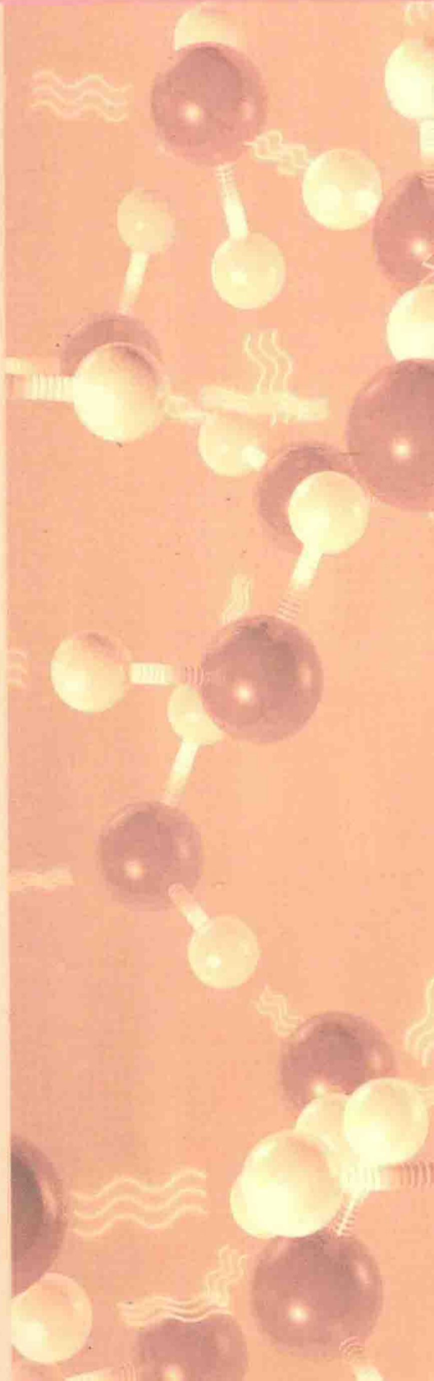
● 大学英语拓展课程系列

拓展课程
ESP

Advanced Physics through Diagrams
牛津物理学英语图示教程

Stephen Pople



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叶谋仁　注释

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PHYSICS
through diagrams

Stephen Pople

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出版说明

教育部最新颁布的《大学英语课程教学要求》将大学英语的教学目标确定为“培养学生的英语综合应用能力，特别是听说能力，使他们在今后学习、工作和社会交往中能用英语有效地进行交际，同时增强其自主学习能力，提高综合文化素养，以适应我国社会发展和国际交流的需要”，并提出：“将综合英语类、语言技能类、语言应用类、语言文化类和专业英语类等必修课程和选修课程有机结合，确保不同层次的学生在英语应用能力方面得到充分的训练和提高。”《大学英语课程教学要求》明确要求大学英语教学中开设选修课，以满足大学生的实际需求。

依据《大学英语课程教学要求》，上海外语教育出版社邀请国内外英语教学专家开发编写了选修教材，通过教材的出版引领、促进了大学英语选修课程设置的发展，丰富了我国大学英语教学。这些教材品种丰富，涵盖面广，包括以下多个系列：大学英语应用提高阶段专业英语系列教材、大学英语综合应用能力选修课系列教材、职场英语选修教程系列、大学目标英语、牛津专业英语基础丛书等。这些年来，全国数百所高校使用了这些教材，部分老师对教材的内容和编写形式提出了宝贵的建议，为我们进一步完善教材提供了实践依据。

虽然很多高校多年来一直尝试开设选修课，专家学者也进行了理论研究，但目前此类课程在大学英语教学中所占比重并不大，仍处于探索阶段。多数教学专家对大学英语选修课程的具体教学目标和教学内容范围未形成统一认识，教育主管部门亦未出台具体的选修课教学要求。为了进一步推动大学英语选修课教学的发展，外教社在多年选修课教材使用情况调研的基础上，结合专家学者的最新研究成果和建议，充分考虑我国目前的大学英语教学现状、师资条件、实际需求等因素，重新策划编写了“大学英语拓展课程系列”，该系列教材包括EAP、ESP和EOP三个子系列。

- EAP（English for Academic Purposes）

  学术英语类，侧重高级水平英语听、说、读、写、译等技能的培养，为大学生出国留学、攻读研究生、进行科研等学术活动打下更扎实的英语基础。此类课程包括：演讲听说、跨文化交际、文学赏析、学术英语写作等。适合需要继续在学术上深造的大学生使用。

- ESP（English for Specific Purposes）

  专业英语类，侧重提升专业英语能力，在培养学生听、说、读、写、译等基本语言技能的基础上，教授与该专业相关的英语词汇和表达，并尽可能传授专业知识，以使大学生轻松通过英语媒介获取本专业知识和信息。此类课程适合相关专业学生学习，针对性强。

- EOP（English for Occupational Purposes）

  职场英语类，侧重提升职场英语能力，为大学生将来在英语环境中工作打下扎实的职场交际基本功。此类课程多数适合所有大学生使用，有部分教程与专业结合，适合相应专业学生使用。

除了重新修订已出版的教材外，我们还通过邀请更多海内外英语教学专家参与编写、和国外出版社合作出版等方式，扩大本系列教材的选题规模，以满足各专业大学生的学习需求。本系列教材具有时代感强、实用性强、课堂可操作性强等特点，相信会给我国大学英语教学带来新风向。

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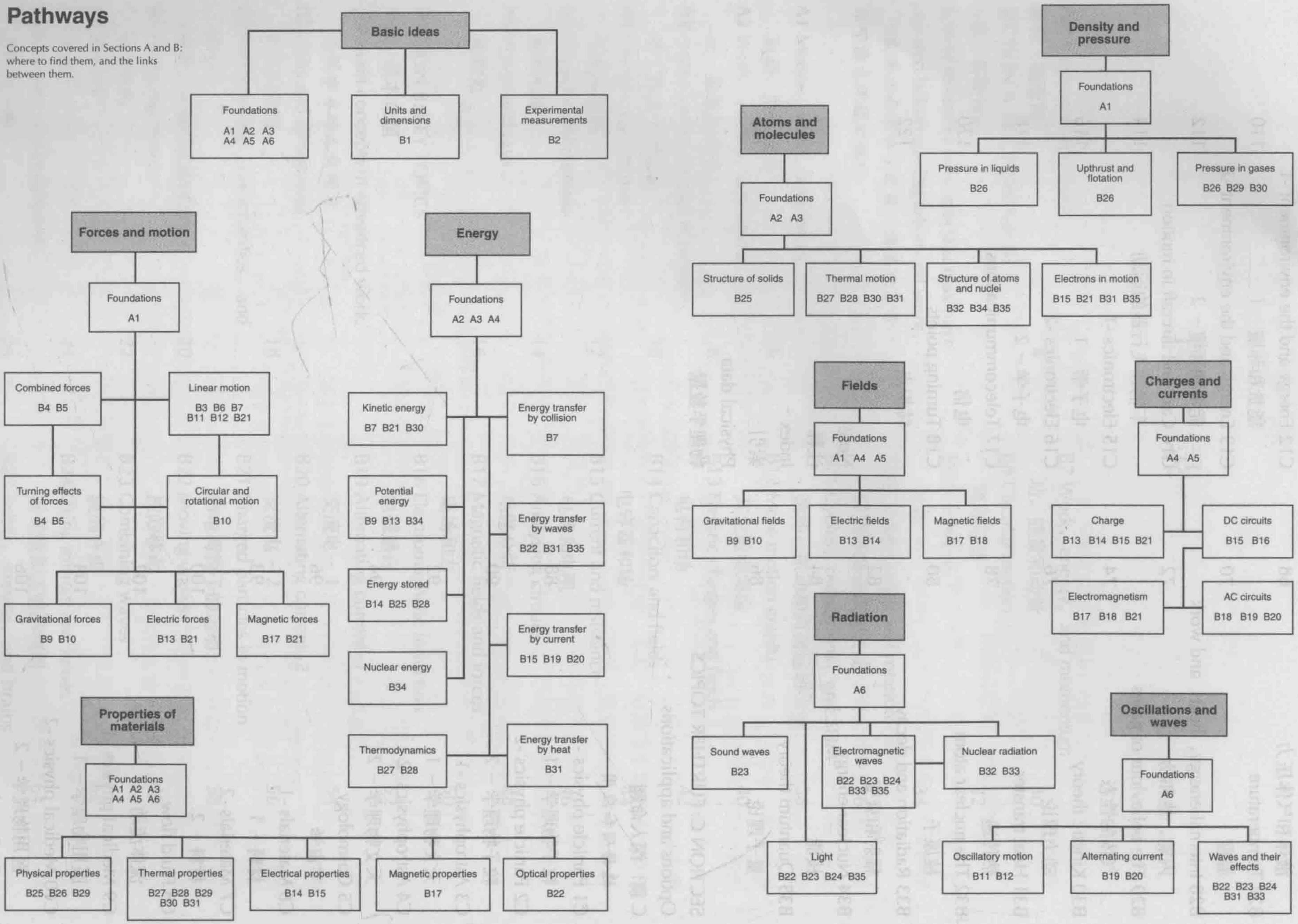
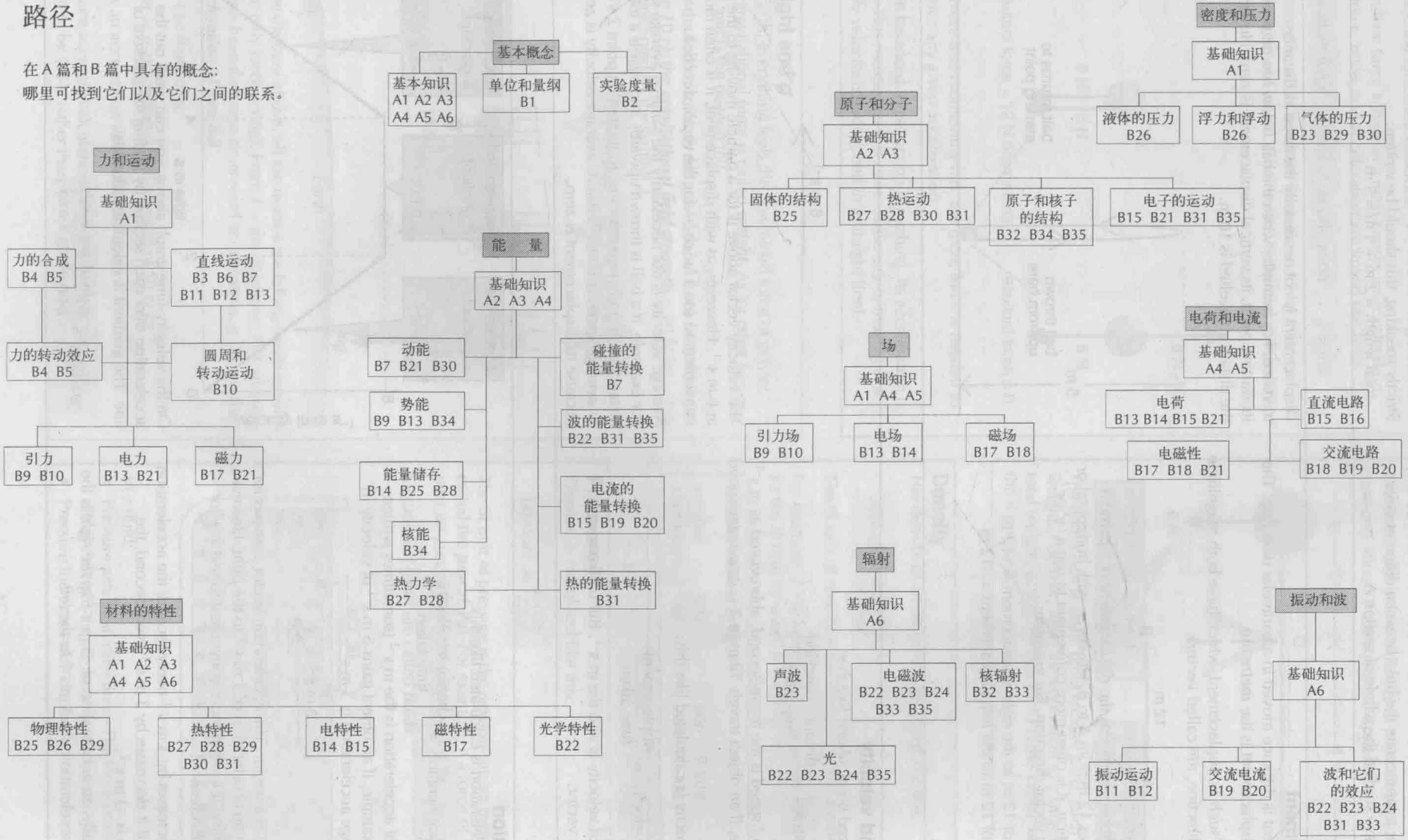
Pathways

Concepts covered in Sections A and B: where to find them, and the links between them.



路径

在 A 篇和 B 篇中具有的概念:
哪里可找到它们以及它们之间的联系。



A1 Motion, mass, and forces

Units of measurement

Scientists make measurements using SI units such as the metre, kilogram, second, and newton. These and their abbreviations are covered in detail in B1. However, you may find it easier to appreciate the links between different units after you have studied the whole of section A.

For simplicity, units will be excluded from some stages of the calculations in this book, as in this example:

total length = 2 + 3 = 5 m

Strictly speaking, this should be written:

total length = 2 m + 3 m = 5 m

Displacement

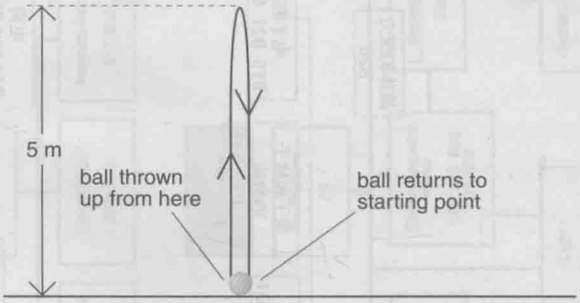
Displacement is distance moved in a particular direction. The SI unit of displacement is the ***metre*** (m).

Quantities, such as displacement, which have both magnitude (size) and direction, are called ***vectors***.

The arrow above represents the displacement of a particle which moves 12 m from A to B. However, with horizontal or vertical motion, it is often more convenient to use a '+' or '–' to show the vector direction. For example:

Movement of 12 m *to the right*: displacement = +12 m
Movement of 12 m *to the left*: displacement = –12 m

Displacement is not necessarily the same as distance travelled. For example, when the ball below has returned to its starting point, its vertical displacement is zero. However, the distance travelled is 10 m.



Speed and velocity

Average speed is calculated like this:

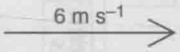
$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

The SI unit of speed is the metre/second, abbreviated as m s^{-1}. For example, if an object travels 12 m in 2 s, its average speed is 6 m s^{-1}.

Average velocity is calculated like this:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time taken}}$$

The SI unit of velocity is also the m s^{-1}. But unlike speed, velocity is a vector.



The velocity vector above is for a particle moving to the right at 6 m s^{-1}. However, as with displacement, it is often more convenient to use a '+' or '–' for the vector direction.

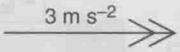
Average velocity is not necessarily the same as average speed. For example, if a ball is thrown upwards and travels a total distance of 10 m before returning to its starting point 2 s later, its average speed is 5 m s^{-1}. But its average velocity is zero, because its displacement is zero.

Acceleration

Average acceleration is calculated like this:

$$\text{average acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

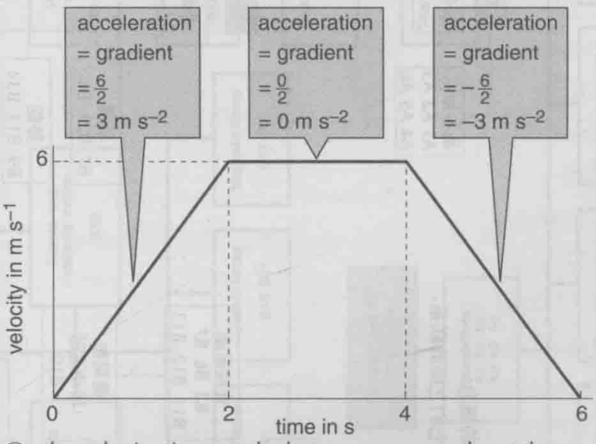
The SI unit of acceleration is the m s^{-2} (sometimes written m/s^2). For example, if an object gains 6 m s^{-1} of velocity in 2 s, its average acceleration is 3 m s^{-2}.



Acceleration is a vector. The acceleration vector above is for a particle with an acceleration of 3 m s^{-2} to the right. However, as with velocity, it is often more convenient to use a '+' or '–' for the vector direction.

If velocity *increases* by 3 m s^{-1} every second, the acceleration is +3 m s^{-2}. If it *decreases* by 3 m s^{-1} every second, the acceleration is –3 m s^{-2}.

Mathematically, an acceleration of –3 m s^{-2} *to the right* is the same as an acceleration of +3 m s^{-2} *to the left*.



On the velocity-time graph above, you can work out the acceleration over each section by finding the *gradient* of the line. The gradient is calculated like this:

$$\text{gradient} = \frac{\text{gain along } y\text{-axis}}{\text{gain along } x\text{-axis}}$$

Force

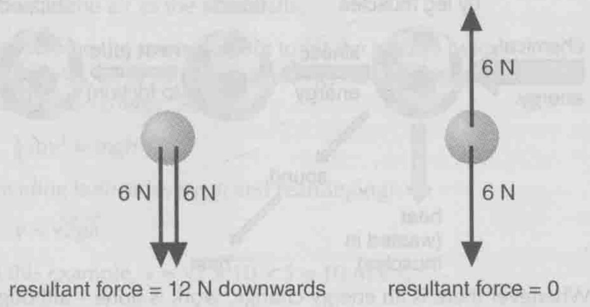
Force is a vector. The SI unit is the ***newton*** (N).

If two or more forces act on something, their combined effect is called the ***resultant force***. Two simple examples are shown below. In the right-hand example, the resultant force is zero because the forces are ***balanced***.

A resultant force acting on a mass causes an acceleration. The force, mass, and acceleration are linked like this:

resultant force = mass × acceleration $F = ma$

For example, a 1 N resultant force gives a 1 kg mass an acceleration of 1 m s^{-2}. (The newton is defined in this way.)



The more mass something has, the more force is needed to produce any given acceleration.

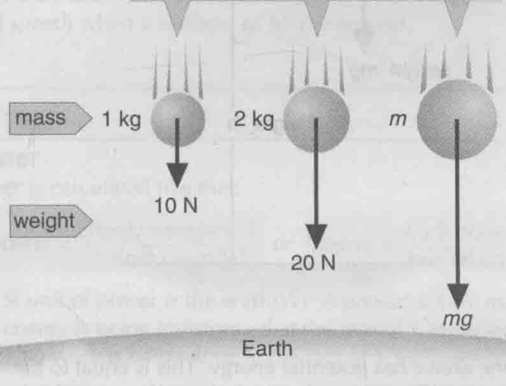
When balanced forces act on something, its acceleration is zero. This means that it is *either* stationary *or* moving at a steady velocity (steady speed in a straight line).

Weight and *g*

On Earth, everything feels the downward force of gravity. This gravitational force is called ***weight***. As for other forces, its SI unit is the newton (N).

Near the Earth's surface, the gravitational force on each kg is about 10 N: the ***gravitational field strength*** is 10 N kg^{-1}. This is represented by the symbol *g*.

$$\text{acceleration} = \frac{\text{weight}}{\text{mass}} = 10 \text{ m s}^{-2} = g$$



In the diagram above, all the masses are falling freely (gravity is the only force acting). From $F = ma$, it follows that all the masses have the same downward acceleration, *g*. This is the ***acceleration of free fall***.

You can think of *g*:

either as a gravitational field strength of 10 N kg^{-1}

or as an acceleraton of free fall of 10 m s^{-2}

In more accurate calculations, the value of *g* is normally taken to be 9.81, rather than 10.

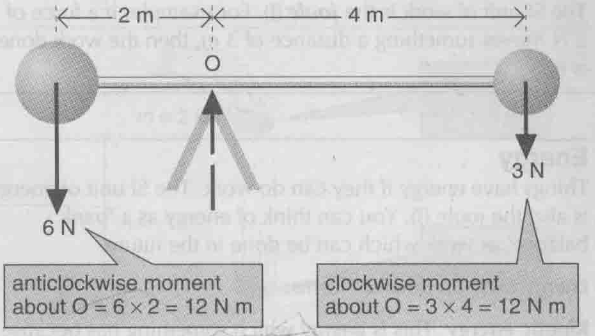
Moments and balance

The turning effect of a force is called a ***moment***:

moment of force about a point = force × perpendicular distance* from point

* measured from the line of action of the force.

The dumb-bell below balances at point O because the two moments about O are equal but opposite.



The dumb-bell is made up of smaller parts, each with its own weight. Together, these are equivalent to a single force, the total weight, acting through O. O is the ***centre of gravity*** of the dumb-bell.

Density

The density of an object is calculated like this:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The SI unit of density is the kilogram/cubic metre (kg m^{-3}). For example, 2000 kg of water occupies a volume of 2 m^3. So the density of water is 1000 kg m^{-3}.

Density values, in kg m^{-3}

alcohol	800	iron	7 900
aluminium	2 700	lead	11 300

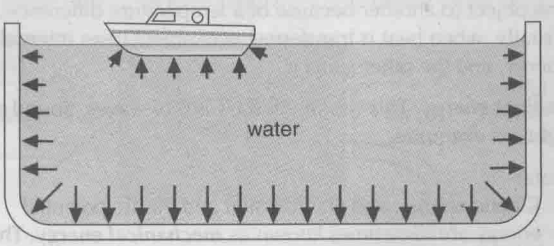
Pressure

Pressure is calculated like this:

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

The SI unit of pressure is the newton/square metre, also called the ***pascal*** (**Pa**). For example, if a force of 12 N acts over an area of 3 m^2, the pressure is 4 Pa.

Liquids and gases are called ***fluids***.



In a fluid:

- Pressure acts in all directions. The force produced is always at right-angles to the surface under pressure.
- Pressure increases with depth.

A2 Work, energy, and power

Work

Work is done whenever a force makes something move. It is calculated like this:

work done = force × distance moved in direction of force

The SI unit of work is the ***joule*** (J). For example, if a force of 2 N moves something a distance of 3 m, then the work done is 6 J.

Energy

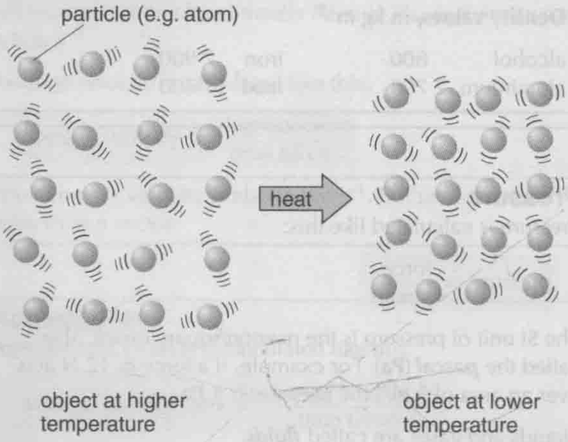
Things have energy if they can do work. The SI unit of energy is also the joule (J). You can think of energy as a 'bank balance' of work which can be done in the future.

Energy exists in different forms:

Kinetic energy This is energy which something has because it is moving.

Potential energy This is energy which something has because of its position, shape, or state. A stone about to fall from a cliff has ***gravitational*** potential energy. A stretched spring has ***elastic*** potential energy. Foods and fuels have ***chemical*** potential energy. Charge from a battery has ***electrical*** potential energy. Particles from the nucleus (centre) of an atom have ***nuclear*** potential energy.

Internal energy Matter is made up of tiny particles (e.g. atoms or molecules) which are in random motion. They have kinetic energy because of their motion, and potential energy because of the forces of attraction trying to pull them together. An object's internal energy is the total kinetic and potential energy of its particles.



Heat (thermal energy) This is the energy transferred from one object to another because of a temperature difference. Usually, when heat is transferred, one object loses internal energy, and the other gains it.

Radiant energy This is often in the form of waves. Sound and light are examples.

Note:

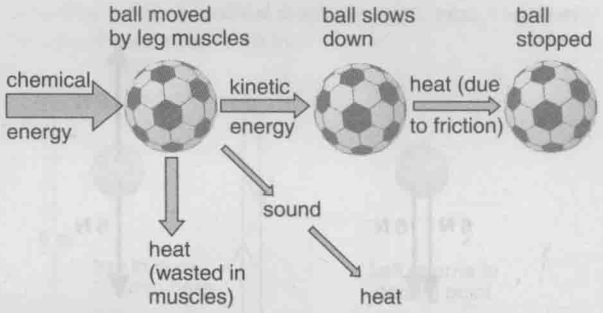
- Kinetic energy, and gravitational and elastic potential energy are sometimes known as ***mechanical energy***. They are the forms of energy most associated with machines and motion.
- Gravitational potential energy is sometimes just called potential energy (or PE), even though there are other forms of potential energy as described above.

Energy changes

According to the ***law of conservation of energy***:

Energy cannot be made or destroyed, but it can be changed from one form to another.

The diagram below shows the sequence of energy changes which occur when a ball is kicked along the ground. At every stage, energy is lost as heat. Even the sound waves heat the air as they die away. As in other energy chains, all the energy eventually becomes internal energy.



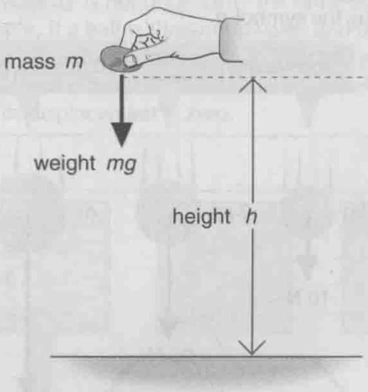
Whenever there is an energy change, work is done – although this may not always be obvious. For example, when a car's brakes are applied, the car slows down and the brakes heat up, so kinetic energy is being changed into internal energy. Work is done because tiny forces are making the particles of the brake materials move faster.

An energy change is sometimes called an energy transformation. Whenever it takes place:

work done = energy transformed

So, for each 1 J of energy transformed, 1 J of work is done.

Calculating potential energy (PE)



The stone above has potential energy. This is equal to the work done in lifting it to a height h above the ground.

The stone, mass m, has a weight of mg.
So the force needed to overcome gravity and lift it is mg.

As the stone is lifted through a height h:

work done = force × distance moved = $mg \times h$

So potential energy = mgh

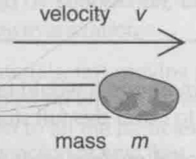
For example, if a 2 kg stone is 5 m above the ground, and g is 10 N kg^{-1}, then the stone's PE = $2 \times 10 \times 5 = 100$ J.

Calculating kinetic energy (KE)

The stone on the right has kinetic energy. This is equal to the work done in increasing the velocity from zero to v. B7 shows you how to calculate this. The result is:

$$\text{kinetic energy} = \tfrac{1}{2} mv^2$$

For example, if a 2 kg stone has a speed of 10 m s^{-1}, its KE = $\tfrac{1}{2} \times 2 \times 10^2 = 100$ J



PE to KE

The diagram on the right shows how PE is changed into KE when something falls. The stone in this example starts with 100 J of PE. Air resistance is assumed to be zero, so no energy is lost to the air as the stone falls.

By the time the stone is about to hit the ground (with velocity v), all of its potential energy has been changed into kinetic energy. So:

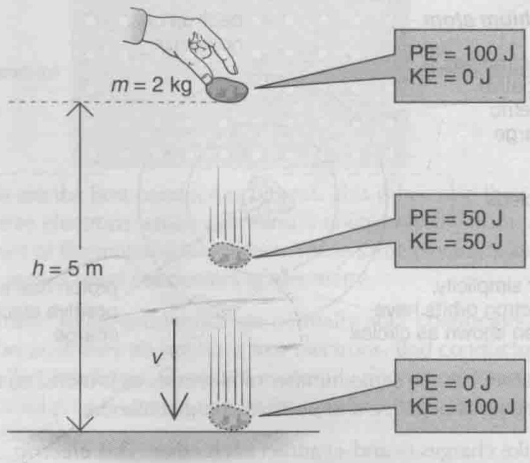
$$\tfrac{1}{2} mv^2 = mgh$$

Dividing both sides by m and rearranging:

$$v = \sqrt{2gh}$$

In this example, $v = \sqrt{2 \times 10 \times 5} = 10$ m s^{-1}.

Note that v does not depend on m. A heavy stone hits the ground at exactly the same speed as a light one.

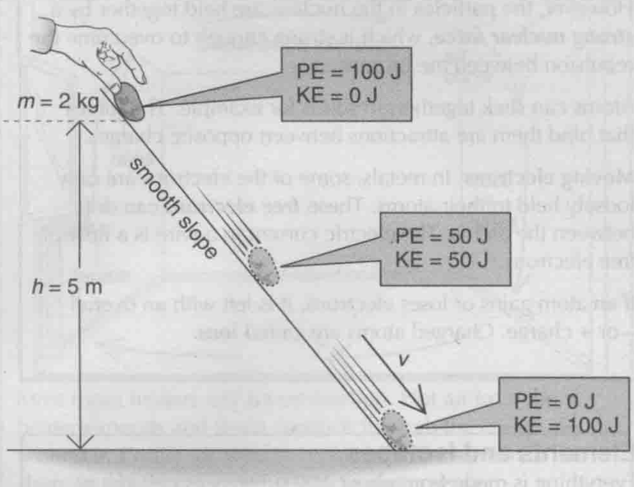


Vectors, scalars, and energy

Vectors have magnitude and direction. When adding vectors, you must allow for their direction. In A1, for example, there are diagrams showing two 6 N forces being added. In one, the resultant is 12 N. In the other, it is zero.

Scalars are quantities which have magnitude but no direction. Examples include mass, volume, energy, and work. Scalar addition is simple. If 6 kg of mass is added to 6 kg of mass, the result is always 12 kg. Similarly, if an object has 6 J of PE and 6 J of KE, the total energy is 12 J.

As energy is a scalar, PE and KE can be added without allowing for direction. The stone on the right has the same total PE + KE throughout its motion. As it starts with the same PE as the stone in the previous diagram, it has the same KE (and speed) when it is about to hit the ground.



Power

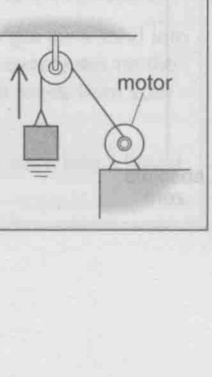
Power is calculated like this:

$$\text{power} = \frac{\text{energy transferred}}{\text{time taken}} \quad \text{or} \quad \text{power} = \frac{\text{work done}}{\text{time taken}}$$

The SI unit of power is the **watt** (W). A power of 1 W means that energy is being transformed at the rate of 1 joule/second (J s^{-1}), so work is being done at the rate of 1 J s^{-1}.

Below, you can see how to calculate the power output of an electric motor which raises a mass of 2 kg through a height of 12 m in 3 s:

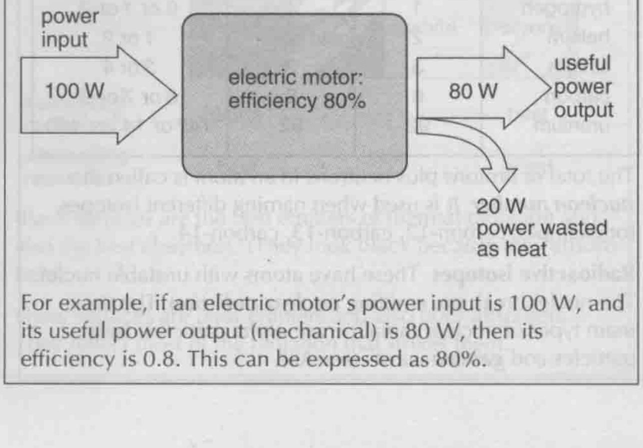
$$\begin{aligned} \text{PE gained} &= mgh \\ &= 2 \times 10 \times 12 = 240 \text{ J} \\ \text{power} &= \frac{\text{energy transferred}}{\text{time taken}} \\ &= \frac{240}{3} = 80 \text{ W} \end{aligned}$$



Efficiency

Energy changers such as motors waste some of the energy supplied to them. Their ***efficiency*** is calculated like this:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} = \frac{\text{useful power output}}{\text{power input}}$$



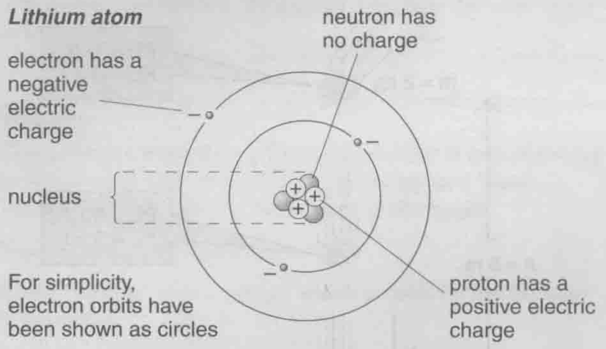
For example, if an electric motor's power input is 100 W, and its useful power output (mechanical) is 80 W, then its efficiency is 0.8. This can be expressed as 80%.

A3 Atoms and molecules in motion

Atoms

All matter is made from ***atoms***. It would take more than a million million atoms to cover this full stop.

An atom has a tiny central ***nucleus*** made of ***protons*** and ***neutrons*** (apart from the simplest atom, hydrogen, whose nucleus is a single proton). Orbiting the nucleus are much lighter particles called ***electrons***.


Lithium atom

An atom has the same number of electrons as protons, so the amounts of negative and positive charge balance.

Unlike charges (– and +) attract each other. This ***electric force*** holds electrons in orbit around the nucleus.

Like charges (– and –, also + and +) repel each other. However, the particles in the nucleus are held together by a ***strong nuclear force***, which is strong enough to overcome the repulsion between the protons.

Atoms can stick together, in solids for example. The forces that bind them are attractions between opposite charges.

Moving electrons In metals, some of the electrons are only loosely held to their atoms. These ***free electrons*** can drift between the atoms. The electric current in a wire is a flow of free electrons.

If an atom gains or loses electrons, it is left with an overall – or + charge. Charged atoms are called ***ions***.

Elements and isotopes

Everything is made from about 100 substances called ***elements***. Each element has a different number of protons (and therefore electrons) in its atoms.

Elements exist in different versions, called ***isotopes***, each with a different number of neutrons in its atoms. Examples are shown below (italic numbers are for rarer isotopes).

Element	Electrons	Protons	Neutrons
hydrogen	1	1	0 or *1* or *2*
helium	2	2	*1* or 2
lithium	3	3	*3* or 4
carbon	6	6	6 or *7* or *8*
uranium	92	92	*142* or *143* or 146

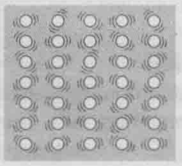
The total of protons plus neutrons in an atom is called the ***nucleon number***. It is used when naming different isotopes, for example: carbon-12, carbon-13, carbon-14.

Radioactive isotopes These have atoms with unstable nuclei. The nuclei break up, emitting ***nuclear radiation***. The three main types of nuclear radiation are ***alpha*** particles, ***beta*** particles and ***gamma*** waves (see A6).

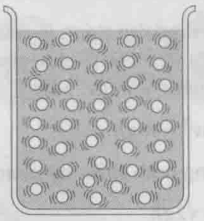
Solids, liquids and gases

According to the ***kinetic theory***, matter is made up of tiny, randomly moving particles. Each particle may be a single atom, a group of atoms called a ***molecule***, or an ion. The three normal ***phases*** of matter are solid, liquid, and gas.

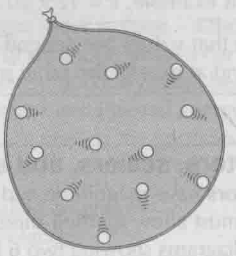
Solid The particles are held close together by strong forces of attraction. They vibrate, but about fixed central positions, so a solid keeps a fixed shape and volume.



Liquid The particles are held close together. But the vibrations are strong enough to overcome the attractions, so the particles can change positions. A liquid has a fixed volume, but it can flow to fill any shape.



Gas The particles move at high speed, colliding with each other and with the walls of their container. They are too spread out and fast-moving to stick together, so a gas quickly fills any space available. Its pressure is due to the impact of its particles on the container walls.



Temperature

The particles in, for example, a gas move at a range of speeds. However, the higher the temperature, the faster the particles move on average.

If two objects at the same temperature are in contact, there is no flow of heat between them. This is because the average kinetic energy of each particle due to its vibrating or speeding motion is the same in each object, so there is no overall transfer of energy from one object to the other.

Celsius scale On this scale, pure water freezes at 0 °C and boils at 100 °C (under standard atmospheric conditions).

Kelvin scale This has the same sized 'degree' as the Celsius scale, but its 'zero' is ***absolute zero*** (–273 °C), the temperature at which particles have the minimum possible kinetic energy. (The laws governing the behaviour of atoms do not permit zero energy).