Методичні вказівки
до вивчення фахової термінології
з метрології для студентів
освітньо-кваліфікаційного рівня бакалавра

Міністерство освіти і науки України
Вінницький національний технічний університет

Методичні вказівки до вивчення фахової термінології з метрології для студентів освітньо-кваліфікаційного рівня бакалавра

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Методичні вказівки до вивчення фахової термінології з метрології для студентів освітньо-кваліфікаційного рівня бакалавра / Уклад. Л. М. Магас, О. В. Столяренко. – Вінниця : ВНТУ, 2016. – 60 с.

У даних методичних рекомендаціях наводяться основні тексти та вправи до вивчення, закріплення лексичних одиниць та формування професійної лінгвістичної компетенції з дисципліни «Іноземна мова за професійним спрямуванням».

Методичні рекомендації призначені для використання студентами ОКР бакалавра за спеціальністю «Метрологія та інформаційно-вимірювальні технології» та «Метрологія, стандартизація та сертифікація».

ЗМІСТ

ПЕРЕДМОВА

Методичні вказівки призначені для студентів II курсу технічного вузу, майбутніх спеціалістів з метрології. Вони складені з урахуванням вимог програми цільової підготовки фахівців з іноземної мови і призначені для самостійної роботи в аудиторії під керівництвом викладача та поза аудиторією.

Кожен тематичний розділ містить:

1) два основні тексти;

2) коментарі до ключових слів та виразів;

3) лексичні та словотворчі вправи для закріплення термінології за фахом.

Запропоновані завдання складені на основі матеріалів оригінальних джерел англійської та американської фахової літератури та Інтернет-джерел. Головне завдання тексту – навчитися інтерпретувати науково-технічну літературу, самостійно вести пошук потрібної інформації, узагальнювати інформацію і, відповідно, удосконалювати професійні знання.

Лексичні вправи мають на меті закріплення та активізацію засвоєння навчального матеріалу, а також розвиток навичок усного та писемного мовлення. Словотворчі вправи охоплюють різноманітні способи словотворення.

SECTION 1
CONCEPTS OF MEASUREMENT

LESSON 1
TEXT 1

METROLOGY AND ITS TYPES

Metrology word is derived from two Greek words such as metro which means measurement and logy which means science. Metrology is the science of precision measurement. The engineer can say it is the science of measurement of lengths and angles and all related quantities like width, depth, diameter and straightness with high accuracy. Metrology demands pure knowledge of certain basic mathematical and physical principles. The development of industry largely depends on the engineering metrology. Metrology is concerned with the establishment, reproduction and conservation and transfer of units of measurements and their standards. Irrespective of the branch of engineering, all engineers should know about various instruments and techniques. Measurement is defined as the process of numerical evaluation of a dimension or the process of comparison with standard measuring instruments. The elements of the measuring system include the instrumentation, calibration standards, environmental influence, human operator limitations and features of the work-piece. The basic aim of measurement in industries is to check whether a component has been manufactured to the requirement of a specification or no.

There are such types of metrology: legal, scientific, industrial, dynamic, deterministic and dimensional. Legal metrology is the part of metrology which treats units of measurements, methods of measurements and the measuring instruments, in relation to the technical and legal requirements. Scientific metrology focuses on developing new systems of measurement and standardizing existing ones. Industrial metrology applies the principles of measurement science to manufacturing. Dynamic metrology is the technique of measuring small variations of a continuous nature. The technique has proved very valuable, and a record of continuous measurement, over a surface, for instance, has obvious advantages over individual measurements of an isolated character. Deterministic metrology is a new philosophy in which part measurement is replaced by process measurement. The new techniques such as 3D error compensation by Computer Numerical Control systems and expert systems are applied, leading to fully adaptive control. This technology is used for very high precision manufacturing machinery and control systems to achieve microtechnology and nanotechnology accuracies. Dimensional metrology is the science of calibrating and using physical measuring equipment to quantify the physical size of or distance from any given object. Inspection is a critical step in product development and quality control. It requires the use of a variety of physical scales to determine dimension, with the most accurate of these being holographic etalons or laser interferometers.

TEXT 2

IMPORTANCE OF METROLOGY AND ITS AIMS

The importance of the science of measurement as a tool for scientific research (by which accurate and reliable information can be obtained) was emphasized by Galileo and Goethe. This is essential for solving almost all technical problems in the field of engineering in general, and in production engineering and experimental design in particular. The design engineer should not only check his design from the point of view of strength or economical production, but he should also keep in mind how the dimensions specified can be checked or measured. Unfortunately, a considerable amount of engineering work is still being executed without realizing the importance of inspection and quality control for improving the function of product and economical production.

Higher productivity and accuracy is called for by the present manufacturing techniques. This cannot be achieved unless the science of metrology is understood, introduced and applied in industries. Improving the quality of production necessitates proportional improvement of the measuring accuracy, and marking out of components before machining and the in-process and post-process control of the dimensional and geometrical accuracies of the product. Proper gauges should be designed and used for rapid and effective inspection. Also automation and automatic control, which are the modern trends for future developments, are based on measurement. Means for automatic gauging as well as for position and displacement measurement with feedback control have to be provided.

Objectives of metrology

Although the basic objective of a measurement is to provide the required accuracy at a minimum cost, metrology has further objectives in a modern engineering plant with different shapes which are:

- Complete evaluation of newly developed products.
- Determination of the process capabilities and ensure that these are better than the relevant component tolerances.
- Determination of the measuring instrument capabilities and ensure that they are quite sufficient for their respective measurements.
- Minimizing the cost of inspection by effective and efficient use of available facilities.
- Reducing the cost of rejects and rework through application of Statistical Quality Control Techniques.
- To standardize the measuring methods.
- To maintain the accuracies of measurement.
- To prepare designs for all gauges and special inspection fixtures.

EXERCISE 1

Translate and remember the following words

mean, measurement, science, precision, length, angle, quantity, width, depth, accuracy, demand, development, depend on, unit, branch, dimension, comparison, manufacture, develop, apply, technique, surface, advantage, equipment, require, aim.

EXERCISE 2

Pay attention to the pairs of the words from different parts of speech

adjective	**noun**	**noun**	**verb**
wide	width	meaning	mean
deep	depth	demand	demand
long	length	development	develop
scientific	science	appliance	apply
accurate	accuracy	equipment	equip
technical	technique	requirement	require
precise	precision	user	use

EXERCISE 3

Answer the following questions to the texts

1. What does the word «metrology» mean?
2. Are aims of industrial and scientific metrology the same?
3. What's necessary to make accurate measurements?
4. What is the main aim of metrology?
5. Who stressed the importance of accurate measurement?

EXERCISE 4

Complete the sentences with the correct form of the verb in brackets (past simple or present perfect)

1. She *arrived* ten days ago. (arrive)
2. I .... lunch with Nigel. (just/have)
3. It's the first time I .... in hot springs. (swim)
4. They ....four matches so far this season. (win)
5. It is the third time she .... the film. (see)
6. .... you ever .... parachuting? (try)
7. I .... very upset when I heard she was in hospital. (feel)
8. She .... to Australia three times since the beginning of the year. (go)
9. The last time I .... her was in 1978. (see)
10. I first .... my girlfriend in 1989. (meet)
11. .... she .... her baby yet? (have)
12. The flowers you bought yesterday .... (already/die).

LESSON 2
TEXT 3

METROLOGY AT WORK

Metrology is critical to the success of many different industries. Metrologists help to develop technology by designing or performing tests to determine a product's effectiveness. They also calibrate existing devices, such as fuel gauges or radio antennas, to keep them in working order.

There are many industries that employ metrologists. In the following industries, descriptions of metrology work provide a glimpse of the broad range of projects that rely on the science of measurement.

Aerospace. Complex machinery like airplanes requires metrology workers to consider both function and safety. Metrologists in aerospace supervise the manufacture of planes and are responsible for testing their components, including turbines and landing gear. Calibration technicians also regularly check the assembly process to ensure that the machinery is functioning correctly.

Metrologists' contributions to the aerospace industry extend beyond structural assembly. For example, the instruments in a cockpit, such as the navigation system and altimeter, are subject to metrologists review and calibration. Metrology also helps to ensure the safety of passengers inside the plane. Fabric in the plane's cabin is designed to be fire resistant, and metrologists set standards for measuring flammability and help test and develop new flame-retardant products.

Communications. Without metrology, dependable and secure digital networks couldn't exist. In computer network security, for example, metrologists thwart hackers by developing new programs to measure network activity and flag suspicious actions. Cell phone production also benefits from metrology work. Metrologists help to test the phones numerous components, recording under what circumstances the phones can function.

Construction. Metrology aids the construction industry in a number of ways. Metrology tools developed for building managers help them to determine the cost-effectiveness of worksite decisions. By researching new methods to automate the construction process, metrologists help to reduce labor costs. And the production of cheaper, more resistant building materials relies on measurement science.

Metrologists are also involved in building design and may study structural durability. To help guide construction standards, metrology workers develop tests to evaluate a structure's resistance to daily stress from both people and the environment. For example, metrologists create trials to measure a home's resistance to earthquakes and fires.

Energy. All energy companies rely on the work of metrologists. Every building has a meter that displays its energy consumption, and calibration technicians ensure that these meters provide accurate readings. Consumption measurements are the underpinning of the energy industry; without them, energy companies wouldn't be able to charge customers by use.

In a power plant, calibration technicians are also needed to continually verify its many gauges and measurements. The potential consequences of a power plant failure range from loss of electricity to nuclear meltdown.

Metrologists are also involved in «green» energy. They help to develop wind turbines and solar panels by testing energy output and construction methods. And metrology is critical for measuring the power consumption of new energy-efficient household appliances.

Healthcare. For many patients, the proper functioning of medical devices is a matter of life and death. And metrologists are required to calibrate and certify medical devices, such as external pacemakers and fetal monitors. By fine tuning machinery, metrology workers ensure the accuracy of medical tests to allow the best possible diagnoses.

TEXT 4

SKILLS, TRAINING AND ADVANCEMENT

Workers in metrology often follow indirect career paths to their jobs. There are, however, some skills and training common to workers in metrology occupations. And experience may lead to increased responsibilities in other metrology work.

Skills. Highly skilled metrologists – those developing new tests and product designs in laboratories – must be proficient in mathematics, the sciences and engineering. They must also have excellent communication skills, because they often work on teams with other researchers and scientists.

Metrologists at the technician level need mechanical aptitude. Technicians also must be able to maintain high levels of concentration while making slight, precise adjustments to equipment.

Training. Unlike other sciences, metrology has a relatively low profile with few formal education programs. There are several degree programs for metrologists at the associate-degree level. Some 4-year universities offer metrology specializations in their engineering departments.

Many metrologists who have a bachelor's or higher degree study science or engineering disciplines other than metrology. Some research metrologists, for example, might have a physics or mechanical engineering degree. Others have a degree specific to the industry in which they are employed; for example, metrologists working in the aerospace industry might have a degree in aerospace engineering.

Metrologists at the technician level usually don't need a degree. Most have a high school diploma and receive on-the-job training. The U.S. military also offers many training programs in the study of metrology.

Advancement. Assuming more responsibility in jobs related to metrology, like jobs in many fields, often depends on gaining experience. Technicians may advance to more sophisticated metrology jobs with experience and instruction, including through formal or informal mentorships. For example, a quality control technician working on a factory floor might be coached to consider more complex design issues.

Mid-level metrologists might work as technicians or scientists, but either worker may find advancement to other metrology-related jobs. Because of their expertise, the most experienced usually work as managers or supervisors of other metrologists.

EXERCISE 1

Translate and remember the following words

success, successful, successive, succeed, critical, criticize, calibrate, calibration, both…and, flammability, cell phone, resistance, rely on, meter, gauge, verify, verification, skills, advance, advantage, because, because of.

EXERCISE 2

Write antonyms to the following words

often	low
formal	indirect
dependence	help
advancement	employment
responsible	input
sophisticated	accurate
with	

EXERCISE 3

Answer the following questions to the texts

1. What industries can metrologists be employed in?
2. How can metrologists prevent hackers' attacks?
3. Can metrologists be of any help for people having their own house?
4. What do you have to know to become a qualified specialist?
5. Is it necessary to get at least a bachelor's degree to become a metrologist in Ukraine?

EXERCISE 4

Circle the correct verb form in the sentences

1. We generally *eat/are eating* quite early during the week.
2. Right now I *learn/am learning* to play the saxophone.
3. With the regard to my financial situation, for the time being I *work/am working* in a children's hospital.
4. I *am writing/write* in response to your advertisement which I saw in the Daily Times.
5. At the moment I *am enjoying/ enjoy* myself in my new job.
6. It is always at this time of year that my family *are visiting/visit* my grandfather's grave.
7. At present I *study/am studying* for my International Baccalaureate.
8. In France people *buy/are buying* fresh bread every day.
9. I *am currently working/currently work* on an alternative energy project.
10. Right now I *am needing/need* to improve my social English for my job.

LESSON 3
TEXT 5

METHODS OF MEASUREMENT

These are the methods of comparison used in measurement process. In precision measurement various methods of measurement are adopted depending upon the accuracy required and the amount of permissible error.

The methods of measurement can be classified as:

1. Direct method;
2. Indirect method;
3. Absolute or Fundamental method;
4. Comparative method;
5. Transposition method;
6. Coincidence method;
7. Deflection method;
8. Complementary method;
9. Contact method;
10. Contactless method.

Direct method of measurement:

This is simple method of measurement, in which the value of the quantity to be measured is obtained directly without any calculations. For example, measurements by using scales, vernier callipers, micrometers, bevel protector. This method is most widely used in production. It is not very accurate because it depends on human insensitiveness in making judgment.

Indirect method of measurement:

In indirect method the value of quantity to be measured is obtained by measuring other quantities which are functionally related to the required value. E.g. Angle measurement by sine bar, measurement of screw pitch diameter by three wire method etc.

Absolute or Fundamental method:

It is based on the measurement of the base quantities used to define the quantity. For example, measuring a quantity directly in accordance with the definition of that quantity, or measuring a quantity indirectly by direct measurement of the quantities linked with the definition of the quantity to be measured.

Comparative method:

In this method the value of the quantity to be measured is compared with known value of the same quantity or other quantity practically related to it. So, in this method only the deviations from a master gauge are determined, e.g., dial indicators or other comparators.

Transposition method:

It is a method of measurement by direct comparison in which the value of the quantity measured is first balanced by an initial known value A of the same quantity, and then the value of the quantity measured is put in place of this known value and is balanced again by another known value B. If the position of the element indicating equilibrium is the same in both cases, the value of the quantity to be measured is AB. For example, determination of a mass by means of a balance and known weights, using the Gauss double weighing.

Coincidence method:

It is a differential method of measurement in which a very small difference between the value of the quantity to be measured and the reference is determined by the observation of the coincidence of certain lines or signals. For example, measurement by vernier calliper micrometer.

Deflection method:

In this method the value of the quantity to be measured is directly indicated by a deflection of a pointer on a calibrated scale.

Complementary method:

In this method the value of the quantity to be measured is combined with a known value of the same quantity. The combination is so adjusted that the sum of these two values is equal to predetermined comparison value. For example, determination of the volume of a solid by liquid displacement.

Method of measurement by substitution:

It is a method of direct comparison in which the value of a quantity to be measured is replaced by a known value of the same quantity, so selected that the effects produced in the indicating device by these two values are the same.

Method of null measurement:

It is a method of differential measurement. In this method the difference between the value of the quantity to be measured and the known value of the same quantity with which it is compared is brought to zero.

TEXT 6

UNITS OF MEASUREMENT

Unit is a quantity or dimension adopted as a standard measurement. Much of physics deals with measurements of physical quantities such as length, time, velocity, area, volume, mass, density, temperature and energy. Many of these quantities are interrelated. For example, velocity is length divided by time. Density is mass divided by volume. Volume is a length times a second length, times a third length. Most of the physical quantities are related to length, time and mass, therefore all the systems of physical units are derived from these three fundamental units.

Practically there are three main systems of measurement in use today: the British system of units, the Metric system of units and the quite recently adopted SI Units (System of International Units). With a few exceptions nearly all the nations of the world use the Metric system. The value of the MKS (meter-kilogram-second) system is that its various units possess simple and logical relationships among themselves, while the British system (the fps-foot-pound-second) is a very complicated one. For example, in the British system 1 mile is equal to 1,760 yards, 1 yard is equal to 3 feet, and 1 foot is equal to 12 inches. In the English system converting one unit into another is a hard and monotonous job, while in the MKS system conversions of one unit to another can be carried out by shifts of a decimal point (comma in Russian writing).

The standard meter of the world was originally defined in terms of the distance from the north pole to the equator. This distance is close to 10,000 kilometers or 10^7 (ten to the seventh power) meters. By international agreement the standard meter of the world is the distance between two scratches (штрих) made on a platinum-alloy bar. It is kept at the International Bureau (bjua'rou) of Weights and Measures in France.

The square meter (m^2) is an MKS unit of area while the cubic meter is an MKS unit used to measure volume.

In fact, the SI Units is an internationally agreed coherent system of units derived from the MKS system. It is replacing all the other systems. The seven basic units in it are: meter (m), kilogram (kg), second (s), ampere (a), Kelvin (K), mole (mol) and candle (свіча) (cd).

EXERCISE 1

Translate and remember the following words

depending on, dependent, dependence, depend, dependency; production, produced, produce, producing, producer, product, productivity, reproduce, reproducer, reproductive; accurate, accuracy, occur, occurance; value, valuable, valuables, valueless, valuer, valve; relate, relation, relationship, rely on, relative, related, relating to, relatively**.**

EXERCISE 2

Translate and pay attention to prefixes, some of them may have negative meaning

predetermined
prepaid
prewash
irrational
iron
subdivision
substantial
substance
subway
subtext
impossible
immobile
unlimited
unlock
undecided
understand
underproduce
incorrect
indirect
increase
include
inactive
immensely

EXERCISE 3

Fill in the gaps

1. …method isn't very accurate because… .
2. In…method only the deviations from a master gauge are determined.
3. Coincidences of certain lines or signals is observed in…method.
4. Zero is introduced in method of… .
5. The standard meter is kept in… .

EXERCISE 4

Complete the dialogue with the present perfect simple or continuous form of the verb in brackets

CAROL: Do you want a magazine?
TOM: No, thanks *I've read* (read) them all.
CAROL: Oh, how long[2] .... (you/wait)?
TOM: I feel as if I[3] .... (wait) for hours but I suppose I[4] .... (only/be) here for fifteen minutes.

CAROL: What time is your appointment?
TOM: I[5] .... (not/make) an appointment.
I[6] .... (just/drop in) on the off-chance of seeing someone.
CAROL: Have you got bad toothache then?
TOM: Yes, it[7] .... (give) me trouble for over a week now.
CAROL: [8] .... (you/be) to this dentist before?
TOM: No, it's the first time I [9] ....(ever/be) here.
CAROL: Well, I [10] .... (come) here for about five years. They're very good.
TOM: [11] .... (you/just/come in) for a check-up?
CAROL: No, I [12] .... (lose) a filling so it needs replacing.
WOMAN: Mr. Hill, the dentist will see you now. [13] .... (you/fill in) the card yet?
TOM: Yes, I [14] .... (already/give) it to the receptionist.
WOMAN: Thank you. Perhaps you could go up to Surgery 2. Mr. Sharp is ready for you.
CAROL: Good luck!

LESSON 4
TEXT 7

CERTIFICATION

According to the law «About certification of goods and services» certification is a method of the objective control of the quality of product, its correspondence to established requirements, and also to Environmental Protection, safeguarding of life, health, property of citizens. The presents of the certificate helps customers in competent choice of goods and is a certain guarantee of its good quality.

The certification confirms a quantitative index of goods, declared by the producer, and facilitates export and import of goods, increases competitiveness. It can be of obligatory and voluntary nature.

Obligatory certification – is confirmation by an authorized body of correspondence of goods to obligatory requirements. An obligatory requirement is a requirement of a normative document subjected to obligatory fulfillment with the purpose of achievement of correspondence to this document. Usually obligatory requirements are those in safeguarding of security of people, their property and environment, technical and information compatibility and variability of goods and some others, connected with the necessity of safeguarding of methods of control and marking.

A list of products subjected to obligatory standardization and also their factors, indices, characteristics are determined in accordance with effective in our country normative documents and legislation.

The obligatory requirement includes indices of safety for a consumer and environment. Thus, at obligatory certification of goods the consumer gets assurance of safety while using.

Voluntary certification is introduced under the initiative of producers, suppliers and salespeople of product with the view to confirmation its accordance to not only obligatory requirements of normative documents, but also to publicized characteristics and indices. The system of voluntary certification is usually introduced for product at the expense of information about high quality and safety of product, ensuring higher mutual confidence of suppliers and consumers, great possibilities of consumers in the choice of product. At voluntary certification, both the producer of goods and society of consumers or enterprises of trade have the right to choose its any scheme and also a normative document.

TEXT 8

STANDARDS

The term standard is used to denote universally accepted specifications for devices. Components of processes ensure conformity and interchangeability throughout a particular industry. A standard provides a reference for assigning a numerical value to a measured quantity. Each basic measurable quantity has been associated with an ultimate standard. Working standards are those used in conjunction with the various measurement making instruments.

The national institute of standards and technology (NIST) formerly called National Bureau of Standards (NBS), was established by an act of congress in 1901, and the need for such body had been noted by the founders of the constitution. In order to maintain accuracy, standards in a vast industrial complex must be traceable to a single source, which may be national standards.

The following is the generalization of echelons of standards in the national measurement system.

1. Calibration standards
2. Metrology standards
3. National standards

Calibration standards: Working standards of industrial or governmental laboratories.

Metrology standards: Reference standards of industrial or Governmental laboratories.

National standards: It includes prototype and natural phenomenon of SI (Systems International), the world wide system of weight and measures standards.

Application of precise measurement has increased so much, that a single national laboratory isn't able to perform directly all the calibrations and standardization required by a large country with high technical development. It has led to the establishment of a considerable number of standardizing laboratories in industry and in various other areas. A standard provides a reference or datum for assigning a numerical value to a measured quantity.

Classification of Standards

To maintain accuracy and interchangeability it is necessary that standards to be traceable to a single source, usually the National Standards of the country, which are further linked to International Standards. The accuracy of National Standards is transferred to working standards through a chain of intermediate standards in a manner given below.

- National Standards
- National Reference Standards
- Working Standards
- Plant Laboratory Reference Standards
- Plant Laboratory Working Standards
- Shop Floor Standards

Evidently, there is degradation of accuracy in passing from the defining standards to the shop floor standards. The accuracy of particular standard depends on a combination of the number of times it has been compared with a standard in a higher echelon, the frequency of such comparisons, the care with which it was done and the stability of the particular standard itself.

EXERCISE 1

Translate and remember the following words

denote, care, carefull, careless, apply, apply for, application, appliance, transmission, difference, differ, current, use, user, useful, useless, quantity, quality, conformity, confirm, confirmation, confirmative, confirmed, safety, safe, save, safeguarding, compatible, compatibility, variable, variability, value.

EXERCISE 2

Find pairs of synonyms

1) obtain	a) significant
2) field	b) instrument
3) research	c) quantity
4) solve	d) size
5) dimension	e) experiment
6) considerable	f) cope with
7) gauge	g) branch
8) objective	h) some
9) provide	i) purpose
10) keep in mind	j) get
11) magnitude	k) support
12) several	l) remember

EXERCISE 3

Answer the following questions to the texts

1. Is certification a «must do thing» for everybody?
2. Is a certified product always a quality product?
3. Who is interested in voluntary certification?
4. Is a national laboratory able to perform all the country's calibrations and standartization?
5. What does the accuracy of particular standard depend on?

EXERCISE 4

Choose the correct form of the verb (past simple or past perfect) in these sentences

1. By the time we arrived, they *ate/had eaten* all the strawberries.
2. When I got to the restaurant, I suddenly *didn't feel/hadn't felt* hungry.
3. He was completely out of breath as he *ran/had run* all the way to the station.
4. The children were in high spirits as they just *finished/had just finished* their exams.
5. When the old men *got up/ had got up* to speak, everyone applauded.
6. They were chatting as if they *knew/had known* each other all their lives.
7. She wasn't frightened when she saw his cut. She *saw/had seen* blood many times before.
8. When he *saw/had seen* her come through the door, he jumped up in surprise.

TEXT 9

ACCURACY OF MEASUREMENTS

The purpose of measurement is to determine the true dimensions of a part. But no measurement can be made absolutely accurate. There is always some error. The amount of error depends upon the following factors:

1. The accuracy and design of the measuring instrument
2. The skill of the operator
3. Method adopted for measurement
4. Temperature variations
5. Elastic deformation of the part or instrument etc.

Thus, the true dimension of the part cannot be determined but can only by approximate. The agreement of the measured value with the true value of the measured quantity is called accuracy. If the measurement of dimensions of a part approximates very closely to the true value of that dimension, it is said to be accurate. Thus the term accuracy denotes the closeness of the measured value with the true value. The difference between the measured value and the true value is the error of measurement. The lesser the error, the more is the accuracy.

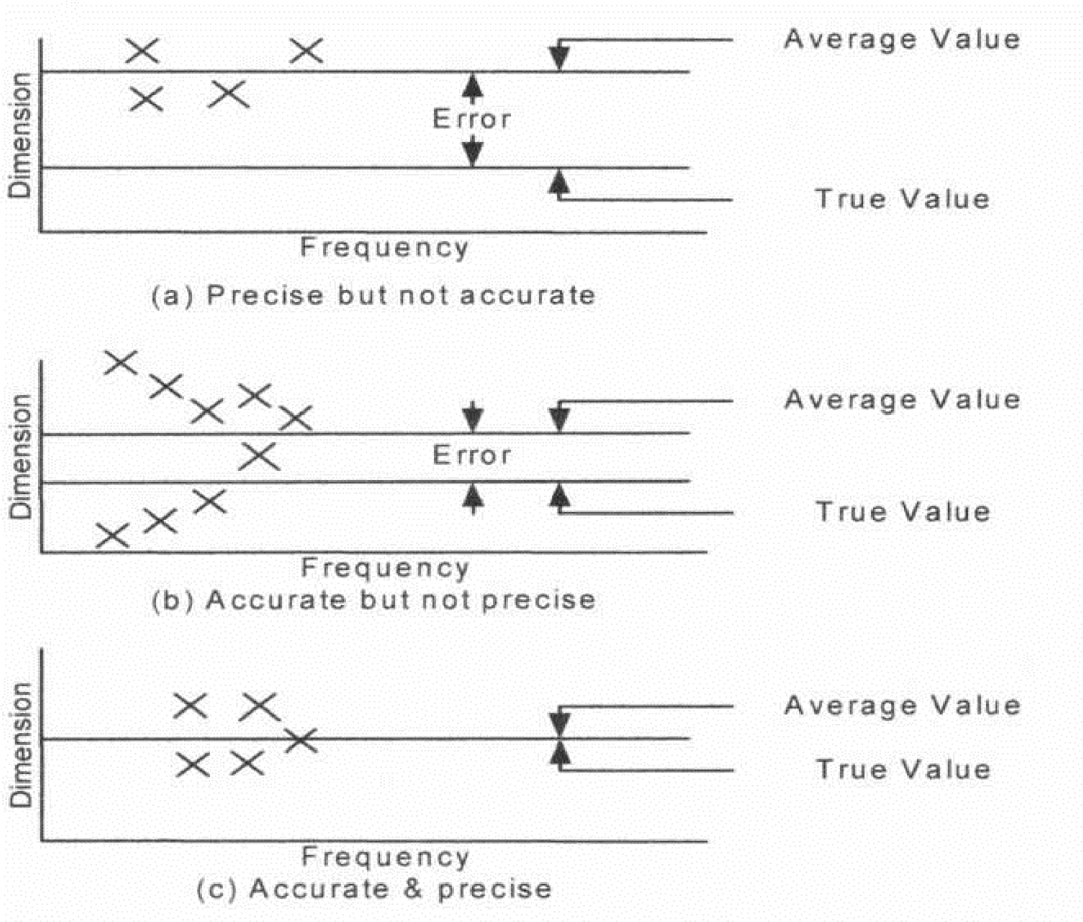
Precision

The terms precision and accuracy are used in connection with the performance of the instrument. Precision is the repeatability of the measuring process. It refers to the group of measurements for the same characteristics under identical conditions. It indicates to what extent the identically performed measurements agree with each other. If the instrument is not precise it will give different (widely varying) results for the same dimension when measured again and again. The set of observations will scatter about the mean. The scatter of these measurements is designated as o, the standard deviation. It is used as an index of precision. The less the scattering, the more precise is the instrument. Thus, the lower the value of a, the more precise is the instrument.

Accuracy

Accuracy is the degree to which the measured value of the quality characteristic agrees with the true value. The difference between the true value and the measured value is known to be the error of measurement. It is practically difficult to measure exactly the true value and therefore a set of observations is made whose mean value is taken as the true value of the quality measured.

Accuracy is very often confused with precision though much different. The distinction between the precision and accuracy will become clear by the following example. Several measurements are made on a component by different types of instruments (A, B and C respectively)



and the results are plotted. In any set of measurements, the individual measurements are scattered about the mean, and the precision signifies how well the various measurements performed by same instrument on the same quality characteristic agree with each other. The difference between the mean of the set of readings on the same quality characteristic and the true value is called as error. The less the error, the more accurate is the instrument. The figure shows that the instrument A is precise since the results of number of measurements are close to the average value hence it is not accurate. The readings taken by the instruments are scattered much from the average value and hence it is not precise but accurate as there is a small difference between the average value and true value.

LESSON 5
TEXT 10

SENSITIVITY

Sensitivity may be defined as the rate of displacement of the indicating device of an instrument, with respect to the measured quantity. In other words, sensitivity of an instrument is the ratio of the scale spacing to the scale division value. For example, if on a dial indicator, the scale spacing is 1.0 mm and the scale division value is 0.01 mm, then sensitivity is 100. It is also called as amplification factor or gearing ratio.

The sensitivity may be constant or variable along the scale. In the first case we get linear transmission and in the second non-linear transmission. Sensitivity refers to the ability of measuring device to detect small differences in a quantity being measured. High sensitivity instruments may lead to drifts due to thermal or other effects, and indications may be less repeatable or less precise than that of the instrument of lower sensitivity.

Readability

Readability refers to the case with which the readings of a measuring instrument can be read. It is the susceptibility of a measuring device that has its indications converted into meaningful number. Fine and widely spaced graduation lines ordinarily improve the readability. If the graduation lines are very finely spaced, the scale will be more readable by using the microspore; however, with the naked eye the readability will be poor. To make micrometers more readable they are provided with vernier scale. It can also be improved by using magnifying devices.

Calibration

The calibration of any measuring instrument is necessary to measure the quantity in terms of standard unit. It is the process of framing the scale of the instrument by applying some standardized signals. Calibration is a pre-measurement process generally carried out by manufacturers. It is carried out by making adjustments such that the read out device produces zero output for zero measured input. Similarly, it should display an output equivalent to the known measured input near the full scale input value. The accuracy of the instrument depends upon the calibration. Constant use of instruments affects their accuracy. If the accuracy is to be maintained the instruments must be checked and recalibrated if necessary. The schedule of such calibration depends upon the severity of use, environmental conditions, accuracy of measurement required etc. As far as possible calibration should be performed under environmental conditions which are very close to the conditions under which actual measurements are carried out. If the output of a measuring system is linear and repeatable, it can be easily calibrated.

Repeatability

It is the ability of the measuring instrument to repeat the same results for the measurements for the same quantity, then:

– the measurement are carried out by the same observer;
– with the same instrument;
– under the same conditions;
– without any change in the location;
– without change in the method of measurement;
– the measurements are carried out in short intervals of time.

It may be expressed quantitatively in terms of dispersion of the results.

Reproducibility

Reproducibility is the consistency of pattern of variation in measurement, i.e. closeness of the agreement between the results of measurements of the same quantity, when individual measurements are carried out:

– by different observers;
– by different methods;
– using different instruments;
– under different conditions, location, time etc.

EXERCISE 1

Translate and remember the following words

accurate, accuracy, inaccurate, error, performance, precision, scatter, deviation, sensitivity, sense, amplification, slope, scale, ability, carry out, carry on, carry.

EXERCISE 2

Answer the following questions to the texts

1. What does the error in measurement depend on?
2. Is there any difference between accuracy and precision?
3. How is called the ratio of the scale spacing to the scale division value?
4. What makes micrometers more readable?
5. How to keep the device working properly?

EXERCISE 3

Pay attention to the translation of the following words and learn them by heart

reproducibility	відтворюваність, повторюваність
scale	масштаб, шкала
ability	вміння, здібність
schedule	розклад, графік, таблиця
precision	збіжність, погрішність
accuracy	точність, безпомилковість
scatter	розсіювати, розсіювання
value	значення, величина, показник
performance	параметри, продуктивність
repeatability	повторюваність, відтворюваність
average	середній
device	прилад, пристрій
ratio	коефіцієнт, співвідношення
drift	зсув, сповзання, відхилення
vernier scale	штангенциркуль

EXERCISE 4

Complete the dialogue using the verbs in brackets and the correct form of will, going to or present continuous. The cues in italics will help you

JOHN: What[1] *are* you *doing* (you/do) this weekend, Mike? (arrangement)

MIKE: I[2] .... (not/do) anything special. What about you? (arrangement)

JOHN: Well, I've promised to help a friend of mine, Alison, move a piano into her flat some time tomorrow.

MIKE: I[3] .... (give) you a hand if you like. (offer)

JOHN: I rather hoped you'd say that!

MIKE: What time[4] .... (you/meet) her? (arrangement)

JOHN: I'm not sure yet. I[5] .... (give/her/a ring) this afternoon to find out. (intention)

MIKE: O.K.

JOHN: I[6] .... (let/you/know) as soon as I can. (promise)

MIKE: O.K. I[7] .... (be) in all evening. (prediction)

JOHN: What? On a Friday evening?

MIKE: Yes, I[8] .... (watch) the U2 concert on TV. (intention)

JONH: O. K. I[9] .... (call) you later. (decision)

LESSON 6
TEXT 11

ERRORS IN MEASUREMENTS

It is never possible to measure the true value of a dimension, there is always some error. The error in measurement is the difference between the measured value and the true value of the measured dimension.

Error in measurement = Measured value - True value

The error in measurement may be expressed or evaluated either as an absolute error or as a relative error.

Absolute Error

True absolute error:

It is the algebraic difference between the result of measurement and the conventional true value of the quantity measured.

Apparent absolute error:

If the series of measurement are made then algebraic difference between one of the results of measurement and the arithmetical mean is known as apparent absolute error.

Relative Error:

It is the quotient of the absolute error the value of comparison used or calculation of that absolute error. This value of comparison may be the true value, the conventional true value or the arithmetic mean for series of measurement. The accuracy of measurement, and hence the error depends upon so many factors, such as:

– calibration standard;
– work piece;
– instrument;
– person;
– environment.

Types of Errors

1. Systematic Error

The error includes calibration errors, error due to variation in the atmospheric condition, variation in contact pressure etc. If properly analyzed, these errors can be determined and reduced or even eliminated hence also called controllable errors. All other systematic errors can be controlled in magnitude and sense except personal error. These errors result from irregular procedure that is consistent in action, repetitive in nature and is of constant and similar form.

2. Random Error

These errors are caused due to variation in position of setting standard and work-piece error. Due to displacement of level joints of instruments, due to backlash and friction, these errors are induced. Specific cause, magnitude and sense of these errors cannot be determined from the knowledge of measuring system or condition of measurement. These errors are non-consistent and hence the random errors.

3. Environmental Error

These errors are caused due to effect of surrounding temperature, pressure and humidity on the measuring instrument. External factors like nuclear radiation, vibrations and magnetic field also lead to error. Temperature plays an important role where high precision is required, e.g. while using slip gauge, due to handling the slip gauges may acquire human body temperature, whereas the work is at 20°C. A 300 mm length will go in error by 5 microns which is quite a considerable error. To avoid errors of this kind, all metrology laboratories and standard rooms worldwide are maintained at 20°C.

Calibration

It is very much essential to calibrate the instrument so as to maintain its accuracy. In case when the measuring and the sensing system are different it is very difficult to calibrate the system as a whole, so in that case we have to take into account the error producing properties of each component. Calibration is usually carried out by making adjustment such that when the instrument is having zero measured input then it should read out zero and when the instrument is measuring some dimension it should read it to its closest accurate value. It is important very much that calibration of any measuring system should be performed under the environmental conditions that are much closer to that under which the actual measurements are usually to be taken.

Calibration is the process of checking the dimension and tolerances of a gauge, or the accuracy of a measurement instrument by comparing it to the instrument/gauge that has been certified as a standard of known accuracy. Calibration of an instrument is done over a period of time, which is decided depending upon the usage of the instrument or on the materials of the parts from which it is made. The dimensions and the tolerances of the instrument/gauge are checked so that we can come to whether the instrument can be used again by calibrating it or is it worn out or deteriorated above the limit value. If it is so then it is thrown out or it is scrapped. If the gauge or the instrument is frequently used, then it will require more maintenance and frequent calibration. Calibration of instrument is done prior to its use and afterwards to verify that it is within the tolerance limit or not. Certification is given by making comparison between the instrument/gauge with the reference standard whose calibration is traceable to accepted National standard.

TEXT 12

DIMENSIONAL AND GEOMETRIC TOLERANCE

In the design and manufacture of engineering product a great deal of attention has to be paid to the mating, assembly and fitting of various components. In the early days of mechanical engineering during the nineteenth century, the majority of such components were actually mated together, their dimensions being adjusted until the required type of fit was obtained. These methods demanded craftsmanship of a high order and a great deal of very fine works was produced. Present day standards of quantity production interchangeability, and continuous assembly of many complex compounds, could not exist under such a system, neither could many of the exacting design requirements of modern machines be fulfilled without the knowledge that certain dimensions can be reproduced with precision on any number of components. Modern mechanical production engineering is based on a system of limits and fits, which while not only itself ensuring the necessary accuracies of manufacture, forms a schedule or specifications to which manufacturers can adhere.

In order that a system of limits and fits may be successful, following conditions must be fulfilled:

1. The range of sizes covered by the system must be sufficient for most purposes.
2. It must be based on some standards; so that everybody understands alike and a given dimension has the same meaning at all places.
3. For any basic size it must be possible to select from a carefully designed range of fit the most suitable one for a given application.
4. Each basic size of hole and shaft must have a range of tolerance values for each of the different fits.
5. The system must provide for both unilateral and bilateral methods of applying the tolerance.
6. It must be possible for a manufacturer to use the system to apply either a hole-based or a shaft-based system as his manufacturing requirements may need.
7. The system should cover work from high class tool and gauge work where very wide limits of sizes are permissible.

EXERCISE 1

Translate and remember the following words

dimension, conventional, mean, friction, backlash, pressure, humidity, maintain, tolerance, prior to, assembly, craftsmanship, range, quotient, treat, reveal, circular.

EXERCISE 2

Complete the sentences with the correct form of the verb in brackets

1. If you can lend me £10, I *'ll pay* (pay) you back tomorrow.
2. John would probably have to borrow money from the bank if his parents .... (not/give) him extra money every month.
3. Don't worry. My parents .... (not/mind) if you stay the night.
4. .... (you/buy) the shoes if they were in sale?
5. I .... (definitely/have) a party if I pass all my exams.

6. I'd come with you to the film if it .... (not/finish) so late.
7. If I didn't have extra English lessons, I .... (not/be able to) stay in this class.
8. How .... (you/get) home if you miss the last train?

EXERCISE 3

Answer the following questions to the texts

1. What is the error of measurement?
2. Is there any difference between true and apparent absolute errors?
3. How many types of errors do you know?
4. What is a standard temperature in a metrology laboratory?
5. What to do with a worn out device?

EXERCISE 4

Find pairs of antonyms

1) never	a) external
2) absolute	b) past
3) these	c) always
4) regular	d) rarely
5) this	e) irregular
6) much	f) relative
7) close	g) without
8) with	h) those
9) early	i) less
10) either…or	j) far
11) internal	k) that
12) frequently	l) neither…nor

LESSON 7
TEXT 13

MEASUREMENT UNCERTAINTY

In ordinary use the word «uncertainty» does not inspire confidence. However, when used in a technical sense as in «measurement uncertainty» or «uncertainty of a test result» it carries a specific meaning. It is a parameter, associated with the result of a measurement (e. g. a calibration or test) that defines the range of the values that could reasonably be attributed to the measured quantity. When uncertainty is evaluated and reported in a specified way, it indicates the level of confidence that the value actually lies within the range defined by the uncertainty interval.

Any measurement is subject to imperfections; some of these are due to random effects, such as short-term fluctuations in temperature, humidity and air-pressure or variability in the performance of the measurer. Repeated measurements will show variation because of these random effects. Other imperfections are due to the practical limits to which correction can be made for systematic effects, such as offset of a measuring instrument, drift in its characteristics between calibrations, personal bias in reading an analogue scale or the uncertainty of the value of a reference standard.

The uncertainty is a quantitative indication of the quality of the result. It gives an answer to the question, how well does the result represent the value of the quantity being measured? It allows users of the result to assess its reliability, for example for the purposes of comparison of results from different sources or with reference values. Confidence in the comparability of results can help to reduce barriers to trade.

A result is often compared with a limiting value defined in a specification or regulation. In this case, knowledge of the uncertainty shows whether the result is well within the acceptable limits or only just makes it. Occasionally a result is so close to the limit that the risk associated with the possibility that the property that was measured may not fall within the limit, once the uncertainty has been allowed for, must be considered.

Suppose that a customer has the same test done in more than one laboratory, perhaps on the same sample, more likely on what they may regard as an identical sample of the same product. Would we expect the laboratories to get identical results? Only within limits, we may answer, but when the results are close to the specification limit it may be that one laboratory indicates failure whereas another indicates a pass. From time to time accreditation bodies have to investigate complaints concerning such differences. This can involve much time and effort for all parties, which in many cases could have been avoided if the uncertainty of the result had been known by the customer.

The standard ISO/IEC 17025:2005 (*General requirements for the competence of testing and calibration laboratories*) specifies requirements for reporting and evaluating uncertainty of measurement.The problems presented by these requirements vary in nature and severity depending on the technical field and whether the measurement is a calibration or test. Consequently, calibration laboratories are used to evaluating and reporting uncertainty. In accredited laboratories the uncertainty evaluation is subject to assessment by the accreditation body and is quoted on calibration certificates issued by the laboratory.

TEXT 14

UNCERTAINTY EVALUATION

Uncertainty is a consequence of the unknown sign of random effects and limits to corrections for systematic effects and is therefore expressed as a quantity, i.e. an interval about the result. It is evaluated by combining a number of uncertainty components. The components are quantified either by evaluation of the results of several repeated measurements or by estimation based on data from records, previous measurements, knowledge of the equipment and experience of the measurement.

In most cases, repeated measurement results are distributed about the average in the familiar bell-shaped curve or normal distribution, in which there is a greater probability that the value lies closer to the mean than to the extremes. The evaluation from repeated measurements is done by applying a relatively simple mathematical formula. This is derived from statistical theory and the parameter that is determined is the standard deviation.

Uncertainty components quantified by means other than repeated measurements are also expressed as standard deviations, although they may not always be characterised by the normal distribution. For example, it may be possible only to estimate that the value of a quantity lies within bounds (upper and lower limits) such that there is an equal probability of it lying anywhere within those bounds. This is known as a rectangular distribution. There are simple mathematical expressions to evaluate the standard deviation for this and a number of other distributions encountered in measurement. An interesting one that is sometimes encountered, e. g. in EMC measurements, is the U-shaped distribution.

The method of combining the uncertainty components is aimed at producing a realistic rather than pessimistic combined uncertainty. This usually means working out the square root of the sum of the squares of the separate components (the root sum square method). The combined standard uncertainty may be reported as it stands (the one standard deviation level), or, usually, an expanded uncertainty is reported. This is the combined standard uncertainty multiplied by what is known as a coverage factor.

The greater this factor, the larger the uncertainty interval and, correspondingly, the higher the level of confidence that the value lies within that interval. For a level of confidence of approximately 95% a coverage factor of 2 is used. When reporting uncertainty, it is important to indicate the coverage factor or state the level of confidence, or both.

Sector-specific guidance is still needed in several fields in order to enable laboratories to evaluate uncertainty consistently. Laboratories are being encouraged to evaluate uncertainty, even when reporting is not required; they will then be able to assess the quality of their own results and will be aware whether the result is close to any specified limit. The process of evaluation highlights those aspects of a test or calibration that produce the greatest uncertainty components, thus indicating where improvements could be beneficial. Conversely, it can be seen whether larger uncertainty contributions could be accepted from some sources without significantly increasing the overall interval. This could give the opportunity to use cheaper, less sensitive equipment or provide justification for extending calibration intervals.

Uncertainty evaluation is best done by personnel who are thoroughly familiar with the test or calibration and understand the limitations of the measuring equipment and the influences of external factors, e.g. environment. Records should be kept showing the assumptions that were made, e.g. concerning the distribution functions referred to above, and the sources of information for the estimation of component uncertainty values, e.g. calibration certificates, previous data, experience of the behaviour of relevant materials.

EXERCISE 1

Translate and remember the following words

uncertainty, define, definition, defined, imperfection, perfect, fluctation, variability, variable, drift, quantity, quality, assess, assessment, access, sample, complaint, complain, evaluate, evaluation, deviation, bound, square, square root, highlight, improvements, improve, improved, prove, assumption, assume.

EXERCISE 2

Find pairs of antonyms and synonyms

1) import	a) plus
2) increase	b) facilitate
3) obligatory	c) need
4) vendor	d) export
5) limited	e) voluntary
6) requirement	f) thanks to
7) help	g) extremely
8) constant	h) decrease
9) due to	i) unlimited
10) drastically	j) customer
11) advantage	k) so
12) thus	l) permanent

EXERCISE 3

Answer the following questions to the texts

1. What is called «measurement uncertainty»?
2. Are there any random effects influencing imperfect measurement?
3. Will the result of measurement done by few laboratories be the same on the same product?
4. What is known to be a coverage factor?
5. What is the reason of encouraging laboratories to evaluate uncertainty?

EXERCISE 4

Transform the following active sentences into passive ones

1. Nobody will know the result of the election until late tonight.

....

2. The hotel staff clean the rooms thoroughly every day.

....

3. They have postponed the match until next Saturday.

....

4. They were raising money during the evening for charity.

....

5. Someone is repairing the video at this very moment.

....

6. They should have posted the parcel on Thursday.

....

7. They are going to redecorate the college during the holidays.

....

8. They discovered some Roman treasure in the middle of a cornfield in Sussex last week.

....

SECTION 2
HISTORY OF MEASUREMENTS

LESSON 1
TEXT 1

EGYPTIAN CUBIT

Let us first comment on what, in broad terms, is the meaning of measurement. It is associating numbers with physical quantities and so the earliest forms of measurement constitute the first steps towards mathematics. Once the step of associating numbers with physical objects has been made, it becomes possible to compare the objects by comparing the associated numbers. This leads to the development of methods of working with numbers.

The earliest weights seem to have been based on the objects being weighed, for example seeds and beans. Ancient measurement of length was based on the human body, for example, the length of a foot, the length of a stride, the span of a hand and the breadth of a thumb. There were unbelievably many different measurement systems developed in early times, most of them only being used in a small locality. One which gained a certain universal nature was that of the Egyptian cubit developed around 3000 BC. Based on the human body, it was taken to be the length of an arm from the elbow to the extended fingertips. Since different people have different lengths of arm, the Egyptians developed a standard royal cubit which was preserved in the form of a black granite rod against which everyone could standardize their own measuring rods.

To measure smaller lengths required subdivisions of the royal cubit. Although we might think there is an inescapable logic in dividing it in a systematic manner, this ignores the way that measuring grew up with people measuring shorter lengths using other parts of the human body. The digit was the smallest basic unit, being the breadth of a finger. There were 28 digits in a cubit, 4 digits in a palm, 5 digits in a hand, 3 palms (so 12 digits) in a small span, 14 digits (or a half cubit) in a large span, 24 digits in a small cubit and several other similar measurements. Now one might want measures smaller than a digit, and for this the Egyptians used measures composed of unit fractions.

It is not surprising that the earliest mathematics which comes down to us is concerned with problems about weights and measures for this indeed must have been one of the earliest reasons to develop the subject. Egyptian papyri, for example, contain methods for solving equations which arise from problems about weights and measures.

TEXT 2

BABYLONIAN FOOT

A later civilization whose weights and measures had a wide influence was that of the Babylonians around 1700 BC. Their basic unit of length was, like the Egyptians, the cubit. The Babylonian cubit (530 mm), however, was very slightly longer than the Egyptian cubit (524 mm). The Babylonian cubit was divided into 30 kus which is interesting since the kus must have been about a finger's breadth but the fraction $^1/_{30}$ is one which is also closely connected to the Babylonian base 60 number system. A Babylonian foot was $^2/_3$ of a Babylonian cubit.

Now we commented in the previous paragraph about a subdivision of a Babylonian unit which was closely related to their number system. This presents a problem as we look at developing systems of measures. Many early number systems tended to be based on ten for the obvious reason that we have ten fingers on which to count. Most such systems were not positional systems, so the reason to use multiples of ten in measurement subdivision was less strong. Also ten is an unfortunate number into which to divide a unit of measurement since it only divides naturally into $^1/_2$, $^1/_5$, $^1/_{10}$. Basing subdivisions on 12, mean that $^1/_2$, $^1/_3$, $^1/_4$, $^1/_6$, $^1/_{12}$ are natural subdivisions, giving much more range for trading quantities. However, since most measuring systems seem to have grown up as a combination of different «natural» measures, no decision about a number to subdivide by would arise. One exception, and the earliest known decimal system of weights and measures, is the Harappan system.

Harappan civilisation flourished in the Punjab between 2500 BC and 1700 BC. The Harappans appear to have adopted a uniform system of weights and measures. An analysis of the weights discovered in excavations suggests that they had two different series, both decimal in nature, with each decimal number multiplied and divided by two. The main series has ratios of 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200 and 500. Several scales for the measurement of length were also discovered during excavations. One was a decimal scale based on a unit of measurement of 1.32 inches (3.35 centimetres) which has been called the «Indus inch». Of course ten units is then 13.2 inches (33.5 centimetres) which is quite believable as the measure of a «foot», although this suggests the Harappans had rather large feet! Another scale was discovered when a bronze rod was found to have marks in lengths of 0.367 inches. It is certainly surprising the accuracy with which these scales are marked. Now 100 units of this measure is 36.7 inches (93 centimetres) which is about the length of a stride. Measurements of the ruins of the buildings which have been excavated show that these units of length were accurately used by the Harappans in their construction.

EXERCISE 1

Translate and remember the following words

constitute, constitution, compare, compared, comparing, comparator, foot, feet, comparable, seed, bean, stride, span, breadth, thumb, Egypt, Egyptian, BC, AD, arm, elbow, extend, extending, extended, royal cubit, preserve, preserved, preserving, rod, divide, division, subdivision, finger, palm, influence, range, inch.

EXERCISE 2

Answer the following questions to the texts

1. What parts of human body were used by ancient people for length measurement?
2. Who made a standard royal cubit?
3. Do you know the size of a Babylonian cubit?
4. Can you name where the earliest decimal system of weights and measures was used?
5. Is 10 or 12 more natural for further subdivision?

EXERCISE 3

Write the simple past and the past participle of each of the following verbs

	Simple past	Past participle
run	ran	run
speak	....	....
fly	....	....

drive	....	....
throw	....	....
ride	....	....
spend	....	....
put	....	....
give	....	....
teach	....	....
forget	....	....
know	....	....

EXERCISE 4

Translate the following sentences paying attention to Participles

1. Radiowaves are emitted from a conductor carrying the alternating current.
2. Being heated magnetized steel loses its magnetism.
3. X-rays are produced when matter is bombarded by a fast moving stream of negatively charged particles.
4. The current passing through a wire will heat it.
5. Computers sort the data received.
6. The experiments referred to in our article demonstrate new approaches to standards.
7. The method suggested by a designer was of great practical importance.
8. Having been published in 1687, the three laws of motion are still the basic for many scientific achievements.
9. The temperature used depended on the substances entering the reaction.
10. The program developed was offered by NIST.

LESSON 2
TEXT 3

EARLY MEASUREMENTS IN EUROPE

European systems of measurement were originally based on Roman measures, which in turn were based on those of Greece. The Greeks used as their basic measure of length the breadth of a finger (about 19.3 mm), with 16 fingers in a foot and 24 fingers in a Greek cubit. These units of length, as were the Greek units of weight and volume, were derived from the Egyptian and Babylonian units. Trade, of course, was the main reason why units of measurement were spread more widely than their local areas. In around 400 BC Athens was a centre of trade from a wide area. The Agora was the commercial centre of the city and we know from the plays of Aristophanes the type of noisy dealing which went on there. Most disputes would arise over the weights and measures of the goods being traded, and there a standard set of measures kept in order that such disputes might be settled fairly. The size of a container to measure nuts, dates, beans and other such items, had been laid down by law and if a container did not conform to the standard, its contents were confiscated and the container destroyed.

The Romans adapted the Greek system. They had as a basis the foot which was divided into 12 inches (or ounces for the words are in fact the same). The Romans did not use the cubit but, perhaps because most of the longer measurements were derived from marching, they had five feet equal to one pace (which was a double step, what is the distance between two consecutive positions of where the right foot lands as one walks). Then 1,000 paces measured a Roman mile which is reasonably close to the British mile as used today. This Roman system was adopted, with local variations, throughout Europe as the Roman Empire spread. However, if one looks at a country like England, it was invaded at different times by many peoples bringing their own measures. The Angles, Saxons and Jutes brought measures such as the perch, rod and furlong. The fathom has a Danish origin, and was the distance from fingertip to fingertip of outstretched arms while the ell was originally a German measure of woollen cloth.

In England and France measures developed in rather different ways. We have seen above how the problem of standardization of measures always presented problems, and in early 13th century England a royal ordinance *Assize of Weights and Measures* gave a long list of definitions of measurement to be used. On one hand it was an extremely successfully attempt at standardization for its definitions lasted for nearly 600 years. The Act of Union between England and Scotland decreed that these standards would hold across the whole of Great Britain. Locally, however, these standards were not always adhered to and districts still retained their own measures. Of course, although an attempt had been made to standardize measures, no attempt had been made to rationalize them and Great Britain retained a bewildering array of measures which were defined by the ordinance as rather strange subdivisions of each other. Scientists had long seen the benefits of rationalizing measures and those such as Wren had proposed a new system based on the yard defined as the length of a pendulum beating at the rate of one second in the Tower of London.

TEXT 4

IDEAS OF INTERNATIONAL SYSTEM OF MEASUREMENT

In France, on the other hand, there was no standardization and as late as 1788 Arthur Young wrote in «*Travels during the years* 1787, 1788, 1789» published in 1793:

In France the infinite perplexity of the measures exceeds all comprehension. They differ not only in every province, but in every district and almost every town.

In fact it has been estimated that France had about 800 different names for measures at this time, and taking into account their different values in different towns, around 250,000 differently sized units. To a certain extent this reflected the powers which resided in the hands of local nobles who had resisted all attempts by the French King over centuries to standardize measures. Diderot and d'Alembert in their *Encyclopédie* greatly regretted the diversity, but saw no possible acceptable solution to the problem. Some French scientists had proposed uniform systems at least 100 years before the French Revolution. Gabriel Mouton, in 1670, had suggested that the world should adopt a uniform scale of measurement based on the mile, which he defined as the length of one minute of the Earth's arc. He proposed that decimal subdivisions should be used to determine the lengths of shorter units of length. Lalande, in April 1789, proposed that the measures used in Paris should become national ones, an attempt at standardization but not rationalization. This proposal was put to the National Assembly in February 1790 but in March a different suggestion was made. Talleyrand put to the National Assembly a proposal due to Condorcet, namely that a new measurement system be adopted based on a length from nature. The system should have decimal subdivisions, all measures of area, volume, weight etc. should be linked to the fundamental unit of length. The basic length should be that of a pendulum which beat at the rate of one second. The proposal was adopted.

This proposal was not designed to bring in a French system of measurement but to design an international system of measurement, so agreement was sought from other countries. An immediate problem was that the pendulum length depended on the latitude at which the experiment was performed so latitude had to be chosen. The French proposed 45° which conveniently fell in France, the British proposed London, and the United States proposed the 38th parallel which was conveniently close to Thomas Jefferson's estate. Diplomatic wording allowed an international agreement to be reached, but in March 1791 Borda, as chairman of the Commission of Weights and Measures, proposed using instead of the length of a pendulum, the length of $^{1}/_{10,000,000}$ of the distance from the pole to the equator of the Earth. They might have got international agreement on this had they not declared that this distance would be determined by an accurate survey of the distance between Dunkerque and Barcelona. The Royal Society in London declared this was based on a measurement of France, the Americans were not prepared to accept the word of the French mathematicians for its length and even in France it was claimed that the whole project was really proposed in order to gain information on the shape of the Earth. Indeed, probably Laplace and others were more interested in finding the shape of the Earth rather than the length of the metre.

EXERCISE 1

Translate and remember the following words

origin, originally, originate, volume, data, dates, datum, lay down, destroy, derive, through, throughout, although, adopt, adopted, adoption, adhere, retain, rate, pendulum, infinite, take into account, power, accept, acceptance, acceptable, accepted, accepting, suggest, suggestion, instead of, rather than, area.

EXERCISE 2

Answer the following questions to the texts

1. Who laid the foundation of the European system of measurement?
2. Do you know the Greek units of weight and volume?
3. How long is a pace?
4. What countries made an impact into English measures?
5. What was accepted as the first basic unit of length?

EXERCISE 3

Write the opposite of these adjective in the correct column

Adjective	Add prefix	Change suffix
usual	unusual	–
thoughtless	–	thoughtful
careless	....	....
emotional	....	....
harmful	....	....
kind	....	....
original	....	....
safe	....	....
selfish	....	....
tactless	....	....

EXERCISE 4

Translate the following sentences paying attention to the Absolute Participle Complex

1. Thermistors are very sensitive to light, this property being very important.
2. The principle of action being extremely simple, the device was widely used for various purposes.

3. Many metals are good conductors, silver presenting one of them.

4. The speed of light being very great, we can't measure it by ordinary methods.

5. The designers used some new scales, the characteristics remain the same.

6. The engineers using semiconductors, good results have been achieved.

7. Some radioactive materials have been found in nature, uranium being one of them.

8. Transistors being very sensitive to light, engineers use this property.

9. The current in a circuit was decreased when the resistance was increased, other factors remaining the same.

10. Electron moving through conductor, electrical energy is generated.

LESSON 3
TEXT 5

METRIC SYSTEM

Delambre and Méchain measured the meridian from Dunkerque and Barcelona between 1792 and 1798. However, between these dates the French Revolution progressed to the stage where the Académie des Sciences was abolished in August 1793 but before that Borda, Lagrange and Laplace had computed a provisional value for the metre based on the survey carried out by Cassini de Thury in 1740. The metric system was passed into law by the National Assembly and a metre bar together with a kilogram weight were dispatched to the United States in the expectation that they would adopt the new measures. Congress hesitated because the standards were provisional. Britain became hostile to the metre as did Germany which wanted a standard based on the pendulum.

An International Commission began work in September 1798 to replace the provisional values with precise ones computed from the data collected by Delambre and Méchain. By June of the following year the Commission had produced a platinum bar which became the official definition of the metre, and in September 1799 the metre was required by law to be used in the Paris region. However, as one might expect, introducing the new measure was easier said than done. Part of the problem was that Greek and Latin prefixes like kilo- and centi- had been proposed to help make the new system internationally acceptable but were strongly disliked in France. It was also a law which was essentially impossible to enforce and, again as one might expect, many traders took the opportunity to cheat their customers. Teaching the metric system became compulsory in schools and the hope was that at least the next generation would accept it even if the current generation would not.

In November 1800 an attempt was made to make the system more acceptable by dropping the Greek and Latin prefixes and reinstating the older names for measures but with new metric values. In September of the following year it became illegal to use any other system of weights and measures anywhere in France but it was largely ignored. It did not last long for, on 12 February 1812, Napoleon returned the country to its former units. The metre standard was still used in the sense that a fathom was declared to be 2 metres, there were 6 feet in a fathom and 12 inches in a foot.

Now, despite this retrograde move, Napoleon had a major effect on the spread of the metric system. French conquests of the Low Countries had seen the metric system introduced there and, on the defeat of Napoleon and the restoring of monarchy in those countries, they retained the system. The decimal metric system was required to be used by law in the Low Countries in 1820. In 1830 Belgium became independent of Holland and made the metric system, together with its former Greek and Latin prefixes, the only legal measurement system. Perhaps the fact that the French had scrapped the system they invented helped its acceptance in other European countries. In 1840 the French government reintroduced the metric system but it took many years before use of the old measures died out.

TEXT 6

BRITISH OPPOSITION

In the 1860s Britain, the United States and the German states all made moves towards adopting the metric system. It became legal in Britain in 1864 but a law which was passed by the House of Commons to require its use throughout the British Empire never made it through its final stages on to the statute books. Similarly in the United States it became legal in 1866, although its use was not made compulsory. The German states passed legislation in 1868 which meant that on the unification of these states to form Germany, use of the metric system was made compulsory.

It is interesting that many leading British scientists were opposed to the introduction of the metric system in Britain in 1864, which is one reason that it only became legal but not compulsory. George Airy and John Herschel argued strongly against it, as did William Rankine who composed the poem *The Three-Foot Rule*:

Some talk of millimetres, and some of kilograms,
And some of decilitres, to measure beer and drams;
But I'm a British Workman, too old to go to school,
So by pounds I'll eat, and by quarts I'll drink, and I'll work by my three foot rule.
A party of astronomers went measuring the Earth,
And forty million metres they took to be its girth;
Five hundred million inches, though, go through from Pole to Pole;
So lets stick to inches, feet and yards, and the good old three foot rule.

In 1870 an International Conference was convened by the French in Paris. Invitations had been sent to scientists from countries around the world with the aim of improving international scientific cooperation by having the metric system as the world-wide standard. War broke out between France and Prussia just before the delegates were due to arrive, however, and the German delegation did not attend. Wishing that any decision be a truly international one, the conference was postponed and met again in 1872. The outcome was the setting up of the International Bureau of Weights and Measures, to be situated in Paris, and the Convention of the Metre of 1875 which was signed by seventeen nations. Further countries signed up over the following years.

In 1889 the International Bureau of Weights and Measures replaced the original metre bar in Paris by a new one and at the same time had copies of the bar sent to every country which had signed up to the Convention of the Metre. The definition now became the distance between two lines marked on a standard bar made from 90 percent platinum and 10 percent iridium. This remained the standard until 1960 when the International Bureau of Weights and Measures adopted a more accurate standard for international science when it defined the metre in terms of the wavelength of light emitted by the krypton-86 atom, namely 1,650,763.73 wavelengths of the orange-red line in the spectrum of the atom in a vacuum. The metre was redefined again in 1983, this time as the distance which light travels in a vacuum in $^{1}/_{299,792,458}$ seconds. This remains the current definition. Note that in all these redefinitions, the length of the metre was always taken as close as possible to the value fixed in 1799 by data from the Delambre-Méchain survey.

Notice that the current definition defines the metre in terms of the second. Now Borda had argued against using the length of a pendulum which beats at the rate of one second to define the metre in 1791 on the reasonable grounds that the second was not a fixed unit but could change with time. Indeed the second, then defined as 1/86,400 of the mean solar day, does change but a fixed definition was introduced in 1956 by the International Bureau of Weights and Measures, as $^{1}/_{31,556,925.9747}$ of the length of the tropical year 1900. Although this fixed the value, it was seen as an unsatisfactory definition since the length of the year 1900 could never be measured after 1900. It was changed in 1964 to 9,192,631,770 cycles of radiation associated with a particular change of state of the caesium-133 atom. By 1983 when the metre was defined in terms of the second, Borda's objection was no longer valid as the definition of the second by then did not have the astronomical definition which was indeed variable.

EXERCISE 1

Translate and remember the following words

abolish, compute, computing, computed, computer, dispatch, hostile, likes, dislike, law, lawyer, require, requirement, required, cheat, cheap, compulsory, despite, in spite of, similar, similarly, argue, attend, decision, decide, indeed, valid, validation, definition, define, variable, vary.

EXERCISE 2

Answer the following questions to the texts

1. Who measured the meridian of the Earth?
2. What was the reason of the refusal of many countries to adopt metric system?
3. How to convince people to trust and accept something new and unusual?
4. What made France in winter 1812 stop using new metric system? Did it have any impact on its further adoption?
5. When and where was the International Bureau of Weights and measures set up?

EXERCISE 3

Complete the table

Noun	Adjective	Adverb
accident	accidental	accidentally
....	energic	....
music	....	....
....	....	emotionally
....	intellectual	....
....	natural	....
....	critical	....
....	fortunate	....
physique	....	....

EXERCISE 4

Use words from the table above to complete the sentences

1. She found the literature course intellectually stimulating.
2. After her operation she was in a .... condition for several days.
3. Good disco music gives me the .... to dance all night.
4. All new theatres have special access and seating for .... handicapped people.
5. It was a very violent storm, but .... no one was hurt.
6. The country is in the middle of a serious economic ....
7. Unfortunately, Gary didn't have the .... strength to be a dancer.
8. He broke the glass .... while he was washing up.

LESSON 4
TEXT 7

NECESSITY OF TIMEKEEPING

Time has played a central role in mathematics from its very beginnings, yet it remains one of the most mysterious aspects of the world in which we live. The beginnings of civilization on Earth required knowledge of the seasons, and the mysteries surrounding the length of the year, the length of the day and the length of the month began to be studied. All the world religions gave time a central role, be it in astrology, stories of creation, cyclical world histories, notions of eternity, etc. Philosophers have tried to come to grips with the concept; some have argued that time is a basic property of the universe while others have argued that it is an illusion or a property of the human mind and not of the world. A huge effort has been put into making devices to measure time with ever increasing accuracy from the beginnings of recorded history to the present day.

Quantum mechanics and relativity theory in the 20th century have shown the complexities, and sometime apparent paradoxes, in the notion of time. Yet basic mathematics takes time as understood and develops the calculus around a particle whose position at time t is given by $x(t)$, its velocity is $^{dx}/_{dt}$, the derivative of $x(t)$ with respect to time, and its acceleration is the second derivative. This requires time to be continuous and a time interval to always be divisible, yet quantum theory tells us that time is quantized and quite unlike mathematical time which forms the basis of applied mathematics.

Mathematics almost certainly began through the study of time, particularly the need to record sequences of events. An understanding of the seasons is vital for the successful growing of crops. When should crops be planted? When would the rains come? When would rivers flood? When should one harvest the crops? The natural timekeepers in the sky are the daily passage of the sun and the monthly phases of the moon. The fact that knowing the length of a year was vitally important, yet much less visible from the timekeepers in the sky, led to calculation. It was also necessary to count days and months and this gave rise to calendars. The earliest evidence of timekeeping goes back around 20000 years; evidence from markings made on sticks and bones in Europe around this time are thought to be records of days between successive new moons. Many ancient calendars were created but as an example let us look briefly at an Egyptian one from around 4500 BC.

TEXT 8

CALENDARS

It was important for the Egyptians to know when the Nile would flood and so this played a large role in the way their calendar developed starting from an early version around 4500 BC which was based on months. From 4236 BC the beginning of the year was chosen as the heliacal rising of Sirius, the brightest star in the sky. The heliacal rising is the first appearance of the star after the period when it is too close to the sun to be seen. For Sirius this occurs in July and this was taken to be the start of the year. The Nile flooded shortly after this so it was a natural beginning for the year. The heliacal rising of Sirius would tell people to prepare for the floods. The year was computed to be 365 days long and by 2776 BC it was known to this degree of accuracy. A civil calendar of 365 days was created for recording dates. Later a more accurate value of $365^{1}/_{4}$ days was worked out for the length of the year but the civil calendar was never changed to take this into account. In fact two calendars ran in parallel, the one which was used for practical purposes such as the sowing of crops, harvesting crops etc. being based on the lunar month.

Dividing the year into months was natural, yet complicated since there were not an integral number of months in a year. Similarly dividing the month into days was complicated for the same reason. A day was a long period of time and there was clearly a need for dividing the day, but it was less obvious how this might be done. In around 3000 BC the Sumerians divided the day into 12 periods, and divided each of these periods into 30 parts. The Babylonian civilization, which grew up around 1000 years later, in the same area of present day Iraq as that of the earlier Sumerians, divided the day into 24 hours, each hour into 60 minutes, each minute into 60 seconds. It is their division of the day which gives us the widely used modern units of time. We should note, of course, that these modern units, although deriving from the Babylonian versions, are today not defined from astronomical data. We should also note that many early units of time varied throughout the year as the length of the day and night varied with the seasons.

Now units of time require some way of measurement and, not surprisingly, because of their astronomical definitions the early devices to measure time used the sun. From around 3500 BC the gnomon was used, consisting of a vertical stick or thin monument whose shadow indicated the time of day. Later, by about 1500 BC, the sundial was in use. The problem with the sundial was that the sun took a different path through the sky throughout the year. To ensure that the sundial registered roughly the correct time all the year round the gnomon had to be set at exactly the correct angle. The sundial developed into a more accurate instrument with the introduction of the hemispherical sundial around 300 BC. By the time the Roman architect Vitruvius wrote *De architectura* shortly before 27 BC, he was able to describe 13 different designs of sundial in Book 9 of his work.

Of course, the sun could not be used to tell the time at night and *clepsydras* or water clocks were in use in Egypt by 1500 BC. Water ran out through a hole in the bottom of a vessel, the inside of which had lines to indicate the passage of time. Early versions did not allow for the fact that the water ran out more slowly as the pressure dropped. Sand was also used in the still familiar hour glass where sand trickles from a container, taking a set length of time to run out.

EXERCISE 1

Translate and remember the following words

remain, remind, mystery, eternity, eternal, effort, effortless, particle, velocity, derivative, bases, basis, particle, particular, particularly, timekeeping, vital, vitally, curriculum vitae, evidence, flood, heliacal, work out, sowing, harvesting, definition, define, defined, defining, clepsydra, bottom, top, inside.

EXERCISE 2

Answer the following questions to the texts

1. Do you know the formula of time? Who can argue it?
2. Why did people begin to observe time and start timekeeping?
3. When was New Year's celebration in old Egypt?
4. Who divided the day into 24 hours, each hour into 60 minutes…?
5. What type of clocks was used by ancient people at night?

EXERCISE 3

Write each adjective with the correct prefix (un-/in-/dis-/ir-) which forms its opposite

ambitious
loyal
enthusiastic
experienced
replaceable
honest
responsible
organized
reliable
sensitive
efficient

EXERCISE 4

Translate the following sentences paying attention to different Infinitive forms and functions

1. The programmer must do a program to give accurate instructions to the computer.
2. To do the program for a computer is the main duty of the programmer.
3. To do the program the programmer must have a good understanding of the problem.
4. To build up a magnetic field requires the expenditure of a certain amount of energy.

5. The best way to understand the current is to see how it acts in a circuit.
6. The air must be compressed to occupy a smaller volume.
7. Cells to be connected in parallel should be of the same type and voltage.
8. The designer has to test the system to be used in the laboratory.
9. The purpose of the experiment is to convert heat directly into electricity.
10. Academic Yoffe was the first to notice the great use of transistors for future technology.

LESSON 5
TEXT 9

MECHANICAL CLOCKS

There was some progress in clocks to measure periods of time going in the period when St. Augustine was contemplating the puzzle. The developments were not, however, in new types of clock, merely in improved designs of sundials and water clocks. Mechanical devices were added to water clocks to strike bells, move hands on a dial, open doors to display figures like the modern cuckoo clock but these did nothing to improve the basic time keeping. There was much interest in clocks, however, and in the first century BC, the Tower of the Winds was constructed in Athens. This had both sundials, and water clocks which drove mechanical devices to display the hour on a 24 hour scale. It had other features relating to time such as displaying the season, and various astrological dates.

Progress in timekeeping in Europe was non-existent from around 500 AD to 1300 AD, but in other countries progress did continue with mechanical clocks being introduced in China. However, the invention of the verge escapement in Europe in the 14^{th} century led to a revolution in mechanical clocks. The verge escapement worked by having a wheel with cogs which was prevented from spinning by a pair of metal leaves which moved up and down to allow the cog wheel to move forward one cog at a time. The leaves were attached to a foliot, a weighted crossbar, on which the small weights could be moved back and forward to adjust the rate at which the bar oscillated. The whole of the mechanism was powered by heavy weights which drove the cog wheel. Such clocks were more accurate than any of the earlier ways of measuring time, but they were very difficult to adjust to obtain that accuracy. The speed which the clock ran at was still completely dependent on the power applied by the weights, and by the amount of friction in the mechanism.

An early example of such a mechanical clock was the one constructed in Strasbourg between 1352 and 1354. The Clock of the Three Kings was built in Strasbourg Cathedral and stood twelve metres high. Clocks at this time needed to be big so that the weights had a long drop, otherwise the weights required to be wound up frequently, but the Strasbourg clock was more than just a clock for it related time to all its astronomical origins. In addition, the clock was a work of art in terms of both the decoration and the novelty of the automata. The lowest portion of the clock consisted of a calendar, above which was an astrolabe, while above that again there was a statue of the Virgin and Child. Every hour figures of the Magi appeared and bowed before the Virgin and Child while chimes rang out and an automaton cock crowed and flapped its wings.Time had gained a certain status which it had not enjoyed earlier. Mechanical clocks were an important status symbol but towns only required their own local times, and it would be another 500 years before the advent of the train made standard time zones a necessity.

TEXT 10

LONGTITUDE AND ABSOLUTE TIME

During the 16th century the solution of problems relating to time became of utmost importance because of its relation to finding the longitude. In an age of exploration on a world scale, determining position became a crucial problem and much effort was put into its solution. The realization that an absolute time standard for the world would allow the calculation of the longitude of any position by comparison with local time was a major driving force in efforts to devise accurate clocks. It also led to a clear distinction in people’s minds between an absolute time and a local time.

In the 17th century Galileo discovered a «clock» in the sky which recorded «absolute time», namely the times of the eclipses of Jupiter’ s moons. Theoretically this provided a solution to the longitude problem, but in practice observing the eclipses of Jupiter’s moons from the deck of a ship was essentially impossible. Several large prizes were offered for a solution to the problem of determining longitude and Galileo tried the persuade the Spanish Court in 1616 that he could determine absolute time using Jupiter’s moons and, after failing to convince them, tried to persuade Holland of his method when they offered a large prize in 1636.

This was not the only contribution Galileo made to the study of time. Long before his discovery of Jupiter’s moons he discovered the fundamental property of the pendulum in 1583. While attending services in Pisa cathedral be noticed that a swinging lamp in the cathedral took the same time to swing irrespective of how large the displacement. Of course one might reasonably ask how he discovered this since in Galileo’s time there was no device to accurately measure small intervals of time. In fact Galileo used the biological clock built into his body, for he used his own pulse to compare the time taken for the pendulum to swing. Galileo does not seem to have realized that his discovery might be used to design an accurate clock until many years later, but around 1640 he did design the first pendulum clock. Galileo died in early 1642 but the significance of his clock design was certainly realized by his son who tried to make a clock to Galileo’s design, but failed.

The first to succeed in making a pendulum clock was Huygens in 1656. This invention brought a new accuracy to the measurement of time, with his early versions achieving errors of less than 1 minute a day. With a later improved design Huygens was able to build a clock accurate to within 10 seconds in a day. Hooke used the natural oscillation of a spring to control the balance of a clock and some years later Huygens also experimented with a balance wheel and spring assembly which can still be found in mechanical wrist watches.

EXERCISE 1

Translate and remember the following words

sundial, strike, striking, astonishing, display, clock, watch, feature, future, invention, invent, inventor, lead, led, leader, wheel, forward, back, adjust, adjustment, oscillator, oscillate, statue, advent, longitude, solution, solve, solvable, unsolved, displacement, fail, failure, wrist watch.

EXERCISE 2

Answer the following questions to the texts

1. What discovery caused a revolution in mechanical clocks?
2. What mechanical clock is mentioned in the text both as an accurate mechanism and as a masterpiece?
3. When and why the problem of longtitude became urgent?
4. What solution was offered by Galileo?
5. Who made a pendulum clock? Who also contributed into it?

EXERCISE 3

Circle the correct preposition in these sentences

1. There has been a substantial fall *of/in* temperature this week.
2. Did you hear the result *of/from* the football match?
3. They have made an urgent request *to/for* international aid.
4. There has been no improvement *in/of* his health since Monday.
5. What sort of relationship do you have *to/with* your parents?
6. The solution *to/of* problem is quite simple: we need more time.
7. Have you had any more complaints *with/about* the food?
8. I am shocked at the increase *in/of* the price of CDs.

EXERCISE 4

Translate the following sentences paying attention to Infinitive complexes

1. We know Pascal to be the first inventor of the mechanical computer.
2. Our engineers want the complex problems to be solved by computers.
3. They watched the vernier scale be used in practice.
4. The ancients thought the current to be the invisible fluid.

5. We consider nuclear energy to be the prime source of heat energy.

6. We know an alternating current to be continually changing by rising, falling and changing direction.

7. We know pressure to be required for forcing water through a pipe.

8. He appears to know everything about the properties of the TV-set.

9. The input and output units are known to be the parts of a computer.

10. New developments in materials are believed to be due to new manufacturing forms and vice versa.

LESSON 6

TEXT 11

CLOCKS AND WRISTWATCHES

When we think of a clock, we picture the familiar face with numbers, two hands and maybe a sweeping second hand, but that picture is too narrow. Over the centuries, people have developed all manner of machinery to tell time. The Chinese invented the incense clock between 960 and 1279, and its use spread throughout eastern Asia. In one type of incense clock, metal balls were attached to the incense with string. When the incense burned up, the ball would drop, sounding a gong that announced the hour.

Other clocks used color, and some used different scents at different times. Candle clocks had numbered markings down their lengths. When the candle burned down to a mark, the dial noted the time. Sometimes the lines were not numbered, and the person using the candle clock would need to know how long it took the candle to burn down to each mark.

The discovery in the 1400s that coiled springs could move the hands of a clock made smaller timepieces possible. Pocket watches were the order of the day for men for centuries, and wristwatches were considered jewelry – but for women only. All of those fashion rules changed during World War I, when taking out a pocket watch was impossible during battle. For most of the remainder of the 20th century, almost everyone – especially men – wore wristwatches. The gift of a watch symbolized your passage into manhood, and many companies presented you with a gold watch upon your retirement.

As we advance through the 21st century, the ubiquitous wristwatch may once again be fading from style and use. While at work, we can check the time on the computer's clock, and while we're out, our cell phones or MP3 players display accurate times around the clock. Still, an informal survey by a «Houston Chronicle» reporter showed that many people say they will never give up their wristwatches.

Days, hours and minutes are the same in all countries, but how people view them varies. In some countries – Germany, for instance, – punctuality is all-important. Being late for an appointment is the height of rudeness and may earn you a rebuke from your host. In laid-back Brazil, however, time often is ignored, and locals sometimes run hours late for meetings, doctor appointments, even college classes.

Springs or weights operate the gears inside a mechanical clock, but when the quartz clock came along, electricity of a sort began to move the hands. The mineral quartz – usually with the help of a battery – powers a quartz clock. Quartz is piezoelectric, meaning that when a quartz crystal is squeezed, it generates a small current of electricity, which causes the crystal to vibrate when the current passes through. All quartz crystals vibrate at the same frequency. Quartz clocks use a battery to create the crystal vibration and a circuit to count the vibrations. The circuit uses this information to generate one pulse every second. These pulses power the gears in a mechanical clock or power the display in a digital clock. Quartz clocks still dominate the market because of their accuracy and the low production cost.

Although the name sounds rather menacing, atomic clocks are not dangerous at all. They measure time by tracking how long it takes for an atom to switch its energy state from positive to negative and back again. The official time standard for the United States is set by NIST F-1, the cesium atomic clock at the National Institute of Science and Technology (NIST) in Boulder, Colo. NIST F-1 is a fountain clock, named for the movement of atoms. Scientists introduce cesium gas into the clock's vacuum chamber and then direct infrared laser beams at 90-degree angles to the center of the chamber. The lasers force the atoms together into a ball, which gets tossed through a microwave-filled area. The scientists measure the number of atoms with altered states and tune the microwaves to different frequencies until most of the atoms are altered. This final frequency is the natural resonance frequency for cesium atoms and constitutes the number of oscillations that define a second. It sounds complicated, but it results in a worldwide standard for seconds; clocks around the world can automatically set to the NIST standard by time zone. The atomic clock keeps track of time on the most miniscule level, and calendars help us cope with larger blocks of time.

TEXT 12

FIRST WEIGHT STANDARDS

Each succeeding civilization added to mankind's knowledge, building an accumulation of measuring standards and techniques. Some contributed weight measures. Others showed us how to measure time. Still others gave us methods for surveying big areas of land and establishing boundaries.

In techniques for measuring weights, the Babylonians made important improvements upon the invention of the balance. Instead of just comparing the weights of two objects, they compared the weight of each object with a set of stones kept just for that purpose. In the ruins of their cities, archaeologists have found some of these stones finely shaped and polished. It is believed that these were the world's first weight standards.

The Babylonians used different stones for weighing different commodities. In modern English history, the same basis has been used for weight measurements. For the horseman, the «stone» weight was 14 pounds. In weighing wool the stone was 16 pounds. For the butcher and fishmonger, the stone was 8 pounds. The only legal stone weight in the imperial system was 14 pounds.

The Egyptians and the Greeks used a wheat seed as the smallest unit of weight, a standard that was very uniform and accurate for the times. The grain is still in limited use as a standard weight. However, wheat seeds are no longer actually put in the pan of the balance scale. Instead, a weight that is practically the same as that of an average grain of wheat is arbitrarily assigned to the grain. The Arabs established a small weight standard for gold, silver and precious stones which very often were a part of trade or barter deals. To weight the small valuable quantities, they used as a weight standard a small bean called a karob. This was the origin of the word carat which jewelers still use to express the weight of gems and precious metals.

In trading between tribes and nations, many of these methods for measuring weights and distances gradually became intermixed, particularly by the Romans who spread this knowledge throughout the known world at that time, also adding some standards of their own. As the Roman soldiers marched, they kept track of the distance they travelled by counting paces. A pace was the distance covered from the time one foot touched the ground until that same foot touched the ground again, or the length of a double step.

EXERCISE 1

Translate and remember the following words

face, hands, incense, insect, string, spring, scent, candle, burn, battle, gift, retirement, advance, cell phone, menace, menacing, alter, altered, alternating, alternative, boundary, stone, butcher, bean.

EXERCISE 2

Answer the following questions to the texts

1. What unusual now types of clocks can you name?
2. Receiving a wristwatch meant…?
3. Is it still popular to wear a wristwatch? What type?
4. Who is considered to be very punctual?
5. Is atomic clock dangerous?

EXERCISE 3

Translate these synonyms and remember them

desire (v), want, wish
avoid (v), escape, avert, evade
total (adj), entire, complete, whole
should (v), must, have to
assume (v), suppose
vary (v), change, differ, alter
condition (n), circumstance
appropriate (adj), suitable, proper
since (conj), as, for
extract (v), draw out

EXERCISE 4

Translate the following sentences paying attention to Infinitive complexes

1. He described the principle to be used in all modern systems.
2. P. H. Yablochkov is known to be the inventor of the electric current.
3. The method proposed by the young engineer is said to be very effective.
4. Electronics is believed to begin when the valve was invented.
5. Electronic equipment is said to have already been applied at the beginning of the XX century.
6. Electronics is sure to find an ever growing application.
7. Automation is believed to be the highest stage in the development of the technology.
8. Electronic equipment has been proved to save millions of man and machine hours.
9. The action to be referred to is known to be cathode bombardment.
10. The experiment is expected to be conducted in time.

LESSON 7
TEXT 13

WEIGHING

Weighing – by which we mean using a balance to measure the weight of an object or to compare the weight of two objects – has been undertaken for thousands of years. Images from the earliest civilisations in the Middle East show items being weighed using a beam balance and the process continued almost unchanged until the twentieth century. The Science Museum in London has an example of an early Egyptian quartz beam about 80 mm long with leather support thongs. This, it is believed, was used to weigh gold found in the sands of the river Euphrates and used as a barter medium. The only way of quantifying the gold was to compare its weight, using a beam balance, with a «standard weight» – the *Beqa*, equivalent to 200 grains of barley corn. This was the «kilogram» of the day (not literally!), 5000 years ago, and is thought to be both the origin of the use of gold as a currency and the beginning of the gold standard.

As recently as medieval times, when wealth was measured in land (and most of the land belonged to the monarch) even money was measured by weighing. The only coin was the silver penny, chiselled into two pieces for a *halfpenny* and four for a quarter-penny or *farthing* (fourthing). The pennyweight was 1/240 of the *Pound of Troye* (named after the city in France which was the centre of mercantile trade in the 12th century). This pound was 5 760 grains – barleycorn grains selected in a precise manner (with a consistent mass and length, so that they were used as a basis for small units of length measurement as well). The Troy weight system (20 pennyweights to the Troy Ounce and 12 ounces to the pound) was used for all precious materials and also for bread, the price of which was controlled by law from the 12th until the 19th century. In 1280 a *farthing loaf* weighed about 3½ pounds.

A later system of weights introduced the *haber de peyse* or *Avoirdupois* pound, which was eventually fixed at 7 000 grains and divided into 16 ounces each of 16 drams. The only connection between the values of the Troy and Avoirdupois systems was the grain of barleycorn! After land, precious metals and stones, the next most important measure of wealth was wool, which by the 15th century accounted for over half of England's export trade. Fine weighings were needed for medicines and the Apothecary's measure was based on the Troy ounce – 20 grains to the *Scruple*, three Scruples to the *Drachm* and eight Drachms to the *ounce*. This measuring system remained in use until very recently. When dealing with all these different systems of weight measurement the benefit of a single-universally accepted system soon became apparent.

TEXT 14

THE KILOGRAM

In 1790 the French National Assembly obtained Louis XVI's assent to commission the country's leading scientists to recommend a consistent system for weights and measures. The report which the French scientists Lalande, Laplace, Borda, Monge and Concordet presented to the Academy of Sciences on 19 March 1791 recommended a system based on a unit of length, the metre, equal to one ten-millionth part of the distance from the Earth's pole to the equator. The unit of mass would be equal to the mass of a defined volume of water at its freezing point.

After the 1791 report, measurements were made to decide an appropriate volume of water for the standard of mass. In 1799 it was agreed that the unit should be the mass of one cubic decimetre of water at a temperature of 4 °C, which would be called a kilogram (kg). The mass of one cubic centimetre of water would be called a gram (g). Brass weights were made with mass equal to the new unit, the kilogram, then later a weight of platinum was made and adjusted to the value for the new unit. The platinum weight became known as the *kilogram des archives* and effectively became the standard of mass for most of Europe.

International interest in measurement standards grew quickly and in 1870, and again in 1872, the French Government called meetings to discuss the construction and distribution of new metric standards. At the third meeting, in 1875, eighteen countries subscribed to a treaty called the Convention du Metre. At the same time the Comite International des Poids et Mesures (International Committee on Weights and Measures – CIMP) and the Bureau International des Poids et Mesures (International bureau of weights and measures – BIMP) were set up to be responsible for the custody and verification of metric standards. The convention agreed that a new kilogram weight (artefact, not definition) should be made using an alloy of 90% platinum and 10% iridium because of its stability and ability to withstand handling.

After many attempts in France, a successful casting of the alloy was made by George Matthey of Johnson, Matthey and Co of London and in 1879 three cylindrical pieces of the alloy were delivered to the metallurgist St-Claire Deville in France. The cylinders were hammered in a press, and then polished and adjusted and finally compared with the kilogram des archives by M. Collot, a maker of weights and balances. By 1883 the CIPM were convinced that one of the cylinders «was indistinguishable in mass from that of the *kilogram des archives*» and this weight was chosen as the international prototype of the kilogram and called *K*.

A further 40 one-kilogram weights were ordered from Johnson, Matthey Co in 1882 and delivered in 1884; after re-melting and hammering, to increase their density, these were adjusted – had material removed by polishing – to be close in mass to the selected international prototype. In 1889 the signatories of Convention du Metre (by now including 20 countries) were each allocated one of the weights. The allocation was made by lot and the UK was given Copy No 18. The certificate which accompanied «Kilogram 18» on its first journey to the UK gave its mass as 1 kg + 0.070 mg, with an uncertainty of ±0.002 mg, and its volume at 0 °C as 46.414 ml.

To this day Kilogram 18 is the cornerstone of measurements of mass in the UK. It has been back to the BIPM and intercompared with *K* on numerous occasions and in 1991 it took part in what was called the *Third Periodic Verification* – a period during which all copies of the Kilogram were systematically compared. At that time its mass was found to be 1 kg + 0.053 mg ±0.002 3 mg, and its volume at 0 °C (calculated from the original value in millilitre) as 46.414 9 cm^3.

EXERCISE 1

Translate and remember the following words

chisel, half, quarter, barleycorn, ounce, apparent, assent, consist, consistent, brass, custody, verification, verify, hammer, hummer, adjust, adjustment

EXERCISE 2

Answer the following questions to the texts

1. What unit was used for original gold weighing?
2. There was a universal weight system used both for gems and bread, wasn't it?
3. Who initiated a generally accepted measurement system?
4. What materials were used for making a kilogram artifact?
5. What does weighing mean?

EXERCISE 3

Translate these synonyms and remember them

magnitude (n), value, size, meaning
understand (v), realize
make up (v), constitute, form, build up
considerably (adv), very, greatly
calculate (v), compute
sufficient (adj), enough
matter (n), affair, business
similar (adj), alike, the same
earlier (adv), previously, before
device (n), instrument, appliance

EXERCISE 4

Translate the following sentences paying attention to Gerund

1. When applying mathematical methods for solving technical problems engineers are interested in obtaining finite numerical results.
2. In modern computers RAM/ROM memories are used for executing sophisticated operations.
3. Students get practical training when they are working at various plants.
4. A memory unit is used for storing information.
5. The designer was able to construct a new device by using a new approach.
6. The Periodic Law pointed out the possibility of discovering new elements.
7. Heating of the gas increases the speed of the molecules.
8. Testing a new receiver for the application in this system was the prime engineer's task.
9. Without testing the equipment it's impossible to use it in the experiment.

TECHNICAL TERMS

Measurement

Measurement is the act, or the result, of a quantitative comparison between a predetermined standard and an unknown magnitude.

Range

It represents the highest possible value that can be measured by an instrument.

Scale sensitivity

It is defined as the ratio of a change in scale reading to the corresponding change in pointer deflection. It actually denotes the smallest change in the measured variable to which an instrument responds.

True or actual value

It is the actual magnitude of a signal input to a measuring system which can only be approached and never evaluated.

Accuracy

It is defined as the closeness with which the reading approaches an accepted standard value or true value.

Precision

It is the degree of reproducibility among several independent measurements of the same true value under specified conditions. It is usually expressed in terms of deviation in measurement.

Reliability

It is defined as the closeness of agreement among the number of consecutive measurement of the output for the same value of input under the same operating conditions. It may be specified in terms of a given period of time.

Systematic errors

A constant uniform deviation of operation of an instrument is known as systematic error. Instrumentation error, environmental error, systematic error and observational error are systematic errors.

Random errors

Some errors result though the systematic and instrument errors are reduced or at least accounted for. The causes of such errors are unknown and hence, the errors are called random errors.

Calibration

Calibration is the process of instrument checking and adjusting to make sure its accuracy is within the manufacturers' specifications.

Certification

Certification is a method of the objective control of the quality of product, its correspondence to established requirements.

Measuring system

Measuring system exists to provide information about the physical value of some variable measured. It may consist of a single unit as well as of several separate elements in more complex measurements.

ДОДАТОК

Physical Quantities and its unit

Physical Quantity	Standard Unit	Definition
Length	Meter	Length of path travelled by light in an interval of 1/299,792,458 seconds
Mass	Kilogram	Mass of a platinum-iridium cylinder kept in the International Bureau of Weights and Measures, Sevres, Paris
Time	Second	9.192631770×10^3 cycles of radiation from vaporized cesium 133 (an accuracy of 1 in 10^{12}) or one second in 36,000 years
Temperature	Degrees	Temperature difference between absolute zero Kelvin and the triple point of water is defined as 273.16 k
Current	Ampere	One ampere is the current flowing through two infinitely long parallel conductors of negligible cross section placed 1 meter apart in vacuum and producing a force of 2×10^{-7} newtons per meter length of conductor
Luminous	Candela	One candela is the luminous intensity in a given direction from a source emitting monochromatic radiation at a frequency of 540 terahertz (Hz $\times 10^{12}$) and with a radiant density in that direction of 1.4641 mW/steradian (1 steradian is the solid angle, which, having its vertex at the centre of a sphere, cuts off an area of the sphere surface equal to that of a square with sides of length equal to the sphere radius)
Substance	Mole	Number of atoms in a 0.012-kg mass of carbon 12

Metric convertion chart

English to Metric

English		Metric
Inch (in)	–	2.54 = centimeters
Foot (ft)	–	30.48 = centimeters
Yard (yd)	–	91.44 = centimeters
Mile (mi)	–	1.609 = kilometers
Mile (INM)	–	1.852=kilometres
Square inch (in2)	–	6.54 = square centimeters
Square foot (ft2)	–	929 = square centimeters
Square yard (yd2)	–	0.836 = square meter
Acre	–	0.405 = hectare
Cubic foot (ft3)	–	0.028 = cubic meter
Cord (cd)	–	3.624 = cubic meters
Quart (lq) (qt)	–	1.14 = liters
Gallon (gal)	–	4.564 = liters
Ounce (avdp) (oz)	–	28.35 = grams
Pound (avdp) (lb)	–	453.59 = grams
Horsepower (hp)	–	0.7 = kilowatt

Metric to English

Metric		English
Centimeter (cm)	–	0.39 = inch
Meter (m)	–	3.3 = feet
Meter (m)	–	1.1 = yards
Kilometer (km)	–	0.6 = mile
Sq. centimeter (cm2)	–	0.2 = square inch
Square meter (m2)	–	10.8 = square feet
Square meter (m2)	–	1.2 = square yards
Hectare (ha)	–	2.5 = acres
Cubic meter (m3)	–	35.3 = cubic feet
Liter (l)	–	1.1 = quarts (lq)
Cubic meter (m3)	–	284.2 = gallons
Gram (g)	–	0.04 = ounce (avdp)
Kilogram (kg)	–	2.2 = pounds (avdp)
Kilowatt (kW)	–	1.3 = horsepower

Units of Length and Measure

Length
12 inches .... 1 foot
36 inches or 3 feet .... 1 yard
1760 yards or 5280 feet .... 1 mile

Liquid Measure
8 ounces .... 1 cup
16 ounces or 2 cups .... 1 pint
32 ounces or 4 cups or 2 pints .... 1 quart
64 ounces or 4 pints or 2 quarts .... 1/2 gallon
128 ounces or 16 cups or 8 pints or 4 quarts .... 1 gallon

Temperature Conversions

From Fahrenheit to Centigrade

To convert from degrees Fahrenheit to degrees Centigrade, subtract 32 degrees from the temperature and multiply by 5/9:

Fahrenheit	0	10	20	30	40	50	60	70	80	90	100
Centigrade	–18	–12	–7	–1	4	10	16	21	27	32	38

From Centigrade to Fahrenheit

To convert from degrees Centigrade to degrees Fahrenheit, multiply the temperature by 1.8 and add 32 degrees:

Centigrade	–10	–5	0	5	10	15	20	25	30	35	40
Fahrenheit	14	23	32	41	50	59	68	77	86	95	104

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