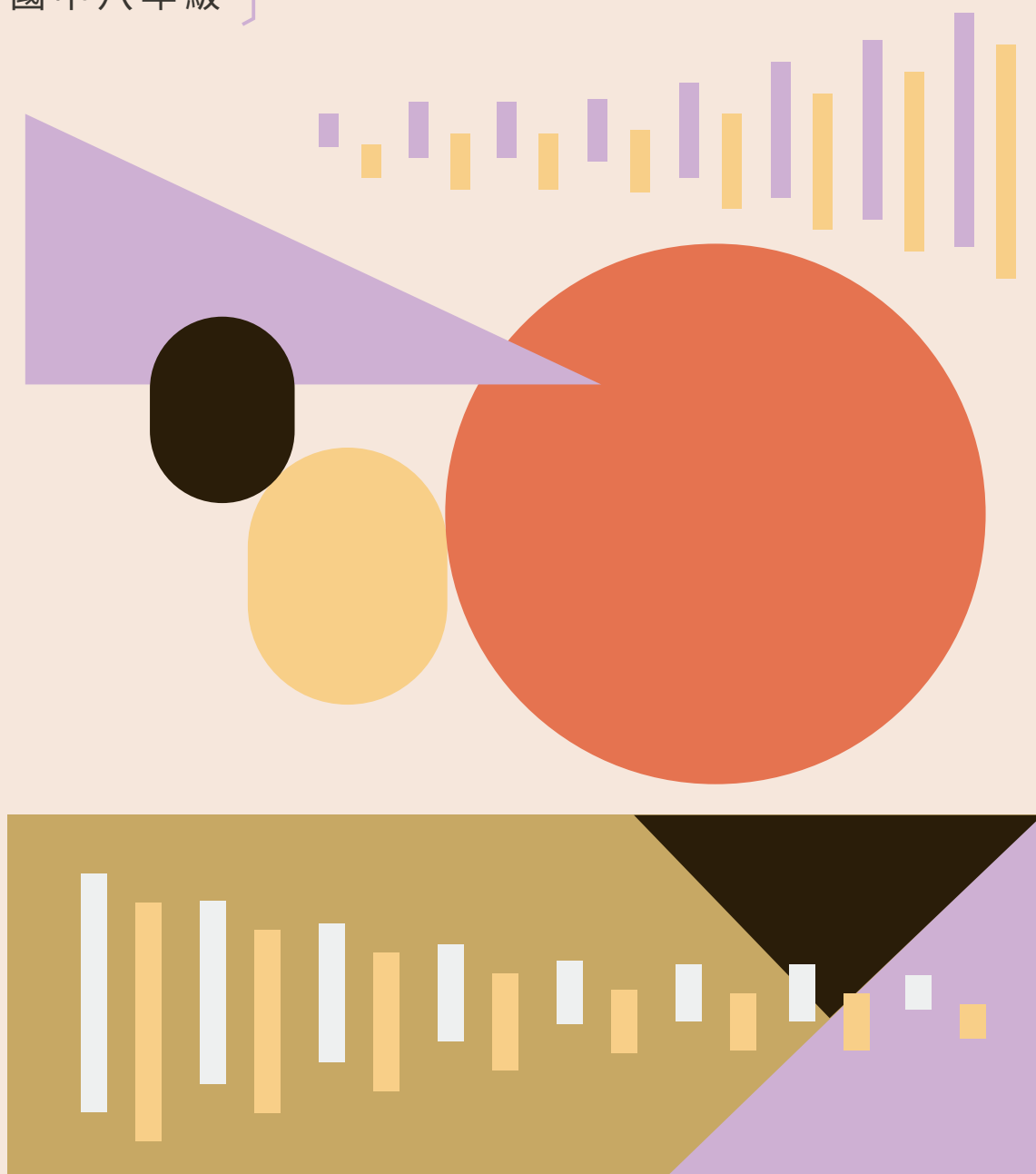國中自然領域

雙語教學資源手冊 物理科英語授課用語

A Reference Handbook for Junior High School Bilingual Teachers in the Domain of Natural Sciences (Physics): Instructional Language in English

〔 國中八年級 〕

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★主題一　基本測量★
Fundamental Measurements

國立彰化師範大學物理系　曾于恩、林妍君

■ 前言 Introduction

本章從生活中常用的基本物理量切入，講解國際間制定的共同測量標準與單位—國際單位制，也引導學生選擇適當的工具進行測量。介紹不同物理量之間的關係以及衍生物理量的推導、單位間的換算，及測量值的表達方式。

1-1 長度、質量與時間
Length, Mass, and Time

■ 前言 Introduction

介紹國際單位制在長度、質量與時間的單位及其定義。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
unit	單位	mass	質量
numerical value	數值	kilogram (kg)	公斤
International System of Units (SI)	國際單位制	gram (g)	公克
length	長度	milligram (mg)	毫克
meter (m)	公尺	balance / scale	天平
kilometer (km)	公里	conversion / convert	換算(n)/(v)
centimeter (cm)	公分	hour	時
millimeter (mm)	毫米	minute	分
		second	秒

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____, the symbol _____, is the SI unit of _____.

例句：Second(s), **the symbol** is s**, is the SI unit of** time.

時間的國際單位是秒，符號 s。

❷ **Units that we commonly use to indicate** _____ **are** _____, _____, **and** _____.

例句：**Units that we commonly use to indicate** length **are** millimeter (mm), centimeter (cm), meter (m), **and** kilometer (km).

我們常用來代表長度的單位，有毫米(mm)、公分(cm)、公尺(m)以及公里(km)。

❸ **We know that** _____ **is equal to** _____, **thus we may convert** _____ **to** _____.

例句：**We know that** 1 kilogram (kg) **is equal to** 1000 grams (g), **thus we may convert** kilogram (kg) **to** gram (g) and vice versa.

我們知道 1 公斤(kg) 等於 1000 公克(g)，所以公斤(kg) 可與公克(g) 互相轉換。

■ 問題講解 Explanation of Problems

❦ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following :

一、了解如何正確使用天平測得質量。

　　Understand how to measure the mass of an object by operating a balance properly.

二、能比較單位的大小，並正確轉換數值大小。

　　Be able to compare the relationships among different units and convert their magnitudes correctly.

ᘒ 例題講解 ᘓ

例題一

說明：學生能掌握天平的使用方法與流程。

Students can use a balance and know the weighing process.

（英文）The list below is compiled by A-Me. The first and second entries are the reminders and the corresponding reasons before handling an equal arm balance. Choose correct reasons from the options given that are appropriate.

	Reminders	Reasons
1	Adjust the balance until the pointer is at the zero point before weighing.	Calibration can reduce the probability of inaccurate weights
2	Handle the weights with the tweezers. The weights cannot be used by hands.	Proper handling can reduce the probability of weights getting rusty.

(A) Both are appropriate　　　　　　(B) None is appropriate

(C) Only the first reason is appropriate

(D) Only the second reason is appropriate.

（中文）下表為阿梅整理的甲、乙二項使用上皿天平時的注意事項及其對應原因，關於其對應原因是否合理，下列敘述何者正確？

	注意事項	對應原因
甲	測量物品前，應做好歸零動作再測量	可減少測量質量時的誤差
乙	拿取砝碼時不可用手拿取，應用砝碼夾拿取	可減少砝碼生鏽的機會

(A)兩者皆合理　　　　(B)兩者皆不合理

(C)甲合理，乙不合理　　(D)甲不合理，乙合理。

（110 年國中會考 1）

解題 Solution：

使用天平測量物品質量前，應做好歸零動作再測量，若沒有校正歸零，測得的數據會不準確。拿取砝碼時應使用砝碼夾或鑷子夾取，以免手上的溼氣造成砝碼生鏽，所以答案是(A)。

Before a balance is used to weigh the mass of an object, calibration is necessary to ensure an accurate measurement. It is suggested to use the tweezers or other specialized lifting devices to handle the weights. This is to avoid rusty weights caused by the moisture of hands, so A is correct.

Teacher: Do you still remember what we should do before weighing the mass of an object with a balance?

Student: We make sure the balance is well calibrated.

Teacher: That is correct! What effect will it be on the measured results if a balance is not calibrated?

Student: The measured results will be wrong.

Teacher: Exactly. Say this balance now is read 0.3 grams before calibration. If we do not zero the balance, do we need to subtract or add 0.3 grams to the results?

Student: We add 0.3 grams back?

Teacher: No, we should subtract the 0.3 grams from the measured value. That is why it is necessary to zero a balance to ensure an accurate reading. Calibration can keep us out of trouble of fixing weighing mistakes.

Teacher: Now, how should we handle the weights?

Student: We should use the tweezers to handle the weights.

Teacher: Why can we not handle them by hands?

Student: It is because the hands will make the weights rusty.

Teacher: Excellent. The moisture or stains of our hands will cause the weights to rust. The rust will change the mass of the weights and our measurement will be inaccurate.

老師： 大家還記得使用天平測量質量前應該先做什麼嗎？

學生： 確定天平是否已經歸零。

老師： 沒錯！那麼如果沒有歸零會對測量結果造成什麼影響呢？

學生： 測量結果會不準。

老師： 沒錯，例如，天秤還沒規零前的讀數是 0.3 g，那麼所測量的結果，需要加 0.3 g 或減 0.3 g 呢？

學生： 是加上 0.3 g 嗎？

老師： 應該要扣回原有的 0.3 g，所以必須減 0.3 g，因此測量前天平需先歸零，以避免測量不準確，或免去每次都要修正的麻煩。

老師： 那我們應該如何拿取砝碼呢？

學生： 應該使用砝碼夾夾取。

老師：　為什麼不能用手直接拿呢？

學生：　因為那會使砝碼生鏽。

老師：　很好，手上的手汗或是髒污，都可能使砝碼生鏽，造成砝碼質量的變化，影響
　　　　測量的準確性。

例題二

說明：學生能正確地轉換不同大小的單位。

　　　　Students can correctly convert one type of physical unit to another.

（英文）After Xiao-Zhen enters junior high school, her dad is thinking about a new desk for his daughter. They go to three different furniture stores and try to buy the same desk from the most competitive bid. It turns out that these three furniture stores offer different prices for the same desk. Even the measurements for the same desk vary as well. The desk at the first store is measured 1.32 m, while the one at the second store is 132.0 cm. The desk at the third one is 1,320 mm. Choose the correct answer from the options given below.

(A) All the furniture stores offer the same length for the desk but with different physical units.

(B) The length of the desks at all the furniture stores are incomparable because their physical units are different.

(C) The first furniture store offers the longest desk because the physical unit of its length is longer than the others.

(D)The third furniture store offers the longest desk because the numerical value of its length is bigger than the others.

（中文）小蓁上了國中之後，爸爸想幫她買張新的書桌，俗話說：「貨比三家不吃虧」，於是她跟爸爸到家具行進行比價，結果發現同一款式的書桌在不同家店不僅價格不同，連長度都標示不一。甲店的書桌標示 1.32 公尺(m)，乙店標示 132.0 公分(cm)，丙店則是 1320 毫米(mm)，下列敘述何者正確？

(A)甲、乙、丙三間店的書桌長度相同，單位不同。

(B)甲、乙、丙店的書桌長度無法比較，因為單位不同。

(C)甲店的書桌最長，因為單位最大。

(D)丙店的書桌最長，因為數字最大。

解題 Solution：

若要比較書桌長度，須統一所有數據的單位。例如：將所有數據的單位轉換為毫米，可知甲、乙、丙店的書桌皆為 1320 毫米，因為 1 公尺(m)=100 公分(cm)=1000 毫米(mm)，所以換算之後，三家店的書桌長度都相同。

Before we compare the length of these three desks, their physical units should be unified first. For example, all the physical units should be converted into millimeter. In this sense, the length of the desks at the first, second, and third furniture stores are all 1,320mm. Because 1m = 100cm = 1,000mm, the length of the desks at the three stores are the same after conversion.

Teacher: To compare three different physical quantities of the desk, we need to unify their physical units first. Which unit do you have in mind?

Student: Can we convert the units to millimeter?

Teacher: Yes, you can. How much meter is 1mm equal to?

Student: 1 mm is equal to 100cm and 1cm is equal to 10mm. So, 1m is equal to 1000 mm.

Teacher: Correct! So what mm are the desks at the first and second furniture stores?

Student: The length of the desks at the two stores are the same, 1,320 mm. The same length means that all three stores offer the same desk.

Teacher: Exactly. If we convert the length of the desk at the first store to mm, we can get 1.32 m × (1,000 mm/1 m) = 1,320 mm. That number tells us the size of the desks offered at the first and third furniture store are the same. It also tells us that the 132cm at the second store is equal to 1,320mm.

老師：　為了比較三家書桌的大小，我們需先統一它們的單位，你們想把數據中的單位都換成什麼呢？

學生：　換成毫米。

老師：　好，那 1 公尺(m)等於幾毫米(mm)呢？

學生：　1 公尺等於 100 公分，1 公分又等於 10 毫米，所以 1 公尺等於 1000 毫米。

老師：　沒錯！那甲店和乙店的書桌長度分別是幾毫米呢？

學生：　都是 1320 毫米，所以三間店的書桌一樣長。

老師：　沒錯，將甲店的桌長換算成毫米：1.32 m×(1000 mm/1 m)=1320 mm，所以甲店與丙店之桌子一樣長。比照相同的推算法，也可以得到乙店的 132 cm 等於 1320 mm。

1-2 測量與估計
Measurement and Estimation

■ 前言 Introduction

使學生了解測量的意義與方法，以及誤差的概念，知道測量結果的表示必須包含數字與單位兩部分，並介紹如何估計，來提高測量的精確度。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
measurement / measure	測量(n)/(v)	calibration, scale	刻度
data	數據	error	誤差
estimation / estimate	估計(n)/(v)	digit	位數
accurate value	準確值	average value	平均值
estimated value	估計值	record	計錄

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **The measurement can be recorded as _____, of which _____ is the accurate value and _____ is the estimated value. The data implies that the minimum scale of the _____ is _____.**

例句：**The measurement can be recorded as** 166.9 cm, **of which** 166 cm **is the accurate value** and 0.9 cm **is the estimated value**. **The data implies that the minimum scale of the** ruler **is** 1 centimeter.

測量結果可記錄為 166.9 cm，其中 166 cm 為準確值，而 0.9 cm 就是估計值。表示量尺的最小刻度為 1 公分。

❷ **We can measure _____ several times to _____.**

例句：**We can measure** the length **several times to** minimize the error and improve the precision of measurement.

我們可以透過多次測量長度，以減少誤差使測量結果更精確。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☜

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following:

一、了解數據的表達方式

　　Understand how to represent data.

二、理解測量的概念

　　Understand the concept of measurement.

ᗧ 例題講解 ᘓ

例題一

說明：學生須要了解測量的方法，能夠完整記錄精確值及估計值。
　　　　Students can understand how to take and record accurate values and estimated values.

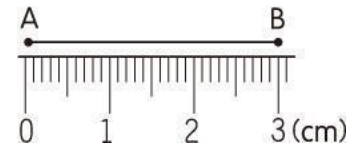（英文）Based on the right diagram, determine which value of Line AB is the most appropriate?

（中文）測量右圖中 AB 線段的長度，下列何項測量結果的記錄最為適當？

(A)3 cm　　　　　　　(B)3.0 cm

(C)3.00 cm　　　　　　(D)3.000 cm

（91 年第一次基測 29）

解題 Solution：

因為測量工具最小刻度為 0.1 cm，測量值必須記錄準確值加一位估計值。故 AB 線段的長度記錄為 3.00 cm，其中的 3.0 cm 為精確值，而百分位(最右邊)的 0，則為估計值。

Because the smallest mark of the ruler in the diagram is 0.1cm, the measured value needed to include one accurate value and one estimated value in one digit. Line AB is measured 3.00cm in length. The value of 3.0cm is accurate, and the last digit of 0 is estimated.

Teacher:	When we describe physical quantities, what two parts should we include?
Student:	A numerical value and a physical unit.
Teacher:	What is it that the numerical value should have?
Student:	An accurate value and estimated one.
Teacher:	How should we record them?
Student:	The accurate value should be recorded by determining the smallest marks on a measuring device. The estimated value should be the next digit after the known value.
Teacher:	What is the smallest mark of this ruler?
Student:	The smallest mark of this ruler is 0.1cm, so the measurement of Line AB can be read as 3.00cm.
Teacher:	That is correct. The 3.0 cm is accurate value, and the last digit 0 is estimated.
Teacher:	The estimated will be determined by the one who uses the ruler. In this question, the estimated value is 0, but not all the estimated ones are necessarily zero.

老師：　測量的完整數據，應包含哪兩個部分？

學生：　數字和單位。

老師：　那數字部分又包含哪兩個部分？

學生：　準確值和一位估計值。

老師：　準確值和估計值應該如何記錄？

學生：　準確值應記錄至最小刻度的位數，而估計值為最小刻度的下一位。

老師：　這支尺的最小刻度是什麼單位？

學生：　最小刻度為 0.1 cm，所以可以記錄成 3.00 cm。

老師：　沒錯，其中的 3.0 cm 為精確值，而百分位(最右邊)的 0，則為估計值。

老師：　估計值需由操作者判斷估計，這個例子的估計值為 0，但並不是所有估計值都必須是零。

例題二

說明：能理解測量的意義。

　　　Students can understand the meaning of measurement.

（英文）Which of the following statement is incorrect?

　　(A)When we make a measurement, we need to choose proper measuring devices and units

　　(B)Measurement errors are inevitable, so a measured value needs to be included an estimated value.

　　(C)A physical quantity should include a numerical value and a physical unit.

　　(D)When an estimated value included as many digits as possible, it makes the measurement more accurate.

（中文）有關測量的意義，何者錯誤？

　　(A)測量時必須選擇適當的工具及單位。

　　(B)測量一定有誤差，所以測量值必含有估計部分。

　　(C)完整的測量必須包含數字及單位兩部分。

　　(D)估計值位數愈多位，表示測量愈準確。

（翰林題庫）

解題 Solution：

估計值是依據測量工具的最小刻度，往下估計一位，因此多出的估計值沒有依據，故不準確，且無意義。所以，無法透過增加估計值之位數，來提高測量的準確性。

The estimated value is plus one figure beyond the _smallest_ measurable digit of a measuring instrument. Adding more than one estimated digit to the estimated value will only make the measurement more uncertain. It is also meaningless. More estimated digits in a measurement can not improve the accuracy of measurement.

Teacher:	A physical quantity should include a numerical value and a physical unit. What two parts should the numerical value include?
Student:	An accurate value and one digit of estimated value.
Teacher:	How many digits should we record in an accurate value?
Student:	The accurate value can be determined by reading the smallest marks of a measuring instrument.
Teacher:	That is correct. How about our estimated value?
Student:	It is one additional digit to the smallest measurable digit.

Teacher:　Exactly! Only one additional digit is allowed for our estimated value.

Student:　So, D is wrong because the estimated value can only be one digit.

Teacher:　That is correct. Adding more than one estimated digit is not significant and meaningless.

老師：　完整的數據應包含數字及單位，那數字中又包含哪兩個部分？

學生：　準確值和一位估計值。

老師：　準確值應記錄到哪裡？

學生：　應記錄到測量工具的最小刻度。

老師：　是的，那麼估計值又應該如何記錄呢？

學生：　須由最小刻度，估計其下一位的數值。

老師：　沒錯！所以估計值只有一位喔。

學生：　所以(D)選項是錯的，估計值只有一位。

老師：　是的，再繼續往下估計已經沒有依據，所以沒意義了。

1-3 體積與密度
Volume and Density

■ 前言 Introduction

介紹測量體積的排水法，定義密度，並透過實驗探討物體的質量、體積與密度之關係，認識關係圖的用法及其意義。也讓學生了解，若要討論自然現象或事物，必須選用適當的工具及刻度，才能精準地描述物理量的大小及彼此的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
volume	體積	liquid level	液面
density	密度	liter (L)	公升
shape	形狀	graph	關係圖
graduated cylinder	量筒	vertical ordinate	縱坐標
displacement method	排水法	horizontal ordinate, abscissa	橫坐標
cubic meter (m^3) / kiloliter (kL)	立方公尺/公秉	origin of coordinates	坐標原點
cubic centimeter (cm^3) / milliliter (mL)	立方公分/毫升	set to zero	歸零

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **Taking _____ as the vertical ordinate and _____ as the horizontal ordinate (abscissa), draw the relational graph of _____ versus _____ of _____.**

例句：**Taking** the mass **as the vertical ordinate and** the volume **as the horizontal ordinate (abscissa), draw the relational graph of** mass **versus** volume **of** the aluminum block.

以質量為縱坐標，體積為橫坐標，描繪出鋁塊的質量和體積的關係圖。

❷ **_____ be proportional to _____.**

例句：When two different objects have the same volume, their masses and volumes **are** directly **proportional to** each other.

物體的體積相同時，其質量與密度成正比。

■ 問題講解 Explanation of Problems

❤ 學習目標 ❤

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following:

一、了解如何利用排水法算得物體體積，包含沉體與浮體。

　　They can understand how to use the water displacement method to determine the volume of different objects including the floating and sinking ones.

二、釐清密度(d)、體積(V)與質量(M)三者間的關係：d=M/V，所以密度的常用單位為 g/mL 或 kg/m^3 。

　　Clarify the relationship between density (d), volume (V) and mass (M):d=M/V, hence commonly used units of density are g/mL or kg/m^3.

❧ 例題講解 ❧

例題一

說明：掌握排水法的測量浮體體積的原則：待測物須完全沒入水中。

Students can manage to find the volume of a floating object using the water displacement method. The key is that the object to be measured needs to be completely submerged in water.

（英文）Xiao-Yu uses the water displacement method to measure the volume of a plastic ball. During the measuring process, she finds that the ball will float on the water, so she adjusts some steps of the experiment. Her experimental steps are listed below:

1. Find a graduated cylinder that is large enough to hold the ball being measured. Fill the cylinder with adequate water and record the initial water level prior to submerging the ball. Mark this value as X_1 mL.

2. Place the plastic ball into the cylinder and wait until the water settles down. Record the secondary water level. Mark this value as X_2 mL.

3. Using a string to tie the plastic ball and the metal ball. Now, place both balls into the cylinder. Wait until they are submerged into the water and the water settles down. Mark the third water level as X_3 mL.

4. Untie the plastic ball only and take the ball out from the cylinder. Submerge the metal ball and the string. Allow some time for the water to settle and mark the final water level as X_4 mL.

X_1 mL is known for the initial water level prior to either the plastic or metal ball being submerged in the water in the steps 2, 3, and 4. Find the volume of the plastic ball.

(A) $(X_3 - X_4)$ cm^3

(B) $(X_4 - X_2)$ cm^3

(C) $(X_3 - X_4 - X_1)$ cm^3

(D) $(X_4 - X_2 - X_1)$ cm^3

（中文）小玉利用排水法測量一個塑膠球的體積，在過程中她發現塑膠球會浮在水面上，所以將實驗步驟做了一些調整。她進行的所有步驟如下：

一、取適當大小的量筒，在量筒中裝入水，記錄水面位置刻度 X_1 mL。

二、將塑膠球放入量筒中，待水面靜止後，記錄水面位置刻度 X_2 mL。

三、以細繩的兩端分別綁住塑膠球及金屬球，將兩者放入量筒中，待兩者完全沉入水面下，且水面靜止後，記錄水面位置刻度 X_3 mL。

四、解開綁住塑膠球的細繩，將塑膠球取出量筒，細繩及金屬球放入量筒中，待其完全沉入水面下，且水面靜止後，記錄水面位置刻度 X_4 mL。

已知在實驗步驟二、三、四中，未放入塑膠球或金屬球時，量筒內水面位置刻度均為 X_1 mL，則塑膠球的體積應為多少？

(A) $(X_3 - X_4)$ cm^3

(B) $(X_4 - X_2)$ cm^3

(C) $(X_3 - X_4 - X_1)$ cm^3

(D) $(X_4 - X_2 - X_1)$ cm^3　　　　　　　　　　　　　　（108 年國中會考 42）

解題 Solution：

由步驟三可知塑膠球、金屬球及細繩完全沉入水中，故(塑膠球+金屬球+細繩)的體積 $=(X_3 - X_1)$ cm^3，而由步驟四可知(金屬球+細繩)的體積 $=(X_4 - X_1)$ cm^3，因此塑膠球的體積 $=(X_3 - X_1)-(X_4 - X_1)=(X_3 - X_4)$ cm^3。(註:1 mL=1/1000 L=1 cc=1 cm^3)。

In Step 3, the plastic ball, metal ball, and string are all submerged in the water. So, the formula for the total volume of all the three items in this step can be written as $(X_3 - X_1)$ cm^3. In Step 4, we know that the total volume of both the metal ball and the string is equal to $(X_4 - X_1)$ cm^3. With these two equations, we can come to the volume of the plastic ball.

That is $(X_3 - X_1)-(X_4 - X_1)=(X_3 - X_4)$ cm^3. (Note: 1 mL=1/1000 L=1 cc=1 cm^3).

Teacher:　What items are there in the water from the water level measured in Step 3?

Student:　There are a plastic ball, metal ball, string, and water.

Teacher:　So how should we find the total volume of all these four items?

Student:　X_3 (= the total volume of the plastic ball+ metal ball + string + water) minus X_1 (=the volume of the water) = $(X_3 - X_1)$ cm^3.

Teacher:　Then, what items are there in the water from the water level measured in Step 4?

Student:　There are a metal ball, string, and water.

Teacher: How can we know the total volume of both the metal ball and string, but without water?

Student: X_4 (= the total volume of the metal ball + string + water) minus X_1 (=the volume of the water) = $(X_4 - X_1)$ cm^3.

Teacher: Now, these two equations can bring us the answer to the volume of the plastic ball.

Student: The volume of the plastic ball is $(X_3 - X_1)$-$(X_4 - X_1)$=$(X_3 - X_4)$ cm^3.

Teacher: Excellent. By observing the changing water levels in a graduated cylinder, we can measure the volume of an object. This method is called water displacement. The key of this method is that an object being measured needs to be submerged in the water.

Student: If an object cannot be submerged, how can its volume be measured?

Teacher: If that is the case, we need to have a sinker like the metal ball in this word question. A sinker can make the object stay below the water and then we can measure the volume of the plastic ball.

老師： 步驟三中，量筒中的水位，代表哪些東西的體積？

學生： 有塑膠球、金屬球、細繩還有水。

老師： 所以塑膠球、金屬球和細繩的體積總和，該如何推算？

學生： (塑膠球+金屬球+細繩+水)的體積(X_3)減去水的體積(X_1)=$(X_3 - X_1)$ cm^3。

老師： 那步驟四中，量筒中的水位，代表哪些東西的體積？

學生： 有水、金屬球及細繩。

老師： 那金屬球和細繩的體積總和該如何表示呢？

學生： (金屬球+細繩+水)的體積(X_4)減去水的體積(X_1)=$(X_4 - X_1)$ cm^3。

老師： 根據我們寫下的兩個式子就可以知道塑膠球的體積是多少了。

學生： 塑膠球的體積是$(X_3 - X_1)$-$(X_4 - X_1)$=$(X_3 - X_4)$ cm^3。

老師： 很好，透過量筒中的水位變化，我們可以測量出物體的體積，稱為「排水法」。透過排水法測量物體的要點是，物體需完全沒入水中。

學生： 塑膠球無法完全沉入水中，要怎麼測量它的體積呢？

老師： 本題因塑膠球本身無法沉入水中，所以需透過另外一個沉體(如：金屬球)，來幫忙使塑膠球沉入水中，以成功測得塑膠球的體積。

例題二

說明：學生能掌握密度與體積、質量的關係。

　　　　Students can understand how density, mass, and volume are related.

（英文）Xiao-Cui conducts the experiment below. She measures different volumes and masses of an unknown liquid in the graduated cylinder, and plot the results in the graph of volumes versus masses.

Which of the following graph made by Xiao-cui is correct?

(Mass (g)Volume (mL)）

（中文）小翠進行如下圖步驟的實驗，並根據實驗結果，以量筒中液體的質量與體積繪圖，並延伸出此液體在不同質量時與體積的關係，小翠繪製出的圖應為下列何者才正確？

| (A) | (B) | (C) | **(D)** |
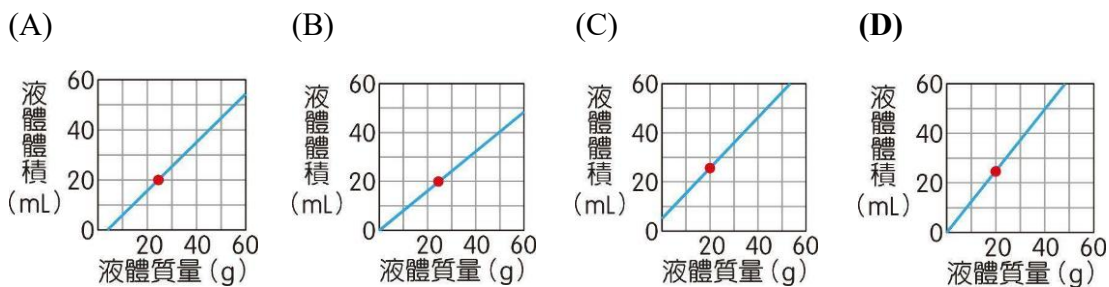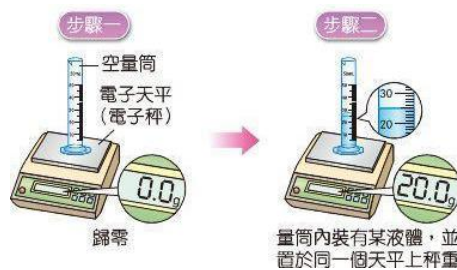
（106 年國中會考 19）

解題 Solution：

由圖可知(1)沒有液體時，電子秤之讀數需先歸零(體積=0 時，質量=0)，所以關係曲線應通過原點。(2)對同一種液體而言，密度固定，所以體積與質量成正比，關係曲線會形成斜直線。(3)當液體體積為 25.0 mL 時，質量為 20.0 g。因此推得關係線應為通過原點以及點(20.0，25.0)的斜直線。

According to the graph, we know

1) before the water is poured in the cylinder, the reading of the digital weighing scale should be zero (when mass = 0 and volume = 0). It tells us that the line that shows how different volumes and masses are related should go through the origin (0,0).

2) the density of different amounts of the same liquid is always the same. The line plotted will be straight showing that as the volume increases, mass increases by the same amount.

3) when the volume of the liquid is 25.0 mL, its mass will be 20.0 g. In this sense, this line should be straight and go through both the origin and the data point (20.0, 25.0).

Teacher:	Can you see what steps Xiao-Cui takes in the diagram? What are the results?
Student:	Firstly, she puts an empty graduated cylinder on the balance and zero it, so the mass of this empty cylinder is zero.
Teacher:	Good job. What else on the diagram can you find that shows the volume of the liquid verse its mass?
Student:	We can draw a line that shows the relationship between the volume of the liquid and its mass. This line will go through the origin (0,0).
Teacher:	That is correct. What are the measured results Xiao-Cui gets in the second step?
Student:	The volume of the liquid is 25.0 mL and its mass is 20.0 g.
Teacher:	Excellent! Because Xiao-Cui uses the same liquid, its volume and mass are proportional to each other. In this sense, what remains constant?
Student:	Density remains constant.
Teacher:	Great job! Now, do you know which graph to choose?
Student:	(D).
Teacher:	That is correct, so the answer is that a fine, straight line will go through the origin and the data point (20.0, 25,0).
Teacher:	Based on the definition of density, find the density of the liquid in her experiment using graph D.
Student:	1.25.
Teacher:	How about the unit?
Student:	g/mL.
Teacher:	That is correct. The density of the liquid in her experiment is 1.25 g/mL. Our answer should always have a numerical value and a physical unit so that we can express "how big" a physical quantity is in a meaningful way.

老師： 圖中的步驟一，小翠做了什麼動作？結果顯示為何？

學生： 小翠將空的量筒放在電子秤上，並將電子秤歸零，所以沒有液體時的量筒，所測得質量為零。

老師： 很好，因此圖一可以推得，液體體積對質量的關係圖上有何特徵？

學生： 關係圖會通過原點。

老師： 沒錯，那麼圖中的步驟二，小翠的測量結果又是什麼？

學生： 液體體積為 25.0 mL，質量為 20.0 g。

老師： 沒錯！而且同一種液體可發現它們的體積與質量成正比，所以可推得同一液體的什麼會保持固定？

學生： 密度不變。

老師： 很好，所以答案應該選擇哪一項？

學生： (D)。

老師： 答對了，所以答案是一條通過原點的斜直線，且通過點(20.0, 25.0)。

老師： 根據密度的定義，請從(D)圖中推算液體的密度大小？

學生： 1.25。

老師： 單位呢？

學生： g/mL。

老師： 是的，液體密度是 1.25 g/mL，包含「數字」與「單位」才能完整描述物理量的「大小」。

★主題二 物質的世界★
The World of The Matter

國立彰化師範大學物理系　曾于恩、林妍君

■ 前言 Introduction

從大自然的物質世界出發，分辨物理和化學變化，透過實驗認識物質的性質，學習實驗的操作方法，並討論混合物與純物質的特性。介紹常見的濃度表示方法以及溶解度與溫度之間的關係。最後講解物質的分離方法，讓學生思考如何解決生活中物質分離的問題，培養解決問題之能力。

2-1 認識物質
Know About the Matter

■ 前言 Introduction

介紹三態變化以及分辨物理和化學變化的方法，討論物質的性質，並區分混合物與純物質，透過實驗學習氣體的製造與性質。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
matter	物質	melting / melt	熔化(n)/(v)
state	狀態	solidification / solidify	凝固(n)/(v)
solid	固態	sublimation / sublime	昇華(n)/(v)
liquid	液態	deposition / deposit	凝華(n)/(v)
gas	氣態	vaporization / vaporize	熔化(n)/(v)
physical change	物理變化	condensation / condense	汽化(n)/(v)
chemical change	化學變化	evaporation / evaporate	凝結(n)/(v)
physical properties	物理性質	boiling / boil	蒸發(n)/(v)
chemical properties	化學性質	melting / melt	沸騰(n)/(v)
pure substance	純物質		
mixture	混合物		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ is the _____ state of _____.

例句：Ice **is the** solid **state of** water.

冰是水的固態。

❷ **The process of a _____ becoming a _____ is called _____.**
In contrast, a _____ becoming a _____, is called _____.

例句：**The process of a** cube of ice **becoming a** drop of water **is called** melting. **In contrast, a**
drop of water **becoming a** cube of ice **is called** solidification.

固體變為液體的過程稱為熔化。相反地，液體變為固體則稱為凝固。

❸ _____ varies with _____.

例句：The temperature of air **varies with** time and location.

空氣的溫度會隨時間、地點不同而變化。

■ 問題講解 Explanation of Problems

ℭ𝔰 學習目標 𝔰ℭ

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following:

一、能正確判斷物理變化與化學變化。

　　Distinguish between physical and chemical changes.

二、了解地球大氣的主要成分及其特性。

　　Understand the main constituents of Earth's atmosphere and their properties.

৪ 例題講解 ೮

例題一

說明：學生須了解物理變化及化學變化的差異，並判斷不同變化分別屬於哪種變化。

Students understand the differences and be able to distinguish between physical and chemical changes.

（英文）The following picture shows two operations that A and B do to a copper billet, respectively. Which operation makes the chemical change?

(A) Both of the two operations do

(B) Neither of the two operations does

(C) Only operation A does

(D) Only operation B does

（中文）下圖為對兩塊銅塊分別進行甲和乙兩種操作的示意圖，關於這兩種操作造成外觀上的改變是否為化學變化，下列判斷何者正確？

(A)兩種都是

(B)兩種都不是

(C)只有甲操作是

(D)只有乙操作是
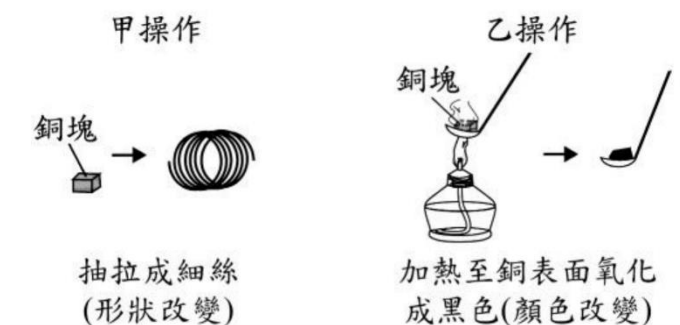
（106 年國中會考 4）

解題 Solution：

甲操作中只是形狀改變，不涉及材料分子結構的變化，所以為物理變化；乙操作中銅氧化後，銅的分子結構已經改變為氧化銅，故為化學變化。

In operation A, the only thing that changes is the shape of the copper billet, not the molecular structure of the material; therefore, it is a physical change. In operation B, the molecular structure made the copper become copper oxide after the oxidation. Thus, operation B is a chemical change.

Teacher: The changes in matter can be categorized as either physical change or chemical change. What are the difference of the changes in the two?

Student: Physical change only makes a difference in the look, shape, or the bulk, but not on the structures or the properties.

Student: Chemical change generates new matter by changing the structures and properties of the matter.

Teacher: What changes in operation A? Why?

Student: Operation A is a physical change because only the shape is changed, but there is no difference in the structure of the matter.

Teacher: Good. Copper is still copper, even as it becomes thinner, so it's just a physical change.

Teacher: What about operation B? What changes in it, and why?

Student: Operation B is a chemical change because the surface of the copper is oxidized.

Teacher: Yes. Since copper becomes copper oxide with the heat, and copper oxide is a different material from copper, this is a chemical change.

老師：　物質的變化分為物理變化和化學變化，請問兩種變化發生後分別會怎樣呢？

學生：　物理變化後物質的組成與性質不變，但外觀、形狀和體積可能發生改變。

學生：　化學變化後物質組成與性質發生改變，並產生新的物質。

老師：　那甲操作是什麼變化？為什麼？

學生：　甲操作是物理變化，因為只有形狀改變，沒有物質組成的變化。

老師：　很好，銅變細了，仍然是銅，所以只是物理變化。

老師：　那乙操作是什麼變化？為什麼？

學生：　乙操作是化學變化，因為表面的銅被氧化了。

老師：　是的，銅已因為加熱變成氧化銅了，氧化銅是新的物質，所以這是化學變化。

例題二

說明：了解組成地球大氣的幾種主要氣體的占比，與其特性及用途。

Students understand the percentage of the main gases that the air consists of and their properties and usages.

（英文）As the following picture shows, the gases that the air consists of are A, B, C, and D. Which of the following statements about the four elements is correct?

(A) A is an inert gas exists as monatomic.

(B) B is neither flammable nor combustible. It is often used as the filler of food packaging to avoid from oxidizing.

(C) C is combustible and has active chemical properties. It is the gas that flora and fauna need for breathing.

(D) D is the compound gas including carbon dioxide and hydrogen.

（中文）如下圖所示，地球地表大氣的組成由甲、乙、丙和丁代表。關於這四個成分的說明，下列何者正確？

(A)甲：以單原子形式存在空氣中的惰性氣體。

(B)乙：不可燃也不助燃，常用於填充食品包裝，以避免氧化腐敗。

(C)丙：具有助燃性，化學性質活潑，為動植物呼吸所需的氣體。

(D)丁：為混合氣體，包含有二氧化碳、氫氣等氣體。
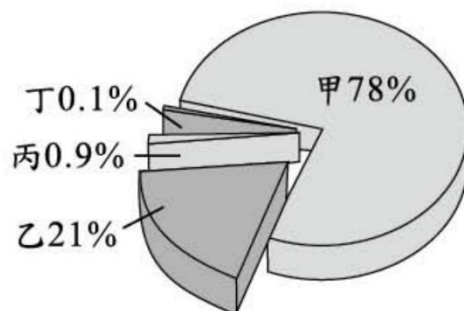
（103 年國中會考 24）

解題 Solution：

甲為氮氣 N_2，以雙原子分子形式存在；乙為氧氣 O_2，也是雙原子分子的氣體，不可燃但有助燃性；丙為氬氣 Ar，是一種單原子分子，屬於惰性氣體的一種，因為其化學性質並不活潑；丁為混合氣體，含有 CO_2、H_2、H_2O 等。故選(D)。

A is nitrogen (N_2) that exists as diatomic. B is oxygen (O_2) that exists as diatomic. It is not flammable but combustible. C is argon (Ar) that exists as a monatomic and one of the inert gases due to its inactive chemical properties. D is a compound gas containing CO_2, H_2, and H_2O. The answer is (D).

Teacher: The diagram shows that gas A is contained the most proportion of the air. What do you think gas A is?

Student: Nitrogen is contained the most proportion in the air, so gas A is nitrogen (N_2).

Teacher: Good. What can nitrogen be used for?

Student: Nitrogen (N_2) exists as diatomic and is inflammable and combustible. It is often used as the filler of food packaging.

Teacher: So now we know that option A is incorrect. Gas B accounts for 21% of the air. What is gas B?

Student: Gas B is oxygen.

Teacher: Right! Oxygen (O_2) is combustible, so option B is incorrect.

Teacher: The question says that gas B is often used as the filler of food packaging to avoid oxidizing, and gas B means nitrogen (N_2). What is gas C, then? And what are the properties?

Student: C is argon (Ar), a kind of inert gas. Therefore, the answer is (D).

Teacher: Exactly. D includes carbon dioxide, hydrogen, and water vapor, but the sum of them only accounts for 0.1% of the air.

老師： 圖中顯示氣體甲含量最高，你們覺得甲是什麼氣體呢？

學生： 空氣中含量最多的是氮氣，所以甲是氮氣 N_2。

老師： 很好，那麼氮氣有什麼用途呢？

學生： 氮氣 N_2 以雙原子分子形式存在，不可燃也不助燃，常填充於食品包裝中。

老師： 所以(A)選項不對。氣體乙在空氣中佔有 21%，乙是什麼氣體呢？

學生： 乙是氧氣 O_2。

老師： 沒錯！氧氣 O_2 氣會助燃，(B)選項錯誤。

老師： 題目說「乙：常用於填充食品包裝，以避免氧化腐敗」是指氮氣 N_2。那丙是什麼氣體？有什麼特性？

學生： 丙為氬氣 Ar，是惰性氣體的一種。所以答案是(D)。

老師： 完全正確，圖中的丁包含了二氧化碳、氫氣、還有水蒸氣等，但加總也僅佔空氣的千分之一。

2-2 溶液與濃度
Solution and Concentration

■ 前言 Introduction

介紹水溶液的組成，討論重量百分濃度、體積百分濃度及百萬分之一等常見濃度表示法。最後探討溫度對於溶解度的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
solution	溶液	weight percentage concentration	重量百分率濃度
solvent	溶劑	volume percentage concentration	體積百分率濃度
solute	溶質	parts per million (ppm)	百萬分之一（濃度）
aqueous solution (aq)	水溶液	solubility	溶解度
dissolve	溶解	undersaturated solution, unsaturated solution	未飽和溶液
concentration	濃度	saturated solution	飽和溶液

■ 教學句型與實用句子　Sentence Frames and Useful Sentences

❶ The _____ the concentration of _____, the _____ it will _____ and the _____ it will be.

例句：**The** higher t**he concentration of** brown sugar water, **the** sweeter **it will** taste **and the** darker **it will be**.

黑糖水的濃度愈高，嚐起來就愈甜，顏色也愈深。

❷ The weight percentage concentration of _____ is ___%, which means that every 100 grams of ____ contains ____ grams of _____.

例句：**The weight percentage concentration of** the sugar water **is** 75**%, which means that every 100 grams of** sugar water **contains** 75 **grams of** sugar.

糖水的重量百分率濃度為 75％，代表每 100 公克糖水中，含有 75 公克的糖。

❸ The _____ increases with increasing/decreasing _____.

例句：**The** solubility of most solid solutes **increases with increasing** water temperature.

大部分固體溶質的溶解度，會隨著水溫升高而增加。

■ 問題講解 Explanation of Problems

ଔ 學習目標 ଓ

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following:

一、能正確計算溶質的溶解度。

Calculate the solubility of solutes correctly.

二、能區分飽和溶液及未飽和溶液。

Distinguish between saturated solutions and unsaturated solutions.

❧ 例題講解 ☙

例題一

說明：了解溶解度的定義，並計算水溶液溶解度。

Students can understand what solubility is and calculate the solubility of aqueous solution.

（英文）There is a glass of 150g citrate solution with 40% weight percentage concentration. After adding 65g citric acid to the solution, mixing, filtering, dry and weigh the filter paper, there is still 5g of citric acid not dissolved. If the temperature of the solution never changes during the process, which answer is the closest to the solubility of the citrate solution under this temperature?

(A) 45g / 100g water　　　　　(B) 80g / 100g water

(C) 91g / 100g water　　　　　**(D) 133g / 100g water**

（中文）在某一溫度下，有一杯重量百分濃度 40% 的檸檬酸水溶液 150 g，再加入檸檬酸 65g 攪拌過濾，將濾紙烘乾並秤重後，發現有 5g 檸檬酸未溶解。若過程中溶液溫度均未改變，則在此溫度時檸檬酸的溶解度最接近下列何者？

(A) 45 g / 100 g 水　　　　　(B) 80 g / 100 g 水

(C) 91 g / 100 g 水　　　　　**(D) 133 g / 100 g 水**

（103 年國中會考 45）

解題 Solution：

原來溶液中含有檸檬酸 $150 \times 40\% = 60$ g，所以水有 $150 - 60 = 90$ g，最終融在水中的檸檬酸 $65 - 5 + 60 = 120$ g。

計算溶解度：$120 / 90 = X / 100$，$X = 133$，故溶解度為 (D) 133 g / 100 g 水。

The citric acid contained in the solution was $150 \times 40\% = 60$ g, so the water was $150 - 60 = 90$ g.

The citric acid dissolved in the water is $65 - 5 + 60 = 120$ g.

Then the solubility is: $120 / 90 = X / 100$, $X = 133$. Therefore, the solubility is (D) 133g / 100g water.

Teacher:	The weight percentage concentration of citrate solution is 40% means how many grams of citric acid in every 100g of citrate solution?
Student:	40 grams.
Teacher:	What if the concentration remains the same, how much citric acid will there be in 150g citrate solution?
Student:	$150 \times 40\% = 60$g.

Teacher: Great. According to the question, "after adding 65g of citric acid to the solution, mix, filter, dry, and weigh the filter paper, there is still 5g of citric acid not dissolved," how many grams of citric acid are further dissolved? And how many grams of citric acid are in the solution now?

Student: 65 – 5= 60 g citric acid is further dissolved. There are 120g of citric acid in the solution in total.

Teacher: The definition of solubility is "the amount of the solute that every 100 grams of the solvent can dissolve." According to this, how could you express the solubility of citrate solution?

Student: 120 / 90 = X / 100, X = 133.

Teacher: So, the answer is (D) 133 g / 100 g water.

Teacher: We learn that the weight percentage concentration of solution can be more than 100% from the answer. As the answer shows, the weight of a solvent can be bigger than the weight of a solution.

老師： 檸檬酸水溶液的重量百分率濃度為 40%，代表每 100 公克檸檬酸水中，含有多少克的檸檬酸呢？

學生： 40 克。

老師： 那如果相同濃度，150 g 的檸檬酸水溶液中，含有多少檸檬酸呢？

學生： 150 × 40% =60 g。

老師： 很好，「再加入檸檬酸 65 g 攪拌過濾，發現有 5 g 檸檬酸未溶解」請問又溶解了幾克？水溶液中總共有幾克檸檬酸呢？

學生： 又溶解了 65 – 5= 60 g 。總共有 120 g 檸檬酸。

老師： 溶解度的定義是：「每 100 公克溶劑可溶解的溶質公克數」，那此檸檬酸水溶液的溶解度是可以怎麼表示？

學生： 120 / 90 = X / 100，X = 133。

老師： 所以答案是(D) 133 g / 100 g 水。

老師： 從答案中，我們也可發現，水溶液的重量百分濃度，有可能超過 100%。因為，溶質的重量有可能超過溶劑的重量，正如此題所顯示。

例題二

說明：利用溶解度的概念，判斷溶液是否飽和。
　　　Identify if the solution is saturated by utilizing the concept of the solidity.

（英文）The diagram below shows the solubility as a function of temperature of material A and B. Ming is conducting a solubility experiment according to the information from the graph. Ming adds material A and B to glass X and Y, which contains 10g of water, respectively. The water neither evaporates nor decreases during the process, and the temperature of the solution remains at 40°C (as shown in the two diagrams on the right). Which is the most likely result of the experiment?

(A) Precipitate in both X and Y

(B) Precipitate in neither X nor Y

(C) Precipitate in X but Y

(D) Precipitate in Y but X

（中文）下圖是甲、乙兩種物質的溶解度與溫度之關係圖。曉明依據此資料進行溶解度實驗，在各裝有 10 g 水的 X、Y 兩杯中，分別加入甲、乙兩種物質，過程中水未蒸發減少，且溶液的溫度維持 40°C，如右圖所示。下列何者最可能是曉明觀察到的結果？

(A)兩杯都有沉澱　　　　　　　　(B)兩杯都無沉澱

(C) X 杯有沉澱，Y 杯無沉澱　　　(D) X 杯無沉澱，Y 杯有沉澱
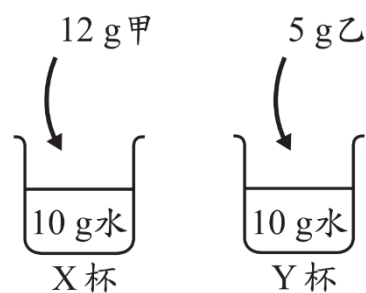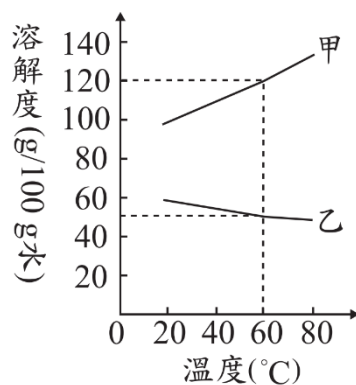
（109 年國中會考 15）

解題 Solution：

由圖可知甲物質的溶解度隨溫度降低而減少。當溫度為 60°C 時，甲物質的溶解度為 120 g / 100 g 水，因此可知 10 g 水可溶解 12 g 的甲物質。而當溫度降為 40°C 時，溶解度也隨之減少，此時 10 g 水可溶解的甲物質小於 12 g，故 X 杯有沉澱。由圖可知乙物質的溶

解度隨溫度降低而增加。當溫度為 60°C 時，乙物質的溶解度為 50 g／100 g 水，因此可知 10 g 水可溶解 5 g 的乙物質。而當溫度降為 40°C 時，溶解度隨之上升，此時 10 g 水可溶解的乙物質大於 5 g，故 Y 杯無沉澱。

From the graph above, we know that the solubility of A decreases with decreasing water temperature. When the temperature is 60°C, the solubility of material A is 120g／100g of water, so every 10 grams of water dissolves 12 grams of A. When the temperature drops to 40°C, the solubility decreases. This is when 10 grams of water dissolves less than 12 grams of A, and there is precipitation in glass X. From the graph it is known that the solubility of B increases with decreasing water temperature. When the temperature is 60°C, the solubility of material B is 50g／100g of water. Therefore, 10 grams of water dissolves 5 grams of B. While the temperature drops to 40 °C, the solubility increases so that every 10 grams of water dissolves more than 5 grams of B. As the result, there is no precipitation in glass Y.

Teacher:	Solubility of most solid solutes increases with increasing water temperature. According to the left diagram, the solubility of A meets the above-mentioned conditions. So, what is the solubility of A when the temperature remains at 40°C?
Student:	It's hard to tell. But we know that the solubility of A is less than 120 g／100 g of water.
Teacher:	Correct. When the temperature is 60°C, 10 grams of water dissolves 12 grams of A, but when the temperature drops to 40°C, the solubility decreases as well. At this moment, every 10 grams of water dissolves less than 12 grams of A. So, is there precipitation in glass X?
Student:	Yes, there is.
Teacher:	Great. Then is the solubility of B more or less than 50 g／100 g of water when the temperature is 40°C?
Student:	The solubility of B is more than 50 g／100 g of water.
Teacher:	That's right. The left diagram shows that the solubility of B increases with decreasing water temperature. When the temperature is 60°C, the solubility of B is 50 g／100 g of water, every 10 grams of water dissolves 5 grams of B; when the temperature drops to 40°C, the solubility increases, and 10 grams of water dissolves more than 5 grams of B.
Student:	Oh! That's why the answer is (C).

老師：　大部分固體溶質的溶解度會隨著水溫升高而增加。根據左圖可知甲物質的溶解度符合剛才所述的情況。當溫度維持 40°C 時，甲物質對水的溶解度是多少？

學生：　看不出來耶！不過甲物質的溶解度小於 120 g / 100 g 水。

老師：　沒錯！當溫度為 60°C 時，10 g 水可溶解 12 g 的甲物質。而當溫度降為 40°C 時，溶解度也隨之減少，此時 10 g 水可溶解的甲物質小於 12 g。所以，X 杯中的水溶液是否會有沉澱物呢？

學生：　會的。

老師：　很好，那乙物質在 40°C 時對水的溶解度，應該大於或小於 50 g / 100 g 水呢？

學生：　乙物質的溶解度大於 50 g / 100 g 水。

老師：　對！左圖中顯示，乙物質的溶解度隨溫度降低而增加，當溫度為 60°C 時，乙物質的溶解度為 50 g / 100 g 水，因此 10 g 水可溶解 5 g 的乙物質。而當溫度降為 40°C 時，溶解度隨之上升，此時 10 g 水可溶解的乙物質大於 5 g。

學生：　哦～所以答案要選(C)。

2-3 混合物的分離
Separation of Mixtures

■ 前言 Introduction

介紹過濾法、結晶法、色層分析法等分離混合物的方法與其運作原理。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
mixture	混合物	crystallization	結晶法
separation / separate	分離 (n)/(v)	chromatography	色層分析法
filtration	過濾法	filter paper	濾紙
filter	過濾	adsorption	吸附 (n)

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **We can separate** _____ **from** _____ **by** _____.

例句：**We can separate** salt **from** salt solution **by** crystallization.

我們可以藉由結晶法將鹽從鹽水中分離出來。

❷ _____ **can be used to separate** _____ **from** _____.

例句：Coffee filter **can be used to separate** coffee grounds **from** coffee.

濾紙可以用來將咖啡中的咖啡渣濾掉。

■ 問題講解 Explanation of Problems

∞ 學習目標 ∞

在學習完本單元後，學生應習得以下觀念：

By the end of this section, students should be able to do the following:

一、能分辨混合物相應的分離方式。

　　Distinguish the corresponding separation method of the mixture.

二、能區分各種混合物分離法的運作原理。

　　Distinguish the principles used in different kinds of separation of mixtures.

∞ 例題講解 ∞

例題一

說明：知道將鹽從鹽水中分離出來的方法，並從選項中選出正確的實驗方法示意圖。

　　　Students know how to separate salt from salt solution and can identify the correct abridged general view of the experiment.

（英文）Which of the following approaches separates salt from salt solution?

　　　(A) absolute alcohol; salt solution

　　　(B) ring stand; salt solution; filter paper

　　　(C) salt solution; evaporating dish; spirit lamp

　　　(D) DC power supply; salt solution

（中文）下列各圖所表示的操作，哪一項可以將鹽水中的鹽分離出來？

　　　(A) 純酒精；鹽水

　　　(B) 鐵架；鹽水；濾紙

　　　(C) 鹽水；蒸發皿；酒精燈

　　　(D) 直流電源供應器；鹽水
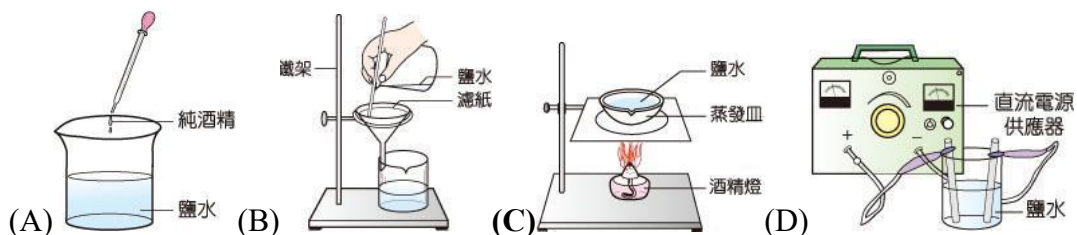
（91 年第一次基測 3）

解題 Solution：

加熱過程中，沸點較低的水會先蒸發，沸點較高的食鹽則會殘留在蒸發皿上。故選(C)。
選項(B)的濾紙是依據顆粒大小來分離物質，鹽已溶解在水中，顆粒大小可以通過濾紙，
跟水一樣都可以通過濾紙，因此無法分離。

Solution: Water has lower boiling point than that of salt, so water evaporates and salt sticks to
the evaporating dish after heating. The answer is (C). In (B), filter paper separates matter owing
to the differences among different material particles' sizes. Since salt is dissolved in the water,
the particle is small enough to pass the filter paper similar to water, the filter paper cannot
separate salt from water.

Teacher:	What property can we use to separate salt and water?
Student:	Salt and water have different boiling points.
Teacher:	Correct! Which has the lower boiling point, salt or water?
Student:	Salt does.
Teacher:	Then what evaporates first when heating the salt solution?
Student:	It's water.
Teacher:	Exactly. We can separate salt from salt solution by crystallization. Which option is crystallization?
Student:	The answer is (C).
Teacher:	Who knows why approach (B) cannot separate salt and water?
Student:	I know! The size of particles of dissolved salt can pass the filter paper, so this approach doesn't help separate salt from water.

老師：	我們可以利用哪種性質來分離鹽跟水呢？
學生：	鹽跟水的沸點不同。
老師：	沒錯！鹽跟水的沸點，哪個比較低呢？
學生：	鹽。
老師：	所以，鹽水加熱過程，什麼會先蒸發？
學生：	水。
老師：	是的，所以我們可以藉由結晶法將鹽從鹽水中分離出來。哪個選項是結晶法呢？
學生：	答案是(C)。
老師：	那有誰知道選項(B)的方法為什麼不能分離鹽跟水呢？
學生：	我！鹽已經溶解了，顆粒大小可以通過濾紙，所以此方法無法分離兩種物質。

例題二

說明：區分不同混合物分離法的分離原理，及分離後所得之物質特性。

Students can distinguish the principles used in different kinds of separation of mixtures and the properties of the separated substance.

（英文）Which of the following statements about separating pure substance form mixture is not true?

(A) Paper chromatography separates substance through the differentiation of solubilities.

(B) Filtration separates substances using the differentiation of the size of particles.

(C) Crystallization separates substances using the differentiation of solubilities.

(D) The filtrate generated from filtration might be mixture.

（中文）下列有關混合物分離出純物質的方法何者錯誤？

(A) 濾紙色層分析法是利用溶解度不同來分離物質。

(B) 過濾法是利用顆粒大小的不同來分離物質。

(C) 結晶法是利用溶解度的不同來分離物質。

(D) 過濾法所得到的濾液可能是混合物。

（翰林十分鐘輕鬆考）

解題 Solution：

濾紙色層分析法，是利用混合物中的物質對濾紙吸附能力不同來分離物質，而非溶解度。

Paper chromatography separates substance using the differentiation of the absorption ability of the materials in mixture, not solubility.

Teacher:	What property does chromatography use to separate substances?
Student:	It uses the differentiation between the absorption ability of different substances in mixture.
Teacher:	What separation method do you think that uses the different solubility to separate substance like it is said in (A)?
Student:	I have no idea. Is it filtration?
Teacher:	It is extraction. Like decaffeinate coffee, it uses the solubility of coffee to different solvents to extract caffeine and decrease the concentration of caffeine in coffee.
Student:	Oh, I get it.

老師：　濾紙色層分析法，利用什麼特性分離物質？

學生：　利用混合物中，物質對濾紙吸附能力不同來分離物質。

老師：　那你們覺得(A)所說，利用溶解度不同來分離物質是什麼分離法？

學生：　不知道耶！是過濾嗎？

老師：　是萃取法。像是市面上販售的無咖啡因咖啡，就是利用咖啡因對於不同溶劑
　　　　的溶解度不同，將咖啡因萃取出來，降低咖啡中咖啡因的濃度。

學生：　哦～我懂了。

★主題三 波動與聲音★
Wave Motion and Sound

國立彰化師範大學物理系　曾于恩、林妍君

■ 前言 Introduction

透過生活中波動的現象，引導學生認識週期波的特徵，熟悉週期波相關物理量之間的推導計算。也深入探討「聲音」的力學波特性。最後，介紹聲音三要素：響度與振幅、音調與頻率、音色與波形，以及回聲和超聲波在科技及自然界中的應用。

3-1 波的傳播與特徵
The Propagation and Features of Waves

■ 前言 Introduction

介紹生活中波動的現象，將波動以「傳遞時需要介質與否」區分為力學波及非力學波兩種。或者，以波的振動方向與傳遞方向垂直或平行，分成橫波或縱波兩種。學生需要認識週期波的相關物理量，並能推算出波速。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
wave	波(波動)	rarefaction wave	疏密波
ripple	(水波)波紋	wave velocity	波速
wave source	波源	periodic wave	週期波
vibration source	振源	full wave	全波
propagation	傳播	wave crest	波峰
medium	介質	wave trough	波谷
vibration	振動	wavelength	波長
mechanical wave	力學波	amplitude	振幅
non-mechanical wave	非力學波	frequency	頻率
transverse wave	橫波	Hertz (Hz)	赫茲(Hz)
longitudinal wave	縱波		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ is perpendicular/parallel to _____.

例句：The wave whose source vibration direction **is perpendicular to** its traveling direction is called transverse wave.

當波源振動方向與波前進方向互相垂直，這種波稱為橫波。

❷ _____ vibrates once, _____ is generated.

例句：The vibration source **vibrates once,** a full wave **is generated.**

振源每振動一次，就產生一個全波。

❸ The _____, the _____ the period will be.

例句：**The** slower the wave source swings, **the** longer **the period will be**. And the frequency must be smaller.

若波源來回擺動得愈慢，波的週期會愈大，頻率就愈小。

■ 問題講解 Explanation of Problems

◔ 學習目標 ◕

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、熟悉週期波的各項特徵，所代表的意義。

　　become familiar with the meanings of the characteristics of periodic waves.

二、了解波傳播時只傳送波形和能量，不會傳送介質。

　　Understand that wave propagation only transmits the waveform and energy, not the medium.

❀ 例題講解 ❀

例題一

說明：學生須熟悉週期波之頻率與週期的關係，且了解介質振動的平均速度。

Students are familiar with the relationship between the frequency and period of periodic waves and understand the average velocity of the vibration of a medium.

（英文）A periodic wave travels through a rope; the wavelength is 60 cm, the amplitude is 25 cm, and the frequency is 2 Hz. When t = 0 s, the waveform is as shown in the figure below. It is known that point P is on the rope; what is the average velocity of point P during t = 0~2.5 s?

（中文）一週期性繩波的波長為 60 cm，振幅為 25 cm，頻率為 2 Hz，在時間 t＝0 s 時的波形如圖所示，已知 P 為繩上一點，則在 t＝0～2.5 s 期間，P 點移動的平均速度大小為多少？

(A) 0
(B) 20 cm/s
(C) 120 cm/s
(D) 200 cm/s

圖（二十二）
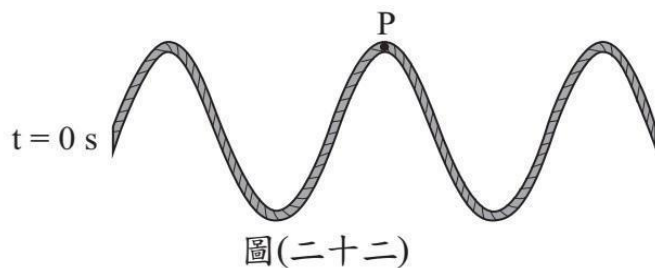
（109 年會考補考 45）

解題 Solution：

波傳播時只傳送波形和能量，並不傳送介質，所以 P 點只會上下原地震盪。週期性繩波的頻率 f＝2 Hz，頻率和週期互為倒數，故週期 T＝1/2 s＝0.5 s。在 t＝0～2.5 s 期間，P 點上下來回震盪共 5 次(2.5/0.5＝5)，意即 P 點經過 2.5 s 後，又回到原位置，位移為零，因此，[平均速度=位移/時間=0/2.5 =0]，答案為(A)。

Wave propagation only transmits the waveform and energy, not the medium. As a result, point P simply moves up and down. Period is the reciprocal of the frequency, and the frequency if f = 2 Hz, so the period is T = ½ s = 0.5 s. The motion of point P repeats 5 times (2.5/0.5=5) during t = 0~2.5 s, which means that point P moves back to the initial position after 2.5 seconds, and the displacement is 0. According to the formula, "average velocity = displacement/time," we can get the average velocity=0/2.5 = 0, so the answer is (A).

Teacher: Is the wave on a rope a transverse wave or a longitudinal wave?

Student: It is a transverse wave.

Teacher: Good. How does point P move?

Student: Point P moves rightwards.

Teacher: A wave on a string is a transverse wave, and it only transfers waveform and energy, not the medium.

Student: Oh! Point P only oscillates up and down.

Teacher: That's right. What is the period when the frequency of the wave is 2 Hz?

Student: The period is the reciprocal of the frequency, so the period is 0.5 s.

Teacher: Period is 0.5 s means that it takes 0.5 second for point P to make a complete movement. Where is point P when t = 2.5 s if when t = 0 s is as shown in the figure?

Student: During the time period, point P makes 5 complete oscillations and gets back to the initial position eventually.

Teacher: Good. Since the definition of average velocity is the displacement per unit time, what is the average velocity of point P?

Student: Point P gets back to the initial position, thus the displacement is zero. The average velocity is then zero.

老師： 繩波是縱波還是橫波？

學生： 橫波。

老師： 很好，所以繩上的 P 點應該如何運動呢？

學生： P 點會向右移動。

老師： 繩波是橫波喔！而且傳播時只傳送波形和能量，並不傳送介質。

學生： 喔！P 點只會上下震盪。

老師： 沒錯！波的頻率為 2 Hz，週期為何？

學生： 週期為頻率的倒數，所以週期是 0.5 s。

老師： 週期 0.5 s 代表 P 點來回一次需要 0.5 s， t＝0 s 時波形如圖， t＝2.5 s 時 P 點在哪裡呢？

學生： P 點會來回震盪共 5 次，所以最後恰好回到原先的位置。

老師： 很好！平均速度的定義是單位時間的位移，P 點移動的平均速度大小是多少呢？

學生： P 點會回到原位置，所以位移為零，因此平均速度也是零。

例題二

說明：了解波傳播時，只傳送波形和能量，並不傳送介質。

　　　　Students understand that the wave propagation only transmits the waveform and energy, not the medium.

（英文）As shown in the following figure: throwing a coin into a fountain on one windless afternoon, and the coin falls at point O, ripples are generated on the water. It is known that the radius of the wave increases by 1 m per second. There are two leaves on point P and Q, respectively, which are 1 and 2 meters long from point O. If O, P, and Q are on the same straight line, then what will the distance between the two leaves be, 3 seconds after the coin is thrown into the water?

（中文）如下圖所示，在平靜無風的下午，在許願池上 O 點丟入一枚硬幣，使水面上產生一個圓形水波，已知圓形水波的半徑每秒增加 1 m。若丟入硬幣前，在水面上距離 O 點 1 m 及 2 m 的 P、Q 兩點，分別有一片落葉，且 O、P、Q 在同一直線上，則硬幣丟入水中 3 秒後，兩片落葉的距離約為多少？

(A) 3 m
(B) 5 m
(C) 6 m
(D) 9 m
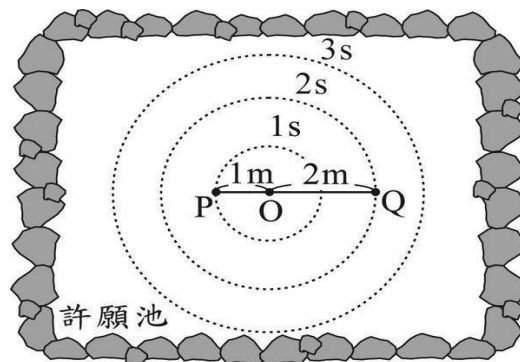
圖(二十)

（103 年國中會考 35）

解題 Solution：

因為介質的振動與波傳遞方向垂直，所以水波是一種橫波。介質受到擾動（能量）產生波動時，僅能傳遞能量與波形，不會傳播介質。在水面上距離 O 點 1 m 及 2 m 的 P、Q 兩點，分別有一片落葉，且 O、P、Q 在同一直線上，受到圓形水波擾動，因為兩片落葉不會被傳走，只會原地上下振動，所以兩片落葉距離仍是保持 3 m，故(A)是正確選項。

Ripple is a kind of transverse wave because the vibration of the medium and the direction that the wave propergates are perpendicular. When the medium is interfered by energy and generates the wave, the only thing delivered is energy and waveform, not the medium.

There are two leaves on point P and Q that were 1 and 2 meters away from point O, respectively. Also, point O, P, and Q are on the same straight line and are interfered by the ripple. The two leaves would not be transmitted along the wave, whereas they only oscillate up and down at their original positions. So, the distance between the two leaves remains 3 m. The answer is (A).

Teacher: Point O is the vibration source because we throw a coin into point O. The ripple spreads in all directions. How do the two leaves that are on point P and Q move, respectively?

Student: They moved along the wave. The leaf on point P moves leftwards and the one on point Q moves rightwards.

Teacher: According to the feature that the propagation of wave only transmits the waveform and energy, not the medium, is a ripple a transverse wave or a longitudinal wave?

Student: The ripple is a transverse wave, so the leaves on point P and Q oscillate up and down as the wave spreads.

Teacher: Exactly! What is the distance between the two leaves at point P and Q?

Student: The distance between the two leaves remains 3 m. It doesn't change.

Teacher: Great. Similarly, the medium of the longitudinal wave won't move along the wave neither. It only oscillates back and forth.

老師： 在 O 點丟入一枚硬幣，所以 O 點為振源，水波往四面八方前進，那 P、Q 兩點的落葉分別會怎麼運動呢？

學生： 隨著波往外擴散，P 點的落葉往左，Q 點的落葉往右。

老師： 波傳播時只傳送波形和能量，並不傳送介質，水波屬於橫波還是縱波?

學生： 水波是一種橫波，所以 P、Q 兩點的落葉，會隨著波的前進，上下起伏。

老師： 沒錯！所以 P、Q 兩點的落葉間距應該是多少?

學生： P、Q 兩點的落葉間距不會改變，依然是 3 m。

老師： 很好，再補充一點:如果是縱波，介質仍不會隨著波動前進，只會左右震盪。

3-2 聲音的形成
The Formation of Sound

■ 前言 Introduction

說明聲音是藉由聲源的「振動」而產生，聲音傳播需要依靠介質，且聲波的傳播速率僅與介質特性有關，與聲源的振動幅度無關。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
strike	敲擊	disturbance	擾動
source of sound	聲源	Robert Boyle	羅伯特·波以耳
tuning fork	音叉	speed of sound	聲速

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ disturbs the surrounding air, causing the air to _____.

例句：A vibrating tuning fork **disturbs the surrounding air, causing the air to** change in density and propagate the sound wave.
振動中的音叉會擾動周圍的空氣，使空氣產生疏密變化，並將聲波向外傳播出去。

❷ **When** _____ **hits** _____, **we can clearly hear** _____, **indicating that sound can also travel through** _____.

例句：**When** our neighbors **hit** the connecting wall with a hammer, **we can clearly hear** the knocking sound, **indicating that sound can also travel through** solid objects.

隔壁鄰居以鐵鎚敲打牆壁時，我們能夠清楚地聽見敲擊聲，表示聲音也可經由固體傳播。

❸ _____ **travels more quickly through** _____ **than through** _____.

例句：Sound **travels more quickly through** solids **than** those of liquids and gases.

在固體中，聲音傳播速率，比在液體或氣體中更快。

■ **問題講解 Explanation of Problems**

ଔ **學習目標** ଛ

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解波速與波長、頻率間的關係。

　　understand the relationship among wave speed, wavelength, and frequency.

二、知道聲波需要介質才能傳遞。

　　know that sound waves need a medium to travel.

❧ 例題講解 ☙

例題一

說明：能夠根據關係圖，推出波動的頻率。

Students can determine the frequency of the wave from a graph.

（英文）A tuning fork makes a sound that has a single frequency, and the feature of it is as shown in the figure. Y-axis represents the displacement of the vibration. Which of the following is the frequency of the sound of the tuning fork?

（中文）某音叉發出單一頻率的聲音，它的特性顯示在儀器上，如圖所示，y 為其振動的位移。此音叉發出聲音的頻率為下列何者？

(A)1000 Hz
(B)800 Hz
(C)400 Hz
(D)100 Hz。
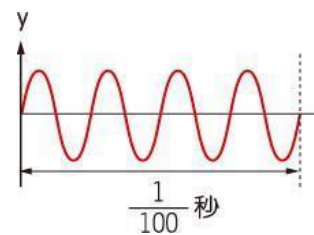
（97-2 基測 41）

解題 Solution：

由圖可知，波經歷 1/100 秒的時間，共傳遞 4 個週期，因此 1 個週期為 T=Δt/總次數=(1/100) 秒/4 次=1/400(秒/次)。頻率(次/秒)與週期(秒/次)互為倒數，故頻率為 400 (次/秒)=400(1/秒)=400 Hz （因為"次數"並非物理量，故可在單位中刪除），答案選(C)。

From this figure, we learn that the wave travels for 1/100 second, and there are 4 periods totally. Thus, the period T = Δt/times = (1/100) s/4 times = 1/400 (s/time). Since the frequency and period are reciprocals of each other, the frequency is 400 (times/s) = 400 (1/s) = 400 Hz. The answer is (C). (Note: because "the times of oscillation" is not a physical quantity, it can be deleted in units.)

Teacher:　In this figure, the x-axis represents the time duration, the unit is second, and the y-axis represents the displacement of the vibration. How many waveforms are generated in 1/100 seconds?

Student:　Four complete waveforms are generated.

Teacher:　Good. The time that generating one complete waveform is called "period" (second/time); then what is the period of this wave?

Student:　Four complete waveforms were generated in 1/100 second, so one wave is generated in (1/1000)/4=1/400 second. The periods would be 1/400 (second/time).

Teacher:　Great! Since we know that the frequency (time/second) and period (second/time) are reciprocals of each other, what is the frequency of this wave?

Student:　The frequency is the reciprocal of the period, which is 400.

Teacher:　That's right. What about its unit?

Student:　It's time/second.

Teacher:　Exactly. The unit of frequency is time/second = 1/second = Hz. And Hz is the most used unit for frequency.

老師：　圖中橫軸是時間，單位為秒，縱軸是振動的位移。在 1/100 秒鐘產生了幾個完整的波形呢？

學生：　產生 4 個完整的波形。

老師：　很好，產生 1 個完整的波形所花費的時間稱為 1 個週期(秒/次)。此波的週期為何呢？

學生：　1/100 秒產生 4 個完整的波形，所以每 1/400 秒產生一個波，週期為 1/400(秒/次)。

老師：　太棒啦！我們知道頻率(次/秒)與週期(秒/次)互為倒數，那此波的頻率呢？

學生：　將週期倒數就得到頻率為 400。

老師：　正確，頻率的單位呢？

學生：　次/秒。

老師：　沒錯，頻率的單位是：次/秒=1/秒=Hz。Hz 是我們最常使用的頻率單位名稱。

例題二

說明：透過實驗，驗證聲波需要介質才能傳遞。

　　　To prove that sound wave needs a medium to deliver through an experiment.

（英文）As the following figure shows, an electric bell is put in a glass cover with an aspirator. The bell was stricken by the hammer that is connected to electricity and made the sound. After that, we aspirate the air out of the glass cover gradually, which of the following statement is true regarding the change of the sound?

(A) The frequency of the bell vibrating changes.

(B) The sound of the bell is evacuated by the aspirator.

(C) Losing air makes less barrier for the sound propagation.

(D) Losing air means lacking the medium of sound propagation.

（中文）如下圖，取一電鈴放在抽氣機的玻璃罩內，通電後鈴槌敲擊電鈴發出聲音。然後將玻璃罩內空氣漸漸抽出，關於電鈴音量變化的原因，下列敘述何者正確？

(A) 鈴槌振動頻率改變。

(B) 鈴聲被抽氣機抽走了。

(C) 空氣減少，聲音傳播時所受阻礙變小。

(D) 空氣減少，缺乏傳播聲音的介質。

抽氣孔　　　抽出空氣
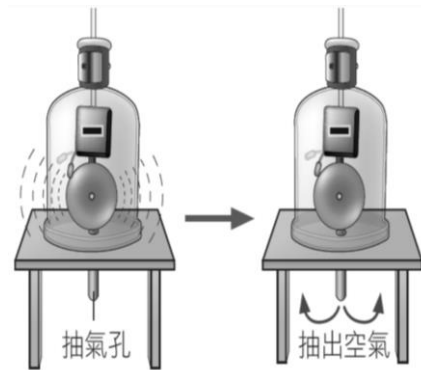
（109 年國中會考 15）

解題 Solution：

聲波是力學波，需要依靠介質(像是空氣、水，或玻璃)才能傳遞。

Sound wave is a kind of mechanical wave that requires medium, such as air, water, or glass, to propagate.

Teacher: A British scientist, Robert Boyle, conducted an experiment that he put a bell in a closed glass cover and kept striking the bell with a small hammer. After that, he aspirated the air out with an aspirator. If the bell were replaced with an electric bell, what would the result be?

Student: The sound volume decreases.

Teacher: Why is that?

Student: Because sound propagation needs a medium.

Teacher: Good, then what is the medium in this experiment?

Student: The medium is air. The aspirator reduces air, which is the medium, and the sound cannot be delivered without air.

Teacher: That's right. Before aspirating the air out, we could hear the bell because there was a medium delivering the sound. What else delivers sound except for the air?

Student: Nothing else does.

Teacher: The glass cover is also a medium, so the whole process of sound propagation includes air and the glass cover. Glass is solid and it transmits sound. Whether solid, liquid, or gas can transmit sound, so we can hear sound when we are swimming in the pool.

老師： 英國科學家波以耳之前做過一個實驗，在一個密閉玻璃罩內放入鈴鐺，並用小鎚持續敲擊鈴鐺發聲，接著用抽氣機把空氣慢慢抽出，今天把鈴鐺換成電鈴，結果會怎樣呢？

學生： 聲音會慢慢減小。

老師： 為什麼呢？

學生： 因為聲音需透過介質才能傳播出去。

老師： 很好，所以此實驗的介質是什麼？

學生： 空氣，抽氣機使空氣(介質)變少了，沒有空氣聲音就無法傳遞。

老師： 沒錯，那麼還沒有抽氣之前，我們可以聽到鈴聲，其中傳遞聲音的介質，除了空氣，還有沒有其他東西呢？

學生： 好像沒有了耶！

老師： 還包含玻璃罩喔，所以聲音傳遞的過程，包含空氣與玻璃罩。玻璃是固體，也可以傳遞聲音。無論是固體、液體、或是氣體，都可以傳遞聲音。所以我們在游泳池游泳時，仍然可以聽到聲音。

3-3 多變的聲音
Three Elements of Sounds

■ 前言 Introduction

介紹聲音三要素：響度與振幅、音調與頻率、音色與波形，並介紹聲音強度的單位—分貝，也討論噪音對人體的影響。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
play	演奏	timbre	音色
loudness	響度	waveform	波形
decibel (dB)	分貝(dB)	musical tone	樂音
tone	音調	noise	噪音
air column	空氣柱	regularity	規律性

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **Every increase of ＿＿＿＿ on the decibel scale is equal to a ＿＿＿＿ increase in ＿＿＿＿.**

例句：**Every increase of** 10 dB **on the decibel scale** is equal to **a** 10-fold **increase in** sound intensity.

每增加 10 分貝，聲音強度會增加 10 倍。

❷ **The _____made by _____ depends on _____.**

例句：**The** tone of sound **made by** a string instrument **depends on** the length and mass density of the string.

弦樂器所發出聲音的音調高低，取決於弦的長度與質量密度。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☜

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、能夠判斷聲波的各項特徵之間的關係。

　　Be able to determine the relationships among the characteristics of the wave and sound.

二、了解聲波的音量（響度）與振幅之關係。

　　To understand the relationship between the loudness and the amplitude of sound waves.

☜ 例題講解 ☞

例題一

說明：能夠判斷聲音三要素，所對應到波動的物理量。

　　　Students can correctly connect the three main characteristics of a sound to its corresponding physical quantities.

（英文）In music sheets, f, p, or other dynamic markings are commonly found, which mean the volume (loudness) of certain notes. These markings signal a gradual change to the dynamics. Which of the following characteristic of a sound wave is mostly related to such markings?

　　(A) Wavelength　　　　　　(B) Wave velocity

　　(C) Frequency　　　　　　 **(D) Amplitude**

（中文）樂譜上常用 f、p 等力度記號，來表示樂曲在此處的音量(響度)，應該如何變化，此類力度記號與聲波的下列何種特性最相關？

　　(A)波長　　　　　　　　　(B)波速

　　(C)頻率　　　　　　　　　**(D)振幅**

（109 年國中會考 10）

解題 Solution：

音量的大小取決於聲音傳播的能量強度，因此與聲波的振幅大小有關，故答案為(D)。

The loudness of a sound is determined by the intensity of that sound where sound wave travels.

This tells us that the loudness of sound is related to its amplitude, so the answer is D.

Teacher:	Which characteristics of a sound wave describes its loudness?
Student:	Frequency?
Teacher:	No…Let's imagine, when you strike a drum harder, which feature of the sound change?
Student:	The sound becomes louder!
Teacher:	That is correct. When the volume of an audible sound increases, the energy that sound carries increases. That means the drum needs to be struck harder to achieve this effect.
Teacher:	Rope waves are another example. When a rope is swung higher, that creates higher crests and lower troughs. The amplitude increases. That means, our hands generate more energy.
Student:	I see. A higher wave results in louder sound and vice versa. Volume (Loudness) is determined by the amplitude of the sound.
Teacher:	Exactly. A harder strike generates a greater amplitude of a sound wave. That tells us more energy is generated, but the frequency of that sound won't change. Neither its waveform (timbre) nor its wave velocity varies.

老師：	音量大小對應到波的哪個性質呢？
學生：	是頻率嗎？
老師：	不是喔。想想看，敲鼓敲得越大力，鼓聲會產聲什麼變化呢？
學生：	會越大聲！
老師：	沒錯！音量越大，表示傳過來的聲音能量強度越大，所以需要敲得越大力。
老師：	就像用繩子產生繩波一樣，甩得越大力波峰就會越高，波谷就會越低，振幅也會越大。此時，我們的手就送出越多的能量。
學生：	哦～所以聲波的振幅越大，聲音就會越大，音量的大小與聲波的振幅大小有關。
老師：	是的，敲得越大力只會聲波的振幅，代表能量越強；但是，不會影響聲音的頻率（高低音），也不會影響波形（音色），更不會影響波速喔！

例題二

說明：了解音量與聲波的振幅有關。
　　　Students can understand the relationship between volume and amplitude.

（英文）Now a day, many apps (applications) are available for smartphones. Some of the apps can measure the volume of sound waves in our environment. When the sound is getting louder, the figures on sound-meter apps increase. Which of the following characteristic of the sound wave may best describes this phenomenon?

(A) Wavelength 　　　　　　　(B) Wave velocity

(C) Amplitude 　　　　　　　(D) Frequency

（中文）現今智慧型手機可下載許多不同的 App（應用程式），其中一些可用來量測周遭聲波的音量，當音量愈大時，App 顯示的數值也愈大，則此數值的大小主要與聲波的何種性質有關？

(A)波長 　　　　　　　　　　(B)波速

(C)振幅 　　　　　　　　　　(D)頻率

（105 年國中會考 24）

解題 Solution：

音量的大小與聲音傳遞的能量有關，而能量大小會表現在聲波的振幅大小。故選(C)。

The loudness of sound is related to how much energy that sound wave carries. It also means that the magnitude of the energy can be seen in the amplitude of that sound wave, so the answer is C.

Teacher: Which characteristic of a sound wave can describe volume?
Student: Amplitude.
Teacher: That is correct! What does a greater amplitude tell us?
Student: The volume of a sound is higher.
Teacher: Exactly! The higher the volume of a sound, the more energy it carries. Its medium vibrates more and the amplitude of that sound wave increases.

老師：　音量大小是取決於波的哪個特徵呢？
學生：　波的振幅。
老師：　答對了！那波的振幅越大，音量會怎麼變化呢？
學生：　音量會變大。
老師：　沒錯！因為音量越大，表示送出的聲音能量越強，所以介質的振動幅度越大，聲波的振幅就越大。

3-4 聲波傳播與應用
The Propagation and Application of Sound Waves

■ 前言 Introduction

解釋波遇到障礙物會產生反射，而聲波的反射稱為回聲，也介紹超聲波在科技及自然界中的應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
reflection	反射	interference	干擾
obstacle	障礙物	ultrasound	超聲波/超音波
echo	回聲	sonar	聲納
absorption	吸收		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **Sound is _____ to _____ when it hits a _____ surface.**

例句：**Sound is** more likely **to** reflect **when it hits a** smooth and hard **surface.**
當聲音碰到光滑、堅硬的物體表面較容易發生反射。

❷ **The frequency range of sound that _____ can hear is about _____ Hz.**

例句：**The frequency range of sound that** people **can hear is about from** 20 to 20,000 **Hz (times/second).**
一般人所能聽到的聲音頻率範圍，大約在 20～20000 赫(次/秒)之間。

■ **問題講解 Explanation of Problems**

⊱ 學習目標 ⊰

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解不同動物可以聽見的聲波頻率範圍不同，並掌握各種動物的頻率範圍。

To understand the different frequency ranges of sound waves that different animals can hear, and be able to identify the specified frequency range.

二、認識波的反射及聲波反射的應用。

To know wave reflection and the application of sound wave reflection.

⊰ 例題講解 ⊱

例題一

說明：從波速及波長，推算此波動的頻率，並從表中找出適用的動物。

Students can determine the frequency of a sound wave according to its velocity and wavelength, and then identify the animal that can hear in the given ranges.

（英文）The table below shows the ranges that elephants and rabbits can hear. If an audible sound wave is measured 1,000cm in 15°C air, at 34,000 cm/s, which of the following statements is the most reasonable?

(A) Both the animals can hear this sound

(B) None of the animals can hear this sound

(C) Only elephants can hear this sound

(D) Only rabbits can hear this sound

（中文）下表為兩種動物所能聽見聲音的頻率範圍。在空氣溫度為15°C，聲波波速為34000 cm/s 的環境下，若發出波長為 1000 cm，且音量足夠大的聲波，則參閱表中的資訊，下列有關此兩種動物是否能聽到此聲波的敘述何者最合理？

(A) 兩種動物都聽得到此聲波。

(B) 兩種動物都聽不到此聲波。

(C) 此聲波大象聽得到，而兔子聽不到。

(D) 此聲波兔子聽得到，而大象聽不到。

動物	聽覺頻率範圍(Hz)
大象	16 ～ 12000
兔子	360 ～ 42000

（107 年國中會考 32）

解題 Solution：

因為表中所提供的是，兩種動物的聽覺頻率範圍，所以需依據題目的已知，推算出此聲波的頻率。根據波速 v 與頻率 f、波長 λ 的關係為 v＝f×λ，因此聲波頻率為 34000÷1000＝34 Hz，對照表中資訊，只有大象聽得到此頻率的聲波。

The table provides the ranges that the two animals can hear, and the frequency of the sound given can be determined based on what is known about that sound wave. The relationship among v (wave velocity), f (wave frequency), and λ (wave length) is v = f × λ. This formula can determine the frequency of the sound, which is f=v/λ=1,000 / 34,000 = 34 Hz. According to the hearing ranges shown in the table, the answer is C. Only elephants can hear this sound.

Teacher: This table shows us the ranges that the two animals can hear. We only know the velocity and the wavelength of this sound. How to find its frequency?

Student: We can calculate the frequency of this sound wave based on its velocity and the wavelength.

Teacher: That is correct. Now, what is the relationship of these three qualities?

Student: The relationship between v (wave velocity), f (wave frequency), and λ (wave length) can be written as v = f × λ. This formula can determine the frequency of this sound. That is f=v/λ=1,000 / 34,000 = 34 Hz.

Teacher: Fantastic! Which of the animals in the table can pick up this sound wave?

Student: Elephants can hear a sound at the frequency of between 16 and 12,000 Hz, so only elephants can hear!

Teacher: That also means that rabbits cannot hear this sound. Is the frequency of this sound too high or too low?

Student: The frequency of this sound is too low.

Teacher: Correct. The frequency of 34 Hz we got here is too low for a rabbit to hear as rabbits can only hear frequencies over 360 Hz.

老師： 題目中的表格告訴我們動物的聽覺頻率範圍，可是我們只知道此聲波的波速和波長，要怎麼得知聲波的頻率呢？

學生： 可以從波速與波長，推算出頻率。

老師： 很好，那它們之間的關係為何呢？

學生： 波速 v 與頻率 f、波長 λ 的關係為 v＝f×λ，因此聲波頻率為 34000÷1000＝34 Hz.

老師： 太棒啦！依照表中的資訊，誰可以聽得到此聲波呢？

學生： 大象可以聽到 16~12000 Hz 的聲波，只有大象聽得到此聲波。

老師： 那兔子聽不到，是因為此聲音的頻率太高或太低？

學生：　頻率太低。

老師：　答對了，完全正確。我們所算出的 34 Hz，比兔子能聽到的聲音最低頻率 360 Hz 還小，所以兔子聽不到。

例題二

說明：知道聲波遇到障礙物會反射。

Students can understand a sound wave reflects when it hits an obstacle.

（英文）In the diagram below, we cup the hands around our mouths to amplify sound while talking to people at a distance. Then people are more likely to hear what we have said. Which of the following statement explains this phenomenon?

(A) Sound waves can propagate via different mediums

(B) Sound waves are created because of the vibration of an object.

(C) Sound waves reflect when hitting an obstacle.

(D) Different frequencies of sound waves come with different tones.

（中文）如圖所示，我們對遠處的人說話時，常會用手圍住嘴巴，讓聲音不易分散，使對方較容易聽清楚我們所說的話，此現象主要是利用聲波的哪一種特性？

(A)聲波可以利用不同介質來傳播。

(B)聲波是因為物體的振動而產生。

(C)聲波傳播時遇到障礙物會被反射 。

(D)不同頻率的聲波會有不同的音調。
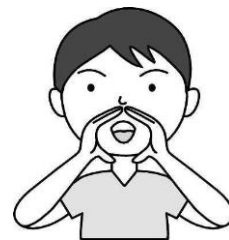
（100 年北北基聯測 18）

解題 Solution：

說話時用手圍住嘴巴，可讓原本向四面八方傳播的聲波，因聲波碰到手掌反射，而往正前方傳播，使聲音傳得更遠，故選(C)。

When we talk, the sound waves from the mouths start traveling in every direction. Using the hands cupping around our mouths allows the sound waves to reflect due to the obstacles. Thus the sound and reflected sound can travel along the same direction, allowing the sound propagates farther. The answer is C.

Teacher: We know that sound waves propagate in every direction. We also know that we cup the hands around our mouths to make sound waves travel in one direction and people at a distance can hear us more clearly. Do you know the reason behind this logic?

Student: Because sound waves that hit our palms, then reflect. This makes the sound reach longer distances.

Teacher: That is correct. After the reflection, the sound waves coming from the vibration of our vocal cords repeatedly sends the reflected sound waves further forward. That is why our voice can travel longer distances. What are other examples happening in our lives that illustrate the reflection of sound waves?

Student: When we shout out in mountains, we can hear echoes.

Teacher: Fantastic!

老師：　聲波原本向四面八方傳播,用手圍住嘴巴讓聲音不易分散,遠方的人就可以聽得較清楚,這是為什麼?

學生：　聲波碰到手掌反射,讓聲音可以傳得更遠。

老師：　沒錯!聲音被手掌反射後,其振動的能量,會疊加在原本向正前傳播的聲波,才使得聲音傳得更遠。生活中還有什麼現象是因為聲波反射呢?

學生：　在山中大喊可以聽見回音!

老師：　真是太棒了!

★主題四　光、影像與顏色★
Light, Image and Color

國立彰化師範大學物理系　宋德致、王瑞德

■ 前言 Introduction

本章透過一些生活中常見的例子，解釋光對我們的生活所造成的影響，進而帶出光的性質與成像原理，以及顏色的關係，讓學生們能將所學的物理知識和日常生活做出連結，並比較兩者之差異。

4-1 光的傳播
The Propagation of Light

■ 前言 Introduction

透過「針孔成像」探究活動來讓學生了解光的直進傳播方式，並透過日晷的運作機制及手影遊戲，來解釋影子的產生與光的直進性質有關。此外，也引入光的速度。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
light	光	light source	光源
image	影像	velocity	速度
color	顏色	speed	速率
propagation	傳播	vacuum	真空
pinhole imaging	針孔成像	medium	介質
analemma/ sundial	日晷	inverted	上下顛倒的
shadow	影子	relation	關係
move straight forward	直線前進	opaque	不透明的
real image	實像		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **When light hits a/an _____ object, it _____.**

例句：**When light hits an** opaque **object, it** creates a shadow behind it.

當光線照射到不透明的物體上時，它會在其背後產生影子。

❷ **People invented _____ to help _____.**

例句：In the olden days, **people invented** sundials, which work on the principle of straight-line propagation of light **to help** them measure time.

古代的人們利用光的直進性，製作出日晷來幫助他們計時。

❸ **If you _____, you know that _____, and you also know that _____.**

例句：**If you** hear thunder after seeing lightning for a period of time, **you know that** the thunder is far away, **and you also know that** light travels in the air much faster than how sound does.

如果看見閃電後一段時間才聽見雷聲，可知道打雷的距離很遠，也可知道光在空氣中的傳播速度比聲音快很多。

■ 問題講解 Explanation of Problems

cs 學習目標 so

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解光的直線傳播性質

　　Understand the phenomenon that light propagates in straight-lines

二、認識光的傳播速度

　　Know the speed at which light travels

❧ 例題講解 ☙

例題一

說明：讓學生了解何謂光的直線傳播。

Students are able to understand how light propagates in straight lines.

（英文）Students in Mr. Chang's class give various examples of how light travels in straight lines when the unit about light is introduced.

Which of the following statements would not be explained only with straight-line propagation of light?

(A) Grandpa needs a magnifying glass to make text on the newspaper larger while reading it.

(B) You see a shadow on the screen when someone passes by in the middle of a movie.

(C) if a rod is set straight up on a sunny day, its shadow is formed on the ground.

(D) Rays of sunlight that shine through the small gaps of tree leaves and branches cast spotted shadows of the tree on the ground.

（中文）阿誠老師上課時，談到「光」的單元，同學們提出下列各種現象中，何者無法僅用光的直線傳播來說明或解釋？

(A)阿公看報紙需要拿放大鏡，將報紙上的字放大。

(B)電影院的螢幕前有人走過，螢幕上會產生黑色的人影。

(C)在陽光下，若地面上豎立一支竿子，則地面上可見竿影。

(D)陽光透過樹葉間細小的空隙，在樹蔭的地面上，形成亮點。

（98 年第二次基測 2）

解題 Solution：

首先在(B)和(C)選項中，由於直線前進的光被某一物體擋住了所以在物體後方產生影子，皆可僅用光的直線傳播來解釋。選項(D)由於大部分的光被樹葉擋住，僅有部分的光能夠穿過空隙直射到地面上形成一個個小亮點，所以也可以只用光的直線傳播來解釋。接著回來選項(A)提到的放大鏡，其實就是凸透鏡，其成像的原理，除了與光的直進有關之外，還與光在不同介質間會折射有關，光的折射原理之後會深入探討，所以此題答案為(A)。

Firstly, Option B and C can be explained only with straight-line propagation of light. In either option, there is an opaque object that blocks the path on which light travels, and a shadow is formed behind that opaque object. Option D can also be explained only with this nature of light as most sunlight is blocked by tree leaves and branches. Only a small portion of the sunlight makes it through the small holes and to the ground. Back to Option A with a magnifying glass. That glass itself is a convex lens. How it projects images involves how light propagates in straight lines and how light refracts in different media. The principle of refraction will be explored later on. Option A is, therefore, the answer to this question.
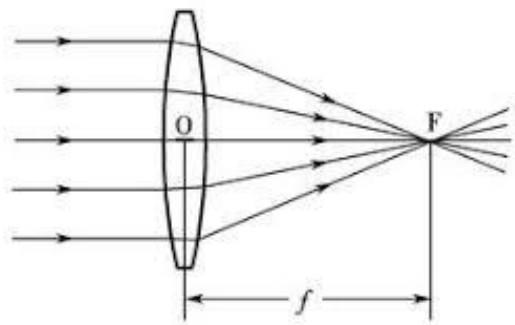
放大鏡的折射現象
How a magnifying glass refracts light rays

Teacher: What do you think this question is meaning to ask?

Student: What is straight-line propagation of light.

Teacher: That is correct and what does this nature of light tell us?

Student: Light travels in straight lines.

Teacher: Now, what if there is an opaque object on the path where light travels?

Student: Light is blocked and a shadow is formed behind that object.

Teacher: That is correct. The two diagrams depict how shadows are formed from two different light sources. Now, can you see which of the statements given are examples of shadows?

Student: B, C, and D.

Teacher: Excellent. How about Option A with a magnifying glass? We could enlarge images using a magnifying glass. How to explain it with straight-line propagation of light?

Student: Magnifying glass can enlarge images should also be an example of straight-line propagation of light.

Teacher: That is correct, but how lenses magnify images also involves the principle of refraction. Light refracts when passing through two different media, which are air and lenses in the case of a magnifying glass. We will explain more thoroughly about this principle later on.

Teacher: Light refracts when traveling through different media. But this does not compromise the straight-line path of light travelling in the same medium.

老師：　大家覺得這個題目想問的重點是什麼？

學生：　什麼是光的直線傳播。

老師：　沒錯！那麼什麼是光的直線傳播呢？

學生：　光走的路徑是一直線的。

老師：　好，那既然光是走一直線的，遇到障礙物會怎麼樣？

學生：　被擋住，因此在物體後方造成影子。

老師：　沒錯，就如下方兩個圖所示。所以哪一些選項是涉及影子的現象呢？
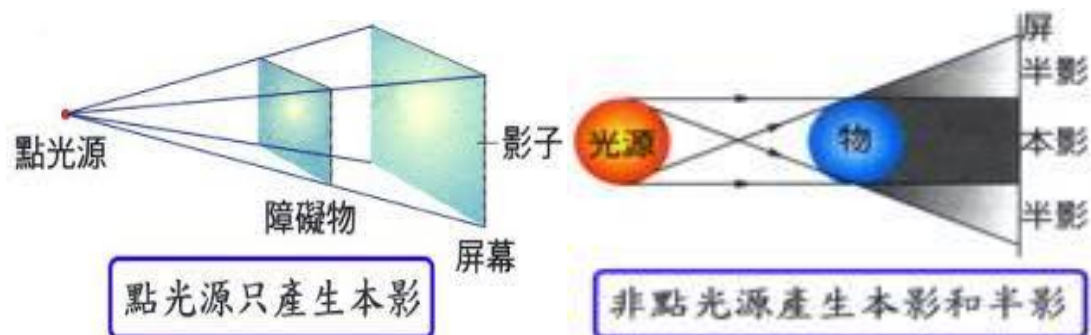
學生：　(B)、(C)、(D)

老師：　很好，那答案(A)所提及的放大鏡，放大影像的效果，是否也包含光的直進呢？

學生：　應該也有包含光的直進現象。

老師：　是的，但是放大鏡的成像，同時還涉及光在空氣與鏡片之間，因為介質變化而造成的折射現象。折射原理會在之後詳細說明。

老師：　放大鏡在不同介質間，雖然會"折射"，但是在同一介質內，如：空氣、玻璃鏡片，仍會維持直進的現象。所以，光的直進現象只能在同一的介質（材料）中，才會成立。

例題二

說明：了解光速遠大於音速，並利用兩者的差異，計算自身與閃電的距離。

Understand the speed of light is much faster than the speed of sound in air. Students can figure out the distance between them and the thunder using this time difference.

（英文）After you see a flash of lightning, you hear the thunder 5 seconds later. How far away does the lightning strike from your observation point? (If the speed of sound at that time is about 340 m/second)

（中文）如果看見閃電之後，經過 5 秒鐘才聽見雷聲，請估計發生閃電處距離觀測地點大約多少公尺？(假設當時聲速為 340 公尺/秒)

(A)1650　　　(B)1600　　　(C)850　　　**(D)1700**

（康軒自然課次卷 4-1）

解題 Solution：

由於光速大約為 $3 \times 10^8 (^m/_s)$，速度非常快，而聲速則僅為 340 公尺/秒，因此光速遠大於聲速，所以閃電發出的光從發出點到達我們眼睛所花的時間可以視為零。故觀測地點與發生閃電處的距離約為雷聲所傳遞的時間:340 公尺 / 秒 × 5 秒 = 1700 公尺。

Light travels very fast through air - around $3 \times 10^8 (m/s)$, but the speed of sound is approximately 340 meters per second only. As a result, the speed of light is much faster than the speed of sound. For this reason, it is acceptable to assume that we immediately see the lightning once it occurs. Therefore, the traveling distance of the thunder can be determined by the speed of sound and the time required to hear: 340 m/second x 5 seconds =1700 meters.

雷聲和閃電由於傳播速度的不同，所以不會在同一時間感覺到。雷聲會比閃電電慢

Because of this difference in time taken for light and sound to travel, you won't sense both of them at the same time. Thunder (sound) travels more slowly than lightning (light).

Teacher: Do you know what is the speed of light in air?

Student: It is around $3 \times 10^8 (m/s)$.

Teacher: That is correct. What if we compare that speed with the speed of thunder given in the question? What is the time difference between light and sound?

Student: Light travels much faster. To be precise, the speed of light is about 10^6 or 1 million times faster than the speed of sound.

Teacher: Exactly. That also tells us that light has already arrived at the destination when sound is just hitting the road. So we could neglect the traveling time that light takes?

Student: Yes, it is.

Teacher: Excellent. Now, how can we calculate the traveling distance that the thunder takes from the lightning strike to us?

Student: We can have the time at which sound travels multiplied by the time we hear the sound of thunder after seeing the flash of lightning.

Teacher: That is correct, so the distance we are looking for is 340 m/second × 5 seconds = 1700 meters.

老師： 同學們知道光的速度是多少嗎？

學生： 大約是$3 \times 10^8 (^m/_s)$。

老師： 正確，那如果把光的速度和題目中所給的聲音的速度相比呢？相差大約多少倍呢？

學生： 光的速度快很多，大概相差約10^6倍，也就是一百萬倍。

老師： 沒錯，那這樣就好像光已經到達目的地而聲音才剛出發而已，所以我們是否可以忽略光所走的時間？

學生： 可以。

老師： 很好，所以可以如何計算閃電距離呢？

學生： 在看到閃電之後，把雷聲的聲速乘以其所花的時間就好了。

老師： 正確，所以閃電發生的距離為340 公尺／秒×5 秒＝1700 公尺。

4-2 光的反射與面鏡成像
Reflection of light and Mirror imaging

■ 前言 Introduction

光在照射到物體上的時候會產生反射現象，也因此我們才得以看見該物體。光的反射符合反射定律，即光的反射角會等於入射角。若將光照在不同的面鏡，如凸面鏡、凹面鏡或平面鏡，則因面鏡的表面曲度的差異，可以把物體的像放大、縮小或不變。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
reflection	反射(n.)	normal	法線
plane mirror/ flat mirror	平面鏡	scattered reflection	散射
convex mirror	凸面鏡	virtual image	虛像
concave mirror	凹面鏡	reversibility	可逆性
incident light	入射光	converge	會聚(v.)
reflective light	反射光	diverge	發散(v.)
incidence angle	入射角	focal point	焦點
reflection angle	反射角	interface	介面

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____ be made from_____ to _____.

例句：Rare-view mirrors for buses and traffic mirrors for driveways **are made from** convex mirrors **to** improve visibility.

凸面鏡可製成用來增廣視野的公車後照鏡和道路反射鏡。

❷ **When _____ from a concave mirror, _____ mirror _____ to form a/an _____ image.**

例句：**When** an object is placed away **from a concave mirror,** the **mirror** converges light rays **to form a** real and inverted **image.**

物體離凹鏡面較遠時，光線將會聚形成倒立實像。

❸ _____ smooth surfaces _____ reflection of lights _____.

例句：Many objects in daily life have **smooth surfaces** that allow complete **reflection of lights** and clear images are formed by reflection.

生活中有許多表面光滑的物體，因具有良好的反射效果而能成像。

■ 問題講解 Explanation of Problems

✦ 學習目標 ✦

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解如何根據光的入射路徑推導其反射路徑。

　　Understand how to determine the reflected path of light based on its incident path.

二、了解平面鏡的成像原理。

　　Understand how images are formed by plane mirrors.

∞ **例題講解** ∞

例題一

說明：引入法線的概念，以觀測入射角與反射角，並掌握光的入射角等於反射角的關係。

Be able to adopt the normal line and identify its relationship with the angles of incidence and reflection. Also, can grasp the equal relation between the angle of incidence and that reflection in terms of plane mirrors.

（英文）Xiao-fu conducts an experiment using a laser pointer to prove the law of reflection. On the diagram, a laser beam bounces off the plane mirror and changes its direction. Which of the following paths is the direction that the reflected light travels.

（中文）<u>小甫</u>用雷射筆對著平面鏡作反射定律的實驗，如圖所示。雷射筆發出的光線經平面鏡反射後，其行進的路線為圖中的哪一條線？

(A)甲
(B)乙
(C)丙
(D)丁
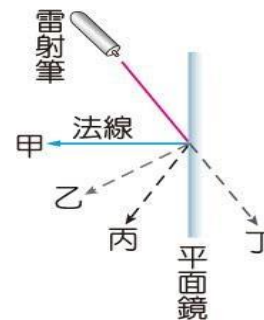
（99 年第二次基測 5）

解題 Solution：

首先，根據平面鏡的方位(上下)，決定法線的方向應該垂直於介面，法線應該向左(如圖所標示)。再根據光的反射定律，其入射角會等於反射角，因此，可由圖中所標示的法線選擇正確的反射路徑，答案為(C)。

The direction of the normal line should be determined first. The normal line is supposed to be perpendicular to the surface of a reflecting material, which should be pointing to the left.

According to the law of reflection, the angle of incidence is equal to the angle of reflection. Therefore, the direction that the reflected beam travels can be determined based on where the normal line is. Option C is the correct answer.
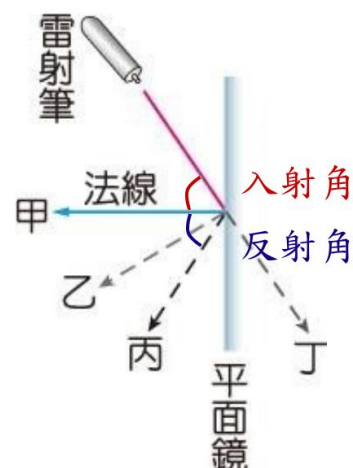
根據此圖我們可知正確反射路徑為丙路徑
According to the diagram, C is the correct path on which the light beam travels after reflecting

Teacher: Do you know the relationship between the angles of incidence and reflection?

Student: They are equal.

Teacher: That is correct. What line can help us to determine that the angle of incidence is equal to the angle of reflection?

Student: The normal line!

Teacher: Excellent. Which line in the diagram given is the normal line? What information can we base on to determine where the normal line is?

Student: We should find the surface at the point where light reflects. In this question, that surface is the plane mirror.

Teacher: That is right. Now, is the normal line vertical or perpendicular to the surface of the plane mirror?

Student: Perpendicular.

Teacher: Yes, the plane mirror in the question is set up vertically, so the normal should be a horizontal line, pointing to the left as the diagram shows.

Teacher: Now tell me which path is the most reasonable one on which the light beam travels after reflecting?

Student: Option C.

Teacher: That is correct. Let's draw the angles of incidence and reflection together on the diagram according to the law of reflection.

老師： 同學們知道光的入射角和反射角之間有什麼關係嗎？

學生： 會相等。

老師： 沒錯，那我們要以哪條線為基準判斷入射角和反射角相等呢？

學生： 法線！

老師： 說的好，那圖中的法線方向，是如何決定的?法線的方向是以什麼東西當作參考基準？

學生： 是以介面為參考基準，在本題就是平面鏡。

老師： 很好，那麼法線應該與介面平行或是垂直呢？

學生： 垂直。

老師： 沒錯，因為平面鏡為直立，所以法線應該是水平，也就是向左，如題目所標示。

老師： 那根據題目上的圖，哪一條反射路徑是最合理的呢？

學生： 丙路徑。

老師： 答對了。讓我們一起在圖中利用入射角等於反射角的原理，標示出此題入射角及反射角吧。

例題二

說明：了解平面鏡的成像原理。

Understand how images are formed by plane mirrors.

（英文）On a sheet of white paper, you write down two English letters in lower case, pb, and stand this paper upright at a distance of 5 cm in front of a plane mirror. Which of the following English letters will look the same in the plane mirror?

（中文）在白紙上由左而右寫上英文字「pb」，並正立放置在直立的平面鏡前 5 cm 處，則下列哪一個是在鏡中由左而右所成的像？

(A) dq

(B) dp

(C) pd

(D) qb

5 cm

平面鏡
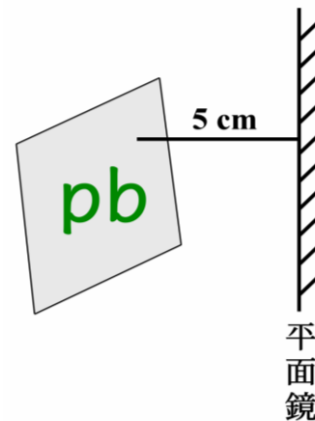
（示意圖）

（翰林十分鐘輕鬆考 CH4）

解題 Solution：

根據平面鏡的成像原理，其所成的像是與物體大小相同、左右相反的正立虛像，所以將「pb」左右倒過來就變成了「dq」。

5 cm　5 cm

pb　dq
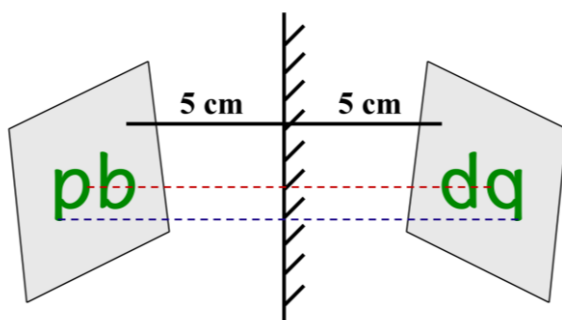
（示意圖）　平面鏡　每一點直線延伸到
另一邊的白紙上

Based on how images are formed by plane mirrors, the image formed in the plane mirror is virtual and as the same as the object in size. Even though this image is upright as the object, but the left and the right is flipped. As a result, the two English letters appear left-right reversed in the mirror – dq.

Teacher: Now, if there is an object in front of a plane mirror, what is the size of the image formed in a plane mirror in relation to that object.

Student: The image would be the same size as that object.

Teacher: That is correct. Is this image virtual or real? Is it erect or inverted vertically?

Student: This image is virtual and erect.

Teacher: Exactly, are the left side and the right side of this image the same as the original object?

Student: No, both sides are flipped.

Teacher: Excellent. Now, we know the image formed in a plane mirror is the same as the object in size. This image is also inverted laterally, erect, and virtual. If we write two English letters, pb, on a sheet of white paper, what we will see in a plane mirror?

Student: dq.

老師： 請問如果把一物體放在一平面鏡前，其所成的像的大小和物體之間有什麼關係呢？

學生： 像的大小和物體相同。
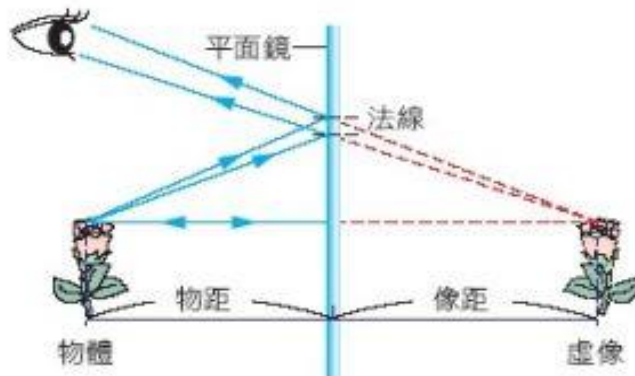
老師： 對，那像是實像還是虛像呢？正立還是倒立呢？

學生： 正立虛像。

老師： 沒錯，那麼左右有和原本的物體一樣嗎？

學生： 沒有，左右是相反的。

老師： 很好，那我們現在知道平面鏡所成的像是與物體大小相同、左右相反的正立虛像了，那麼如果在白紙上由左而右寫上英文字「pb」的話，我們在鏡中會看到什麼字呢？

學生： 「dq」。

4-3 光的折射
Refraction of Light

■ 前言 Introduction

說明光的折射定律，並結合反射定律，進而介紹常見的生活實例及應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
reflection	反射	refracted angle	折射角
refraction	折射	speed of light	光速
incident ray	入射線	apparent depth	視深
reflected ray	反射線	real depth	實深
refracted ray	折射線	object	實物
normal	法線	image	像
medium	介質	virtual image	虛像
interface	介面	real image	實像
incident angle	入射角	principle of reversibility	可逆原理
reflected angle	反射角		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **Please observe _____.**

例句：**Please observe** the changes in the direction of propagation of light when it travels from air to water.

請大家觀察光從空氣到水中的路徑變化。

❷ **Light obeys _____ when _____.**

例句：**Light obeys t**he law of reflection **when** it reflects any interface.

光在任何介面反射時，必遵守反射定律。

❸ **Light refracts _____ from one medium to another.**

例句：**Light refracts** when it travels through the interface **from one medium to another.**

光在不同介質的介面，會產生折射。

❹ **_____ states that _____.**

例句：The principle of reversibility **states that** light follows the same path if the direction of light is reversed.

如果光從反方向射過來，仍可沿著原來路徑回逆回來，此為光的可逆原理。

❺ **According to the law of _____, you would _____.**

例句：**According to the law of** refraction**, you would** see a virtual image in the water, which apparent depth is shallower than its real depth.

由於光的折射定律，你們會看到物體在水中的虛像深度，通常比實際深度來得淺。

■ 問題講解 Explanation of Problems

ᘒ 學習目標 ᘐ

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解光的折射原理。

　　Understand the principle of refraction of light.

二、能自行畫出光的反射及折射圖。

　　Be able to draw diagrams involving light reflection and refraction.

ᘐ 例題講解 ᘒ

例題一

說明：了解光從空氣進入到水中的折射現象。

　　　Understand how light refracts when it moves from air to water.

（英文）We also know that the light enter the water from air. In which path given is the one that the light refract in water?

（中文）光線從空氣中進入到水中，關於它們行進的路徑，下列示意圖何者正確？

(A)　　　　　　　(B)　　　　　　　(C)　　　　　　　(D)
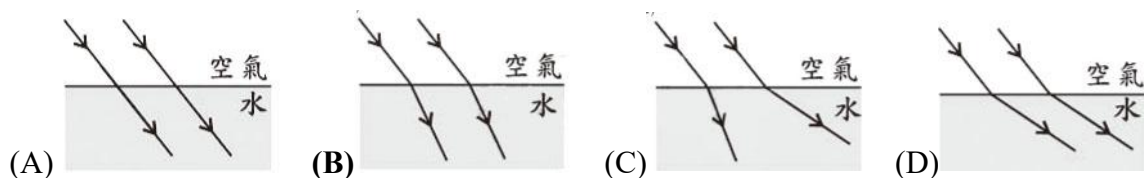
（99 年第一次基測 41）

解題 Solution：

根據折射定律，光速在水中較空氣來的慢，因此，在水中的折射線會更靠近法線。首先在圖中先補上法線，以方便我們推理，法線為垂直於空氣與水的介面(水平方向)，所以法線為鉛直方向，如右圖的虛線。

光線從空氣進入水中，可能走(A)(B)(C)中的哪一條路徑呢？

(A)是維持原本在空氣的路徑，(C)是遠離法線，而(B)則是靠近法線，所以答案是(B)。
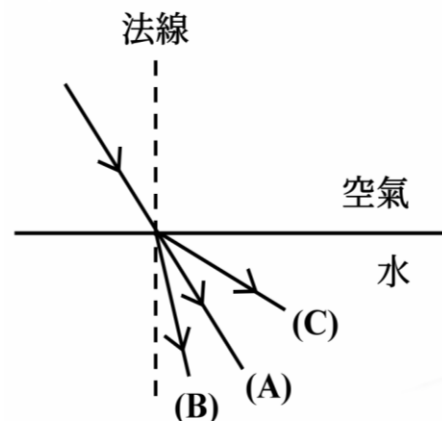
According to the law of refraction, light travels more slowly through water than it does through air. Therefore, the rays of light refract more toward the normal as the light rays enter the water. The normal line should be marked in the diagram first to extrapolate the correct light path. We know that the normal line is perpendicular to the surface of water (see the horizontal line), so the normal line should be running vertically as marked the dotted line in the diagram at the right. Path A remains the same direction as the light travel through air. Path C is the direction that the light bend away from the normal line and path B is the direction that the light bend toward the normal line. Path B is the answer to this question.

Teacher:	I am sure you still remember the experiment about light enter the water from air.
Student:	Gee, it does not ring the bell.
Teacher:	How can I say…How about this – is the speed of light faster in water or in air?
Student:	In water.
Teacher:	No! the speed of light is faster when light travels in a medium that is less dense. Which one has more density - water or air?
Student:	Water has more density than air.
Teacher:	That is correct, so through which medium light travels faster – water or air?
Student:	Light travels faster through air than it does through water.
Teacher:	Good job. That also means that the speed of light is slower when it travels through water. What does the law of refraction tell us when light travels in a less dense medium? Does light bend away or toward the normal line?
Student:	The more slowly light travels, the closer it gets to the normal line.
Teacher:	That is correct. Now, let's mark the normal line first. Please draw it on the diagram.
Teacher:	Excellent! The normal, or the dotted line, is perpendicular to the surface of a reflecting material.
Teacher:	After the normal line is marked, you will see which path is the most possible path when light enters the water.
Student:	Oh! I see it now. It is Path B.
Teacher:	That is correct. Only Path B is the direction that light bends toward the normal line. Path A remains the same direction as the light travel through air. Path C is the direction that the light bend away from the normal line.
Teacher:	Make sure you understand the law of refraction. If you have any questions, my door is always open.
Student:	Will do.

老師： 請大家回想一下光從空氣進入水中的實驗。

學生： 忘記了，哈哈哈。

老師： 真拿你沒辦法，那請問光速在水中較快還是在空氣中？

學生： 水中。

老師： 在空氣中啦！光在密度越小的介質中，光速通常比較大，水的密度比空氣大還是小?

學生： 水的密度比較大。

老師： 沒錯，所以光在哪裡的速度比較大？是水中還是空氣中？

學生： 在空氣中的光速比較大。

老師： 很好，所以光在水中的速度比較小，那麼，折射定律說，光速越小的介質，光線會遠離或靠近法線呢？

學生： 光速越小，越靠近法線。

老師： 答對了，我們先決定法線在哪裡？請同學先在圖上畫出來。

老師： 沒錯，法線會垂直於介面，也就是虛線的方向。

老師： 法線確定後，就可看出光從空氣進入水的路徑應該是圖中(A)(B)(C)的哪一個?

學生： 喔喔我懂了，答案是(B)。

老師： 很好，只有(B)是靠近法線的路徑，(A)維持原來在空氣的路徑，而(C)則遠離法線。

老師： 折射定律的觀念一定要搞清楚哦，不懂可以問老師。

學生： 好。

例題二

說明：學會從介面判斷法線，並利用折射定律推導出折射路徑。

Understand where the normal line is situated from reflecting surfaces and how to determine the reflected path of light based on the law of refraction.

（英文）The diagram shows different possible directions for a ray of light that enters a waterdrop, spherical in shape, and exits it into the air. If this light ray travels on a plane which happens to pass through the center of this waterdrop, which of the followings is the most reasonable path for light?

（中文）光線自空氣中進入圓球狀水滴，再從水滴內到空氣中，其可能的行進路線如圖所示。假設圖中所標示光線可能的行進路徑位於某一個平面上，且此平面通過圓球狀水滴的球心，則下列何者最可能為光的行進路徑？
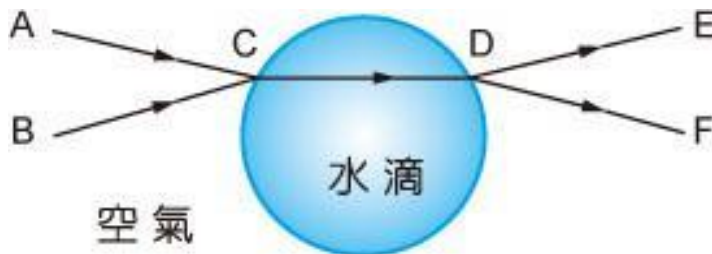
(A)A→C→D→E　　　　　　　　　(B)A→C→D→F

(C)B→C→D→E　　　　　　　　　**(D)B→C→D→F**

（95 年第一次基測 51）

解題 Solution：

1. 根據圓球介面方向，決定法線方向，法線會與圓球介面垂直，所以法線應通過圓心。

2. 根據折射定律，光速越慢的介質，光的路徑越靠近法線。因光在水中的光速比空氣小，所以光在水滴的路徑較靠近法線。

3. 因此，水滴左側，光由空氣進入水滴，(A)(B)路徑，只有路徑(B)在空氣比在水滴中遠離水滴。所以，(B)路徑才正確，(A)違反折射定律。

4. 同理，在水滴右側，(E)(F)路徑中，只有(F)在空氣比在水滴中遠離法線。(F)符合折射定律。

5. 所以，正確的折射路徑是 B→C→D→F，選項(D)。
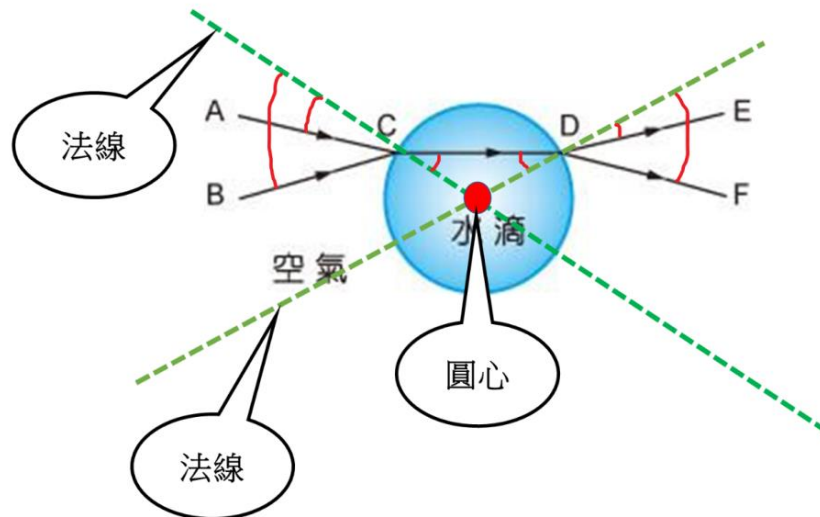
1. The normal line is determined based on where the surface of this sphere-shaped waterdrop is. Because the normal line is perpendicular to the surface of this sphere, the normal line should pass through the center of the sphere (see Point 1 and Point 2).

2. The law of refraction states that the more optically dense the medium, the slower the light travels. Because the speed of light is more slowly in water than it is in air, light shifts toward the normal line when travelling from the air to the waterdrop.

3. As Path A and Path B showed on the diagram, light enters the waterdrop from the left side. However, only Path B is further away from the normal when light strikes the surface of the waterdrop and slows down in the waterdrop. As a result, Path B is correct. Path A fails to obey the law of refraction (see Point 3 and Point 4).

4. For the same reason, on the right side of this waterdrop there are Path E and Path F. Only Path F obeys the law of refraction because this path is further away from the normal line when light leaves the waterdrop and speeds up in air.

5. As a result, the correct refracted line should be B→C→D→F. D is the answer to this question.

Teacher:	Do you still remember what we have learned in the math class. How a line behaves to the boundary of a sphere or a ball when this line passes through the center of a sphere or a ball?
Student:	This line is perpendicular to the boundary.
Teacher:	Yes, that is what this question is meaning to ask – explore how light travels in different media. What should we mark on the diagram first?

Student: The normal line. We can use this line to determine how light travels from one medium to another. When light travels more slowly, it bends toward the normal line. When light bends further away from the normal, it travels faster.

Teacher: Excellent. Because the speed of light is more slowly in water than it is in air, light bends toward the normal line.

Student: Here! The normal is the line that crosses the center of that sphere.

Teacher: We are close to the answer of this question.

Student: When light travels through air, Path B is further away from the normal than Path A is, and path F is further away from the normal than path E is. The correct path is B→C→D→F.

老師： 我們數學課是不是有教過，凡經過球心或圓心的線，他必定與球面或圓邊如何？

學生： 垂直。

老師： 所以說這題是在探討光穿越不同介質的路徑狀況，首先，我們必須在題目給的圖上畫什麼？

學生： 法線，用來判斷光的路徑，距離法線愈近，光行進速度越慢，反之。

老師： 非常好，光速在水中比空氣還慢，故會更靠近法線。

學生： 老師快看，法線就是穿過圓心的線。

老師： 那答案也快出來囉！

學生： 在空氣中的話，B 比 A 更偏離法線，F 也比 E 偏離法線，所以路徑是 B→C→D→F。

4-4 透鏡成像
Image of The Lens

■ 前言 Introduction

透過觀測物與凹、凸透鏡之間的距離變化，觀察其成像特性、大小與位置；並結合折射定律，探討成像原理並歸納其特性。最後介紹生活中透鏡的應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
convex lens	凸透鏡	object distance	物距
concave lens	凹透鏡	image distance	像距
object	物	focal length	焦距
imaging	成像	magnifying glasses	放大鏡
real image	實像	nearsighted eyes	近視
virtual image	虛像	farsighted eyes	遠視
focal point	焦點	screen	屏幕
principle axis	主軸	microscope	顯微鏡

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **Observe the images of _____.**

例句：**Observe the images of** either near or far objects formed by convex (concave) lenses.
請觀察物體在不同的物距下，透過凸（凹）面鏡所形成的像。

❷ **If ___ _____, ___ _____ will ___ _____.**

例句：**If** an object is placed between a convex lens and its focal point, the image of that object formed by the mirror **will** be virtual.
如果物在焦點到凸透鏡中間，會形成虛像。

❸ **_____, when _____.**

例句：A vertically inverted image of an object is formed **when** the focal length of a convex lens is less than the distance between the lens and that object.
當凸透鏡的物距超過焦距時，可得到倒立實像。

❹ **Could anyone give applications of _____? For example, _____.**

例句：**Could anyone give some applications of** lenses in our daily life? **For example,** nearsighted glasses are one of the applications of concave lenses.
有人想舉出些透鏡的生活應用嗎？比如凹透鏡應用於近視眼鏡中。

■ 問題講解 Explanation of Problems

� 學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、充分了解透鏡成像。
　　A full understanding of how lenses form images.
二、知道透鏡的應用。
　　Know applications of lenses.

∞ 例題講解 ∞

例題一

說明：熟悉凸面鏡的成像原理。

Understand how images are formed by convex lenses.

（英文）The diagram shows an experiment setup where Xiao-yun can observe how a convex lens forms an image. She uses a convex lens having a focal length of 10cm and moves the candle that has been placed in the A section to the C section. If Xiao-yun now wants to see the image of the candle flame, which of the following arrangements should she make?

(A) Move the paper screen to the D section and find the image.

(B) Move the paper screen to the F section and find the image.

(C) Move the paper screen to either the A or the B section and find the image.

(D) Remove the paper screen and look in the convex lens from either the D, E, or F section to find the image.

（中文）圖為小芸作凸透鏡成像觀察的實驗裝置圖，凸透鏡的焦距為 10 cm。她將原本擺放在甲區的蠟燭，移至丙區的位置，若她想觀察移動位置後蠟燭所成的像，則以下列哪一個方式進行最可能達成目的？
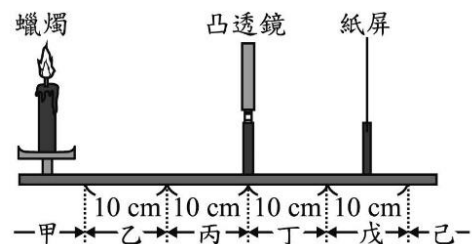
圖(三十三)

(A)將紙屏移動至丁區，找尋蠟燭所成的像。

(B)將紙屏移動至己區，找尋蠟燭所成的像。

(C)將紙屏移動至甲區或乙區，找尋蠟燭所成的像。

(D)移除紙屏，由丁區、戊區或己區以眼睛透過透鏡觀察蠟燭所成的像。

（107 年國中會考 43）

解題 Solution：

由於凸透鏡的焦距為 10cm，當蠟燭移到丙區時，其物距小於焦距，故會形成正立放大虛像。虛像無法顯示在紙屏上，只能透過眼睛觀察。

The focal length of the convex lens is 10cm. When the candle is moved to the C section, the lens forms a virtual image that is erect and enlarged as the distance between the candle and the convex lens at this time is shorter than the focal length of the lens. Virtual images cannot be shown on the screen but by looking at it through our eyes.

由繪圖法依題目要求：

凸透鏡

正立放大虛像 →

F

平行後
穿過焦點的光

甲　乙　丙　丁　戊　己

焦點(F)

蠟燭(物)

過鏡中點的光
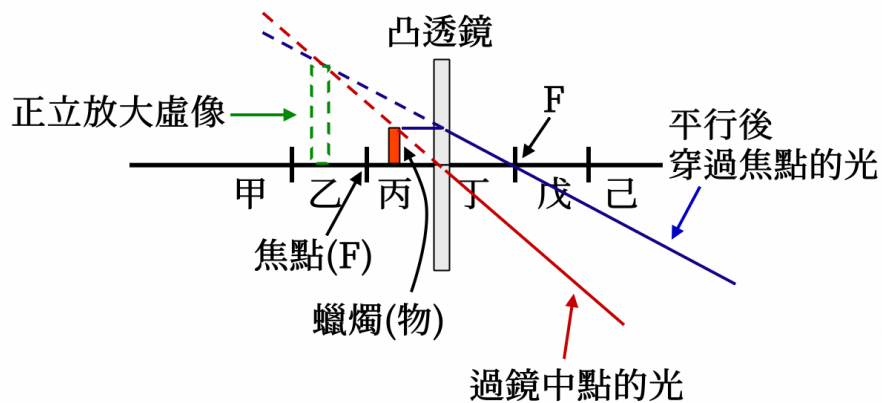
Teacher:	This question is about image formation by convex lenses. To answer this question, we need to depict a ray diagram that shows how convex lenses form images.
Student:	I know how to draw this diagram! Convex lenses will converge any parallel rays at the focal point. I can use this concept and take a shortcut by assuming that light that passes through the focal point all travel in straight lines without refraction for constructing this ray diagram of the candle flame. Whether the image of the candle flame is real can be determined by looking through the lens, since a virtual image cannot be formed on the screen. Even though light rays drawn on the diagram seem to come from one single light source and an image is formed from that single source, the image to be observed is actually projected by many light rays. As a result, we can see a complete image of that object as this image is formed by countless light rays.
Teacher:	Excellent! Ray diagrams also allow us to observe the location and orientation of images in relation to lenses.
Student:	I see.
Teacher:	Make sure that the distance between objects needed and their orientation on the diagram is correctly constructed. I suggest using a straight edge to guide you through.
Student:	Will do!

老師：　這是透鏡成像題，我們只要畫個簡單的成像圖就好。

學生：　我知道，利用平行光經過透鏡會匯聚在焦點現象，外加上我們可以約略看成通過透鏡終點光不偏折，由此畫出物發出的光之路線，經由透鏡後觀察是否光匯聚成實像，或在鏡後無法匯聚而成虛像。雖然我們所畫的光之路線是由一光點發出，後形成一光點像，但可以想像觀測物是由許多光點構成，因此除了我們就能看到此物之外，無數的光路徑就構成了完整的像。

老師：　非常清楚哦！透過作圖法還可觀察像的正立或倒立、位置。

學生： 好的。

老師： 記得圖形的距離、平行或垂直要畫正確，建議用尺畫圖，以免引響判斷。

學生： 好的。

例題二

說明：了解眼睛構造，凹凸透鏡在眼鏡上的應用

Understand how human eyes work and how to utilize concave and convex lenses as eyeglasses.

（英文）Zhi-xin designs an experiment that simulates a nearsighted eye before and after correction. The experiment procedure is shown on the diagram (there is one error in the design). Which of the followings is the most effective way to amend this error?

(A) Change the B concave lens to a convex lens having a shorter focal length than the A lens.

(B) Change the B concave lens to a convex lens having a longer focal length than the A lens.

(C) Change the C concave lens to a convex lens having a focal length to better fit the experimental environment.

(D) Re-locate the C concave lens at a position between the B lens and the screen.

（中文）智新設計實驗來模擬近視眼及其矯正後的情形，其步驟如圖所示：（此實驗設計有一個錯誤）關於修正此錯誤的方式，下列何者最適當？
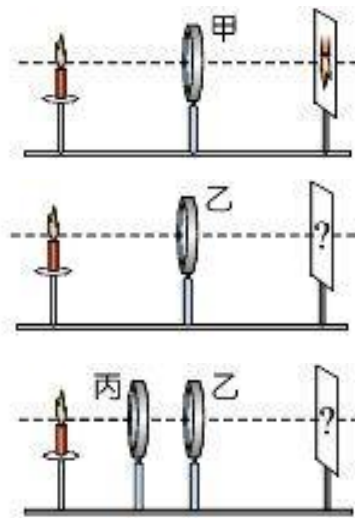
步驟1. 模擬正常視力眼睛的成像情形：以凸透鏡甲表示水晶體，屏幕表示視網膜，調整適當位置使其在屏幕上成像清晰。

步驟2. 模擬近視眼的成像情形：在凸透鏡甲的位置改放凹透鏡乙，表示近視眼睛的水晶體，凹透鏡乙與凸透鏡甲的焦距相同，屏幕上成像模糊。

步驟3. 模擬矯正近視眼：挑選適當的凹透鏡丙，表示矯正用的近視眼鏡，放置在凹透鏡乙與蠟燭之間的固定位置，使其在屏幕上成像清晰。

(A) 將實驗中的凹透鏡乙改為焦距較甲短的凸透鏡。

(B) 將實驗中的凹透鏡乙改為焦距較甲長的凸透鏡。

(C) 將實驗中的凹透鏡丙改為適當焦距的凸透鏡。

(D) 將步驟 3 中的凹透鏡丙改放置在凹透鏡乙與屏幕之間。

（105 年國中會考 43）

解題 Solution：

眼睛的水晶體必為凸透鏡，而近視眼是因水晶體變得太凸，使焦距變短，造成像距縮短，形成的像落在視網膜之前。所以近視眼鏡需用凹透鏡，先讓光線擴散，再透過水晶體的凸透鏡匯聚，讓成像恰好落在視網膜之上。

Our eye crystalline lenses are convex lenses. A nearsighted eye is caused by an eye crystalline lens that has become too thick, which reduces its ability to adjust the focal length for distant objects. A thick eye lens focuses images of distant objects before the retina. As a result, eyeglasses for a nearsighted eye require a concave lens to diverge light rays first which are then converged by a thick eye lens so that the image of distant objects can be hit right on the retina.

Teacher: Let's compare convex lenses with concave lenses first. Which of the lenses converges light rays?

Student: Convex lenses.

Teacher: That is right. How about concave lenses?

Student: Concave lenses diverge light rays.

Teacher: Excellent. What do you think of our eye crystalline lenses? Are our eye lenses convex lenses or concave lenses?

Student: Convex lenses.

Teacher: That is correct. What does it tell us that a nearsighted eye is caused by? Eye lens that has become too thick or still has room to grow thicker?

Student: Eye lens are too thick.

Teacher: That is right. Does an overly-thick eye lens reduce or increase the focal length?

Student: It reduces the focal length.

Teacher: That is correct! Because a near-sighted eye has a short focal length, where the image of a distant object is formed, in front of or behind the retina?

Student: The image of a distant object is formed in front of the retina.

Teacher: Exactly. To move the image onto the retina at the back of the eye, eyeglasses to amend nearsightedness should be able to diverge light rays from that object first. This also tell us which of the lenses required for nearsighted eyeglasses – a convex lens or a concave one?

Student: A concave lens.

Teacher: That is correct. Nearsighted eyeglasses are concave lenses. If you are short sighted, please take off your eyeglasses for a moment and inspect the glasses with your nearby classmates.

Teacher: Now, we should have the answer to this question. Step 2 is not true. A nearsighted eye should be a convex lens having a short focal length.

Teacher: No matter nearsighted or farsighted, our eye lenses are always convex lenses. These two types of eye defects alter the focal length of our eyeballs, which fail to focus the image of a distant object right onto the retina. As a result, the images of objects appear blurred.

老師： 讓我們先比較一下凸透鏡跟凹透鏡的差別。哪一種可以匯聚光線？

學生： 凸透鏡。

老師： 沒錯，那麼凹透鏡對光線的效果呢？

學生： 凹透鏡會擴散光線。

老師： 很好，那麼大家覺得眼睛的水晶體，是凸透鏡還是凹透鏡？

學生： 凸透鏡。

老師： 很好，那麼近視眼的同學，是因為水晶體太過凸，還是不夠凸呢？

學生：　太凸。

老師：　沒錯，水晶體太凸，所以焦距會增大或減小呢？

學生：　焦距減小。

老師：　答對了，因為焦距太小，所以近視眼看到的像，會落在視網膜的前面或後面呢？

學生：　會落在視網膜的前面。

老師：　是的，為了讓眼睛的成像從視網膜前面往後移，所以近視眼鏡的效果應該先將光線擴散，所以近視眼鏡是凸透鏡或凹透鏡呢？

學生：　凹透鏡。

老師：　很好，近視眼鏡是凹透鏡，有近視的同學可以摘下眼鏡讓旁邊的同學一起看看。

老師：　所以，這題的步驟 2 是錯誤的，近視眼的眼睛應該是焦距變短的凸透鏡。

老師：　所有人的眼睛，無論是否近視或遠視，水晶體都是凸透鏡。只是，因為近視或遠視而改變了眼球的焦距大小，使得成像無法精準落在視網膜上，造成模糊的像。

4-5 色散與顏色
Chromatic Dispersion and Color

■ 前言 Introduction

白色的陽光並不是單一色光，透過三稜鏡的色散現象，可以發現它是由七彩色光混合而成。色散是因不同顏色的光在介質中的折射角度，會有些微的差異而造成。而我們看到物體會有不同的顏色，則是因為不同色光進入我們的眼睛所造成，可能來自光的反射或是透射。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
dispersion	色散	rainbow	彩虹
triangular prism	三稜鏡	three primary colors	三原色
decompose	分解(v.)	absorb	吸收

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **If you let the sunlight pass through a _____, it will _____.**

例句：**If you let the sunlight pass through a** triangular prism, **it will** disperse the light into different colors.

如果使陽光通過三稜鏡，會散射出不同顏色的光線。

❷ **The three _____ of _____ are _____, _____, and _____.**

例句：**The three** primary colors **of** light **are** red, green, **and** blue, since there are only these three types of color sensors in the human eyes.

光的三原色為紅、綠、藍，因為人眼只有這三種顏色的感應細胞。

❸ **The _____ of _____ we _____ is related to the _____.**

例句：**The** color **of** objects **we** see **is related to the** properties of their surfaces that absorb or reflect light.

我們所見物體的顏色，與其表面吸收或反射光有關。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☜

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解物體表面吸收或反射的光線與其顏色有關。

Understand that light could absorbed or reflected by the surface of an object, and thus forms its color.

二、了解顏色的由來。

Learn about the origin of colors.

❀ 例題講解 ❀

例題一

說明：了解物體表面對不同顏色色光的吸收與反射特性，以及光的三原色。

Understand the characteristics of absorption and reflection of objects' surfaces, thus form different colors of lights. And know the three primary colors.

（英文）With white light, Da-shung sees that Jingle has a blue head, black eyeballs, white cheeks, and a red mouth (as shown in the picture). What does Da-shung most likely see under a blue light?

(A) A blue head, black eyeballs, white cheeks, and a red mouth

(B) A blue head, black eyeballs, green cheeks, and a purple mouth

(C) A blue head, black eyeballs, blue cheeks, and a black mouth

(D) Jungle's head, eyeballs, cheeks, and mouth are all blue

（中文）在白色光的照射下，大雄看見小叮噹的頭是藍色，眼珠是黑色，臉頰是白色，嘴巴是紅色，如右圖所示。若以藍色光照射，則當大雄看著小叮噹時，最可能看到下列哪一種情況？

(A)頭是藍色，眼珠是黑色，臉頰是白色，嘴巴是紅色。

(B)頭是藍色，眼珠是黑色，臉頰是綠色，嘴巴是紫色。

(C)頭是藍色，眼珠是黑色，臉頰是藍色，嘴巴是黑色。

(D)頭、眼珠、臉頰及嘴巴四部位皆是藍色。

（94 年第一次基測 4）

解題 Solution：

由於光的三原色是紅、藍、綠，如果用藍色光照射，原本是藍色的頭就維持不變，黑色的眼珠則會吸收所有色光所以維持黑色，白色的臉頰會反射所有色光所以變為藍色，紅色的嘴巴只會反射紅光所以變為黑色。

物體顏色	可反射的色光	被吸收的色光
紅色物體	紅光、白光中的紅光	綠光、藍光
綠色物體	綠光、白光中的綠光	紅光、藍光
藍色物體	藍光、白光中的藍光	紅光、綠光

The primary three colors are red, blue, and green. Under a blue light, the initially blue head remains blue. The black eyeballs absorb all colored lights to remain black. The white cheeks reflect the incident blue light to appear blue. And the red mouth can only reflects red light, so it turns black.

Teacher: Do you know a surface with what color absorbs all the colors of colored lights and with what reflects all the colors?

Student: A black surface absorbs all colors of lights, and a white surface reflects all colors of light.

Teacher: Good. Do "all colors" mean the three primary colors or rainbow colors?

Student: Rainbow colors.

Teacher: Both the three primary colors and rainbow colors are right. In fact, human's eyes can only sense the signal of the three primary colors, including red, blue, and green. Rainbow colors, such as yellow or purple, are made of these three colors.

Teacher: What does a blue surface mean, it reflects blue light or absorb blue light?

Student: A blue surface only reflects blue light.

Teacher: Good, what about a red surface?

Student: A red surface only reflects red light.

Teacher: What color will the object be if all the color lights are absorbed by the object surface?

Student: It will be black.

Teacher: That's right! Then you get the answer.

老師： 同學們知道哪種顏色的表面會吸收所有顏色的色光嗎？還有哪種顏色的表面會反射所有顏色的色光呢？

學生： 黑色表面會吸收所有顏色的色光，白色表面會反射所有顏色的色光。

老師： 很好，所謂「所有顏色」指的是三原色，或是七彩顏色呢？

學生： 七彩顏色。

老師： 師七彩或是三原色都對，其實，我們人的眼睛只能接收三原色的信號，包含紅、藍、綠，至於七彩的顏色，如:黃色、紫色，則都是這三個顏色組合而成的。

老師： 那麼藍色的物體表面，是代表物體會反射藍色光，還是吸收藍色光呢？

學生： 藍色表面只會反射藍色光。

老師： 很好，那紅色物體呢？

學生： 紅色只會反射紅色。

老師： 那麼如果所有色光都被吸收了物體表面吸收了，物體會呈什麼顏色呢？
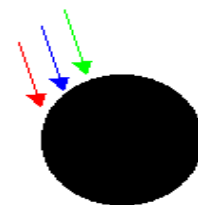
完全吸收光線沒有反射光線，看到黑色

學生：　黑色。

老師：　沒錯！那麼這題就解得出來了。

例題二

說明：了解物體的顏色，是來自物體反射光而得。

　　　　Students understand that the color of objects is the result of the reflective light.

（英文）Why do apples present red?

(A) Apples reflect red light　　　　(B) Apples refract red light

(C) Apples absorb red light　　　　(D) Apples radiate red light

（中文）蘋果會顯現紅色是因為下列何種原因？

(A)蘋果反射紅光　　　　(B)蘋果折射紅光

(C)蘋果吸收紅光　　　　(D)蘋果放射紅光

（翰林十分鐘輕鬆考 CH4）

解題 Solution：

根據光的三原色，白光的七彩色光，可由紅光、藍光、綠光所組成。蘋果看起來是紅色的原因，是因為蘋果表面把除了紅光以外的色光，包含藍色光及綠色光都吸收了，只留下紅光反射進入我們眼中，所以蘋果看起來會是紅色的。

According to the three primary colors of light, the rainbow colors of white light can be made of red light, blue light, and green light. The reason why apples look red is because that the surface of apples absorbs the colored light except for red light, including blue light and green light, and reflects only red light to our eyes. As a result, apples look red.

Teacher: How do we see things?

Student: Objects reflect lights to our eyes, so we can see them.

Teacher: That's right. So, with the same concept, why do apples look red?

Student: Apples reflect red light to our eyes.

Teacher: Good. Why do apples only reflect red light when they are under white light?

Student: Because the surface of apples absorbs some certain colored light.

Teacher: Exactly. Then what colored light do red apples absorb? And what are the three primary colors of light?

Student: They are red, blue, and green.

Teacher: Great. So, what colored of light do apples absorb if they reflect red light?

Student: They absorb blue and green lights.

Teacher: Very good. Exactly.

老師： 我們是怎麼能看見一個物體的呢？

學生： 物體反射出的光線進入我們的眼睛，所以我們得以看見物體。

老師： 沒錯，那以此類推，蘋果看起來是紅色的是什麼原因呢？

學生： 蘋果反射出了紅光進入了我們的眼睛。

老師： 很好，白色光照到蘋果，為何只會反射紅光呢？

學生： 因為蘋果表面會吸收某些顏色的光。

老師： 是的，哪麼紅色的蘋果，吸收了那些顏色的光呢？光的三原色是哪些？

學生： 紅、藍、綠。

老師： 很好，所以蘋果反射紅光，表示它吸收的那些色光呢？

學生： 藍光及綠光。

老師： 非常好，完全正確。

★主題五 溫度與熱★
Temperature and Heat

國立彰化師範大學物理系　宋德致、王瑞德

■ 前言 Introduction

本章介紹溫度和熱的觀念，以及透過熱能變化所造成的效果，帶出與生活相關的現象，也說明溫度計的製造及原理、熱量及比熱的關係。最後，介紹熱的傳播方式，並透過生活實例，幫助學生體會不同熱傳播方式的區別。

5-1 溫度與溫度計
Temperature and Thermometer

■ 前言 Introduction

在生活中，溫度的使用非常普遍，過去物理學家們，為了建立一個溫度的量化依據，而定義了溫標，以數值方式描述溫度的高低。之後用來測量溫度的各種儀器也相繼出現，在本節中我們利用物質熱脹冷縮的原理，製造簡易溫度計，幫助學生們更加了解溫度的測量與原理。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
temperature	溫度	Celsius	攝氏
heat	熱	Fahrenheit	華氏
thermometer	溫度計	fever	發燒
ear thermometer	耳溫槍	boiling point	沸點
forehead thermometer	額溫槍	expansion	膨脹(n.)
measure	測量(v.)	contraction	收縮(n.)
thermal expansion	熱脹冷縮	burn	燃燒(v.)
alcohol	酒精	absolute zero	絕對零度
temperature scale	溫標		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **The effect of _____ of alcohol is more obvious than that of _____.**

例句：**The effect of** temperature on the volume expansion and contraction **of alcohol is more obvious than that of** water.

溫度對酒精體積膨脹收縮的影響，比對水的影響明顯。

❷ **What is the _____ used to make _____?**

例句：**What is the** principle **used to make** mercury thermometers?

水銀溫度計是利用什麼原理製成的呢？

❸ **_____ is the physical quantity we use to describe _____.**

例句：Temperature **is the physical quantity we use to describe** how hot or cold an object is.

溫度是我們用來描述物體冷熱程度的物理量。

■ 問題講解 Explanation of Problems

ભ 學習目標 ᔈ

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、學習利用物質的狀態，判斷其可能的溫度範圍。

　　Learn to use the state of a substance to determine its possible temperature range.

二、了解物體固態液態可能共存，以及共存的溫度。

　　Understand the temperature at which objects coexist in solid and liquid states.

❧ 例題講解 ☙

例題一

說明：學會根據物質的狀態，判斷其可能的溫度區間。

Learn to determine the possible temperature range according to the state of a substance.

（英文）The following table shows the melting points and boiling points of four substances at one atm. Which of the following options has the highest temperature at one atmosphere?

	熔點(°C)	沸點(°C)
鐵	1535	2750
氮	-210	-196
水	0	100
鋁	660	2467

(圖表對照詞彙：熔點-melting point/ 沸點-boiling point/ 鐵-iron/ 氮-nitrogen/ 水-water/ 鋁-aluminum)

(A) liquid iron

(B) liquid nitrogen

(C) solid water

(D) solid aluminum

（中文）下表為四種物質在一大氣壓下的熔點及沸點。在一大氣壓下，下列何者的溫度最高？

	熔點(°C)	沸點(°C)
鐵	1535	2750
氮	-210	-196
水	0	100
鋁	660	2467

(A)液態的鐵

(B)液態的氮

(C)固態的水

(D)固態的鋁

（106 年國中會考 15）

解題 Solution：

(A)液態的鐵→1535°C < T < 2750°C；(B)液態的氮→–210°C < T < –196°C；(C)固態的水→T < 0°C；(D)固態的鋁→T < 660°C。故溫度最高為液態的鐵，選(A)。

(A) Liquid iron: 1535℃ < T < 2750℃; (B) liquid nitrogen: →–210℃ < T < –196℃; (C) solid water: T < 0℃; (D) solid aluminum: T < 660℃. Since the liquid iron has the highest temperature, the answer is (A).

Teacher: Let's check option (A) first. According to the table, what is the range of the temperature of liquid iron?

Student: The range is from 1535℃ to 2750℃.

Teacher: Good. Let's check option (B) now. What is the temperature of liquid nitrogen?

Student: The temperature ranges from –210℃ to –196℃.

Teacher: What about option (C). What is the temperature of solid water?

Student: It is less than 0℃.

Teacher: Finally, option (D). What is the temperature of solid aluminum?

Student: Less than 660℃.

Teacher: So, we can tell that liquid iron has the highest temperature by comparing the ranges of the four options. Therefore, the answer is (A).

老師： 首先我們先看選項(A)，根據圖表，液態的鐵的溫度應該在哪個區間呢？

學生： 1535℃到 2750℃。

老師： 很好，再來是選項(B)，液態的氮的溫度應該是多少呢？

學生： –210℃到–196℃。

老師： 再來是選項(C)，固態的水的溫度應該是多少呢？

學生： 小於 0℃。

老師： 最後是選項(D)，固態的鋁的溫度應該是多少呢？

學生： 小於 660℃。

老師： 因此，比較四個選項的溫度區間，我們可以發現溫度最高的，應該是液態的鐵，所以選(A)。

例題二

說明：知道水的熔點及凝固點，以及固液態共存的溫度。

Understand the melting point and freezing point of water as well as the temperature at which liquid and solid water coexist.

（英文）There are four experiments operated at 1 atmosphere. Each container of the four experiments has one thermometer and ice/water. The following pictures show the results of the experiments when they strike thermal balance. If one thermometer shows 4°C, which experiment does it represent?

(圖表對照詞彙：溫度計-thermometer/ 冰-ice/ 水-water/ 杯中水完全結冰-only completely frozen water in the cup/ 杯中有水及大量冰塊-water and a lot of ice in the cup/ 杯中有水及少量冰塊-water and a little ice in the cup/ 杯中只有水無冰-only water in the cup)
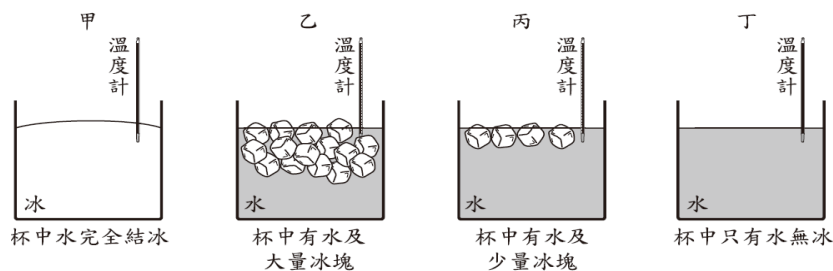
圖(二十八)

(A) A　　(B) B　　(C) C　　**(D) D**

（中文）在一大氣壓下，甲、乙、丙、丁四組實驗中的容器內，分別裝有一支溫度計及冰或水，當四組實驗分別達熱平衡時，如下圖所示。已知此時其中一支溫度計的溫度顯示為 4℃，則此溫度計應屬於哪一組實驗？
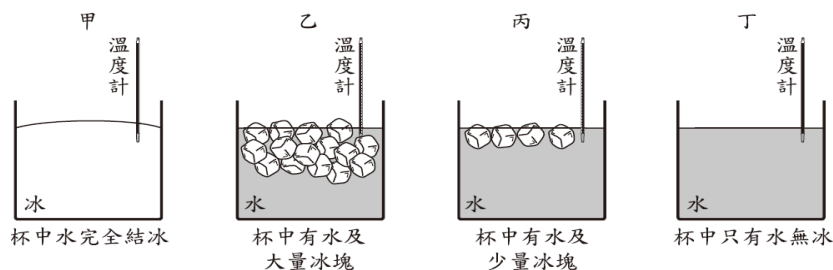
圖(二十八)

(A)甲　　(B)乙　　(C)丙　　**(D)丁**

（109 年國中會考 39）

解題 Solution：

一大氣壓下，冰的熔點和水的凝固點均為 0°C，所以溫度 T 甲≦0°C，T 乙=T 丙=0°C，T 丁 ≧0°C，溫度計溫度顯示 4°C，只有丁組實驗才有可能。故選(D)。

At 1 atmosphere, the melting point and freezing point of water are both 0°C. As a result, $T_A \leqq 0°C$, $T_B = T_C = 0°C$, $T_D \geqq 0°C$. And since only experiment D could have the result with a thermometer showing 4°C, the answer is (D).

Teacher:	Do you know at what temperature water freezes?
Student:	The freezing point of water is at 0°C, so water starts to freeze when it is 0°C.
Teacher:	That's right, so the final temperature of experiment (A) must be at or under 0°C. What is the temperature at which ice and water coexist, then?
Student:	Ice and water coexisting means that the solid state and liquid state of water exist at the same time. Based on the following graph, the temperature of the whole system equals the temperatures of the melting point and freezing point, which is 0°C.
Teacher:	Exactly. We can learn from the graph that ice maintains at 0°C when it's melting. So, although (B) and (C) have different amount of ice, the temperatures are both 0°C. And which environment coincides the condition the question talks about, which is a 4°C environment?
Student:	It can only be the cup with liquid water.

老師： 同學們知道水在幾度的時候會結成冰嗎？

學生： 水的凝固點是 0°C，所以是 0°C 開始水會結成冰。

老師： 沒錯，所以（甲）測得的溫度必然等於或小於 0°C，那如果冰塊和水共存呢？溫度會是多少？

學生： 冰塊和水共存，代表固態液態共存，根據下圖，其系統的溫度會等於熔點和凝固點的溫度，也就是 0°C。
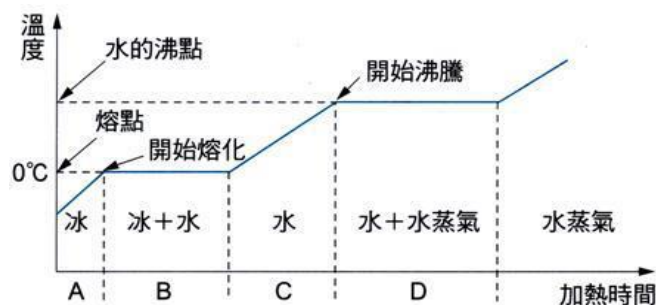
老師： 沒錯，我們可以透過上圖的關係曲線，得知，冰在熔化過程中，一直維持在 0°C。所以，（乙）和（丙）所含的冰雖然不一樣多，但溫度都是 0°C。而題目問的是 4°C 的環境，哪個環境是唯一可符合此條件的呢？

學生： 只可能是液體水的（丁）了。

5-2 熱量
Heat

■ 前言 Introduction

熱量為一種能量傳遞的形式，經由熱源發出，傳遞到接收熱能的物體，吸熱的物體可能升高溫度，或產生相態的改變。自然狀態下，熱量會由高溫傳遞到低溫。舉例來說，當熱水倒入冷水時，冷水會吸收到由熱水送出的熱能，最後兩者達到相同的溫度，稱為熱平衡，過程中冷、熱水的熱能轉移，也會相等。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
heat	熱量、加熱	mass	質量
heat source	熱源	temperature variation	溫度變化
beaker	燒杯	thermal equilibrium	熱平衡
ceramic fiber mesh	陶瓷纖維網		

■ **教學句型與實用句子 Sentence Frames and Useful Sentences**

❶ **For _____, the _____ is proportional to the_____.**

例句：**For** stable heat sources, **the** heat provided **is proportional to the** heating time.

對穩定熱源而言，提供的熱量與加熱時間成正比。

❷ **_____ is a _____, and the _____ the _____ acts on the object, the _____the _____ of the object will _____.**

例句：Fire **is a** heat source**, and the** longer **the** heat source **acts on the object, the** higher **the** temperature **of the object will** rise.

爐火為一種熱源，隨著熱源作用在物體的時間愈久，物體的溫度就會上升得愈高。

❸ **In addition to being obtained by contacting with _____, heat may also be transferred without _____.**

例句：**In addition to being obtained by contacting with** a high temperature object, **heat may also be transferred without** a medium.

熱量除了可藉由接觸高溫物體來得到，也可能不需透過介質來傳遞。

■ **問題講解 Explanation of Problems**

CB **學習目標** ∞

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解穩定熱源所提供的熱量，與加熱時間成正比。

　　Understand that for a stable heat source, the heat provided is proportional to the heating time.

二、了解熱量的計算方式以及其應用。

　　Learn how heat is calculated and its applications.

❀ 例題講解 ❀

例題一

說明：推導熱量與溫度變化的關係。

　　　　Derive the relationship between heat and temperature variation.

（英文）Hua adds solution A, B, and C into three same beakers, respectively. The three types of solution are 50 grams and 20℃ and heated on the same stable heat source. The results are shown in the following table. If 1000 cals are required to heat solution A from 20℃ to 40℃ as well as to heat solution B from 32℃ to 56℃, how many cals are required to heat solution C from 20℃ to 90℃ (assuming the heat that the heat source provides are all absorbed)?

溫度加熱(℃)　時間　溶液	0 分鐘	1 分鐘	2 分鐘	3 分鐘	4 分鐘	5 分鐘
甲	20	30	40	50	60	70
乙	20	32	44	56	68	80
丙	20	34	48	62	76	90

(圖表對照詞彙：溫度加熱-temperature/ 溶液-solution/ 時間-time/ 分鐘-minute(s)/ 甲-A/ 乙-B/ 丙-C)

(A)1500　(B)2000　**(C)2500**　(D)3000

（中文）小華在三個相同燒杯中，各加入 50 公克、溫度 20℃的甲、乙、丙三種不同的溶液，放在相同的穩定熱源上加熱，得到如下表的資料。若甲溶液由 20℃加熱至 40℃，需要 1000 卡的熱量；乙溶液由 32℃加熱至 56℃，也需要 1000 卡的熱量，則丙溶液由 20℃加熱至 90℃需要多少卡的熱量？（假設熱源供給的熱量均被溶液吸收）

(A)1500　(B)2000　**(C)2500**　(D)3000

（90-2 年國中基測 38）

解題 Solution：

甲溶液由 20℃加熱至 40℃，花了 2 分鐘，需要 1000 卡的熱量；乙溶液由 32℃加熱至 56℃，也花了 2 分鐘，也需要 1000 卡的熱量。因此，可得知加熱 2 分鐘供應 1000 卡熱量，則每 1 分鐘熱源供應 1000 卡/2=500 卡/分，故丙溶液由 20℃加熱至 90℃共計 5 分鐘，需要 500 卡/分·5 分鐘＝2500（卡）熱量。故選(C)。

It requires 2 minutes and 1000 cals to heat solution A from 20℃ to 40℃ and solution B from 32℃ to 56℃. From this, we can learn that 2-minute heating provides 1000 cals and that the heat source provides 1000 cals/2minutes=500 cals/minute. Therefore, heating solution C from 20℃ to 90℃ takes 5 minutes and requires 500 cals/minute × 5 minutes = 2500 (cals). The answer is (C).

Teacher:	Let's analyze according to the question statement. It takes 2 minutes to heat solution A from 20℃ to 40℃ and requires 1000 cals.
Teacher:	Also, heating solution B from 32℃ to 56℃ requires 2 minutes and 1000 cals. So, under the condition that the heat source provides heat stably, how many cals does this source provide per minute?
Student:	It provides 500 cals.
Teacher:	Sure, 1000 cals ÷ 2 minutes = 500 cals/minute. So, this heat source provides 500 cals per minute. According to the table, how does it take to heat solution B from 20℃ to 90℃?
Student:	Five minutes.
Teacher:	Then, according to the idea that the heat provided is proportional to heating time, how many cals does it require?
Student:	500 (cals/minute) × 5 (minutes) = 2500 cals.

老師：	我們根據題目的敘述來分析，甲溶液由 20℃加熱至 40℃，花了 2 分鐘，需要 1000 卡的熱量。
老師：	乙溶液由 32℃加熱至 56℃，也花了 2 分鐘，也吸收了需要 1000 卡。所以，在相同的穩定熱源下，這個熱源每分鐘提供多少卡的熱量呢？
學生：	500 卡。
老師：	沒錯，1000 卡÷2 分=500 卡/分，所以此熱源每分鐘提供 500 卡的熱量，那根據表格中的資訊，丙溶液由 20℃加熱至 90℃需要多久的時間呢？
學生：	5 分鐘！
老師：	那根據提供的熱量與加熱時間成正比的概念，需要多少卡的熱量？
學生：	500（卡/分）×5（分）＝2500 卡。

例題二

說明： 了解比熱的意義，並推導熱量與物體溫度變化的關係。

Understand the meaning and derive the relationship between heat and the temperature variance of objects.

（英文）In room temperature, Yun heats an iron cube weighs 56 grams to make it absorb 700 cals. It is known that it requires about 0.1 cal to heat 1-gram iron to rise by 1℃. Assuming that temperature changes in the unit ℃, which of the following option could you use to find the temperature that the iron rises?

(A)700÷0.1×56　　　　　　　　**(B)700÷0.1÷56**

(C)700×0.1×56　　　　　　　　(D)700×0.1÷56

（中文）在室溫下，小雲將質量 56 克的鐵塊加熱，使它吸收 700cal 的熱量。已知質量為 1 克的鐵，溫度上升 1℃，大約需要吸收 0.1cal 的熱量。假設溫度的變化以 ℃為單位，下列何項可算出鐵塊上升的溫度？

(A)700÷0.1×56　　　　　　　　**(B)700÷0.1÷56**

(C)700×0.1×56　　　　　　　　(D)700×0.1÷56

（92-2 年國中基測 49）

解題 Solution：

由熱量公式 $H = m \times S \times (T - T_0)$，其中 S 是比熱，m 是質量，帶入已知 0.1cal=1g×s×1℃，可以知道鐵的比熱 s=0.1(cal／g℃)。接著，將算出的比熱，帶入題目給的數值中：700cal $= 0.1$(cal／g℃)$\times 56g \times (T - T_0)$ (℃)，所以（$T - T_0$）$= 700÷0.1÷56$。故選(B)。

In the formula $H = m \times S \times (T - T_0)$, S represents specific heat and m represents mass. Apply the given numbers to the formula and we get 0.1cal=1g×s×1℃. So, we know that the specific heat of iron is S=0.1(cal/g℃). And then, apply the specific heat back to get 700cal $= 0.1$(cal/g℃) $\times 56g \times (T - T_0)$ (℃). The result will be ($T - T_0$) $= 700÷0.1÷56$. The answer is (B).

Teacher:　What is the formula to calculate heat?

Student:　It is $H = m \times S \times (T - T_0)$.

Teacher:　Right. What does the S mean in this formula?

Student:　It means specific heat.

Teacher:　Good. What is the unit of specific heat?

Student:　cal/g℃.

Teacher:　Yes. Specific heat means how much heat that a 1-gram object requires to rise 1℃.

Teacher: In this question, we need to find the temperature variance. What part is missing in this formula?

Student: The specific heat of iron.

Teacher: Exactly. How do you find the specific heat with the formula $H＝m×S×(T－T_0)$?

Student: Translocate the formula and apply the given numbers from the statement "it requires about 0.1 Cal to heat 1-gram iron to rise by 1℃."

Teacher: Excellent. So, we can know that the specific heat of iron (S) = 0.1(cal/g℃) from the equation 0.1 cal = 1g×S×1℃.

Teacher: Finally, how do you calculate the temperature that the iron rises?

Student: Apply the specific heat and the given numbers to the formula.

Teacher: Correct. According to 700cal＝56g×0.1(cal/g℃)·$(T－T_0)$(℃), we can conclude that $(T－T_0)＝700÷0.1÷56$.

老師：　同學們請問計算熱量的公式是什麼？

學生：　$H＝m×S×（T－T_0）$。

老師：　沒錯，其中的 S 指的是什麼？

學生：　比熱。

老師：　很好，比熱的單位是什麼？

學生：　cal／g℃。

老師：　是的，比熱的意思是每一克的物體，升高每一度 C，需要多少卡的熱量。

老師：　那此題中我們需要求溫度的變化，公式中還缺少了什麼參數呢？

學生：　鐵的比熱。

老師：　對，那依據 $H＝m×S×（T－T_0）$，我們怎麼求出鐵的比熱呢？

學生：　將公式移項並由「1 克的鐵，溫度上升 1℃，大約需要吸收 0.1cal 的熱量」這個敘述帶入數值去求。

老師：　說的好，所以 0.1cal=1g×S×1℃，可以知道鐵的比熱 S=0.1(cal／g℃)。

老師：　最後，我們要怎麼推算鐵塊上升的溫度呢？

學生：　將算出來的比熱，配合題目的敘述將相應的數值帶入公式中。

老師：　正確，根據 700cal＝56g×0.1(cal／g℃)×（T－T_0）(℃)，所以（T－T_0）＝700÷0.1÷56。

5-3 比熱
Specific Heat

■ 前言 Introduction

由實驗可知，當不同物體受熱時，雖然給予相同熱能，但不同物體產生的升溫程度不同。但是，相同材料，每單位質量、升高單位溫度，所需的熱量相同，因此定義「比熱」(S)，代表物質加熱升溫的難易程度。

比熱公式為 $S=H/m\Delta T$，單位為 $cal/g°C$。「比熱」只與物質種類有關，與物質的質量大小，或溫差大小，皆無關。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
specific heat	比熱	energy	能量
heat	熱、吸熱	heat transfer	熱的傳播
temperature	溫度	thermal expansion	熱膨脹/熱脹冷縮
heating	加熱	shrink, contraction	收縮
state of matter	物質狀態	mass	質量
matter	物質	elevated temperature, warm up	升溫
molecule	分子	temperature lowering, cool down	降溫
atom	原子		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **When we input _____, we will finally find _____.**

例句：**When we input** the same heat into two objects, **we will finally find** different temperature changes of the two objects.

當我們給予不同的物體相同的熱量，最後會得到不同的溫差。

❷ **Heat _____ from _____ to _____.**

例句：**Heat** transfers **from** objects with high temperature **to** those of low temperature.

熱量從高溫的物體傳到低溫。

❸ **_____ is used to _____ .When _____.**

例句：Specific heat **is used to** describe the difference of different materials. **When** different materials with the same mass absorbing the same heat, the temperature changes of them would be different.

比熱是描述不同材料的性質，相同質量的不同材料，吸收相同熱量，所造成的溫差會有所不同。

■ 問題講解 Explanation of Problems

 C3 學習目標 80

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、學會運用比熱推算熱量。

　　Learn how to calculate heat by means of specific heat.

二、了解比熱的定義。

　　Understand the definition of specific heat.

❧ 例題講解 ❧

例題一

說明：透過比熱公式，推導熱量與不同材料的溫差。

Calculate the heat and temperature variance of different materials by the formula of specific heat.

（英文）Please answer question (1) after reading the following information:

金屬塊	甲	乙	丙	丁
材質	鐵	鐵	鋁	鋁
初始溫度（℃）	80	60	80	60
質量（g）	100	200	100	200
比熱（cal/g・℃）	0.113	0.113	0.217	0.217

(圖表對照詞彙：金屬塊-metal/材質-material/初始溫度-initial temperature/質量-mass/比熱-specific heat/鐵-iron/鋁-aluminum)

The information of the four solid metal materials A, B, C, and D with different conditions is shown on the table. The temperatures of all the four materials drop to 20℃ after being in room temperature (20℃) for a while.

(1) Which of the four solid metal materials (A, B, C, and D) losses the most heat by the time the temperatures drop to 20℃ from their initial temperatures?
(A)A　　(B)B　　(C)C　　**(D)D**

（中文）請閱讀下列敘述後，回答(1)題：

金屬塊	甲	乙	丙	丁
材質	鐵	鐵	鋁	鋁
初始溫度（℃）	80	60	80	60
質量（g）	100	200	100	200
比熱（cal/g・℃）	0.113	0.113	0.217	0.217

今取四個不同條件的金屬塊甲、乙、丙、丁，四者條件的資訊如表所示。四個金屬塊放置在室溫 20℃的環境下一段時間後，四者的溫度均降為 20℃

(1)甲、乙、丙、丁四個金屬塊由初始溫度降至 20℃時，何者所散失的熱量最多？
(A)甲　　(B)乙　　(C)丙　　**(D)丁**

（103 年國中會考 51）

解題 Solution：

根據比熱定義，可推得吸熱 $H＝m×S×\Delta T$ 公式。根據上述給的條件帶入即可比較大小

$H_甲$：$100×0.113×（80－20）$、$H_乙$：$200×0.113×（60－20）$、$H_丙$：$100×0.217×（80－20）$、

$H_丁$：$200×0.217×（60－20）$。

另外，因本題是找出散熱最多的選項，所以也可利用比較法求解。因 $H_甲$ 與 $H_丙$ 的質量（m）、溫差（ΔT）相同，但甲的比熱（S）較丙小，所以甲放熱較丙小（$H_甲<H_丙$），故（A）$H_甲$ 刪掉。

$H_丙$ 再與 $H_丁$ 比較，因兩者比熱（S）相同，因此比較兩者之 $m×\Delta T$ 大小，$H_丁$ 勝出。

最後再拿丁與乙比較，兩者 $m, \Delta T$ 皆相同，因此根據比熱（S）得知，$S_丁>S_乙$，所以 $H_丁$ 最大，答案為（D）。

It is known that the formula of heat is that $H＝m×S×\Delta T$. We just need to apply the information to the formula to get the results and compare them: H_A: $100×0.113×(80－20)$; H_B: $200×0.113×(60－20)$; H_C: $100×0.217×(80－20)$; and H_D: $200×0.217×(60－20)$.

Also, the question asks for the option that losses the most heat, so comparative method works, too. Since the mass (m) and temperature changes (ΔT) of H_A and H_C are the same, yet H_A has smaller specific heat (S) than H_C, we can infer that A losses heat less than C ($H_A<H_C$) and is not the answer.

Then compare H_C with H_D. Because they both have the same specific heat (S), it is only needed to compare their $m×\Delta T$. And H_D is bigger.

Finally, compare H_D and H_B. It can be observed that they share the same m and ΔT, so we learn that $S_D>S_B$. Therefore, H_D is the most and is also the answer.

Teacher:	Specific heat is used to describe the heat that different materials need to absorb when one unit of mass rises one unit of temperature. It takes more heat for an object with more specific heat to rise one Celsius degree.
Student:	So, to rise one Celsius degree, the required heat is less when the specific heat of the object is less.
Teacher:	Then does a cup of water need more heat to rise one or ten Celsius degrees?
Student:	To rise ten Celsius degrees.
Teacher:	Good. So, please remember the three main variables that influence the required heat (H) are mass (m), specific heat (S), and temperature changes (ΔT). All you have to do is multiply them, and the formula is $H＝m×S×\Delta T$.
Student:	Now we get it. Thank you, teacher.

老師：	比熱是描述不同材料，在單位質量，升高單位溫度，所需要吸收的熱量。比熱越大的物體溫度上升一度，所需吸收的熱量也越大。
學生：	嘿對！所以比熱越小的物體溫度上升一度，所需吸收的熱量也越小。
老師：	那同一杯水，上升一度跟上升十度誰需要的熱量較大啊？
學生：	十度。
老師：	很好，所以要記得，影響物體所需吸熱（H）的變因有質量（m）、比熱（S）、及溫度變化（ΔT）這三大因數，然後把他們相乘就可以了。公式是 $H＝m×S×ΔT$。
學生：	原來如此，謝啦老師。

例題二

說明：從比熱公式推導同質量的水，吸熱與溫度變化的關係。

Infer the relationship between heat and temperature changes of water with the same mass from the heat formula.

（英文）When 100g water is added into a beaker and heated from 20℃ to 40℃, the heat that the water absorbs is H_A; when it is heated from 40℃ to 50℃, the heat it absorbs is H_B. If the loss of heat and evaporation are ignored and the specific heat remains during heating, which of the following statements is true?

(A)$H_甲＝H_乙$　(B)$H_甲＝2H_乙$　(C)$2H_甲＝H_乙$　(D)$4H_甲＝5H_乙$

（中文）在燒杯中加入 100g 的水，將水由 20℃ 加熱至 40℃ 時，水增加的熱量為 $H_甲$，再由 40℃ 加熱至 50℃，水增加的熱量為 $H_乙$，若加熱過程中，水的熱量散失及蒸發量忽略不計，且水的比熱固定不變，則下列何者正確？

(A)$H_甲＝H_乙$　(B)$H_甲＝2H_乙$　(C)$2H_甲＝H_乙$　(D)$4H_甲＝5H_乙$

（102 年國中基測 38）

解題 Solution：

由 $H＝m×S×ΔT$ 可知，加熱物的質量與比熱固定不變，熱量變化與溫度變化成正比，$H_甲$ 使水上升 20℃；$H_乙$ 使水上升 10℃。故選(B)。

From $H＝m×S×ΔT$, we can learn that when the mass and specific heat of a material are stable, the heat changes and temperature changes are proportional. H_A makes the water rise by 20℃, and H_B makes the water rise by 10℃. The answer is (B).

Teacher: In this question, the loss of heat and evaporation of water are not considered. And it is known that the water is heated from the beginning to the end. What formula will be used for this question, please?

Student: H＝m×S×ΔT.

Teacher: Correct. This question tells us that the mass and specific heat remain stable and the only thing changes is the temperature changes. So, what is the relationship between temperature changes and heat?

Student: They are proportional.

Teacher: That's right.

老師： 題目中不考慮水的熱量散失和蒸發量，我們可以知道題目是由同一杯水從頭加熱到尾，請問大家，這題會運用到什麼公式？

學生： H＝m×S×ΔT。

老師： 正確，所以由題目可知，質量和比熱固定，唯一改變的只有溫差。所以，溫差跟吸熱大小成什麼關係？

學生： 溫差跟吸熱大小成正比！

老師： 答對了。

5-4 熱的傳播方式
Heat Transfer

■ 前言 Introduction

熱量會從高溫傳到低溫，並可能有三種傳播的方式，包含：傳導、對流、與輻射。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
heat transfer	光	vacuum	真空
heat conduction, thermal conduction	影像	air	空氣
heat convection, thermal convection	顏色	liquid	液體
heat radiation, thermal radiation	傳播	gas	氣體
metal	針孔成像	solid	固體
wood	日晷	medium	介質

■ 教學句型與實用句子　Sentence Frames and Useful Sentences

❶ _____ **in three ways:** _____, _____, **and** _____.

例句：Heat can transfer **in three ways:** conduction**,** convection**, and** radiation.

　　　熱有三種傳播方式:傳導、對流與輻射。

❷ _____ **can only** _____ **in** _____ **by** _____.

例句：Heat **can only** transmit **in** vacuum **by** thermal radiation.

　　　真空中只能透過輻射傳播熱。

❸ In general, _____ **more easily than** _____.

例句：**In general,** metals conduct heat **more easily than** non-metals.

　　　一般而言，金屬比非金屬更容易導熱。

■ 問題講解 Explanation of Problems

☞ 學習目標 ☜

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解熱的傳播，並認識生活實例。

　　To know what heat transfer is and its examples in our daily life.

二、掌握熱輻射不需介質的獨特性。

　　Comprehend the unique nature of thermal radiation without media.

ॐ **例題講解** ☪

例題一

說明：認識熱的傳播，與生活應用。

Understand heat transfer and application in daily life.

（英文）Ming is replicating a scientific experiment called "tea bag lantern" from the Internet, and the steps are as shown in Picture 24. The experiment is undertaken in a windless environment. The ash of the burnt tea bag floats in the air like a mini lantern at the end of the experiment. Ming thinks that the cause of this phenomenon is probably related to heat convection. When the air above the tea bag becomes hotter and goes upwards, the cool air comes after, and heat convention is formed. Therefore, the light ash of the tea bag floats in the air because of the flow of the air.

剪去茶包上端　展開茶包，　讓茶包呈圓　在茶包上端　茶包燃燒後
　　　　　　　將裡面的茶　桶狀立於桌面　點火，茶包　的灰燼飄向空中
　　　　　　　葉倒出　　　　　　　　　由上而下燃燒
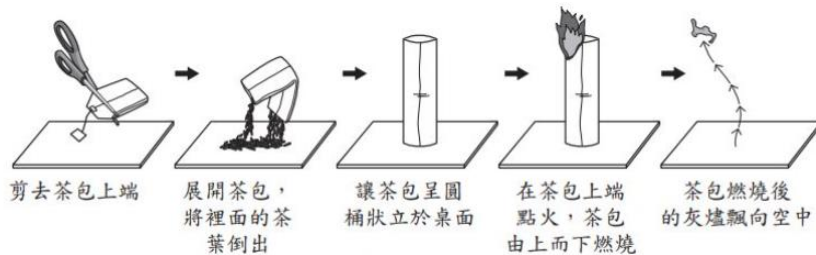
圖(二十四)

(剪去茶包上端-cut off the top off the tea bag/ 展開…倒出-open the tea bag and remove the tea/ 讓…桌面-make the tea bag a column standing on a table/ 在…燃燒-light fire on the top of the tea bag, it burns from the top/ 茶包…空中-the burnt tea bag floats into the air)

When the experiment is done, Ming wants to study this phenomenon, so she makes a datasheet (as shown in Table 11).

表(十一)

實驗日期：＿＿＿＿	茶包長度	灰燼最大飛行高度			
		第一次	第二次	第三次	平均
氣溫：＿＿＿	12.0 cm				
溼度：＿＿＿	10.0 cm				
大氣壓力：＿＿＿	8.0 cm				
	6.0 cm				
	4.0 cm				

(圖表對照詞彙：表十一-Table 11/ 實驗日期-date/ 氣溫-temperature/ 溼度-humidity/ 大氣壓力-atmosphere/ 茶包長度-length of the tea bag/ 灰燼最大飛行高度-the highest height of the flying ash/ 第一次-first time/ 第二次-second time/ 第三次-third time/ 平均-average)

According to this story, if Ming wants to give another example which shares the same principle after explaining the reason of the "tea bag lantern" experiment, which of the following option is the most appropriate?

(A) Sun transmits heat to Earth.

(B) Air conditioners are installed at higher places in a room.

(C) Gas tanks or oil storage tanks are painted in light color.

(D) Pan holders are often made with woods or plastics.

（中文）

請閱讀下列敘述後，回答50～51題

斯　小敏複製網路上「茶包天燈」這個科學實驗，其流程如圖(二十四)所示。她 在無風的環境進行實驗，當實驗進行到最後，茶包燃燒後的灰燼會飄向空中，如同一個小天燈。小敏認為此現象的成因應該與熱對流有關，茶包上方的空氣 受到加熱而上升時，周圍的冷空氣遞補而形成熱對流，茶包灰燼因重量很輕而 受到空氣的帶動飄向空中。

剪去茶包上端　展開茶包，將裡面的茶葉倒出　讓茶包呈圓桶狀立於桌面　在茶包上端點火，茶包由上而下燃燒　茶包燃燒後的灰燼飄向空中

圖(二十四)

上述步驟完成後，小
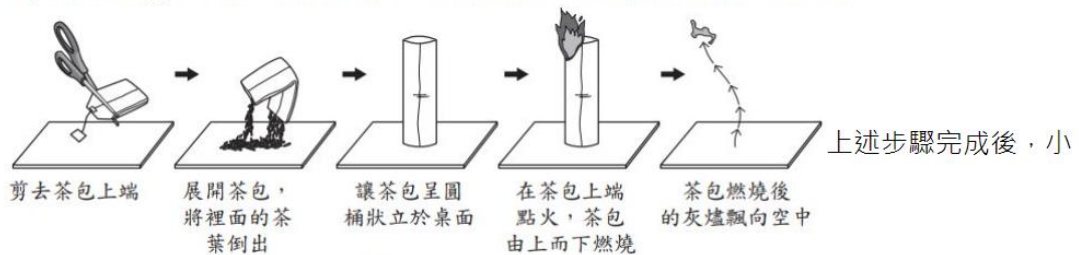
敏想對「茶包天燈」現象作進一步的研究，她設計了 一張實驗紀錄表，如表(十一)所示。

表(十一)

實驗日期：＿＿＿＿	茶包長度	灰燼最大飛行高度			
氣溫：＿＿＿＿		第一次	第二次	第三次	平均
濕度：＿＿＿＿	12.0 cm				
大氣壓力：＿＿＿＿	10.0 cm				
	8.0 cm				
	6.0 cm				
	4.0 cm				

根據本文，若小敏在向同學說明「茶包天燈」成因後，想要再舉一個科學原理相同的例子，則下列何者最合適？

(A)太陽將熱能傳播至地球。

(B)冷氣機裝在房間較高處。

(C)瓦斯儲氣槽或儲油槽漆成淺色。

(D)鍋子的把手通常使用木頭或塑膠材質。

（110年國中會考51）

解題 Solution：

茶包天燈原理為熱對流的應用，而(A)太陽是透過熱輻射傳到地球，因為過程中是真空，只有熱輻射可以在真空中傳遞熱量；(B)冷氣機所吹出的冷空氣，因熱對流使低溫的冷氣向下流動，所以冷氣需裝在房間較高處；(C)物體漆成淺色，可以因熱輻射效應較小，而減少吸入環境的熱量；(D)木頭或塑膠是熱傳導較低的材料，可以有效阻止鍋子把手的傳熱效果。故選(B)。

The tea bag lantern is an application of heat convection. The principle of option (A) is heat radiation. Sun transmits heat to Earth through heat radiation due to vacuum. Heat can only be transmitted through heat radiation in vacuum. In option (B), the cool air comes from an air conditioner moves downwards because of heat convection. That's why air conditioners are installed at higher places in a room. Option (C) suggests that objects are painted in light color. Light colors cause objects absorb less heat dur to minor heat radiation. The woods and plastics mentioned in option (D) are the materials that conduct heat less effectively and can block heat conduction to a pan holder. As a result, the answer is (B).

Teacher:	The key point of this section is heat transfer and examples of it.
Teacher:	Quick review, what are the three kinds of heat transfer?
Student:	Conduction, convection, and radiation.
Teacher:	Good. What kind of transfer does not require any medium?
Student:	It's radiation.
Teacher:	Right. Which process of these options can exist in vacuum without medium?
Student:	(A) Sun transmits heat to Earth.
Teacher:	So, we know that Sun transfer heat through heat radiation. Does color affect the rate of transfer of radiation?
Student:	Yes. The darker the color is, the faster the radiation transfers.
Teacher:	Option (C) considers the relationship between the speed of radiation and color. Painting the oil tank into a light color prevents it from absorbing too much heat and rising temperature.
Teacher:	How to distinguish convection and conduction? Both of them require a medium, but what is the difference between them?
Student:	The flow of the medium is a must for convection to transfer heat. But for conduction, the medium only transfer heat, the medium does not move.
Teacher:	So, the medium of convection must be liquid or gas. Which option might be about convection?

Student: (B) Air conditioners are installed at higher places in a room. The fact that cool air flows downwards due to low temperature is to make heat convection. By doing so, the indoor temperature could maintain uniform, preventing cool air from staying beneath and warm air staying above.

Teacher: Finally, (D). Using woods or plastics as pan holders can prevent us from contact burns. Which kind of heat transfer is this related to?

Student: Conduction. Comparing with metals, woods and plastics conduct heat less effectively. It's about heat conduction.

Teacher: Good. Solid materials can only transfer heat in the form of conduction and cannot cause heat convection.

老師： 本小節的重點是了解熱的傳播，和它的生活例子與應用。

老師： 我們先複習一下，熱的傳播有哪三種方式？

學生： 傳導、對流、輻射。

老師： 很好，那麼哪一種形式的熱傳播，不需要介質？

學生： 輻射。

老師： 沒錯，那麼題目中的選項，哪一項的傳遞過程，沒有介質，也就是過程中是真空？

學生： (A)太陽的熱傳到地球。

老師： 所以，太陽光是以輻射方式傳遞，那麼輻射的傳熱速率，跟顏色是否有關呢？

學生： 有關，顏色越深，輻射越快。

老師： 所以，選項(C)是考量輻射快慢與顏色的關係，油桶漆成淺色，可以避免吸收太多外界的輻射熱，而升溫過高，造成危險。

老師： 接著，對流與傳導，要如何區分呢?兩者都需要介質，但彼此有何差異呢？

學生： 對流是透過介質流動，來傳遞熱流的，但傳導則只有熱量流動，介質不動。

老師： 所以，對流的介質必須是液體或氣體，稱為流體。哪一選項可能與對流有關呢？

學生： (B)冷氣機裝在房間較高處，冷空氣因為低溫而下降，為了使產生熱對流傳遞，使室內溫度均衡，防止冷空氣一直在下層，熱空氣一直在上層，故為之。

老師： 最後，剩下(D)鍋子把手選擇木頭或塑膠，可以避免燙傷，是涉及哪一種熱的傳播形式呢？

學生： 傳導，鍋子的把手使用木頭或塑膠，比起金屬，木頭或塑膠材質導熱較差，才不會燙手，為熱的傳導。

老師： 非常好。固體的材質只能透過熱傳導的形式傳播熱量，無法產生熱對流。

例題二

說明：了解熱輻射不需介質傳輸的特性。

Understand the nature that heat radiation does not require any medium to transfer.

（英文）Please answer the question after reading the following article.

Solar power is a kind of renewable resource. One of the ways that solar power generation is using the parabolic collector shown in Diagram 1 to collect the energy. The reflector makes sunlight to converge on the receiver. By heating the substance that passes through inside the receiver, electric power can be generated.

Diagram 2 shows the inner part of the receiver. It is a stainless-steel tube on the inside and the outside is a glass shield. Between the stainless-steel and the glass shield is in a vacuum. The vacuum prevents the tube from oxidizing and losing heat effectively.
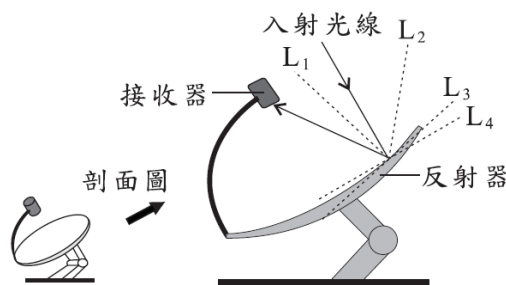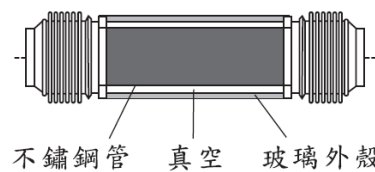
圖(二十五)　　　　　　　　　圖(二十六)

(圖表對照詞彙：剖面圖-sectional view/ 接收器-receiver/ 反射器-reflector/ 入射光線-incident light/ 不鏽鋼管-stainless-steel tube/ 真空-vacuum/ 玻璃外殼-glass shield)

Which of the following option describes the underlined part of this article?

(A) Conduction and convection

(B) Convection and radiation

(C) Conduction and radiation

(D) Conduction, convection, and radiation

（中文）請閱讀下列敘述後，回答問題：

太陽能是一種再生能源，其中一種太陽能發電方式是使用如圖(二十五)所示的拋物面碟式收集器來收集太陽能。圖中的反射器可使太陽光會聚於接收器，加熱流經接收器內部的物質，進而達到發電的目的。圖(二十六)為接收器內部構造的示意圖，其內部為一個不鏽鋼管，外罩一個玻璃外殼，玻璃外殼與不鏽鋼管之間為真空部分，真空部分可有效的減少熱量的損失與管壁的氧化。
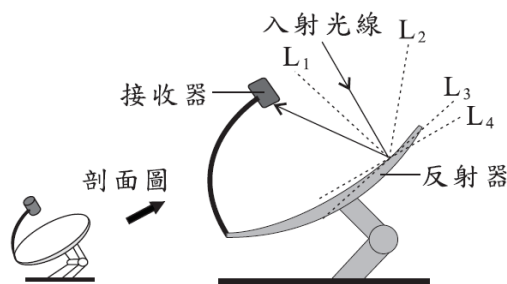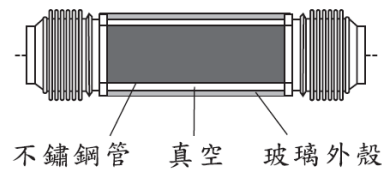
圖(二十五)　　　　　　　圖(二十六)

關於文中畫有雙底線處所提到的現象，下列敘述何者正確？
(A)傳導、對流
(B)對流、輻射
(C)傳導、輻射
(D)傳導、對流、輻射

（108 年國中會考 48）

解題 Solution：

熱輻射不需要介質來傳遞熱，故抽真空可以防止熱傳導和熱對流的發生，但不會影響熱輻射。故選(A)。

Thermal radiation does not require any medium to transfer heat, so vacuuming prevents heat conduction and convection from happening and does not affect heat radiation. the answer is (A)

Teacher: In a vacuum, there is no medium to transfer heat. So, in what way can heat be transferred? Conduction, convection, or radiation?

Student: Radiation it is.

Teacher: Yes. So, to decrease the loss of heat, vacuuming is the way adopted. Vacuum prevents heat convection and conduction from happening but not the transfer of heat radiation.

老師： 在真空中，缺少的傳播熱量的介質，熱量只能透過什麼方式傳播？1.傳導、2.對流、3.輻射

學生： 輻射。

老師： 是的，因此透過刪減接觸，以減少熱量傳遞的損失，我們抽真空，可以抵擋熱對流及熱傳導，但不能抵擋熱輻射的傳遞。

例題三

說明：了解比熱為材料的一種特性及其意義，比熱不會受到其它變因，如：形狀、顏色、質量、熱量、溫度…等而改變，同時整合比熱與熱輻射兩項概念，並區別現象上之差異。

Understand that specific heat is one nature of materials and its meaning. Specific heat cannot be changed by other variables, such as shape, color, mass, heat, temperature etc. Also, organize the concepts of specific heat and heat radiation and distinguish the differences of the phenomenon.

（英文）A and B are two metal balls have the same temperature, material, and volume. A is painted into white and B into black. Both of the two are hung up in the air with thin strings and left under sunlight for 20 minutes. Later, B is 3°C higher than A. which of the following statement is the main cause of this result?

(A) White color can increases the specific heat of the metal ball.

(B) Black color can increases the specific heat of the metal ball.

(C) White ball is more likely to absorb radiant heat.

(D) Black ball is more likely to absorb radiant heat.

（中文）取溫度、材質及體積相同的甲、乙兩金屬球，將甲球漆成白色，乙球漆成黑色，再將兩球以細線並排懸吊於空中，放置在陽光下曝曬，20 分鐘後測量兩者溫度，結果乙球比甲球高 3°C，下列何者是此現象發生的主要原因？

(A)白色可增加金屬球的比熱。

(B)黑色可增加金屬球的比熱。

(C)白色金屬球較易吸收輻射熱。

(D)黑色金屬球較易吸收輻射熱。

（105 年國中會考 4）

解題 Solution：

比熱為材料的一種特性，不會受到外在因素而改變。因甲乙兩球的材質相同，只有表面顏色不同，故比熱相同，(A)、(B)刪去，最後需要用到熱輻射(5-4)的觀念，黑色較易吸收輻射熱，故選(D)。

Specific heat is a characteristics of materials and cannot be altered by external factors. A and B have the same material but different surface colors, so they have the same specific heat. Take (A) and (B) away. And from the idea of heat radiation (5-4), we know that black color is more likely to absorb radiant heat. The answer, therefore, is (D).

Student: Why are (A) and (B) wrong?

Teacher: Specific heat is a characteristics of materials. The same material has the same specific heat and it is not influenced by external factors like shape, color, mass, heat, temperature, and so on.

Student: Still don't understand well.

Teacher: For example, the specific heat of water must be 1(cal/g°C). If it is not, it can't be water.

Teacher: A and B are made of the same material, so they must have the same specific heat. No matter the metal balls are painted into black, white, or any other colors, the specific heat of this metal material remains still.

Student: I see.

Teacher: As for black and white, they have different rate of absorbing radiant heat. Black absorbs the heat of sunlight but doesn't reflect it, so black absorbs radiant heat the most possibly. In contrast, white reflects every colored light, so white absorbs radiant heat the least possibly. As a result, the temperature of the black ball gets higher faster than the white ball under the sunlight.

Teacher: The principles of specific heat and heat radiant are related to the temperature changes of an object, but the reasons and results are quite different.

學生： (A)、(B)為什麼錯？

老師： 比熱為材料的一種特性，相同材料的比熱相同，不會受到外在因素而改變，如:形狀、顏色、質量、熱量、溫度…等。

學生： 還是不太了解。

老師： 如水的比熱一定是 1(cal/g°C)，若不是 1(cal/g°C)，那一定不是水。

老師： 所以甲乙兩球，因為是相同材質，所以比熱必然相同，不論是把金屬球塗成黑色、白色或其他顏色，都不能改變此一金屬材質的比熱。

學生： 了解。

老師： 至於黑色與白色的區別，則在於吸收輻射熱的速度不同。黑色會將太陽光之能量吸收而不反射，故黑色最易吸收輻射熱；而白色則會反射各色光，所以白色球，最不易吸收輻射熱。因此，在太陽照射下，白色球的升溫比黑色球來得慢。

老師： 所以，比熱與熱輻射的原理，都與物體之溫度變化有關，但兩項原理的原因與效果，都不相同。

★單元六 力與壓力★
Force and Pressure

國立彰化師範大學物理系　宋德致、王瑞德

■ 前言 Introduction

本章介紹力的種類及測量，以及壓力。配合生活中常見的現象，來說明力的成因及效果。也教導學生，如何運用向量來計算合力的大小與方向，進而引入「力平衡」之概念及應用。

6-1 光的傳播
Force and Balance

■ 前言 Introduction

根據力的作用來源，可分為接觸力和超距力兩種，本節定義力的意義，以及測量大小的方式。並透過向量計算合力的大小及方向。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
contact force	接觸力	weight	砝碼
force at a distance	超距力	force balance	力平衡
gravity	重力	resultant force	合力
kilogram weight	公斤重	magnitude	大小(力)
gram weight	公克重	direction	方向
deformation	形變	point of application	作用點
spring	彈簧		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **We can divide the** _____ **into** _____**and** _____ **according to** _____**.**

例句：**We can divide the** force **into** contact force **and** force at a distance **according to** whether the source of applying force is in contact with the object or not.

我們可以根據施力來源是否與物體接觸，將力分為接觸力與超距力。

❷ **If** _____**, it means** _____**.**

例句：**If** an object changes its shape or state of motion**, it means** that there is a force.

物體若發生形狀或運動狀態改變的現象，代表有受力。

❸ **Within** _____**, the** _____**, the** _____ **will** _____**.**

例句：**Within** a certain limit**, the** more weights are hung**, the** longer the spring **will** stretch.

在一定限度內，掛上的砝碼數量愈多，彈簧拉伸的長度會愈長。

❹ **When an object with mass** _____**, it will** _____**.**

例句：**When an object with mass** is on the Earth**, it will** be exerted by a force directed towards the center of the Earth.

具有質量的物體在地球上，會受到指向地心的作用力。

■ 問題講解 Explanation of Problems

છ 學習目標 ৯

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解力的測量方式。

　　Understand how force is measured.

二、學習如何使用彈簧秤測量力的大小。

　　Learn how to use a spring balance to measure the magnitudes of forces.

৯ 例題講解 છ

例題一

說明：理解力之測量。

　　Understand how force is measured.

（英文）A, B, and C are three same springs hanging on a horizontal stick. There is nothing on A; a W_1-gram weight hanging on B; and two weights which are W_1 grams and W_2 grams on C. The diagram shows the lengths of the three springs when it strikes static balance. Let's assume that the mass of the springs is small enough to be ignored, and B and C can recover without weights. According to the information, what is $W_1{:}W_2$?

(A)1：2　**(B)2：1**　(C)2：3　(D)3：2

（中文）甲、乙、丙三條完全相同的彈簧懸掛在一根
　　　　水平橫桿上，甲彈簧無懸掛物品，乙彈簧懸
　　　　掛重量為 W_1 公克重的砝碼，丙彈簧懸掛重
　　　　量為 W_1 公克重及 W_2 公克重的砝碼，靜止平
　　　　衡時，三者的長度關係如右圖所示。若三條
　　　　彈簧質量均很小忽略不計，且乙、丙兩彈簧
　　　　在取下砝碼後，均可恢復原長，由上述資訊判斷 $W_1{:}W_2$ 應為下列何者？

　　　　(A)1：2　**(B)2：1**　(C)2：3　(D)3：2
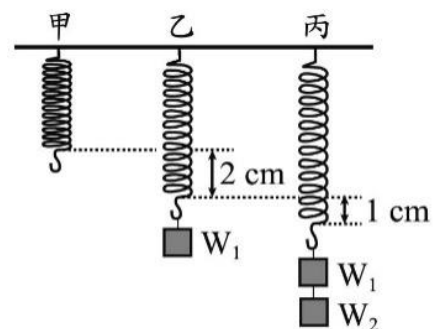
（108 年國中會考 8）

解題 Solution：

根據虎克定律，彈簧所受外力與伸長量成正比，所以 $W_1 : W_2 = 2 : 1$。故選(B)。

According to Hooke's law, the force that a spring receives and the distance it extends are proportional, so $W_1:W_2 = 2:1$. The answer is (B).

Teacher: How long does a spring extend when there is a W_1-gram weight hanging on it?

Student: Two centimeters.

Teacher: That's right. What if a W_2-gram weight is added?

Student: It extends 1 more centimeter.

Teacher: Exactly. The key for solving this question is Hooke's law. According to Hooke's law, how are the force that a spring receives and its extension related?

Student: The force and the distance of extension are proportional.

Teacher: Right. And now we can get the answer. W_1-gram weight makes a spring extend by 2cm, and W_2-gram weight makes a spring extend by 1cm.

Teacher: So, what is $W_1:W_2$?

Student: It's 2:1.

Teacher: Great. So, (B) is the correct answer.

老師： 請問當在彈簧下方掛上重量為 W_1 的砝碼後，彈簧伸長了多少呢？

學生： 2 cm。

老師： 沒錯！那麼再掛上重量為 W_2 的砝碼後呢？

學生： 再拉長 1cm。

老師： 對！那麼這題的關鍵是虎克定律喔，請問根據虎克定律彈簧所受外力和伸長量之間有什麼關係呢？

學生： 彈簧所受外力與伸長量成正比。

老師： 沒錯，所以此題就可以解出來了，由於掛上重量為 W_1 的砝碼伸長量為 2cm 而掛上重量為 W_2 的砝碼伸長量為 1cm。

老師： 所以 $W_1 : W_2$ 等於什麼呢？

學生： 2 : 1。

老師： 很好，因此選項(B)為正確答案。

例題二

說明：透過「力平衡」，了解彈簧秤的使用。

Understand how to use a spring balance through "force equilibrium."

（英文）As shown in the diagram, an 100gw horizontal force is applied at each of the ends of spring balance A in opposite directions, and spring balance A remains static balance. The reading is X_A. Spring balance B is hanging under a holder. When an 100gw force is applied downwards vertically, spring balance B remains static balance. The reading is X_B. If the spring balances are light and negligible, and they do not exceed the elastic limits during the experiment, how many are X_A and X_B?
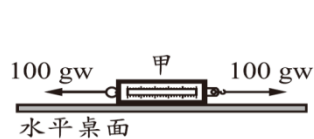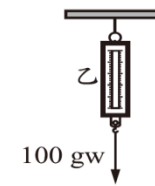
（圖表對照詞彙：甲-A/ 乙-B/ 水平桌面-horizontal tabletop/ 圖（二十六）-Diagram 26/ 圖（二十七）-Diagram 27）

(A)$X_A = 0$, $X_B = 100$ gw　　　　　　(B)$X_A = 100$ gw, $X_B = 0$

(C)$X_A = 100$ gw, $X_B = 100$ gw　　(D)$X_A = 200$ gw, $X_B = 100$ gw

（中文）如下圖所示，對彈簧秤甲兩端同時施以方向相反、大小同為 100gw 的水平力，彈簧秤甲仍保持靜止平衡狀態，讀數為 $X_甲$。如左圖所示，彈簧秤乙吊掛在支架下，對其施以鉛直向下、大小為 100gw 的力，彈簧秤乙保持靜止平衡狀態，讀數為 $X_乙$。若彈簧秤的重量很輕可以忽略，且過程中兩彈簧秤均未超過彈性限度，則 $X_甲$、$X_乙$ 應為多少？
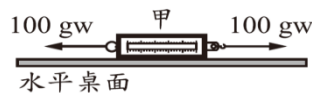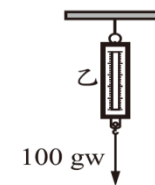
(A)$X_甲 = 0$，$X_乙 = 100$ gw　　　　　(B)$X_甲 = 100$ gw，$X_乙 = 0$

(C)$X_甲 = 100$ gw，$X_乙 = 100$ gw　(D)$X_甲 = 200$ gw，$X_乙 = 100$ g

（109 年國中會考 38）

解題 Solution：

根據彈簧秤呈現平衡狀態，得知合力=0，因此，彈簧秤兩端所受的彈力大小相等，且其讀數相當於此彈力大小。故 $X_甲$=100gw，$X_乙$=100gw。故選(C)。

The resultant force is 0 because the spring balances are static balance. From this, we know that the forces at both ends of a spring balance are the same, and the readings represent the force. Therefore, X_A = 100 gw, X_B = 100 gw. The answer is (C).

Teacher:	From this question, how do the spring balances change?
Student:	They are static balance.
Teacher:	Yes. What is the resultant force of the spring balances?
Student:	The resultant force is 0.
Teacher:	Good. So, the forces at both ends should be equivalent.
Teacher:	What do you see from Diagram 26?
Student:	Each of the left and right ends is applied 100gw force, and the forces are opposite.
Teacher:	That's right. The forces applied at both sides are against each other, and "the reading = elastic force= force = 100."
Teacher:	What do you see from Diagram 27, then?
Student:	There is an 100gw force applied downwards at the bottom of the spring balance.
Teacher:	Yes. But be aware of that the top of the spring balance is also applied 100gw force upwards. This force comes from the holder and makes the resultant force zero. That's why it remains static balance.
Student:	We get it.
Teacher:	Now we know that both ends of the spring balances in these two diagrams are applied with 100gw force. Do you know what the reading of a spring balance depends on?
Student:	It depends on how big of the forces applied at the two ends.
Teacher:	Exactly. And we get that X_A = 100gw, X_B = 100gw. (C) is the correct answer.
Student:	Sir, but aren't the spring balances affected by gravity?
Teacher:	Sure, it is. But the question says that the spring balances are light enough to be neglected. This means that gravity doesn't count.
Student:	I see. Thank you, sir.

老師：　請問大家在題幹中，得知彈簧秤的運動現象是什麼呢？

學生：　維持靜止。

老師：　是的，所以彈簧秤的合力，應該如何呢？

學生：　合力=0。

老師：　很好，所以彈簧秤兩邊所受的外力，應該相等。

老師：　再從圖(二十六)中，看到什麼？

學生：　彈簧秤的左右兩邊各被施加了 100gw 的力，且兩力的作用方向相反。

老師：　沒錯，此時，左右兩力互相抗衡，而[彈簧讀數=彈力=所施外力=100gw]。

老師：　那你們在圖(二十七)中看到了什麼呢？

學生：　彈簧秤下方受到一 100gw 的作用力向下。

老師：　對，但是要注意彈簧秤的上方，也同時受到了 100gw 的作用力向上，這個力來自支架，使得彈簧秤的合力為零，才能保持靜止狀態。

學生：　好的，我們了解了。

老師：　所以我們知道了兩張圖中的彈簧秤兩端，都各受到 100gw 的作用力，那麼大家知道彈簧秤的讀數取決於什麼嗎？

學生：　彈簧秤的讀數為其兩端所受的力的大小。

老師：　沒錯，故 $X_{甲}$=100gw，$X_{乙}$=100gw，選項(C)為正確答案！

學生：　老師！但我想請問彈簧秤不是也會受到重力嗎？

老師：　說得對，但題目上說彈簧秤的重量很輕可以忽略，這個意思就是讓我們忽略彈簧秤所受的重力。

學生：　原來如此，謝謝老師！

6-2 摩擦力
Frictional Force

■ 前言 Introduction

摩擦力存在於兩物體間的接觸面，可能阻止物體運動，也可能加速物體運動。依照物體與接觸面之間是否相互滑動，可以分成靜摩擦力與動摩擦力兩種。本章節介紹影響摩擦力大小的因素，以及生活中各種和摩擦力相關的應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
contact surface	接觸面	foam	泡棉
abrasive paper	砂紙	desk mat	桌墊
static friction force	靜摩擦力	chain	鍊條
kinetic friction force	動摩擦力	wheel	輪子
block wood	木塊	lubricating oil	潤滑油
glass plate	玻璃板		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ **When a _____, making _____.**

例句：**When a** person walks, the foot exerts a force backward to the floor, and resulting a forward frictional force exerted by the floor, **making** the person move forward.

人走路時，腳向後對地面施力，使得腳受到地面向前的摩擦力，因而使人向前進。

❷ **When _____, friction is generated between _____ and the _____.**

例句：**When** a car is accelerating, **friction is generated between** the rotating wheels **and the** ground.

汽車在加速時，轉動的車輪與地面之間，會產生摩擦力。

❸ **When a _____ is working, _____ will _____.**

例句：**When a** machine **is working,** the existence of friction **will** reduce the efficiency of the machine's operation.

當機械在作用時，摩擦力的存在，會降低機械運轉的效率。

■ 問題講解 Explanation of Problems

❈ 學習目標 ❈

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解摩擦力的計算方式。

　　Know how frictional force is calculated.

二、了解影響動摩擦力大小的因素。

　　Understand the factors that affect the magnitude of kinetic frictional force.

৪০ 例題講解 ৫৪

例題一

說明：結合牛頓第二運動定律，及虎克定律，應用於彈力與摩擦力的現象。

Understand Newton's second law of motivation and Hooke's law applied on the phenomenon of elastic force and frictional force.

（英文）As shown in Diagram 1, a 600gw block metal is hanging on a 10cm spring, and the full length of the spring when it strikes static balance is 15 cm. In Diagram 2, the spring and block metal are put in a horizontal tabletop. One end of the spring is connected to the wall, and the other end is connected to the bock metal. A 600gw force is applied to the block metal leftwards. When it strikes static balance, the full length of the spring is 14 cm. It is known that the spring recovers to the original length after the experiment. Without considering the effects of the mass of the spring, what are the magnitude and direction of the frictional force that the block metal receives?

(圖表對照詞彙：天花板-ceiling／ 水平桌面-horizontal tabletop／ 牆壁-wall)

(圖一)　(圖二)
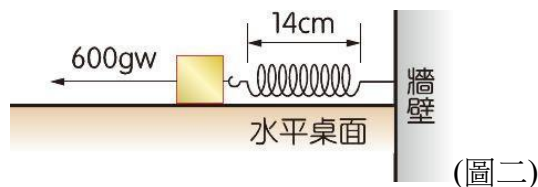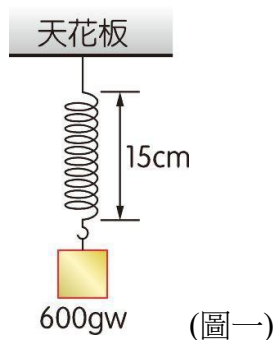
(A)40gw, leftwards

(B)40 gw, rightwards

(C)120gw, leftwards

(D)120 gw, rightwards

（中文）如圖（一）所示，在一原長為 10 cm 的彈簧下，吊掛一個重量為 600 gw 的金屬塊，靜止平衡時彈簧的全長為 15 cm。如圖（二）所示，改將此彈簧與金屬塊置於水平桌面上，彈簧一端連接牆壁，另一端連接金屬塊，對金屬塊施予一個大小為 600 gw，水平向左的拉力，靜止平衡時彈簧全長為 14 cm。已知彈簧在實驗後皆能恢復原長，若忽略彈簧質量的影響，則此金屬塊所受桌面摩擦力的大小及方向，應為下列何者？

(圖一) (圖二)
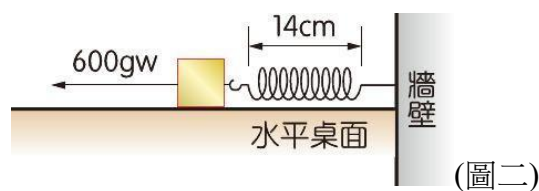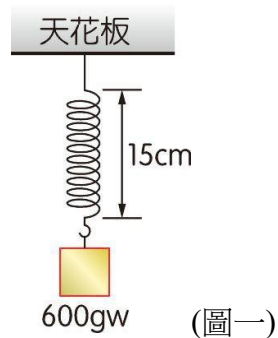
(A) 40 gw，方向向左
(B) 40 gw，方向向右
(C) 120 gw，方向向左
(D) 120 gw，方向向右

（106 年國中會考 41）

解題 Solution：

$600/(15-10) = X/(14-10) \rightarrow X = 480$(gw)，金屬塊不動，所受合力為零。$600 = 480 + f \rightarrow f = 120$(gw) 向右。故選(D)。

$600/(15-10) = X/(14-10) \rightarrow X = 480$ (gw). The motionless block metal means the resultant force is zero. $600 = 480 + f \rightarrow f = 120$ (gw) (rightwards). The answer is (D).

> Teacher: Do you know why the spring receives the same pull in Diagram 1 and 2 but they extend by different distances?
>
> Student: Because there is a frictional force in Diagram 2.
>
> Teacher: Yes. How do you know the magnitude of the frictional force?
>
> Student: Use Hooke's law?
>
> Teacher: Yes. You can get the resultant force through the fact that the force and the distance of extension are proportional. Later, you just need to use it to minus the pull. The result is a negative number. Take the absolute value, and you will get the magnitude of the frictional force.

Teacher: The equation is 600/(15-10) = X/(14-10) → X = 480 (gw). 600 = 480 + f → f = 120 (gw).

Student: Understood. What about the direction?

Teacher: The shorter distance it extends in Diagram 2 means the elastic force the spring receives is smaller than in Diagram 1. So, the frictional force is rightwards and offsets partial pull, and the elastic force gets smaller.
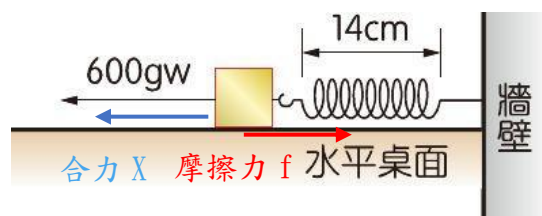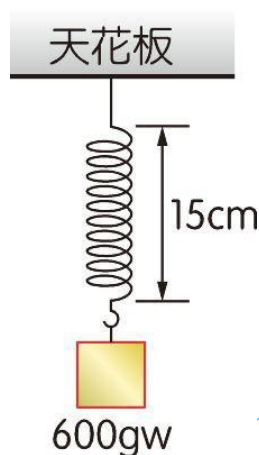
老師：　同學們知道為什麼(圖一)和(圖二)中，彈簧明明受了相同的拉力，但伸長量卻不一樣嗎？

學生：　因為(圖二)中還有摩擦力在作用。
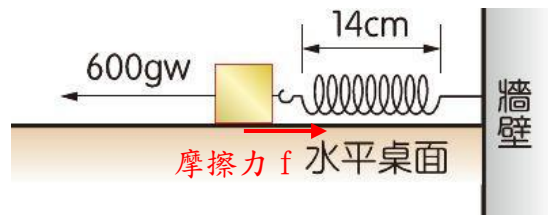
老師：　沒錯，那我們要怎麼算出摩擦力的大小呢？

學生：　是利用虎克定律嗎？

老師：　沒錯，彈簧所受外力與伸長量成正比可以得出彈簧所受的合力，之後再將合力減去彈簧所受的拉力就行，這邊合力減去彈簧所受的拉力會是負值，取絕對值之後就會是摩擦力的大小！

合力=金屬塊所受的重力

老師：　計算方式為 600/(15－10) = X/(14-10) → X = 480(gw)，600 = 480 + f → f = 120(gw)。

學生：　原來如此，那麼摩擦力的方向呢？

老師：　因為圖二的伸長量較小，表示彈簧所受的彈力比圖一小，所以摩擦力向右，抵銷了部分的外力，使彈力減小。

例題二

說明：透過「動摩擦公式」，與「力平衡」，比較動摩擦及靜摩擦力之大小。

Compare the magnitudes of kinetic friction force and static friction force through the "kinetic friction formula" and "force equilibrium."

（英文）There are four ways of applying forces at the static block wood on a horizontal tabletop shown in the diagrams. Each of the arrows is 1kgw force, and a block wood is 3kgw. The block wood in Diagram B isn't moved by the force, but in the other diagrams, the block woods move horizontally. In these four diagrams, the block woods receive different magnitudes of frictional forces, they are f_A, f_B, f_C, and f_D, respectively. which of the following options best describes their relationship?

(A)$f_A > f_D > f_C > f_B$　　　　　　　(B)$f_A > f_C > f_D > f_B$
(C)$f_D > f_B > f_A > f_C$　　　　　　　(D)$f_D > f_A > f_B > f_C$

（中文）水平桌面上一個原本靜止不動的木塊，分別以四種方式施力，如圖所示。若圖中附有箭號的線段皆代表 1kgw 的力，木塊重為 3kgw。施力後，乙圖的木塊仍然不動，其它三種施力情況下，木塊均沿水平方向運動。在這四種情形下，木塊所受到的摩擦力大小不同，分別為 $f_甲$、$f_乙$、$f_丙$、$f_丁$，則下列關係何者最適當？

(A) $f_甲 > f_丁 > f_丙 > f_乙$　　　　　(B) $f_甲 > f_丙 > f_丁 > f_乙$
(C) $f_丁 > f_乙 > f_甲 > f_丙$　　　　　(D) $f_丁 > f_甲 > f_乙 > f_丙$

（96-2 年國中基測 43）

解題 Solution：

影響動摩擦力的因素，包括：(1)接觸面的性質，和(2)物體的重量與向下作用力之和（正向力），所以，物體所受正向力愈大，則摩擦力愈大。圖中乙木塊未受水平方向推力，故摩擦力為 0，而木塊所受桌面的正向作用力大小為甲＞丁＞丙，故摩擦力大小為甲＞丁＞丙＞乙。

The factors influence kinetic friction force include: (1) the nature of the contact surface and (2) the sum of the weight of an object and the force (normal force). When the object receives the bigger normal force, the bigger the frictional force is. In Diagram B, the block wood doesn't receive any horizontal force, so the frictional force is 0. The normal forces the block wood receives from the table are A>D>C. Therefore, the magnitudes of the frictional forces are A>D>C>B.

Teacher:	Do you know what factors affect the magnitude of kinetic friction force?
Student:	The normal force of the object and the nature of the contact surface.
Teacher:	Yes. The normal force means the force that the object receives from the contact surface, including the weight of the object and the vertical force.
Teacher:	We can see the magnitudes of normal force that the block wood applies to the tabletop are A>D>C, so the magnitudes of frictional force are A>D>C. What about block wood B?
Student:	Block wood B is motionless, which means static friction. Because there is no horizontal force, the frictional force is zero.
Teacher:	Good. So, we can get that the magnitudes of these frictional forces are A>D>C>B. the answer is (A).

老師：	大家知道有哪些因素，會影響動摩擦力的大小嗎？
學生：	物體的正向力與接觸面的性質。
老師：	好好其中的正向力是指物體受到接觸面的作用力，包含物體重量，加上外力的鉛直分量。
老師：	那我們可以看到，木塊對桌面的正向作用力大小為甲＞丁＞丙，所以摩擦力的大小為甲＞丁＞丙，那麼乙木塊呢？
學生：	乙木塊因為靜止，所以是靜摩擦，因為乙未受到水平推力，所以摩擦力為 0。
老師：	很好，那我們現在知道了摩擦力大小為甲＞丁＞丙＞乙，故答案選(A)。

6-3 壓力
Pressure

■ 前言 Introduction

本節介紹壓力的定義及應用。透過實驗了解壓力的作用，並觀察氣體之壓力、溫度、體積的關係與變化，但不帶入理想氣體狀態方程式之計算。最後介紹帕斯卡原理及探究壓力的科學史。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
pressure	壓力	pascal	帕
force	力	normal force	正向力
symbol	符號	scalar	純量
perpendicular	垂直	Fluid	流體
per unit area	每單位面積	bar	巴
distribute	分布	mercury	汞
scaling of unit	單位換算	elevation	提高
atmosphere	大氣	Pascal's principle	帕斯卡原理
standard atmospheric pressure	標準大氣壓力(atm)	constant	固定的
millimeter of mercury	毫米汞柱(mmHg)	temperature	溫度
Torr (mmHg)	托；毫米汞柱		

■ 教學句型與實用句子 Sentence Frames and Useful Sentences

❶ _____is defined as____, and it is_____.

例句：Pressure **is defined as** force per unit area**, and it is** perpendicular to the surface of the stress.
每單位面積所受的力為壓力，且壓力與受力面積垂直。

❷ Press _____, proving that _____ from _____to_____.

例句：**Press** a plastic water bottle can make the water spray**, proving that** when fluid flows **from** high **to** low pressure, the speed would increase.
按壓寶特瓶使水噴出，證明了流體若從壓力大流向壓力小的過程，流速會增快。

❸ When _____, it is_____.

例句：**When** we drink beverage with a straw**, it is** an application of atmospheric pressure.
當我們用吸管喝飲料，這就是大氣壓力的應用。

❹ _____ is caused by_____.

例句：The atmospheric pressure **is caused by** the weight of the air.
空氣的重量造成大氣壓力。

❺ According to _____ principle, we can _____.

例句：**According to** Pascal's principle, **we can** easily lift heavy objects.
根據帕斯卡原理，我們能輕易地舉起重物。

■ **問題講解 Explanation of Problems**

◇ 學習目標 ◇

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解壓力的定義。

　　Understand the definition of pressure.

二、了解壓力的應用。

　　Understand the applications of pressure.

◇ 例題講解 ◇

例題一

說明：結合「力平衡」，及靜止流體之壓力(正比於其液體深度及密度)，推導出靜止液體
　　　各點之壓力大小。

　　　Understand "force equilibrium" and the pressure of fluid statics (which is proportional to
　　　the depth and density of the fluid) and infer the pressure on every point of the fluid statics.

（英文）There are two devices on a horizontal tabletop in one atmosphere (as shown in the
diagram). Point P and R are on the fluid surface inside the glass tubes, and point Q and
S are on the fluid surface in the container outside the glass tubes. Which two points
are in one atmosphere?

玻璃管
P　　　　　R
76 cm　　76 cm
Q　　　　　S
水銀　　　　水
水平桌面
圖(十九)
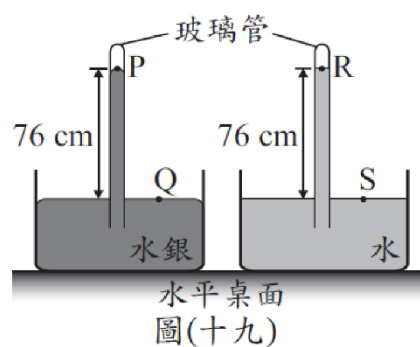
(圖片對照詞彙：玻璃管-glass tube/水銀-mercury/水-water/水平桌面-horizontal
tabletop/圖(十九)-Diagram 19)

(A)P, Q　(B)R, S　(C)P, R　**(D)Q, S**

（中文）在一大氣壓的環境下，靜置於水平桌面的兩裝置如圖所示。圖中 P、R 兩點位於玻璃管內的液面，Q、S 兩點位於玻璃管外容器內的液面，其中哪兩個點的氣壓為一大氣壓？

圖(十九)
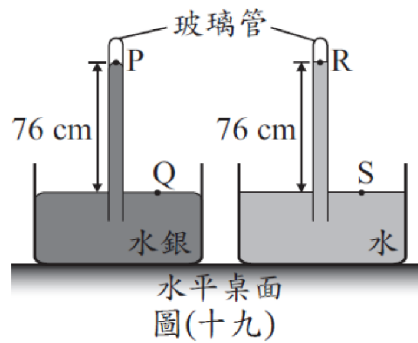
(A)P, Q　(B)R, S　(C)P, R　**(D)Q, S**

（110 年國中會考 37）

解題 Solution：

因圖中之液體均維持靜止，故每一點皆滿足「力平衡」:合力=0。Q 點及 S 點之液體，因直接與外界接觸，所以這兩點之壓力等於 1atm。同時，靜止流體之壓力大小，隨深度與密度成正比，所以 P、R 點的氣壓會比 1atm 小，因為液體深度比 Q、S 點還小。且已知:1atm=76cm 水銀柱，所以 P 點之氣壓=0，而 R 點氣壓>0，但小於 1atm，故答案為(D)。
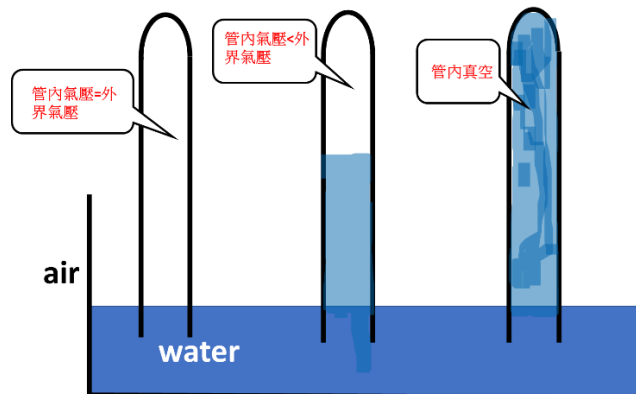
The fluid in this diagram is static, so every point fulfills the condition "force equilibrium": the resultant force = 0. Point Q and S contact with the outside directly, so they are in one atmosphere. Also, the pressure of fluid statics is proportional to the density as the depth changes. The atmospheric pressure at point P and R is less than one atmosphere because the depth of the fluid at point P and R is less than at point Q and S. It is known that 1 atm = 76 cm mercury column, so the atmospheric pressure of point P is zero, and the atmospheric pressure of point R is not zero just less than one atmosphere. The answer is (D).

Teacher: If you drink beverages very often, you are supposed to be familiar with the principle of this question.

Student: Why?

Teacher: When we drink with a straw, the air in the straw is the first to be drained, and the drink raises into our mouth. Does anyone know why?

Student: Because of atmospheric pressure.

Teacher: That's right. When the air in the straw is drained, there will be no pressure caused by the weight of air. And the atmospheric pressure outside the straw squeezes the drink. Thus, the drink goes towards where has less pressure. It is the same for this question.

Student: Could you please elaborate, sir?

Teacher: If the atmospheric pressures inside and outside the tube are the same, there will be no fluid to be squeezed and raises. The fact that the fluid at point P and R is higher means that the atmospheric pressure at P and R is less than one atmosphere as the outside is. Also, because 1 atm = 76 cm mercury column, the atmospheric pressure of point P is 0. As for point R, because the pressure cause by 76 cm water column is less than 76 cm mercury column, the pressure at point R is a bit smaller than 1 atm but not 0. That's why the answer for this question is (D).

Student: Understood.

老師：　這一題的原理，如果常常在喝飲料的人應該不陌生。

學生：　為什麼啊。

老師：　當我們在用吸管喝飲料的時候，是先把吸管內的空氣吸走，飲料就會自動上升到我們口中，有人知道為什麼嗎？

學生：　大氣壓力。

老師：　沒錯，當吸管內的空氣被吸走後，管內沒有空氣重量造成的壓力，使得外界的氣壓擠壓飲料，當然，飲料就往壓力小的地方跑。這題也是一樣。

學生：　可以再多做說明嗎？

老師：　若柱體內部氣壓與外部氣壓一致，則不會有液體能被擠壓上升。所以，既然 P、R 兩點的液體都比較高，表示 P、R 兩點的氣壓，都小於外面空氣的 1atm，而 1atm=76cm 水銀柱，所以 P 點之氣壓=0，至於 R 點，由於 76 公分水柱造成的壓力小於 76 公分水銀柱，所以 R 點之氣壓是略小於 1atm 而非零，故此題答案應選(D)。

學生：　了解。

例題二

說明：根據「帕斯卡原理」，了解靜止流體之壓力與面積、受力的關係。

Understand the relationships among the pressure, area, and force of the fluid statics on the basis of Pascal's principle.

（英文）There are connecting tubes filled with water on a horizontal tabletop. The diameters of them are from small to big as from the left to the right. Plugs A, B, and C put on the nozzles of the tubes match with each tube, respectively. The plugs perfectly fit in the tube wall and water surface and can freely slide. Let's assume that the frictional force between the plug and the wall is negligible. When the three plugs are static balance, the water in the three tubes are at the same height as shown in the diagram. Which of the following statement is true about the weights of the three plugs?
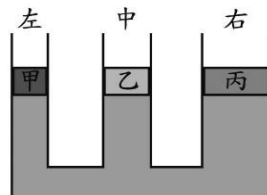
圖(十八)

圖表對照詞彙：左-left /中-middle/ 右-right/ 甲-A /乙-B /丙-C

(A) A=B=C

(B) B>A=C

(C) A>B>C

(D) C>B>A

（中文）在水平桌面上，放置一個從左至右，管口口徑依序變大的盛水連通管。今在三管管口上，各放置與管口口徑相同的甲、乙、丙三活塞，活塞與管壁、水面完全密合且可以在管壁上自由滑動。忽略活塞與管壁間的摩擦力，當三活塞達到靜止平衡時，三管內的水面齊高，如右圖所示，則關於活塞甲、乙、丙的重量大小關係，下列何者正確？
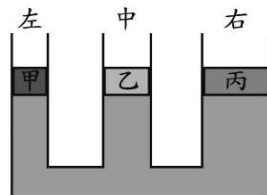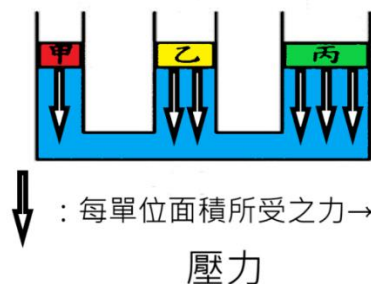

圖(十八)

(A)甲＝乙＝丙
(B)乙＞甲＝丙
(C)甲＞乙＞丙
(D)丙＞乙＞甲

（108 年國中會考 39）

解題 Solution：

依據「帕斯卡原理」，流體容器中，相同高度的不同位置，壓力相等。因圖中顯示三物同高，代表三者之壓力相同。再根據[壓力=受力/面積]，可推得面積越大的地方，所受的重量越大，透過面積的大小比較，故選(D)。

：每單位面積所受之力→

壓力

According to Pascal's principle, pressures at the same height but different points in a fluid container are equivalent. The diagram showing that the three plugs are at same height means that they have the same pressure. And based on the formula [pressure = force/area], it can be inferred that the larger the area is, the more weight it takes. By comparing the areas, we can know that the answer is (D).

Teacher: Do you guys understand Pascal's principle?

Student: Yes, but could you please explain it to us again?

Teacher: Are you aware of that the three plugs are at the same height above water? What does this mean?

Student: They cause the same pressure to water.

Teacher: Exactly. If the pressures are the same, does the larger contact area mean the bigger or smaller force?

Student: It means the bigger force.

Teacher: Sure. So, which plug is the heaviest?

Student: C is the heaviest.

Teacher: Correct. The answer is (D).

老師： 大家有沒有理解帕斯卡原理啊？

學生： 有，但老師可不可再講一次。

老師： 大家有沒有發現三個物體與水的接觸面等高？這代表什麼？

學生： 三物對水造成的壓力一樣。

老師： 沒錯，如果壓力相同，那麼接觸面積越大，就代表施加總力越大還是越小呢？

學生： 施力越大。

老師： 沒錯，所以哪一個重量最大？

學生： 丙的重量越大。

老師： 正確，因此答案是(D)。

6-4 浮力
Buoyancy

■ 前言 Introduction

了解浮力原理及概念推理，透過實驗觀察浮力特性，但不涉及複雜計算，同時介紹浮力原理之發展史。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
buoyancy	浮力	driving force	推動力
upward	向上的	convection	對流
weight	重量	spontaneous	自發的
average	平均	separation	分開
density	密度	volume	體積
submerge	（使）潛入	downward force	向下力
sink	沉	gravity	重力
float	浮	displaced fluid	排開之液體

■ 教學句型與實用句子　Sentence Frames and Useful Sentences

❶ **Because _____ is greater than _____, _____.**

例句：**Because** the pressure of the lower water **is greater than** that of the upper water regarding an object, buoyancy is formed.

因為物體受到下層水的壓力大於上層水，故造成浮力。

❷ **Through _____, we found that _____ by _____.**

例句：**Through** experiments**, we found that** buoyancy is equal to the weight of the liquid displaced **by** the object.

透過實驗，我們發現浮力等於物體排開的液體重量。

❸ **_____, so _____.**

例句：Water and air are both fluids**, so** buoyant can exist in the air.

水與空氣都為流體，故空氣也有浮力。

❹ **Does anyone _____?**

例句：**Does anyone** know why objects with density greater than water sink in water**?**

有人知道為什麼密度比水大的物體，會沉到水裡嗎？

❺ **_____ is most famous for _____ _____.**

例句：Archimedes **is most famous for** the discovery of buoyancy.

阿基米德最有名的，就是浮力的發現。

■ 問題講解 Explanation of Problems

CR 學習目標 SO

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to know that:

一、了解浮力原理。

　　Understand the principle of buoyancy.

二、了解浮力的應用。

　　Understand the application of buoyancy.

SO 例題講解 CR

例題一

說明：了解物體在水中的浮力大小。

　　　Understand buoyancy of objects in water.

（英文）Solid objects A and B are put into two same graduated cylinders filled with 200 ml water, respectively. When the water is static balance, the readings of the graduated cylinders and how the objects float are shown in the diagram. The two objects neither absorb water nor react with water. It is known that the density of water is 1 g/cm^3, what can be inferred?
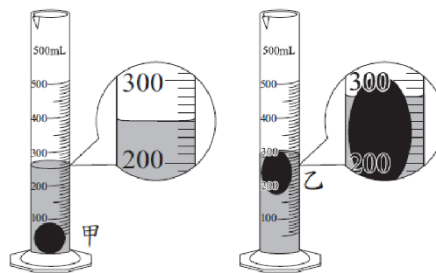
圖(二十二)

(A) The mass of A is 50 g, and the mass of B is 80 g.

(B) The mass of A is 50 g, and the volume of B is 80 cm^3.

(C) The volume of A is 50 cm^3, and the volume of B is 80 cm^3.

(D) The volume of A is 50 cm^3, and the mass of B is 80 g.

（中文）兩個完全相同的量筒中，原本皆裝水 200 mL，今分別置入甲、乙兩個實心物體待液面靜止平衡後，物體的浮沉情形與量筒的讀數如圖所示。若兩物體皆不與水發生化學反應且不吸水，已知水的密度為 1 g/cm³，則可推論出下列哪些資訊？
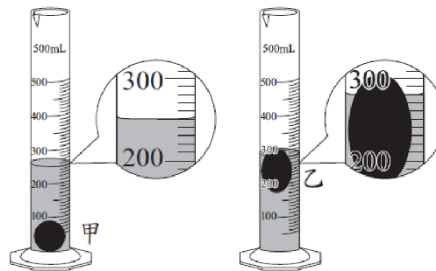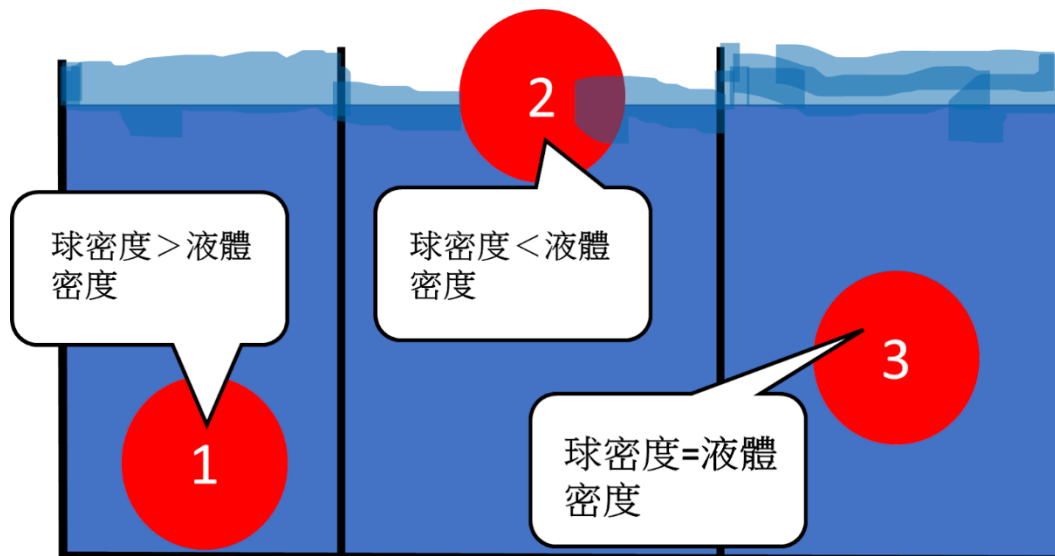

圖(二十二)

(A)甲的質量為 50 g，乙的質量為 80 g

(B)甲的質量為 50 g，乙的體積為 80 cm³

(C)甲的體積為 50 cm³，乙的體積為 80 cm³

(D)甲的體積為 50 cm³，乙的質量為 80 g

（110 年國中會考 40）

解題 Solution：

甲體積等於排開液體體積:甲體積＝250–200＝50cm3，但因甲沉在水底，故重量必大於浮力，質量必大於 50g。而乙因為是浮體，所以乙的重量=浮力=排開液體重量，所以乙的質量=排開水之質量=280–200＝80g。

乙是浮體，所以體積會大於排開之水體積：乙體積＞280–200＝80cm³。故選(D)。

球密度＞液體密度

球密度＜液體密度

球密度=液體密度

The volume of A equals the volume of the displaced water: Volume A = 250-200 = 50 cm^3. However, since A sinks at the bottom of water, the weight must be larger than the buoyancy, which means its mass is over 50 g. And because B is a floating body, its weight = buoyancy = the weight of displaced water. This is how we get that the mass of B = the weight of displaced water = 280-200 = 80 g. because B is a floating body, its volume will be larger than the volume of displaced water: the volume of B > 280-200 = 80 cm^3.

Teacher: Through this experiment, we find that the buoyancy equals the weight of the displaced fluid, right?

Student: Yes.

Teacher: When the weight of an object is larger than its buoyancy, the object sinks to the bottom. Vice versa, the object is partially out of water, and the weight of the object decides how much it will be out of water. The lighter the object is, the less buoyancy it needs to strike a balance, and the less the weight of displaced fluid will be. As a result, there will be more volume that is out of water.

Student: Sir, but in this question, object B neither completely sinks nor completely floats.

Teacher: Good observation. This means that the buoyancy is quite close to the weight of the object. By knowing that the buoyancy depends on the volume and density of the displaced water, we can infer that the mass of B equals the mass of the displaced water.

Student: Now we get it. Thank you, sir.

老師：　透過實驗，我們發現浮力等於物體排開的液體重量，對嗎？

學生：　是。

老師：　當物體重量比浮力大，就會下沉到底部。反之，則露出水面，露出水面的多寡取決於物體的重量。物體越輕，所需力平衡的浮力越小，物體所需排開的液重也越小，故會有較多體積露在水面。

學生：　老師，但這題的乙物體既沒有完全沉下去，也沒有完全浮起來。

老師：　觀察力很好哦，這代表浮力非常接近物體重量，而浮力取決於所排開之水體積和密度，所以我們可以藉由這個現象，得知乙的質量等於排開水之質量。

學生：　了解了！謝謝老師。

例題二

說明：能透過「力平衡」，推導出物體在水中的浮力大小。
　　　Infer the buoyancy of an object in water by "force equilibrium."

（英文）Scuba diving is an activity that a diver carries a diving tank (a steel cylinder contains compressed air) and dives underwater. The diver wears a vest that is inflatable and deflatable. The volume of the vest as well as the buoyancy of the diver can be changed by the tank inflating or deflating. By inflating the vest, the diver can spontaneously float without paddling; and by deflating the vest, the diver can spontaneously sink in water without paddling. If the vest is appropriately adjusted, the diver can stay at the same depth without paddling. This technique of adjusting how much to inflate the vest to maintain the diver at the same depth is called "neutral." Scuba diving is an activity that requires companions to attend so that they can look after each other. Proper plans are needed to scuba dive, and records are also needed after scuba diving. The diagram is the records showing the time duration and depth of scuba diving.
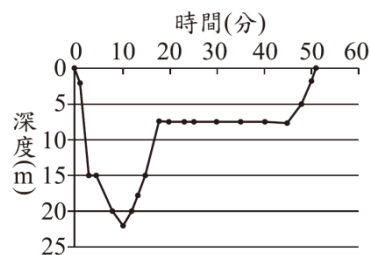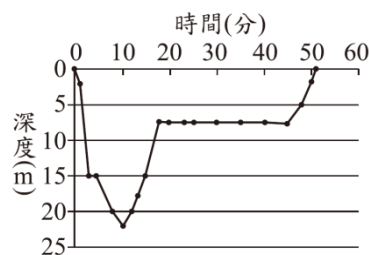

圖(三十一)

The volume of a diver without equipment is V_D, the mass is M_D, and the density is D_D; and the volume of the equipment is V_E and the mass is M_E; and the density of water is D_W. From which of the following equation can keep a diver moving at 10 m underwater with "neutral?"

(A)$V_D \times D_W = M_D$

(B)$(V_D + V_E) \times D_D = M_D$

(C)$(V_D + V_E) \times D_W = M_D + M_E$

(D)$V_D \times D_W + V_E \times D_D = M_D + M_E$

（中文）水肺潛水是一項由潛水員攜帶氣瓶(內含壓縮空氣的鋼瓶)在海面下所進行的活動，潛水員會穿上一種可充氣或放氣的背心，藉由氣瓶對背心的充放氣來改變背心的體積大小，調整潛水員在海中的浮力大小，在背心內多充入一些空氣，潛水員可在不施力划水的情形下自然向海面浮起，從背心中多放出一些空氣，潛水員可在不施力划水的情形下自然向海底下沉。若背心的充氣量調整適當，潛水員可在不施力划水的情形下於海面下維持同樣的深度，此種調整背心的充氣量而能夠在海面下維持同樣深度的技術，稱為「中性浮力」。水肺潛水需要找同伴一起進行活動，可以互相照顧，每次潛水前也都要有適當的規劃，潛水後也要做紀錄。右圖為一位潛水員的潛水時間與潛水深度的紀錄。

圖(三十一)

若未攜帶裝備潛水員的體積為 $V_人$、質量為 $M_人$、密度為 $D_人$，潛水員所攜帶的所有裝備體積為 $V_裝$、質量為 $M_裝$，海水的密度為 $D_海$，則下列哪一關係式的情況，可讓潛水員維持在海面下 10m 的深度以「中性浮力」活動？
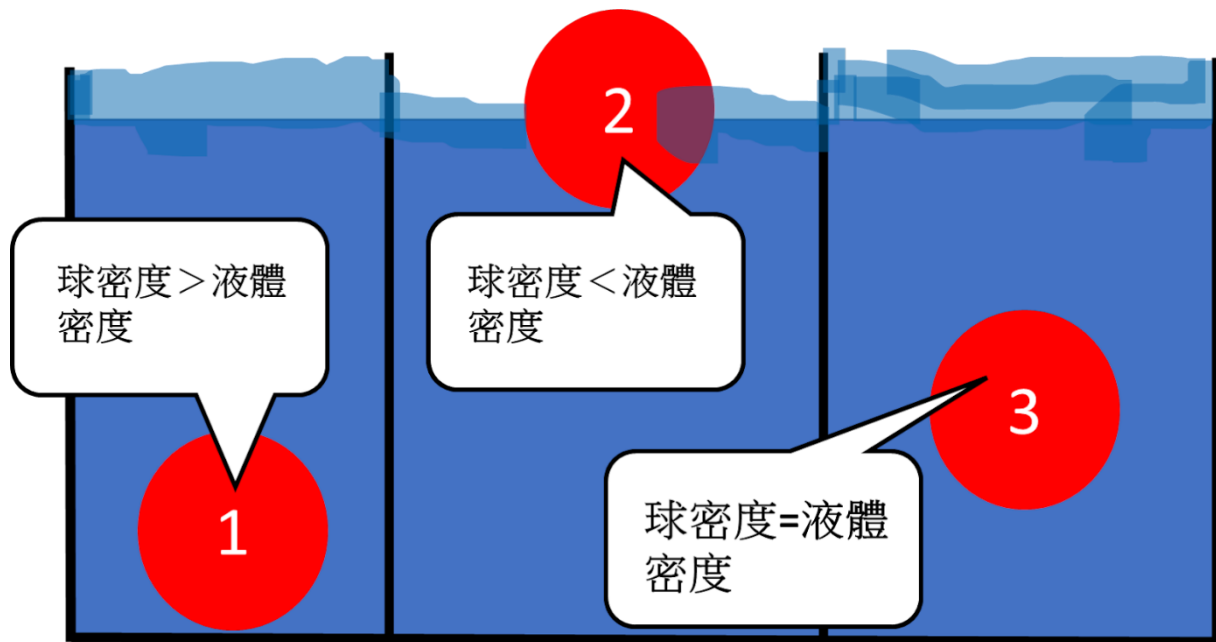
(A)$V_人 \times D_海 = M_人$

(B)$(V_人 + V_裝) \times D_人 = M_人$

(C)$(V_人 + V_裝) \times D_海 = M_人 + M_裝$

(D)$V_人 \times D_海 + V_裝 \times D_人 = M_人 + M_裝$

（109 年國中會考 46）

解題 Solution：

「中性浮力」能在海面下維持同樣深度，表示此時[浮力=總重量]，而浮力=排開水的總體積($V_人 + V_裝$)，乘以海水密度，故選(C)。

"Neutral state" keeps a diver at the same depth underwater and means [the buoyancy = total weight] at the moment. And buoyancy = the total volume of displaced water ($V_D + V_E$) times the density of water. The answer is (C).

Teacher: I suggest that you read the article after reading the question.

Student: Okay.

Teacher: Why can a diver keep himself at the same depth?

Student: Because of static force equilibrium. The weight equals the buoyancy.

Teacher: Good. Then why does the vest floats on the water? Is it because it gets lighter?

Student: I think it's because the total weight doesn't change but the total volume of the vest becomes larger, so more water is displaced, and the buoyancy gets bigger.

Teacher: Excellent. I'll give you a thumb up.

Teacher: So, how do you calculate the buoyancy of the diver?

Student: The volume of displaced water times the density of water.

Teacher: Yes. The volume of displaced water equals [the volume of the diver and equipment], so the buoyancy = $(V_D+V_E) \times D_W$.

Teacher: Also, it's "force equilibrium," so [the buoyancy = total weight]: $(V_D+V_E) \times D_W = M_D+M_E$. The answer is (C).

老師：　建議大家先看完題之後，再閱讀文章。

學生：　好的。

老師：　請問為什麼潛水員，能使自己維持同樣的深度呢？

學生：　靜力平衡，重量等於浮力。

老師：　很好，那為什麼背心充氣後，會往上浮出水面？是重量變輕嗎？

學生：　我覺得總重量不變，但背心的總體積加大，排開的水量變多，浮力變大。

老師：　非常優秀，給你一個讚。

老師：　所以這題，潛水員的浮力應該如何推算呢？

學生：　排開水的體積乘以海水密度。

老師：　沒錯，排開水體積相當於[人+裝備的體積]，所以所受浮力= $(V_{人} + V_{裝}) \times D_{海}$

老師：　又因為此時達「力平衡」，所以[浮力=總重量]: $(V_{人} + V_{裝}) \times D_{海}$ 。

　　　　　所以答案是 C 。

國內外參考資源 More to Explore

PBS LearingMedia
有科學類的影片，分年級分類別，推薦影片及提供影片內可詢問學生的問題，部分影片有閱讀材料。 https://www.pbslearningmedia.org/

MIT opencourseware
此網站為 MIT 的開放式課程，包含講義及課程設計及實驗設計。 https://ocw.mit.edu/

Khan Academy
可汗學院，有分年級的物理教學影片及有問題的討論。 https://www.khanacademy.org/

Interactive Simulations, University of Colorado Boulder
互動式電腦模擬，除了物理，還有其他自然科。 https://phet.colorado.edu/

Collection of Physics Experiments, Charles University in Prague
探究物理實驗設計及結果，並包含原理解說。 https://physicsexperiments.eu/en/physics

PhysPort, PER

物理教育研究資源庫，分享評量相關工具，包含迷思概念，情意成效，學習觀等。
https://www.physport.org/assessments/

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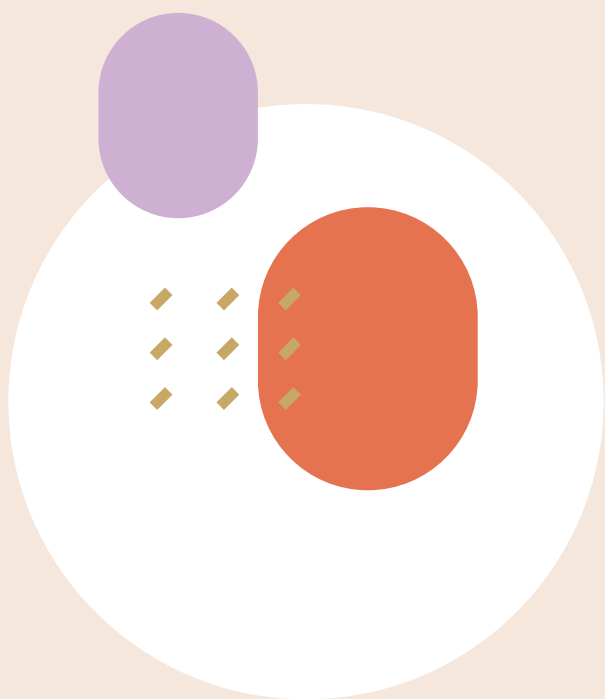
此網站是以設計給學生學習物理相關知識為目的。
https://www.islephysics.net/

雙語教學資源手冊：物理科 英語授課用語
[八年級]
A Reference Handbook for Junior High School Bilingual Teachers in the Domain of Natural Sciences (Physics): Instructional Language in English
[8th grade]

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- 指導單位：教育部師資培育及藝術教育司

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