普通高等教育“十三五”规划教材

ENGLISH IN ENERGY AND POWER ENGINEERING

能源与动力工程专业英语

《能源与动力工程专业英语》编写组　编

中国石化出版社
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内　容　提　要

本书由精通英语的能源与动力工程专业的教师在总结多年科技英语和专业英语教学经验的基础上编写而成。全书包括热工基础、热工设备、热工应用三个部分。其中热工基础部分包括传热与热力学、燃料与燃烧、热工仪表及控制原理等内容；热工设备部分包括锅炉、汽轮机、制冷设备等内容；热工应用部分包括热能利用及专业英语写作等内容。全书共有 44 个单元，每个单元则由课文、课文词汇表、练习作业等组成。

本书有较强的知识性和实用性，可作为高等院校能源动力类本科生的专业英语教材，也适合作为从事相关专业的工程技术人员的学习参考材料。

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第二版前言

本书第一版《热能与动力工程专业英语》于2008年出版，出版后得到许多院校师生的认可，多次重印。本版根据高等院校新的专业名称设置，更名为《能源与动力工程专业英语》。

大学本科学生在学完基础英语之后，在高年级可通过学习专业英语课程做到大学四年英语学习不间断，熟悉科技与专业英语的特点，扩大科技与专业英语词汇量，提高科技与专业英语阅读能力。本教材是在目前尚不具备在某些专业课中直接使用英文教材和使用英语讲授的条件下，由精通英语的能源与动力工程专业的专业教师在总结多年科技英语和专业英语教学经验的基础上编写成的。通过学习本书，可使能源与动力工程专业的大学本科生巩固专业知识，提高专业英语的阅读水平。

本书覆盖了能源与动力工程专业的基本内容。全书包括传热与热力学、燃料与燃烧、热工仪表及控制原理、锅炉、汽轮机、制冷设备、换热器、能源利用及专业英语写作等内容。

本书选材较为新颖，文体规范，难度适中。为了适应专业英语教学方面的要求，本书既全面覆盖了学生学过的内容，又拓宽了专业领域的知识。书中每篇英文阅读材料都安排了课后练习，可使学生对所学知识进一步巩固与提高。为了便于读者阅读本书，在每篇阅读材料后都附有词汇表。为提高学生的专业英语综合能力，本书还特地增加了专业英语写作方面的内容。

全书共分三个部分，其中第一部分由战洪仁、王立鹏、寇丽萍、王翠华编写。第二部分由王翠华、张先珍、李雅侠、战洪仁、曾祥福编写。第三部分由曾祥福、张先珍、寇丽萍、王立鹏、李雅侠编写。本书由沈阳化工大学金志浩教授审阅。感谢刘鹏、刘彦超参与本书的校对。

由于编者水平有限，书中不足之处在所难免，恳请广大读者批评指正。

编　者

目　　录

PART Ⅰ BASIC OF PYROLOGY

Unit 1 Heat Transfer

Heat transfer is the science that seeks to predict the energy transfer that may take place between material bodies as a result of a temperature difference.

The usual progression in the educational process of the thermal systems engineering generally starts with the study of energy in a beginning physics course, progresses to the thermodynamics sequence, followed by a beginning heat transfer course, and then goes on to specialized courses in more advanced treatment of the basic modes of heat transfer and/or to applications oriented courses.

Thermodynamics teaches that this energy transfer is defined as heat. The science of heat transfer seeks not merely to explain how heat energy may be transferred, but also to predict the rate at which the exchange will take place under certain specified conditions. The fact that a heat-transfer rate is the desired objective of an analysis points out the difference between heat transfer and thermodynamics. Thermodynamics deals with systems in equilibrium; it may be used to predict the amount of energy required to change a system from one equilibrium state to another; it may not be used to predict how fast a change will take place since the system is not in equilibrium during the process. Heat transfer supplements the first and second principles of thermodynamics by providing additional experimental rules which may be used to establish energy-transfer rates. As in the science of thermodynamics, the experimental rules used as a basis of the subject of heat transfer are rather simple and easily expanded to encompass a variety of practical situations.

As an example of the different kinds of problems that are treated by thermodynamics and heat transfer, consider the cooling of a hot steel bar that is placed in a pail of water. Thermodynamics may be used to predict the final equilibrium temperature of the steel bar-water combination. Thermodynamics will not tell us how long it takes to reach this equilibrium condition or what the temperature of the bar will be after a certain length of time before the equilibrium condition is attained. Heat transfer may be used to predict the temperature of both the bar and the water as a function of time.

One generally identifies three basic mechanisms of transport: conduction, convection, and radiation. Of these mechanisms, conduction and radiation can be considered as pure in the sense that they can take place as the only propagating mechanisms. Convection, on the other hand, is a mixture of conduction and mass transport of energy, with radiation present in significant or insignificant amounts depending on the fluid present and the temperature levels. One might also want to include phase change as a basic mechanism; however, even more so than convection, phase change is a mixture of conduction and complicate mass transport processes in the fluid portion, in addition the actual change of phase mechanism. It is, therefore, generally considered to be in a category by itself. Since most heat transfer occurrences involve more than one mode, it will be necessary to critically examine the basic modes before considering more general happenings. In the discussion to follow, then, we focus only on the three basic modes and their concepts and definitions.

Conduction Heat Transfer

When a temperature gradient exists in a body, experience has shown that there is an energy transfer from the high-temperature region to the low-temperature region. We say that the energy is transferred by conduction and that the heat-transfer rate per unit area is proportional to the normal temperature gradient:

$$\frac{q}{A} \sim \frac{\partial T}{\partial x}$$

When the proportionality constant is inserted,

$$Q = -kA\frac{\partial T}{\partial x} \tag{1-1}$$

Where Q is the heat-transfer rate and $\partial T/\partial x$ is the temperature gradient in the direction of the heat flow in calculus notation. When the temperature is a function of only one variable (distance x, for example), we can express the temperature gradient by means of the differential operator d as $\mathrm{d}T/\mathrm{d}x$. We can then express Equation (1-2) in the following form:

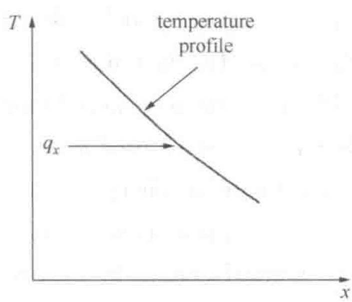

Fig.1.1 Sketch showing direction of heat flow

$$Q = -kA\frac{\mathrm{d}T}{\mathrm{d}x} \tag{1-2}$$

The positive constant k is called the thermal conductivity of the material, and the minus sign is inserted so that the second principle of thermodynamics will be satisfied; i.e., heat must flow downhill on the temperature scale, as indicated in the coordinate system of Fig 1.1. Equation (1-1) is called Fourier's law of heat conduction after the French mathematical physicist Joseph Fourier, who made very significant contributions to the analytical treatment of conduction heat transfer. It is important to note that Equation (1-1) is the defining equation for the thermal conductivity and that k has the units of watts per meter per Celsius degree in a typical system of units in which the heat flow is expressed in watts.

The thermal-conductivity k is generally a function of temperature. For solids, the variation with temperature is usually not a strong one, but for liquids and gases, k can be a strong function of temperature.

Words and Expressions

1. thermodynamics [θəːməudaiˈnæmiks] *n.* 热力学
2. combination [ˌkɔmbiˈneiˈʃən] *n.* 结合，联合，合并，化合，化合物
3. function [ˈfʌŋkʃən] *n.* 功能，作用；函数
4. conduction [kənˈdʌkʃən] *n.* 引流；输送，传播；传导性[率]
5. convection [kənˈvekʃən] *n.* (=transmission) 传达；(热) 对流

6. radiation [ˌreidiˈeiʃən] *n.* 放射，辐射；发射；发光
7. mechanisms [ˈmekənizəm] *n.* 机械，机械装置[结构]
8. significant [sigˈnifikənt] *adj.* 有意义的，重大的，重要的；表明……的（of）
9. gradient [ˈgreidiənt] *n.* 坡度；梯度；陡度；斜率；（温度，气压的）变化率
10. proportionality [prəˌpɔːʃəˈnæliti] *n.* 比例（性），均衡（性），相称
11. calculus [ˈkælkjuləs] *n.* 微积分(学)
12. heat transfer 传热（学）
13. starts with 以……开始
14. principles of thermodynamics 热力学定律
15. energy-transfer 能量转换
16. equilibrium temperature 平衡温度
17. on the other hand 另一方面
18. phase change 相变，换相
19. in addition 另外
20. temperature gradient 温度梯度
21. proportionality constant 比例常数
22. thermal conductivity 导热性（系数）

Exercises

1. Put the following into Chinese.

（1）energy-transfer （2）equilibrium temperature （3）principles of thermodynamics
（4）temperature gradient （5）heat transfer

2. Answer the following question, according to text.

（1）What is heat transfer?

（2）What is the difference between heat transfer and thermodynamics?

3. Translate the paragraph 3, 4 of the text into Chinese.

Unit 2 The Convection Mode

When a fluid at rest or in motion is in contact with a surface at a temperature different from the plate, energy flows in the direction of the lower temperature as required by the principle of thermodynamics. We say that heat is convected away, and we call the process convection heat transfer. Fig. 1.2 shows some possibilities.

For both situations shown in Fig. 1.2, we express the overall effect of convection, we use Newton's law of cooling:

$$Q=hA(T_W-T_\infty) \tag{1-3}$$

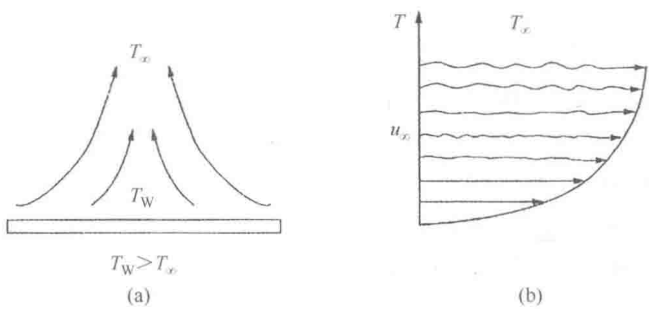

Fig. 1.2 Convection concepts for a fluid in contact with a solid surface:
(a) fluid far from surface at rest, and (b) fluid far from surface. In motion with respect to the surface.

The temperature T_W is that directly at the surface in contact with the plate, and the temperature T_∞ is the fluid temperature far enough away from the surface so that no influence of the surface is evident. The area A is the surface area in contact with the fluid and we should note that A is perpendicular to the direction of the heat flux Q. The proportionality factor h is called the heat transfer coefficient (also the unit area conductance or the convective conductance) and depends on the geometrical arrangement, orientation, and surface condition (smooth or rough), as well as on the properties and velocity of the fluid.

There are two convection modes: forced convection and natural convection. If a heated plate were exposed to ambient room air without an external source of motion, a movement of the air would be experienced as a result of the density gradients near the plate. We call this natural convetion (or free convection), as opposed to forced convection, which is experienced in the case of the fan blowing air over a plate.

Table 1.1 lists some representative values for the heat transfer coefficient under a variety of engineering conditions.

Table 1.1 Representative values for the heat transfer coefficient

Condition	h/ ($Btu/h \cdot ft^2 \cdot F$)	h/ ($kW/m^2 \cdot K$)
Free convection, air	1~6	0.006~0.035

续表

Condition	h/ (Btu/h · ft² · F)	h/ (kW/m² · K)
Forced convection, air	5~150	0.028~0.851
Free convection, water	30~200	0.170~1.14
Forced convection, water	100~4000	0.570~22.7
Boiling water	1000~15000	5.70~85
Condensing steam	10000~30000	57~170
Forced convection, sodium	20000~40000	113~227

Convection Energy Balance on a Flow Channel

The energy transfer expressed by Equation (1-3) is used for evaluating the convection loss for flow over an external surface. Of equal importance is the convection gain or loss resulting from a fluid flowing inside a channel or tube, as shown in Fig. 1.3. In this case, the heated wall at T_W loses heat to the cooler fluid which consequently rises in temperature as it flows from inlet conditions at T_i to exit conditions at T_e. Using the symbol i to designate enthalpy (to avoid confusion with h, the convection coefficient), the energy balance on the fluid is

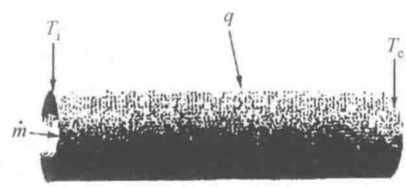

Fig. 1.3 Convection in a channel

$$q=\dot{m}(i_e-i_i) \qquad (1-4)$$

Where $\dot{m}$ is the fluid mass flow rate. For many single phase liquids and gases operating over reasonable temperature ranges $\Delta i=c_p\Delta T$ and we have

$$q=\dot{m}c_p(T_e-T_i)$$

which may be equated to a convection relation like Equation (1-3)

$$q=\dot{m}c_p(T_e-T_i)=hA(T_{w,\,avg}-T_{fluid,\,avg}) \qquad (1-5)$$

In this case, the fluid temperatures T_e, T_i and T_{fluid} are called bulk or energy average temperatures. A is the surface area of the flow channel in contact with the fluid.

Words and Expressions

1. perpendicular [ˌpəːpənˈdikjulə] *adj.* 垂直的，正交的；*n.* 垂线
2. property [ˈprɔpəti] *n.* 性质，特性
3. representative [ˌrepriˈzentətiv] *n.* 代表；*adj.* 典型的，有代表性的
4. consequently [kɔnsikwəntli] *adv.* 从而，因此
5. confusion [kənˈfjuːʒən] *n.* 混乱，混淆
6. enthalpy [ˈenθælpi，enˈθælpi] *n.* 【物】焓，热函
7. at rest 安眠，长眠，静止
8. surface area 表面积
9. convection heat transfer 对流传热
10. Newton's law of cooling 牛顿冷却定律

11. proportionality factor 比例因子，比例系数
12. heat transfer coefficient 传热系数
13. properties of the fluid 流体的物性
14. forced convection 强迫对流
15. natural convection 自然对流
16. flow channel 液流通路;流动（试验）水槽;气流道
17. mass flow rate 质量流量
18. average temperatures 平均温度

Exercises

1. Put the following into Chinese.

(1) forced convection (2) natural convection (3) average temperatures

(4) at rest (5) mass flow rate

2. Answer the following question, according to text.

(1) What is convection heat transfer?

(2) What are the modes of convection heat transfer?

3. Translate the paragraph 3, 4 of the text into Chinese.

Unit 3 Radiation Heat Transfer

In contrast to the mechanisms of conduction and convection, where energy transfer through a material medium is involved, heat may also be transferred through regions where a perfect vacuum exists. The mechanism in this case is electromagnetic radiation. We shall limit our discussion to electromagnetic radiation which is propagated as a result of a temperature difference; this is called thermal radiation.

Thermodynamic considerations show that an ideal thermal radiator, or blackbody, will emit energy at a rate proportional to the fourth power of the absolute temperature of the body and directly proportional to its surface area. Thus

$$q_{emittid} = \sigma A T^4 \quad (1-6)$$

Where σ is the proportionality constant and is called the Stefan-Boltzmann constant with the value of $5.669\times10^{-8}W/m^2 \cdot K^4$. Equation (1-6) is called the Stefan-Boltzmann law of thermal radiation, and it applies only to blackbodies. It is important to note that this equation is valid only for thermal radiation; other types of electromagnetic radiation may not be treated so simply.

Equation (1-6) governs only radiation emitted by a blackbody. The net radiant exchange between two surfaces will be proportional to the difference in absolute temperatures to the fourth power, i. e.

$$\frac{q_{netexchange}}{A} \propto \sigma \left(T_1^4 - T_2^4\right) \quad (1-7)$$

Where $q_{netexchange}$ is the net radiant exchange.

We have mentioned that a blackbody is a body that radiates energy according to the T^4 law. We call such a body black because black surfaces, such as a piece of metal covered with carbon black, approximate this type of behavior other types of surfaces, such as a glossy painted surface or a polished metal plate, do not radiate as much energy as the blackbody; however, the total radiation emitted by these bodies still generally follows the $T_1{}^4$ proportionality. To take account of the "gray" nature of such surfaces, we introduce another factor into Equation (1-7), called the emissive $\in$, which relates the radiation of the "gray" surface to that of an ideal black surface. In addition, we must take into account the fact that not all the radiation leaving one surface will reach the other surface since electromagnetic radiation travels in straight lines and some will be lost to the surroundings. We therefore introduce two new factors in Equation (1-6) to take into account both situations, so that

$$q = F_{\in} F_G \sigma A \left(T_1^4 - T_2^4\right) \quad (1-8)$$

where $F_{\in}$ is an emissive function, and F_G is a geometric "view factor" function.

Radiation in an Enclosure

A simple radiation problem is encountered when we have a heat-transfer surface at temperature T_1 completely enclosed by a much larger surface maintained at T_2. The net radiant exchange in this case can be calculated with

$$q=\in_1\sigma A_1(T_1^4-T_2^4) \qquad (1-9)$$

Values of $\in$ are given in Appendix A.

Radiation heat-transfer phenomena can be exceedingly complex, and the calculations are seldom as simple as implied by Equation (1-9).

Summary

We may summarize our introductory remarks very simply. Heat transfer may take place by one or more of three modes: conduction, convection, and radiation. It has been noted that the physical mechanism of convection is related to the heat conduction through the thin layer of fluid adjacent to the heat-transfer surface. In both conduction and convection Fourier's law is applicable, although fluid mechanics must be brought into the convection problem in order to establish the temperature gradient.

Radiation heat transfer involves a different physical mechanism-that of propagation of electromagnetic energy. To study this type of energy transfer we introduce the concept of an ideal radiator or blackbody, which radiates energy at a rate proportional to its absolute temperature to fourth power.

It is easy to envision cases in which all three modes of heat transfer are present, as in Fig. 1.4. In this case the heat conducted through the plate is removed from the plate surface by a combination of convection and radiation. An energy balance was given as

$$-kA\left.\frac{\mathrm{d}T}{\mathrm{d}y}\right|_{\mathrm{wall}}=hA\ (T_{\mathrm{W}}-T_{\infty})\ +F_{\in}F_{\mathrm{G}}\sigma A\ (T_{\mathrm{W}}^4-T_{\mathrm{S}}^4) \qquad (1-10)$$

where

T_{S} = temperature of surroundings

T_{W} = surface temperature

T_{∞} = fluid temperature

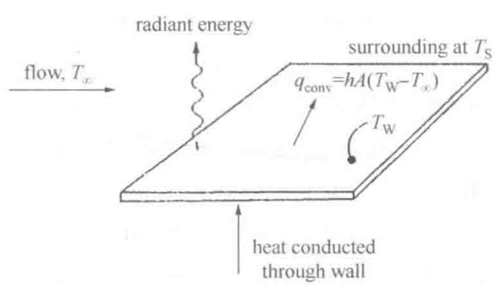

Fig. 1.4 Combination of conduction, convection, and radiation heat transfer

To apply the science of heat transfer to practical situations, a thorough knowledge of all three modes of heat transfer must be obtained.

Words and Expressions

1. electromagnetic [ilektrəʊ'mægnetik] *adj.* 电磁的
2. Stefan-Boltzmann 斯蒂藩波尔兹曼

3. radiate ['reidieit] *vt.* 放射，辐射，传播，广播；*vi.* 发光，辐射，流露
4. emissive [i'misiv] *n.* 【物】发射率
5. geometric [dʒiə'metrik] *adj.* 几何的，几何学的
6. enclosure [in'kləuʒə] *n.* 围住，围栏，四周有篱笆或围墙的场
7. in contrast to 和……形成对比
8. electromagnetic radiation 电磁辐射
9. thermal radiation 热辐射
10. thermal reactor 热反应堆
11. Stefan-Boltzmann law 斯蒂藩波尔兹曼定律
12. carbon black 黑烟末
13. in addition 另外
14. take into account 重视，考虑
15. view factor 角系数
16. blackbody 黑体

Exercises

1. Put the following into Chinese.

(1) in contrast to (2) carbon black (3) in addition

(4) take into account (5) Stefan-Boltzmann law

2. Answer the following question, according to text.

(1) What is radiation heat transfer?

(2) What are the factor related to radiation heat transfer?

3. Translate the paragraph 1, 4 of the text into Chinese.

Unit 4 Basic Concepts of Thermodynamics

Thermodynamics is a basic science that deals with energy and has long been an essential part of engineering curricula all over the world. This introductory text contains sufficient material for two sequential courses in thermodynamics, and it is intended for use by undergraduate engineering students and by practicing engineers as a reference. The objectives of this text are to cover the basic principle of thermodynamics.

The basic abstraction of thermodynamics is the division of the world into systems delimited by real or ideal boundaries. The systems not directly under consideration are lumped into the environment. It is possible to subdivide a system into subsystems, or to group several systems together into a larger system. Usually systems can be assigned a well-defined state which can be summarized by a small number of parameters.

Thermodynamic Systems

A thermodynamic system is that part of the universe that is under consideration. A real or imaginary boundary separates the system from the rest of the universe, which is referred to as the environment. A useful classification of thermodynamic systems is based on the nature of the boundary and the flows of matter, energy and entropy through it. There are three kinds of systems depending on the kinds of exchanges taking place between a system and its environment:

- *isolated* systems: not exchanging heat, matter or work with their environment. An example of an isolated system would be an insulated container, such as an insulated gas cylinder.
- *closed* systems: exchanging energy (heat and work) but not matter with their environment. A greenhouse is an example of a closed system exchanging heat but not work with its environment. Whether a system exchanges heat, work or both is usually thought of as a property of its boundary, which can be

  * *adiabatic* boundary: not allowing heat exchange;
  * *rigid* boundary: not allowing exchange of work.

- *open* systems: exchanging energy (heat and work) and matter with their environment. A boundary allowing matter exchange is called permeable. The ocean would be an example of an open system.

In reality, a system can never be absolutely isolated from its environment, because there is always at least some slight coupling, even if only via minimal gravitational attraction. In analyzing an open system, the energy into the system is equal to the energy leaving the system.

Thermo Dynamics and Energy

Thermodynamics can be defined as the science of energy. Although everybody has a feeling of what energy is, it is difficult to give a precise definition for it. Energy can be viewed as the ability to cause changes.

The name thermodynamics stems from the Greek words therme (heat) and dynamics (power). which is most descriptive of the early efforts to convert heat into power. Today the same name is broadly interpreted to include all aspects of energy and energy transformations, including power generation, refrigeration and relationships among the properties of matter.

One of the most fundamental laws of nature is the conservation of energy principle. It simply states that during an interaction, energy can change from one form to another but the total amount of energy remains constant. That is, energy cannot be created or destroyed. A rock falling off a cliff, for example, picks up speed as a result of its potential energy being converted to kinetic energy (Fig. 1.5). The conservation of energy principle also forms the backbone of the diet industry: a person who has a greater energy input (food) than energy output (exercise) will gain weight (store energy in the form of fat), and a person who has a smaller energy input than output will lose weight (Fig. 1.6). The change in the energy content of a body or any other system is equal to the difference between the energy input and the energy output, and the energy balance is expressed as $E_{in} - E_{out} = \Delta E$.

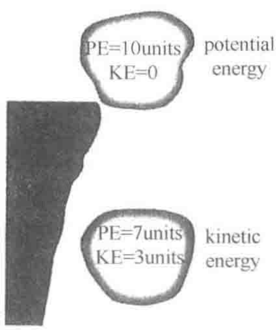

Fig.1.5 Energy cannot be created or destroyed; It can only change forms (the first law)

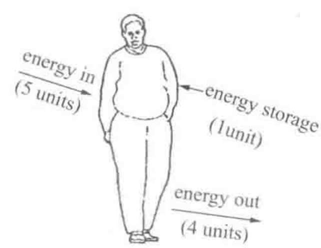

Fig.1.6 Conservation of energy principle for the human body

Words and Expressions

1. boundary [ˈbaundəri] *n.* 边界，控制面
2. entropy [ˈentrəpi] *n.* [物]熵，[无]平均信息量
3. permeable [pə: miəbl] *adj.* 有浸透性的，能透过的
4. fundamental [ˌfʌndəˈmentl] *adj.* 基础的，基本的；*n.*基本原则，基本原理
5. absolutely [ˈæbsəlu: tli] *adv.* 完全地，绝对地
6. kinetic [kaiˈnetik] *adj.* （运）动的，动力（学）的
7. dynamics [daiˈnæmiks] *n.* 动力学
8. conservation [ˌkɔnsə(:)ˈveiʃən] *n.* 保存，保持，守恒
9. energy principle 能量原理
10. conservation of energy 能量守恒
11. power generation 发电
12. energy balance 能量平衡
13. kinetic energy 动能
14. isolated systems 孤立系统