and Kroemer?
5. Was Robert Noyce also awarded the Nobel Prize?
6. What predictions did the Chairman of Nobel Prize physics committee make?
7. Was he right?
8. What are the main features of quantum electronic devices?
9. What quantum device is being used to measure the levels of atmospheric pollution?
10. What where the main developments in nanotechnological research in 2001?

PART 2

FROM THE HISTORY OF ELECTRON DEVICES

LESSON 8

Exercise 1

Translate the following words paying attention to affixes.

Radiation, radiate, irradiate, radiating, irradiated, radiator, detect, detected, detection, detecting, detectable, detective, travel, traveled, travelling, traveller, local, locality, locate, location, locator, train, training, trained, trainer, trainee, trainman, trainmaster, efficient, efficiency, efficiently, inefficient, proper, properly, property, improperly, surprisingly, surprised, surprise, surprising, act, active, actively, activity, inactivate, activate, deactivate, interaction, actuator, actress.

Exercise 2

Match the synonyms.

1. to begin	1. to change
2. to investigate	2. to teach
3. to radiate	3. wonderful
4. aid	4. adequate
5. able	5. to act
6. to function	6. to emit
7. to modulate	7. to use
8. to generate	8. to start
9. to employ	9. valve
10. surprising	10. greatly
11. tube	11. help
12. vastly	12. to study
13. to train	13. capable
14. proper	14. to produce

Exercise 3

Translate the following sentences paying attention to tenses.

1.There is a growing scientific evidence that prolonged exposure to some kinds of radio waves does cause at least low-level changes in the movements, working and possibly structure of molecules and cells in living tissue. 2. Naturally, optoelectronics engineers would love to make VCSELs from silicon, but the material does not emit light easily. 3. For 50 years hard disks have acted as relatively dumb devices, simply serving as storing blocks of data. 4. The drive manufacturers have to some extent become victims of their own success. 5. In both ATA- and SCSI-based systems, computers commonly divide a data file into a set of so-called logical blocks whose size ranges from 512 bytes to 4096 bytes and up. 6. The person who comes up with application thinks differently than the scientist who lays the foundation. 7. The principal application of any sufficiently new and innovative technology always have been and will continue to be applications created by that new technology. 8. Right now, wireless markets are moving into a stage where subscribers can freely substitute wireless service for fixed line service. 9.Straightforward as this change seems, the transition from providing wireless telephony to a complicated mix of data and other non-voice services is difficult and risky. 10. Once the spectrum and regulatory landscape stabilized in the 1970s, the industry increased capacity and efficiency many times. 11.People use Internet as much as they do these days because bandwidth in the fixed networks is almost free. 12. As the early test results have been good the team is working on methods of cheaply mass producing the substrates. 13.Not only do the defects shorten the lifetime of lasers, they also drive up the cost of the devices. 14. In February, a group of nine technology companies announced that they will jointly establish specifications for a new video recording format that marries a blue-violet laser to a 12 cm (CD or DVD size) optical disk. 15. Toshiba is asking that anyone who wants to propose a blue-laser format present it to the working group. 16. In 2000, Sony and Pioneer demonstrated a prototype blue-laser format they have developed jointly. 17.Technology is evolving so rapidly that any standard may well prove merely temporary.

Exercise 4

Match the English words with their Ukrainian translations.

1. high bandwidth	1. роздільна здатність
2. aircraft detection	2. основна частина
3. output resonator gap	3. мікрохвилева піч

4. cavity magnetron	4. поза межами видимости
5. traveling wave tube	5. виявлення літака
6. comprehensive system	6. багаторезонаторний магнетрон
7. broadband capability	7. велика ширина смуги
8. microwave oven	8. вихідна щілина резонатора
9. high-resolution	9. всеосяжна система
10. core element	10. лампа біжної (прямої) хвилі
11. line-of-sight	11. широкосмугова здатність

Microwave Tubes

During the 1930s, the Bell Telephone Laboratories began investigating the use of shortwave electromagnetic radiation for long-distance communications. The high bandwidths that could be achieved, as well as the potential for line-of-sight transmissions over many miles, was promising. The U.S. Army and Navy were also interested in shortwave electromagnetic waves as navigational aids and for aircraft detection systems. But progress was hampered by the lack of electron tubes able to function at the necessary frequencies of a gigahertz or more.

Then in 1937, working at Stanford University with his brother Sigurd, Russell Varian invented the klystron; the first successful microwave tube, it could oscillate and amplify signals at frequencies as high as 3 GHz, corresponding to a wavelength of 10 centimetres. Klystrons modulate a stream of electrons traveling along the tube axis into bunches that generate microwave radiation at an output resonator gap. Like all microwave tubes, their high-frequency operation does not depend on small device dimensions.

A bit later Henry Boot and John Randall invented the cavity magnetron at Birmingham University. These British physicists employed a resonant cavity structure in a magnetron for the first time. It was a huge success, generating kilowatts of microwave power at 10 cm - far more than klystrons could then achieve. Soon after U.S. physicists and engineers learned about this surprising electron device in 1940, the MIT Radiation Laboratory was established to develop comprehensive radar systems with the cavity magnetron as the core element. Small klystrons served as local oscillators in these systems, which eventually operated above 10 GHz by the end of World War II. Radar proved crucial to the Allied victory.

Originally trained as an architect, Austrian emigrant Rudolf Kompfner invented another kind of microwave tube, the traveling-wave tube, at

Birmingham in 1943. After he learned about this invention during the War, Bell Labs engineer John Pierce developed a working theory of its operation, based on the interaction between an electron beam and slower electromagnetic waves traveling within the tube. His theory contributed to the tube's stability and the realization of its broadband capabilities. Pierce developed other new features that vastly improved these tubes - such as a convergent electron gun now named after him. Kompfner came to Bell Labs in the early 1950s and worked with Pierce to adapt traveling-wave tubes for satellite communications, which began in the 1960s with the Echo and Telstar satellites. Traveling-wave tubes are the only electron devices able to supply the proper combination of high output power and bandwidth needed for satellite communications.

Today, modern traveling-wave tubes are still used extensively in microwave and satellite communications systems because of their high efficiency, long lifetimes and excellent reliability. And modern klystrons can produce astonishing levels of peak and average power - more than 100 MW peak and 1 MW average. They power particle accelerators used for physics research and cancer therapy, and are employed in high-resolution radar systems. Magnetrons are also widely-used today because they are efficient, low-cost sources of microwave power. Every commercial microwave oven contains a magnetron.

Exercise 5

Continue the following questions to the text.

1. When did Bell Labs … ?
2. What were the U.S. Army and Navy … ?
3. Why was the progress …?
4. What did the brothers Varian …?
5. How do klystrons … ?
6. Where was cavity magnetron … ?
7. How did the U.S. physicists … ?
8. Did small klystrons …?
9. When was the traveling-wave tube … ?
10. What was Pierce’s theory … ?
11. What improvements … ?
12. What electron devices are able to … ?
13. Why are modern traveling-wave tubes …?
14. Where are klystrons and magnetrons … ?

LESSON 9

Exercise 1

Translate the following words paying attention to word-building affixes.

Microwave, waveform, wavelength, waveguide, waveband, wavefront, waveshaping, microphone, superheterodyne, superconductivity, semicircle, semiconductors, semiaxis, semioscilation, hemisphere, conjecture, conjectural, conjectured, trap, trapping, trapped, formation, forming, formed, deform, uniform, non-uniform, uniformity, uniformly, unidirectional, universal, uninteresting, advantage, disadvantage, advantageous, line, linear, linearity, nonlinear, convert, convertible, reconvert, conversion, cooperate, coordinate, coexist, closely, close, disclose, displace, dissimilar, disregard, out, output, outside, outsider, outward .

Exercise 2

Translate the following paying attention to noun groups.

1.Bluetooth was developed initially by Ericsson as a short-range (10meters) cable replacement for linking portable consumer electronic products, but it also can be adapted for printers, fax machines, keyboards, toys, games, and virtually any other digital consumer application. 2. More than 2000 organisations have joined the Bluetooth Special Interest Group (SIG) and most of them are currently developing Bluetooth-enabled products. 3. A Bluetooth radio consists of a radio-frequency (RF) transceiver portion, baseband link control unit, and the associated link management software, plus an antenna subsystem. 4. The radio uses Frequency-hopping spread-spectrum technology to support both point-to-point and point-to-multipoint connections. 5. The Bluetooth baseband protocol allows for both circuit- and-packet switching, making it suitable for both voice and data. 6. Hoping to speed the Bluetooth products to market the SIG has formed the Bluetooth Measurement Initiative, whose task is to work with test equipment manufacturers to develop hardware and software for interoperability testing. 7. In October Tektronix began shipping the CMU 200 universal radio communication tester announced in June. 8. With several companies, mostly start-ups like San Diego's Silicon Wave and Britain's Cambridge Silicon Radio it is going to be difficult to face the reality of creating electronics products with an entirely new communication interface. 9. The new standard specifies a set of wavelengths for use in what is known as coarse wavelength-division multiplexing (CWDM) system.10. When powered only by its on-board nickel-metal hybrid batteries, the robot can walk for about twenty minutes at most. 11. Its browser-like interface, which is independent of the underlying network topology, is integrated with a speech synthesis system.

12.Much of the research into optical interconnects in the U.S. have been funded by a US $ 70 million program run by the U.S. Defence Advanced Research Projects Agency. 13.Since 1992, drive storage capacity has been increasing at an annual rate of 60 percent, and over 100 percent in recent years – a rate exceeding the 18-month doubling of Moore's law for IC complexity. 14.Wireless network engineers will have to add bandwidth management to the frequency planning and the code and noise management skills. 15. The spin-on and chemical deposition processes differ basically in how they deposit a thin low-*k* dielectric film on a silicon wafer. 16. The Coral and Black Diamond dielectrics are made by adding carbon to silicon dioxide recipe in a chemical vapor deposition (CVD) process that yields carbon-doped oxide.

Exercise 3

Match the antonyms.

1. common	1. disadvantage
2. to receive	2. to finish
3. to increase	3. outside
4. to trap	4. special
5. before	5. previous
6. failure	6. same
7. advantage	7. success
8. to push	8. separately
9. easy	9. difficult
10. far	10. to decrease
11. inside	11. to liberate
12. together	12. after
13. next	13. to pull
14. different	14. close
15. to begin	15. to send

Exercise 4

Match Ukrainian translations to the following English phrases .

1. solid-state	1. транзистор з точковим контактом
2. "field-effect" amplifier	2. суміжні шари

3. point-contact transistor	3. легований домішками
4. junction transistor	4. дійсно величезний
5. adjacent layers	5. твердотільний
6. “doped” with impurities	6. підсилювач на польовому транзисторі
7. hearing aids	7. площинний транзистор
8. truly immense	8. слухові апарати

Exercise 5

Pay attention to translation of the following phrases.

1. it proved a failure - виявився невдалим ;
2. stumbled upon a way to overcome - спотикалися на шляху до переборення ;
3. it took several major advances - це потребувало кількох значних успіхів ;
4. had begun to have a major impact - почала дуже впливати ;
5. push back the scientific frontiers even further -

   ще ширше розсунути межі науки.

The Invention of the Transistor

Solid-state electron devices originated with the crystal rectifiers that were commonly used as detectors in radio receivers until displaced by vacuum diodes during the 1920s. Such nonlinear electron devices convert AC radio signals into DC waveforms. When microwave transmissions became possible during the late 1930s, scientists and engineers turned increasingly to silicon rectifiers to serve as detectors of these signals because vacuum diodes then available could not operate at gigahertz frequencies. The radar systems of World War II used such crystal rectifiers - based on a chip of silicon or germanium with a metal point contact stabbing into its surface - in the superheterodyne circuits of their receivers.

Well before the War, scientists and engineers dreamed of inventing solid-state amplifiers using the semiconductors then available. At Bell Labs, William Shockley had several ideas for fashioning such a device; he convinced Walter Brattain to try to fashion one of them out of copper oxide, but it proved a failure. However, a vastly improved understanding of semiconductors - particularly germanium and silicon - emerged from the radar program during the War. In 1945, Bell Labs set up a new Solid State Physics department with

Shockley as leader to take advantage of all the new knowledge and push back the scientific frontiers even further.

In the spring of that year, Shockley conceived what he called a "field-effect" amplifier based on the new semiconductors, but attempts by Brattain and others to make such a device using silicon failed completely. Examining the theory of this device in 1946, theoretical physicist John Bardeen conjectured that electrons trapped on the semiconductor surface were blocking the electric fields, keeping them from penetrating into the material and modulating the flow of electrons inside. Working together over the next two years, Bardeen and Brattain verified this theory and stumbled upon a way to overcome the blocking effect of the surface electrons. In December 1947 they invented the first solid-state amplifier, called the "point-contact transistor." (The word "transistor" was actually coined by John Pierce in May 1948.) This device closely resembled the crystal rectifiers of World War II radar receivers, with two very closely spaced metal points (instead of one) poking into the surface of a germanium chip. One point contact carried the input signal, which modulated the output signal flowing through the other contact. By the time Bell Labs announced the invention in mid-1948, its engineers had already developed prototype radio and telephone circuits based on point-contact transistors.

Meanwhile, in January 1948, Shockley conceived yet another idea for a transistor, called the "junction transistor." It was essentially a sandwich made of three adjacent layers of germanium or silicon "doped" with different impurities to induce radically different electrical characteristics among them. Electrical signals applied to the central layer would modulate currents flowing through the entire sandwich from one end to the other. Shockley figured that his junction transistor would be much easier (than the point-contact transistor) to manufacture with uniform, reliable characteristics. But it took several major advances in materials science before Bell Labs scientists and engineers finally succeeded in making one, proving Shockley's insights and precise mathematical theory to be indeed correct.

In the 1950s, junction transistors produced by GE, RCA, Transitron, Texas Instruments and Japan's SONY Corporation began to be employed as amplifiers in commercial devices such as hearing aids and transistor radios. By the early 1960s, they had displaced electron tubes in most computer circuits. The manipulation of electrons in semiconductors had begun to have a major impact upon commerce and industry. And it would become truly immense by the end of that decade.

Exercise 5

Transform the following sentences into disjunctive (tag) questions.

1. Solid-state devices originated with crystal rectifiers, …?

2. They were displaced by vacuum diodes, …?
3. Such nonlinear devices convert AC signals into DC waveforms, ..?
4. Vacuum diodes then available could not operate at gigaherts frequencies, ..?
5. William Shockley had several ideas, …?
6. In 1945 Bell Labs set a new department, …?
7. The electrons on the surface were blocking the electric fields, …?
8. During 2 years scientists could not overcome this effect, ...?
9. John Pierce coined the term “transistor”, …?
10. Circuits based on point-contact transistors had been developed by 1948, …?
11. Such junction transistor would be much easier to manufacture, …?
12. Transistors have displaced electron tubes, …?
13. They are being used as amplifiers, …?

LESSON 10

Exercise 1

Translate the following words paying attention to word-building affixes.

Exist, existing, coexist, co-existence, purify, purified, purifying, ultrapure, impurity, pure, purely, invent, inventing, inventive, invention, inventor, inventory, real, really, realistic, reality, unreal, realize, realization, labour, labourist, elaborate, laboratory, laborious, elaboration, advance, advanced, advancement, perfect, perfection, perfected, imperfect, imperfection, perfectly, perfectible, perfectibility, hear, hearing, heard, hearer, sensitive, sensor, sensitivity, sense, senseless, insensitive.

Exercise 2

Translate the following paying attention to participles.

1.Sumitomo’s substrates are far from defect free, having dislocation densities around 500 000 per square centimetre. 2. Sumitomo, which has 10 full-time researchers working on GaN substrates, is not the only Japanese giant betting heavily on GaN. 3. Instead of a single omnidirectional or sectorized antenna, these systems use an array of radiating elements. 4. Analyzing the complex signal received from each subscriber the smart array decomposes it into a number of simpler signals, each characterized by its strength, direction and time of arrival. 5.The signal will undergo multipath distortion – that is, it will take multiple paths to the base station, bouncing off various objects, being attenuated to various degrees, and undergoing various delays, depending on the different path length. 6.Taking advantage of those processors, Navini Networks uses the technology, versions of which operate in both the licensed and unlicensed bands in the vicinity of 2.5 GHz. 7. But having been removed from the cell, the charge has to be written back in to be available for the next read access. 8. At maximum output, with all those motors and processors going at once, the robot consumes over 150 W. 9. Data integrity is ensured by sophisticated algorithms that clean up the raw data from the disk using digital error checking and correction codes (ECC). 10. Ionic current flowing through the plug is then measured as a voltage appearing across resistor, with a 4.7V zener diode in parallel to limit output voltage in the range – 4.7 to 0.7V. 11. The instrument described is a cable tester having been used under real conditions when installing and maintaining private cable tv networks. 12. Two 741 op-amps are used as logarithmic amplifiers, the type having a moderate thermal drift. 13. Capacitors are used as mounting contacts, soldered to ground by one leg and supporting a diode cathode with the other. 14. Knowing reflection index, one always can define the power gain with the signal propagating in an unmatched transmission line. 15. This resulted in two tones appearing in the same level. 16.The standing currents are modified by signal current through the gain defining resistor, connected between pins 2 and 3. 17. The signal was applied to pin 1 only, pin 4 being grounded, i.e. as an unbalanced input. 18.Products designed to that specification are foreseen entering the market by the end of 2003. 19 Spin-on dielectrics are carbon or silicon-based polymers applied by pouring liquid mixtures on rapidly spinning wafers.

Exercise 3

Match Ukrainian translations to the following English phrases .

1. alloy-junction transistor	1. струми втрат
2. astride an intervening layer	2. дифузія домішок
3. quantum-mechanical tunneling	3. очищення плавної зони
4. reactivity	4. по обидва боки проміжного шару
5. conduction band	5. стоплений площинний транзистор
6. minority carriers	6. хімічна активність
7. gap	7. квантово-механічне тунелювання
8. leakage currents	8. зона провідности

9. float-zone refining — 9. заборонена зона, проміжок

10. impurity diffusion — 10. неосновні носії

Exercise 4

Pay attention to translation of the following phrases.

1. by melting pellets of indium - наплавляючи гранули індію;
2. adopted this approach rather than set up - запровадили цей спосіб замість придбання;
3. serendipitous outgrowth of these efforts - несподівано щасливий наслідок цих зусиль;
4. zealously pursued the quest of - завзято продовжував пошук шляхів;
5. pushed the doors open wide - широко відчинили двері.

Bipolar Junction Transistors

Although Bardeen and Brattain's invention of the point-contact transistor came first, it was the bipolar junction transistor conceived by Shockley a month later that really made these electron devices a commercial reality. In January 1948 he had the key insight of "minority carrier injection" - that electrons and holes can briefly coexist in the bulk semiconductor material and flow in the intimate presence of one another. In July 1949 Shockley published his ideas in an article, “The Theory of P-N Junctions in Semiconductors and P-N Junction Transistors”. He further elaborated these ideas in his 1950 book “Electrons and Holes in Semiconductors”, which became the bible of the new field read by thousands of practitioners.

Important advances in materials science helped get junction transistors out of the laboratory and into production. William Pfann's invention of zone refining at Bell Labs provided ultrapure germanium samples with impurity levels of less than a part per billion. Meanwhile, chemist Gordon Teal perfected a technique for growing large single crystals of germanium; he and Morgan Sparks then figured out how to introduce small impurities into the melt and form pn junctions as well as three-layer structures directly in the resulting crystals. Announced in July 1951, such "grown-junction" transistors were used in hearing aids and radios by the mid-1950s. Texas Instruments manufactured the germanium transistors used in the first transistor radio, the Regency TR1, which reached customers by Christmas 1954.

Another approach to making junction transistors had been invented by John Saby at General Electric laboratories in Schenectady, New York, and developed for mass production by RCA. In 1951, he fabricated the so-called alloy-junction transistor by melting pellets of indium on the opposite sides of a thin slab of germanium; the molten indium alloyed with the germanium to form two *pn*-junctions astride a narrow intervening layer of n-type germanium. Alloy-junction transistors proved easier to manufacture than the grown-junction variety and many transistor producers, large and small, adopted this approach rather than set up elaborate crystal-growing equipment. Philco, for example, made high-frequency alloy-junction transistors by narrowing their base layers as much as technically possible at the time.

One serendipitous outgrowth of these transistor-fabrication efforts came at SONY, which began selling transistor radios in 1955. In 1957, while experimenting on heavily doped germanium pn junctions as part of efforts to reach high frequencies above 100 MHz, Leo Esaki invented the tunnel diode; he observed that some of the electrons were actually traversing the barrier due to quantum-mechanical tunneling. He shared the 1973 Nobel Prize in physics for this fundamental scientific discovery.

Meanwhile, researchers at Bell Labs and other institutions had begun to recognize the limitations of germanium and were turning to silicon as the element of choice for transistors and other semiconductor devices. Being much more difficult to purify due to its higher melting temperature and great reactivity, silicon has a significantly larger gap between its valence and conduction bands. This higher band gap means that silicon transistors are far less sensitive to temperature changes, their leakage currents being far lower than for germanium devices.

Having joined Texas Instruments in 1953, Gordon Teal zealously pursued the quest of making silicon transistors. Before leaving Bell Labs, he had adapted his crystal-growing techniques to work with silicon; at TI he hired physical chemist Willis Adcock to lead a group aimed at developing silicon transistors. In April 1954 they succeeded in making a grown-junction transistor using high-purity silicon. Although Morris Tanenbaum also fabricated silicon transistors at Bell Labs that same year, the TI devices were the first silicon transistors to reach market.

The knotty problem of purifying the silicon was finally solved by Bell Labs metallurgist Henry Theurer, who developed the float-zone refining technique in 1955. This breakthrough and the fabrication of pn junctions by impurity diffusion were the technological advances that pushed the doors open wide for silicon semiconductor devices. By the end of the 1950s, germanium was in decline.

Exercise 5

Find in the text synonyms for the following words.

Thoughts, manufacture, in the meantime, to improve, a plate, to apply, to work out, to start, organisation, complicated, really, to manage, to employ, to head, to produce, to get to, less, highly, apparatus, to create, methods, doping, to finish.

Exercise 6

Make up 10 questions to the text beginning with "When".

LESSON 11

Exercise 1

Translate the following words paying attention to word-building affixes.

Inexpensive, expense, expensive, expensively, require, requirements, required, requiring, inhabit, uninhabited, inhabitant, emerge, emergence, emergency, re-emerge, emergent, emerged, emerging, diffusion, non-diffusing, diffuse, diffused, diffusible, diffusive, amplify, amplification, amplifier, amplified, amplifying, protection, protective, protect, protector, unprotected, protectorship, protecting, apply, application, applying, applied, misapply, misapplication, appliance, applicant, applicable.

Exercise 2

Translate the following paying attention to modals and their equivalents.

1. Like cable network providers before them, wireless network providers will not have to create the new services themselves. 2. A few years from now, you may be replacing your current DVD player with one that will record an entire high-definition movie on a single disk, which means a capacity of about 25GB, or more than five times that of today's 4.7GB DVDs. 3. The specification is to be completed in a few month, and licensing will begin. 4. The challenge they have to meet is to establish communication links with signal-to-noise ratios high enough to support broadband communications with easily installed, preferably indoor, antennas. 5. Small wonder, then, that this sort of technology could not even be considered for commercial application until cheap and

powerful signal processors became available. 6. It's surprising to realize that buyers of IP blocks used in SOC devices may not be entirely aware of what they're getting and how it works. 7.SOC providers could shorten their time to market considerably if they didn't have to spend up to 70 percent of it verifying that their designs will plug and play. 8. When RTL code is fed into a design verification program, the program can check to determine whether the block behaves as it should. 9. But Deutsche Telecom may have some reorganising to do itself. 10. For a start, engineers could rework the architecture of chips and boards to shorten the distances over which signals have to travel. 11. This may not solve all the industry's problems, but it's a step in the right direction. 12.Intel can move data at 10 GHz over a copper wire on the board and should be able to push it to at least 20 GHz. 13. If disk drives were enabled to perform a host of tasks that have traditionally been the work of CPUs, dramatic low-cost improvements could be made in computing environments ranging from laptops to storage networks. 14.Adding intelligent drive features may require changing the standards, and may also require changes in operating system and application software. 15. The only universal rule is: when checking any hf devices, one should make the connection between tester and tested as short as possible. 16.If the range is to be tuned, the equivalent resistance of the crystal and tuning network at the new series-resonant frequency should be found. 17. A single 3.5-inch disk that can hold a few feature-length films today could have the capacity to hold a personal library of a thousand films if the computer storage industry achieves terabit-per-square-inch densities.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. selenium photocells	1. застосування у віддалених місцях
2. light meters	2. космічні супутники
3. trace impurities	3. аварійні придорожні телефони
4. manufacturing costs	4. оксидне маскування
5. competitive	5. мікродомішки
6. remote applications	6. витравлювати складні схеми
7. electric-power grid	7. конкурентоспроможний
8. space satellites	8. лічильники світла
9. emergency roadside telephones	9. процес виготовлення
10. an order of	10. електричні мережі
11. oxide masking at	11. прорив

12. etch intricate patterns — 12. селенові фотоелементи
13. breakthrough — 13. на порядок
14. manufacturing process — 14. виробничі видатки

Exercise 4

Pay attention to translation of the following phrases.

1. overnight sensation - неподівана сенсація;
2. media heralding its supposedly non-polluting energy -
   медіа проголосили її екологічно чистою енергією;
3. came down gradually over the ensuing decades -
   поступово знижувався протягом наступних десятиліть;
4. vigorously pursued applications - рішуче займались застосуваннями;
5. precariously exposed pn junctions that could easily be contaminated -
   ризиковано незахищеними переходами, що легко могли забруднитися.

Photovoltaic Cells and Diffused-Base Transistors

Ever since Russell Ohl's 1940 discovery of *pn*-junctions in silicon, scientists had recognized that these devices could convert light to electricity with fairly high efficiency, an order of magnitude better than for the selenium photocells then used in light meters. But it took until the early 1950s to develop a relatively inexpensive process to produce large-area pn junctions. Calvin Fuller was experimenting at Bell Labs on the use of diffusion to introduce trace impurities into germanium and silicon, forming pn junctions just beneath the semiconductor surface. Gerald Pearson soon recognized that this approach might yield the large-area pn junctions required for photovoltaic cells; in 1954 he worked with Fuller and Darryl Chapin to develop the Solar Battery, a boron-doped silicon photovoltaic cell that could convert sunlight to electricity at efficiencies up to 6 percent.

Announced to the public in April 1954, the solar cell became an overnight sensation, with the media heralding its supposedly cheap, non-polluting energy. But due to their high manufacturing costs, these cells were not able to compete with conventional sources of electricity except in remote applications well off the electric-power grid. Fortunately, an application emerged in the late 1950s for which silicon photovoltaic cells were ideal: powering space satellites. By then, further development had pushed their energy conversion efficiencies above 10 percent. Photovoltaic cells powered the Vanguard and Explorer satellites, which first orbited in 1958 - and almost every Earth satellite since then.

As their costs came down gradually over the ensuing decades, these cells have been used to power pocket calculators, emergency roadside telephones, and many other remote, off-grid applications. Large arrays of silicon photovoltaic cells are now beginning to appear on the rooftops of homes, schools and businesses - generating electricity for the inhabitants and feeding excess power to the grid.

Bell Labs had also vigorously pursued applications of diffusion in fabricating high-frequency transistors able to operate above 100 MHz, which required that they have very narrow base layers only microns thick. In early 1955, Morris Tanenbaum made the first diffused-base silicon transistor. Together with the development of the float-zone refining process, this breakthrough convinced Vice President Jack Morton that the manufacture of semiconductor devices would soon depend almost entirely on silicon and diffusion.

Another key advance in 1955 was the development of oxide masking at Bell Labs by Carl Frosch and Link Derick. They learned how to form a glassy, protective SiO_2 layer on the silicon surface and use it as a selective mask against the diffusion of impurities. Employing these techniques, one could now etch intricate patterns in the oxide layer for use in producing tiny, diffused-base transistors. The Fairchild Semiconductor Company and Texas Instruments were manufacturing such "mesa" transistors by 1958. These transistors were able to find a ready market in military applications and began appearing in computers and other circuits that required high-frequency amplifiers and switches.

As the decade ended, Jean Hoerni and his Fairchild colleagues invented the "planar" manufacturing process that was soon to revolutionize the semiconductor industry. Instead of making mesa transistors with precariously exposed pn junctions that could easily be contaminated, he embedded the junctions in the silicon beneath the oxide layer, where they were naturally protected. Within a year, Robert Noyce figured out how to employ this planar process in the manufacture of silicon integrated circuits.

Exercise 5

Find in the text antonyms to the following words.

Darkness, low, worse, absolutely, costly, above, unusual, close, unfortunately, to disappear, early, abruptly, unable, to finish, wide, separately, partially, simple, to vanish, to purify, to attack.

Exercise 6

Make up questions to the text starting with "What".

LESSON 12

Exercise 1

Translate the following words paying attention to word-building affixes.

Frequent, frequency, frequently, infrequent, serve, served, servant, service, serving, serviceable, achieve, achievement, achieving, unachievable, achieved, desire, desirable, undesirably, desired, desiring, multiple, multiply, multiplication, multiplied, multiplier, multiplex, multiplicity, deposit, deposited, deposition, depositing, deposit, depositor, depository, supply, supplier, supplied, supplying, supplies, research, researching, researcher, scrupulous, scrupulosity, solve, solution, unsolved, dissolved, solvable, soluble, solubility, integrated, integrate, integral, integrity, governed, government, govern, governor.

Exercise 2

Translate the following paying attention to gerunds.

1. Using a set of three identical Varicaps of the type used in broadcast fm receivers or tv channel selectors gives a 1.8:1 tuning ratio in all three sub-bands. 2.While on-line shopping appears to have less impact on the environment than driving to the mall, the net effect of e-commerce remains unclear. 3. Zinc-air batteries have long had a reputation for excellent energy-storage capability but not for being able to deliver lots of power. 4. Energy is put into or taken out of a battery by electrically charging or discharging it. 5. Refuelling here means mechanically replacing the metal oxide with fresh metal, recharging means replacing the energy electrically – as with ordinary rechargeable cells. 6. So what do you call an electrochemical device that generates electricity by oxidizing a light metal and can be either refuelled or recharged? 7. Assuming that it works as expected, the revolutionary power cell (RPC) has several attributes that make it attractive for powering electric vehicles. 8. At least since Alan Turing tackled Enigma in World War II, building machines to crack codes has been the domain of computer scientists and engineers. 9. Lately they have joined biologists in cracking humanity's most important code - the human genome, the complete set of our genetic information. 10. Sequencing the human genome is essentially putting in order the over three billion chemical units that

encode the instructions on how to build and operate a human being. 11. Leading scientists were quick to point out that just knowing the raw data set that makes up the genome is not an end in itself. 12.Reverse engineering is the process of analysing an existing system to identify its components and their interrelationships and create representations of the system in another form or at a higher level of abstraction. 13. Semiconductor Insights turned the experience into a profitable part of its business – namely, helping banks, credit card issuers, check the security of their smart card products. 14. The company does that by seeing how easy, or hard, it is to hack into the cards' embedded microprocessor and memory chips. 15. Major Taiwanese capacitor makers have vigorously denied having made any bad components, but the crisis has had a chilling effect on the island's whole industry. 16. Makers of the polishing tools responded by reducing or even eliminating abrasives and using more chemicals for removal, as well as lowering the force on the rotating head.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. phase-shift oscillator	1. не надто віддалене
2. intricate circuit elements	2. вкраплені (вбудовані)
3. protective layer	3. МОНПТ (МДНПТ)
4. impregnated into	4. проникнуть у
5. metal-oxide-semiconductor field-effect transistor (MOSFET)	5. генератор із зсувом фази
6. not-too-distant	6. складні елементи кола
7. would permeate	7. захисний шар

Exercise 4

Pay attention to translation of the following phrases.

1. penned a prophetic entry into his logbook -

   записав пророчі слова до свого робочого журналу;

2. a far-sighted article … by stating -

   прозорливу статтю … визначенням;

3. boldly extrapolated this exponential growth -

   сміливо поширив це експоненційне зростання.

Integrated Circuits

Miniaturization of electronic circuits was a frequent topic of discussion in the late 1950s, especially in the U.S. armed services because of their needs for compact, lightweight electrical equipment. But it took the inventive genius of electrical engineer Jack Kilby to come up with a practical way to achieve this goal. On July 24, 1958, he penned a prophetic entry into his Texas Instruments logbook: "Extreme miniaturization of many electrical circuits could be achieved by making resistors, capacitors and transistors & diodes on a single slice of silicon."

By September Kilby had built and operated a phase-shift oscillator on a chip of germanium having a transistor, capacitor and the resistors on it, linked by gold wires. This crude prototype oscillated at 1.3 MHz, demonstrating that integrated circuits were indeed achievable. That autumn Kilby began refining his designs and working with Jay Lathrop to adapt the techniques of photolithography for defining intricate circuit elements in chips of both germanium and silicon.

That same year Jean Hoerni invented the planar manufacturing process at Fairchild Semiconductor Corporation in California. In January 1959, while thinking about other possible uses for this process, Robert Noyce conceived another way to fabricate integrated circuits. "In many applications," he wrote, "it would be desirable to make multiple devices on a single piece of silicon in order to be able to make the interconnections between them as part of the manufacturing process." Noyce's distinctive approach used fine aluminum lines deposited directly upon the silicon-dioxide protective layer to connect circuit elements defined in the underlying silicon by Hoerni's planar process. Fairchild scientists and engineers under Gordon Moore quickly began working out the many details of manufacturing such an integrated circuit.

By 1961 both companies had silicon integrated circuits ready for market-TI's family of Solid Circuits and Fairchild's Micrologic series. At first, however, the only customers interested were the armed forces and other companies supplying them lightweight electronics and computers. The Air Force's Minuteman program was an important driving force, as was NASA's Apollo project later that decade.

In producing these integrated circuits, both companies used bipolar junction transistors impregnated into silicon by diffusion processes. At Fairchild, meanwhile, a group of researchers that included Bruce Deal, Andrew Grove, Chih-Tang Sah, and Ed Snow began addressing the problems of manufacturing metal-oxide-semiconductor (MOS) field-effect transistors, which had been invented at Bell Labs and further developed at RCA. One of the big problems they faced was the stability of these transistors; they eventually solved it by depositing a thin silicon nitride layer atop the silicon dioxide and scrupulously eliminating any sources of sodium ions in the microchip manufacturing process. By the decade's end, MOS transistors were beginning to displace bipolar transistors in many integrated circuits.

It was Moore who envisioned the immense potential that integrated circuits held for electronics. He began a far-sighted article in the April 1965 issue of Electronics by stating," The future of integrated electronics is the future of electronics itself." Moore foresaw a day in the not-too-distant future when that integrated circuits would permeate home computers, portable communications devices, and automobile control systems. Since the number of circuit components on a microchip had grown from ten to about fifty in only four years, he boldly extrapolated this exponential growth for another decade and predicted that integrated circuits would contain 65,000 components by 1975. This prediction, which has come to be known as Moore's Law, turned out to be true; it has governed the explosive growth of the semiconductor industry ever since.

Exercise 5

Give synonyms to the following words.

1. miniature (adj)	10. use (n)
2. frequent (adj)	11 techniques (n)
3. late (adj)	12. indeed (adv)
4. require (v)	13 probable (adj)
5. equipment (n)	14. conceive (v)
6. goal (n)	15. manufacture (n)
7. achieve (v)	16. fine (adj)
8. link (v)	17. quickly (adv)
9. demonstrate (v)	18. contain (v)

Exercise 6

Make up general questions to the text.

LESSON 13

Exercise 1

Translate the following words paying attention to word-building affixes.

Respond, response, irresponsible, responding, responsibility, corresponding, correspondent, correspondingly, initial, initialise, initialised, initialisation, initials, initially, observation, observe, observable, observance, observant, observational, observer, observatory, announce, announced, announcer, announcing, announcement, encourage, encouragement, courage, courageous, encouraged, encouraging, pursue, pursuit, pursuer, lumen, luminescent, luminescence, luminosity, luminous, bright, brightness, brighter, attempt, attempting, attempted, curious, curiosity, curiously .

Exercise 2

Translate the following paying attention to infinitives.

1. Companies are obliged to shareholders to produce products and profits, which makes it difficult for them to sponsor research at the expense of their core businesses. 2. The new services will have to be attractive and useful for customers to be willing to pay for them by the megabyte. 3. The list includes blue, green, and white light-emitting diodes and blue and violet semiconductor lasers, which are supposed to revolutionise first digital video players and then perhaps laser printers. 4. It is the first such substrate to emerge from any laboratory in quantities sizable enough to be used in a full-scale testing program. 5. A lifetime of at least 10 000 hours is assumed to be needed for the devices if they are to be commercially successful. 6. It remains to be seen whether this approach will find a niche or be superseded by the rapid advance of blue-laser development. 7. The first generation system required a directional antenna to be installed on the subscriber's premises within sight of a base station antenna. 8.Each element is fed a version of the signal to be transmitted that differs from the others only by its amplitude and phase. 9.The numbers seem to indicate that we have a way to go before serious demand for high-speed Internet access develops among wireless users. 10. To set up a network in a four-story hotel four base stations were required, plus considerable testing to decide on that number and on where to place the base stations for complete coverage. 11.At a first glance, Web-based shopping seems to have benefits for both the consumer and the environment. 12. Above all, NASA wanted the crew to have the flexibility to work around last-minute problems manually. 13. While concerned about the risks most space experts agreed that further waiting would be unlikely to reduce risks.14.Naturally, qualification requirements are expected to evolve

as test equipment and procedures become available. 15. It is of course not permissible to increase the analyser's sensitivity to set the two tones back to the reference level. 16. Two diodes are considered to have been selected in a pair if their forward resistance coincide in three points (in the three sub-bands) to within 5%. 17. It turned out to be possible to measure a reflection coefficient of 0.06 to an accuracy of about 10%. 18. So far, the only motherboard maker to admit to the problem is ABIT Computer Corp. and the only major PC maker to acknowledge being affected is IBM Corp. 19. But the problem is likely to be more widely spread. 20. To remain competitive globally, however, European semiconductor suppliers will need more than one fab not only to expand the capacity but also to have a local presence in key developing markets. 21.A laptop PC is an example of a visible technology; we expect it to fail and so we perform daily routines such as backing up files in anticipation of its failure.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. interface	1. плоский телеекран
2. light-emitting diode	2. фосфат галію
3. flat-panel television display	3. задні габаритні ліхтарі
4. dramatically altered	4. напилення у рідкій фазі
5. gallium phosphide	5. вуличне світлове табло
6. chemical-vapor deposition	6. інтерфейс (межа між двома шарами)
7. gallium-arsenide substrate	7. хімічне нанесення (нашарування) у паровій фазі
8. liquid-phase epitaxy	8. світловипромінювальні діоди
9. taillights	9. галій-арсенідова підкладка
10. outdoor lighting display	10. докорінно змінив

Exercise 4

Pay attention to translation of the following phrases.

1. before this curious phenomenon was understood to be due to - до того, як зрозуміли, що це цікаве явище зумовлене;
2. initially took a back seat to other - спочатку поступалося іншим;

3. steadily boosted LED efficiencies -

неухильно підвищували ефективність світлодіодів.

Early Semiconductor Lasers and Light-Emitting Diodes

The fact that semiconductors can emit light in response to electric currents has been recognized at least since the early 1930s, when Russian researcher Oleg Losev noticed such emissions from silicon carbide - at what probably were naturally occurring pn junctions. Another two decades elapsed, however, before this curious phenomenon was understood to be due to electron-hole recombination at these interfaces. But research on such light-emitting diodes initially took a back seat to other electroluminescent techniques at companies interested in developing flat-panel television displays.

The advent of III-V compound semiconductors dramatically altered this situation during the early 1960s, when scientists at Bell Labs, GE, IBM, MIT, RCA and Texas Instruments began examining the infrared and visible-light emissions from gallium phosphide and gallium arsenide. At the 1962 Solid-State Device Research Conference, Bob Keyes and Ted Quist from MIT Lincoln Laboratory reported observing over 85 percent quantum efficiency for the production of infrared radiation at pn junctions formed in GaAs. This announcement encouraged several groups to try to generate stimulated, coherent radiation at these junctions. Within just a few months, three teams succeeded in achieving such laser action. That autumn a General Electric group led by Robert Hall, one from IBM headed by Marshall Nathan, and an MIT group under Robert Rediker reported observing infrared laser radiation from GaAs junctions at liquid-nitrogen temperatures (77 K).

In October 1962, a GE team led by Nick Holonyak observed visible laser light at 77 K in alloys of GaAs and GaP (commonly written $GaAs_{1-x} P_x$, where $0 < x < 1$). This achievement stimulated researchers at Hewlett Packard led by Egon Loebner to employ such solid solutions, formed epitaxially by chemical-vapor deposition on gallium-arsenide substrates, in their attempts to mass-produce light-emitting diodes (LEDs). While TI developed infrared-emitting GaAs diodes and Bell Labs pioneered red-emitting GaP LEDs, HP and Monsanto pursued the manufacture of numeric displays for scientific equipment. By 1968 these companies were mass-producing red-emitting GaAsP alloy LEDs; HP briefly dominated the market for displays in watches and pocket calculators - which was taken over in the 1970s by liquid-crystal displays.

These early LEDs generated only 0.1 lumen per watt, while gallium phosphide LEDs managed to achieve 0.4 lumen per watt. While at Monsanto in the early 1970s, George Craford introduced nitrogen into GaAsP and GaP LEDs, thereby generating red and green emissions at about 1 lumen per watt. During the 1970s and 1980s, the increasing use of liquid-phase epitaxy, metal-organic chemical-vapor deposition techniques and semiconductor heterostructures steadily boosted LED efficiencies. High-brightness green and blue LEDs emerged during the 1990s after a group at Nichia Chemical Industries led by Shuji Nakamura fabricated heterojunctions based on gallium nitride, indium gallium nitride, and aluminum gallium nitride.

LED efficiencies have thus improved to the point where they now exceed the performance of halogen lamps, and the best available laboratory devices generate over 100 lumens per watt. High-brightness LEDs are available today in all three of the primary colors needed for full-color displays. Light-emitting diodes are finding rapidly-growing applications in traffic lights, automobile taillights, and outdoor lighting displays such as the towering, eight-story high NASDAQ billboard in New York's Times Square, which contains over 18 million LEDs.

Exercise 5

Form nouns from the following verbs.

1. conduct	13. act
2. emit	14. generate
3. combine	15. introduce
4. research	16. improve
5. initiate	17. announce
6. develop	18. depose
7. observe	19. apply
8. examine	20. find
9. form	21. contain
10. produce	22. react
11. radiate	23. perform
12. achieve	24. light

Exercise 6

Make up questions to the text beginning with "When".

LESSON 14

Exercise 1

Translate the following words paying attention to word-building affixes.

Inspiration, inspire, inspiring, inspired, inspirator, memory, memorial, memorable, commemorate, memo, memorise, memoir, concept, conception, conceptual, predict, predicted, unpredictable, predictive, prediction, predictor, interface, interfacing, interfaced, high, higher, highly, highest, height, heighten, proceed, procedure, proceeded, proceedings, procedural, succeed, succession, successive, successively, successor, eliminating, eliminate, eliminated, eliminator, involve, involvement, involved, non-involving.

Exercise 2

Translate the sentences paying attention to conditional clauses.

1. This leads to significant second harmonic distortion unless some measure, such as negative feedback is used to control it. 2. If the oscillator's amplitude is too high, the integrator's output voltage drops, as does the gain of *IC* and the loop gain of the oscillator. 3. If they were forewarned of an impending drive failure, users could take steps to back up their data onto another storage device. 4. If any error occurs during compression, all those files will be at risk. 5.Kroemer says that if we are going to make something truly new, we won't know what to do with it until after we've brought it into being. 6. The cellular industry must convert to such appliances if it wants to continue enjoying the growth rates of the past 10 years. 7. If Navigator or Java became sufficiently popular software, developers might write lots of applications to run on Navigator or Java, which, in turn, could itself run on any operating system. 8.Provided that happened, consumers would no longer need to install Windows, nor developers need to write applications for it. 9. They ask that Microsoft be banned from binding Internet Explorer to the Windows operating system unless it also offers, at a lower price, an alternative version of Windows minus such functionality. 10.If it is possible for the electronics component to be beloved, surely Nixie tubes were. 11. If something degrades the channel's signal-to-noise ratio, the data transfer rate is reduced, but communication does not stop. 12.Competitors like SBC Communications fear that Microsoft, unless restrained, will design its Windows PC operating systems to interact optimally only with Microsoft server operating systems. 13. If people want to reach the speed of 40-Gb/s, exploring some material system other than lithium niobate is certainly

worth doing. 14.Provided these recommendations were turned into regulations, manufacturers would have to ensure that devices in the same band did not interfere with each other. 15. Had some form of the technology existed 30 years ago for analog products, the consumer VCR might never have reached the market. 16. Even if CMOS drivers could be made of hydrogenated amorphous silicon used for the rest of the display, they would be too slow.

Exercise 3

Match Ukrainian translations to the following English phrases .

1. charge-coupled device	1. відеокамера (CAMera+reCODER)
2. magnetic-bubble memory	2. висока чутливість
3. contemporaneous work	3. пам’ять на циліндричних магнітних доменах
4. diode array camera tube	4. детектор часточок
5. buried channel	5. базовий кремнієвий кристал
6. bulk silicon	6. одночасна робота
7. to eliminate "bottleneck"	7. пристрій з зарядовим зв'язком
8. high sensitivity	8. усунути перешкоду
9. camcorder	9. передавальна (ТВ) трубка на діодній матриці
10.particle detector	10. вбудований канал

Exercise 4

Pay attention to translation of the following phrases.

1. surmount the potential problem of charge trapping by surface-state electrons - подолати проблему захоплення заряду поверхневими електронами;

2. sporting millions of pixels per square inch – хизуючись мілionами пікселів на квадратний дюйм.

Charge-Coupled Devices

Soon after the charge-coupled device was invented at Bell Labs in 1969, the knee-jerk reaction of many semiconductor researchers was, "I should have thought of that!" Almost all the required MOS fabrication techniques had been available for nearly a decade; what was needed in addition was the inspiration to apply them in assembling the appropriate configuration. This encouragement came in part from Jack Morton, who prodded his colleagues to develop a semiconductor device that was analogous to the then-popular magnetic-bubble memory. Contemporaneous work on the silicon diode array camera tube also played an important role.

That autumn, Willard S. Boyle and George E. Smith busted this conceptual block by suggesting that a linear array of MOS capacitors could be used as charge-storage and transfer devices. In October the first CCD was fabricated, a simple array of ten MOS capacitors; it performed much as predicted. Boyle and Smith published their work the following spring in the Kelt Labs Technical Journal and presented it in a few IEEE meetings - including Smith's memorable talk at the 1970 Seattle Device Research Conference.

Modifications of the basic CCD idea quickly followed, including a serious but short-lived application to computer memory. With a Bell Labs engineer, Boyle and Smith conceived the "buried channel" approach, whereby the charge is stored in the bulk silicon rather than at its interface with the silicon-dioxide surface layer. Marvin White and his colleagues at Westinghouse developed techniques to reduce noise, which eliminated a "bottleneck" in low-light-level imaging devices.

When Jim Early (who had left Bell Labs for Fairchild in 1969) encountered the buried-channel approach in 1971, he became convinced that this was the best way to proceed, as it could surmount the potential problem of charge trapping by surface-state electrons. He hired Gilbert Amelio from Bell Labs to work on buried-channel CCDs under a Fairchild contract with the U.S. Navy. The resulting devices had high sensitivity and extremely low noise. Other companies such as GE, Hughes Aircraft, RCA and Texas Instruments were involved in the race to develop CCDs, but it was Fairchild that succeeded in bringing these devices into the commercial marketplace.

This research and development led to many of the charge-coupled devices commonly in use today. Sporting millions of pixels per square inch, CCD's can now be found at the heart of digital cameras, camcorders, and professional TV cameras. They are also employed in a growing variety of scientific applications, such as at the focus of large optical telescopes like the Hubble Space Telescope and at the heart of gigantic particle detectors used in high-energy physics.

Exercise 5

Translate the synonyms.

1. device, apparatus, equipment;

2. to apply, to use, to utilise;

3. to assemble, to gather, to collect;

4. to begin, to start, to commence;

5. to store, to keep;

6. simple, easy;

7. to change, to modify, to alter;

8. to trap, to catch, to grasp;

9. to reduce, to lower, to decrease;

10. to result in, to lead to;

11. equal, similar, same;

12. to stop, to cease, to quit, to discontinue;

13. to transmit, to carry, to transport, to conduct, to convey;

14. to select, to choose, to pick, to elect, to opt;

15. to oscillate, to vibrate, to fluctuate, to swing;

16. to associate, to connect, to join, to link, to unite;

17. to decline, to refuse, to reject.

Exercise 6

Make up alternative questions to the text.

LESSON 15

Exercise 1

Translate the following words paying attention to word-building affixes.

Equal, equality, equally, equation, non-equal, similar, similarly, dissimilar, similarity, understand, misunderstanding, understood, understandable, establishment, establishing, establish, re-establish, re-established, confine, confinement, confining, confined, confines, mobile, mobility, mobilised, immobilising, mobilisation, versatile, versatility, allow, allowance, allowing, allowed, extreme, extremist, extremity, extremely, measure, measurements, measuring, immeasurably, measurable, possible, possibility, possibly, impossible, variety, vary, variant, variety, variation, varying, lay, laid, overlaying, layer, thickest, thickness, thick, thicken, thickening, thicker.

Exercise 2

Translate the following sentences paying attention to adjectives and adverbs.

1. The new architecture is a little more complex than conventional designs. 2.The telecommunication industry being in trouble, some parts are in less trouble than others. 3. Though at the moment it is more expensive to communicate with light than with electric current, the day is coming when only optical technologies will be able to keep up with the demands of ever-more-powerful microprocessors. 4. So, thinner – and especially longer – wire means a lower bit rate. 5. Such spacing raises the spectre of problems shared with electrical wires: as they get closer and operate at higher rates, the threat of electrical interference between the adjacent channels increases. 6. A sandwich of metal-semiconductor-metal creates MSM photodetectors that work much the same way, at a higher speed than ***p-i-n*** photodiodes but with less sensitivity. 7.LEDs, unfortunately, are not as useful as more powerful, more focused lasers. 8.The progression should be from expensive, intensive computer systems to simpler, cheaper ones, as well as from longer to shorter distances. 9. The larger the amplitude, the more positive the dc component. 10. The amount of distortion is mostly set by *IC* and as its band-width is approximately four to five times higher than the highest oscillation frequency of most fundamental mode AT-cut crystals, the effect of IC band-width is negligible. 11. It is true in the latter case that too much ***I*** really is better than too little – but not much better, and AB still comes a poor third in linearity to Classes A and B. 12.The substrates used today for GaN, such as sapphire, are all relatively costly or poorly matched to the semiconductor. 13. More importantly, it brings closer to reality the mass production of devices such as blue-violet laser diodes suitable for the next generation of home digital video consoles. 14. Successfully extracting maximum power from a cluster is itself not an easy task. 15. The use of multiple carriers makes the most efficient use of available spectrum, data rates being higher when multiple bits are sent on multiple channels at the same time. 16. The closer the wires (in both dimensions), the greater the capacitance and the longer it takes for the signal to propagate down the line.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. III-V compounds	1. складні напівпровідники
2. tetrahedral structure	2. широкі світлові канали
3. carrier mobilities	3. хімічні сполуки елементів III – V груп
4. versatile band structures	4. квантові кишені
5. high-frequency oscillators	5. сканери штрихкоду
6. higher performance	6. занадто вузькі ділянки
7. narrow-band-gap	7. багаторезонаторний
8. inner layer	8. чотиригранна структура
9. liquid-phase epitaxy	9. індекси заломлення
10. molecular-beam epitaxy	10. рухливість носіїв
11. tightly confined spaces	11. вузька енергетична заборонена зона
12. quantum wells	12. високочастотні генератори
13. multiple-cavity	13. рідинна епітаксія
14. surface emitting	14. структури з різними енергетичними зонами
15. compound semiconductors	15. внутрішній шар
16. refractive indices	16. поверхневе випромінювання
17. bar-code scanners	17. вищі робочі характеристики
18. vast highways of light	18. молекулярна епітаксія

Exercise 4

Pay attention to translation of the following phrases.

1. flash away at the heart - спалахують у серці;
2. elements in fiber-optic systems that span the globe -
   елементи у волоконно-оптичних системах, що оповивають земну кулю.

Compound Semiconductor Heterostructures

Researchers have long recognized that so-called III-V compounds such as GaAs, AlSb and InP make excellent semiconductors. Possessing equal numbers of atoms of elements in the third and fifth column of the Periodic

Table, they have the same tetrahedral crystal structure as carbon and silicon - and therefore similar physical properties. Working at Siemens-Schuckert research laboratory in Erlangen, Germany, Heinrich J. Welker pioneered the understanding of these compounds in the 1950s. He and his colleagues established that they often have wider band gaps and greater carrier mobilities than semiconductors made of germanium and silicon. Although III-IV compounds are not likely to displace silicon in traditional semiconductor uses, their versatile band structures have been widely exploited for high-frequency oscillators and opto-electronic devices.

After the invention of semiconductor lasers in 1962, it took almost another decade to achieve room-temperature devices. In 1963 Herbert Kroemer, then at Varian, and Zhores Alferov in Leningrad suggested that higher-performance lasers could be realized using a three-layer "double heterostructure" in which a narrow-band-gap semiconductor is sandwiched between two wide-band-gap layers. For example, a thin layer of p-type GaAs might be sandwiched between n- and p-type layers of AlGaAs. Higher populations of electrons and holes can be confined within the inner layer, which also serves as a waveguide for radiation from electron-hole recombination.

At the 1967 Solid-State Device Research Conference in Santa Barbara, Jerry Woodall reported that his IBM group had developed liquid-phase epitaxy to grow such AlGaAs layers on GaAs substrates. Using such an approach, Izuo Hayashi and Mort Panish of Bell Labs built a successful double-heterostructure laser that operated at room temperature, announcing their breakthrough at the 1970 Device Research Conference in Seattle. At about the same time, Alferov's group at the Ioffe Physico-Technical Institute reported similar results.

Improved techniques since then have allowed researchers to grow extremely thin layers on GaAs and InP substrates. In the late 1970s and early 1980s, Al Cho pioneered molecular-beam epitaxy at Bell Labs, while Russell Dupuis and Harold Mansevit developed metal-organic chemical vapor deposition at Rockwell. Extremely delicate, detailed heterostructures (often with one or more dimensions measured in nanometers) have been fabricated using these techniques. To describe the movement of electrons and holes in such tightly confined spaces requires use of quantum mechanics, hence these structures are often called quantum wells.

Practical applications of these heterostructures began to emerge in the 1980s. With the thin-layer control that had become available, multiple-cavity quantum-well lasers and vertical-cavity surface-emitting lasers were now possible. In the latter devices, cavity mirrors are formed by alternating layers of compound semiconductors with substantially different refractive indices. These heterostructure-growth technologies also permitted a rich field of device research and the production of a new family of high-frequency transistors. In addition to the heterojunction bipolar transistor, a variety of high-electron-mobility transistors found use in microwave applications.

The highest expression of the heterostructure art developed so far is the quantum cascade laser developed in the mid-1990s by a Bell Labs team led by Federico Capasso. This structure contains hundreds of ultrathin layers of gallium indium arsenide and aluminum indium arsenide, each at most a few nanometers thick, laid down by molecular-beam epitaxy. The result is a sequence of many similar, quantum wells, each with a precisely determined energy level. A single electron descending this "quantum staircase" emits dozens of identical photons at infrared wavelengths.

Today semiconductor lasers flash away at the heart of opto-electronic devices ranging from CD and DVD players to laser printers and bar-code scanners. Along with a great variety of semiconductor photodetectors, they are the critical active elements in fiber-optic systems that span the globe, providing broadband telecommunications on vast highways of light.

Exercise 5

Give antonyms of the following words.

1. equal (same)	9. possible	17. to find
2. to understand	10. to appear	18. high
3. often	11. alternating	19. at most
4. wide	12. latter	20. to descend
5. likely	13. different	21. to emit
6. to displace	14. new	22. far
7. thin	15. to permit	23. great
8. to unite	16. to add	24. active

Exercise 6

Render the meaning of each paragraph in one or two sentences.

E.g. Having excellent semiconductor properties, caused by their versatile band structures, III-V compounds are used for high-frequency oscillators and opto-electronics devices.

LESSON 16

Exercise 1

Form new words by means of word-building affixes.

Evolve, oxide, passive, dissipate, maintain, primary, sequential, result, certain, create, pattern, cross, wire, purpose.

Exercise 2

Translate the following paying attention to tenses passive.

1.The machine with a computing speed of 35.6 trillion mathematical operations per second has been installed at the Earth Simulator Research and Development Center in Yokohama, where it will allow climate changes to be simulated. 2. Some of these broadband systems use regions of the spectrum that have, in the past three decades, been opened for public and private use. 3.Human body's most common molecules, including water, have an irregular distribution of charge, so that they are influenced by an electric field or a magnetic one. 4.When a processor or other chip component asks for the data, the stored charge is removed from the memory cell, sensed, and sent to the output pins of the array. 5. An economically attractive approach is to base multiplexing systems on channels that are spaced apart, and for some years companies have been deploying such systems while a standard was being developed. 6.The circuit is thus also balanced as far as the signal is concerned. 7. When a grounded-emitter transistor is driven from a very high impedance source, i.e. a constant current generator, the collector current is determined principally by the base current and the device's current gain. 8. To the best of my knowledge, the influence of input stage bias current on amplifier distortion was dealt with and worked out to any extent in only a few works. 9.Since the biasing system has been described above, only the remaining subsystems are dealt with here. 10.Once power output and impedance range are decided, the heat sink thermal resistance to ambient is the main variable to manipulate. 11. Resistor ***R*** has been increased to minimise power dissipation, as there seems to be no significant effect on linearity, however with the resistor omitted altogether, linearity *will* be affected. 12. If the compositional variation of the heterostructure is compressed right at the emitter-to-base junction of a bipolar transistor, so that carriers are injected from a wider-gap emitter into a narrower-gap base, the quasi-electric fields become quasi-electric potential barriers. 13.Though Kroemer wasn't pleased by Varian's decision, the Gunn effect (a phenomenon in which microwave oscillations are produced when a certain voltage is applied to opposite faces of a semiconductor) which had just been discovered, interested him. 14. Things at Fairchild had not gone well, because the company was dedicated to silicon technology and

Kroemer's interests had long been elsewhere. 15. Though his name had been mentioned over the years, Kroemer knew that the Nobel Prise was almost invariably awarded for fundamental discoveries, not for applied research. 16.Now the line's capacitance is being lowered by changing the material that insulates it from the surrounding silicon chip as well as from the neighbouring wire.

Exercise 3

Match Ukrainian translations to the following English phrases.

1. thermal oxidation	1. біполярні КМОН транзистори
2. standby operation	2. введення іонів
3. BiCMOS transistors	3. ізоляційна чи провідна плівка
4. photoresist	4. режим очікування
5. insulating or conductive film	5. термічне окислення
6. lithography and etching	6. світлочутливий шар
7. ion implantation	7. літографія та витравлювання

Exercise 4

Pay attention to translation of the following phrases.

1. breaching the micron level - перейшовши мікронний рівень;
2. by exposing a light-sensitive layer (photoresist) with an image of this pattern - шляхом освітлення фоторезисту, на який нанесена потрібна схема.

Microchip Manufacturing

Microchip manufacturing has evolved rapidly since the invention of the integrated circuit. Silicon rapidly became the material of choice for fabricating microchips because a high-quality insulating and passivating layer is easily formed on its surface by thermal oxidation. This oxide layer can be readily patterned to serve as an isolation layer, as masks for diffusion and ion-implantation, as well as for the critical transistor components.

Silicon-device technology development took off on several fronts after the 1960 demonstration of MOS field-effect transistors and the 1963 invention of CMOS (Complementary MOSFETs), which dissipate very little power in standby operation. Circuit designers used bipolar transistors for their speed, p-channel and n-channel MOSFETs for their process simplicity, and CMOS for their low power dissipation. BiCMOS combined bipolar and CMOS transistors on the same silicon chip. As their dimensions have become ever smaller over the years, breaching the micron level during the 1980s, CMOS devices steadily improved in speed while maintaining their low power dissipation. Since the early 1990s, CMOS has become the technology of choice for digital devices; bipolar and BiCMOS transistors are primarily used for analog and microwave applications.

Microchip fabrication involves the sequential application of many processing steps. For example, CMOS manufacturing employs literally hundreds of individual steps - of a few basic types. The most important is photolithography, in which a pattern is created on the chip surface by exposing a light-sensitive layer (photoresist) with an image of this pattern; the developed image in the photoresist is then used as a selective mask in removing the underlying material. The resolution of this process determines the minimum size of the transistors that can be fabricated and hence the density of components on the resulting microchip. By the end of the 20th century, individual features of CMOS transistors were about 250 nanometers across, and gigabit micro-chips had become possible.

Another basic process entails the formation of insulating or conductive films. Silicon dioxide films are readily formed by thermal oxidation or deposition, while films of other materials can be formed using various processes such as chemical vapor deposition. By employing a combination of lithography and etching, microchip manufacturers can then pattern these films as desired. Local oxide films, for example, can be formed by masked oxidation of silicon.

A third basic microchip manufacturing process involves increasing the level of certain impurities in selected areas of the silicon. This is achieved by diffusing these impurities from a source material or by implanting ions of them. Silicon-oxide or silicon-nitride films are commonly used as diffusion masks, while the layers of photoresist or other films serve as masks for ion implantation. These processes can be used to change the conductivity types of selected regions from p-type to n-type, or vice-versa, thus creating pn junctions in the silicon.

The fabrication of a microchip typically has two main parts, the front end and the back end. The former consists of forming individual devices in the silicon, while in the latter metal wires are added to interconnect them into the desired circuit and system functions. The silicon wafer is then sliced into individual microchips, which are placed on a module or board containing wires whose purpose is to make interconnections among the microchips and to other system components.

Exercise 5

Give synonyms and antonyms to the following words.

1. big	large	small
2. easy		
3. ready		
4. to integrate		
5. to combine		
6. little		
7. possible		
8. individual		
9. increase		
10. to form		
11. pure		
12. desirable		
13. main		
14. the former		
15. end		
16. to add		
17. to change		

Exercise 6

Make a short outline of the text.

PART 3

P I O N E E R S

ALESSANDRO VOLTA
(1745 – 1827)

It is well known that Volta invented the primary battery and in so doing moved electrical science into an age of electrodynamics. What is less well known is that he proposed a fundamental unit of electric tension some years before that invention, when scientists were still deep in the age of electrostatics. It is perfectly appropriate then that the unit for electromotive force (a term he introduced) is named after him. We may be thankful, though, that his original unit was never accepted; it is roughly equal to 13 350 volts!

Volta was already an established scientist with a reputation for experimental work when he announced the invention of the "Pile", the first electric battery. The importance of the invention was instantly recognised as being of the first rank and it opened new avenues of enquiry, including electrochemistry and electrodynamics. It quickly led to experimental electric light and industrial electroplating.

Volta was born in Como in the duchy of Milan in Northern Italy on the 18th February 1745 and died there 82 years later on the 5th March 1827. On his mother's side he came from a family with a *leaning towards the law*[1]*;* his father's family was devoted to the church. One of his three paternal uncles was a Dominican, one a canon, and the third an archdeacon.

Alessandro was seven when his father died. When he was 12 one of his uncles took charge of his education, which began at a Jesuit college and nearly led to him becoming a Jesuit. His uncles decided they did not want that and so his education continued elsewhere. It was a wealthy friend, Giulio Cesare Gattoni, who provided the books and equipment which helped him to begin studying electricity.

The uncles had by now chosen his future career: the law. Somehow he avoided this path and continued to study what he termed his genius: electricity. Boldly, he wrote to leading scientists to discuss problems he encountered. One, Beccaria, recommended his own writings and also told Volta to experiment. So

[1] *з нахилами до юриспруденції*

Volta began to develop his gift for making inexpensive but effective instruments.

Slowly, from the mid-1760s he learned the science and practice of electricity and in October 1774 he received his first academic appointment, at the Gymnasium in Como. The next year he was appointed professor of experimental physics. About the same time he made his first important invention, the electrophorus, and followed that with the discovery of methane.

The electrophore was probably the most significant electrical invention since the ***Leyden Jar capacitor***[2]. After considerable experimentation, in June 1775, he announced his "elettroforo perpetuo". It was an inductive device for repeatedly charging a tin-foil covered shield which, in turn, was used to build up a large charge on a Leyden Jar capacitor. Whilst others had come close, only Volta produced a sturdy and usable instrument.

In 1776, he briefly turned to the study of gases and discovered a new gas which we know as methane. "Inflammable air" (hydrogen) had been isolated chemically ten years earlier and was known to exist naturally. Volta became intrigued by the "different kinds of air" and searched the countryside for the telltale bubbles until he found a new gas at Lake Maggiore. Hydrogen, however, was more explosive and it was hydrogen and air (oxygen), not methane, that Volta used in an "inflammable air pistol" which was fired by an electric spark. The pistol fired a lead ball, denting wood at 15 feet. From related experiments he concluded that about 20% of common air was oxygen. He *narrowly missed synthesizing water*[3], but his method was successfully used later by Lavoisier, Laplace and Monge in France.

His discovery of methane obviously enhanced his scientific reputation and his reward was a travel grant, which took him to Switzerland and Alsace. The grant came from the Austrian government which then ruled Northern Italy. Then came Volta's appointment to the professorship of experimental physics at the University of Pavia; his popular professorship there ran for nearly 40 years. In 1781/82 he visited France and England, and in 1784 he went to Germany. On such state-financed trips he bought new equipment for the laboratory at Pavia. Most of the instruments he built up were destroyed in a fire in 1899.

Politically, Volta had much to be thankful for to the Austrians, but in l796 they were driven out of Northern Italy by the French, led by Napoleon. Volta was chosen in May of that year as one of a delegation to represent Como in honouring Napoleon. Later, he became an official of the new Government of Como but it was a position from which he soon resigned; his lingering loyalty to the Austrians, the damage done to his laboratory by French troops and his coldness towards the French led to his expulsion from Pavia for a while. It did

---

[2] *конденсатор "банка Лейдена"*

[3] *мало не синтезував воду*

him no harm, however, when the Austrians retook the country in 1799: though they closed the university, Volta remained free.

Thirteen months later the French were back. The university was reopened, Volta was once again a professor and accepted his status as a citizen of the new republic. A trip to Paris to express the university's thanks to Napoleon became a triumph for Volta. The primary battery was by then well known and its chemical power had made scientific headlines. Even Napoleon attended his demonstrations at the French Academy and Volta was awarded a gold medal.

In many ways Volta's discoveries captured Napoleon's heart and he continued to be an admirer. A prize of 60,000 francs was announced for "whoever by his experiments and discoveries makes a contribution to electricity and galvanism comparable to Franklin's and Volta's". Volta was later given a pension, and ***made a count and a senator*** [4] in the kingdom of Italy.

Volta's pile

The roots of Volta's invention go back to the discovery by his fellow Italian, Luigi Galvani, of frog legs fame. A full account was published in 1791 and caused great excitement amongst both physicists and the medical fraternity. The latter wondered if the "vital principle" had at last been found and pondered the possibilities for new treatments. Galvani was the second to report what we would now recognise as an electrochemical effect, the Swiss J.G. Sulzer having noted in 1762 that two dissimilar metals placed on the tongue gave a sensation of taste.

At first, Volta considered Galvani's reports to be unbelievable. Pressed by colleagues, he at last investigated the phenomenon and, by the April 1, 1791, had begun the series of careful step-by-step experiments which led him to the electric battery.

Galvani explained the excitation of the dead frog's legs as being caused by animal electricity, an explanation which Volta firmly rejected. Volta was led to believe that the current flow was caused by the contact of two different metals. In that he too was wrong. It was another Italian, G.V. Fabroni, who got the right explanation by pointing to a chemical action between the liquid, which always seemed to be present in both Galvani's and Volta's work, and the two different metals.

Volta repeated Sulzer's as well as Galvani's work. In one experiment he brought insulated zinc and copper discs into contact and found that they were charged on separation. By experiment he found that zinc and silver discs best suited his purpose and eventually he arranged pairs of them in a pile. Each pair

[4] *став графом та сенатором*

was separated from neighbouring pairs by a piece of cardboard soaked in water or brine to provide, as he believed, a conducting path between the pairs. Letting all pairs touch one another, he knew, provided only the same effect as a single pair of discs.

The finished pile of discs and cardboard multiplied the effects of a single pair many times and he was able to receive a shock from his pile similar to that from a charged Leyden Jar capacitor. The vital differences were that Volta's pile did not need to be immediately recharged and could give a continuous current.

News of the invention was announced in a letter to the Royal Society in London: "The apparatus of which I speak," wrote Volta, "will doubtless astonish you." The continuous current almost appeared as perpetual motion, "but it is nonetheless true and real, and can be touched with the hands."

Volta's pile, "as high as can hold itself without falling," consisted of 30, 40, or 60 cells. From such primitive origins grew today's huge international industry. As an alternative to the pile, Volta also used pairs of metals soldered together with each end dipping into water or brine contained in glasses; this arrangement he called the crown of cups. Again, 30 or more cells could be arranged to produce a battery of cells. The word battery had, of course, been used earlier, not only for a battery of guns but for a battery of charged Leyden Jars.

Improvements were soon made by others. For greater voltages more cells were needed in the pile, which increased the weight and squeezed out the electrolyte from the cardboard discs. In Germany, J.W. Ritter turned up the edges of his metal discs and obtained batteries which lasted for two weeks! A horizontal wooden trough provided an even better battery: zinc plates, for example, could be fixed vertically to a support and lowered into the trough between vertical plates of the other metal. This trough arrangement has been suggested as the origin of our circuit symbol for the battery.

Volta received many honours in his lifetime, including recognition by learned societies in London, Paris and Berlin. His financial rewards from his university salary were boosted in 1805 by the annuity he received from Napoleon and, in 1809, by his senatorial salary. For the last two decades of his life he had the income of a wealthy man.

Task I

Speak on Volta’s scientific interests and experiments.

Task II

Dscribe Volta’s pile and explain its work.

THOMAS ALVA EDISON

(1847-1931)

Thomas Edison, American inventor, is one of the greatest inventors of all time. Edison began to work at an early age and continued to work right up until his death. Throughout his prolific career as an inventor, he was well known for his focus and determination. During his career Edison patented more than 1,000 inventions, including the electric light, the phonograph, and the motion-picture camera. These three inventions gave rise to giant industries - electric utilities, phonograph and record companies, and the film industry - thus changing the work and leisure habits of people throughout the world. The period from 1879 to 1900, when Edison produced and perfected most of his devices, has been called the Age of Edison.

Early Life

Edison's family was part Dutch and part British. His ancestors, who supported the king in the American Revolution (1775-1783), fled to Canada with more than 30,000 others when the war ended. In 1837 Edison's father became engaged in an unsuccessful revolution against the Canadian government and was forced to flee back to the United States. Thus, Thomas was born in Milan, Ohio, in 1847.

In 1854 the family settled in Port Huron, Michigan, where Edison attended school for three months. This was his only formal public education. His mother continued his education, teaching him reading, writing, and arithmetic. She also read to him from well-known English writers, such as Edward Gibbon, William Shakespeare, and Charles Dickens.

Edison earned by selling newspapers, apples, and candy on the Detroit and Port Huron branch of the Grand Trunk Railroad when only 12 years old. Around this time his hearing began to decline, possibly due to a childhood attack of scarlet fever. Edison once said that he sometimes considered his partial deafness almost an asset, particularly when he wanted to concentrate on an experiment. However, in a poignant entry in his diary some years later, he wrote, "I haven't heard a bird sing since I was 12 years old."

When 15 years old, while still working on the railroad, Edison bought a small secondhand printing press and 136 kg of type. He installed the press in a baggage car and soon began producing a newspaper, the *Weekly Herald,* which he printed, edited, and sold on the Grand Trunk Railroad.

In the summer of 1862, Edison saved a boy from being run over by a boxcar. The boy, only three years old, was the son of the stationmaster in Mount Clemens, Michigan. In gratitude, the stationmaster offered to teach Edison how to operate the telegraph. Edison had already experimented with the telegraph at home and gladly accepted the offer. For five months, he learned to send and receive dispatches, and for the next four years he traveled thousands of miles as a telegrapher. During this period he spent most of his salary on various laboratory and electrical instruments, which he would take apart and rebuild.

Family Life

Edison met his first wife, Mary Stilwell, in 1871. She was 16 years old and working in one of his companies when the inventor first met her. Edison married Stilwell on Christmas Day of that year. They had a daughter, Marion, born in 1873, and two sons, Thomas, Jr., born in 1876, and William, born in 1878.

Soon after his first wife's death in 1884, Edison met and fell in love with Mina Miller, the daughter of a wealthy manufacturer. The two married in February 1886. They had a daughter, Madeleine, born in 1888, and two sons, Charles and Theodore, born in 1890 and 1898.

Edison focused on his work so much that he spent little time with his family. He avoided most social situations, and he often wore dirty shirts and shabby working clothes. Many of his associates also spoke of Edison's virtues, however, such as good humor, even disposition, honesty, and genuine affection for his family.

EARLY INVENTIONS

Edison acquired his knowledge of electricity and telegraphy (use of a telegraph system to communicate at a distance) as a teenager. In 1868, at age 21, he developed a *telegraphic vote-recording machine*[1], the first of his inventions to be patented. The next year, Edison invented an improved version of the *stock ticker*[2], which printed stock market quotations and gold prices on a paper tape. Unlike older stock tickers, Edison's was fully automatic, and it did away with the need for a special attendant to operate each machine.

These early inventions brought Edison no financial returns. The first invention to bring him money was another improvement on the stock ticker. Edison created a central mechanism by which all the receiving tickers could be put in unison with the main sending apparatus. For this invention, Edison

[1] *апарат, що фіксує результати голосування*
[2] *апарат біржових новин*

received $40,000, which would be worth $530,000 in 2000. He and a business partner, who operated a machine shop, used the money to start a new company to manufacture Edison's improved stock ticker. For the next five years Edison spent up to 18 hours a day in his workshop in Newark, New Jersey, inventing and manufacturing a variety of electrical devices. One important device that he designed during this period was the quadruplex, a highly efficient telegraph that could send four messages at a time over a telegraph wire, instead of just one.

MENLO PARK LABORATORY

In 1876, Edison established a laboratory at Menlo Park, New Jersey, the first laboratory dedicated to industrial research in the world. Within ten years people throughout the world knew of Edison as the Wizard of Menlo Park.

The Telephone

Edison's first major achievement at Menlo Park was an improvement on the telephone. The telephone that Alexander Graham Bell invented in 1876 could not operate over distances of more than 3 to 5 km. After hundreds of experiments, Edison improved the telephone to such an extent that it could carry speech clearly over almost unlimited distances. In March 1878, Edison's telephone system connected New York City to Philadelphia, Pennsylvania, a distance of 172 km .

The Phonograph

While working on the telephone, Edison also worked on perhaps his most original invention. He had noticed how the phone's diaphragm, a thin membrane in the microphone, vibrated in tune with the voice. He thought that if these vibrations could somehow be recorded, so that the diaphragm could be made to vibrate in exactly the same manner at any future time, then speech, music, and other sounds could be preserved and reproduced. Edison tested the strength of the diaphragm vibrations by holding a needle against the diaphragm with his finger, so that the needle pricked his finger with a force that varied with the loudness of the sounds.

In a later experiment, he applied one end of the needle to the diaphragm and the other end to a strip of waxed paper. He then pulled the paper along underneath the needle while repeatedly shouting, "Hello!" The needle, activated by the vibrations of the diaphragm, created grooves in the paper. When the paper was again pulled along underneath the needle, the needle followed the grooves it had formed earlier and pushed against the diaphragm, making the diaphragm reproduce Edison's shouts. This first crude experiment, performed in 1877, marked the beginning of the phonograph.

Edison obtained a patent on the phonograph in February 1878. By this time he had replaced the waxed paper with metal cylinders covered with tinfoil. He postponed further development of the phonograph, however, for some years.

The Incandescent Lamp

After patenting the phonograph, Edison set out to develop an incandescent lamp, which would produce light by heating a wire until it glowed brightly. People already used electric arc lights, which produced light by creating an arc of electricity between two wires. However, *the blinding glare these arc lights gave off* [3] made them unsuitable for home use. Edison, like others before him, conceived the idea of a light with a glowing wire, or filament, made of a substance that could endure very high temperatures without fusing, melting, or burning out. After hundreds of trials and more than a year of steady work, Edison developed a high-resistance *carbon-thread filament* [4] that burned steadily for more than 40 hours. Although not the first incandescent electric light, it was the first practical one because it used a small current and, in addition, lasted a long time without burning out.

Electric Power Distribution Systems

Edison realized that widespread use of electric light bulbs would require an efficient system of delivering electricity to homes and businesses. He developed detailed plans for an entire distribution system for electric power. This system included generating the current by means of a central *dynamo* (device that turns mechanical energy into electricity) and then distributing it in small quantities to thousands of homes and commercial buildings. Edison even developed a greatly improved dynamo to reduce the cost of generating electricity. The system Edison suggested in 1879 included the parallel circuits, safety fuses, insulating materials, and copper-wire networks used in modern electrical systems.

By 1881 Edison had set up a complete electric lighting system at his Menlo Park home. That same year his system took top honors at the Paris Electrical Exhibition in France. In 1882 at Holborn Viaduct in London, the Edison Electric Lighting Company completed and began operating the first commercial generating station for incandescent lighting in the world. This installation used an underground main and feeder circuit to supply power for

[3] *сліпучий блиск цих ламп електричної дуги*

[4] *нитка розжарення, що містить вуглець*

2,000 lamps. Later in 1882 Edison established the first permanent incandescent light and power station for private consumers, called the Pearl Street generating station, in New York City.

The Edison Effect

While Edison was working on the electric light, he made a scientific discovery that would become important to future generations. Edison noticed that particles of carbon from the filament blackened the insides of his light bulbs. This effect was caused by the emission of electrons from the filament, although Edison made the discovery before he and other scientists knew the electron existed. Not until 1897 did British physicist J. J. Thomson prove that the blackening observed by Edison was caused by the emission of electrons. This so-called Edison effect became the foundation of all modern electronics. Radio, television, radar, and computers all depend on it.

In 1884 Edison received a patent for a device based on the Edison effect. The device was designed to indicate variations in the output from electrical generators. The indicator proved ineffective because obtaining a good vacuum in devices at that time was difficult, but this was the first patent for a device that made use of the emission of electrons. It marked the beginning of the field of electronics.

GLENMONT

In 1884 Edison's first wife died of typhoid fever, and thereafter the inventor rarely returned to his laboratories at Menlo Park. After his second marriage in 1886, Edison bought Glenmont, a large country estate in West Orange, New Jersey, where he established a new laboratory. He remained there for 45 years. Glenmont and the laboratory are preserved as part of the Edison National Historic Site in West Orange and are open to the public.

Motion Pictures

In 1888 Edward Muybridge, an English pioneer in stop-motion photography, showed Edison his photographs of horses in full gallop. Muybridge had taken the photographs using a series of cameras, equipped with *fast-action shutters*[5], which he arranged along the side of a racetrack.. The shutter of each camera was released when a horse broke through a string stretched across the track. By this method, Muybridge obtained a series of pictures showing a short cycle of motion. The pictures could be passed in rapid

[5] *швидкодійний заслін об’єктива*

succession in front of a peephole, giving the viewer the illusion that the horses were moving.

Muybridge's visit inspired Edison, who had already recorded sound, to think of recording movement photographically. He began work almost immediately on what was to become the first motion-picture camera. His first crude apparatus consisted of a photographically sensitive cylinder that revolved in synchrony with the camera shutter to take about 40 pictures per second. In 1889 the Eastman Dry Plate and Film Company produced and patented a *celluloid roll film* [6] and Edison promptly replaced his bulky cylinder with 15-m strips of the Eastman film. The new machine, completed in 1890, was the prototype of all modern motion-picture cameras.

For the showing of his motion pictures, Edison built a mechanism, called the Kinetoscope, which used positive film moving past a peephole. (Positive film shows the correct areas of light and darkness in a photograph, while the negative shows the opposite.) Although only one viewer at a time could see the film, it gave much clearer and steadier pictures than did available screen and projector devices.

Edison's Studio

In 1893 Edison constructed the first motion-picture studio. The building was 15.2 m long and had a *hinged roof* [7] that could be raised to admit sunlight. The whole building was mounted on a pivot and could swing around to follow the sun. Edison had the walls on the inside painted black because this background helped the cameras produce sharper pictures. In 1893 and 1894, Edison produced numerous one-minute films. His moving pictures included figures such as French ballet girls; Japanese dancers; American showman "Buffalo Bill" Cody with accompanying Indians in the first Western movie; and American prizefighter "Gentleman Jim" Corbett sparring with other boxers.

The Electric Battery

In 1900 Edison set out to produce an improved electrical storage battery. Batteries convert chemical energy into electrical energy. In storage batteries, two metal rods, called electrodes, are connected by a circuit and immersed in a liquid, called an electrolyte. The rods chemically react with the electrolyte to produce a flow of electrons through the circuit. The storage batteries of the time were called lead-acid batteries because they had electrodes made of lead and lead dioxide and an electrolyte made of acid. They were heavy, bulky, difficult

[6] *целулоїдна рулонна плівка*
[7] *дах на шарнірах*

to recharge, and susceptible to rapid corrosion. To reduce corrosion, Edison decided to use an alkaline solution instead of acid for the electrolyte in his battery. Finding a suitable electrode, however, proved difficult. After conducting thousands of experiments on various materials, Edison finally decided on a combination of nickel flake and nickel hydrate for the positive electrode and pure iron for the negative electrode. He used an electrolyte of potassium hydroxide with a small amount of lithium hydroxide.

By the time Edison had perfected his storage battery, he had spent eight years and a million dollars on it. The battery was widely used in electric cars and even to power submarines. People still use storage batteries based on Edison's original principles in lamps for miners, powers signals along railroad tracks, isolated airway beacons, and emergency power supplies.

After his exhausting work on the alkaline storage battery, Edison again turned his attention to the phonograph. In 1912 he marketed the Edison Diamond Disk Phonograph and disk records. These records measured about 6 mm thick and had a surface of Bakelite varnish, an early form of plastic.

Rubber

In the 1920s it became apparent that in the event of a national emergency, the United States would not be able to obtain an adequate supply of rubber because it relied heavily on imports. At the age of 80, Edison set out to find plants that could grow in the United States and were suitable for producing rubber. In the next four years he tested 17,000 different plants, finding rubber in 1,200 of them but worthwhile quantities in only about 40. He chose to produce rubber from the ***goldenrod*** [8] plant because it would grow in most parts of the country, it grew to maturity in just one season, and it could be harvested by machines. These characteristics made the plant easy to grow and harvest on the large scale required to produce rubber efficiently. By crossbreeding, Edison produced a goldenrod plant 4 m (13 ft) tall and raised its rubber content from 4 percent to 12 percent. Edison's assistants vulcanized (chemically strengthened) this rubber to make it useful for products about ten days before his death.

Attitude Toward Work

Edison worked on his experiments with extraordinary intensity. He lived in his laboratory, getting along on four hours of sleep a day and eating meals brought to him by an assistant. He often kept vigils of 48 and even 72 hours when an experiment neared completion. Often, as in the cases of the electric light, the storage battery, and the experiments on synthetic rubber, success or

---

[8] *золотушник (бот.)*

failure depended on the discovery of a suitable material. In each case, he conducted thousands of experiments to find the right materials.

Before starting an experiment, Edison tried to read all the literature on the subject to avoid repeating experiments that other people had already conducted. Perhaps the best illustration of Edison's working methods is his own famous statement: "Genius is one percent inspiration and 99 percent perspiration."

Honors

During Edison's lifetime, he received honors from all parts of the world. In 1881 he was awarded the French Legion of Honor for developing electric power distribution systems. Italy made him a Grand Officer of the Crown in 1889, and he received awards from the governments of Chile, Britain, Japan, Russia, and many other nations. American businessman Henry Ford spent several million dollars to erect a museum of industry in Dearborn, Michigan. The museum consisted largely of a collection of Edison's inventions. In 1929 the museum held a celebration, called Light's Golden Jubilee, to mark the 50th anniversary of the invention of the electric light.

When Edison died, the U.S. government considered turning off all electric current in the country for a minute or two as a tribute to him. It became apparent, however, that the operation of the great electrical distribution systems of the nation could not be interrupted even for a moment without possibly disastrous effects. Within Edison's lifetime, the system that he had pioneered had become essential to the nation's way of life.

Task I

Explain with examples from Edison’s life his famous phrase “Genius is one percent inspiration and ninety-nine percent perspiration.”

Task II

Speak on Edison’s inventions which you consider to be the most important.

Task III

Describe Edison’s influence on film-producing industry.

AMBROSE FLEMING

(1849 – 1945)

You probably would not think of building a radio detector from a light bulb, but that is what Ambrose Fleming did in 1904. The result was what he called the "oscillation valve", now better known as the thermionic diode. It was only two years later when Lee de Forest added a third electrode to make the first primitive triode. These two classic inventions led to a fight between the two inventors, but they also led to the now-vast, worldwide industry we call electronics.

The story begins with that great American inventor, Thomas Edison. In 1883, he probed inside an incandescent light bulb, first with a wire and then with a metal plate. He found that if this electrode was connected to the positive end of the filament via a galvanometer then a current was detected. If it was connected to the negative end, no current flowed. A little later, using a separate battery in the plate or anode circuit, J. Elster and H. Geitel showed the unidirectional nature of the current flow.

This "Edison effect" was studied by many people over the following 20 years, particularly to examine thermionic emission. Fleming studied it "carefully" in 1883 and again in 1896, and he may have discussed it with Edison when he met "the Wizard" during his trip to the USA in 1884. Certainly, for 20 years it was a well known phenomenon before anyone thought of an important application for it.

Fleming's real invention was the use he found for the established Edison effect as a rectifier of high-frequency oscillations. Edison kicked himself when he realised the opportunity he had missed, even though he held what is now seen as the first patent in electronics - the effect used as a voltage indicator (1884).

Fleming's career, meanwhile, had progressed over those 20 years. In 1896 he experimented with methods of focusing cathode rays and three years later he was appointed scientific adviser to the Marconi's Wireless Telegraph Company. In this role he specified equipment for the famous transatlantic signal transmission of 1901.He had also gained extensive experience of consultancy, to the National Telephone Company and the Ediswan Electric Light Company. With all this highly relevant experience he was in an ideal position from which to make his famous contribution to electronics.

Very happy thought

It was in October 1904 that Fleming had what he described as "a sudden, very happy thought." Telephones and meters were too slow to register the positive-negative cycling of a high-frequency radio signal and therefore only indicated the average value, which was zero. Knowing that a light bulb with a hot filament and an insulated plate sealed within it would only pass current in one direction, he speculated that this might act as a rectifier for the high-frequency currents. He asked his assistant, G.B. Dyke, to test the idea - and it worked. The next month he wrote to Marconi, "I have been receiving signals on an aerial with nothing but a mirror galvanometer and my device." It would be nice to think that Fleming made his fortune from this pivotal invention, but it brought him relatively little joy. Marconi held the patent, and manufactured and used some diodes. But in this early form they were no panacea for all radio detection problems and they played only a small part in the early years of radio.

A couple of years later H. H. Dunwoody, of the De Forest Wireless Co., produced an important rival - the crystal detector. This was part of De Forest's determined effort to challenge Marconi's dominance of the radio scene. In 1905 De Forest patented the two-electrode valve with the double-battery Elster-Geitel connection instead of the single battery circuit used by Fleming. He called his diode an "audion". Fleming felt that his invention had been hijacked and he accused De Forest of plagiary. ***A bitter row ensued***[1].

In October 1906, De Forest added the third electrode to make the first triode. Unfortunately he still called it an "audion", the name he used for his diode, and confusion reigned. The dispute with Fleming was prolonged. However, ***at no time did Fleming ever claim to have invented***[2] the triode. Though he experimented with zigzag wires as alternatives to metal plates for the anode he never used the two together. As he himself wrote, "Sad to say, it did not occur to me to place the metal plate and the zigzag wire in the same bulb and use an electric charge of positive or negative on the wire to control the electron current to the plate.

Nonagenarian

John Ambrose Fleming lived to the ripe old age of 95, and late in life became very deaf - this was seemingly a family trait, for his sister suffered similarly. One story from his time as Professor of Electrical Engineering at University College, London, recalled a loud conversation between the two of them in which his sister told him not to be so cantankerous - at times his colleagues thought his deafness varied at will to suite his purposes, becoming "impenetrable" when he so wished.

Fleming was born at Lancaster on 29 November, 1849, the oldest of the seven children of a Congregational minister. His father, he said, was descended

[1] *розпочалась запекла колотнеча*
[2] *ніколи не претендував на винайдення*

from "a long line of Scotch ancestors of Flemish origin." His mother's family came from Swanscombe in Kent and were pioneers of the manufacture of Portland cement.

In 1854 his parents moved to London where Fleming was to spend almost 70 years of his life. When he finally retired at 77, after ***an action-packed working life***[3], he moved to the seaside, to Sidmouth, where he enjoyed nearly another 20 years before his death on 18 April, 1945. He married twice but had no children. His first wife, Clara Ripley, died in 1917 but his second, Olive Franks, whom he married in 1933, survived him.

Fleming started school at about the age of ten, attending a private school where he particularly enjoyed geometry. Prior to that his mother tutored him and he had learned, virtually by heart, a book called the "Child's Guide to Knowledge," a popular book of the day - even as an adult he could quote from it. His schooling continued at the University College School where, although accomplished at maths, he ***habitually came bottom***[4] of the class at Latin.

Even as a boy he wanted to become an engineer. At 11 he had his own workshop where he built model boats and engines. He even built his own camera, the start of a lifelong interest in photography. Training to become an engineer was beyond the family's financial resources but he reached his goal via a route which alternated education with work.

He enrolled for a BSc degree at University College, London, in the mid-1860s and studied under the mathematician A. de Morgan and the physicist G. Carey Foster. After two years he left because of a shortage of money and took a job with a shipbuilder in Dublin. The work was so dull that he quit after a few months and found work with a ***stock jobbing firm***[5] on the London Stock Exchange.

For two years he earned his living in the financial world. Later, as a teacher, he preached that every boy and girl should have some practical training in "***the bulls, the bears and the stags of The Stock Exchange***[6]" and "their efforts to make money out of the trustful and optimistic public."

At the Stock Exchange his work finished at the early hour of 4 o'clock. So it was not only about the bulls and bears that he learned, for he completed his degree through evening study, graduating in 1870 with a first class degree.

For 18 months, from January 1871, he replenished his funds as a science teacher at Rossall School before resigning to return to his studies, this time as a student of chemistry at the Royal College of Science in South Kensington (now

---

[3] *діяльне трудове життя*
[4] *зазвичай був серед гірших*
[5] *біржова маклерська фірма*
[6] * *механізми дії фондової біржі*

Imperial College). It was while there that he first studied the voltaic battery which become the subject of his first scientific paper. This turned out to be a unique honour, for it was the first paper to be read to the new Physical Society of London (now the Institute of Physics) and appears on page one of volume one of their Proceedings.

Financial problems again forced him to work for his living and in the summer of 1874 he became science master at Cheltenham College, a public School, earning £400 a year. His own scientific research continued and he corresponded with James Clerk Maxwell at Cambridge University. After saving £400, and securing a grant of £50 a year, in October 1877 he once again enrolled as a student, this time at Cambridge. He was now 28 years old.

Maxwell's lectures, he admitted, were difficult to follow. Maxwell, he said, often appeared obscure and had "a paradoxical and allusive way of speaking", and on occasions Fleming was the only student at those lectures.

In due course Fleming again graduated, this time with a first class degree in chemistry and physics. He then got a DSc from London and served one year at Cambridge as a demonstrator of mechanical engineering before being appointed as the first Professor of Physics and Mathematics at the University of Nottingham. But after less than a year he left.

Up to this stage in his career Fleming had proved himself as a brilliant scholar and a gifted teacher, but with a stronger aptitude for learning than for being an employee. While he might have appeared as a perpetual student he was now about to find his forte in life.

Consultant

Cousins can be useful - Fleming's was a Mr Arnold White who happened to be secretary to the Edison Telephone Company in London, and through him Fleming was offered the post of consultant. The telephone business went through a period of great change, including mergers and the extension of the Post Office monopoly from telegraphs to telephones, and Fleming took an active part in the *ensuing litigation*[7].

White was also the secretary of the new Edison Electric Light Company and Fleming duly became scientific adviser there too. He appears to have obtained a number of orders for the company including one for the first Admiralty Ship to have electric lighting. It was on behalf of this company (by that time merged with the Swan Electric Light Company) that he visited America in 1884, during which visit he met Edison.

[7] *подальшій судовій суперечці*

By that time Fleming's reputation was such, that in 1885 he was invited to become the first Professor of Electrical Engineering at University College, London. At last he had a position which really suited his many and varied talents. London always appealed to him and his light teaching duties (one hour a week during the first few years) allowed plenty of time for consultancy.

When he took up his new position, which he retained until his retirement, the only equipment he received was "a blackboard and a piece of chalk!" However he persuaded the authorities to give him a small room and a £150 grant. Largely due to his efforts £5000 was received in 1896 to establish an electrical laboratory.

His interests ranged widely over the years. At various times he specialised in transformer tests (acting as consultant to Ferranti), standards and measurements, incandescent lamps and photometry, the effects of low temperatures on the electrical resistance of metals (with Sir James Dewar), and (of course) thermionics. In his retirement he was for 15 years president of the Television Society of London. He received many honours, including the Fellowship of the Royal Society in 1892, medals from scientific and engineering institutions and, in 1929, a knighthood. He has been described as a born teacher and gave meticulously prepared public lectures. Showmanship however, was not allowed into his student lectures. As we have seen he was also an accomplished photographer. In addition, he painted water-colours and enjoyed climbing in the Alps. His interests were not those which ***entailed much socialising***[8] and he disliked organised games.

He was also a devout Christian and preached on one occasion at St Martin-in-the-Fields in London. Having no children, he bequeathed much of his estate to Christian charities, especially those that helped the poor. But of his many achievements his enduring fame rests on turning a light bulb into the first electronic valve.

Task I

Speak about Fleming’s studies for scientific degrees.

Task II

Explain “a sudden very happy thought” of Fleming and its effects on further development of electronics.

---

[8] *не передбачали широкого спілкування*

LEON CHARLES THEVENIN

(1857-1926)

Thevenin's theorem is known and used throughout the world, but as is usual with such things, little thought is now given to the man whose name it bears. He has been described as a humble man and a model engineer and employee. He was hard working, held strict principles, was scrupulously moral and kind at heart. That alone would make a wonderful epitaph.

He is remembered today almost entirely for one small piece of work. His theorem, published in 1883, was based on his study of Kirchoff"s Laws and is found in every basic textbook on electrical circuits. It has made his name familiar to every student of electrical circuits and to every electrical and electronics engineer.

Leon Charles Thevenin was born at Meaux just outside Paris on March 30, 1857. He graduated from the Ecole Polytechnique in 1876 and two years later joined the Corps of Telegraph Engineers. The public telegraph service was to be his working life until his retirement in 1914 on the eve of the first World War. During those 36 years he showed himself to be a great engineer, an excellent administrator and, perhaps ***first and foremost*** [1], a teacher. He continued some of his teaching duties to the end of his life.

At the start of his career, Thevenin joined the department responsible for long-distance underground telegraph lines which was then vastly expanding its service and requiring most of the newly trained young engineers leaving the ***Ecole Superieure*** [2]. But he did not stay there long. His unusual talents were recognised and, he moved to the Department of Materials and Construction which had started to tackle the problems involved in the construction of power lines. His standardisation of the rules for the erection of overhead power lines stayed in force for many years.

Teaching

In 1882 Thevenin was asked to take on the job of teaching the young inspectors of the engineering department at the Ecole Superieure. This was the start of his teaching career and his introduction to the work that led to his famous theorem.

---

[1] *перш за все та понад усе*
[2] *(фр) вища школа*

He developed an interest in electrical measurement and, with his former teacher Jules Raynaud, he translated a British work on units and physical constants into French. Translation of such foreign publications was part of the routine work of the School. In conjunction with this work, Thevenin made a very careful study of Kirchoff’s Laws and discovered the rule which he then expressed in his theorem, having proved it by a clever application of the already established Superposition Principle.

Thevenin's Theorem was published in three separate scientific journals in 1883 in a paper entitled "Extension of Ohm's Law to complex electrical circuits". It was introduced as a "new theorem of dynamic electricity" and gave a simple method of calculating the current that would flow in a new conductor when it was added to an existing network. Nowadays it is expressed rather differently (in terms of an equivalent circuit consisting of a voltage source and a series resistor) but it is the same theorem. It was Thevenin's first article and appeared in the same year as the publication of the joint translation with Raynaud.

Three further articles followed in that year. The first gave a method of using a galvanometer to measure potential, and made use of the new theorem. The second described a method for measuring resistance, and the third was on the use of the Wheatstone Bridge.

A Good Launch

Publication of the theorem in three journals gave it a good launch, but Thevenin also taught it himself in his courses to telegraph engineers in France. By 1889, a century ago, others were already writing of it as the "theorem de Thevenin". It is an early example of practical engineering theory, in this case telegraph theory, being originated by an engineer and taught by an engineering school quite outside the scientific tradition of mathematical physics.

All was not, however, without problems. Thevenin reported his discovery to the French Academy of Sciences but first he disclosed it to another French telegraph engineer whom he deeply admired, A. Vaschy. Vaschy found the concept attractive but thought the theorem was wrong. Others were consulted and controversy grew as to whether it was right or wrong.

Though Thevenin ***produced a rush of publications***[3] in 1883, he seems to have published nothing thereafter. Yet his career continued to advance and his teaching skills were sought outside the PTT. In 1885 he was asked to teach a course in industrial tools, and later one on industrial electrical engineering, at a school of commerce. The Institut National Agronomique employed him from

[3] *опублікував низку робіт*

1891 to teach mechanics, and later to lead seminars in applied mathematics. He continued all of these teaching appointments until his death in 1926.

He had already proved himself as head of the Bureau des Lignes (where he improved and unified the construction of lines and personally supervised the implementation of his policies) when in 1896 he was appointed director of the telegraph engineering school. It was a job which brought him immense satisfaction.

Having no ambition to rise further he ***had almost to be prised out of that position*** in 1901 ***to take over as engineer-in-chief***[4] of the workshops, a position he held with distinction until his retirement in January 1914.

A Crucial Theorem

His theorem is now a fundamental part of the theory of electrical engineering and was crucial in developing transmission network theory. It was to prove of immense practical value to engineers. It is now usually taught alongside its complementary theorem, Norton's Theorem, which dates from 1926 - the year Thevenin died. However, both theorems, are said to have been anticipated by the German physicist Helmholtz in l853.

Thevenin remained a bachelor for life, but provided a home for his mother's widowed cousin and her two children. Later he adopted the children.

His favourite recreation was angling and he owned a boat which he used on the River Marne for fishing. His students at the Institut Agronomique nicknamed him The Admiral. He was also a talented violinist but played only in private.

Late in 1926, Thevenin was taken to Paris for medical treatment and it was there that he died on September 21. A kindly man of simple tastes, Thevenin had requested that only his family should attend the cemetery and that a single rose from his garden should decorate his coffin. So it was when he was buried in his home town of Meaux.

Task I

Speak on Thevenin’s theorem and its impact on electrical sciences.

Task II

Retell about Thevenin’s life describing his human qualities.

---

[4] *майже насильно довелося переводити на посаду головного інженера*

LEE DE FOREST:
last of the great inventors
(1873-1961)

Although for a long time he did not have a full understanding of how it worked, Lee de Forest invented the triode, or audion as he called it. For nearly half a century it, and its descendants, dominated electronics. De Forest was also one of the earliest inventors of electronic circuits. Justifiably he could claim, therefore, to be one of the founders of electronics. Over 300 patents were filed in his name and many have regarded him as the last of the great individual inventors: but his own hope of a Nobel Prize was never fulfilled.

The name de Forest was of Huguenot origin. Lee's father, Henry Swift de Forest, was a ***Congregational minister***[1] and principal of a school for Negroes in Talladega, Alabama. It was there that Lee grew up, having been born in Iowa at Council Bluffs on August 26, 1873. His mother, Anna Margaret Robbins, was the daughter of a Congregational minister.

A ***wealthy ancestor's endowment of a scholarship***[2] at Yale University enabled de Forest to study for a bachelor's degree in mechanical engineering and he was awarded this in 1896. He followed it with a Ph.D. in 1899 for a study of the reflection of electromagnetic (Hertzian) waves from the ends of parallel wires, possibly the first Ph.D. thesis in America on a topic closely related to radio telegraphy.

By the age of 16, de Forest had announced his intention of becoming an inventor. This ambition had not dimmed by the time he left university and he determined to win fame and fortune as an inventor, with Nikola Tesla as his idol. He has also been quoted as saying that Marconi and Edison were his inspiration.

On leaving Yale, de Forest joined Western Electric in Chicago at $8 a week. But because he was never enthusiastic about working for others it was not long before his interest in radiotelegraphy led him to seek to challenge Marconi, who by then was famous. De Forest wanted his own radio system, independent of Marconi's patents, and his own company. In fact he was to found several companies over the years but he lacked the business skills which would have enabled any to survive.

At Western Electric his tinkering with radio brought no official acclaim. One day, according to his diary, he was told, "Look here, de Forest. You'll never make a telephone engineer. ***As far as I'm concerned***[3] you can go to hell, in your

[1] *парафіяльний священник*
[2] *спадок по заможному родичеві у формі стипендії*
[3] *як на мене*

own way. Do as you damn please." He took the words literally and worked full time on his own system for the remainder of his fairly short time with the company.

In Business

With an acquaintance, Smythe, who was also helping to finance him, de Forest filed for a patent in 1900 for a new radio detector which he called a "responder" and which he hoped would evade Marconi's patents. He then started his first company, bringing in another acquaintance, Freeman. Publicity was gained for their new system, which had a reported range of four miles. Then in 1901 there came the chance to demonstrate his system against Marconi who had contracted to provide ship-to-shore reporting of the America's Cup Yacht races. De Forest's trial has been described as a failure. During the races he is said to have tossed Freeman's transmitter overboard!

Technically the detector remained de Forest's big problem. Financially he moved on to bigger things. In 1902 a Wall Street financier helped him start the American de Forest Wireless Telegraph Company, capitalized at $3M. Smythe and Freeman were left behind.

Early success was achieved with orders from the Army and the Navy and for a radio link between Costa Rica and Panama. But the company's grandiose plans led to its downfall. An American network was envisaged; over 90 stations were erected and others planned, but many never sent a message. Shareholders closed the operation in 1907 and sold its assets. De Forest was forced to resign, taking his patents with him. Amongst other things they covered the, as yet unused, triode.

Immediately the De Forest Radio Telephone-Company was formed, with a capital of $2 000 000. Again the Navy bought some equipment, with mixed success. *Stock sales staved off bankruptcy*[4] and de Forest's talent as a showman maintained publicity. Broadcasts from the Eiffel Tower in 1908 and the first opera broadcast (starring Caruso) in January 1910 kept public awareness alive. Despite making some excellent equipment (the US Navy was its best customer), the company became bankrupt in 1911.

In May 1912, de Forest and his associates *were charged with fraud*[5] over some of the methods used to promote the company. De Forest was exonerated but two of his colleagues were jailed. The significance of the new technology

[4] *продаж акцій компанії відвернув банкрутство*
[5] *звинувачені у шахрайстві*

was not widely understood and the words of the government prosecutor have often been quoted, accusing the defendants of selling stock "in a company incorporated for $2 000 000, whose only assets were de Forest's patents chiefly directed to a strange device like an incandescent lamp which he called an Audion and which device had proven worthless". That worthless device was the triode.

Towards the Triode

The story of the invention of the triode is confused. De Forest's early attempts to design a new detector were frustrated by ***court cases for infringement of others' patents***[6], e.g. those of Reginald Fessenden. Eventually he returned to an observation he had made in 1900 that a gas flame dimmed when sparks were generated by his induction coil. This suggested that a gas flame could be used as a radio wave detector. In fact he found that the effect was caused by sound waves from the spark, not radio waves.

Despite that, he maintained a firm conviction that in the heated gases surrounding incandescent electrodes there must nevertheless exist a response, in some electrical form, to high-frequency electrical oscillations. This conviction led to experiments with electrodes in the flame of a Bunsen burner, and with gas inside a glass bulb ionized by a potential between a cathode and an anode. In this way de Forest started to experiment with thermionic diodes, invented by J.A. Fleming in 1904.

De Forest apparently regarded the ionized gas inside the valve as essential. He wanted an incoming signal to trigger the gas from one conducting state to another, in a manner parallel to that achieved in the popular coherer whose resistance changed dramatically in the presence of electromagnetic waves. It was a long time before he accepted the true explanation of how a vacuum diode worked, based on O.W. Richardson's 1903 explanation of thermionic emission.

So, in seeking to cause the trigger effect he wanted in the gas inside the diode, de Forest introduced a third electrode to which he applied the input signal. Although none of the many permutations of shape and size for the third electrode produced a very good detector, he found that the best was an open grid of fine wire. Hence the invention of what we know as the triode. De Forest used the term audion for both diodes and triodes.

[6] *судові справи за порушення патентного права*

Patent Battles

Experts seem to differ as to whether de Forest actually began with Fleming's diode and then used the gas flame experiments to try to fight off the accusation of infringing Fleming's patent, or whether de Forest's account is the truth. De Forest was always sensitive to the possibility of a suit for infringement of Fleming's patent, which was owned by the Marconi Company. When the suit did come, Marconi won.. Some accept de Forest's explanations of how he made his invention as being the way it was, others see them virtually as disinformation designed to protect himself against this possible suit.

The triode was invented in 1906 and a patent filed in January 1907. De Forest seems to have regarded it as a finished product and did not seek further improvements. He turned his attentions to radio telephony. For years the triode was simply another radio detector, sometimes better, sometimes worse than the more popular crystal or electrolytic detectors.

What transformed the triode into the basis of electronics were the improvements made by industrial laboratories following the discovery of how to use it to amplify and oscillate. These circuit inventions were made independently by several people in 1912 and 1913, de Forest being one of them. The arrival of the amplifier was of great significance to the telephone companies as well as the those involved in radio telegraphy. AT&T bought the repeater rights to the triode for $50 000 in 1913 and later the radio rights as well.

The value of the triode as an oscillator was that it could be used to generate continuous electromagnetic waves for radio transmitters. Four men contested the patent rights to the invention, with de Forest eventually winning the legal battles. The longest patent litigation in American radio history was that between de Forest and Edwin Armstrong over the invention of the feedback or regenerative circuit. When Armstrong won the first round in 1917, de Forest sold his patents and any future valve inventions he might make to AT&T for $250 000. From then on he seemed to lose interest in radio, turning instead to talking pictures. The *final legal judgement however went to*[7] de Forest, with engineers generally feeling that Armstrong had been let down.

Success

Once the triode had found important uses as an amplifier and oscillator, industrial scientists were quick to understand its mode of operation. De Forest's gas was evacuated to produce a high-vacuum device and a filament life of 1000

[7] *остаточний вердикт був на користь*

hours was achieved in 1913. ***Oxide-coated filaments***[8] increased emission and more new circuits were invented such as the ***push-pull amplifier***[9] (E.H. Colpitts, 1912) and the Colpitts and Hartley oscillators. The First World War provided further stimulus for improvements and use. A somewhat similar path was followed in Europe where Robert von Lieben patented first a diode (1906) and then a triode (1910).

In 1911, when de Forest's company was in severe financial difficulty, he took a job with the Federal Telegraph Company in Palo Alto, California. California then became his home.

Above all, de Forest was a prolific inventor, not a businessman nor a scientist. Amongst his other patented inventions were a high-frequency ***surgical cautery device***[10], several types of microphones and loudspeakers, and stereoscopic and large-picture television. Naturally he received many medals and decorations but the decision not to award him the Nobel Prize is said to have left him heartbroken. He seems to have had ***the knack of inspiring intense loyalty***[11] in some people, but antipathy in others.

For the last two years of his life illness kept him bedridden, almost totally incapacitated, and financially drained. He died on June 30, 1961, at his home in Hollywood, California, in his 88th year and just four years after his last patent was issued. His fourth wife, Marie, survived him. He was one of the last great individual inventors.

Task I

Tell about Lee de Forest's business activity.

Task II

Tell the history of triode development and improvements.

Task III

Speak on de Forest's inventions.

---

[8] *нитки розжарення з оксидним покриттям*
[9] *двотактовий підсилювач*
[10] *хірургічний пристрій для припікання*
[11] *властивість викликати щиру прихильність*

EDWIN HENRY COLPITTS
(1872-1949)

Think back to when oscillators were something new to you and exciting and you will probably recall the names of two of the great telephone engineers who worked for the Bell Telephone system in the first half of this century: Colpitts and Hartley. The Colpitts and Hartley oscillators have survived long after their inventors died. Today they are transistorised and can be stabilised by quartz crystals, but they are still recognisable as the fundamental circuits invented during the First World War.

Edwin Henry Colpitts was born on January 9, 1872, at Pointe de Bute in Canada, though he was sometimes described by his contemporaries as an honorary American. A bachelors degree with honours from Mount Allison University, Sackville, New Brunswick, was followed by another at Harvard in 1896, and a masters the next year after completing a postgraduate course in physics, mathematics and engineering. He continued at Harvard for another two years as an assistant to Professor Trowbridge in the Physics Laboratory, until joining the American Bell Telephone Co in 1899.

For the next 38 years he *served the Bell System in one capacity or another*[1], steadily rising through the ranks until he retired in 1937 as Vice-President of Bell Telephone Laboratories. But it was up to about 1920 that most of his efforts were directly involved with hands-on engineering or scientific contributions to telephone engineering. From then until his retirement he held positions which were mostly executive, leaving little time for direct contributions to engineering. When Colpitts began his career with Bell, telephones were no longer new, though much of the science-based work which led to vastly improved performance still lay in the future.

In 1924 Frank Jewett, Chief Engineer at Western Electric, wrote:"Almost from the day he entered the modest laboratories in Boston, Colpitts took a prominent part in the solution of the problems which were to revolutionise telephonic and telegraphic communication." Colpitts, he continued, was a central figure in the fundamental work which lifted the art of telephone engineering to a higher plane and established it as a science on a firm foundation of exact knowledge.

As well as exact knowledge, exact measurements were now required. The methods and instruments which George A Campbell and Colpitts developed for measuring high-frequency alternating currents were to play a big part in the

---

[1] *працював у компанії «Белл» на тій, чи іншій посаді*

development of telephony. Colpitts himself "made many of the first high-frequency determinations on lines and apparatus".

In this period up to 1907, under Campbell's direction, Colpitts worked long and hard on the development and application of loading coils to open wire and cable circuits, first suggested by Heaviside but patented by Pupin in 1899. "To those of us who were privileged to witness and occasionally to take part in this work there comes to mind a picture of Colpitts in the early morning hours hard at work in some test room ***or far afield in sunshine or storm***[2] on a line inspection," wrote Jewett.

Jewett also recorded for us the contribution that Colpitts made to solving, what he called, the threat to the very existence of long distance and even local telephone services in the first few years of this century. That threat was the inductive interference brought about by the introduction of alternating current for the propulsion of trolley buses and trains.

Colpitts ***threw himself***[3] into the work, "sometimes in the laboratory, but now more frequently in rough clothes in the mountains of Pennsylvania or the ***brush of Georgia***[4] or in rubber boots in the winter mud of Indiana." In the end solutions to the problems were found by joint collaboration with Westing-house power engineers. Jewett ***credited Colpitts "in large measure" with helping bring about***[5] the closer understanding between communication and power engineers which came about in the first two decades of the century.

In 1907 the Bell System was reorganised and Colpitts moved to the Western Electric Company (part of Bell) in New York. There he began ***his climb up the administrative ladder***[6], first as head of the Physical Laboratory, later as Director of the Research Laboratories (1911) and eventually as Assistant Chief Engineer (1917). The technical highlights of that period for Bell were the transcontinental telephone line of 1914, the transatlantic radio telephone experiments of 1915 and of course the introduction of the thermionic valve to experimental and practical engineering. Colpitts was involved with them all.

When he transferred back to AT&T in 1924 as the newly appointed Assistant Vice-President (Development and Research) he was described as possessing a keen analytical ability, the creative imagination of the thoroughly trained physicist, a direct approach, and an integrity of intellect. These personal characteristics received even further career reward in 1934 when Bell's research laboratories merged and he became Vice-President of the Bell Telephone Laboratories.

---

[2] *на віддаленій ділянці за будь-якої погоди*
[3] *поринув*
[4] *у чагарниках Джорджії*
[5] *вважав, що К. сприяв великою мірою*
[6] *просування вгору адміністративними сходами*

Oscillator

The Colpitts oscillator is one of the standard circuits of electronics and has been such almost from the day of its invention. Research engineers at Bell began their development work of the new triode (De Forest's audion) and its use in circuitry in 1912 when AT&T paid De Forest $50,000 for the right to use the triode as a telephone repeater. In 1914 they paid another $90,000 for the radio receiver rights to the triode, marking the start of electronic circuits.

Progress was rapid in the early years. The first important circuit was the positive-feedback, or regenerative, amplifier and 1913 saw ***many claimants to its invention***[7] in both America and Europe. Patent litigation in America dragged on for 20 years. But Colpitts invented one of the most famous and enduring of electronic circuits - the push-pull amplifier - on November 4, 1912.

Two years later came a circuit for producing and modulating high-frequency oscillations. This was an extension of work performed by G A Campbell, also at Bell, to discover the causes of "singing" in telephone amplifiers. Then, in March 1915, came the Colpitts oscillator, a month after Hartley had revealed the circuit named after him.

In the Second World War he was recalled from retirement to work on ***submarine warfare***[8], specifically on echo ranging systems and attack directors as "Head Technical Aide" of the National Defense Research Committee. For this effort, on April 5, 1948, he received the Medal for Merit, the USA's highest civilian award. The citation stated that it was for " outstanding services to the United States from June 1940 to June 1946". It seems ironic that before the war he had received a Japanese award, the Order of the Rising Sun, for a series of lectures he gave in Japan for the Iwadare Foundation.

In 1941 he also found time to accept the position of Director of the Engineering Foundation. This body, a joint agency of four US engineering societies, had been set up in 1914 for "***the furtherance of research***[9] in science and engineering and the advancement of engineering and the good of mankind". It would seem that a man of Colpitts's calibre does not retire easily.

Colpitts died at the age of 77 at his home in Orange, New Jersey, USA, on March 6, 1949, after a lengthy illness and was survived by his second wife, Surah Grace. His first wife, Annie Dove Penney, whom he married in 1899, died in 1940. He was also survived by a son from the first marriage and by three brothers.

[7] *багато претендентів на цей винахід*
[8] *військова тактика підводних човнів*
[9] *сприяння дослідженням*

But long before his death he had been honoured as a distinguished telephone engineer of the pioneering period of continental and transcontinental wire and radio telephony, a respected administrator, holder of 24 patents, and a *member of the relevant engineering and scientific institutes*[10] of America.

Task I

Speak on engineering problems Colpitts had to deal with while working for Bell Telephone Laboratories.

Task II

Tell the history of Colpitts's biggest invention.

Task III

Describe Colpitts's oscillator.

RALPH HARTLEY
(1889 – 1970)

No account of Colpitts's work would be complete without a mention of Ralph Hartley, who invented the complementary oscillator.

Hartley graduated from the University of Utah in 1909 *to become a Rhodes Scholar* [11] at Oxford, graduating with a BA in 1912 and a BSc in 1913. He joined the laboratories of Western Electric in September 1913 and was in charge of early development of radio receivers for Bell System's radio telephone tests of 1915. By then he must have met Colpitts who was in charge of research there. It was at this time of radio receiver design, in a period of rapid circuit development, that Hartley revealed the oscillator named after him on February 10, 1915.

---

[10] *член відповідних інженерних та наукових інституцій*
[11] *щоб стати стипендіатом Rhodes*

During the First World War Hartley suggested that the human sense of direction is perceived by the phase difference between sound waves reaching the two ears, one set of waves having to travel further than the other. After the war his interests turned more towards voice and carrier transmission and telephone repeaters, first at Western Electric and then at Bell Telephone Labs.

Hartley is also remembered for his major contributions to Information Theory. He was the first to state the law named after him relating information to bandwidth and time: "The total amount of information which may be transmitted over a system is proportional to the product of the frequency range which it transmits by the time during which it is available for the transmission." This was first published in February 1926 although he had been working on it for several years.

A fuller account, "Transmissions of Information", was given at an international meeting in Italy in 1927 and further published in 1928. Hartley's work on Information Theory followed that of Nyquist and "provided the guiding rules for transmission engineers for 20 years" until the next major advance in 1948 when Claude Shannon included the effects of noise in the system.

In 1929, at the age of 40, illness forced Ralph Hartley to give up work and it was ten years before he could return, as a consultant on transmission problems. During the Second World War he worked on various projects, most notably on servo-mechanisms for radar and fire control systems.

He retired from Bell Laboratories in 1950, holding 72 patents, and lived with his wife at Summit, New Jersey. He died ***at the ripe old age***[12] of 81 on May 1, 1970.

Task I

Tell about Hartley's contribution to Information Theory.

Task II

Explain Hartley's law.

Task III

Speak on Hartley's scientific interests and inventions.

[12] *у доволі похилому віці*

HARRY NYQUIST

(1889 - 1976)

American physicist, electrical and communications engineer, a prolific inventor who made fundamental theoretical and practical contributions to telecommunications.

The Sweden years

Harry Nyquist's parents Lars Jonsson and Katarina Eriksdotter got married 1879. The year after they bought a farm in Tomthult. An interesting fact is that the family was baptists when the Swedish church is Lutheranian. The name Jonsson had to be changed because just hundred meters away there lived another Lars Jonsson and there was huge problem with the mail delivery. Therefore they agreed to change names, which not was a rare thing to do at this time. Harry's father changed the name to Nyquist.

Harry was the fourth child of eight and was born on 7 February 1889 in Nilsby, Sweden. The family was far from rich, but still the children were allowed to study six years in school and after that the continuing school with more concentrated education. Simultaneously Harry helped his father in his shoemaker's shop and the farm.

Harry's teacher Modén put a lot of confidence in Harry and Harry could even borrow books from his teacher (not common in those days). Modén wanted Harry to be a teacher. When Harry pointed out that his family was poor the teacher suggested that he should emigrate to America because the chances were bigger there. Two of Modén's sons had already done that. Harry was at that time 14 years old. The following years he worked at the construction of the sulphate factory in Deje in order to fulfil the demands on emigration and to get travel money: 10 dollars and a guarantee that he has a job in America. It took 4 years of hard work to fulfil the goal – to emigrate to America.

Education and Career in the U.S.A.

Nyquist moved to the United States in 1907. He came to the University of North Dakota, Grand Forks, in 1912, where earned his Bachelor of Science in Electrical Engineering degree in 1914 and his Master of Science in Electrical Engineering degree in 1915. Nyquist continued his graduate studies at Yale University, New Haven, Conn., where he received the Ph.D. in physics in 1917.

He was employed at American Telephone and Telegraph Company (AT&T) from 1917 to 1934, in the Department of Development and Research of Transmission, where he was concerned with studies on telegraph picture and voice transmission.

From 1934 to 1954 he was with the Bell Telephone Laboratories, Inc., where he continued in the work of communications engineering, especially in transmission engineering and systems engineering. At the time of his retirement from Bell Telephone Laboratories in 1954, Nyquist was Assistant Director of Systems Studies.

During his 37 years of service with the Bell System, he received 138 U.S. patents and published twelve technical articles. His many important contributions to the radio art include the first quantitative explanation of thermal noise, signal transmission studies which laid the foundation for modern information theory and data transmission, the invention of ***the vestigial sideband***[1] transmission system now widely-used in television broadcasting, and the well-known Nyquist diagram for determining the stability of feedback systems.

Some of Nyquist's best-known work was done in the 1920s and was inspired by telegraph communication problems of the time. Because of the elegance and generality of his writings, much of it continues to be cited and used. In 1924 he published "Certain Factors Affecting Telegraph Speed," an analysis of the relationship between the speed of a telegraph system and the number of signal values used by the system. His 1928 paper "Certain Topics in Telegraph Transmission Theory" refined his earlier results and established the principles of sampling continuous signals to convert them to digital signals. The Nyquist sampling theorem showed that the sampling rate must be at least twice the highest frequency present in the sample in order to reconstruct the original signal. These two papers by Nyquist, along with one by R.V.L. Hartley, are cited in the first paragraph of Claude Shannon's classic essay "The Mathematical Theory of Communication" (1948), where their fundamental role in the development of information theory is acknowledged.

In 1927 Nyquist provided a mathematical explanation of the unexpectedly strong thermal noise studied by J.B. Johnson. The understanding of noise is of critical importance for communications systems. Thermal noise is sometimes called Johnson noise or Nyquist noise because of their pioneering work in this field.

In 1932 Nyquist discovered how to determine when negative feedback amplifiers are stable. His criterion, generally called the Nyquist stability

[1] *смуга частот бічних сигналів*

theorem, is of great practical importance. During World War II it helped control artillery employing electromechanical feedback systems.

His remarkable career included advances in the improvement of long-distance telephone circuits, picture transmission systems, and television. Dr. Nyquist's professional, technical, and scientific accomplishments are recognized worldwide. It has been claimed that Dr. Nyquist and Dr. Claude Shannon, another signal procession pioneer, are responsible for virtually all the theoretical advances in modern telecommunications. He was credited with nearly 150 patents during his 37-year career. His accomplishments underscore the excellent preparation in engineering that he received at the University of North Dakota. In addition to Nyquist's theoretical work, he was a prolific inventor and is credited with 138 patents relating to telecommunications.

Nyquist and FAX

In 1918 H. Nyquist began investigating ways to adapt telephone circuits for picture transmission. By 1924 this research bore fruit in "telephotography" - AT&T's fax machine. The principles used in 1924 were the same as those used today, though the technology was comparatively crude. A photographic transparency was mounted on a spinning drum and scanned. This data, transformed into electrical signals that were proportional in intensity to the shades and tones of the image, were transmitted over phone lines and deposited onto a similarly spinning sheet of photographic negative film, which was then developed in a darkroom.

The first fax images were 5x7 photographs sent to Manhattan from Cleveland and took seven minutes each to transmit.

Nyquist's Signal Sampling Theory

In the late 1920s, the only technology to preserve musical recordings was to copy sound waves in wax. Harry Nyquist, an AT&T scientist, thought there was a better way. He wrote a landmark paper (Nyquist, Harry, "Certain topics in Telegraph Transmission Theory," published in 1928) describing the criteria for what we know today as sampled data systems. Nyquist taught us that for periodic functions, if you sampled at a rate that was at least twice as fast as the signal of interest, then no information (data) would be lost upon reconstruction. And since Fourier had already shown that all alternating signals are made up of nothing more than a sum of harmonically related ***sine and cosine waves***[2], then audio signals are periodic functions and can be sampled without

[2] *синусоїдальні та косинусоїдальні хвилі*

lost of information following Nyquist's instructions. This became known as the Nyquist frequency, which is the highest frequency that may be accurately sampled, and is one-half of the sampling frequency.

Harry Nyquist (1920's) showed that to distinguish unambiguously between all signal frequency components we must sample at least twice the frequency of the highest frequency component, Figure 1.

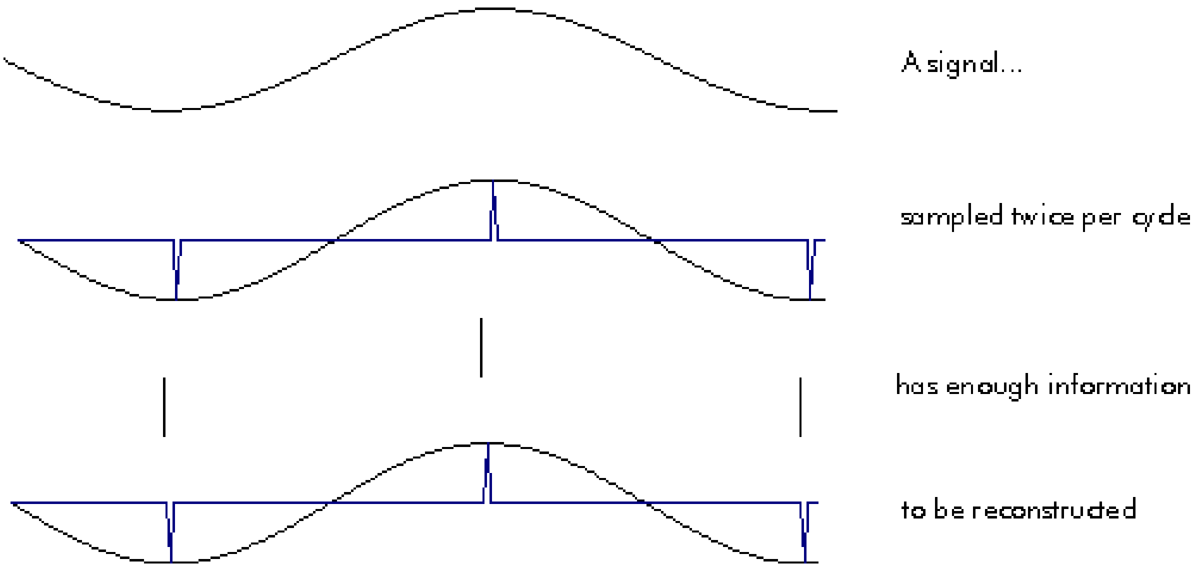

Figure 1: In the diagram, the high frequency signal is sampled twice every cycle. If we draw a smooth connecting line between the samples, the resulting curve looks like the original signal. This *avoids aliasing*[3]. The highest signal frequency allowed for a given sample rate is called the Nyquist frequency.

Harry Nyquist thought of a way to take an analog signal (such as voice) and code it (just like with the Morse code) using ones (1) and zeros (0). For this, he invented something called a "CODEC" or coder-decoder. This thing that today is the size of a fingernail (a microchip) measures the input analog signal, codes the result of the measurement and sends this code down the telephone lines and trunks. It does so often enough so its peer at the other end of the line can reconstruct the voice signal almost as good as it was at the calling side. N. Erd calls the measuring of the signal "sampling." Good old Harry Nyquist also recommended that the number of samples per second for a good representation of the signal has to be twice as big as the number of Hertz of the fastest sine wave contained in the analog signal. Since the telephone only allows 4 kHz through the phone line, sampling for voice is done 8000 times per second.

[3] *усуває накладання спектрів*

Nyquist Theorem

Signal Sampling Theory was an exercise in frustration[4] for Nyquist, since it needed 30,000 samples a second to make it work, and no system at that time could measure, record, store and reread that much information that quickly. He had to wait for computers, binary language, transistors and integrated circuits - 60 years of technological progress - to make digital recording and playback a reality.

The sampling theorem states that for a limited bandwidth (band-limited) signal with maximum frequency $\mathbf{f_{max}}$, the equally spaced sampling frequency $\mathbf{f_s}$ must be greater than twice of the maximum frequency $\mathbf{f_{max}}$, i.e.,

$$\mathbf{f_s > 2 \cdot f_{max}}$$

in order to have the signal be uniquely reconstructed without aliasing. The frequency $\mathbf{2 \cdot f_{max}}$ is called the Nyquist sampling rate. Half of this value, $\mathbf{f_{max}}$, is sometimes called the Nyquist frequency. The sampling theorem is considered to have been articulated by Nyquist in 1928 and mathematically proven by Shannon in 1949. Some books use the term "Nyquist Sampling Theorem", and others use "Shannon Sampling Theorem". They are in fact the same sampling theorem.

The sampling theorem clearly states what the sampling rate should be for a given range of frequencies. In practice, however, the range of frequencies needed to faithfully record an analog signal is not always known beforehand. Nevertheless, engineers often can define the frequency range of interest. As a result, analog filters are sometimes used to remove frequency components outside the frequency range of interest before the signal is sampled. For example, the human ear can detect sound across the frequency range of 20 Hz to 20 kHz.

According to the sampling theorem, one should sample sound signals at least at 40 kHz in order for the reconstructed sound signal to be acceptable to the human ear. Components higher than 20 kHz cannot be detected, but they can still pollute the sampled signal through aliasing. Therefore, frequency components above 20 kHz are removed from the sound signal before sampling by a band-pass or low-pass analog filter. Practically speaking, the sampling rate is typically set at 44 kHz (rather than 40 kHz) in order to avoid signal contamination from the filter roll off.

What if an engineer is interested in sampling a mechanical signal across ALL frequencies? Most mechanical signals have frequencies limited to below

[4] *теорія дискретизації сигналу була джерелом постійних розчарувань*

100 kHz. Therefore, using a 200 kHz sampling rate should satisfy most mechanical engineering applications. The price for such a high sampling rate will be the huge amount of sample data to be stored and processed. Note that this limit should NOT be applied to electric engineering, where signals can contain much higher frequencies!

Graphically, if the sampling rate is sufficiently high, i.e., greater than the Nyquist rate, there will be no overlapped frequency components in the frequency domain. A "cleaner" signal can be obtained to reconstruct the original signal. This argument is shown graphically in the frequency-domain schematic.

Nyquist and Information Theory

Information theory is often considered to have begun with work by Harry Nyquist (H. Nyquist, Certain factors affecting telegraph speed, *Bell System Technical Journal*, 3, 324-346, 1924). While new knowledge is built by individuals standing on the shoulders of those who performed earlier research, people such as Nyquist can be seen as being extraordinarily creative for putting together previous work to produce a new and unique model.

Writing in the Bell System Technical Journal, Nyquist suggested that two factors determine the "maximum speed of transmission of intelligence". Each telephone cable is implicitly considered to have a limit imposed on it such that there is a finite, maximum speed for transmitting "intelligence". This limit was widely understood by practicing electrical engineers of the era to be related to such factors as power, noise, and the frequency of the ***intelligent signal***[5]. Accepting such a limit as a given, Nyquist was able to work backwards towards the study of what was transmitted. He began referring to what was transmitted as "information."

The two fundamental factors governing the maximum speed of data transmission are the shape of a signal and the choice of code used to represent the intelligence. Responding to the earlier work of Squier and others, Nyquist argues that telegraph signals are most efficiently transmitted when the intelligence carrying waves are rectangular. Given a particular "code", use of square waves allows for intelligence to be transmitted faster than with sine waves in many practical environments.

Once the proper wave form is selected, a different problem arises: how should "intelligence" be represented? Telegraphers had long used Morse code and its variants to transmit text messages across distances. Each character was represented by a set of short or long electronic signals, the familiar dots and

[5] *інформаційнийний (інтелектуаьний) сигнал*

dashes. The letter C, for example, is represented in modern Morse code by a dash dot dash dot sequence. Experienced telegraphers listen to messages at speeds far exceeding the ability of humans to consciously translate each individual dash or dot into a "thought representation" of the symbol; instead, Morse code is heard as a rhythm, with the rhythm for letters and common words *being learned through long periods of listening* [6].

Working backwards from the maximum telegraph speed, Nyquist considered the characteristics of an "ideal" code. Morse code is adequate for many applications, but an "adequate code" is far from being the best or optimal code available. Suggesting that the speed of intelligence transmission is proportional to the logarithm of the number of symbols which need to be represented, Nyquist was able to measure the amount of intelligence that can be transmitted using an ideal code. This is one step away from stating that there is a given amount of intelligence in a representation.

After his retirement, Nyquist was employed as a part time consultant engineer on communication matters by the Department of Defense, Stavid Engineering Inc., and the W.L. Maxson Corporation.

Before his death in 1976 Nyquist received many honors for his outstanding work in communications. He was the fourth person to receive the National Academy of Engineer's Founder's Medal, "in recognition of his many fundamental contributions to engineering." In 1960, he received and the IRE Medal of Honor “for fundamental contributions to a quantitative understanding of thermal noise, data transmission and negative feedback." Nyquist was also awarded the Stuart Ballantine Medal of the Franklin Institute in 1960, and the Mervin J. Kelly award in 1961. He passed away on 4 April 1976.

Task I

Tell about Nyquist’s investigations and inventions.

Task II

Speak on Nyquist Theorem.

Task III

Discuss Harry Nyquist’s contribution to Information Theory.

---

[6] *після тривалих періодів слухання слова запам’ятовуються*

RUSSELL and SIGURD VARIAN
(1898-1959) (1901-1961)

Electronics laboratories do not usually manufacture blackberry jam. But when the first official visitor arrived at the newly-founded Varian Associates in August 1948 he found the jam pot merrily bubbling on an electric cooker and sterilized jars waiting to be filled. The Varian brothers, Russell and Sigurd, already had a reputation for their invention and development of the klystron and they were known to do things in unusual ways.

The visitor, a government official sent to survey the company's facilities, later said that he would not have been surprised if the jam making had been one of Russell's experiments. The truth was more prosaic. Sigurd's wife, Winnie, did not want to waste a good harvest of blackberries.

About Christmas, the same official received a jar of jam through the post, the last of Varian Associates' first product line. Sorry, he was told, but re-orders could not be accepted though they would be happy to discuss any requirements for klystrons or travelling-wave tubes.

So began the corporate life of Varian Associates, an international company now just over 50 years old and long famous for its klystrons which are used in such diverse applications as television broadcasting, defence, medicine and industrial production. Like the Cavity magnetron, the klystron as a device of high power and high frequency came along at the right time to help the Allied cause in the Second World War.

Childhood

Ever since childhood Russell had made inventions and Sigurd had built them. As adults they went their separate ways but were united by strong family ties; Russell struggled to follow an academic career, Sigurd became a dare-devil pilot. Throughout, however, both dreamed and made inventions with Sigurd never losing faith that one day Russell would invent "the big one" which would put them on the path to riches and independence. Eventually, he did.

Russell Harrison Varian was the eldest son of John Varian and his Australian-born wife, Agnes. It was Agnes who bonded the family together. John and Agnes emigrated to America from Dublin ***before the turn of the*** *century* [1] and settled first in California before moving to Washington DC, where Russell was born on April 24,1898.

From Washington they moved to Syracuse, New York, and Sigurd was born there on May 4, 1901. John suffered from asthma and bronchitis and *the family's fortunes went up and down*[2]. After four years on the East Coast John lost his job and for a while *it looked as if the children would have to be cared for*[3] by Agnes's sister. Friends and relatives persuaded them back to California where they settled in Palo Alto in 1902. It was there that their third son, Eric, was born on June 16,1904.

An elderly aunt provided a house, John became a masseur, and life improved. The boys developed a healthy outdoor life-style and the usual indoor one too, as a letter from their mother reveals: "When I got home from San Jose the boys had the house as if a cyclone had gone through it, leaving the dirt from the entire neighbourhood. They had taken it into their heads to make doughnuts and spilt grease all over the floor in great patches, had pillow fights in the parlor and generally played Old Harry." Training the family dog to pull them along on roller skates was another indication of their adventurous spirit.

But their spirit of adventure *must have been satiated* [4] on the night of April 18, 1906, the night of the San Francisco earthquake. The entire family escaped unscathed; but cycling around to see the damage, and particularly the displacement at the San Andreas fault, made a big impression on Russell.

When the boys were in their teens, life once more became hard. A new law required all masseurs to be registered, but John was self-taught and could not get a licence. *His clientele dried up*[5]. In 1914 the family moved to Halcyon, also in California, where they took over the post office and general store -taking with them the family dog, Russell's beehives and two donkeys. Through inheritances, gifts and loans they bought the shop, its stock and, eventually, a house. "They managed", wrote Dorothy Varian, "but the income from the post office and store was barely enough to keep food on the table."

The house took on a cosmopolitan atmosphere as various guests, paying and non-paying, moved in from time to time, some for treatment from John. All were treated with love and some were considered as members of the family. Nan, a lonely Irish girl, was regarded as an adopted niece until her death from tuberculosis - from which Sigurd was later to suffer repeatedly.

---

[1] *наприкінці сторіччя*

[2] *статки родини то зростали, то зменшувалися*

[3] *якийсь час було схоже, що про дітей доведеться дбати*

[4] *напевне задовольнився*

[5] *його клієнтура вичерпалася*

Meanwhile the boys made things for amusement, Sigurd stripping old car engines and Russell learning about the audion bulb (the original thermionic triode).

RUSSELL

The Varian boys attended grammar school in Palo Alto and high school near Halcyon. Russell left to work his way through Stanford University to a bachelor's degree in physics, which he received in 1925. Two years later this was followed by a master's degree - a considerable achievement for someone who, as a boy, had been held back by a few years at school because of his appallingly bad reading and spelling, caused possibly by dyslexia. This awful spelling was to stay with him for life. ***It was sheer persistence and a refined intelligence that saw him through***[6]. Even his career as a student got off to a bad start as surgery and illness wrote off his first year.

Ideally the next step would have been a Ph.D., and a life in academic research, but *that was not to be*[7]. Sigurd was ill with tuberculosis and his parents needed financial help from their eldest son. Bell Labs *turned him down*[8] but he got a job, for six months, with Bush Electric in San Francisco. This was followed by a research post with an oil company in Texas. After five months he was dismissed, almost certainly because of *personality clashes*[9] with his employer. It was some compensation, however, that he had been awarded his first patent.

Back in San Francisco he was offered a position with the Farnsworth Television Laboratory. This was 1930, and America's economic structure was in chaos. But television research was progressing in several places and Philo T. Farnsworth's image dissector was acknowledged as one of the leading contenders. Russell Varian was delighted to join, even when a change of financial backer meant a move to Philadelphia. By mid-1933, though, problems between Farnsworth and Philco, the new backer, led to Farnsworth's shutting down. RCA went on to win the race to produce electronic television in America and Russell returned to Stanford. He applied to study for his long-awaited Ph.D. and was astonished when he was turned down.

At 36 years of age, his future had collapsed. He trained as a teacher but never took up the profession. Instead, at the university he did some tutoring here, some marking there, and what research he could. This prompted Sigurd to

---

[6] *йому допомагали лише наполегливість та витончений розум*
[7] *не судилося*
[8] *його не прийняли*
[9] *особисті конфлікти*

ask, "Is Russell figuring on making money out of scientific papers, or is he just going to advance the cause of science for nothing?"

SIGURD

Sigurd Fergus Varian left school in 1920 and registered at California Polytechnic but quickly dropped out. He was far too adventurous for the academic life. His contribution was not to be the original researcher but the developer and implementer of ideas, the man who got them to work. With a friend, he set up his own business as an electrician, but then joined the Southern California Edison Company. When stringing high power lines near a small airfield, Sig (as he was known) became fascinated by the aeroplanes. Soon he was receiving flying lessons at $4 each. It was the start of a life-long love affair.

In August 1924 Sigurd bought a wartime biplane. Soon the plane was earning money with stunt flying, advertising, selling lessons and giving joy rides. But by now tuberculosis had struck for the first of several times and six months' rest was needed to clear his lungs. The next year he ***hired himself out*** [10] to an electricity company as a flying serviceman and used his plane in other ways to earn a living. By 1926 regulations for flying were being introduced and Sig, and his plane, were duly licensed.

The life he was leading ***took its toll*** [11], however, and tuberculosis struck again. This time it was severe and Sigurd spent a year in a sanatorium, a severe trial for one with a driving, adventurous nature. When he finally accepted his fate he used some of his invalid time to plan for the future and study aerial navigation. He also made his first request to Russell to help improve aircraft navigation instruments: a radio compass was their first serious project, though it did not work out.

Sigurd decided it was time to get a regular job with an airline. He was an excellent pilot and ***was signed up by***[12] Pan American for its subsidiary in Mexico. The job turned out to be extremely well paid and had more than ***its fair share of excitement*** [13], with hunts for emergency landing sites, revolutions and other thrills. He also met and married Winifred Hogg, the daughter of the British consul in Vera Cruz and who, years later, was to make that blackberry jam. Mexico was also where Sigurd learned about the hazards of aircraft navigation and the need for aids, especially for blind landings. The threat of another war in Europe worried him and he pondered how approaching aircraft could be

---

[10] *найнявся на роботу*
[11] *за такий спосіб життя довелося заплатити*
[12] *підрядився працювати на*
[13] *достатньо гострих відчуттів*

detected. Meanwhile the postmen carried letters to and fro between the brothers as they exchanged ideas for inventions and businesses.

By 1935, Sigurd was ready for a change. He took six months' leave and he and Winnie headed for Halcyon and a home laboratory which he set up and shared with Eric and Russell.

The klystron

During his time at Stanford, Russell built up friendships; and one especially, with a physicist called Bill Hansen, was to blossom. Hansen worked on X-ray phenomena and microwaves. Early in the Second World War his teaching notes were classified and used at the famous MIT Radiation Laboratory, where much of the American work on radar was performed and co-ordinated. Before that, however, with Russell Varian he speculated on how to get high velocity electrons without spending a lot of money. The result of Hansen's work was the rhumbatron (named after the rhumba dance), a cavity resonator which was to feature in the invention of the klystron.

When Russell arrived at the home laboratory, Sigurd and Eric were busy developing earlier ideas and still hoping that Russell would invent "the big one". Cities were being bombed in Spain and China, and aircraft detection ***was high on Sig's list of priorities***[14]. They knew that short wave radiation would be suitable but there was no way of generating the high powers required. Of course they did not then know of the secret military work on pulsed radar.

Russell recognized the need for a resonator and thought of Bill Hansen's rhumbatron. He and Hansen talked it over in May 1936 and Russell developed his ideas further. In February 1937 he had the design for a microwave tube and sought permission to use Hansen's resonator. Other ideas developed and Russell ***came to realise that completion of the project was beyond the resources***[15] of their little laboratory.

Sigurd's drive and determination saved them. He believed this was the "big one". Now he proposed to use the laboratories of Stanford University. Russell hesitated. Sig did not. By the end of April they had an agreement with the university that it would provide facilities, the right to consult with staff, a research grant of $100, but no salaries. In return, Stanford got equal shares of any financial return. It was a good deal all round.

[14] *на початку переліку пріоритетів Сіга*
[15] *усвідомив, що для завершення проекту бракувало ресурсів*

Celebration

Once they had started, many ideas and variations on ideas *tumbled out of their minds*[16]. So much so that on June 5, 1937, Russell decided to sit down and classify them all to ensure nothing was overlooked. It was whilst doing his classification that the fundamental idea for the klystron, the velocity grouping or bunching principle, struck him. Sig remembered the date clearly: it was the day be blew the main breaker in the university power house.

With a determined struggle they completed the design and built the first klystron, overcoming many problems on the way. The completion of the first hand-filed hexagonal grids called for a celebration. Building their own detection and measuring equipment proved to be another important problem; and solved it was. In two months the Model A 10cm klystron, encased in a vacuum bell jar, was working - intermittently - on August 19, 1937. By the 30th the device had been rebuilt and gave continuous operation at 13cm. It had cost $50 of Stanford's money.

Up to then the device had been known as the "thing" and the "can". A respectable name was needed. "Tron" was a common suffix for a vacuum tube and "klyso" was chosen as representing the bunching of waves on a beach, hence klystron.

Further detailed development work was needed. Instead of just three men (Russell, Sigurd and Bill Hansen) a whole team was now involved and a lot more effort and money was needed. Sperry Gyroscope agreed to fund the work with up to $25 000 a year. Suddenly it was big business.

The relationship with Sperry, industrial production and war-time use of klystrons are stories in themselves. The brothers *were not cut out to accept direction of their ideas and their work from others*[17] and the relationship with their new employer involved several conflicts. Facilities were moved from California to the East Coast. Russell was engrossed in the vital patent applications and Sigurd's approach to his work brought more tuberculosis and *wrote him off* [18] for almost another year. At one stage, it was rumoured that Sperry wanted to buy the patents and sack the pair of them. It is not surprising that the brothers and their friends laid plans for their own post-war research laboratory.

In mid-1946 Russell returned to Palo Alto, depressed by the failure of his five-year-old marriage. But things were about to improve. He took great joy from hiking and camping and in 1946 he married a fellow camper, Dorothy.

[16] *вирувало у їхніх головах*
[17] *були створені не такими, щоб дозволити керувати їхніми думками та роботою*
[18] *викреслив його з життя*

This marriage lasted until his death in the great outdoors of Alaska on July 28,1959.

The time had come for the long-discussed laboratory to become a reality. Russell found a suitable building measuring 30 by 40 feet on an unpaved street in San Carlos. It was cheap. On April 20, 1948, Varian Associates became a legal reality. Sigurd arrived in May full of energy and enthusiasm. A sum of about $45 000 was needed of which the partners could contribute only $23 000. A new recruit added $5000 but that still left them $17 000 short. Their distrust for big business ruled out going to financiers and it was Bill Hansen who once again ***stepped in to help***[19]. Hansen was then a sick man and would not live another year, but he provided the remaining money, possibly by mortgaging his house. Varian Associates was established.

Honours came their way, including medals from the Franklin Institute and an honorary doctorate for Russell, who had been denied the chance to work for one. Sigurd continued to be plagued by poor health and in later years he spent more and more time in semi-retirement at his home in Mexico, building a workshop and inventing.

On 18 October, 1961, he was flying parts for his workshop back to his Mexican home. It was dark and the airport lights were out. He decided to land on the beach, crashed and was killed. It was probably ***the way the great adventurer would have wanted to go***[20].

Task I

Speak about Varian family and childhood of Russell and Sigurd.

Task II

Tell the history of klystron invention.

Task III

Tell about Russell's life and research..

Task IV

Tell about Sigurd Varian.

---

[19] *прийшов на допомогу*

[20] *саме той шлях, яким би хотів піти з життя великий любитель пригод*

WALTER BRATTAIN
(1902 –1987)

"The only regret I have about the transistor is its use for rock and roll".

Walter Brattain had the hands. Give him the direction and he could build anything. He was a solid physicist who had a good understanding of theory, but his strength was in physically constructing experiments. Working with the ideas of William Shockley and John Bardeen, Brattain's hands built the first transistor.

A Home on the Ranch

His father, Ross, and mother, Ottilie, married just after they'd graduated from Whitman College in Walla Walla, Washington. Ross got a job teaching science and math in China, and Walter Houser Brattain was born on February10, 1902 in Amoy. They didn't stay abroad long: by 1903, the Brattains were back in Washington. Walter spent most of his youth on a large cattle ranch just south of the Canadian border. When he wasn't doing school work, Walter had little time for anything besides helping out on the ranch. He was a cowboy.

Physics Was the Only Thing He Was Good at

In the fall of 1920, Brattain entered Whitman. He claimed he majored in physics and math because they were the only subjects he was good at.

Brattain attended college at a turning point in American science, when physics was being transformed. Older students would have been expected to travel to Europe for a first-class physics education, but Brattain was in the first wave of those who *could do just as well in the US.*[1]

Encouraged by his professor Benjamin Brown to continue his studies, Brattain went on to the University of Oregon for his Masters and to the University of Minnesota for a Ph.D.. Brattain's first job out of graduate school was at the National Bureau of Standards as a radio engineer, but after a year there he wanted to get back to physics. At an American Physical Society meeting, *he was about to ask his thesis advisor, John Tate, for help* [2]. But before he said anything, Tate introduced him to Joseph Becker of Bell Labs. "By the

[1] *міг досягти таких самих успіхів у США*
[2] *збирався попросити допомоги у свого наукового керівника*

way, Becker is looking for a man," he said, and Brattain quickly responded, "I'm interested!" Becker asked for only one qualification: he wanted to make sure that Brattain was the kind of guy ***who'd stand up to his superiors when necessary***[3]. Brattain, raised on a working ranch with a rifle in his saddle bags to shoot rattlesnakes, laughed. On August 1, 1929, Brattain moved to Becker's lab in New York City.

An Off the Cuff Explanation

Working with Becker, Brattain spent most of his time studying copper-oxide rectifiers. The pair thought they might be able to make an amplifier by putting a tiny metal grid in the middle of the device, similar to the design of vacuum tubes. A few years later, William Shockley came to him with a similar idea. *Neither contraption actually worked*[4].

Working with crystals ***eventually paid off***[5]. On March 6, 1940, Brattain and Becker were called into the office of Bell's President, Men/in Kelly. There they saw Russell Ohl 's mysterious crystal that increased voltage whenever light was flashed on it. It turned out to be a very crude P-N junction, but no one knew it at the time. Brattain, who at first thought it was a practical joke, gave ***an off-the-cuff explanation***[6]. that electrical current was being generated at a barrier inside. That theory turned out to be true. Kelly was suitably impressed.

After World War II

Brattain spent the war years working on ways to detect submarines, and then returned to Bell Labs to find Kelly was reorganizing the researchers. Brattain was assigned to a new solid state group with Stanley Morgan and Bill Shockley at the head. John Bardeen, a friend of Brattain's brother Robert, joined the group as well. Bardeen's skill was in theory, while Brattain's was in experimenting. The two men soon learned to work together beautifully — Bardeen would watch Brattain conduct an experiment, and then offer hypotheses about the results.

---

[3] *у разі необхідності не погоджуватиметься зі своїми керівниками*
[4] *жоден з хитромудрих пристроїв насправді не працював*
[5] *зрештою виправдалася*
[6] *спонтанне пояснення*

The First Transistor

The close relationship between Brattain and Bardeen paid off in what has become known as the "Miracle Month." For four weeks the two men came up with one great idea after another. Over the month they built several devices — each one a little better than the previous — and it all came together on Tuesday, December 16. Brattain sat down at their latest attempt to build an amplifier. He turned on the voltage and for once everything seemed to work just right. "This thing's got gain!" Brattain said to no one in particular. That meant amplification.

Rifts in the Lab

After the point-contact transistor was built, a *clash of personalities got the better of what had been a well-tuned research group*[7]. The fight was over just how much credit Shockley would receive. He was the team leader, but he worked on his own research at home and left Bardeen and Brattain alone. A famous company publicity photo of the three men shows how skewed the relationships were: Shockley sat at center stage in front of the microscope as if he had done the critical experiments. It was Brattain's laboratory bench and Brattain's equipment, but Brattain stood behind his boss, as if Shockley had really done the work. In fact, management at Bell Labs insisted that Shockley appear in every publicity picture. He was the head of the group and deserved to be there, the lab management felt. But they kept his name off the patent. That *did not make Brattain or Bardeen feel any better about*[8]. Shockley. Later in life, Brattain would always say to people who really knew him well, that he really hated that photo.

Over the next few years, Brattain continued to work in Shockley's transistor group, but usually wasn't invited to work on the most exciting research. He soon stopped reporting to Shockley of his own accord, and eventually demanded that he be transferred to another group altogether. Much happier away from Shockley, Brattain remained at Bell until he retired in 1967.

The Nobel Prize

At 7 AM, Thursday, November 1, 1956, Brattain was at home when he got a phone call from a reporter. He had been awarded the Nobel Prize for the invention of the transistor. He was soon swamped by the media. Later that

---

[7] *конфлікт особистостей взяв гору над колись добре налагодженою дослідницькою групою*

[8] *це не покращило ставлення до*

morning he attended a meeting in the Labs' Murray Hill auditorium. As he walked into the room, everyone spontaneously stood up and began to clap. It brought tears to his eyes. Later he wrote: "What happened there is a matter of record, except possibly the extreme emotion that one feels on receiving the acclamation of one's colleagues and friends of years, knowing full well that one could not have accomplished the work he had done without them, and that it was really only ***a stroke of luck*** [9] that it was he and not one of them."

Walter Brattain wrote in 1964 on how important he realized their discovery was: "It is of interest to those that ask whether we knew how important this was, that the evening of the first day, when John had come in and suggested the geometry, I told my riding group that night, going home, that I felt that I had that day taken part in the most important experiment I had ever taken part in in my life. And the next evening going home with them I had to swear them to secrecy."

Back to Washington

After he retired from Bell Labs, Brattain moved back to Walla Walla to teach at his alma mater, Whitman College. He worked on biophysics, taught a physics course for non-science majors, and listened to the music being played on campus so loudly thanks to his invention. "The only regret I have about the transistor is its use for rock and roll," he said more than once. He died of Alzheimer's disease at the age of 85 on October 13, 1987.

Task I

Tell about Brattain’s role in the invention of the transistor.

Task II

Comment on his words about his greatest invention.

Task III

Explain the sentence “Walter Brattain had the hands”.

[9] *подарунок долі*

JOHN BARDEEN

(1908 – 1991)

Electrical engineer and physicist John Bardeen remains the only person to win two Nobel Prizes in the same field. Shortly after he was awarded the second prize, a friend congratulated him, "Keep up the good work. Win three times and you get to keep the king."

Bardeen's prize-winning work has been crucial to two fields in electrical engineering. He won his first prize in 1956, along with Walter Brattain and William Shockley, for their research on semiconductors and their invention of the transistor at Bell Labs in 1947. The transistor is quite possibly the single most important and revolutionary technological innovation since World War II. He earned his second prize in 1972 for his work with Leon Cooper and J. Robert Schrieffer on the theory of superconductivity. The BCS theory, as it is commonly called, remains the definitive explanation of superconducting phenomena.

His father, Charles Russell Bardeen, was the first graduate of the Johns Hopkins Medical School and founder of the Medical School at the University of Wisconsin. His mother, Althea Harmer, studied oriental art at the Pratt Institute and practiced interior design in Chicago. He was one of five children.

Education

John received his elementary and secondary education in Madison. He attended the University High School in Madison for several years, and graduated from Madison Central High School in 1923. This was followed by a course in electrical engineering at the University of Wisconsin, where he took extra work in mathematics and physics. After being out for a term while working in the engineering department of the Western Electric Company at Chicago, he graduated with a B.Sc. in electrical engineering in 1928. He continued on at Wisconsin as a graduate research assistant in electrical engineering for two years, working on mathematical problems in applied geophysics and on radiation from antennas. It was during this period that he was first introduced to quantum theory by Professor J.H. Van Vleck.

When Professor Leo J. Peters, under whom his research in geophysics was done, took a position at the Gulf Research Laboratories in Pittsburgh, Pennsylvania, Dr. Bardeen followed him there and worked during the next three years (1930-33) on the development of methods for the interpretation of magnetic and gravitational surveys. This was a stimulating period in which geophysical methods were first being applied to ***prospecting for oil.***[1]

Because he felt his interests were in theoretical science, Dr. Bardeen resigned his position at Gulf in 1933 to take graduate work in mathematical physics at Princeton University. It was here, under the leadership of Professor E.P. Wigner, that he first became interested in solid state physics. Before completing his thesis (on the theory of the work function of metals) he was offered a position as Junior Fellow of the Society of Fellows at Harvard University. He spent the next three years there working with Professors Van Vleck and Bridgman on problems in cohesion and electrical conduction in metals and also did some work on the level density of nuclei. The Ph.D. degree at Princeton was awarded in 1936.

Inventor of the Transistor

From 1938-41 Dr. Bardeen was an assistant professor of physics at the University of Minnesota and from 1941-45 a civilian physicist at the Naval Ordnance Laboratory in Washington, D.C. His war years were spent working on the influence fields of ships for application to ***underwater ordnance and minesweeping.***[2] While at Harvard, Dr. Bardeen had become friends with James B. Fisk, who in 1945 was director of research at Bell Labs. Bardeen also knew Shockley when he was a graduate student at M.I.T. "It was they who persuaded me to join the group rather than return to my academic post at Minnesota. I was the first outsider to be recruited; the rest of the initial group had been at Bell Laboratories for some years."

"My introduction to semiconductors came just after the war, in late 1945, when I joined the Bell Laboratories research group on solid-state physics, which was being formed under the leadership of Stanley Morgan and William Shockley," Dr. Bardeen once related."Following a Ph.D. under Eugene Wigner at Princeton and post-doctoral years with John H. Van Vleck at Harvard, I had been interested in the theory of metals before the war and was anxious to go back to solid-state physics after five years at the Naval Ordnance Laboratory in Washington."

Conditions were rather crowded when he arrived at the Murray Hill, NJ, laboratory. The wind-up of World War II research was still going on. As a new building was under construction, he was asked to share an office with Walter Brattain and Gerald Pearson. "I had known Walter since my graduate student days at Princeton. Although at that time I had not decided what field of solid-state physics I would work in, they soon got me interested in their problems and

---

[1] *розвідка нафтових родовищ*
[2] *підводна артилерія та траління мін*

I became deeply absorbed in trying to learn what was known about semiconductor theory." There he conducted research on the electron-conducting properties of semiconductors, the work that led to the invention of the transistor.

Contributions and Honors

In 1951 Dr. Bardeen left Bell Labs to join the University of Illinois, where he dedicated himself to research superconductivity. There, Bardeen established two major research programs, one in the Electrical Engineering Department dealing with both experimental and theoretical aspects of semiconductors, and one in the Physics Department which dealt with theoretical aspects of macroscopic quantum systems, particularly superconductivity and quantum liquids. The microscopic theory of superconductivity, developed in collaboration with L.N. Cooper and J.R. Schrieffer in 1956 and 1957, has had profound implications for nearly every field of physics from elementary particle to nuclear and from the helium liquids to neutron stars.

During his sixty year scientific career, he made significant contributions to almost every aspect of condensed matter physics from his early work on the electronic behavior of metals, the surface properties of semiconductors and the theory of diffusion of atoms in crystals to his most recent work on quasi-one-dimensional metals. In his eighty-third year, he continued to publish original scientific papers.

He was a member of the National Academy of Sciences (1954) and a Fellow of the American Physical Society. He served also as Council member, Vice President elect (1966), and President (1968-1969) of the American Physical Society. From 1959 to 1962 be served as a member of the President's Science Advisory Committee and later served on the Presidential Patent Committee.

John Bardeen was one of the first to recognize the importance of the xerographic process, was one of the principal advisors to the Xerox Corporation during the development of practical Xerox machines, and is now on the Xerox board of directors. Beyond his great theoretical abilities, his colleagues stand in awe of his uncanny understanding of the world of practicality and its special demands and importance in the affairs of man

He shared the 1956 Nobel Prize for Physics with W.H. Brattain and W. Shockley for research leading to the invention of the transistor and the 1972 Nobel Prize with L.N. Cooper and J.R. Schrieffer for the theory of superconductivity. He received the distinguished Lomonosov Award of the Soviet Academy of Sciences in 1987. In 1990, Bardeen was one of 11 recipients of the Third Century Award honoring exceptional contributions to American creativity. He was also named by Life Magazine as one of the 100 most influential people of the century.

He was a man of unusual humility and was as accessible to students as to Presidents. Wherever Bardeen traveled and the game of golf was played his renown as a golfer quickly approached his reputation as physicist, inventor, and friend of the people. He was held in special, fond regard by his students, colleagues, and friends. He died on 30 January 1991.

Task I

Speak on Bardeen's contribution to the world science.

Task II

Retell how the world rewarded him.

KONRAD ZUSE :
inventor of the first successful computer

" Necessity was not the mother of invention, it was laziness and boredom: the desire to rid himself of those tedious calculations."

The world's first successful digital computer was destroyed by Allied bomb during a raid on Berlin in World War II. Now known as the Z3, it was designed by Konrad Zuse and built at home with the help of friends. Another Zuse computer aided the design of aircraft wings at the Henschel factory in Berlin and was the only German computer to see war service. An improved model was probably captured by the Russians when they overran Berlin in 1945, though Zuse doubts that they knew what to do with it.

Surprisingly, Konrad Zuse is still relatively unknown, despite being recognized as the designer and builder of the first working computer. For a long time it was thought that the Americans had designed the first computers; but then came news of the British code–breaking machines, and then Zuse's work. In fact Zuse began his first design before the war started. He did much of the work in his spare time and even during the war there was relatively little official help. After the war he set up his own company and at one time he was the major continental manufacturer. His firm employed about a thousand people in its heyday.

Zuse is now approaching eighty, and one might expect him to look back reflectively over his life; but not so. He is a successful artist and painting vies with computers as his first love. Whilst he appreciates the honours heaped on him, he is still an active engineer and rather wishes people would give him problems to solve instead of passing him around "like a museum piece".

He was born in Berlin on June 10, 1910, but his parents soon moved: first to Braunsberg in East Prussia and then to Hoyerswerda in Saxony, where his father was the local postmaster. It was here, about 35 miles north east of Dresden, that his school awakened his interest in engineering at a time when his talent as an artist was also developing. This combination and rivalry between art and engineering caused him to drop out of university and is still a part of his life.

At the Technical University in Berlin – Charlottenburg he *found the work stultifying*[1], especially the technical drawing. So he quit the university, horrifying his parents in the process, and decided to become a commercial artist. He also turned to inventing, and devised a machine to develop and print colour photographs automatically.

But times were hard, economies bad, and millions were out of work. So he did the "sensible" thing and went back to university, re–emerging in 1935 with a degree in civil engineering.

The Mother of Invention

The Henschel aircraft works in Berlin offered Zuse a job as a stress analyst. The work proved boring; it involved repetitious calculations for which, thought Zuse, there must be a better way – a machine, perhaps. It was not the first time he had entertained such thoughts because his degree course *had exposed him to equally tedious work with a slide rule*[2].

It was not only the calculations that bothered him but also the "traffic control": noting intermediate solutions, transferring them to other parts of the problem, and so on. His first thoughts (around 1933–34) had been to devise pre–printed forms to control and record the flow of work in a standardized way for some common problems. This was followed by ideas for punched cards and

[1] *вважав ту роботу безглуздою*
[2] *для отримання ступеня йому вже доводилось займатись такою ж нудною роботою з логарифмічною лінійкою*

mechanical calculation. In fact, whilst still a university student, Zuse had already arrived at fundamental ideas for information control, the reduction of problems to a sequence of simple operations, and the concept that a machine could be built to carry out that sequence. By 1934 he was using the terms "memory unit", "seleclor" and "control device". When work at the Henschel factory reinforced his thoughts he set about building a machine in his spare time using the living room of his parents' home in Berlin as his workshop.

Necessity was not the mother of invention, says Zuse, it was laziness and boredom: the desire ***to rid himself***[3] of those tedious calculations.

Launching the V1

One of his first decisions proved crucial to success: to use binary arithmetic instead of decimal). One of the friends whose help was enlisted, Walther Buttmann, was asked to research the published work of Gottfried Liebniz in the Berlin University library. It was Liebniz who had first studied binary arithmetic in the I7th century.

So in l936 Zuse started making the component parts of his first all-mechanical machine: using metal pins and slotted metal plates, the ends of the slots representing ones and zeroes. The memory was to hold 64 binary numbers of 16 bits each and he successfully completed it with help from friends who laboured to make the thousands of parts by hand. However, the more complex arithmetic unit required greater manufacturing precision than they could achieve. Programs were coded by punching series of up to eight holes into discarded 35mm movie film, which was far cheaper than the commercially–available paper tape.

This machine was named the Versuchsmodell-1 (experimental model 1) or V1 for short. It was followed by a V2, both of which were later renamed the Z1 and Z2 to avoid confusion with the V1 - flying bomb and the V2 - rocket.

The Z2 re-used the successful memory of the Z1 but with an arithmetic unit made from second-hand telephone relays. Here another friend, Helmut Schreyer, came into his own. Like others, Schreyer had done his share of cutting out metal plates for the Z1. Now he suggested using electromechanical relays instead of the mechanical pins and slots.

New relays were expensive, and since funding was coming out of their own pockets and those of friends, every penny counted. A fully mechanical computer had proved impracticable and a full-sized relay machine would need thousands of relays; so a test model was built using just 200 second-hand relays.

---

[3] *позбутися*

By this time, Zuse had developed the design of his future computer to the stage where he had achieved the yes–no (binary) logical structure for the machine and recognized that it was independent of the physical methods used to build it.

An Electronic Computer

The possibilities for a relay computer looked optimistic when Schreyer suddenly suggested using electronic valves instead. Though they were not then commonly employed for switching between two states, valves could be used in that way and would be far faster than relays. "At first I thought it was one of his student jokes – he was always full of fun and given to fooling around", Zuse has recalled.

About 2000 valves would be needed. Asking for them, and getting them, were two different things in a Germany then at war. ***Private enterprise stood no chance***[4] so they talked to the German Army Command. Whilst the initial reaction was favourable, the idea foundered when they said it would take about two years to build. "And just how long do you think it'll take us to win the war?" they were asked.

So little help came, but by the end of the war Schreyer had built an experimental computer with just 100 to 150 valves, and gained his doctorate on the way for his work on valve switching circuits. Like the other computers, this too was a casualty of the war. After the war the development of electronic equipment was banned in Germany and so Schreyer emigrated to Brazil. It was there that he died in 1985.

Whilst Schreyer worked part–time on the electronic machine Zuse completed the electromagnetic relay computer, the Z3, encouraged by the Experimental Aircraft Institute. The Z2 had convinced the Institute of the usefulness of Zuse's ideas and so it financed the Z3, though Zuse still had to work alone and at home. And he ***had to escape a recall to active duty for service***[5] on the Eastern Front.

The Z3 was the first general–purpose digital computer in the world. It was completed in 1943. It employed binary numbers, floating-point arithmetic and a 22-bit wordlength, and it has been estimated that it used around 2000 relays (and eight uniselector switches) and cost the equivalent of between $6000 and $7000. "The most important thing", says Zuse, "seemed to be to keep the frequency absolutely even, so that one cycle equaled one addition". This he achieved using a rotating disc or roller, each revolution defining one operation.

---

[4] *на приватні фірми не було жодних надій*
[5] *доводилось ухилятись від призову з запасу на дійсну військову службу*

As the disc's speed could be varied, so too could the operating speed of the computer. Sparking at the relay contacts was eliminated by making or breaking them before any current flowed, so increasing reliability. Postwar Zuse machines are said to have been "legendary" for their reliability."

Although the Z3 was completed (with the help of friends) it served mainly as an experimental machine and it never went into routine use probably because of the limited capacity of its memory. There are no doubts, however, that it was fully functional, because there are several witnesses to its operation. Though the original Z3 was *blitzed out of existence*[6] a reconstruction was made years later, based on the surviving patents, and is now in the Deutsches Museum in Munich.

The Survivor

Somehow Zuse found time to build other computers as well. The S1 was a non-programmable machine using hard-wired programs. It served in the design of the Henschel flying bomb HS-293, a pilotless aircraft guided by radio from a bomber. It replaced a dozen calculators. An improved design, the S2, was too late for routine service and is the one that Zuse thinks might have been captured by the Russian army. But the big one was the Z4: a full-sized general-purpose computer, the only one to survive the war.

Construction of the Z4 began in 1943, even before the Z3 was finished. For this large machine Zuse returned to his successful mechanical memory design. Whilst this now seems a retrograde step it was the only way he could achieve a large memory (1024 32-bit words) in a reasonable volume.

Work on the computer began in Berlin but Allied bombing *posed an everpresent threat*[7]. "My workshop was damaged several times, and three times during the war we had to move the Z4 around Berlin." As allied bombing increased in 1945, the authorities decided to move Zuse and his new computer out of the capital to Göttingen, 160 miles to the west. There construction was completed and on April 28, 1945, demonstration programs were run for the authorities. "This was the moment for which I had waited for 10 years–when my work finally brought the success I desired." The irony for Zuse was that the machine was immediately dismantled, because the American army was by then just a few miles away.

The odyssey continued as they were ordered to underground works in the Harz mountains where the V1 and V2 weapons were being built. Zuse has described the conditions there as terrible. "We refused to leave the machine there." With great difficulty it was moved to an alpine village just north of the

---

[6] *загинула під час бомбардуваня*

[7] *бомбардування союзників складали постійну загрозу*

Austrian border where it was set up in a barn. There it stayed until 1949 when it was rescued, rebuilt and established in the Technical University in Zürich in 1950. For a time it was the only functional digital computer on the continent.

After the War

Zuse continued to develop his ideas for computers and planned what was probably the first algorithmic computer language. The game of chess served as a test subject.

In 1949 he re-established his own firm which became known as Zuse KG. With contracts initially from Switzerland and then Germany the firm prospered and for many years was second only to IBM in Germany. The Z series continued with relay computers and then fully electronic machines. The last of the relay machines was the ZII ***which became a byword for reliability***[8]. As competition grew, and technology changed, so life got tougher and outside funding was required. This eventually led to the company's being absorbed by Siemens.

Zuse is still a consultant; but even more he is a painter, whose work had been described as "a synthesis of expressionism and surrealism, in brilliant colours". One engineering task that he did take up in the 1980s, however, was to rebuild the ZI from memory – as a museum piece.

Task I

Comment on Zuse’s words ” Necessity was no the mother of inventions, it was laziness and boredom: the desire to rid himself of those tedious calculations.”

Task II

Speak on history and characteristics of Z1.

Task III

Describe other Zuse’s computers.

---

[8] *котра стала уособленням надійности*

RUDOLPH KOMPFNER
(1909-1977)

"There is nothing like a goodly amount of dissatisfaction and unhappiness to bring on invention."

TWTs have been used in a variety of electronic applications and are part of *the farthest flung* [1] human machines, spacecraft, which are becoming mankind's first interstellar ambassadors.

The travelling-wave tube was invented by Kompfner in his spare time. Officially, he was working at the University of Birmingham as part of the war effort in World War II, trying to improve the klystron amplifier for use in radar receivers. It was in the same department that Randall and Boot invented the cavity magnetron. Whilst Kompfner's official work was leading nowhere, his evening hobby was heading for the jackpot. As Kompfner himself wrote, "I must emphasise again that all this work was carried on outside the laboratory; it was, so to speak, my spare-time amusement."

Architect

Kompfner was known as Rudi. "Few who knew him knew him as Kompfner or Dr Kompfner, and none as Rudolph," says J. R. Pierce, the American physicist who worked with him for many years. Rudi was born on the 16th May, 1909 in Vienna, the elder child, and only son, of Bernhard Kompfner and his wife Paula Grotte. Bernhard was an accountant, but also an accomplished musician who composed Viennese songs and waltzes. Rudi inherited a lifetime love of music.

World War I raged whilst Kompfner was a young boy and Vienna was blockaded. *Suffering from malnutrition*[2], he was evacuated by the Red Cross and put on a train to Sweden. His parents, apparently, did not know exactly where he was and it must have been a nightmare for them and for him. World War II was also to have troubles in store, but before that there were happier times. He graduated in 1931 from the Technische Hochschule in Vienna with a degree in

---

[1] *найдалекосяжніші*

[2] *потерпаючи від недоїдання*

engineering (architecture). Two years later, in his mid twenties, he completed his studies of architecture in Vienna.

The 1930s were dangerous times for Jews in Austria, but Kompfner had a cousin in England. Her husband helped him to get to England in 1934 and then found him a job. From 1936 to 1941, Rudi Kompfner was the managing director of Franey's building firm.

By that time, Kompfner's interest had been well and truly awakened in physics, as well as architecture. In fact, it would appear that architecture was never his first choice; it has been dictated by his father. His interest in physics, however, was self-generated and was sparked by the writings of the French physicist Arago, an early 19th century contemporary of Ampere.

One ***oft-repeated*** [3] story of Kompfner's training as an architect is worth one more repetition because it has a lesson for anyone. Kompfner had been told to design a house and he sat and stared at his blank sheet for hours without drawing a stroke. "An infinity of possible solutions to the problem occurred to me, but I could not see why I should single out any particular one by starting with it." A senior arhitect came to help and simply drew a square. When Kompfner objected to the square as an unlikely shape for a house it was changed. When the change was criticised it, too, was changed, and so on. Gradually an acceptable design evolved. "The secret of starting," he had learned, "is to start." "Starting means at least doing something."

Internment

Once in London, Kompfner ***pursued his love of physics***[4] by visiting the Patent Office library in the evenings and reading publications. In 1935 he started to keep notebooks in which he recorded his ideas and two years later he received his first patent for a television pickup device. He tried to market it, but without success. Also in 1935, another love of his life developed when he met Peggy Mason at the Westminster swimming club; Kompfner was a keen swimmer. They married on the 29th April, 1939 and subsequently had two children, a boy and a girl.

One day in June, 1940, Peggy returned home from work to find that her husband had been taken to Brixton police station and ***interned as an enemy alien***[5]. His internment was spent on the Isle of Man where he shared quarters with Wolfgang Fuchs, the mathematician. Apparently, they talked about physics.

---

[3] *часто повторювана*

[4] *плекав свою любов до фізики*

[5] *інтернований як громадянин ворожої держави*

Kompfner's internment was thankfully short. Before he was detained he had sent a paper on magnetrons to the magazine Wireless Engineer, the editor of which had brought the paper to the attention of the Admiralty. Kompfner had meanwhile ***declared himself to be stateless***[6] and friends were petitioning for his freedom. He was duly released in December, 1940, after six months. Then, "I was more or less drafted to the physics department of the University of Birmingham," Kompfner wrote in 1964. It was there, under the guidance of Professor Mark Oliphant, that the Admiralty had set up a secret research group with the task of making a practical centimetre radar system. Kompfner arrived in 1941 and within two years had invented the travelling-wave tube.

Travelling-wave Tube

At Birmingham, Kompfner was assigned to work with researchers P.B. Moon and R.R. Nimmo. "I owe a lot to them," he wrote. They taught him physics and electronics, how to experiment and how to set up theoretical models. He learned well.

His task was to further develop the klystron amplifier and improve its noise figure. He followed the received wisdom of how to do this and "spent two years building klystrons along these lines and getting very discouraged with it in the process". "There is nothing like a goodly amount of dissatisfaction and unhappiness to bring on invention," he has remarked.

Outside work, he began to follow a quite different idea to that of the klystron: he would move the field with the electrons. His notebook for the 6th September 1940 records the idea of making the field move at the same velocity as the electrons. He needed to reduce this velocity and, after discussions with colleagues, the idea of using a helix as a transmission line was born. Kompfner then went to see the acknowledged expert on transmission lines at Birmingham. The expert thought it a poor idea but, when Kompfner tried it, he found that it did work. "I was tactful enough not to go back and tell the expert, but I did not consult him again," said Kompfner. "I might remark that there is no harm in getting expert advice. But don't take it."

The story of the invention of the travelling-wave tube is too complex to describe fully here, and Kompfner himself has given a detailed account elsewhere. Ideas changed, *blind alleys*[7] were followed (six months were wasted down one), the helix was abandoned and then returned to and colleagues pointed out mistakes in his theories.

---

[6] *оголосив себе людиною без громадянства*

[7] *глухі кути*

In August, 1943, the group at Birmingham broke up and half the staff were moved to Los Alamos to work on the atom bomb. With others, Kompfner decided to stay in England where he would now be allowed to work officially on his, now well known, homework. Despite setbacks, progress was made. Then in 1944 the group at Birmingham was dispersed and he was moved to the Clarendon Laboratory at Oxford University.

At Oxford, he was visited by Dr John Pierce from Bell Laboratories who had read some of the secret wartime memoranda which described his work. (Incidentally, the first British publication describing the TWT appeared in Wireless World in 1946.) Back in America, Pierce was able to develop the theory of the tube, but it was Kompfner who, virtually ***single handedly***[8], conceived the idea and built working travelling-wave tubes. They were the first of a family of devices which came to be used in radar and space communications.

After the war ended, Kompfner became a ***British subject***[9] (1947) and in 1951 he received a ***D.Phil*** [10], in physics from Oxford. Meanwhile, Pierce had persuaded him to move to Bell Laboratories in the USA. After a long wait for a visa he joined Bell on the 27th December 1951 and continued his research on microwave tubes. In 1955 he became Director of Electronics Research.. By 1962 he was Associate Executive Director of Research and Communication Sciences Division and his influence was felt on research programmes as varied as masers, lasers, superconducting magnets and optical communications. Also, he had taken out American citizenship.

Satellites

In 1958 Kompfner and Pierce became interested in the idea of communication satellites. They wrote a paper exploring the possibilities for such satellites and Rudi's team designed the first one: Echo I. It was launched on the 12th August 1960. Pierce says the work was carried out under Kompfner's "inspiration and direction". Kompfner was also deeply involved with Telstar (1962), the first communications satellite to carry live television across the Atlantic.

Kompfner retired from Bell Labs in July 1973 and thereafter split his time between Stanford University (where he spent the winters) and All Souls College, Oxford (where he enjoyed the summers). At Oxford, his work centred on the use of fine lasers in scanning optical microscopes, whereas at Stanford he turned his attention to acoustical as well as optical microscopes. He left behind

---

[8] *одноосібно*

[9] *британський підданий*

[10] *ступінь доктора філософії*

him a reputation as a generous and warm-hearted man who readily gave time and sound advice to his students. "No-one ever found him too busy to listen," wrote Pierce. No matter how many projects he had in hand, he always found time to discuss a new one.

Pierce has recounted many anecdotes about Kompfner. At one time Rudi used to conduct seminars for freshmen at his home and in his garage. He and the students suggested projects and one was chosen by vote. One year, he was very disappointed that his own favourite lost by one vote. It was to build a very small swimming pool in which one could swim long distances against a current without moving with respect to the pool. It still sounds like a great idea.

Another of his little inventions was a cat door which would ***prevent the entry of raccoons***[11] but still alow the cat in. An abandoned baby raccoon became a pet and he built it a house with an aerial tramway to take it food in winter. There seems to have been a large number of such diversions, including four-legged tables and chairs which would sit evenly on an uneven floor. Another, which Pierce describes as "unqualified success" was a mat or coaster to allow the port and madeira to slide easily along the table.

His short book describing the invention of the travelling-wave tube reveals a good-humoured modesty and the ability to joke and laugh at oneself. In his closing remarks, he stated that if he could live through it all again "I would try not to be so stupid". His mathematics was inadequate, he did not know enough physics, his soldering and glass-blowing were sloppy, he says. “I wanted to get jobs done quickly and therefore did them badly and often had to do them all over again. I found that ***it pays to take pains***[12].”

A professional lesson he learned was ***not to get side-tracked***[13]; doing so cost him far too much time. Yet on one occasion he resisted being side-tracked and missed discovering ferromagnetic resonance; a colleague ***followed up the lead***[14] and made the discovery instead. On two occasions he took expert advice only to be misled into not following through his own convictions. Finally, he remarked, a research worker must have imagination. His travelling-wave tube worked over the entire range of his signal source (60MHz). "That was fine with me," he says. "I should have had more imagination here," he added. "I little realised that I had a device that had a potential of several octaves. Pierce did."

Kompfner's life was not all work, however. As we have seen, he loved swimming and music and he was also a good skier. He met his future wife at a swimming club where he not only swam but played water polo as well. After he suffered a severe heart attack in December 1967, swimming and long walks

---

[11] *не пропускати єнотів*

[12] *докладені зусилля не минають марно*

[13] *не дозволити збити себе зі шляху*

[14] *дотримався цього напрямку*

were part of his ***recuperation process***[15]. His love of music extended to playing as well as listening. Though he never mastered reading music he could play the piano well enough to accompany orchestral music from a record or the radio.

He was also something of a romantic, loving the ceremonial side of life at Oxford and delighting in having crossed the Atlantic in Concorde. Presumably he also enjoyed the collection of scientific medals and awards and honorary degrees he received. The latter came from both Oxford and Vienna, and the medals flowed from both sides of the Atlantic.

Late in 1977, Rudi suffered another heart attack. He was rushed from his home to Stanford hospital in California. Although he started to make a sustained recovery, ***it was not to be***[16] and he died on the 3rd December, 1977. He left a legacy of engineering achievements - and research scientists he had trained to listen to expert advice, but not necessarily take it.

Task I

Explain the words:"The secret of starting is to start. Starting means at least doing something".

Task II

Tell what made Kompfner write the following "I might remark that there is no harm in getting expert advice. But don't take it".

Task III

Prove that Kompfner was really a generous and warm-hearted man.

Task IV

Speak on Kompfner's scientific interests, researches and his most important invention.

[15] *процес відновлення сил*

[16] *цьому не судилося статися*

ALAN MATHISON TURING (1912-1954):

the solitary genius who wanted to build a brain.

A long-distance runner and cyclist, Turing has been described as a ***self-reliant misfit*** [1] who ran against the social norms of his time. He was a homosexual at a time when this was not only illegal but was deemed to be a security risk. He paid the price of being found out, if that is the right expression, for Turing was deeply honest to himself and never concealed his homosexuality.

In his trial at Knutsford in 1952 he was described as "a national asset" and "one of the most profound and original mathematical minds of his generation". It was true, but he was still found guilty and ***was given probation*** [2] on condition that he accepted hormone treatment - in effect, chemical castration. According to his biographer, Andrew Hodges, Turing rode the storm. But a little over two years later, on June 7, 1954, he doused an apple with cyanide and killed himself.

Turing's claim to fame is as one of the fathers of electronic computers. His 1936 paper "On Computable Numbers" is the classic in its field. He dreamed of making a "brain", his Universal Machine. His influence was felt by all the early pioneers of computers from von Neumann in the USA to the teams that built the first post-war British computers. The National Physical Laboratory's ACE computer was his concept of a Universal Machine. Today his memorial is The Turing Institute in Glasgow, dedicated to research and training in artificial intelligence.

Childhood

They say the child is the father of the man and that seems to have been true of Alan Mathison Turing. For long periods he was separated from his parents, especially his father. Later in life he was a confirmed solitary, one with whom many found ***it difficult to get along*** [3]. Turing was born a Londoner, in Paddington, on June 23,1912. His mother, formerly Ethel Stoney, was a distant relative of George Johnstone Stoney, the Irish physicist who gave the electron its name. Alan's father, John Mathison Turing, served the Empire through the Indian Civil Service. For the first decade of his life Alan and his elder brother,

---

[1] *незалежний та непристосований до життя*
[2] *засудили умовно*
[3] *тяжко знайти спільну мову*

another John, stayed in England whilst their parents lived in India, except for their often long visits to England.

When Alan was about 12 years old, his father resigned from the Indian Civil Service and settled for an early retirement in France, at Dinard in Brittany. School French lessons suddenly acquired a purpose. So far he had been educated by his mother, at a private day school, and then at a preparatory school near Tunbridge Wells. He was particularly interested in maps and formulae.

For public school it was decided that he should go to Sherborne in Dorset. When he arrived at Southampton from France in 1926 there were no trains because of the General Strike. He set out on his bicycle and arrived on the second day. Later in life he rejected an offer of an official car in favour of his bike. Cycling and running were to be his great loves.

At Sherborne his ability at mathematics developed, as did his passion for science. He took an avid interest in astronomy to which he was introduced by a fellow student with whom he developed an intense, but doomed, friendship. Tuberculosis killed his friend in 1930. But Sherborne fulfilled its purpose and in 1931 he progressed to King's College, Cambridge - Britain's Mecca for a mathematician. Turing gained his degree in mathematics with distinction in 1934 and was awarded a research studentship of £200. This was followed in 1935, at the tender age of 22, ***by a coveted Fellowship***[4] at £300. At last the had the academic freedom to pursue his ideas.

Computable Numbers

Almost simultaneous with his election to a Fellowship was the publication of his first paper, a slight improvement on earlier work by the master mathematician John von Neumann. As it happened, von Neumann arrived in Cambridge shortly afterwards to spend the summer away from his home university of Princeton in America. Turing almost certainly attended his course of lectures; but his main problem now lay in choosing his field of research.

His interest in mathematical logic had been aroused by Newman's lectures in 1935. These included problems posed at the end of the 19th century by the German mathematician David Hilbert. One of these remained unsolved and in 1928 Hilbert himself proposed the problem - "to find a method for deciding whether or not a given formula is a logical consequence of some other given formulae".

Turing solved the remaining problem and went on to postulate a logical machine that could solve any problem of logic provided it was given a suitable

[4] *жадана стипендія*

set of instructions. *This ran counter to the prevalent belief* [5] that different calculating machines were needed for different mathematical problems. Turing showed that it was possible logically, if not physically, to have one machine to do all. The concept was soon to be known as a "Turing machine". Within ten years such machines had "descended from the sky to the firm ground of information technology".

Turing's paper was called "On Computable Numbers" for short. Alan Turing had solved a major problem to mathematics with a fresh, direct and "simple" approach. Though it would take a little time to establish his reputation, that reputation was now assured.

He was not the only one to tackle the problem, however, for it had just been solved by an established American mathematician, Alonzo Church, at Princeton University. Though Turing's approach was radically different from Church's, the discovery of Church's work must have been a painful experience. Max Newman wrote to Church asking for help in getting Turing to Princeton so that he could be at the centre of things for a time and "*so that he should not develop into a confirmed solitary*"[6]. Alan Turing duly sailed for America on September 23, 1936.

Princeton University had acquired the status of being the place for a mathematician to be. The Institute for Advanced Study had been set up there in 1932 and the double institute, as it could be viewed, attracted leading scientists; Einstein was there, for example.

As with many great ideas when they are new, "Computable Numbers" did not cause a sensation though Church's review of it coined the expression "Turing machine". Turing described his work at a poorly-attended seminar and the paper was published whilst he was at Princeton. He was offered a second year in America, accepted, and submitted for a Ph.D. after a brief return to Cambridge.

Bletchley Park

By the time he received his Ph.D. in June 1938, a number of things had happened which set his course for the next few years. Von Neumann had become aware of, and admired, "Computable Numbers" and had offered him a research assistantship at the Institute of Advanced Study. Turing had built an electronic multiplier and developed his earlier interest in codes and ciphers. And Hitler's war was threatening.

[5] *це протирічило поширеному переконанню*

[6] *щоб він не перетворився на затятого самітника*

Bravely he turned down von Neumann's offer and returned to Cambridge in the hope that "Hitler will not have invaded England before I come back". He arrived at Southampton on July 18 with his electronic multiplier wrapped in brown paper. Within weeks he was on a course at the Government Code and Cipher School, one of sixty or so ***people earmarked for recruitment if war should break out***[7]. The day after war was declared he reported to Bletchley Park in Buckinghamshire, the home of the Code and Cipher School, and set to work on the German ciphers. He was ideal for the job.

The British effort at breaking the German codes initially depended on work done in Poland. It is a complex story and one that has already been described, for example by Hodges in his biography of Turing. The Germans used a machine called Enigma to encipher their messages but the Poles had, in effect, obtained a logical copy of the basic machine. To break the cipher they had built other machines which, because of the ticking noises they made, came to be known as bombs. The Germans increased the complexity of Enigma and rendered the Polish bombs ineffective.

The Bletchley team, especially Alan Turing and Gordon Welchman, brought new ideas to the problem and new bombs were designed and built. According to Hodges they were "impressive and rather beautiful machines, making noises like that of a thousand knitting needles". There began what Hodges has termed the "relay race" as ***each side sought to stay one step ahead of the other***[8] but with the Germans never believing that Enigma had been broken, only that spies were at work.

When America came into the war Turing ***was dispatched on the Queen Elizabeth to brief them***[9] on the cipher breaking work.. During his visit he spent a couple of months at Bell Laboratories, meeting Nyquist and Claude Shannon amongst others. Meanwhile Max Newman had arrived at Bletchley and had started work on electronic counting machines which became known as the Robinsons. These were followed by a series of electronic computers, each known as Colossus. Turing played little, if any, part. He moved on to a new pet project on speech encipherment which reduced speech to meaningless noise and then recovered it. He designed the machine, built it, called it Delilah - and it worked.

By the end of the war Turing had returned to his pre-war ideas, developed now into a Universal Turing Machine. Strengthened by his experiences with electronics he faced the question of whether this could now become something more than an intellectual concept. Could it become a real machine? He wanted to build an electronic "brain", essentially what we would now recognize as an automatic digital computer with internal program storage.

---

[7] *резервістів на випадок, якщо вибухне війна*

[8] *кожна зі сторін прагнула на крок випереджати іншу*

[9] *відрядили на кораблі"Королева Єлизавета", щоб поінформувати їх*

Of course he was now not alone in thinking such thoughts, for in America the ENIAC was now built and plans had been published for another machine to be called EDVAC. Such news probably influenced the National Physical Laboratory in its plan to build a national computer with Turing's help: a Universal Turing Machine. It was to be known as the Automatic Computing Engine or ACE. Turing's design used binary arithmetic and was to have the simplest possible hardware based on the logical functions And, Or and Not, and a large and fast memory. The rest would be performed by the sets of instructions, the programs. As a design it was unique and ***owed little to the other pioneer computers***[10].

Funds were allocated in 1946 to begin work on a small machine, later known a Pilot ACE. Internal politics and delays did not augur well, however, for the urgency of wartime had not carried forward into peace. Turing left before even the Pilot ACE was completed. He ***was on sabbatical***[11] at Cambridge when the new computer team at Manchester University offered him a position. He accepted in May 1948 and joined them in the autumn. The Manchester prototype ran its first program on June 21, 1948, and in February 1951 the first of the Ferranti Mkl computers was delivered, based on the university machine. Pilot ACE (which is now in the Science Museum, London) ran its first program on May 10, 1950, and the full ACE was not completed until late in 1957. At Manchester, Turing came to spend much of his time in developing programming techniques, even doing manual arithmetic in base 32.

Turing was always a loner. Many found him difficult to get on with. He received the OBE in June 1946 as official thanks for his wartime work. It came through the post. And in March 1951 he was elected a Fellow of the Royal Society, probably a more fitting tribute. Glasgow's Turing Institute opened in 1984.

Task I

Speak on the history of development of the first British and American computers.

Task II

Describe features and functions of Universal Turing Machine.

---

[10] *мало чим завдячував іншим першим комп'ютерам*

[11] *був у науковій відпустці*

JACK KILBY

"I had the fortunate experience of being the first person with the right idea and the right resources available at the right time in history…I'm grateful to the innovative thinkers who came before me, and I admire the innovators who have followed."

Radios. Televisions. Automobiles. Alarm clocks. Microwave ovens. Cell phones. Watches.

You name it; if it uses electricity, it probably packs a microprocessor — a tiny "chip" that contains complex electronic circuitry in a compact package.

The latest computers feature processor chips that contain up to 55 million transistors. They can process more than 1.5 million instructions per second.

But it all started with a *crude-looking device*[1]cooked up in a North Dallas laboratory when Dwight Eisenhower was president, just months after the Soviet Union launched Sputnik, the world's first man-made satellite.

For almost 50 years after the turn of the 20th century, the electronics industry had been dominated by vacuum tube technology. But vacuum tubes had inherent limitations. They were fragile, bulky, unreliable, power hungry, and produced considerable heat.

It wasn't until 1947, with the invention of the transistor by Bell Telephone Laboratories, that the vacuum tube problem was solved. Transistors were miniature in comparison, more reliable, longer lasting, produced less heat, and consumed less power. The transistor stimulated engineers to design ever more complex electronic circuits and equipment containing hundreds or thousands of discrete components such as transistors, diodes, rectifiers and capacitors. But the problem was that these components still had to be interconnected to form electronic circuits, and hand-soldering thousands of components to thousands of bits of wire was expensive and time-consuming. It was also unreliable; every soldered joint was a potential source of trouble. The challenge was to find cost-effective, reliable ways of producing these components and interconnecting them.

The Begining

Born in Jefferson City, Missouri in 1923 Jack St Clair Kilby grew up in Great Bend, Kansas. His interest in electronics can be traced to his high school

[1] *прилад, що виглядав незакінченим*

days when his father was running a small power company scattered across the western part of Kansas. One year, a big ice storm took down all the telephone and many of the power lines, so Jack and his father began to work with amateur radio operators to provide some communications.

Kilby entered the University of Illinois Electrical Engineering Department in the fall of 1941. He completed his first two years before entering the Army. After the war, he returned to campus in January 1946; he earned his bachelor's degree in electrical engineering in 1947. He began his career with the Centralab Division of Globe Union Inc. in Milwaukee, developing ceramic-base, ***silk-screen circuits***[2] for consumer electronic products. He worked in the area of miniaturization, looking for ways to develop smaller and more effective electrical components.

In 1952, Centralab, which had acquired a license for manufacturing transistors from Bell Laboratories, sent Kilby to a transistor symposium at Bell Labs' headquarters in Murray Hill, New Jersey. There, Kilby saw first-hand the ground-breaking technology that was invented by Bell Labs scientists John Bardeen, Walter Brattain and William Shockley in 1947. When he returned to Centralab, he began working on germanium transistors that could be used in hearing aids manufactured by Centralab.

Although germanium was originally the material of choice for transistors, it proved not to be the element that would make the best integrated circuits. In 1954, scientists working on transistor research at Bell Labs found silicon to be a better choice. Not only was it a superior semiconductive element, it was also more available than germanium, thereby reducing the costs of components manufactured.

Kilby agreed with the Bell Labs scientists and embraced silicon as well as the wave of the future. However, Centralab didn't seem likely to change from germanium-based components any time soon. Although Kilby was pleased with his work at Centralab, he realized he wanted to be with a company that was working on the leading edge of the coming technology.

Kilby found what he was looking for at Texas Instruments (TI), which also had acquired a Bell Labs license for manufacturing transistors and had several military contracts for developing silicon transistors. He joined Texas Instruments in 1958, and was employed by them until he retired in the early 1970s.

The Chip that Changed the World

When Kilby arrived at TI in the summer of 1958, he found the place virtually deserted. He had been hired to work in the area of miniaturization, and he

[2] *схеми трафаретного друку*

had the laboratory in that area largely to himself, because ***having not accrued enough vacation time***[3]***,*** he stayed back at the lab when many of his colleagues were taking their summer vacations.

Kilby's challenge was to work on connecting miniaturized components–what TI called the Micro-Module. The company had already developed a prototype that ran wires through a stack of miniature components that were stacked vertically; however, Kilby believed a horizontal layout would be more efficient. With no one else around, he decided to try things his way, hoping he could possibly come up with an alternative to the Micro-Module before everyone came back from vacation.

By manufacturing all pieces together, Kilby believed, there would be no need to wire anything together since all the connections would go inside the chip. And, by eliminating the wiring and the connections, many components could be included on one chip. On July 24, 1958, Kilby wrote in his lab notebook what would come to be known as The Monolithic Idea. It stated that circuit elements such as resistors, capacitors, distributed capacitors and transistors, if all made of the same material, could be included in a single chip.

By September, he was ready to demonstrate a working integrated circuit built on a piece of semiconductor material half the size of a paper clip. Several executives, including former TI Chairman Mark Shepherd, gathered for the event on September 12, 1958. What they saw was a sliver of germanium, with protruding wires, glued to a glass slide. It was a rough device, but when Kilby pressed the switch, an unending sine curve undulated across the oscilloscope screen. His invention worked — he had solved the problem.

Kilby had made a big breakthrough. But while the U.S. Air Force showed some interest in TI's integrated circuit, industry reacted skeptically. Indeed the IC and its relative merits "***provided much of the entertainment*** [4] at major technical meetings over the next few years," Kilby wrote.

In February 1959, Kilby and TI filed a patent for the "Miniaturized Electronic Circuit." The following month, TI introduced the integrated circuit at the Institute of Radio Engineers Show, offering the devices for sale at $450 each. Just four months later, Robert Noyce of Fairchild Semiconductor filed a patent for a semiconductor that was remarkably similar to Kilby's, but based on a different manufacturing process.

This set off a long battle between the two companies over ownership of the integrated circuit concept. In 1962, TI ***filed a lawsuit for patent interference***[5], which wasn't settled until 1969 when the U.S. Court of Customs and Patent Appeals ruled in favor of Noyce's technology. This ruling would prove to have little effect on the blossoming semiconductor industry, which ***would end up paying***

[3] *ще не заробивши відпустки*
[4] *добряче розважали*
[5] *подала судовий позов за порушення патентного права*

licensing fees to both [6] companies for their contributions to the technology - TI for the basic integrated circuit structure and Fairchild for the manufacturing process and interconnection techniques.

Although still the subject of some debate even today, most in the scientific and engineering community agree that Kilby and Noyce deserve joint credit for inventing the integrated circuit. Some distinction is made between the contributions of both men – Kilby often receives credit for building the first working integrated circuit, and Noyce is credited with improving it for industrial purposes. Both men were awarded the National Medal of Science and both were inducted into the National Inventor's Hall of Fame.

Besides being most noted for his work on the integrated circuit, Kilby holds more than 50 patents for his work in this area. He also is the inventor of the miniature calculator, which debuted in 1965. He left TI in 1970 to become a freelance inventor, and was a Distinguished Professor of Electrical Engineering at Texas University from 1978 through 1985.

Impact

The impact of Kilby's tiny chip has been far-reaching. Many of the electronics products of today could not have been developed without it. The chip virtually created the modern computer industry, transforming yesterday's room-size machines into today's array of mainframes, minicomputers and personal computers. The chip restructured communications, *fostering a host of new ways*[7] for instant exchanges of information between people, businesses and nations.

For Texas Instruments, the integrated circuit has played a pivotal role. Over the years, the company has produced billions of chips. But the integrated circuit has done more than help grow TI. It has enabled an entire industry to grow. Since 1961, the worldwide electronics market has grown from $29 billion to nearly $1,150 billion. Projections indicate that it will become the world's single largest industry.

This growth will depend on the continued development of newer and better technologies - like those being developed at TI's new research and development center in Dallas.

Toward the Future

With continuing advances in semiconductors, you can look forward to more new amazing encounters with electronic equipment. Imagine calling your day care

[6] *закінчиться ліцензійними виплатами обом*
[7] *сприяючи розвиткові безлічі нових шляхів*

center to check on your child, and seeing her smiling face in the screen on your cell phone. Imaging turning on the oven from your car phone as you pull out of the parking lot at the end of the day. When you get home, dinner will be nearly done. Imagine setting your car on autopilot, and looking over notes for your next day's meeting on your comming home. Imagine you want to see a movie. You order it from the web, and within a matter of seconds it's ready to view on your television at home.

It sounds like science fiction, but ***new breakthroughs are only a short stride away***[8], with the help of technologies being developed at the Kilby Center at Texas Instruments.

Mr. Kilby has been awarded the National Medal of Science and the National Medal of Technology. He was inducted into the National Inventors' Hall of Fame and Texas Instruments named a new $150 million research center for him. The people who still work in the building where the integrated circuit was born are mindful of the invention, but even more aware of the person who invented it.

But the ultimate honor came in 2000, when Jack Kilby received the Nobel Prize in Physics. He was typically modest in accepting the prestigious award. Kilby shares the prize with Zhores Alferov and Herbert Kroemer, who invented and developed fast opto- and microelectronic components based on layered semiconductor heterostructures. Alferov is a researcher at the A.F. Ioffe Physico-Technical Institute in St. Petersburg, Russia. Kroemer is a German-born researcher at the University of California at Santa Barbara. All three inventors' work has laid a stable foundation for modern information technology.

Jack Kilby is still a consultant for TI and lives in Dallas, Texas.

Task I

Retell the history of IC invention.

Task II

Discuss the influence of microchips on current development of science and engineering.

---

[8] *нові прориви зовсім близько*

ROBERT NOYCE

(1927-1990)

A noted visionary and natural leader, Robert Noyce helped to create a new industry when he developed the technology that would eventually become the microchip.

Starting up

Robert Noyce, the son of an Iowa minister, showed an early love of tinkering and a fascination for discovering how things work, which he had *ample opportunity to indulge as he tore down and rebuilt old Model Ts* [1] and discarded gasoline-powered washing machines that he found in the small Iowa towns in which he grew up. The hours Noyce spent unlocking the secrets of these machines, coupled with his innate good nature and easy manner, gave him a patient, *down-to-earth leadership style*[2] that would become a hallmark of his career.

Noyce's passion for mechanics deepened when he enrolled at Grinnell College in 1946. His goal was a degree in physics, but he spent equal time in engineering classes, where he was introduced to the solid-state transistor, invented in 1947 by a team of scientists headed up by Walter Brattain and William Shockley at Bell Telephone Laboratories in New York. His fascination with the new technology and its potential fueled a lifelong interest in semiconductor theory.

Following graduation from Grinnell, Noyce moved to Boston to pursue a Ph.D. in physical electronics at the Massachusetts Institute of Technology. After receiving his degree in 1953, he went to work for Philadelphia-based Philco, a radio manufacturer that was assembling a team of scientists to work in its transistor division.

At Bell Labs

Noyce left Philco in 1955 to join a team of scientists that William Shockley had gathered to work at his new venture in his former home state of California. Shockley, who would later win the Nobel Prize for his role in the discovery of the transistor, had left Bell Labs in 1954 to pursue his own theories

---

[1] *плекати яку він мав широкі можливості, коли розбирав та переробляв старі «Форди»*

[2] *практичний стиль керівництва*

about the transistor, establishing Shockley Semiconductor Laboratories in Palo Alto.

Shockley's reputation enabled him to hire a corps of talented scientists; however, his rigid adherence to germanium-based technology when the rest of the industry was shifting to silicon frustrated his recruits, who also began to realize that while Shockley's reputation would most likely continue to build, they were not necessarily guaranteed the same recognition or success. After several years a group of the more ambitious scientists, frustrated over their deteriorating relationship with Shockley, left the company to pursue semiconductor research using their own theories. Although Noyce was tempted to join the "traitors," as Shockley referred to them, he elected *to stay behind for the time being*[3].

The seven former Shockley employees drew up a business plan for their new company and approached East Coast investors, finding a sympathetic ear in the investment firm of Hayden Stone, which was involved with a company called Fairchild Camera and Instrument. Quite by chance, Fairchild's president, eager to enter the new solid-state transistor world, had asked for assistance from the investment company at the same time the Shockley defectors arrived with their business plan. Fairchild quickly showed interest, but withheld a final commitment until the group could find a leader with strong management skills to oversee their work and act as a spokesman for the fledgling company.

Noyce, with his easy leadership style and effortless way of taking charge, coupled with his experience in transistor and semiconductor research, was the obvious choice. By this time, he had reached the same conclusion as his former co-workers, and was more than eager to join them. With financing now secured, Fairchild Semiconductor was born in Mountain View, just a few miles away from Palo Alto in Santa Clara County. What happened next would transform the sleepy orchards and misty valleys of the area into today's Silicon Valley.

Founding Fairchild Semiconductor

Fairchild began in business by making silicon transistors, which at the time had to be wired together by hand after they were produced. It was a cumbersome, laborious process, and it soon became clear to Fairchild's founders that the commercial success of their venture rested on the development of a better production method. During the startup phase at Fairchild Semiconductor there had been no sense of bosses and employees. There had been only a common sense of struggle out on a frontier. Everyone *had internalized the goals*

---

[3] *поки залишитись*

of the venture[4]. They didn't need orders from superiors. Besides, everyone had been so young! Noyce, the administrator or chief coordinator or whatever he should be called, had been just about the oldest person on the premises, and he had been barely 30. And now, in the early 1960s, thanks to his athletic build and his dark brown hair, he still looked very young.

As Fairchild expanded, Noyce didn't even bother trying to find "experienced management personnel." Out here in California, in the semiconductor industry, they didn't exist. Instead, he recruited engineers right out of colleges and graduate schools and gave them major responsibilities. There was no "staff," no "top management" other than the eight partners themselves.

Noyce held weekly meetings of people from all parts of the operation, and whatever had to be worked out was worked out right there in the room. Noyce wanted them all to keep internalizing the company's goals and to provide their own motivations, just as they had during the start-up phase. If they did that, they would have the capacity to make their own decisions.

The young engineers who came to work for Fairchild could scarcely believe how much responsibility was suddenly thrust upon them. Some 24-year-old just out of graduate school would find himself in charge of a major project with no one looking over his shoulder. A problem would come up, and he couldn't stand it, and he would go to Noyce and ask him what to do. And Noyce would lower his head, turn on his 100-ampere eyes, listen, and say: "Look, here are your guidelines. You've got to consider A, you've got to consider B, and you've got to consider C." Then he would turn on the Gary Cooper smile: "But if you think I'm going to make your decision for you, you're mistaken."

IC Development

Noyce, in his capacity as director of research and development, joined Fairchild co-founder Gordon Moore in investigating methods of connecting transistors that would eliminate after-production wiring. After a time, they developed a theory that seemed plausible, based on the idea of combining transistors in a solid block of silicon. Noyce began making notes in his lab notebook, ***unaware that a similar theory had already been arrived at*** [5] the summer before in the laboratories of Texas Instruments, where a young scientist named Jack Kilby had spent months wrestling with the same problem.

Texas Instruments would publicly unveil Kilby’s discovery, now called the integrated circuit, at the Institute of Radio Engineers Show in early 1959. This accelerated the efforts at Fairchild Semiconductor, which were now focused on making the connections between the tiny transistors and components

---

[4] *глибоко усвідомлював завдання фірми*

[5] *не знаючи, що подібна теорія вже виникла*

an integral part of the manufacturing process itself. Jean Hoerni, one of Fairchild's original founders, came up with a workable method when he developed the "planar" process. This process, which uses oxidation and heat diffusion to form a smooth insulating layer on the surface of a silicon chip, allowed the embedding of insulated layers of transistors and other elements in silicon. By using the insulation afforded by the planar process, each layer could now be isolated electrically, which eliminated the need to cut apart the layers and wire them back together as had been necessary in the past.

Fairchild Semiconductor filed a patent for a semiconductor integrated circuit based on the planar process on July 30, 1959, *touching off a decade-long legal battle*[6] between Fairchild and Texas Instruments, which previously had filed a similar patent based on Kilby's technology. Eventually, the U.S. Court of Customs and Patent Appeals upheld Noyce's claims on interconnection techniques but gave Kilby and Texas Instruments credit for building the first working integrated circuit.

By 1968, Fairchild Semiconductor, now one of the cornerstones of the semiconductor industry, had become a large company with many divisions. Its discoveries had made its founders wealthy men, and many of them had left the parent company to start businesses of their own. Noyce, noting the success of these young, energetic companies, longed to do it all over again. In 1968, he and Gordon Moore left Fairchild Semiconductor to form a new company that would specialize in developing integrated circuits for the computer industry.

Intel

They called their new company Integrated Electronics, which was quickly shortened to Intel. Although the profits in building silicon transistors were hard to resist, Noyce and his associates decided to take an entirely different tack, instead focusing on developing semiconductor memories that could be used to replace the magnetic core memory systems in older computers.

In short time, the small team of scientists at Intel developed a microchip that could store the ones and zeroes of computer language, introducing its first random access computer memory chip (RAM) in 1970. From there, it was only a matter of time before Intel's researchers figured out the way to contain the entire workings of a computer on one chip, creating the first microprocessor, or microchip. Its creation *set off a veritable whirlwind of*[7] developmental activity as semiconductor companies including Texas Instruments, Motorola, Advanced Micro Devices and others rushed to bring their own versions to market.

---

[6] *спричинивши десятирічну юридичну битву*

[7] *викликало справжній буревій*

As much a futurist as entrepreneur and inventor, Noyce would step aside from day-to-day management of Intel in 1978 to become chairman of the Semiconductor Industry Association, an association started by a group of Silicon Valley executives to address industry-wide concerns that included the growing pressure put on U.S. semiconductor companies by overseas manufacturers, especially those in the Pacific Rim and Asia. In 1988, he became president of Sematech, a joint industry-government research consortium designed to help develop new manufacturing technologies for American chip makers. He would become an ***ardent lobbyist***[8] on behalf of the U.S. semiconductor industry.

Noyce was working to prevent the acquisition of a Silicon Valley materials supplier by a Japanese concern when he died unexpectedly of a heart attack in July 1990 at his home in Austin, Texas. He was 62 years old.

Task I

Speak on Noyce's leadership style.

Task II

Describe the role of Robert Noyce in the development of semiconductor industry.

Task III

Tell about Noyce's role in the development of integrated circuits manufacturing techniques.

HERBERT KROEMER

" If in discussing a semiconductor problem, you cannot draw an energy band diagram, then you don't know what you are talking about."

An unusual condition was imposed on Herbert Kroemer at the start of his research career 50 years ago. He was not allowed to touch anything in his

[8] *палкий захисник*

workplace, the Telecommunications Laboratory of the German Postal Service. The fear was that this recent graduate in theoretical physics would break something. *Far from constraining him, the restriction expanded his horizons*[1].

With just pencil and paper, he began sketching out theories *that would resonate across the entire world*[2] of semiconductor science. And that work would culminate in a Nobel Prize in Physics in 2000 and IEEE Medal of Honor in 2002, the latter for "contributions to high-frequency transistors and hot-electron devices, especially heterostructure devices from heterostructure bipolar transistors to lasers, and their molecular beam epitaxy technology."

While his theories led to products that earned their manufacturers billions of dollars, none of the profits came to Kroemer. "That really doesn't bug me," he says, sitting in his small and modestly decorated office on the Santa Barbara campus of the University of California, where he is now professor of electrical and computer engineering and materials.

IEEE Fellow Kroemer never tried to develop applications of his work - or even predict them. He told *IEEE Spectrum,* “"The principal applications of any sufficiently new and innovative technology always have been and will continue to be applications created by that new technology. " So he *doesn't begrudge others the fruits of his ideas*[3].

"I've always called myself an opportunist," he says. "This is supposed to be a derogatory term, but I'm not one bit ashamed of accepting opportunities. In the scientific sense, I was an opportunist who was looking for challenging problems."

Too Many Lists

In high school in Germany, Kroemer played around with chemistry experiments but soon turned to physics. "I liked the beautiful logic of a structure with a relatively small number of fundamental principles from which you could draw far-reaching conclusions," he says. A university chemistry course that required memorization of lists and lists of chemical reactions destroyed any remaining interest in that science.

He entered the University of Jena in East Germany in 1947, then left for West Germany the next year during the Berlin airlift and was accepted at the University of Gottingen. Four years later he received his Ph.D. for a theoretical dissertation on germanium transistors that discussed electron transport in high electrical fields. It broke little new ground, and he takes no particular pride in it.

---

[1] *зовсім не стримуючи його, це обмеження розширило його горизонти*
[2] *відгукнеться по усьому світі*
[3] *не шкода, щоб інші скористалися з його ідей*

He explained some experiments, he says, but the explanation later proved completely wrong.

Postal Service

In 1952, when Kroemer received his Ph.D., an academic career was out of the question. The *lines of succession*[4] at existing German universities were long, and no new ones were being established. So he joined the Telecommunications Research Laboratory of the German Postal Service in Darmstadt.

The postal service ran the telephone system and had a small semiconductor research group - some 10 scientists - in its telecommunications laboratory. That group hired Kroemer to answer any theoretical questions that arose, to give talks on any subject he thought relevant - and to keep his hands off the research equipment.

"I enjoyed this thoroughly," he recalls. For one, he had liked the role of teacher since high school, when his physics teacher asked him to prepare and deliver a lecture to the class. For another, *being at the researchers' beck and call*[5] presented him with a wide variety of problems in diverse subjects.

In solving one of those problems, he went against the conventional wisdom of the time. Researchers were developing pn junctions of indium and germanium. They did this by depositing a layer of indium on a layer of germanium, then heating the structure to form the pn junction. Kroemer was trying to understand how exactly the junction formed.

Obviously the molten indium dissolved some of the germanium, and the belief was that it *diffused* into the germanium beyond the layer in which the germanium dissolved. But Kroemer concluded that the process was one of recrystallization - the heated indium dissolves some of the germanium, and then upon cooling the germanium precipitates out and recrystallizes, incorporating some of the indium atoms, which replace some of the germanium atoms in the lattice.

What he didn't know was that researchers in the United States, at General Electric Co. and RCA Corp., had simultaneously reached the same conclusion.

But what he did know was that to be at the research forefront, he needed to leave the German Postal Service and get to the United States. He started looking for a way to get there.

---

[4] *черги на посади*

[5] *перебування на побігеньках*

Researchers from other countries occasionally visited the lab in which he worked, curious about this small semiconductor research group. In 1953 one visitor was William Shockley, then at Bell Telephone Laboratories. "I spent about two hours with him," Kroemer said. "We were having a marvelous time. I told him about the work that I'd done for my Ph.D. dissertation, and about some of my ideas of how to make transistors fast by putting an electric field into the base. He seemed intrigued by that."

Kroemer asked him about coming to Bell Labs, but Shockley, as an official visitor, told Kroemer that he would have to go through official channels, starting with informing Postal Service management of his intentions to apply for a job in the United States. The young researcher was so grateful for the job he had at the Postal Service that he ***was "terribly squeamish***[6] about telling my management that I wanted to leave."

Later in 1953, the Darmstadt lab had another U.S. visitor: Ed Herold from RCA. Kroemer asked him whether RCA was working on npn transistors (back then pnp transistors dominated). Herold was careful in his responses; but Kroemer guessed out loud what the RCA researchers were doing, what alloys they were using (lead-antimony), the percentage of the antimony, and the alloy temperatures. His guesses proved quite dose to RCA's experiments, and the impressed Herold didn't hesitate to offer him a job. (All the same, it took a year for Kroemer to obtain a visa, even with RCA's help.)

At RCA in Princeton, N.J., Kroemer did theoretical research on an impurity diffusion process for building transistors. In the diffusion process, the doping of the base region was deliberately graded from a high value at the emitter to a lower value at the collector. Because this gradient introduced a built-in electric drift field into the base, the result was called a drift transistor. The first commercial product to come out of that research - the 2N247 - had a high-frequency performance far beyond that of other commercially available transistors of its time. Its *power gain cutoff frequency*[7] of 132 MHz made it suit-able for use in FM radios.

While Kroemer was theorizing about how a drift field could make transistors switch faster, he had an idea about grading the basic semiconductor itself. If an alloy of two semiconductors replaced the single semiconductor, it could be given a continually varying composition to change its band gap, which is a measure of the amount of energy required to move an electron from a semiconductor's valence band to its conduction band. This varying band gap would be another way to introduce a drift field into the base, again in order to improve transistor frequency performance.

[6] *почувався дуже ніяково*

[7] *частота відтинання коефіцієнта потужності*

He had mentioned varying a material's band gap in a paper while still in Germany, but expanded the idea and in 1957 published two papers about it, one in the RCA *Review,* another in the *Proceedings of the IEEE.*

Theory into Practice

While Kroemer trusted his theory, he didn't know how to build actual semiconductors using his principles. Building them would require either a base region consisting of a graded mix of different semiconductor materials with varying band gaps or else one material in the base but a different material in the emitter.

He tried to build a transistor with germanium-silicon alloy as the emitter on a germanium base. To this end, a gold-silicon blended mixture was alloyed onto germanium at 600 °C, hot enough for the melted mixture to begin eating up germanium, precipitating the germanium-silicon alloy emitter on cooling. Unfortunately, during the cooling, most of the devices cracked. "It was one of those technological ***blind alleys***[8] where you're not exactly embarrassed that you have tried it, but you're not surprised it didn't work," he says.

At the end of 1957, Kroemer decided to get out of transistor research. He had no interest in traditional transistors, and heterostructure transistors, with existing material technology, could not be built.

"I promised myself," he says, "that if a new technology for building heterostructures arose, I'd get back into it."

Kroemer left RCA in 1957 and returned to Germany; he, and more especially, his wife, were homesick. Becoming head of a semiconductor group at Philips Research Laboratory in Hamburg, he pushed for work on gallium arsenide, looking at what happens when you apply large electric fields to gallium arsenide semiconductors. "I thought GaAs was going to be an important material, so it was worthwhile studying it."

Kroemer feels he did little significant work at Philips and, since his wife quickly concluded she preferred the United States after all, in 1959 he went to Varian Associates (Palo Alto, Ca.), where he did a little research on tunnel diodes before turning to other problems.

Back in the Heterostructure Game

Then Kroemer's ideas about heterostructure devices, *shelved for half a dozen years*[9], came back to his attention.

---

[8] *глухі кути*

[9] *що були відкладені на півдесятка років*

It was March 1963. The previous summer, Kroemer and a Varian colleague, Sol Miller, had attended the Annual Device Research Conference, at which GaAs lasers had been introduced. Miller was interested and at Varian's weekly colloquium, he gave a talk about the new lasers. Though scientifically fascinating, he said, the devices could only work at very low temperatures and only for very short pulses, and so would never be truly practical. Asked why, Miller explained that the problem was the lack of charge-carrier confinement: at normal temperatures, electrons would diffuse out of one side of the device as quickly as they were supplied from the other side, as would the holes; therefore the electron-hole pair concentration would never become high enough to cause laser action by stimulated emission. Low temperatures suppressed the effect, but only for brief periods of time.

Kroemer disagreed. Based on his work in heterostructures, the solution, to him, seemed obvious - you just vary the device's band gap, putting a narrower gap in the center and a wider gap in the outer regions, so that the electrons and holes would concentrate in the center [see "Heterostructures Explained"].

Kroemer wanted to start working on the creation of room-temperature lasers at once, but his superiors at Varian told him that such a device would never have any applications.

"This is the classic mistake - judging something not by what applications it might *create,* but by how it could fit into applications we've already thought of," Kroemer says. The applications it was useful for turned out to include fiber-optic communications, CD and DVD players, LED traffic lights, and laser pointers - none of which were around at the time.

Though Kroemer wasn't pleased by Varian's decision, the Gunn effect, which had just been discovered, interested him. This is a phenomenon in which microwave oscillations are produced when a certain voltage is applied to opposite faces of a semiconductor. For the next decade and more, Kroemer explored theories of why this occurred, three of those years at Varian, two at Fairchild Semiconductor Corp. (Palo Alto, Ca.), and nearly eight at the University of Colorado in Boulder.

Halls of Academia

Kroemer was happy to move from industry to academia. Things at Fairchild had not gone well, because the company was dedicated to silicon technology and Kroemer's interests had long been elsewhere. He looked forward to the research freedom and also to teaching.

But he became dissatisfied. "We had hoped to set up a good solid-state engineering graduate program at Boulder, " he says. During the Vietnam War, many students went on to graduate school *to reduce their chances of getting*

drafted [10]. Stanford University typically recruited the academically top 5 percent of graduate students interested in solid-state research, and Boulder drew on the next 5 percent, who were still extremely good. But when graduate enrollments fell after the war's end, that source dried up. "Our ambitious graduate program would not fly - it was clear to me that I would be professionally dead if I stayed there," Kroemer recalls.

Word went out [11] that he was open to a change, and in the fall of 1975, the University of California at Santa Barbara, in the person of Edward Stear, then head of its electrical engineering and computer sciences department, came calling. Santa Barbara at the time didn't have a very good academic reputation; what it did have was a well-equipped semiconductor device teaching laboratory.

"So, Herb, you know about our laboratory," Stear opened. "What would you do with it?" Kroemer momentarily forgot that this visit was actually a job interview. "Sure as hell not what you're doing!"

"It was a rather unfriendly and hostile ," Kroemer recalls. ***He figured he had blown any chance of being hired*** [12]. But then Stear told him, "I'm looking for someone to rock the boat; it looks like you're my man."

Kroemer, Stear tells, "speaks very directly. He is honest, but can be sharp with people, too. He is intense and demanding. He can be a difficult person at times to work with, but people have ended up loving him." In any case, Stear knew that Kroemer could build the kind of program that Santa Barbara needed, and Kroemer was hired.

By the Sea

Kroemer left for Santa Barbara in the summer of 1976. He had persuaded Stear not to compete with Stanford, Berkeley, and other top engineering schools in silicon technology, but instead to focus on compound semiconductors such as GaAs. He gave Santa Barbara even odds for making an impact in that technology.

"You want to be first-rate or absent," Kroemer says.

Kroemer convinced a few former colleagues that they should join him at Santa Barbara, and he also convinced the U.S. Army it should buy him a molecular beam epitaxy machine. He said at the time that he wanted it for making transistors with a gallium phosphide emitter on a silicon base, a crazy project if there ever was one. It was not enough to put Santa Barbara's engineering school on the map.

---

[10] *щоб зменшити вірогідність свого призову до війська*

[11] *поширилась чутка*

[12] *вважав, що знищив будь-який шанс бути прийнятим на роботу*

In the mid-1980s, however, the chancellor of the university, Bob Huttenback, decided to put all available money into improving the College of Engineering. A new dean was hired, and 15 faculty were added. Kroemer says, "Today we have one of the best materials departments in the country - and we still don't have any silicon technology."

At 73, Kroemer remains a full-time member of the faculty. One problem he is working on concerns the influence of high electric fields on electron transport in semiconductor superlattices (alternating thin layers of two or more materials with different band gaps but similar crystal structures and lattice constants). More specifically, he is focused on a concept, called a Bloch oscillator, which can in theory generate oscillations up into the terahertz range, potentially opening up that frequency range for numerous applications. So far, it has never been satisfactorily demonstrated as a continuously running device. "I have some ideas, which may or may not be correct, of what to do about it," Kroemer tells .

He is also looking at the phenomenon of induced superconductivity in semiconductors, created when superconducting materials are deposited on semiconductors and operated at low temperatures.

Tuesday Morning, 3 a.m.

Of all the honors Kroemer has received over the years, the strangest was the naming of an asteroid after him. (Asteroid Kroemer orbits between Mars and Jupiter.) One honor that he thought beyond the grasp of a physicist who dealt in such a ***down-to-earth area***[13] as semiconductors (compared to those who deal with invisible particles) was the Nobel Prize.

"Oh, my name had been mentioned over the years," Kroemer told. But the Nobel Prize is almost invariably awarded for fundamental discoveries, not for applied research, and so I never believed the rumors."

The rumors grew stronger in 1996, when Kroemer was invited to give a talk at a Nobel symposium. "I still didn't catch on," he said. "I looked around at the attendees and saw Horst Stormer, and thought he was the most likely candidate of the group. When he received the prize in 1998, I was enthusiastic and didn't envy him at all - after all, my work was applied." (Stormer and two colleagues received the Nobel Prize for discovering that electrons acting together in strong magnetic fields can form new types of particles with charges that are fractions of the electronic charge.)

Although Kroemer never believed the Nobel would come to him, he did continue to pay attention to it. On 9 October 2000, the Nobel Prize in Physics

[13] *приземленій (практичній) сфері*

was to be announced the next day. He went to bed that evening thinking, "Wouldn't it be funny if I would get a 3 a.m. phone call? But then I said to myself, Stop being silly, go to sleep!" (Noon in Stockholm, when Nobel announcements are typically made, is 3 a.m. in California.)

But when the phone did ring shortly before 3 a.m., his first response was panic - were his children all right? Had something happened to his grandson? His wife answered, and passed him the phone, saying "It's Stockholm."

"If my life depended on it, I could not reconstruct the next two or three sentences," Kroemer says. Then the caller put a friend of Kroemer's on the phone, to reassure him that it was not a joke, warning him that he had about 15 minutes before the public announcement was made and the media circus started.

"At that point all hell did break loose and the phone ***was ringing off the hook*** [14], starting with German news agencies, since I'm German and it was already midday there. I literally couldn’t put the phone down."

The Nobel Prize in Physics that year was shared by three people - Jack S. Kilby for his part in developing the IC, and Kroemer and Zhores I. Alferov, for "developing semiconductor heterostructures used in high-speed and opto-electronics." Alferov, working in Russia, had made similar discoveries in parallel with, but separately from, Kroemer; the two first met in 1972 and have since become friends, even though they are, in a sense, competitors.

Kroemer's Nobel citation emphasizes the general principle of the heterostructure, not the individual devices. And that suits him just fine, because he ***has routinely deferred*** [15] the question of applications. "Certainly, when I thought of the heterostructure laser, I did not intend to invent compact disc players," he says. "I could not have anticipated the tremendous impact of fiber-optic communications. I really didn't give a damn about what the uses were."

"That's not what I do. The person who comes up with applications thinks differently than the scientist who lays the foundation."

And Kroemer laid one fine foundation.

HETEROSTRUCTURES EXPLAINED

Heterostructures exploit the properties of a semiconductor's band gap, which is the energy required to move an electron from the valence band to the conduction band. The structures are built from several thin layers of different semiconductors with differing band gaps.

---

[14] *розривався* *

[15] *зазвичай відкладав*

In a single-material semiconductor, the band gap is the same throughout. When an electric field, E, is applied, the valence and conduction bands tilt; the slope of the tilt supplies the force on the charge-carriers, the electrons, F_e, or holes, F_h The forces on electrons and holes are opposite in direction.

In a heterostructure, the band gap varies. Typically, a layer of a higher-bandgap semiconductor, like aluminum gallium arsenide, is placed next to a lower-bandgap semiconductor, like gallium arsenide itself. The transitional region between the two materials is the heterojunction; it may be graded or abrupt.

Because the change in the material means a variation in the electron band gap, the valence and conduction band edges can no longer be parallel edges in the heterojunction. The slopes of the band edges create the equivalent of an electric field and act as forces on electrons and holes. This Kroemer named a quasi-electric field. It even becomes possible - and is in fact very common - to have the forces on the electrons and holes act in the same direction, something that is fundamentally impossible to achieve with ordinary electric fields alone.

Kroemer considers this disconnection of the forces from the true electric field the fundamental design principle of all heterostructures, an idea first explicitly spelled out in his 1957 *RCA Review* paper.

If the compositional variation of the heterostructure is compressed right at the emitter-to-base junction of a bipolar transistor, such that carriers are injected from a wider-gap emitter into a narrower-gap base, the quasi-electric fields become quasi-electric potential barriers. In the case of a pnp transistor (the kind of device dominating transistor technology at the time Kroemer first developed his ideas), the transition in band gap bars the escape of electrons from the base into the emitter; consequently, the base can be doped more heavily, reducing its resistance and greatly increasing device speed.

In the double-heterostructure laser two wider-gap semiconductors sandwich a lower-gap semiconductor between them, so as to create wells for both the electrons and the holes. When a voltage is applied, the electrons and holes are trapped in the well, recombine, and emit energy as photons.

Today, heterostructures and devices based on them employ not just GaAs and AIGaAs, but essentially all III-V semiconductors, including the nitrides, as well as II-VI semiconductors and even the combination of silicon with a silicon-germanium alloy.

Task I

Speak on Kroemer’s scientific interests, researches and investigations.

Task II

Tell about his teaching experience and achievements.

Task III

Discuss Kroemer’s attitude to Nobel Prize and his discoveries.

Task IV

Speak on heterostructures.

Appendix 1

ABBREVIATIONS

AIEE	American Institute of Electrical Engineers
AMD	Advanced Micro Devices
ASIC	Application specific integrated circuit
ATA	Advanced technology attachment
CMOS	Complementary metal-oxide semiconductor
CSS	Content scramble system (copying prevention encryption)
CVD	Chemical vapor deposition
CWDM	Coarse wavelength division multiplexing (120nm apart)
DSL	Digital subscriber line
DTCP	Digital transmission context protection
DTV	Digital TV
DVI	Digital video interface
DWDM	Dense wavelength division multiplexing (1 nm apart)
ECC	Error checking and correction
EMR	Extraordinary magnetoresistance
ESR	Equivalent series resistance
GE	General Electric
GMR	Giant magnetoresistance
HDMI	High-definition multimedia interface
H-P	Hewlett-Packard
IBM	Individual Business Machine
IDE	Integrated drive electronics
IEEE	Institute of Electrical and Electronics Engineers
IP	Intellectual property
IRE	Institute of Radio Engineers

LOS	Line-of-sight
MIST	Metal-insulator-semiconductor transistor
MIT	Massachussets Institute of Technology
MMDS	Multichannel multipoint distribution service
MSM	Metal-semiconductor-metal
NIXy	Numeric indicator experimental (set of diodes in a glass tube containing neon gas)
NLOS	Non-line-of-sight
OBE	Officer (of the Order) of the British Empire
OFS	Optical fiber system
PDA	Personal digital assistant
p-i-n	p-type, intrinsic, n-type (semiconductor which generates current when is struck by a photon)
R&D	Research and development
RCA	Radio Corporation of America
SCSI	Small computer system interface
Smart	Self-monitoring and reporting technology
SOC	System on chip
TI	Texas Instruments
TWT	Travelling-wave Tube
USB	Universal serial bus
VCR	Videocassette recorder
VCSEL	Vertical-cavity surface-emitting lasers
VHS	Video home system

Appendix 2

BRITISH AND AMERICAN SPELLING DIFFERENCES

British	***American***
trave***ll***ing	trave***l***ing
col***our***	col***or***
civil***ise***	civil***ize***
medi***ae***val	medi***e***val
refl***exion***	refl***ection***
me***tre***	me***ter***
catalo***gue***	catalo***g***
def***ence***	def***ense***
dra***ught***	dra***ft***
enclose	***in***close
che***que***	che***ck***
fulfi***l***	fulfi***ll***

Appendix 3

NUMERICAL PREFIXES

Meaning	***Greek***	***Latin***
half	hemi- (hemisphere)	semi- (semiconductor)
one	mono- (monogram)	uni- (unidirectional)
two	di- (dioxide)	bi- (bipolar)
three	tri- (triode)	ter- (tercentenial)
four	tetra- (tetrahedral)	quadri- (quadrilateral)
five	penta- (pentangle)	quinque- (quinquereme)
six	hexa- (hexagonal)	sex- (sextant)
seven	hepta- (heptane)	sept- (September)
eight	oct(a)- (octagon)	oct(o)- (October)
nine		nona- (nonet)
ten	deca- (decathlon)	decem- (December)
many	poly- (polygon)	multi- (multiplex)
all	pan- (panacea)	omni- (omnidirectional)

Appendix 4

PREFIXES FOR *SI* UNITS

Prefix	*Multiple*	*Meaning*	*Symbol*	*Example*
pico-	10^{-12}	million-millionth	p	pF (picofarad)
nano-	10^{-9}	thousand-millionth	n	ns (nanosecond)
micro-	10^{-6}	millionth	μ	μF (microfarad)
milli-	10^{-3}	thousandth	m	mv (milivolt)
centi-	10^{-2}	hundredth	c	cm (centimetre)
deci-	10^{-1}	tenth	d	decimal
deca- or deka-	10	ten times	da	decametre
hecto-	10^{2}	hundred times	h	ha (hectar)
kilo-	10^{3}	thousand times	k	kg (kilogram)
mega-	10^{6}	million times	M	MW (megawatt)
giga-	10^{9}	thousand million times	G	Gb (gigabyte)
tera-	10^{12}	million million times	T	TH (terahertz)

Перелік використаних джерел:

1. Матеріали IEEE “50 Years of Electron Devices”;
2. Журнали “Electronics World +Wireless World”;
3. Журнали “Spectrum”;
4. Тексти з позначкою * з журналів “Electronics World +Wireless World” написані Тоні Атертоном ;
5. В.Ф. Лісовський, І.К.Калугін “Англо-русский словарь по радиоэлектронике” –М.”Русский язык”, 1984
6. А.П.Ткаченко, В.Н.Цацулін “ Англо-русский словарь по телевидению, аудио- и видео-технике” –Мн.: БелЭн, 1998
7. Інтернет сайти:
   http://www.invent.org/hall_of_fame
   http://www.dotpoint.com/xnumber/kilby.htm
   http://www.ce.org/publications/hall_of_fame/noyce_r_
   http://www.desmoinesregister.com/extras/iowans/noyce
   http://www.gazetteonline.com/special/impact/imp043
   http://www.nap.edu/books/0309048478/html/154
   http://www.nt1.alp.dillingen.de/telumm/schilfglossar/glossar
   http://www.si.edu/lemelson/Quartz/inventors/
   http://www.forbes.com/asap/1997/0825/102.
   http://www.buet.ac.bd/eee/iba/simulation.html
   http://www.ideafinder.com/history/inventors
   http://www.grinnelliowa.org/tour/historyfiles/
   http://www.pbs.org/transistor/album1/addlbios/
   http://www.digitalcentury.com/encyclo/update

Навчальне видання

Людмила Михайлівна Потупейко

From the History of Electronics

Навчальний посібник з англійської мови

Оригінал-макет підготовано автором

Редактор В.О.Дружиніна

Навчально-методичний відділ ВНТУ

Свідоцтво Держкомінформу України

серія ДК № 746 від 25.12.2001

21021, м.Вінниця, Хмельницьке шосе, 95, ВНТУ

Підписано до друку

Формат 29,7х42,25

Друк різографічний

Тираж прим.

Зам.№

Гарнітура Times New Roman

Папір офсетний

Ум. друк. арк.

Віддруковано в комп’ютерному інформаційно-видавничому центрі
Вінницького національного технічного університету

Свідоцтво Держкомінформу України

серія ДК № 746 від 25.12.2001

21021, м.Вінниця, Хмельницьке шосе, 95, ВНТУ

Перелік використаних джерел:

1. Матеріали IEEE "50 Years of Electron Devices";
2. Журнали "Electronics World +Wireless World";
3. Журнали "Spectrum";
4. Тексти з позначкою * з журналів "Electronics World +Wireless World" написані Тоні Атертоном ;
5. В.Ф. Лісовський, І.К.Калугін "Англо-русский словарь по радиоэлектронике" –М."Русский язык", 1984
6. А.П.Ткаченко, В.Н.Цацулін " Англо-русский словарь по телевидению, аудио- и видео-технике" –Мн.: БелЭн, 1998
7. Інтернет сайти:
   http://www.invent.org/hall_of_fame
   http://www.dotpoint.com/xnumber/kilby.htm
   http://www.ce.org/publications/hall_of_fame/noyce_r_
   http://www.desmoinesregister.com/extras/iowans/noyce
   http://www.gazetteonline.com/special/impact/imp043
   http://www.nap.edu/books/0309048478/html/154
   http://www.nt1.alp.dillingen.de/telumm/schilfglossar/glossar
   http://www.si.edu/lemelson/Quartz/inventors/
   http://www.forbes.com/asap/1997/0825/102.
   http://www.buet.ac.bd/eee/iba/simulation.html
   http://www.ideafinder.com/history/inventors
   http://www.grinnelliowa.org/tour/historyfiles/
   http://www.pbs.org/transistor/album1/addlbios/
   http://www.digitalcentury.com/encyclo/update

Навчальне видання

Людмила Михайлівна Потупейко

From the History of Electronics

Навчальний посібник з англійської мови

Оригінал-макет підготовано автором

Редактор В.О.Дружиніна

Навчально-методичний відділ ВНТУ

Свідоцтво Держкомінформу України

серія ДК № 746 від 25.12.2001

21021, м.Вінниця, Хмельницьке шосе, 95, ВНТУ

Підписано до друку

Формат 29,7х42,25

Друк різографічний

Тираж   прим.

Зам.№

Гарнітура Times New Roman

Папір офсетний

Ум. друк. арк.

Віддруковано в комп’ютерному інформаційно-видавничому центрі
Вінницького національного технічного університету

Свідоцтво Держкомінформу України

серія ДК № 746 від 25.12.2001

21021, м.Вінниця, Хмельницьке шосе, 95, ВНТУ