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МЕТОДИЧЕСКИЕ УКАЗАНИЯ

ПО ОБУЧЕНИЮ ЧТЕНИЮ ТЕХНИЧЕСКОЙ ЛИТЕРАТУРЫ НА АНГЛИЙСКОМ ЯЗЫКЕ ПО ТЕПЛОМАССОБМЕНУ

Москва 1988

Данные методические указания издаются в соответствии с учебным планом.

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Методические указания предназначены для студентов старших курсов факультетов Э и М. В них подобраны тексты из оригинальной технической литературы, охватывающие основные разделы теории тепломассообмена. Студенты знакомятся с основной терминологией по данной специальности, повторяют основные грамматические конструкции, характерные для языка технической литературы. Часть текстов предназначена для изучающего чтения, другие – для реферирования и аннотирования.

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PART I

TEXT A: Fluid Properties and the Continuum.

Термины, слова и словосочетания к тексту А. /Слова даны в той последовательности, в какой они встречаются в тексте/.

1. motion - движение
   to collide – сталкиваться
   history - история, изменение по времени
   property – свойство
2. quantity – количество, величина
   regardless of –независимо от
   per unit area – на ед.площади
   to result from – получаться в результате ч.-л.
   average – средняя
   impact – удар
   discontinuous-неравномерный, прерывистый
   reproducible – воспроизводимый
   mean free – средняя длина
   path – пути пробега
   order of magnitude – порядок величины
   smallest significant length – наименьшая значащая длина
   under consideration in question – рассматриваемый
   lower bound – нижняя граница, предел
   continuum – сплошная среда
   continuous – непрерывный, сплошной
3. behavior – поведение, характеристика
   to treat – рассматривать
4. density per unit volume – плотность на ед.объема
   specific volume – удельный объем
   reciprocal – обратный
   specific gravity (weight) – удельный вес
   ratio – отношение
5. adjacent – соседний, примыкающий
   average translational kinetic energy – средняя кинетическая энергия поступательного движения
   equality – равенство
6. species – вид, род, разновидность
7. to interrelate – взаимосвязывать
8. fluid properties – свойства потока жидкости
9. domain – область
10. surroundings – окруж.среда

1. Дайте перевод следующих существительных, основываясь на значениях глаголов:

to collide – collision	to continue – continuum
to measure – measurement	to determine – determination
to reduce – reduction	to interrelate – interrelation
	to relate - relation

2. Прочитайте текст, найдите в тексте определения таких понятий как: “свойство”, “давление”, “средняя длина пути свободного пробега /молекулы/”.

3. Переведите текст, обращая внимание на :

а) перевод инфинитива в начале предложения (1-ый абз.); б) перевод причастия с предшествующим союзом (2-ой абз.); в) значения союзов “as”, “since” – т.к., поскольку.

TEXT A: FLUID PROPERTIES AND THE CONTINUUM

1. To understand matter it is necessary to consider its molecules, which are in constant motion, colliding and rebounding not unlike billiard balls. To describe matter the history of each molecule must be known. This requires knowing each molecule’s velocity and acceleration which is quite impossible except statistically. In engineering applications, however, we are interested only in the manifestations of the molecular motion, i.e., what can be sensed and expressed in measurable terms? The answer is properties.

2. A property (an observable quantity) always has the same value when measured under the same conditions, regardless of how those conditions were reached. Consider a small closed container of gas. What happens as the number of molecules is reduced? The force per unit area on the wall of the container resulting from the collision of molecules, which is the pressure “p”, is decreased, since pressure is the effect of the average force resulting from repeated impacts of the molecules on the wall. There is a point, however, below which a reduction in one molecule produces a pressure which is discontinuous; hence, it is not reproducible when brought to the same conditions, and therefore it is not a property. This occurs when the mean free path of the molecules, the average distance traveled by the molecules between collisions, is of the same order of magnitude as the smallest significant length (the side of the container in the case under consideration). This point where behavior changes determines the lower bound of the continuum. The continuum results from a continuous distribution of matter.

3. A property has meaning only in a continuum. Noncontinuum behavior is treated in statistical mechanics and the kinetic theory of gases.

4. The property density "p" is defined as the mass per unit volume. Specific volume "v" is the reciprocal of density; that is, v=I/p. Specific gravity "S" is the ratio of the density of a substance to that of pure water at 4^0C and 76 cm Hg.

5. Temperature "T" is a property which enables us to determine whether two bodies or two adjacent fluid elements are in thermal equilibrium. It is a measure of the average translational kinetic energy of the molecules. We use the terms "hot" and "cold" in reference to high and low temperatures. Although temperature is a familiar property, it is difficult to define because the definition must be indirect, through the concept of equality of temperature.

6. The property concentration "w" is of value when dealing with mixtures, such as dye in water or lemon in iced tea. In a diffusing mixture, the mass of individual species per unit volume, mass concentration, may be significant as in the example of having enough sugar in one's coffee.

7. Properties are interrelated. For example, water and sulforic acid, initially at the same temperature, will rise in temperature when they are mixed. The amount of temperature rise depends on the concentration.

8. The interrelation of fluid properties is in the domain of thermodynamics. During the conversion of energy within the fluid or between the fluid and its surroundings, the condition and motion of the fluid are affected. An equation of state relates the properties of the fluid as it undergoes a change. Fortunately, for most substances of engineering interest, the equation of state has a simple mathematical form.

TEXT B: MEDIA

Терминология, слова и словосочетания

solid – твердое тело
fluid – жидкость (жидкая или газообразная среда)
liquid – жидкость
to subject – подвергать
shearing stress – касательное напряжение
mode – режим, способ
medium – среда (м.ч. media)
substance – вещество
shape – форма
to conform – соответствовать
to compress – сжимать
compressible – сжимаемый
incompressible – несжимаемый

1. Переведите текст, обращая внимание на пассивную конструкцию с глаголами “to affect”: The transfer processes are affected by the medium… - На процессы переноса влияет среда…

2. Обратите внимание на определения слов “solid” и “fluid”; объясните разницу между словами “fluid” и “liquid”. Сравните определения, взятые из текста, и определения, взятые из словаря Хорнби. SOLID – a firm substance; not liquid or a gas. FLUID – able to flow easily, like water or a gas, not solid, as fluid substances. LIQUID – a substance that is neither a solid nor a gas, e.g. Air is a fluid but not a liquid. Water is both a fluid and liquid.

TEXT B: MEDIA

1. All matter is made up of solid, liquid, or gas or a combination of them. Since the transfer processes are affected by the medium in which the changes occur, it is imperative to understand the characteristics of each state.

2. A solid is generally thought of as a substance which offers resistance to change of shape (deformation), whereas, a fluid will deform continuously when subjected to a shearing stress, no matter how small. The mode of resistance distinguishes between a solid and a fluid.

3. A fluid may be either liquid or gas or a combination of the two. Fluids conform to the shape of their container. A liquid has a free surface, but a gas fills the entire container and has no free surface.

4. We readily think of water and air as fluids, but many other substances which behave quite differently are also fluids, e.g. asphalt, glass. Blood is a fluid whose behavior varies widely, depending upon its content of hemocytes (blood cells), sugar, and plasma.

5. Fluids whose density changes are insignificant in a given process are said to be incompressible. Under normal conditions liquids are considered incompressible: gases and vapors may be compressible since their density may change considerably.

TEXT C: UNITS AND DIMENSIONS

1. Прочитайте текст без словаря:

а) обратите внимание на различие понятий “dimensions” и “unit”; б) сравните метрические и английские единицы мер длины.

TEXT C: UNITS AND DIMENSIONS

A set of basic entities expressing our observations of the magnitudes of certain quantities is known as a dimension. Many units can be used to describe a dimension. For example, 36 inches = 3 feet = 1 yard = 91.44 centimeters.

Inches, feet, yard, and centimeters are units, but they all represent a measure of length – dimension. In transport processes the basic dimensions are defined to be force “F”, length “L”, time “T”, temperature “Q”, and mass “M”.

PART II.

TEXT A. Fundamentals of Transport Phenomena

Термины, слова и словосочетания к тексту A

1. to yield – производить, давать
   accurate – точный
2. discrete – дискретный, отдельный
   particle – частица
   to be advantageous – давать преимущества
   e.g. – например

rather than – а не

3. in terms of – через, в единицах
4. stress – напряжение
   strain – деформация
   specification – определение
5. ordered set of three quantities – упорядоченные множества из 3-х величин
   magnitude – величина
   to constitute - составлять

1. Прочитайте текст и дайте ответы на следующие вопросы:

1. How does the author explain the difference between lagrangian and eulerian method of analysis? 2. What examples of fields are given in this text? 3. What definitions of such quantities as “scalar”, “vector” and “tensor” are given in this text?

2. Из приведенных ниже значений глагола to involve выберите наиболее подходящее для данного текста.
1. включать в себя; заключать; содержать, подразумевать, предполагать. 2. влечь за собой; вызывать; приводить к ч.л. 3. вовлекать; впутывать, запутывать.
4. погружаться во что-либо. 5. окутывать.

TEXT A: FUNDAMENTALS OF TRANSPORT PHENOMENA

1. We can study transport phenomena from two viewpoints, lagrangian or eulerian, and it is important to adopt the one which will yield accurate answers to our physical problems in the most straightforward manner.

2. In elementary solid mechanics the lagrangian method of analysis is used. It describes the behavior of discrete particles, or point masses, as they move in space. Fundamental laws, such as Newton's second law, apply directly to the discrete masses under consideration. The same viewpoint can also be used to study transport phenomena, but consider the complexity of describing the behavior of a particle of fluid as it flows through a region in space. Not only is it difficult to follow, but its shape may change continuously. Therefore, it is more advantageous to describe what happens at a fixed point or in a fixed region in space. This method, the eulerian method, allows us to observe phenomena at points of interest rather than trying to follow a particle throughout a region in space, e.g., the temperature at the nose of a rocket, the pressure at an elbow in a water main, the velocity at the tip of a compressor blade. The eulerian method is used primarily here, but whenever results are easier to obtain by the lagrangian method, we shall use the latter.

FIELDS

3. A field is a region where things happen – observable things. We describe a thermal field in terms of temperatures at various locations, an electrical field by point potentials, and a fluid field by velocities at different points. An acoustic field produced, say, by a band playing music may cause interactions in the form of dancing. We are a product of our environment, interacting with fields about us.

4. It is possible, that several fields coexist in any given region. An airliner responds to the thrust of its jets (force field), required to overcome the effects of its gravitational field, while perturbing the ocean of air (aerodynamic field) through which it moves, at the same time being affected very slightly by the polar magnetic field. Interacting fluid, electric, magnetic, and thermal fields influence plasmas. While it is important to be able to predict phenomena resulting from interactions, it is necessary to segregate fields in order to understand their behavior.

5. In studying fields we encounter three types of quantities: scalars, vectors, and tensors. A tensor is an ordered set of n quantities, say (M_1, M_2, …, M_n). A second-order tensor involves nine components and arises in fields in such quantities as stress and strain. The components are represented by scalars, which require only the specification of magnitude for a complete description.

6. Many other physical phenomena, e.g., force, velocity, and acceleration, occur in ordered sets of three quantities. These phenomena can be represented by a first order tensor, commonly called a vector. A vector is designated mathematically as $V \equiv V(x,y,z,t)$ as in case of velocity, or by the use of three scalar components each of which represents its magnitude in one of three orthogonal directions:

$V_x \equiv f_1(x,y,z,t)$ $V_y \equiv f_2(x,y,z,t)$ $V_z \equiv f_3(x,y,z,t)$

Thus a vector possesses both magnitude and direction. Such quantities as temperature, concentration, volume, mass, and energy are scalars. Scalars are zero-order tensors.

7. A continuous distribution of these quantities – scalars, vectors, and tensors – described in terms of space coordinates and time constitutes a field.

TEXT B: TRANSFER PHENOMENA

Термины, слова и словосочетания

1. to transfer – передавать, переносить, перемещать, транспортировать
   equilibrium – равновесие
   rate – скорость, степень, расход, производительность
2. to happen - случаться
   throughout – повсюду
   similar – подобный
   amount – количество
   efflux – истечение, реактивная струя, выхлоп
   dye – краска
3. simultaneously - одновременно
   flux – поток, расход, массовый расход
   to interfere – препятствовать, мешать
   coolant – охлаждающая среда, жидкость
   to couple –связывать, соединять
   to obey- подчиняться
   equation- уравнение

I. Прочитайте текст и дайте ответы на вопросы:

1. What characterizes transfer processes?
2. What examples are given by the author to illustrate the processes of mass transfer?

TEXT B: TRANSFER PHENOMENA

1. The transfer process is characterized by the tendency toward equilibrium, a condition of no change. Common to a transfer process are the transport of some quantity, a driving force, and the move toward equilibrium. The characteristics of the mass of material through which the changes occur affect the rate of transport, and the geometry of the material affects the direction.

2. Consider what happens when a drop of dye is placed in water. The mass-transfer process causes the dye to diffuse throughout the water, reaching a state of equilibrium, which is easily detected visually. We can detect a similar change by smell when a small amount of perfume is sprayed into a room. The concentration becomes fainter at a point near the source as the perfume diffuses throughout the room. Anyone who has picked up a hot poker has felt the effects of heat transfer. The change in efflux of hot gases from a rocket engine can be noted by the sound. One can even sense the change by taste, as when a sugar cube dissolves and diffuses in the mouth. Hence, transfer processors are part of every day experience.

3. In general, transfer processes occur simultaneously, and sometimes the individual fluxes interfere with one another. Heat and mass transfer occur simultaneously when a coolant is forced through a hot porous plate. In thermoelectric refrigeration an electric potential is used to extract heat from a storage chamber by causing a thermal potential to develop. In most cases, however, it is possible to separate the individual phenomena, recognizing that although they are coupled in fact, they obey common physical laws and can be described by common mathematical equations.

TEXT C: FLUX DENSITY

I. Прочитайте текст. Дайте определение понятия “flux”. Как можно объяснить разницу между понятиями “flux” и “flow” на основе данного текста.

FLUX DENSITY

Flux F is the transfer rate of some quantity. It may be gallons per minute, as in the case of fluid flow; Btu per hour, as in heat transfers; or, pounds mass per hour, as in the diffusion of water vapor. While the flux of a liquid such as water is obvious, the flux associated with other transfer phenomena may be elusive to the inexperienced. The particular flux depends upon the field under consideration. It is characterized by flow (flux) lines common to the field (streamlines in the case of fluid flow). Flux is a scalar quantity; flux density is a vector.

Слова к тексту.

gallon – 3,785
BTU – британская тепловая единица = 0,252 ккал (1054, 5 Дж)
pounds mass per hour – масса в фунтах в час
vapor – пар
elusive – неуловимый, ускользающий
stream lines – линии, направления обтекания, линии потока

PART III

TEXT A: NEWTON'S VISCOSITY EQUATION

Терминология, слова и словосочетания

1. to confine - ограничивать
   to set in motion – приводить в движение
   Momentum interchange – обмен импульсом
   to assume – предполагать
   solid boundaries – зд. твердые стенки
   to tend – стремиться
   to adhere – прилипать, приставать
   to pour – лить, наливать
   friction – трение
   to exert a drag– оказывать сопротивление
   shear stress – касательное напряжение
   layer – слой
   subscript – нижний индекс
   plane – плоскость
   nomenclature – терминология
   three-dimensional – трехмерный
2. steady-state conditions– установившиеся условия
   born out – зд. подтвержденное
   valid – справедливый
   viscosity – вязкость
   relation – отношение
3. to vary with – зависеть от
4. in order to – чтобы
   stickiness – клейкость, липкость
   product of – произведение
   to give rise – вызывать
   viscous shear – касательное напряжение
   molecular force field – молекулярное силовое поле
5. mass exchange rate – скорость массообмена
6. small bore tube – трубка малого диаметра
   lubricant – смазочное масло
   fuel oil – жидкое топливо
   poise [poiz] – пуаз/ед. вязкости
   stoke – стокс/ед. кинематической вязкости
   conversion – переход, преобразование
   to facilitate – облегчать
7. in accordance with– в соответствии с

I. Прочитайте текст и дайте ответы на вопросы:

1. What example is given by the author at the beginning of the text? 2. How does the author explain the difference between absolute viscosity and kinematics' viscosity? 3.

How do changes in temperature influence the viscosity of gases and liquids? 4. Is the mechanism of momentum exchange the same in liquids and in gases? 5. What units of measurement are used for viscosity?

II. Найдите в тексте и дайте перевод предложений с абсолютным причастным оборотом (абз.1-4). 2.слова-заместители "one"…
3. конструкции типа "for + сущ. + инф". 4. конструкции "It is … which" (абз.4).

TEXT A: NEWTON'S VISCOSITY EQUATION

1. Consider a fluid confined between two parallel plates, the upper one being set in motion at a velocity U by a force F and the lower one being fixed. Assume that the distance "h" between the plates is sufficiently small for the fluid particles to move in parallel paths. From experience we have observed that fluid particles adjacent to solid boundaries tend to adhere to the surface (easily observed when pouring motor oil). This same property generates an internal friction by adjacent fluid particles exerting a drag on each other and producing a shear stress ϑ yx = F/A between adjacent fluid layers. The subscripts "yx" indicate that the stress is in plane perpendicular to "y" and parallel to "x", a nomenclature which is obviously necessary in three-dimensional systems.

2. Under steady-state conditions Newton observed that the shear stress is directly proportional to the velocity gradient.

His observation, repeatedly borne out by subsequent investigators, is equally valid at any position; i.e., ( ) where "u" is the fluid velocity in the "x" direction and " :" is the absolute viscosity. This empirical relation, known as Newton's equation of viscosity, defines absolute, or dynamic, viscosity ": ". It is sometimes more advantageous to define kinematics' viscosity.

3. The viscosity of fluids varies with temperature and pressure being much more sensitive to temperature than pressure. Changes in temperature cause opposite variations in the viscosity of gasses and liquids. An increase in the temperature of a liquid reduces its viscosity but increases the viscosity of a gas. This is intuitive for liquids but not apparent for gases.

4. Although values for viscosity are obtained by macroscopic measurements, let us consider a gas from a microscopic standpoint in order to understand the basic mechanism. From observations we tend to think of viscosity as a property related to "stickiness". Basically, however, it arises because of momentum interchange between molecules. Molecules are constantly in motion, the motion being more pronounced at higher temperatures and lower pressures. As the gas moves, slow-moving molecules strike faster-moving ones, slowing them down. It is this momentum (product of mass and velocity) interchange which gives rise to viscous shear, a measure of which is viscosity. The mechanism of momentum exchange in liquids is the same as in gases qualitatively, but the

physical structure is much more complex since the molecules are closer and the molecular force fields have a greater effect on the momentum exchange in the collision process.

5. By analogy, suppose two trains loaded with coal are running on parallel tracks in the same direction. If workmen begin throwing coal from the slower train to the faster one, the train which "catches" the coal is slowed by the increased mass, because of the momentum component in the direction of motion of the train. Now imagine workmen on both trains, analogous to molecules in adjacent fluid layers, throwing coal back and forth from one train to the other. If the train initially has unequal velocities and the mass – exchange rate is equal for both trains, the faster train is slowed. So it is with the momentum interchange between fluid layers.

6. Viscosity is often measured by observing the time required for a given amount to fluid to flow from a short small-bore tube. Viscosities of fuel oils are measured at 77 and 122°F, of lubricants at 100 and 210°F. Viscosity is often given in metric units which have special names ": ": poise $\underline{=}$1 g/cm=sec $\underline{=}$ 100 centipoises, v : stoke $\underline{=}$ 100 centistokes. The following unites : : 1 ($1b_f$-sec/ft^2) = 479 poises, v : 1(ft^2/sec) = 30.48^2 stokes.

7. Fluids which obey equation (2-5) are known as Newtonian fluids. All gases and most liquids of engineering importance are Newtonian. Fluids which do not behave in accordance with Eq. (2-5), no Newtonian fluids, will not be considered in this text.

TEXT B: THE THERMAL CONDUCTIVITY

I. Прочитайте текст без словаря, перескажите его, давая при этом ответы на следующие вопросы: What does the value of the thermal conductivity depend upon? What does the thermal conductivity vary with? Why does the author say, that the thermal conductivity is analogous to viscosity? Why are good heat conductors also good electric conductors?

II. Используйте следующие слова при пересказе:

Value	To store	Free electron transport
Energy exchange	Specific heat	Linearly
To impart	Lattice vibration	Average value
To transport	Mass density	Specimen

THE THERMAL CONDUCTIVITY

1. The thermal conductivity is analogous to viscosity, since its value depends upon the energy exchange between molecules in motion. Faster-moving molecules impart some of their energy to slower-moving ones in the collision process.

An increase in temperature increases molecular motion, transferring energy from regions of higher temperature to regions of lower temperature. Thermal conductivity varies with temperature and pressure, being much more sensitive to temperature than pressure. For engineering purposes it is independent of pressure in solids, liquids, and most gases below the critical pressure.

2. It is frequently convenient to use the ratio of a material's ability to transport energy to its capacity to store energy. This is the thermal diffusivity, defined as , $x=k/ \Delta c$ where p is the mass density of the material and c is is its specific heat.

3. The energy transfer in solids is by lattice vibration and by free-electron transport. Since in metals, free-electron transport is more prominent than lattice vibration, good heat conductors are also good electric conductors.

4. For many materials thermal conductivity varies linearly with temperature, i.e., $k=k_o (1+aT)$, where k_o is the value at zero temperature and a is a constant which depends upon the material. For such materials it is convenient to use an average value of thermal conductivity in making calculations of heat transfer.

5. Thermal conductivity can be measured in a variety of ways, all of which depend upon the observation of a temperature gradient across a specimen conducting a known amount of heat.

PART IY

TEXT A: HEAT TRANSFER (INTRODUCTORY TEXT)

Термины, слова и словосочетания

1. whereby – посредством чего
   rate of heat transfer – скорость теплопередачи
   feature – особенность
2. thermal motion – тепловое движение
   energy transport – перенос энергии
   surrounding space – окружающее пространство
   radiant emission – теплоизлучение
   relative motion – относительное движении
3. to include – включать в себя
   to employ – использовать
   mastery – совершенное владение
   therefore – поэтому

I. Прочитайте текст, найдите определения конвекции и теплоизлучения.

II. Сделайте письменный перевод 2-х последних предложений второго абзаца.

III. Вспомните возможные значения глагола “to involve” и дайте перевод причастия “involving” (абз.3).

IY. Из приведенных ниже значений слова “technique” (абз.3) выберите наиболее подходящее для данного текста: техника; совокупность технических приемов; технология; методика; метод, способ, процедура.

TEXT A: HEAT TRANSFER (INTRODUCTORY TEXT)

1. The study of heat transfer includes the physical processes whereby thermal energy is transferred as a result of difference or gradients of temperature. The information generally desired is the way in which the rate of heat transfer depends upon the various features of the process.

2. There are two basically different processes whereby thermal energy is transported: conduction and radiation. Energy is conducted through a material in which a temperature gradient exists by the thermal motion of various of the microscopic particles of which the material is composed; energy is diffused through the material by these thermal motions. Radiation is an energy transport from material into the surrounding space by electromagnetic waves. Radiant emission is also due to the thermal motion of microscopic particles but the energy is transmitted electromagnetically. If conduction occurs in a fluid in motion, the diffusion of thermal energy will be affected by the relative motion within the fluid. Conduction processes affected by relative motion are called convection processes.

3. Since the field of heat transfer includes processes involving thermal diffusion, electromagnetic radiation, and fluid motion, the study includes theories from many branches of science and employs many different types of analytic techniques. Therefore the study of heat transfer requires the mastery of many concepts and methods of analysis.

TEXT B: HEAT CONDUCTION AND THERMAL CONDUCTIVITY

Термины, слова и словосочетания

1. rate – скорость, степень, величина, расход, производительность
   directly proportional – прямо пропорционально
   Inversely proportional – обратно пропорционально
2. thermal conductivity – коэффициент теплопроводности
   face – грань, сторона, поверхность
   unit cube – элементарный куб
   to maintain – поддерживать
3. transport property – характеристики переноса
   wide range – широкий диапазон
   to encounter – встречать
   psia/pound per square inch absolute – абсолютное давление в фунтах на кв.дюйм
   ratio – соотношение, пропорция, коэффициент
4. negligible – очень малый, незначительный

5. conduction characteristics – характеристики теплопроводности
grain – фибра, волокно
6. prediction – расчет, прогнозирование
random motion – беспорядочное движение
similar – сходный, подобный
net energy – полезная мощность, мощность нетто, эффективная мощность
space density– пространственная плотность
7. diffusion of momentum – рассеивание импульса
to store – хранить, накапливать
monatomic – одноатомный
diatomic – двухатомный

I. Прочитайте текст и ответьте на следующие вопросы:
1. What does the rate of heat conduction depend upon? 2. What definition of thermal conductivity is given in this text? 3. In what units is thermal conductivity expressed? 4. How is heat conducted in gases?

II. Обратите внимание на перевод причастного оборота “followed by good insulators” (3 абз.). Почему невозможен перевод на русский язык посредством определительного причастного оборота?

III. Напишите реферат текста.

TEXT B: HEAT CONDUCTION AND THERMAL CONDUCTIVITY

1. The rate of heat conduction through a solid material (of fluid without relative motion) is proportional to the temperature difference across the material and to the area perpendicular to heat flow and inversely proportional to the length of the path of heat flow between the two temperature levels. This dependence was established by Furier and is analogous to the relation for the conduction of electricity, called Ohm’s law. The constant of proportionality in Fourier’s low, denoted by K, is called thermal conductivity and is a property of the conducting material and of its state.

2. The thermal conductivity is analogous to electric conductivity. It is equivalent to the rate of heat transfer between opposite faces of a unit cube of the material which are maintained at temperatures differing by one degree. In engineering units in the English system, k is pressed in Btu/h ft2 F/ft =Btu/h ft F.
In metric units, k may be expressed as cal/sec cm^{o}C or watts/cm^{o}C.

3. The transport property, thermal conductivity, varies over a wide range for the various substances commonly encountered. For example, for air at 14,7 psia and 60^{o}F it is 0,015 and for silver it is 240 in English units. This is a ratio of 1:16000. Gases generally have the lowest thermal conductivities, followed by good insulators, nonmetallic liquids, nonmetallic solids, liquid metals, metal alloys, and, finally, the best conductors, pure metals.

4. Thermal conductivity for a given material depends upon its state and may vary with temperature, pressure, and ets. For moderate pressure levels the effect of pressure is small. However for many substances the effect of temperature upon K is not negligible.

5. Many materials have different conduction characteristics in different directions. For example, wood and other fibrous materials have higher thermal conductivities parallel to the grain than perpendicular to it.

6. Theoretical predictions have been made of the value of thermal conductivity for several types of substances. In gases heat is conducted (i.e. thermal energy is diffused) by the random motion of molecules. Higher-velocity molecules from higher-temperature regions move about randomly, and some reach regions of lower temperature. By a similar random process lower-velocity molecules reach higher-temperature regions. Thereby net energy is exchanged between the two regions. The thermal conductivity depends upon the space density of molecules, upon their mean free path and upon the magnitude of the molecular velocities. The net result of these effects for gases having very simple molecules is a dependence of K upon T where T is the absolute temperature. This is a result of the kinetic theory of gases.

7. A similar temperature dependence is found for the viscosity of gases. The viscosity ":" is a measure of the diffusion of momentum. It may be shown that there is a simple relation between k and : involving the specific heat c_v and a factor i, where the value of i depends upon the way in which energy is stored in the gas molecules.

$k = ic_v$ where c_v is the specific heat at constant volume.

<u>TEXT C: CONVECTION</u>

Термины, слова и словосочетания

1. in the absence – при отсутствии
2. to result – зд. возникать (в результате ч.-л.)
   to result in – приводить к ч.-л.
   resulting – получающийся в результате
   buoyant effect – эффект подъемной силы
   buoyancy – подъемная сила
   natural convection – естественная конвекция
   forced convection – вынужденная конвекция
   to introduce – вызывать
   to modify – изменять
   to aid in – помогать, способствовать
   displacement – перемещение, смещение

I. Прочитайте текст. Найдите определение вынужденной конвекции.

II. Обратите внимание на перевод сочетания "The natural convection heat transfer <u>process</u>".

CONVECTION

Energy is conducted through fluids, as through solids. However the heat transfer process in the air is not simple conduction. Even in the absence of wind a flow process results. The buoyant effect in the heated layers of air near the surface causes them to rise and move away from the surface. These layers are replaced by cooler air from below and from farther out from the surface. This effect results in temperature distribution. The resulting heat-transfer process in the outside air is called natural convection. Convection processes in which the fluid motion is induced by heat-transfer are called natural convection.

A wind velocity would further modify the temperature distribution by aiding in the displacement of the heated air layers by cooler air. The effect of a wind velocity, which is imposed upon the natural convection heat-transfer process is called forced convection. For sufficiently high wind velocities, buoyancy effects would be negligible, and the process would be pure forced convection.

TEXT D: THERMAL RADIATION AND EMISSIVE POWER

1. to distinguish – зд. отличаться от
presence – наличие
intermediate carrier – промежуточный носитель
to impede – препятствовать, мешать
space between – зд. Промежуточное пространство
as a consequence- как последовательность
to emit – испускать
energy content – энергосодержание
a quantity – какое-то количество, величина
microscopic arrangement – микроскопическая структура
rate of emission of energy – скорость излучения энергии
surroundings – окруж. среда
2. to promote - способствовать
means – способ, средство
occurrence – случай, явление
incidence – падение, наклон
particular wavelength – определенная длина волн
thermal motion – тепловое движение
thermal radiation – теплоизлучение
amenable – поддающийся, подчиняющийся
to be dependent upon – зависеть от
3. relation – зависимость, связь, соотношение
incident radiation – падающее излучение

I. Прочитайте текст, ответьте на следующие вопросы:

1. What definition of radiation energy-transfer process is given in the text?
2. What are the possible uses of radiant discharge processes?
3. What surface is called “black”?

II. Переведите следующие сочетания слов:

1. Radiant energy transfer <u>process</u>
   Energy carrying electromagnetic <u>waves</u>
   Net energy transfer <u>rate</u>
   The temperature and spatial <u>relationships</u>
2. Radiant energy <u>discharge</u>
   High energy <u>particles</u>
   Heat-transfer <u>phenomena</u>
   Radiant exchange <u>process</u>
   The rate of thermal energy <u>emission</u>
   Energy emission <u>rate</u>

<u>TEXT D: THERMAL RADIATION AND EMISSIVE POWER</u>

1. One of the basic mechanisms by which energy is transferred between regions of different temperature is called radiation. This mechanism is distinguished from conduction by the fact that it does not depend upon the presence of intermediate material to act as a carrier of energy. On the contrary, a radiation transfer process between two regions is usually impeded by the presence of a material in the space between. The radiation energy-transfer process is explained as a consequence of energy-carrying electromagnetic waves. These waves are emitted by atoms and molecules of matter as the result of various changes in their energy content. The amount and characteristics of the radiant energy emitted by a quantity of material depends primarily upon the nature of the material, its microscopic arrangement, and its absolute temperature. The rate of emission of energy is assumed to be independent of the surroundings. However, the net energy-transfer rate depends upon the temperature and spatial relationships of the various materials involved in the radiation-transfer process.

2. A wide variety of radiant energy-discharge processes are known. The various kinds of discharge are promoted by many means – for example, by bombardment with high-energy particles by the occurrence of a chemical reaction, by an electric discharge, or by the incidence of relatively low energy radiation of particular wave-lengths. One type of discharge process of special interest in connection with heat-transfer phenomena is that which arises as the result of the thermal motion of molecules. This type of radiant energy is called thermal radiation. Thermal radiation is composed of waves of many wave-lengths and is amenable to relatively simple laws. Many of the radiant-exchange processes by which appreciable amounts of energy are transferred between surfaces are thermal in nature.

3. The rate of thermal radiant energy emission by a surface is directly dependent upon its absolute temperature. The relation between the energy-emission rate and the temperature is very simple if the surface is “black”. A surface is called “black” if it will absorb all incident radiation.

PART Y

TEXT A: MOLECULAR MASS TRANSFER

Термины, слова и словосочетания

1. driving force – движущая сила
   concentration gradient – градиент концентрации
   component of a mixture – элемент/составляющая смеси
   mechanism – механизм, аппарат, картина, особенность, характер
   molecular diffusion – молекулярная диффузия
   thermal diffusion – термодиффузия
   to arise from – возникать в
   to result from – в результате чего-либо
   pressure diffusion – бародиффузия
   by virtue of – благодаря
   forced diffusion – вынужденная диффузия/обусловленная внешними силами
   interface – внутренняя поверхность, поверхность раздела
2. mode – вид, тип, форма, характер, режим, метод, способ
   To dominate – преобладать, господствовать
3. moisture laden air – сильно увлажненный воздух
   subsequent precipitation – последующий, выпадение/об атмосферных осадках
   to be concerned with – интересоваться, заниматься ч.-л.
   to confront – сталкиваться
   humidification – увлажнение
   cutting – резание
   welding – сварка
   ablation – оплавление
   heat shield – тепловой экран
   deaeration – деаерация
   feed water – питательная вода
   steam boiler – паровой котел
   heat treatment – термическая обработка
   waste treatment – переработка отходов
4. eddy current – завихрение, вихревой ток
   non-equilibrium – неравновесный

I. Прочитайте текст, найдите ответы на следующие вопросы

1. What definition of mass transfer can you give?
2. What mechanisms of mass transfer are mentioned in the text?
3. Can you explain the difference between the words “mechanism” and “mode”?
4. What examples of mass transfer does the author give?
5. Can you add any other examples?

II. Обратите внимание на перевод следующих словосочетаний:

Forced convection mass transfer
Interphase mass transfer
Molecular mass transfer
Convective mass transfer
Moisture laden air

TEXT A: MOLECULAR MASS TRANSFER

1. In this chapter another driving force, concentration gradient, is introduced. This driving force causes the transport of a component of a mixture from a region of high concentration to a region of low concentration. The transport process is known as mass transfer. The mechanisms of mass transfer are varied. They can be classified into eight types: 1. Molecular (ordinary) diffusion, resulting form a concentration gradient. 2. Thermal diffusion, arising from a temperature gradient. 3. Pressure diffusion, which occurs by virtue of a pressure gradient. 4. Forced diffusion, resulting from external forces other than gravity. 5. Forced-convection mass transfer. 6. Natural-convection mass transfer. 7. Turbulent mass transfer resulting from eddy currents in a fluid. 8. Interphase mass transfer occurring by virtue of non-equilibrium at an interface.

2. These types divide naturally into two distinct modes of transport. The first four are molecular mass transfer; the last four are convective mass transfer. Although the two modes often occur simultaneously, one mode usually dominates and we can understand the mechanisms better by considering them separately.

3. Examples of mass transfer in everyday life are legion: the diffusion of sugar in a cup of coffee; vaporization of water in a tea-kettle; the movement of moisture-laden air over the ocean with its subsequent precipitation on dry land; combustion and air-conditioning process, cloud formation; clothes drying. The chemical engineer is concerned with gas absorption, separation, crystallization and extraction, the mechanical engineer confronts the mass-transfer process in humidification, drying, cutting and welding metals, ablation of heat shields in high-speed flight, deaeration of feed water in steam boilers, and the production and heat treatment of metals; and civil engineers make use of mass transfer in waste treatment.

TEXT B: THE DIFFUSION MODE

Термины, слова и словосочетания.

1. binary mixture – бинарная смесь

inverse – обратный, обратное явление/процесс

other than – помимо, кроме

steady state – установившееся/стационарное состояние

to offset – компенсировать, перекрывать

to be constant with time – быть постоянным по времени

to ignore – не учитывать, пренебрегать

species – тип, вид, сорт, разновидность, категория, группа

spacing – шаг, расстояние, интервал, период решетки, параметр кристаллической решетки

I. Прочитайте текст, ответьте на следующие вопросы:

1. What practical application of thermal diffusion is mentioned in this text?
2. What example of forced diffusion does the author give?
3. Why is it possible to say that mass transfer by diffusion is analogous to conduction heat transfer?
4. Why is diffusion rate faster in gases than in liquids?

II. Напишите краткое содержание текста.

TEXT B: THE DIFFUSION MODE

1. This chapter will deal primarily with the molecular (ordinary) diffusion of binary (two-component) mixtures, typifying the diffusion process and being the most significant of the types of diffusion.

2. For the case of thermal diffusion in a binary mixture, the molecules of one component travel toward the hot region while the molecules of the other component tend to move toward the cold region. The inverse is the tendency to generate a thermal gradient with the development of a concentration gradient. Thermal diffusion has been successfully used in the separation of isotopes.

3. Pressure diffusion results when a pressure gradient exists in a fluid mixture, e.g., in a closed tube which is rotated about an axis perpendicular to the tube'q axis (centrifuge). The lighter component tends to move toward the low-pressure region.

4. An external force other than gravity in a mixture when it acts in a different manner on the different components, results in forced diffusion. The diffusion of ions in an electrolyte in an electric field is a classic example of forced diffusion.

5. When thermal, pressure, and/or forced diffusion occur, a concentration gradient is developed, casing ordinary diffusion in the opposite direction. Upon reaching a steady state, the fluxes from the two (or more types of diffusion) sometimes offset each other, resulting in properties at a point being constant with time. The effects of thermal, pressure, and forced diffusion will be ignored in the introductory treatment of this chapter.

6. Mass transfer by diffusion is analogous to conduction heat transfer. Mass is transported by the movement of a species in the direction of its decreasing concentration, analogous to the energy exchange between molecules in the direction of decreasing temperature in conduction.

7. Ordinary diffusion may occur in gases, liquids or solids. Because of the molecular spacing the diffusion rate is much faster in gases than in liquids; it is faster in liquids than in solids.

TEXT C: TYPES OF MOTION

Термины, слова и словосочетания

1. steady flow – установившееся течение
   unsteady local acceleration – неустановившееся местное ускорение
   time dependent – изменяющийся по времени
2. reference axis – исходная ось
   wake – спутная струя
   to disturb – возмущать поток
   finally – в конце концов
3. uniform flow – равномерное течение
   non-uniform – неравномерное convective acceleration – конвективное ускорение
   identical – идентичный, подобный
   magnitude – величина
   displacement – смещение, перемещение, вытеснение
   with respect to – что касается, по
   stream line – линия тока
4. frictionless liquid – невязкая жидкость
   cross section – поперечное сечение
   to curve – изгибать
5. to inject – вводить, впрыскивать
   to feed (fed, fed) – подводить, подавать, вводить
   constant head tank – резервуар с постоянным напором
   distinct – отчетливый, определенный
   relatively – относительно
   smoothly – плавно, ровно
   laminated – слоистый, ламинаризированный
6. to break up – разбиваться, расформировывать
   upstream – вверх по потоку, против потока
   Prior – предварительный

I. Прочитайте текст, ответьте на следующие вопросы:
1. What types of flow are described in the text?
2. What experiment helped Reynolds to observe laminar and turbulent flow?

II. Обратите внимание на форму сослагательного наклонения в последнем предложении 3-го абзаца. Переведите предложение.

III. Переведите письменно 6-ой абзац текста. Какое значение имеет глагол would в 1-ом предложении этого абзаца?

TEXT C: TYPES OF MOTION

1. Steady and unsteady flow. If the local acceleration is zero, the motion is steady. The velocity does not change with time, although it may change from point in space. On the other hand, a flow which is time-dependent is unsteady.

2. Often an unsteady flow can be transformed to steady flow by changing the reference axis. Consider for example, an airplane moving through the atmosphere at a constant speed of V_o. The fluid velocity at a point (x_o, y_o) is unsteady, being zero before the plane reaches the point, varying widely as it passes due to he wake

and waves produced by disturbing he air, and finally becoming zero again as the plane disappears.

3. Uniform and non-uniform flow. If motion is uniform, the convective acceleration is zero. In uniform flow the velocity vector is identical, in magnitude and direction, at every point in the flow field, that is, V/r=0 where "r" is a displacement in any direction. This definition does not require that the velocity itself be constant with respect to time; it requires that any change occur at every point simultaneously; the streamlines must be straight.

4. A frictionless liquid flowing through a long straight pipe is an example of uniform flow. Non-uniform flow is typified by the flow of a frictionless liquid through a pipe of changing cross section or through a pipe which is curved.

5. Laminar and turbulent flow. In 1883, while injecting dyes into flows fed by constant-head tanks Reynolds observed two distinct types of flow. At relatively low velocities fluid particles move smoothly, everywhere parallel. Because the fluid moves in a laminated form, it is termed laminar. For laminar flow the dye moves in a thin, straight line.

6. At relatively high velocities, Reynolds noted that the dye would abruptly break up, diffusing throughout the tube. At higher velocities the breaking point moves upstream until it is finally turbulent throughout. Turbulent flow is always unsteady flow by our prior definition.

SUPPLEMENTARY TEXTS

FUNDAMENTAL CONCEPTS FROM THERMODYNAMICS

In the transfer processes we seek the relationships between fluxes and field intensities in terms of field properties, physical properties of the transfer media, and the dimensions of space and time. Thermodynamics deals with energy quantities which are transferred during the processes – work and heat. Its principles and laws apply to all fields of engineering. This chapter sets forth some fundamental concepts necessary for subsequent study of the transfer processes, unifying the definitions and symbols of thermodynamics and the rate processes.

In its broadest sense the science of thermodynamics considers thee conversion and transfer of energy. Classical, or macroscopic, thermodynamics is based upon man's observations. Its laws were developed inductively. No observable violations have occurred. Media are viewer from a continuum standpoint. Probabilistic, or microscopic, thermodynamics is based upon the interactions of molecules and the probability of their behaving in accordance with a set of laws which are identical to those developed in the classical approach. The two approaches are complementary in that the microscopic viewpoint describes fundamental behavior while the macroscopic viewpoint guarantees repeatability.

Equilibrium. Thermodynamics is based upon an equilibrium condition or a series of equilibrium states. Equilibrium is that state which is characterized by no change. In the preceding chapter we noted that change occurs when the field intensity – any field intensity – varies throughout a region. Therefore, for equilibrium the intensity of all fields must be identical; no potential gradient can exist.

System and control volume. A thermodynamic system is a fixed quantity of matter. It does not vary in mass or identity. Everything outside the system is termed the surroundings. The system and surroundings are separated by boundaries. Consider, for example, filling an automobile gasoline tank from a large tank truck. We may define the system as that amount of gasoline which will be transferred into the smaller tank.

The thermodynamics problem then becomes that of determining what happens to the gasoline between the initial equilibrium state and the final equilibrium; it is a "book-keeping process" of tabulating observable quantities initially and finally.

An alternative method of solving the same problem involves focusing attention on a fixed region in space, say the automobile tank. The fixed region is the control surface (analogous to the system boundary) and observing the gasoline as it crosses.

All thermodynamic problems can be solved by using one of these two concepts, control volume or system. We shall use whichever is more convenient in any given problem. In some cases it will be more feasible to think in terms of a deformable control volume, typified by a balloon. At this point the student should ponder the analogy between the sulerian method of describing field properties and the thermodynamic concept of the control volume.

PROPRTIES AND STATE OF A SUBSTANCE

A thermodynamic property is any measurement or quantity which serves to describe a system. Thermodynamic properties are either intensive or extensive. Intensive properties are independent of mass. Temperature, pressure and density are intensive properties. Extensive properties vary directly with mass. Mass and total volume are extensive properties.

A property of a pure, simple, compressive substance can always be defined in terms of two independent intensive properties. For example, the pressure of a gas can be expressed in terms of its temperature and specific volume: P = p(T,v) (3-5). A pure substance is also homogeneous and of fixed chemical composition.

We sometimes speak of air as being pure: however, thermodynamically it is a mixture of several gases and vapors.

A phase is a quantity of matter which is homogeneous throughout. A substance may exist in any one or a combination of three phases – solid, liquid and vapor. Two or more phases may coexist when in a common state, identified by two or more observable properties such as temperature and pressure. Change of phase and phase equilibrium can be understood by considering water. At a pressure of 14.7 psia water is a solid (ice) when below 32^{o}F solid, vapor and liquid water can coexist. Further increases in temperature cause the liquid water to vaporize (turn to steam) until it is 100 percent water above 212^{o}F. During this transition the quality x, ratio of the mass of vapor to the total mass changes from 0 to 1.00.

Work. Work, one of the basic quantities transferred during a thermodynamic process, is defined from elementary mechanics as a force F acting through a displacement x, where x is positive in the direction of the force; i.e., W = (3-6).

This basic relation enables us to determine the work required to raise weights, propel missiles, etc. But this definition of work is too limited for thermodynamics, where the concern is with the interactions between a system and its surroundings. Therefore, we shall define work compatible with our concepts of systems, properties and processes. Hence, work is done by a system if the sole effect external to the system (on the surroundings) could be the raising of a weight. Work done by a system in assumed to be positive and work done on a system is considered negative. This definition does not state that a weight is raised or that a force actually acts through a distance. This definition is necessary because of the need to distinguish between work and heat in the second law of thermodynamics.

The term “sole effect” in the definition of work implies that another effect might be external to the system.

The term “external” in the definition of work suggests that work is defined only with reference to a system boundary.

Heat. The other form of energy of significance in transfer processes, heat, is defined in terms of temperature. Heat is the energy which is transferred across the boundaries of a system interacting with the surroundings by virtue of a temperature difference.

THE FIRST LAW OF THERMODYNAMICS

Since the first law of thermodynamics is a relation between the fundamental quantities of heat and work, let us look further at their distinctions and similarities.

Neither heat nor work is a property of the system. They are boundary phenomena, path-dependent, inexact differentials. Both are forms of energy in transit and have meaning when a system undergoes a change of state.

The conventional units of work are foot-pounds force; of heat, the British thermal unit. Btu was originally defined as that quantity of heat required to raise1 lb_m of water from 59.5 to 60.5°F, which is referred to as the 60°FBtu.

To understand the first law of thermodynamics we must understand a cycle, defined as the passing of a system through a series of states but returning to its initial condition. Consider an ice-cream freezer. The ingredients, milk, eggs, sugar, etc., are contained in the system chosen. Work is transferred to the system by paddle, causing the temperature of the system to rise, but the heat resulting from the increased temperature is transferred to the surrounding brine. Work goes in; heat comes out.

What happens when all the energy added by work is extracted by the heat transfer? The system returns to its initial state, passing through a cycle. Note that for the system chosen the work is negative and the heat is negative.

The total work and heat transferred in the cycle is different from zero, i.e.,
∗ W#0, ∗ Q#0 (3-7)
As a matter of fact, for the system in question ∗ W<0, ∗Q<0 (3-18). With a little ingenuity we can measure the work and heat transferred. Equipping the input shaft with a pulley and weight will give the work, while the heat transfer can be measured by ice meltage. Before leaving this example, we should observe that more heat must be extracted than added by the work if we are to freeze the ice cream.
In 1843 a British scientist, Joule, carried out a number of experiments similar to the preceding example with various configurations. In all cases, he observed that the work done on the system was directly proportional to the quantity of heat removed from the system. Mathematically, (3-19) cycle, where the proportionality constant J is the mechanical equivalent of heat the value of which depends upon the units chosen. Equation (3-19) is the mathematical statement of the first law of thermodynamics. This law, which is the basic law of the conservation of energy, was deduced from observations. It is given the status of a law only because no contradiction to it has ever been found.

It is evident from Eq. (3-19) that work and heat can be expressed in equivalent units. Expressing work in foot-pounds force and heat in Btu, J = 778 ft-lb_f/Btu. Equation (3-19) does not suggest that heat and work is the same thing, but it does establish the relationship between the two. While discussing units, recall that power is work rate, or work per unit time. Therefore, the following conversion factors will be useful 1 hp – 33,000 ft-lb_f/min = 2545 Btu/hr, 1 kw = 44,200 ft-lb_f/min = 3412 Btu/hr.

Most of our thermodynamic problems are concerned with processes rather than cycles. Systems rarely return to their initial state. Therefore, to be useful the first law should be formulated for easy application to processes.

Specific heats. If a red hot iron ingot of 20-lb_m is quenched in a 20-lb_m pail of cold water, we know intuitively that the iron will cool and the water will become hot. Experience has shown that the temperature change of the iron is not equal to the temperature change of the water. Furthermore, this is the case for all materials. This characteristic is due to a property of the material known as specific heat c. It is the amount of heat required to change the temperature of a unit mass by 1^o under certain conditions.

The third law of thermodynamics. The second-law relationship for entropy can account only for changes in entropy – one state relative to another. Although this is adequate for thermodynamic calculations, it is sometimes advantageous to speak in terms of absolute entropy, which requires the third law of thermodynamics.
Simply stated, it is that the entropy of a pure substance is zero at absolute zero.

In a probabilistic sense, entropy is a measure of the disorder of a system. At absolute zero there is no translational molecular activity, hence no disorder, or zero entropy.

The second law of thermodynamics. The first law of thermodynamics establishes a relationship between heat and work but places no conditions on the direction of transfer. The second law of thermodynamics is the directional law. It may be formulated thus: Heat cannot, of itself, pass form a colder to hotter body.

Limitations of the first law. To illustrate the directional characteristic of the second law, let us return to the example of the ice cream freezer. We added work to the system and extracted heat. Now let us reverse the process – add heat and get work out of the system. There is no conceivable way in which a weight might be returned to its original position by reversing the process. It is impossible to fully convert all heat into work. The process is irreversible.

Consider another example. A flywheel in stopped by a friction brake. In the process of stopping the flywheel the brake gets hot, and its internal energy is increased by an amount equal to the loss if kinetic energy of the flywheel. The first law would be satisfied if the hot brake gave up its energy to the flywheel causing it to resume rotation. But there is no conceivable way in which this can happen. The process is irreversible.

Two bodies at different temperatures are placed in thermal contact in an insulated box. Heat in transferred from the high temperature body in accordance with the first law, causing the low temperature body to get warmer. The energy given up by the high temperature body is gained by the low temperature body in coming to thermal equilibrium. Letting the process be reversed would not violate the first law since it is concerned with the conservation of energy, but the same amount of energy cannot be transferred from the low temperature body to the high temperature body. Heat has never been conserved to “flow uphill”. The process is irreversible.

Some factors which cause irreversibility are (1) friction (2) finite temperature difference, (3) unrestrained expansion, and (4) mixing of different substances.
In a cyclic process it is possible to convert all work into heat, but it is impossible to convert all the heat into work.

Heat engine. A heat engine is any device which operates cyclically and has as its primary purpose the conversion of heat into work. For example, a steam power plant has its working fluid, water, returning periodically to its initial state. Liquid water is pumped into the boiler, where it is vaporized and drives the turbine, producing work, some of which may be used to drive the condensate pump. Choosing the system as shown, only heat and work cross the boundary.

The system can be simplified as receiving heat from a high temperature reservoir (source) and rejecting heat to a low temperature reservoir (sink). A thermal reservoir is a body which can receive or reject heat indefinitely without having

Thermal efficiency Z th is defend as $Z\ th = \frac{\text{energy effect sought}}{\text{energy input required}}$

For the heat engine, the energy effect sought is the work output W, and the energy input required to produce it is the heat input Q_H; therefore, $\acute{\eta}\ th = \frac{W}{Q_H}$.

There are two classic statements of the second law, both of which are negative statements and cannot be proved. However, since neither has ever been experimentally violated, we shall accept them as law. They are: Kelvin – Planck.
It is impossible to construct a device which will operate in a cycle and produce no effect other then the raising of a weight and the exchange of heat with a single reservoir.

Clausius: Heat cannot pass spontaneously from a low temperature body. Proof of the equivalence of these two statements can be establishes by contradiction and is included in any complete treatise on thermodynamics.

DESCRIPTION OF A FLOW FIELD

1. A streamline is an imaginary line in a flow field at an instant of time taken such that the fluid velocity at any point is tangent to it. Since the velocity vector is tangent to the streamline, no matter can cross it. A streamline is analogous to a heat-flow line in the case of heat transfer.

2. A stream filament is a fanaly of streamlines forming a cylindrical passage of infinitesimal cross section. A stream tube is bounded by an infinite number of streamlines forming a finite surface across which there is no flow. If there

is no creation, storage, or destruction of mass within the stream tube, all fluid which enters must leave.

ISOTHERMAL FLOW

The basic differences between laminar and turbulent flow were discussed in Chap 9. The fundamental difference between laminar and turbulent types of flow is the existence of completely random fluctuations in the velocity components for the turbulent case. In addition to purely laminar and purely turbulent flow, we find that transition flow usually exists whenever we have the turbulent case. In the development of any boundary layer, internal or external, there normally exists a laminar leading section which becomes turbulent as the fluid moves downstream. This results in a flow regime between the completely laminar and completely turbulent areas in which the fluid motion is highly unstable, fluctuating between laminar and turbulent characteristics.

FLUID MOTION

1. In the dynamics of solids we are accustomed to describing the motion of particles or rigid bodies by their velocities and accelerations or more exactly by the velocities and accelerations of their centers of mass. For a finite number of particles, the velocity of the i-th particle can be given by the scalar equations

$$u_i = f_i(t) \qquad v_i = g_i(t) \qquad w_i = h_i(t) \qquad (9\text{-}3)$$

where the subscript “i” identifies the particle. In a fluid, however, there is an infinite number of particles whose character may change continuously, making this approach unfeasible. This technique of describing motion of discrete particles with respect to a fixed set of axes, the lagrangian approach, is not normally used for fluids.

2. In the lagrangian method the specification of velocity applies only at a given time, location the particle at some point (a, b, c). Location of the same particle at a subsequent time requires a set of equations:

$$x_i = F_i(t) \qquad Y_i = G_i(t) \qquad Z_i = H_i(t) \qquad (9\text{-}4)$$

3. The more common approach, the eulerian method, permits us to focus attention on a fixed region in space without regard to the identity of the particles which occupy it a given time. An observation is an instantaneous picture of the velocities and accelerations of every particle. To accomplish this it is necessary only to take the space coordinates as independent variables, rather than dependent as in the lagrangian method. The eulerian velocity field is given by

$$V = iu * jv * kw \qquad (9\text{-}5)$$

Where the respective velocities, in Cartesian coordinates, are

$$u = f(x,y,x,t) \qquad v = g(x,y,z,t) \qquad w = h(x,y,z,t) \qquad (9\text{-}6)$$

Similarly, in the cylindrical and spherical coordinate systems, respectively, the velocity is $V = V(r, \phi ,z,t)$

(9-7)

$V = V(r, \phi, \varphi, t)$

(9-8)

4. With the eulerian approach differential changes in velocities must be expressed in terms of partial derivatives, since each component is affected by both space and time.

SUPPLEMENTARY TEXTS

PERFECT FLUIDS

1. We shall consider techniques which will permit us to solve a large class of problems involving perfect fluids. A perfect fluid is one which has viscosity or one which behaves as if the effects due to viscosity were negligible. Obviously, no fluid fits the inviscid portion of this definition, but in many practical cases the flow of a real fluid can be accurately analyzed in terms of the perfect-fluid theory.

2. The flow in the inviscid region can be analyzed by perfect-fluid theory, but the flow in the viscous region cannot be so treated. Technically, the viscous effects are not the predominant criteria in this daze, however, the flow behaves as if they were and can be treated accordingly. Note that any solution in the in viscid region, resulting in a pressure or velocity distribution, for example, must match with that of the viscous region at the edge boundary layer because of the continuous nature of the physical problem.

3. Rotation w is the average angular velocity of any two mutually perpendicular line elements in the plane of the flow.

P cbrfc

4. A flow is irrotational when curl V $\equiv$ 0. The flow of a perfect irrotational fluid is called potential flow. Its mathematical formulation is identical to that in other potential fields, such as thermal, electric and magnetic fields. The differential equations for incompressible potential flow are linear and may be superimposed. Only incompressible fluids will be treated. From the streamline patterns, which are given by perfect-fluid theory, velocity and pressure variations can be obtained throughout a flow field. Lift and drag on a body can then be determined

from the pressure distribution. It is this result which we seek in our study of perfect fluids.

5. What does being irrotational mean in a physical problem? To answer this, recall that our analysis pertains to an element of fluid and not to the motion of a body of fluid as a whole.

ISOTHERMAL FLOW

1. Every real fluid has a finite viscosity which gives rise to shear forces. In many flow fields, this viscosity if quite small, e.g., the kinematics' viscosity of water at room temperature is of order of 10-5 ft/sec, and it would appear that viscous effects in such fields would be negligible compared with other forces in the momentum equation. This condition is generally true in fields far from solid bodies.

2. The small viscosities of such important fluids as air and water presented a formidable barrier to the early study of fluid mechanics. The early Greek mathematicians, familiar with the diminishing velocity of a spear in flight, concluded that it was necessary to apply a force continually to sustain the velocity of a body in motion subjected to no opposing forces. The low viscosity of air prevented them from recognizing the existence of an opposing force, drag, and this hampered their progress in the study of mechanics.

3. During the last half of the nineteenth century the study of fluid dynamics was sharply divided between theoretical and experimental efforts. A complete formulation of the equations of motion of a viscous fluid has been available since 1845. Known as the Navier-Stokes equations, they are largely attributable to the contributions of Navier, Poisson, St.Venant, and Stokes during the period from 1827 to 1845. These equations form a set of nonlinear partial differential equations the solution of which is a formidable task. This fact, coupled with the very small viscosity of air and water, led many theoreticians to conclude that the in viscid-fluid assumption was justifiable and the mathematical theory of perfect-fluid flow was highly developed before the turn of the twentieth century.

4. Practical engineers, on the other hand, were not enthusiastic supporters of mathematical efforts which yielded such absurd results as zero pressure loss for flow of water thought a ripe or air drag for a cylinder subjected to a cross flow of air. It is certainly not surprising that engineering efforts were heavily concentrated toward experimental program and correlation efforts to obtain maximum applicability of the measured data.

5. At this time the field of fluid mechanics was divided into theoretical hydrodynamics and hydraulics, the former being a mathematical science the latter

an empirical one. The reunification of these two branches was largely due to the contribution of Prandtl, who in 1904 presented a paper “On Fluid Motion with Very Small Friction” before the Third International Mathematical Congress in Heidelburg. In this work, Prandtl showed both experimentally and analytically that the flow over a solid body is divided into two regions, a boundary layer adjacent to the body, in which viscous effects are important and an outer flow field, in which perfect-fluid flow theory is applicable. The importance of his wok cannot be overstated. The boundary layer theory permitted Prandtl to mathematically analyze several simple flow problems with meaningful results. Nevertheless, boundary-layer theory was applied and developed only in Prandtl’s own institute in Gottingen for the next 20 years. Following this period of development and demonstrated success, the theory was accepted, applied and developed. Today it is recognized as one of the most important concepts in fluid mechanics.

6. Before we can attempt to threat any real isothermal-flow problem we must have at our disposal the momentum equations containing the viscous forces. Of particular importance to the study of isothermal momentum transport is a working knowledge of the significance of each term in the viscous momentum (Navier-Stokes) equations.

TURBULENT FLOW (OF INCOMPRESSIBLE ISOTHERMAL FLUIDS)

1. The basic differences between laminar and turbulent flow were discussed in Chap.9. The fundamental difference between laminar and turbulent flow is the existence of completely random fluctuations in the velocity components for the turbulent case. In addition to purely laminar and purely turbulent flow, we find that transition flow usually exists whenever we have the turbulent case. In the development of any boundary layer, internal or external, there normally exists a laminar leading section which becomes turbulent as the fluid moves downstream.

This results in a flow regime between the completely laminar and completely turbulent areas in which the fluid motion is highly unstable, fluctuating between laminar and turbulent characteristics.

2. Transition to turbulent flow: flat plate. The development of the turbulent boundary-layer can be explained best for flow along a flat plate. Consider a free-stream uniform-velocity flow approaching a flat plate at zero incidences. As the fluid approaches the leading edge, large shear forces result in the fluid velocity being altered or slowed near the plate. This always results in the development of an initial section of laminar boundary layer. This boundary layer thickens with distance (solutions for the thickness as a function of the length

Reynolds number were presented in Chap.12), and eventually instabilities cause the boundary layer to become turbulent. The turbulent boundary layer is much thicker and because of the velocity perturbations in the “y” direction it has a much flatter velocity profile than laminar flow over most of its thickness. In the laminar sub layer however, there is a very steep gradient. As a consequence, the shear stress at the wall is much greater for the turbulent boundary layer than for the laminar boundary layer.

3. Total drag on a plate is highly dependent upon the location of the transition from laminar to turbulent boundary layer flow. Transition-region flow is highly oscillatory in nature, appearing at one instant in time to be laminar and slightly later to be turbulent. This transition region is actually a finite length, but since we are unable to analyze transitional flow mathematically, we shall simplify our model to consider transition to occur at a single location, the boundary-layer flow ahead of this being laminar and that downstream being turbulent.

4. The transition to turbulent boundary-layer flow depends upon many parameters; the more significant ones are (1) the critical Reynolds number $V\ x_c/v$; (2) the wall roughness, (3) the free-scream turbulence, and (4) the external-flow pressure gradient. For the flat plate at zero incidences to the direction of flow the pressure gradient is zero. For many other practical problems (such as airfoils) this is not the case and the pressure gradient is not only important with regard to transition but also has a decided influence upon separation.