英汉双语教学参考书

[English-Chinese]

The Guide and Solution to College Physics Exercises

英汉大学物理解题指导及习题

■ 主　编　刘传安

■ 副主编　余志核　王卫林

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前　言

物理学是基础，是几乎一切自然科学的基础；物理学是钥匙，人们在创立和发展物理学的同时，物理学也帮助人们揭开了一个又一个的自然之谜；物理学是先导，物理理论和技术的每一次重大突破，几乎都孕育了人类生产方式甚至社会生活形式的重大变革。

因此，帮助学生掌握物理学习方法，提高物理理论素养，同时又能较好地克服语言障碍，与世界发达国家在专业领域内进行学术交流，是我们物理教学工作者的不懈追求和良好愿望。正是基于此，我们尝试编写了这本《英汉大学物理解题指导及习题》，以期对广大在校大学生，尤其是理工类学生对物理学习有所裨益。

全书分三部分：第一部分为序言，介绍了国际单位制及解题方法。第二部分为解题指导及习题，共五章，第一章力学，第二章分子物理学和热力学，第三章电学和磁学，第四章振动和波，第五章光学。每章之前简单介绍了国际单位制与其它单位制之间的换算。每章选取了一些有代表性的习题进行解题指导。每节之前对本章节基本概念、定理和计算公式做了简明介绍，然后精选了数百道习题，可供学生自我练习。为方便学生阅读，以上内容全部英汉对照编排。第三部分为习题答案及附录、附表，为了节省篇幅，这部分仅用中文。

全书内容覆盖面宽，与大学物理同步，以基础内容为主。全书英语词汇以科学出版社出版的《英汉物理词汇》为准。

本书可供理科、工科及师范院校、电大、职大等选作物理双语教学辅助教材或学生学习参考书。

本书在编写过程中得到许多同事的大力支持和帮助，他们提出了许多宝贵的意见和建议，同时，参考了赵凯华、陈熙谋教授编写的《电磁学》，天津大学杨仲耆教授等编写的《大学物理学》，天津大学庞兆芳教授编写的《大学物理学习指导》。此外，还参考了许多其它大学教材，在此不一一指明，特致谢意。本书在编辑出版过程中，得到了天津大学出版社的大力支持。天津大学物理系教授吴萍、任隆良等老师对书稿内容进行了审定。

由于水平有限，书中难免有缺点和错误，恳请读者不吝赐教。

编　者

2004.12.30 于江西宜春学院

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Introduction

1. International System of Units(SI)

Various physical quantities are interrelated by equations which express the relation between them. For example, the acceleration a imparted to a body with the mass m is related to the force F acting upon this body by the equation:

$$F = kma \quad (1)$$

where k is a factor depending on the units in which F, m and a are measured. If the units of mass and acceleration are known, the unit of force can be so selected that the factor k in equation(1) is equal to unity, and thus

$$F = ma$$

With this aim, the unit of force should be the force which imparts a unit of acceleration to a unit of mass.

By treating any newly introduced quantity in the same manner, its unit of measurement can be found from the formula which determines this quantity; thus a system of derived units can be obtained.

Various systems differ from each other by the units taken as the basic ones.

This book is based on the International System of Units(SI) adopted by the Eleventh General Conference on Weights and Measures in 1960. The People's Republic of China State Standard GB 3100 – 93 defines the SI system as the one preferable in all the fields of science, engineering and the national economy, and also in schools and colleges of the P.R.China.

The International System of Units(SI) is divided into several independent systems for various fields of measurement, as follows:

1) System of mechanical units(GB 3102.3 – 93);

2) System of thermal units(GB 3102.4 – 93);

3) System of electrical and magnetic units(GB 3102.5 – 93);

4) System of acoustic units(GB 3102.7 – 93);

5) System of light units(GB 3102.6 – 93).

The basic SI mechanical units are the metre (m), ki-

序　言

1. 国际单位制(SI 制)

各种物理量用表示它们之间关系的方程相互联系。例如，对于一个质量为 m、加速度为 a 的物体与作用在这个物体上的力的关系可以用方程把它们联系起来：

$$F = kma \quad (1)$$

其中 k 是依赖 F、m 和 a 的测量单位的一个常数。如果质量和加速度的单位已知，力的单位能够如此选择，即令方程(1)中的常数 k 等于 1，这样

$$F = ma$$

因此，力的单位就是对一个单位的质量，产生一个单位的加速度的力。

对于任何新引入的物理量可以用同样的方法来研究，在一个单位制下，它的测量单位能够根据决定这个物理量的公式，经过推导而确定。

由于使用的基本单位不同，所以各种单位制互不相同。

本书是以 1960 年第十一届国际计量大会通过的国际单位制为基础的，国际单位制是我国法定计量单位的基础。一切属于国际单位制的单位都是我国的法定计量单位。我国的国家标准 GB 3100—93 规定了可以与国际单位制并用的单位以及计量单位的使用规则。它适用于我国国民经济、科学技术、文化教育等一切领域。

国际单位制(SI 制)被分为几个独立的体制，如测量的各个方面，具体如下：

1)力学单位制(GB 3102.3—93)；

2)热量单位制(GB 3102.4—93)；

3)电学和磁学单位制(GB 3102.5—93)；

4)声学单位制(GB 3102.7 – 93)；

5)光学单位制(GB 3102.6—93)。

logramme - mass (kg) and second (s). Added to these for various fields of measurement are the following basic units: the degree Kelvin for thermal measurements, the ampere for electrical measurements and the candela for luminous intensity.

The SI system also includes two supplementary units - for a plane angle and a solid angle.

The basic and supplementary SI units are given in Table 1.

国际单位制中力学的基本单位是米、千克、秒。为了满足各种测量的需要,还要增加以下基本单位,热量测量的基本单位度、开,电流测量的基本单位安培,光强度基本单位坎德拉,物质的量基本单位摩尔。

国际单位制也包括两种补充单位——平面角和立体角。

国际单位的基本单位和补充单位见表 1。

国际单位制的基本单位和补充单位

The basic and supplementary SI units

表 1(Table1)

Quantity	量	Unit	单位	Symbol 符号
Basic Units 基本单位				
length	长度	metre	米	m
mass	质量	kilogramme	千克	kg
time	时间	second	秒	s
electric current	电流	ampere	安[培]	A
thermodynamic temperature	热力学温度	degree Kelvin	开[尔文]	K
Amount of any substance	物质的量	mole	摩[尔]	mol
luminous intensity	发光强度	candela	坎[德拉]	cd
Supplementary Units 补充单位				
plane angle	平面角	radian	弧度	rad
solid angle	立体角	steradian	球面度	sr

Table 2 gives the prefixes used to form multiples and fractions of SI units.

用于组成国际单位的倍数量和分数量的单位词冠见表 2。

国际单位的倍数量和分数量的词冠

The prefixes used to form multiples and fractions of SI units

表 2(Table2)

Prefix	词冠	Numerical value 数值	Symbol 符号
atto	阿[托]	10^{-18}	a
femto	飞[母托]	10^{-15}	f
pico	皮[可]	10^{-12}	p
nano	纳[诺]	10^{-9}	n

续表

Prefix	词冠	Numerical value 数值	Symbol 符号
micro	微	10^{-6}	μ
milli	毫	10^{-3}	m
centi	厘	10^{-2}	c
deci	分	10^{-1}	d
deca	十	10^{1}	da
hecto	百	10^{2}	h
kilo	千	10^{3}	k
mega	兆	10^{6}	M
giga	吉[咖]	10^{9}	G
tera	太[拉]	10^{12}	T

These prefixes in Table 2 may be attached only to simple quantities (metre, gramme etc.) and never to such as "kilogramme", which already contains the prefix "kilo".

The derived SI units are formed from the basic ones as described above. The relationship between the derived and basic units can be found from dimension formulas. If the basic quantites are designated by l for length, m for mass, t for time, I for electric current, θ for temperature and J for luminous intensity, the dimension formula of a certain quantity X may be written in SI units as follows:

$$[X] = l^{\alpha} m^{\beta} t^{\gamma} I^{\delta} \theta^{\rho} J^{\mu}$$

To find the dimension of X, we must determine the exponents α、β、γ、δ、ρ and μ. These exponents may be positive or negative, integers or fractions.

Example 1. Find the dimension of work. Proceeding from the relation $W = Fl$, we obtain $[W] = L^2MT^{-2}$.

Example 2. Find the dimension of specific heat. Since $c = \frac{Q}{m\Delta\theta}$ and $[Q] = [W]$, we get $[c] = L^2T^{-2}\Theta^{-1}$.

If the dimension of a physical quantity is known in the SI system, it is easy to find the dimension of its unit in this system. Thus, the unit of work obviously has the dimension M^2KGS^{-2} and the unit of specific heat—$M^2S^{-2}DEG^{-1}$, etc.

Tables of derived SI units are given in the respective sections of the book: mechanical units in Chapter 1, ther-

表 2 中的这些词冠可以被加上的仅仅是基本单位(米、克等等),而决不能加到像“千克”这样已经包含有词冠“千”这样的单位。

经过推导的国际单位制是由如上面所描述的一些基本单位而形成的,推导单位和基本单位之间的关系能够根据量纲公式而确定。如果基本量长度用 l 表示,质量用 m 表示,时间用 t 表示,电流用 I 表示,温度用 θ 表示,发光强度用 J 表示,在国际单位制(SI)里,某个量 X 的量纲公式可以写成如下形式:

$$[X] = l^{\alpha} m^{\beta} t^{\gamma} I^{\delta} \theta^{\rho} J^{\mu}$$

为了确定 X 的量纲,必须求出指数 α、β、γ、δ、ρ、μ。这些指数可以是正数、负数、整数或分数。

例 1:求功的量纲。从公式 $W = Fl$ 出发,得到 $[W] = L^2MT^{-2}$。

例 2:求比热的量纲。因为 $c = \frac{Q}{m\Delta\theta}$ 并且 $[Q] = [W]$,得到 $[c] = L^2T^{-2}\Theta^{-1}$。

如果一个物理量的量纲在国际单位制中是已知的,那么很容易求出在此单位制中它的单位的量纲,这样,显然功的单位的量纲为 M^2KGS^{-2},比热的单位的量纲为 $M^2S^{-2}DEG^{-1}$ 等等。

mal units in Chapter 2, electrical and magnetic units in Chapter 3, etc. The same chapters also contain tables which establish the relationship between the SI and other units, including non – system ones.

在本书各章的表中已经给出了国际单位(SI)制的推导单位,力学单位在第一章,热学单位在第二章,电学和磁学单位在第三章等,在同章里还包括国际单位制与其它单位制、非系统制之间的换算表格。

2. Methods of Solving Problems

When solving a problem, first of all establish the physical laws which it is based on. Then use the formulas expressing these laws to solve the problem in symbols, and finally substitute the numerical data in one system of units. Besides the International System of Units, other systems and non – system units are widely used in practice and literature. For this reason the numerical data are not always given in SI units. The relationships between the SI units, and units of other systems and non – system units are given in tables at the beginning of each chapter. To solve a problem in SI units, all the initial data or data taken from reference tables should be converted into SI units . The answer, naturally, will also be in these units.

Sometimes it is not necessary to express all the data in one system. For example, if a quantity is a factor of both the numerator and the denominator, this quantity may obviously be expressed in any units provided they are the same (see Example 2 on p.9).

When a numerical answer is obtained, pay attention to the accuracy of the final result, which should never exceed the accuracy of the initial data. As soon as the numerical data are substituted for the symbols, write the unit of the answer.

If a graph or a diagram is required for solution, select the proper scale and origin of the coordinates, and mark the scale on the graph. The graphs in the answers to some problems are given without a scale, i. e., they show only the qualitative nature of the relationship being sought.

2. 解题方法

解题时,首先确立解题所根据的定律。然后,以符号的形式用公式表达这些解题定律,最后在同一个单位制里换算这些数据。除国际单位制(SI)外,其它体制和非体制单位在实践和著作中也被广泛使用。因此,数据不总是用国际单位制给出,国际单位制单位、其它单位制的单位以及非体制单位之间的关系已在每章开始的各表中给出。用国际单位制解题,所有的原始数据或从关系表取得的数据都必须换算成国际单位制。显然,答案将也是在此单位制内。

有时候不需要所有的数据在一个单位制里来表示,例如,如果一个量是分子、分母两个数的一个商,显然,这个量就可以用,只要保证它们(分子、分母)是用相同单位制的任何一个单位制来表示(参看p.9 例 2)。

当一个数据答案被获得时,要注意最后结果的有效位数,它将不能超过原始数据的有效位数,只要用符号代替数据就可以写出答案的单位。

如果解题需要图解或曲线,就要选择适当的刻度、坐标原点和在图上标出刻度,对于一些问题在答案中仅给出了图像(曲线),而没有标尺刻度,也就是说它们显示的仅仅是所找到的这些关系的定性特性。

Chapter 1 Physical Fundamentals of Mechanics

§ 1 - 1 Mechanical Units

The International System of Units incorporates the MKS system intended for measuring mechanical quantities (GB3102.3 - 93). The basic units in the MKS system are the metre (m), kilogramme (kg) and second (s).

As indicated above, the derived units of this system are formed from the basic units using the relationship between the relevant physical quantities. For example, the unit of velocity can be determined from the relation

$$v = \frac{\Delta l}{\Delta t}$$

Since the unit of length is the metre and that of time the second, the unit of velocity in the MKS system will be 1 m/s. Obviously, the unit of acceleration is 1 m/s^2.

Let us establish the unit of force. According to Newton's second law

$$\boldsymbol{F} = m\boldsymbol{a}$$

The unit of mass is kg and the unit of acceleration m/s^2. Therefore, the unit of force in the MKS system should be the force which imparts an acceleration of 1 m/s^2 to a body with a mass of 1 kg. This unit of force is known as the newton (N).

$$1\ N = 1\ kg \cdot 1\ m/s^2$$

Let us now discuss the relation between the weight and mass of a body. The weight $\boldsymbol{G}$ of a body is the force with which this body is attracted by the Earth, i.e., the force which imparts an acceleration of $g = 9.81\ m/s^2$ to the body. Thus:

$$\boldsymbol{G} = m\boldsymbol{g}$$

As any other force in the MKS system, the weight of a body must be measured in newtons. Sometimes it is measured in kilogrammes. But it should always be borne in mind that the unit of weight (kilogramme) is not a unit of the MKS system. To prevent confusion different symbols will be used for these two utterly different physical quanti-

第一章 力　学

§1-1　力学单位

国际单位制结合 MKS 制用于测量力学量(GB 3102.3—93)。MKS 制的基本单位是米(m)、千克(kg)和秒(s)。

如上所述,这个系统的推导单位是根据用于相关物理量之间关系的基本单位而建立的,比如速度的单位能够根据下列方程式确定

$$v = \frac{\Delta l}{\Delta t}$$

因为长度单位是米,时间单位是秒,显然,在 MKS 制中,速度的单位就是 1 m/s,加速度的单位是 1 m/s^2。

下面确立力的单位。根据牛顿第二定律

$$\boldsymbol{F} = m\boldsymbol{a}$$

质量的单位是 kg,加速度的单位是 m/s^2,因此在 MKS 制中,力的单位就是使质量为 1 kg 物体产生 1 m/s^2 加速度的力,力的单位叫牛顿(N)。

$$1\ N = 1\ kg \cdot 1\ m/s^2$$

现在来讨论一个物体的重量和其质量之间的关系。一个物体的重量 G 是这个物体被地球吸引所受到的力,也就是这个物体获得 $g = 9.81\ m/s^2$ 的加速度的力。这样:

$$\boldsymbol{G} = m\boldsymbol{g}$$

在 MKS 制中一个物体的重量作为一个不同的力必须用牛顿来计量,有时也用千克来计量,但必须时刻记住重量的单位(千克)不是 MKS 制的一个单位。为了防止混淆,对这两个完全不同的物理量,使用不同的符号:千克质量用 kg 来表示,而其重量(力)则用 kgf 来表示。现在来研究重量(千克)的牛顿的关系。千克的重量

ties: a kilogramme of mass will be denoted kg, and one weight (force) – kgf. Let us find the relation between a kilogramme of weight and a newton. A weight of 1 kgf is defined as the weight of a body whose mass is equal to 1 kg, i.e.,

$$1\ \text{kgf} = 1\ \text{kg} \cdot 9.81\ \text{m/s}^2$$

On the other hand

$$1\text{N} = 1\ \text{kg} \cdot 1\ \text{m/s}^2$$

Therefore

$$1\ \text{kgf} = 9.81\ \text{N}$$

The definition of a kilogramme of weight shows that the numerical value of the weight of a body expressed in kgf is equal to the mass of this body in kg. For example, if the mass of a body is 2 kg, its weight is 2 kgf. The weight of a body in kilogrammes must be converted into newtons.

Example. The mass of a body is 4 kg. Find the weight of the body in kgf and in newtons.

Answer: $G = 4$ kgf (not in the MKS system) and $G = 4 \times 9.81$ N(in the MKS system).

The unit of work is determined from the relation:

$$W = F \cdot l$$

The unit of work is obviously the work performed by a force of 1 N over a distance of 1 metre. This unit of work is known as the joule (J).

$$1\ \text{J} = 1\ \text{N} \cdot 1\ \text{m}$$

Power is determined by the formula:

$$P = \frac{W}{t}$$

Therefore the unit of power in the MKS system is the power of a mechanism which performs work of 1 J per second. This unit is known as the watt (W). The same method can be used to determine the derived unit of any physical quantity in the MKS system.

Table 3 gives the basic and the most important derived units for measuring mechanical quantities in the MKS system according to GB3102.3 – 93.

被定义为质量为 1 kg 的物体的重量。重量和牛顿之间的关系，即

$$1\ \text{kgf} = 1\ \text{kg} \cdot 9.81\ \text{m/s}^2$$

另一方面　$1\text{N} = 1\ \text{kg} \cdot 1\ \text{m/s}^2$

所以　$1\ \text{kgf} = 9.81\ \text{N}$

重量(kg)的定义显示，用 kgf 表示的一个物体的重量的数值，等于用 kg 表示的这个物体的质量的数值。比如，如果一个物体的质量是 2 kg，它的重量是 2 kgf，用千克表示的一个物体的重量必须换算成牛顿。

例．一个物体的质量为 4 kg，求这个物体用 kgf 和 N 作单位的重量。

答：$G = 4$ kgf(不是用 MKS 制)

$G = 4 \times 9.81$ N(MKS 制)

功的单位可根据下式确定：

$$W = F \cdot l$$

显然，功的单位是被 1 N 的力移动了 1 m 的距离所做的功，功的单位叫作焦耳(J)。

$$1\ \text{J} = 1\ \text{N} \cdot 1\ \text{m}$$

功率的单位由下列方程确定：

$$P = \frac{W}{t}$$

因此在 MKS 制中，功率的单位是每秒做 1 焦耳的功，这个单位叫作瓦特(W)。同样的方法能用来确定任何物理量在 MKS 制中的推导单位。

根据 GB 3102.3—93，MKS 制中基本单位和最重要的计量力学量的推导单位见表 3。

MKS 单位制中力学基本单位和推导单位

The basic and the must important derived units for measuring mechanical quantities in the MKS system

表 3(Table3)

Quantity and symbol 量和符号		Formula 公式	Unit 单位		Symbol of unit 单位符号	Dimension of quantity 量纲
Basic units 基本单位						
length	长度 l		metre	米	m	L
mass	质量 m		kilogramme	千克	kg	M
time	时间 t		second	秒	s	T
Derived units 推导单位						
area	面积 A	$A = l^2$	square metre	平方米	m^2	L^2
volume	体积 V	$V = l^3$	cubic metre	立方米	m^3	L^3
frequency	频率 ν	$\nu = \frac{1}{T}$	Hertz	赫兹	Hz	T^{-1}
angular velocity	角速度 ω	$\omega = \frac{\Delta\varphi}{\Delta t}$	radian per second	弧度/秒	rad/s	T^{-1}
angular acceleration	角加速度 α	$\alpha = \frac{\Delta\omega}{\Delta t}$	radian per second per second	弧度/秒^2	rad/s^2	T^{-2}
linear velocity	线速度 v	$v = \frac{\Delta l}{\Delta t}$	metre per second	米/秒	m/s	LT^{-1}
linear acceleration	线加速度 a	$a = \frac{\Delta v}{\Delta t}$	metre per second per second	米/秒^2	m/s^2	LT^{-2}
density	密度 ρ	$\rho = \frac{m}{V}$	kilogramme per cubic metre	千克/米^3	kg/m^3	$L^{-3}M$
force weight	力 F 重量 G	$F = ma$	newton	牛顿	N	LMT^{-2}
specific weight	比重 γ	$\gamma = \frac{G}{V}$	newton per cubic metre	牛顿/米^3	N/m^3	$L^{-2}MT^{-2}$
pressure	压强 P	$P = \frac{F}{A}$	newton per square metre	牛顿/米^2	N/m^2	$L^{-1}MT^{-2}$
momentum	动量(冲量) p	$p = m\Delta v = F\Delta t$	kilogramme-metre per second	千克·米/秒	kg·m/s	LMT^{-1}
moment of inertia	转动惯量 I	$I = ml^2$	kilogramme - square metre	千克·米^2	kg·m^2	L^2M
work and energy	功 W 和能 E	$W = Fl$	joule	焦耳	J	L^2MT^{-2}
power	功率 P	$P = \frac{\Delta W}{\Delta t}$	watt	瓦特	W	L^2MT^{-3}
dynamic viscosity	动力粘度(粘滞系数) η	$\eta = \frac{F}{A} \frac{\Delta l}{\Delta v\Delta}$	newton-second per square metre	牛顿·秒/米^2	N·s/m^2	$L^{-1}MT^{-1}$
kinematic viscosity	运动粘滞度 ν	$\nu = \frac{\eta}{\rho}$	square metre per second	米^2/秒	m^2/s	L^2T^{-1}

Table 4 contains the relationship between certain mechanical SI units, and units of other systems and non - system units permitted by GB 3102.3 - 93.

某些力学国际单位与 GB 3102.3—93 标准下的其它体制单位及非体制单位之间的关系见表 4。

国际单位制(SI)和其它单位制之间的换算

The relationshins between certain mechanical SI units, and units of other systems and non - system units

表 4(Table4)

Quantity	量	Unit and its conversion factor to SI units	单位和它与国际单位制的换算因子
length	长度	1 centimetre(cm) = 10^{-2}m 1 micrometre; 1 micron(μ) = 10^{-6}m 1 angstrom(Å) = 10^{-10}m	1 cm = 10^{-2}m 1μm = 10^{-6}m 1Å = 10^{-10}m
mass	质量	1 gramme(g) = 10^{-3} kg 1 ton(t) = 10^3 kg 1 atomic unit of mass (a.u.m) = 1.66 × 10^{-27} kg	1 g = 10^{-3} kg 1 t = 10^3 kg 1 个原子质量单位 = 1.66 × 10^{-27} kg
plane angle	平面角	1 degee(°) = $\frac{\pi}{180}$ rad 1 minute(′) = $\frac{\pi}{108}\times10^{-2}$ rad 1 second(″) = $\frac{\pi}{648}\times10^{-3}$ rad 1 revolution(rev) = 2π rad	1 度 = $\frac{\pi}{180}$ rad 1 分 = $\frac{\pi}{108}\times10^{-2}$ rad 1 秒 = $\frac{\pi}{648}\times10^{-3}$ rad 1 转(rev) = 2π rad
area	面积	1 are(a) = 100 m^2 1 hectare(ha) = 10^4m^2	1 公亩(a) = 100m^2 1 公顷(ha) = 10^4m^2 = 100 公亩 = 15 市亩
volume	体积	1 litre(l) = 1.000 028 × $10^{-3}m^3$	1 公升 = 1.000 028 × $10^{-3}m^3$
force	力	1 dyne(dyn) = 10^{-5} N 1 kilogramme - force(kgf) = 9.81 N 1 ton - force(tonf) = 9.81 × 10^3 N	1 达因(dyn) = 10^{-5} N 1 千克力(kgf) = 9.81 N 1 吨力(tonf) = 9.81 × 10^3 N
pressure	压强	1 dyn/cm^2 = 0.1 N/m^2 1 kgf/m^2 = 9.81N/m^2 1 millimetre of mercury column(mmHg) = 133.0 N/m^2 1 millimetre of water column (mmH_2O) = 9.81N/m^2 1 technical atmosphere (at) = 1 kgf/cm^2 = 0.981 × 10^5 N/m^2 1 physical atmosphere (atm) = 1.013 × 10^5 N/m^2	1 达因/cm^2 = 0.1 N/m^2 1kgf/m^2 = 9.81 N/m^2 1 mmHg = 133.0 N/m^2 1mmH_2O = 9.81 N/m^2 1 个工业大气压 = 1 kgf/cm^2 = 0.981 × 10^5 N/m^2 1 个物理大气压 = 1.013 × 10^5 N/m^2
work, energy, amount of heat	功、能、热能	1 erg = 10^{-7} J 1 kgf·m = 9.81 J 1 Watt hour(Wh) = 3.6 × 10^3 J 1 electron - volt(eV) = 1.6 × 10^{-19} J 1 calorie(cal) = 4.19 J 1 kilocalorie(1 kcal) = 4.19 × 10^3 J 1 physical litre atmosphere (I·atm) = 1.01 × 10^2 J 1 technical litre atmosphere (I·at) = 98.1 J	1 尔格 = 10^{-7} J 1 kgf·m = 9.81 J 1 瓦特小时 = 3.6 × 10^3 J 1 电子伏特 = 1.6 × 10^{-19} J 1 卡路里(cal) = 4.19 J 1 千卡路里(kcal) = 4.19 × 10^3 J 1 物理升大气压(I· atm) = 1.01 × 10^2 J 1 工业升大气压(I·at) = 98.1 J
power	功率	1 erg/s = 10^{-7} W 1 kilogramme - force metre per second (kgf·m/s) = 9.81 W 1 horsepower(hp) = 75kgf·m/s = 736 W	1 尔格/秒 = 10^{-7} W 1 千克力·米/秒(kgf·m/s) = 9.81 W 1 马力 = 75 kgf·m/s = 736 W

续表

Quantity	量	Unit and its conversion factor to SI units	单位和它与国际单位制的换算因子
dynamic (viscosity)	动力粘度(粘滞系数)	1 poise(p) = 0.1 N·s/m^2 = 0.1 kg/m·s	1 泊意斯 = 0.1 N·s/m^2 = 0.1 kg/m·s
kinematic viscosity	运动粘滞度	1 stokes(St) = 10^{-4} m^2/s	1(St)斯托克斯 = 10^{-4} m^2/s

§ 1 – 2 The Guide and Solutions

Example 1. A stone weighing 1.05 kgf and sliding on ice with a velocity of 2.44 m/s is stopped by friction in 10 s. Find the force of friction, assuming it to be constant.

Solution. From Newton's second law we have

$$\boldsymbol{F}\Delta t = m\boldsymbol{v}_2 - m\boldsymbol{v}_1$$

where $\boldsymbol{F}$ is the force of friction under the action of which the velocity of a body with the mass m changes from $\boldsymbol{v}_1$ to $\boldsymbol{v}_2$ during the time Δt. In our case $\boldsymbol{v}_2 = 0$, and

$$\boldsymbol{F} = -\frac{m\boldsymbol{v}_1}{\Delta t}$$

The minus sign shows that the force of friction $\boldsymbol{F}$ is directed opposite to the velocity $\boldsymbol{v}_1$.

In the MKS system $m = 1.05$ kg, $v_1 = 2.44$ m/s and $\Delta t = 10$ s.

Hence

$$F = -\frac{1.05 \times 2.44}{10}\ \text{N} = -0.256\ \text{N}$$

By using Table 4, we can express the answer obtained in other units。

$$|\boldsymbol{F}| = 0.256\ \text{N} = 2.56 \times 10^4\ \text{dyn} = 0.0261\ \text{kgf}$$

Example 2. A man and a cart move towards each other. The man weighs 64 kgf and the cart 32 kgf. The velocity of the man is 5.4 km/h and that of the cart 1.8 km/h. When the man approaches the cart he jumps onto it. Find the velocity of the cart carrying the man.

Solution. According to the law of conservation of momentum

§ 1 – 2 解题指导

例 1. 一颗重 1.05 kgf 的石子,在冰上以 2.44 m/s 的速度滑动,由于摩擦,石子在 10 s 内停止滑动,求摩擦力。假设摩擦力恒定。

解:根据牛顿第二定律有

$$\boldsymbol{F}\Delta t = m\boldsymbol{v}_2 - m\boldsymbol{v}_1$$

其中 $\boldsymbol{F}$ 是摩擦力,在此力的作用下,质量为 m 的石子的速度从 $\boldsymbol{v}_1$ 变到 $\boldsymbol{v}_2$,经过的时间为 Δt,已知 $\boldsymbol{v}_2 = 0$,则

$$\boldsymbol{F} = -\frac{m\boldsymbol{v}_1}{\Delta t}$$

负号说明摩擦力 $\boldsymbol{F}$ 的方向与速度 $\boldsymbol{v}_1$ 的方向相反。

在 MKS 制中,$m = 1.05$ kg, $v_1 = 2.44$ m/s, $\Delta t = 10$ s。

所以

$$F = -\frac{1.05 \times 2.44}{10}\ \text{N} = -0.256\ \text{N}$$

根据表 4,能够用其它单位制表示所获得的结果。

$$|\boldsymbol{F}| = 0.256\ \text{N} = 2.56 \times 10^4\ \text{dyn} = 0.0261\ \text{kgf}$$

例 2. 一个人和一辆大车相向运动,人的重量为 64 kgf,而大车重 32 kgf,人的速度是 5.4 km/h,大车的速度是 1.8 km/h,当人遇到大车时,人跳到大车上,求车载着人的速度。

$$\boldsymbol{p}_1 + \boldsymbol{p}_2 = m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2 = (m_1 + m_2)\boldsymbol{v} \quad (1)$$

where m_1 = mass of the man

$\boldsymbol{v}_1$ = man's velocity before the jump

m_2 = mass of the cart

$\boldsymbol{v}_2$ = velocity of the cart before the man jumps onto it

$\boldsymbol{v}$ = common velocity of the cart and man after the jump

From formula (1)

$$\boldsymbol{v} = \frac{m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2}{m_1 + m_2} \quad (2)$$

Since formula (2) is homogeneous, the masses m_1 and m_2 may be written in any units provided they are the same. Formula (2) also shows that since the units of the masses will be cancelled out, the unit of the velocity $\boldsymbol{v}$ will be the same as that of the velocities $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$. For this reason it is not necessary to convert all the data to MKS units.

The initial velocities of the cart and man were opposite in direction, and therefore their signs were different. Taking the velocity of the man to be positive, we have v_1 = 5.4 km/h and v_2 = − 1.8 km/h. Besides, m_1 = 64 kg and m_2 = 32 kg. By inserting these data into formula (2), we obtain

$$v = \frac{64 \times 5.4 - 32 \times 1.8}{64 + 32} \text{ km/h} = 3.0 \text{ km/h}$$

The velocity $v > 0$. Thus, after the man jumps onto it, the cart will begin to move in the direction in which the man was walking.

Example 3. Water is pumped out of a well 20 m deep by means of a pump with a motor rated at 5 hp. Find the efficiency of the motor if 3.8×10^5 L of water are pumped out during 7 hours of operation.

Solution. The power of the motor P is related to the work W which the motor performs during the time t by the expression

$$P = \frac{W}{t\eta} \quad (1)$$

where η is the efficiency of the pump. The work

解:根据动量守恒定律

$$\boldsymbol{p}_1 + \boldsymbol{p}_2 = m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2 = (m_1 + m_2)\boldsymbol{v} \quad (1)$$

其中 m_1 为人的质量,$\boldsymbol{v}_1$ 为跳之前人的速度,m_2 为大车的质量,$\boldsymbol{v}_2$ 为人跳上车之前大车的速度,$\boldsymbol{v}$ 为人跳上车后,人和车的合速度。

根据方程(1)得

$$\boldsymbol{v} = \frac{m_1\boldsymbol{v}_1 + m_2\boldsymbol{v}_2}{m_1 + m_2} \quad (2)$$

因为方程(2)中质量 m_1 和质量 m_2 是同性的,写成任何单位制的形式结果都相同。方程(2)还显示,因为质量的单位相约,故速度 $\boldsymbol{v}$ 的单位将与速度 $\boldsymbol{v}_1$ 和 $\boldsymbol{v}_2$ 的单位相同,因此,所有的数据不必变换到 MKS 制中。

大车和人的初速度是方向相反,因此它们的符号不同。取人的速度为正,则 v_1 = 5.4 km/h,v_2 = − 1.8 km/h。

另一方面,m_1 = 64 kg,m_2 = 32 kg,把这些数据代入方程(2)则有

$$v = \frac{64 \times 5.4 - 32 \times 1.8}{64 + 32} \text{ km/h} = 3.0 \text{ km/h}$$

因速度 $v > 0$,所以人跳上大车后,大车就开始在与人走的方向一致的方向上运动。

例 3. 用一台具有 5 马力的马达的水泵从 20 米的深井里抽水,如果 7 个小时从井内抽出水 3.8×10^5 升,求马达的效率。

解:马达的功率 P 可以根据马达在时间 t 内所完成的功 W,用下列公式求出

$$P = \frac{W}{t\eta} \quad (1)$$

其中 η 是水泵的效率。质量为 m 的水上升了高度为 h 所做的功为

required to raise a mass m of water to a height h is

$$W = mgh \quad (2)$$

The mass m of the water occupies the volume

$$V = \frac{m}{\rho}$$

then $$m = V\rho \quad (3)$$

where ρ is the density of water. Substitution of $V\rho$ for m in formula (2) and the resulting expression for W in formula (1) gives

$$P = \frac{V\rho gh}{t\eta}$$

Hence $$\eta = \frac{V\rho gh}{Pt} \quad (4)$$

Let us use Table 4 to convert the data of the example to the MKS system. It is expedient to calculate the arithmetic values in the final formula. In our case, $V = 3.8 \times 10^5 L = 3.8 \times 10^5 \times 10^{-3} m^3$, $\rho = 1\ g/cm^3 = \frac{10^{-3}}{10^{-6}}\ kg/m^3$, $P = 5\ hp = 5 \times 736\ W$, $t = 7 \times 3\,600\ s$, $g = 9.81\ m/s^2$ and $h = 20\ m$.

Substituting these data in formula (4), we finally get

$$\eta = \frac{3.8 \times 10^5 \times 10^{-3} \times 10^{-3} \times 9.81 \times 20}{10^{-6} \times 5 \times 736 \times 7 \times 3\,600} = 0.8 = 80\%$$

Example 4. A body falls vertically from the height $h = 19.6$ metres with the initial velocity equal to zero. What distance will be traveled by the body: (1) during the first 0.1 s of motion, (2) during the last 0.1 s of motion? Disregard the resistance of the air.

Solution. (1) The distance traveled by the body during the first 0.1 second of motion is

$$h_1 = \frac{gt_1^2}{2} = 0.049\ m$$

(2) The entire distance will be traveled by the body during $t = \sqrt{\frac{2h}{g}} = 2$ seconds. During the last 0.1 s of motion the body will cover the distance $h_3 = h - h_2$, where h_2 is the distance covered by the body during $t_2 = 2 - 0.1 = 1.9$ s. Since $h_2 = \frac{gt_2^2}{2} = 17.7m$, the distance sought $h_3 = 19.6 - 17.7 = 1.9$ m.

Example 5. A stone is thrown horizontally with the

$$W = mgh \quad (2)$$

质量为 m 的水的体积为

$$V = \frac{m}{\rho}$$

那么 $$m = V\rho \quad (3)$$

其中 ρ 为水的密度，以 $V\rho$ 代替方程(2)中的 m，把 W 的表达式代入方程式(1)，其结果为

$$P = \frac{V\rho gh}{t\eta}$$

所以 $$\eta = \frac{V\rho gh}{Pt} \quad (4)$$

使用表 4 把例题的这些数据变换到 MKS 制中，这对于在最后的方程里计算数值是有利的，其中：$V = 3.8 \times 10^5 \times 10^{-3} m^3$，$\rho = 1\ g/cm^3 = \frac{10^{-3}}{10^{-6}}\ kg/m^3$，$P = 5$ 马力 $= 5 \times 736\ W$，$t = 7 \times 3\,600\ s$，$g = 9.81\ m/s^2$，$h = 20\ m$。

把这些数据代入方程(4)，最后得到

$$\eta = \frac{3.8 \times 10^5 \times 10^{-3} \times 10^{-3} \times 9.81 \times 20}{10^{-6} \times 5 \times 736 \times 7 \times 3\,600} = 0.8 = 80\%$$

例 4. 某物体从 $h = 19.6$ m 高空自由下落(初速度为零)，问在下列情形中，该物体移动的距离是多少？(1) 第一个 0.1 s 内；(2)最后一个 0.1 s 内。忽略空气阻力。

解：(1)在运动的第一个 0.1 s 期间该物体移过的距离为

$$h_1 = \frac{1}{2}gt_1{}^2 = 0.049\ m$$

(2)在运动的最后 0.1 s 期间该物体将走过距离 $h_3 = h - h_2$，其中 h_2 是物体在 $t_2 = 2 - 0.1 = 1.9$ s(因为 $h = \frac{1}{2}gt_{总}^2$，$t_{总} = 2$ s)期间走过的距离。因为 $h_2 = \frac{1}{2}gt_2^2 = 17.7$ m，故所求的距离 $h_3 = 19.6 - 17.7 = 1.9$ m。

例 5. 一颗石子从高 $H = 25$ m 的塔