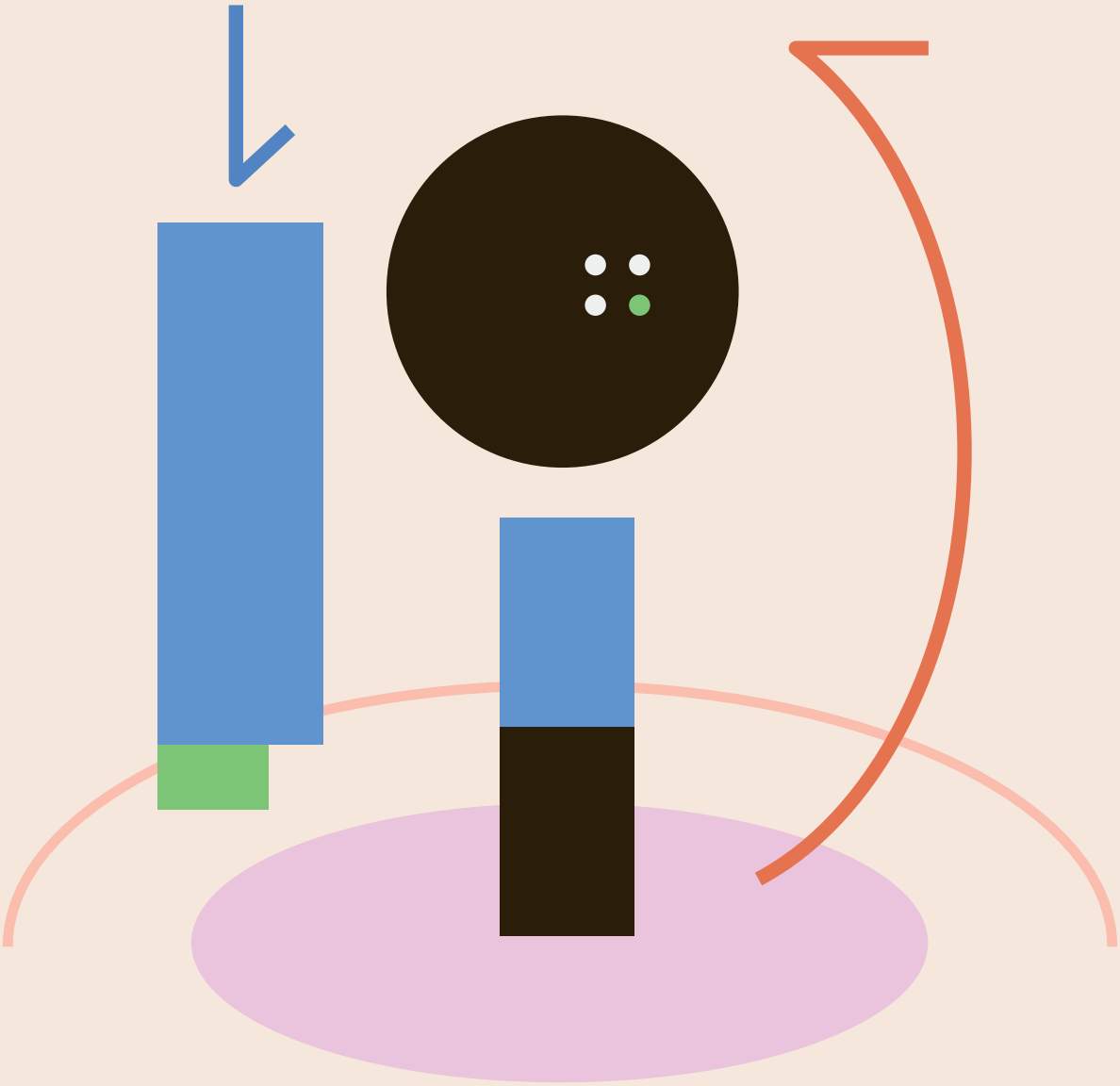
國中自然領域

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

〔國中九年級〕



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★主題一 直線運動★
Linear Motion (One Dimensional Motion)

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■ 前言 Introduction

本章為學生初次接觸運動學，因此，先介紹運動學幾個物理量的定義，再藉由運動相關實驗，使學生透過觀察與歸納物體的運動軌跡，了解一維運動（含等速、等加速運動）的規則性，並以基本數學形式定量描述運動。本章欲使學生熟悉 x-t 圖、v-t 圖、a-t 圖等圖表解讀，但不涉及公式推導與運動方程式的計算。

由於本章內容對學生而言較為抽象，因此需透過語言作為師生問答的媒介，並且提供英語句型範本使學生練習用英語說出實驗觀察結果和歸納結論。

1-1 位置路徑長與位移
Position, Path Length and Displacement

■ 前言 Introduction

描述物體的運動是物理其中一個重要主題，也與日常生活密切相關。例如：地質學家測量板塊運動以嘗試預測地震，汽車安全系統利用運動的測量，來提供駕駛操作的判斷等。本節將由基礎的直線運動出發，定義位置、位移、路徑長之概念，並透過規劃路線等實例，讓學生熟悉這些物理量的應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
position	位置	axis	軸線
path length	路徑長（路程）	initial position	初始位置
displacement	位移	final position	末位置
time	時間	vector	向量
the graph of x versus t	位置對時間關係圖	scalar	純量
coordinate	坐標	direction	方向
origin	原點	magnitude	大小
x/y axis	x/y 軸		

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

❶ Among all the routes, _____ is the shortest one.

例句：**Among all the** possible **routes**, route A **is the shortest one**.
在所有可能的路徑中，A 路徑是最短的。

❷ The displacement from _____ to _____ is _____.

例句：**The displacement from** A **to** B **is** +200 meters.
A 到 B 點的位移是 +200 公尺。

❸ ____(place A) is _____(east/south/west/north) of ____(place B).

例句：The school **is** 500 meters **east/south/west/north of** the post office.
學校在郵局東/南/西/北方 500 公尺處。

❹ _____(direction) and walk for _____(distance), so you can reach _____(place).

例句：Turn right **and walk for** 300 meters, **so you can reach** the post office.
往右走 300 公尺可以抵達郵局。

■ 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、了解位移的定義。

To know the definition of displacement.

二、正確描述相對位置。

To describe the relative position correctly.

例題講解

例題一

說明：理解位移的定義，並與路徑長做區分。

To know the definition of displacement and distinguish its meaning to path length.

（英文）After hitting a home run in a baseball game, Ah Feng starts from home base passing first, second and third bases, and returns to home base. The passing route forms a square, as shown in Figure 6. Which place does Ah Feng passing by form the largest displacement with home base?

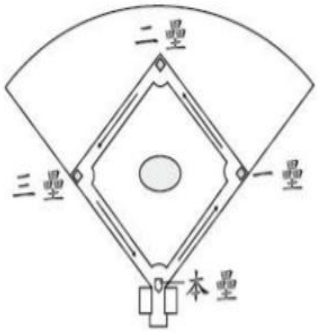
(A) first base　　**(B) Second base**

(C) Third base　　(D) Home Base

（中文）阿峰在棒球比賽中擊出全壘打後，由本壘出發依序經過一壘、二壘、三壘後回到本壘，所經過的路線形成一個正方形，如圖(六)所示。則阿峰經過下列何處時，與本壘間的位移大小最大？

(A)一壘　　**(B)二壘**

(C)三壘　　(D)本壘



圖(六)

（102 年國中試辦會考 11）

解題 Solution：

「位移」的定義為起點到終點的直線距離。本題以本壘為參考點，本壘到一壘、三壘的位移恰好為正方形的邊長，而本壘到二壘的位移為正方形對角線，所以是三段中，長度最長的位移，因此答案為本壘到二壘之位移最大。

“Displacement” is defined as the straight-line distance from the start point to the end point. The title takes the home base as the reference point, the distance from home base to first base and third base is the square side length, and the distance from home base to second base is a square diagonal, which is the longest length in the three sections, so the answer to this question is the displacement from home base to second base is the largest.

Teacher: What is the keyword to this question?

Student: The magnitude of displacement.

Teacher: How do physics define the magnitude of displacement?

Student: The magnitude of displacement is the straight-line distance between two points.

Teacher: Very good! So, according to the question, which position should we take as the reference point?

Student: The home base.

Teacher: That's right! So what we need to look for in this question is which position of first base, second base, third base, and home base shares the longest (furthest) in a straight line with the home base? We take the home base as a reference point and draw arrows to compare, which arrow has the longest length and that is the answer?

Student: The arrow between the home base to the second is the longest.

Teacher: You got the right answer. Displacement is different from path length. If you ask about the path length, it is a circle from home base, and the path length back to home base is the longest. At this time the displacement becomes zero.

老師： 此題要詢問的關鍵字（物理量）是什麼？

學生： 位移大小。

老師： 位移大小的定義是什麼？

學生： 位移大小就是起點到終點的向量大小，也就是這兩點的直線距離。

老師： 非常好！根據題目，我們需以哪個位置為參考點呢？

學生： 本壘。

老師： 沒錯！因此我們在這題裡面需要尋找的是，一壘、二壘、三壘、本壘當中，哪一個位置與本壘的直線距離最大(最遠)？我們以本壘為參考點（箭頭起點），畫出箭頭來比較哪一條箭頭的長度最長，即是答案。

學生： 本壘到二壘畫出來的箭頭最長！

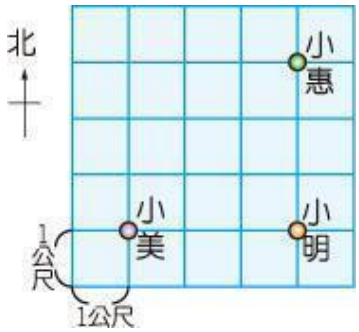
老師： 答對了！位移與路徑長的意義不同，如果問路徑長，則是從本壘繞一圈，跑回本壘的路徑長最長，而此時的位移則變為零。

例題二

說明：能正確描述相對位置之向量。

To describe the vector of relative position correctly.

（英文）The positions of Xiao Hui, Xiao Ming, and Xiao Mei are shown in the figure. Which of the following descriptions of Xiao Hui's location is correct?



(A) Xiao Hui is 4 meters to the north.

(B) Xiao Hui is 4 meters to the northeast.

(C) Xiao Hui is 3 meters north of Xiao Ming.

(D) Xiao Hui is 3 meters northeast of Xiao Mei.

（中文）小惠、小明、小美三個人的位置，如圖所示。下列對小惠位置的描述，何者正確？

(A)小惠在北方 4 公尺處。

(B)小惠在東北方 4 公尺處。

(C)小惠在小明北方 3 公尺處。

(D)小惠在小美東北方 3 公尺處。

（95 年國中基測 5）

解題 Solution：

位置向量的描述，需要有參考點、距離、和方向三要素，A、B 選項缺乏參考點，D 選項應更改為小惠在小美東北方 $3\sqrt{2}$ 公尺處。故答案選 C。

The description of location vector needs to have three elements: reference point, distance, and direction. However, option A and option B lack reference points, and option D should be changed to Xiao Hui at $3\sqrt{2}$ meters northeast of Xiao Mei. Therefore, the answer is C.

Teacher: When we describe a location, we should firstly select a reference of what?

Student: A position of reference.

Teacher: Good! So which two options lack reference positions, and we can delete them first?

Student: Option A and option B.

Teacher: That right! Next, if we take Xiao Ming as a reference point, it is true that Xiao Hui is 3 meters north of Xiao Ming. But can anyone tell me how to amend option D to make it correct?

Student: Xiao Hui should be at the distance of $3\sqrt{2}$ meters northeast of Xiao Mei.

Teacher: Excellent! That's correct!

老師： 描述位置時，首先需要有一個可以參考的什麼？

學生： 參考點。

老師： 很好，因此有哪兩個選項缺乏參考點，可以先刪掉？

學生： A、B。

老師： 沒有錯！接下來我們以小明為參考點的話，的確小惠在小明北方 3 公尺處，正確。但有沒有同學可以告訴我，D 選項應該怎麼修正呢？

學生： 小惠應該在小美東北方距離 $3\sqrt{2}$ 公尺處。

老師： 太棒了！完全正確！

1-2 速率與速度
Speed and Velocity

■ 前言 Introduction

本節旨在區別速率與速度兩個名詞，由於速率與速度在日常生活用語中時常混用，易造成學生混淆，因此可透過多個實例，讓學生練習區辨名詞。同時引進 v-t 圖，以引導學生練習看懂和繪製 v-t 圖，並且練習用句子完整表達這兩個術語的數值、單位、及方向。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
speed	速率	scalar (is directionless)	純量(無方向性)
velocity	速度	vector (has a particular direction)	向量(有方向性)
average speed	平均速率	unit time (per second/per minute)	單位時間（每秒/每分鐘）
average velocity	平均速度	sth. moves at constant(uniform) speed	等速率運動
instantaneous speed	瞬時速率	constant velocity motion	等速度運動
instantaneous velocity	瞬時速度	velocity versus time graph	速度對時間關係圖
area	面積		

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

❶ **From the graph of v-t, we can know that when t=0, the speed of _____ is faster/slower than _____.**

例句：**From the graph of v-t, we can know that when t = 0, the speed of** object A **is faster/slower than** that of object B.

從速度與時間的關係圖中，我們可以判斷在 t=0 的時候，A 物體的速度比 B 快/慢。

❷ **Object A moves with velocity of _____ at _____.**

例句：**Object A moves with velocity of** +10 m/sec **at** t=3 sec.

A 物體在第 3 秒的時候速度為 +10 公尺/秒。

❸ **The total distance of object A moving in _____ is _____, therefore, the average speed of it is _____.**

例句：**The total distance of object A moving** path length **in** 50 seconds **is** 400 meters, **therefore, the average speed of it is** 8 m/sec.

A 物體在 50 秒內移動的路徑長是 400 公尺，因此平均速率為 8 公尺/秒。

❹ **The displacement of object A moving in _____ is _____, therefore, the average velocity of it is _____.**

例句：**The displacement of object A moving in** 50 seconds **is** 0 meter, **therefore, the average velocity of it is** 0 m/sec.

A 物體在 50 秒內位移量為 0 公尺，因此平均速度為 0 公尺/秒。

■ 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、速率、速度之定義。

Understanding of the definition of speed and velocity.

二、正確識讀 v-t 圖，並從中判斷物體的運動狀態。

Can read the v-t graph correctly, and determine the motion state of the object from the graph.

❧ 例題講解 ☙

例題一

說明：了解速度的定義，並計算出平均速度。

Understand the definition of velocity, and can calculate the average velocity

（英文）The car started from a motionless state and traveled 100 meters for 10 seconds on a flat road. Which of the following inferences is most appropriate?

(A)At the end of 10 seconds after starting, the instantaneous speed of the car is 10m/s.

(B)At the end of 10 seconds after starting, the instantaneous acceleration of the car is 1m/s^2.

(C)During the first 10 seconds after starting, the average speed of the car is 10 m/s.

(D)During the first 10 seconds after starting, the average acceleration of the car is 1m/s^2.

（中文）車從靜止狀態起動，在平坦的公路上直線行駛 100 公尺，共花了 10 秒鐘。下列推論何者最適當？

(A)起動後第 10 秒末，該車的瞬時速度大小為 10m／s。

(B)起動後第 10 秒末，該車的瞬時加速度大小為 1m／s^2。

(C)起動後最初 10 秒期間，車子的平均速度大小為 10m／s。

(D)起動後最初 10 秒期間，車子的平均加速度大小為 1m／s^2。

（96 年國中基測 31）

解題 Solution：

因為題目僅提供 10 秒內的總位移，所以無法得知瞬時速度，以及其變化，故平均加速度和瞬時加速度也無從得知，選項(A)、(B)、(D)均無法判斷。而 10 秒內平均速度大小，等於位移大小除以時間：100／10＝10(m／s)，故答案選(C)。

Because the title only provides the total displacement in 10 seconds, we cannot know the instantaneous velocity, the average acceleration and the instantaneous acceleration from the title, therefore we cannot determine the correctness of (A)、(B)、(C); The average velocity within 10 seconds is equal to the displacement divided by time: 100/10=10 (m/s), so the answer is (C).

Teacher: What are the conditions for determining the instantaneous velocity or instantaneous acceleration of an object?

Student: We need a v-t graph or specific description regarding the velocity of each moment.

Teacher: Great! Therefore, we cannot know whether option A and option B are correct or not. How about option C and option D, which one is correct?

Student: The answer is (C).

Teacher: Why?

Student: Because the average velocity is the total displacement divided by the total time, and the title also gives us these two physical quantities, one hundred meters divided by 10 seconds equals 10 m/s. The answer is (C).

Teacher: Very good! Let me add more details. If it is the average acceleration mentioned by option D, it is necessary to divide the amount of velocity changed by time. Through this title we cannot know the magnitude of velocity change so there is no way to know the average acceleration.

老師： 如果想要知道物體的瞬時速度或是瞬時加速度需要有什麼條件？

學生： 需要 v-t 圖或是詳細的題目說明。

老師： 很好，因此 A、B 選項我們無從得知，那 C、D 選項哪一個才是正確的呢？

學生： C。

老師： 為什麼？

學生： 因為平均速度大小，是總位移量值除以總時間，題目給的也是這兩個物理量，因此 100 公尺除以 10 秒鐘等於 10m/s 就是選項 C 的答案。

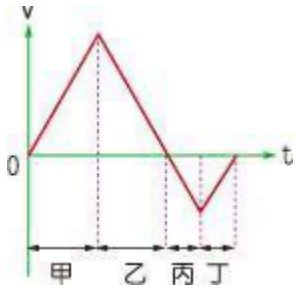
老師： 非常好！老師另外補充，若是 D 選項說的平均加速度，則是需要用速度變化量除以時間，本題無法得知速度變化量，所以也無從得知平均加速度。

例題二

說明：能識讀 v-t 圖，並辨別減速過程之時段。

To comprehend the meaning of the v-t graph, and determine the time duration of the deceleration process.

（英文）The graph on the right shows the relationship between Xiaoqing's motion velocity (v) and time (t). If he initially moved southward, during which of the following periods did his speed become slower and northward?



(A)甲　　(B)乙

(C)丙　　**(D)丁**

（中文）右圖為小清的運動速度（v）與時間（t）的關係圖。若他一開始的運動方向是向著南方，則下列哪一段期間，他的速度愈來愈慢且向著北方？

(A)甲　　(B)乙

(C)丙　　**(D)丁**

（97 年國中基測 53）

解題 Solution：

根據題目敘述，t 軸上方速度為正(向南運動)，t 軸下方速度為負（向北運動）。題目所問：愈來愈慢且向北，表示關係線落在 t 軸下方，且愈來愈接近 v=0，故答案選(D)。

According to the title, the velocity above the t-axis is positive (southward movement) and the velocity below the t-axis is negative (northward motion). The question is: Moving slower and northward represents the direction of the relationship line is below the t-axis and closer to v=0, so the answer is (D).

Teacher: The title is asking the segment that the velocity became slower, regardless of the direction, which option best describes this description?

Student: 乙.

Teacher: Good. 乙 is one of the segments, but there is another segment that the velocity becomes slower and slower.

Student: How can we know?

Teacher: There is a hint for you. The magnitude of the speed is closer to 0.

Student: Is it 丁?

Teacher: That's right! Then next please define the direction, 乙 and 丁 which one is the movement towards the north?

Student: It is 丁.

Teacher: That's right, because the relationship line of 丁 is below t-axis. The negativity is defined as moving northward, so the answer is 丁.

老師： 題目要問的是速度愈來愈慢的一段，先不考慮方向，請問甲乙丙丁哪一段符合此敘述？

學生： 乙。

老師： 很好，乙是其中一段，但還有一段也是速度愈來愈慢的。

學生： 怎麼判斷？

老師： 提示，是速度的「量值」愈接近 0 的。

學生： 是丁嗎？

老師： 沒錯！那接下來請判斷方向，乙和丁哪一段才是朝向北方的運動呢？

學生： 丁。

老師： 是的，因為丁這一段的關係線在 t 軸以下，「負的速度」在此題定義，是向北運動，因此答案選丁。

例題三

說明：熟悉平均速率的計算。

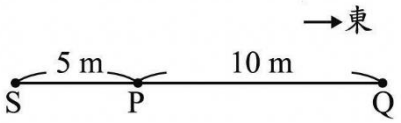
To know how to calculate average speed.

（英文）智耀 does shuttle runs on a straight way. He starts from point P and the path is P→Q→P→Q→P→S. The total time-spend is 15 seconds as shown in the picture. Which following can indicates the average rate of 智耀's shuttle run?

(A)0.33 m/s　(B)0.33 m/s, direction towards west

(C)3 m/s　(D)3 m/s，direction towards west

（中文）智耀在筆直的跑道上折返跑，他從 P 點起跑，其路徑為 P→Q→P→Q→P→S， 總共歷時 15 s，如圖所示。下列何者可表示此次智耀折返跑的平均速率？



圖(五)

(A)0.33 m/s　(B)0.33 m/s，方向向西

(C)3 m/s　(D)3 m/s，方向向西

（105 年國中會考 12）

解題 Solution：

根據定義：平均速率=路徑長/時間，路徑長 = 10 + 10 + 10 + 10 + 5 = 45 m，故平均速率 = 45/15 = 3 m/s，平均速率無方向，只看所行進的總長度。故選(C)。

According to definition: average speed = path length/time duration. The path length (total distance) = 10 + 10 + 10 + 10 + 5 = 45 m. So the average speed = 45/15 = 3 m/s. The average speed is directionless, which depend on the total path length. Therefore we need to choose (C).

Teacher: First, what does the title ask? Average velocity or average speed?

Student: Average speed.

Teacher: Does anyone know what to divide average speed by?

Student: The total path length (total distance) divided by time.

Teacher: That's correct.

Teacher: Can anyone answer the total distance of 智耀 in the 15 seconds?

Student: The total path length is 45 meters.

Teacher: That's right. Can you tell me how you calculate it?

Student: 10 + 10 + 10 + 10 + 5 = 45.

Teacher: Correct. So then we just divide 45 by 15 to get an average rate of 3 m/s.

老師： 首先，請問這個問題問的是平均速度，還是平均速率？

學生： 平均速率。

老師： 有沒有同學知道平均速率該用什麼除以什麼？

學生： 總路徑長除以時間。

老師： 正確。

老師： 有沒有哪位同學可以說出在這 15 秒內，智耀的路徑長為多少？

學生： 總共 45 公尺。

老師： 沒有錯，可以說說看你怎麼算的嗎？

學生： 10 + 10 + 10 + 10 + 5 = 45。

老師： 正確，因此接下來我們只要把 45 除以 15 就可以得到平均速率為 3 m/s。

1-3 加速度運動
Accelerated Motion

■ 前言 Introduction

本節旨在釐清加速度之概念，由於此概念對學生來說較抽象與進階，易與速度快慢混淆，因此透過滑車實驗，讓學生從實驗結果歸納出加速度的概念，並藉由 v-t 圖，讓學生熟悉加速度的推導。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
acceleration	加速度	trolley/cart	滑車
ticker timer	打點計時器	slope	斜坡
(ticker) tape	紙帶	average acceleration	平均加速度
steel strip	擊錘	movement with constant acceleration	等加速度運動

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

❶ **When the direction of acceleration and the direction of velocity are _____, the velocity of the object is getting _____.**

例句：**When the direction of acceleration and the direction of velocity are** the same/different, **the velocity of the object is getting** quicker/slower.

加速度方向與速度方向相同/相反時，物體的速度會愈來愈快/慢。

❷ **When the distance between two adjacent points on the ticker tape are _____, the trolley slides velocity becomes _____.**

例句：**When the distance between two adjacent points on the ticker tape are** greater/shorter, **the trolley slides velocity becomes** faster /slower.

紙帶上相鄰兩點的距離愈來愈大/小，代表滑車滑落的速度愈來愈快/慢。

❸ **In the v-t graph, the _____ the inclination of the line, the _____ the acceleration will be.**

例句：**In the v-t graph**, the greater **the inclination of the line**, **the** greater **the acceleration will be**.

在速度與時間的關係圖中，直線的傾斜程度愈大，加速度量值就愈大。

■ 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、認識加速度之定義，並能計算出平均加速度。

To know the definition of acceleration and be able to calculate average acceleration.

二、能識讀 v-t 圖，並判斷物體之加速度。

Be able to comprehend the meaning of v-t graph and determine acceleration from the graph.

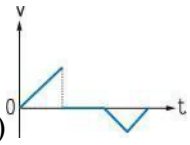
例題講解

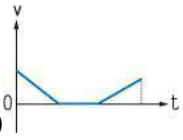
例題一

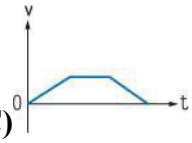
說明：正確判斷單向加速度運動，在 v-t 圖上呈現的意義。

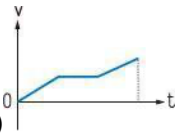
To comprehend the phenomenon of the v-t graph regarding the motion of single direction acceleration.

（英文）"After the green light is on, the car starts to accelerate from standstill. When the car reaches a certain speed, it drives at a constant speed until meeting a red light at the next intersection and then brakes down until it stops." Assuming the car makes linear motion, which v-t graph can possibly describe the motion of the car?

(A) 

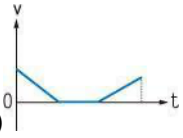
(B) 

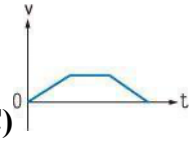
(C) 

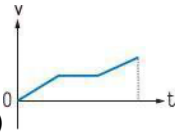
(D) 

（中文）「綠燈亮起後，車子由靜止開始加速，達到某一速度後以等速行駛，直到遇見下一個路口紅燈亮起後，煞車減速，直到停止。」假設車子做直線運動，則在此運動過程中，下列何者最可能為車子運動之速度（v）對時間（t）的關係圖？

(A) 

(B) 

(C) 

(D) 

（94 年第二次國中基測 3）

解題 Solution：

v-t 圖關係線中的斜率可代表其加速度:若往右斜上是代表加速，水平線代表維持等速，往右斜下，則代表減速。

The slop of the v-t graph can represent the acceleration of the object. When the curve tilted to the upper right side, it represents acceleration. If the relationship line is horizontal, it represents constant velocity. If the relationship line tilted to the lower right side, it represents deceleration.

Teacher: In this question all the options are v-t graphs, so we should think about the meaning of the direction of the relationship line on v-t graphs. Can anyone tell me which option best describes the v-t graph of the car starting to accelerate?

Student: (A)(C)(D).

Teacher: Good. Because at the beginning, the car is accelerating from stillness, the v-t graph should start from the zero and appear to tilt to the right. Then, what are the options for the next constant speed of the car that can fit the description of the title?

Student: All the options can fit it.

Teacher: Let's think about it again. There are two options that do not fit the description of uniform motion.

Student: A does not fit it?

Teacher: That's right. Can you explain why?

Student: Because the curve of A, falling back to the x-axis after acceleration, it represents static.

Teacher: Correct! So far we can make sure that the rest of answers are C and D. At last, we should check the final deceleration process of option C whether the relationship line is getting closer and closer to the t-axis?

Student: Option C fits this description.

Teacher: Very good. The line of option D appear to tilt to the right after the horizontal line means that it represents acceleration, so option D is not the answer. We can make sure the answer to this question is option C.

老師： 在這題裡面四個選項都是 v-t 圖，那我們就要回想 v-t 圖的關係線走向，代表什麼意思。有沒有人可以告訴我一開始車子加速的 v-t 圖比較接近哪個選項？

學生： (A)(C)(D)。

老師： 很好，因為剛開始，車子是正由靜止開始加速，所以 v-t 關係圖，應該由零點出發，呈現向右上傾斜。那麼，接下來車子等速行駛，有哪幾個選項符合這個敘述？

學生： 都符合。

老師： 再想想喔，等速行駛，在 v-t 圖中，應呈現水平線，所以(A)(C)(D)其中有一個是不符合的。

學生： (A)不符合嗎？

老師： 沒錯，可以解釋一下為什麼嗎？

學生： 因為(A)的曲線，加速後落回 x 軸，是代表靜止。

老師： 正確！因此答案只剩下(C)(D)。最後需再確認，等速（水平線）之後，為減速回到靜止，所以應該選哪一項？

學生： 選項(C)。

老師： 很好，因為選項(D)在水平線後，呈現向右上傾斜，表示進一步加速，不符題目之敘述，因此本題答案為(C)。

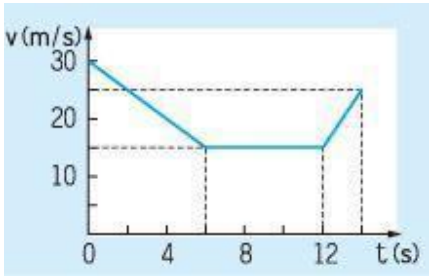
例題二

說明：能正確判別 v-t 圖上的初速和末速，並計算出平均加速度。
To determine the initial velocity and the final velocity on the v-t graph and be able to calculate the average acceleration.

（英文）The graph on the right is the v-t graph of a car driving on the straight road. Which option is the average acceleration during 0-12 seconds of the car?

(A)2.50 m／s^2　　(B)1.25 m／s^2

(C)－1.25 m／s^2　　(D)－2.50 m／s^2



（中文）右圖為一輛汽車在筆直公路上行駛之 v-t 圖。
關於汽車在 0～12 秒內的平均加速度，下列何者正確？

(A)2.50 m／s^2　　(B)1.25 m／s^2

(C)－1.25 m／s^2　　(D)－2.50 m／s^2

（92 年國中基測 34）

解題 Solution：

平均加速度＝（末速－初速）÷時間＝（15－30）÷12＝ －1.25（m／s^2）

Average acceleration = (final velocity − initial velocity) ÷ time = (15−30) ÷ 12 = −1.25(m/s^2)

Teacher: Do you remember how to calculate average acceleration?

Student: The amount of speed change divided by the time.

Teacher: Excellent! So under this question we only need to find the correct time and the amount of speed change. What is the time duration the title requires?

Student: 0-12 seconds.

Teacher: That's right. And then we should pay attention to the velocity corresponding to the 0th second and the velocity corresponding to the 12th second.

Student: The 0th second corresponds to 30m/s and the 12th second corresponds to 10 m/s.

Teacher: Are you sure? Give you one more chance. This relation graph is very small which is easy to see it mistakenly. So we should be careful!

Student: The 12th second corresponds to 15m/s.

Teacher: Correct. Therefore, take (15-30) m/s and divide it by 12 sec and it will be the answer.

老師： 同學還記不記得平均加速度怎麼求？

學生： 全部的速度變化量，除以時間。

老師： 太優秀了！就是這樣，因此本題只要找出對的時間和對的速度變化量即可。本題要問的時間區間是？

學生： 0~12 秒。

老師： 對，然後接下來要注意的，就是找到第 0 秒對應的速度，和第 12 秒對應的速度。

學生： 第 0 秒的速度是 30 m/s，第 12 秒對應到速度 10 m/s。

老師： 是嗎？再給你一次機會。這種關係圖小小的很容易看走眼，要注意喔！

學生： 第 12 秒的速度是 15 m/s。

老師： 正確，因此接下來只要拿(15-30) m/s 再除以 12 sec，就是答案。

1-4 自由落體運動
Free Fall Motion

■ 前言 Introduction

本節旨在介紹地心引力造成的加速度運動，但由於理想化條件下的自由落體運動，與真實狀況觀察到的情形，有許多矛盾之處，造成學生不易體會自由落體運動為等加速度運動。因此除了介紹重力加速度的定義之外，也可藉由觀賞科學影片，並輔以多個生活實例的探討，例如：高空彈跳等，協助學生熟悉重力加速度的意義及應用。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
free fall	自由落體	gravity	重力
air resistance	空氣阻力	free-fall acceleration	重力加速度

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

❶ **Drop light object and heavy object from _____. If we neglect air resistance, two objects will fall _____.**

例句：**Drop light object and heavy object from** the same height. **If we neglect air resistance, two objects will fall** at the same time.

輕物和重物從等高處釋放，若忽略空氣阻力，則兩者同時落地。

❷ **During free fall, the object moves with _____.**

例句：**During free fall, the object moves with** constant acceleration.

在自由落體過程中，物體作等加速度運動。

■ 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、認識重力加速度是因物體與地球間萬有引力所造成，為一個定值，與物體質量大小無關。

To know gravitational acceleration is caused by gravitational force between objects and the Earth, which is a constant, and has nothing to do with the mass of the object itself.

二、認識重力加速度的方向皆指向地心。

To know the direction of gravitational acceleration always pointing to the center of the Earth.

❧ 例題講解 ☙

例題一

說明：了解重力加速度與初速度無關的特性。

（英文）To understand that free-fall acceleration is independent of its initial velocity.

紹文 stands on the hill and throwing three identical tennis balls from the same position toward three different place, 甲、乙、丙, as the picture show. If the direction of 甲 is upward, the direction of 乙 is horizontal and the direction of 丙 is downward. Regardless of the air resistance of the tennis ball. During the flight after the tennis ball is thrown and before it lands, the acceleration magnitude is $a_{甲}$、$a_{乙}$、$a_{丙}$ respectively. Which option best describes the relationship?

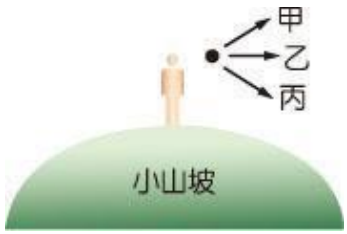
(A) $a_{甲} > a_{乙} > a_{丙}$　　**(B) $a_{甲} = a_{乙} = a_{丙}$**

(C) $a_{乙} > a_{甲} = a_{丙}$　　(D) $a_{丙} > a_{甲} > a_{乙}$

（中文）紹文在一小山坡上，將三個相同的網球由同一位置先後朝向甲、乙、丙三個不同方向拋出，如圖所示。若甲的方向偏上、乙的方向為水平、丙的方向偏下，且不計網球所受的空氣阻力，在網球拋出後且未落地前的飛行期間，它們的加速度大小分別為 $a_{甲}$、$a_{乙}$及 $a_{丙}$，則下列關係何者最適當？

(A) $a_{甲} > a_{乙} > a_{丙}$　　**(B) $a_{甲} = a_{乙} = a_{丙}$**

(C) $a_{乙} > a_{甲} = a_{丙}$　　(D) $a_{丙} > a_{甲} > a_{乙}$



（95 年第二次國中基測 24）

解題 Solution：

甲乙丙三顆球拋出後因不計空氣阻力，都只受鉛直方向的重力影響，因此三顆球的加速度均等於重力加速度，故 $a_{甲} = a_{乙} = a_{丙} = 9.8 m/s^2$。

After the three balls 甲、乙、丙 are thrown, they are only affected by the gravity of the straight direction regardless of air resistance, so the acceleration of the three balls is equal to the acceleration of gravity, so $a_{甲} = a_{乙} = a_{丙}$.

Teacher: This question seems complicated, but as long as it is a movement thrown out in the air, think first, what force is it affected by?

Student: Gravitational force only.

Teacher: What else?

Student: No.

Teacher: Good. Because the object has been thrown, the force from the hand has disappeared the moment it leaves the hand. Therefore the object is only affected by gravity during motion, so the generated acceleration is called free-fall acceleration, near the surface, regardless of the mass of the object, the amount of free-fall acceleration is the same. Therefore, the answer is (B).

老師：　這一題看起來很複雜，但只要是拋出去在空中的運動，就先想一下，他有受到哪些力的作用呢？

學生：　只有重力。

老師：　還有嗎？

學生：　沒有了。

老師：　很好，因為物體已經被拋出，所以手拋的力量在離開手的瞬間，已經消失。故物體在空中只受重力的作用，造成的加速度稱為重力加速度。在地表附近，無論物體的質量多大，重力加速度量值都是一樣的。因此答案選(B)。

例題二

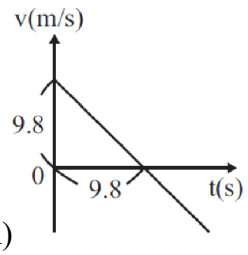
說明：認識速度正負號代表的意義，並能描繪出自由落體的 v-t 圖。

To know the meaning of positive and negative signs of velocity and be able to draw a v-t graph regarding free-fall motion.

（英文）Throw a ball straight up. The ball rises a bit, and then falls down. It is known that the free-fall motion is 9.8m/s^2, and if the influence of air resistance is not taken into account, the direction of velocity is positive with lead straight up and negative with lead straight down. Which of the following options is most likely to be a graph of velocity (v) vs. time (t) of the ball motion?

（中文）將一顆球鉛直上拋，球上升一段高度後便向下墜落。已知此地的重力加速度為9.8m/s^2，若不計空氣阻力的影響，速度方向以鉛直向上為正、鉛直向下為負。下列選項中，哪一個最可能是此球運動過程的速度(v)與時間(t)關係圖？

(A)



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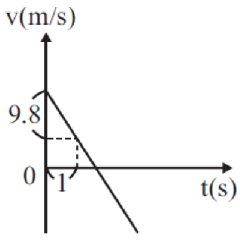
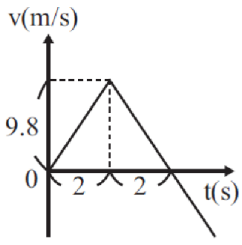
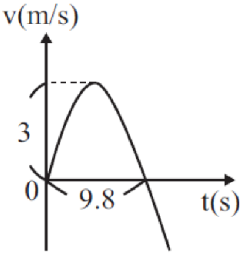


(C)



(D)



（110 年國中會考 43）

解題 Solution：

鉛直上拋，離手時的初速不為 0，但因為重力加速度，速度會隨著高度增加而減慢。到達最高點時，速度為零，接著物體反向下墜，速度變為負值，且速度隨時間增加而加大。

The ball is thrown straight up, the initial velocity is zero, but due to gravitational acceleration, the velocity slows down with increasing height. The velocity is zero when reaching the highest point, and then the object falls in reverse. The velocity becomes negative, and the velocity increases with time.

Teacher: Imagine if there is a velocity when the ball is first thrown?

Student: Yes, the initial velocity is up.

Teacher: Good, then, after the ball is thrown, will the speed increase or slowdown in the process of going up?

Student: decreasing.

Teacher: Good. Therefore, options that match the title are?

Student: A and B.

Teacher: Good. Keep observing. Graph A and graph B look alike, what is the difference between them?

Student: The degree of tilt of the relationship line is not the same.

Teacher: Good. Then which one matches the title?

Student: How to derive?

Teacher: First look at A, after 9.8 seconds, the velocity value decreases by 9.8; then look at B, it's your turn to try.

Student: After 1 second, the velocity value decreases by 9.8.

Teacher: Good. What amount of change does all of this tell us over the period of time?

Student: velocity.

Teacher: So what physical quantity is this telling us?

Student: Acceleration.

Teacher: Very good. Therefore, the acceleration of option B is calculated as $9.8 m/s^2$, which matches the magnitude of the Earth's free-fall acceleration, so the answer is B.

老師： 想像一下，球剛被拋出時，是否有速度？
學生： 有，初速度向上。
老師： 很好，接著，球被拋出後，在往上升的過程，速度會加快還是減慢？
學生： 減慢。
老師： 很好，因此符合題意敘述的選項是？
學生： A、B。
老師： 很好，繼續觀察一下，A、B 兩張圖長得超級像，差在哪裡？
學生： 關係線的傾斜程度不一樣。
老師： 很好，那麼哪一個才是符合題意的？
學生： 要怎麼看？
老師： 先看 A，經過 9.8 秒之後速度量值減少了 9.8；接下來看 B，換你們說說看。
學生： B 的話經過 1 秒之後，速度量值減少了 9.8。
老師： 很好，這些都在告訴我們一段時間內的什麼變化量？
學生： 速度。
老師： 因此這是在告訴我們什麼物理量的資訊？
學生： 加速度。
老師： 非常好，因此 B 選項的加速度算起來是 $9.8 m/s^2$，符合地球重力加速度量值的大小，所以答案選 B。

★主題二 力與運動★
Force and Motion

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■ 前言 Introduction

本章從運動學的定義及運算，進入牛頓三大運動定律，藉由定律及科學史的介紹，還有實驗觀察，使學生了解力與加速度的因果關係。語言部分，此章節比較多有關力的專有名詞以及力的定義介紹。

2-1 慣性定律
Law of Inertia

■ 前言 Introduction

藉由伽利略的思考性實驗(thought experiment)科學史，讓學生認識慣性定律的意義。同時介紹質量可代表物體的慣性，質量愈大的物體，愈不容易改變其運動狀態。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
inertia	慣性	thought experiment	思考性實驗
Newton's first law	牛頓第一運動定律	ramp	斜坡
mass	質量	frictionless surface	光滑平面
inertial mass	慣性質量		

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

❶ The _____ the object is, the _____ it is to change its motion state, which we call the object that has _____ inertia.

例句：**The** more mass **the object is, the** more difficult **it is to change its motion state, which we call the object that has** greater **inertia.**

質量愈大的物體，愈難改變其運動狀態，我們稱此物體具有較大的慣性。

❷ If the velocity of the object is_____, the velocity remains constant at _____ without any external force.

例句：**If the velocity of the object is** zero**, the velocity remains constant at** zero **without any external force**.

若物體速度為零，不受任何外力的情況下，速度恆保持為零。

■ 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、了解牛頓第一運動定律之意義。

To understand the meaning of Newton's first law of motion.

二、了解牛頓第一運動定律之適用條件。

To understand the conditions of Newton's first law of motion.

例題講解

例題一

說明：能判斷符合牛頓第一運動定律之敘述。

To determine the description which conforms to Newton's first law of motion.

（英文）雅婷 and 怡君 respectively shared their own views on Newton's first law of motion, which are described as the followings: 雅婷: If an object is not affected by external force, the object will remain at rest. 怡君: If the resultant force of an object in motion is zero, the object will always move at equal speed. Which of the following is correct in relation to the two?

(A)Both of them are correct.

(B)Neither of them is correct.

(C)Only 雅婷 is correct.

(D)Only 怡君 is correct.

（中文）雅婷和怡君分別對牛頓第一運動定律提出自己的見解，其敘述如下： 雅婷：若靜止的物體不受外力作用，則此物體會一直維持靜止。 怡君：若運動中的物體所受合力為零，則此物體會一直作等速度運動。 關於兩人的敘述下列何者正確？

(A)兩人均合理。

(B)兩人均不合理。

(C)只有雅婷合理。

(D)只有怡君合理。

（106 年國中會考 19）

解題 Solution：

根據牛頓第一運動定律，在物體不受外力或是合力為零的情況下，物體會維持原本的運動狀態。兩人的敘述皆符合上述的條件和結果，為合理敘述，故答案選 A。

According to Newton's first law of motion, an object will maintain its original state of motion when it is not subjected to external forces or the resultant force is zero. Both of their descriptions meet the above conditions and results, and the answer is A.

Teacher: Does anyone know what two conditions required by Newton's first law of motion?
Student: Objects are not subject to external forces.
Student: The resultant force on the object is zero.
Teacher: That's right. If there is no external force, the resultant force would be zero. Then the object is keeping rest or moving at constant velocity.
Teacher: Look at the title, does the description of the two people match this result?
Student: Yes! Both of them do!
Teacher: That's right. Therefore, both descriptions are correct. The answer goes to A.

老師： 牛頓第一運動定律需要的條件為何，有沒有同學知道？
學生： 物體不受外力。
學生： 物體受到的合力為零。
老師： 沒錯，不受外力，就必然合力為零。因此，只要合力為零，物體靜者恆靜、動者恆做等速度運動。
老師： 看一下題目，兩個人的敘述有否符合這個結果？
學生： 有的！兩個都有！
老師： 沒錯，因此兩個敘述皆是合理的，答案選 A。

例題二

說明：根據牛頓第一運動定律計算出物體受力情況。

To calculate the force on an object according to Newton's First law of Motion.

（英文）An object with a mass of 2 kg is placed on a horizontal table without friction. A horizontal right force F1, which is 6 N, is applied to the object to make it move in a straight line. After F1 applies force for 3s, an additional horizontal left force F2 is applied to this object, and the two forces act on the same straight line. It is known that this object moves at equal speed under the simultaneous action of F1 and F2. What is the magnitude of F2?

(A) 2 N　**(B) 6 N**　(C) 12 N　(D) 18 N

（中文）一質量為 2kg 的物體靜置於無摩擦力的水平桌面上，對此物體施以水平向右的力 F1 其大小為 6 N，使物體作直線運動。F1 施力 3s 後，對此物體再多施以一個水平向左的力 F2，且兩力作用在同一直線上，已知此物體在 F1 與 F 同時作用下作等速度運動，則 F2 的大小應為多少？

(A) 2 N　**(B) 6 N**　(C) 12 N　(D) 18 N

（109 年國中會考補考 30）

解題 Solution：

根據題目所知，物體在 F1 與 F2 同時作用下作等速度運動，此情形為牛頓第一運動定律所導致的結果--物體維持原本的運動狀態。因此回推物體受力條件應是和合力為 0，因此 F1 和 F2 為作用在同一物體上，大小相等但方向不同的力。答案選 B。

According to the title, the object moves at a constant velocity under the simultaneous action of F1 and F2. This is the result of Newton's first law of motion which states that object maintains its original state of motion. Therefore, it can be inferred that the net force on the object is zero, and F1 and F2 are forces of equal magnitude but opposite in direction acting on the same object. The answer should be option B.

Teacher: This question is quite long, but if we want to calculate the magnitude of the force, the key is to find the acceleration.

Student: But there is no acceleration in this question.

Teacher: That's correct. The key to this question is uniform motion. Please circle it. Think about what condition an object needs to have in order to undergo uniform motion on a frictionless surface.

Student: No force?

Teacher: But it's clear from this question that the object is subject to a force. Think again. There's another condition that can cause an object to undergo uniform motion on a smooth surface.

Student: The net force is zero?

Teacher: That's right. When the net force on an object is zero, the object remains at rest or moves at a constant velocity, as described by Newton's First Law of Motion. Therefore, knowing that there is no friction on the horizontal surface, what should be the relationship between F1 and F2?

Student: They should be of equal magnitude.

Teacher: Correct, because F1 and F2 act on the same object in opposite directions, for the net force on the object to be zero, the magnitudes of F1 and F2 must be equal and cancel each other out. The answer to this question is B.

老師： 這個題目很長，但此提要計算受力大小的話，關鍵在要找到加速度。

學生： 但這題沒有加速度。

老師： 沒錯，這題的關鍵在於等速度運動，請圈起來。想想看，物體要有什麼條件才能做等速度運動？

學生： 沒有受力？

老師： 但這題明顯可知物體有受力，再想想，還有甚麼可能，也導致物體在光滑平面上坐等速度運動。

學生： 合力為零？

老師： 沒錯，當物體所受合力為零，物體維持靜止或做等速度運動，此為牛頓第一運動定律的敘述。因此已知水平桌面無摩擦力，則 F1 和 F2 的關係應該是？

學生： 大小相等。

老師： 沒錯，因為 F1 和 F2 都作用在同一個物體上，而且方向相反，故要使物體合力為零，則 F1 與 F2 的大小要相等才會互相抵銷。本題答案選 B。

2-2 運動定律
Law of Motion

■ 前言 Introduction

本節旨在介紹牛頓第二運動定律之公式及其意義，也透過滑車實驗，歸納出力與加速度的因果關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
force	作用力	mass	質量
Newton's Second Law of Motion	牛頓第二運動定律	trolley	滑車
external force	外力	mass	砝碼
net force/resultant force	合力	ticker timer	打點計時器
acceleration	加速度	load tray	秤盤

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

❶ When____ is fixed, the greater_____, the smaller_____.

例句：**When** external force **is fixed**, **the greater** the mass of the object is, **the smaller** the acceleration will be generated.

固定外力的情況下，物體的質量愈大，產生的加速度愈小。

❷ When _____ is fixed, the _____ the external force is, the _____the acceleration will be generated.

例句：**When** the mass of an object **is fixed**, the greater **the external force is**, **the** greater the **acceleration will be generated**.

固定物體質量的狀況下，外力愈大，產生的加速度就愈大。

❸ When _____is fixed, the _____ the mass is, the _____ the external force is required.

例句：**When** the acceleration i**s fixed**, **the** greater **the mass is**, **the** greater **the external force is required**.

固定加速度的情況下，質量愈大，需要的外力就愈大。

■ 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、了解合力與加速度之因果關係。

To understand the relationship between total force and acceleration.

二、能應用牛頓第二運動定律於適用的情境。

Be able to apply Newton's second law to suitable contexts.

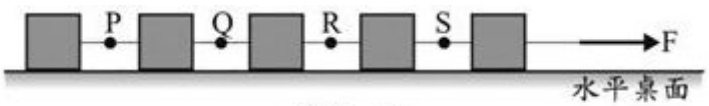
例題講解

例題一

說明：使用牛頓第二定律公式，在外力不變的情況下，推出加速度與質量之關係。

To apply Newton's Second Law to determine the acceleration corresponding to the change of mass when external force is fixed.

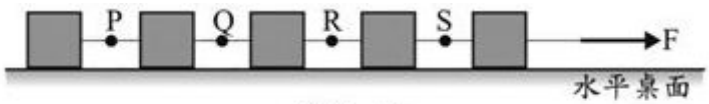
（英文）As shown in figure 18, connect five similar wooden blocks with strings and pull them with fixed horizontal force F, making five wooden blocks move in a straight line at the same speed on a horizontal table without friction. At the beginning, the acceleration of the five wooden blocks is the same as 2 m/s^2 .After a period of time, the string is cut at a certain position. It is known that the wooden block is still pulled by the same horizontal force F after the string was cut and its acceleration becomes 2.5 m/s^2. If the mass of the string is ignored, the cutting position should be which position P, Q, R, S on the figure?



圖(十八)

(A) P
(B) Q
(C) R
(D) S

（中文）如圖(十八)所示，將五個完全相同的木塊以細線連接，再以固定的水平力 F 拉動 木塊，使五個木塊以相同速度在無摩擦力的水平桌面上作直線運動。剛開始五個木塊的加速度大小同為 2 m/s^2 ，一段時間後，將某一位置的細線剪斷，已知剪斷後仍被相同的水平力 F 拉動的木塊其加速度變為 2.5 m/s^2 ，若忽略細線質量， 則剪斷細線的位置，應是圖上 P、Q、R、S 哪一個位置？



圖(十八)

(A) P
(B) Q
(C) R
(D) S

（104 年國中會考 32）

解題 Solution：

根據牛頓第二運動定律，ΣF=ma，在合力 ΣF 為定值的情況下，質量 m 減少，則加速度就會增加，且 m 乘以 a 為合力 F(保持定值)。假設每個木塊值量為 1kg，一開始有五個木塊，總質量為 5kg，加速度=2m/s^2，可算出 F=10N。後來質量改變，加速度變為 2.5m/s^2，根據牛頓第二運動定律，將外力除以加速度即可獲得後來的質量為 4kg，相當於少掉一個木塊，固應該從 P 剪掉線才符合題意，答案選 A。

According to Newton's second law, F=ma, when the external force is fixed, the mass m decreases, the acceleration increases, and m is multiplied by a as the fixed value F. Assuming that each block has a value of 1kg, there are five blocks at the beginning and the total mass is 5 kg, the acceleration = 2m/s^2. Hence F=10N can be calculated. Later, the mass changed, the acceleration became 2.5m/s^2. According to Newton's second law of motion, the external force can be divided by the acceleration to obtain a subsequent mass of 4kg, which is equivalent to missing a wooden block. Therefore, the string should be cut at P which matches the question. The answer goes to (A).

Teacher: The key to this question is to identify what is fixed and what changes in the problem statement.

Student: The external force F is fixed, while the mass m of the object experiencing the force is decreasing.

Teacher: Very good. This means we can apply Newton's Second Law of Motion.

Student: But I don't know the mass of the wooden block.

Teacher: That's right, the title does not provide mass, so let's assume it. Assume that the mass of each wooden block = 1kg. Please calculate the magnitude of the external force based on this information.

Student: The total mass of five wooden blocks is 5 kg. The acceleration is 2m/s^2. 5 times 2 equals 10, and the external force is 10N.

Teacher: That's right, the magnitude of the external force remains unchanged, but the acceleration becomes 2.5m/s^2. Can someone use Newton's second law to calculate the current mass?

Student: Just divide the external force by the acceleration.

Teacher: That's correct, so 10 divided by 2.5 equals 4, when the total mass of the wooden block is 4 kg.

Student: I see, so we need to cut the rope at point P, to allow 4 pieces of wooden blocks left.

老師：　這題關鍵在看題目什麼固定？什麼改變？

學生：　外力 F 固定，受力的質量 m 越來越小。

老師：　很好，所以適用牛頓第二運動定律。

學生：　但是我不知道木塊質量。

老師：　沒錯，題目的確沒有提供質量，所以我們自己假設，假設每個木塊質量=1kg，請根據這個資訊計算出外力的大小。

學生：　五的木塊總共 5kg，加速度為 $2m/s^2$，5 乘以 2 等於 10，外力為 10N。

老師：　沒錯，接下來外力大小不變，但加速度變成 $2.5m/s^2$，可否有人可以利用牛頓第二定律計算出當下的質量？

學生：　拿外力除以加速度就可以。

老師：　是的，因此 10 除以 2.5 等於 4，當時木塊總質量剩下 4kg。

學生：　我懂了，所以要從 P 點剪掉繩子，才會剩下 4 塊木塊。

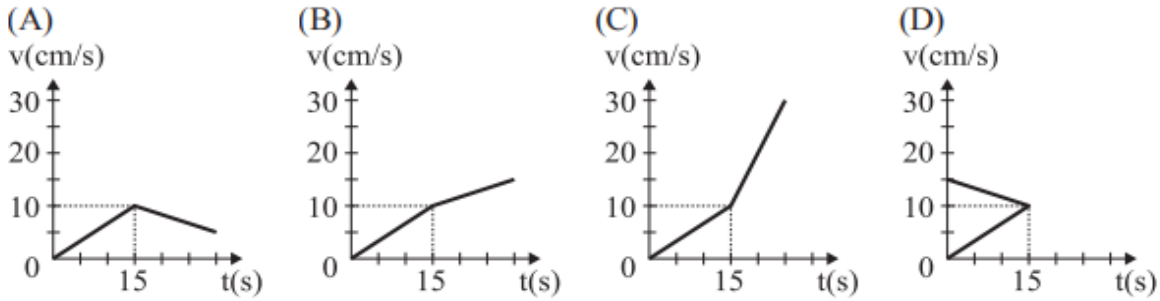
例題二

說明：了解對同一物體施力愈大，造成的加速度會愈大，且加速度具有方向性。

To understand the greater the force applied to the same object, the greater the acceleration caused and the acceleration is directional.

（英文）An object moves in a straight line to the east on a horizontal plane. Before the time t=15 s, the resultant force of the object is experienced F_1, heading east; After the time t=15 s, the resultant force of the object is F_2 and the direction is also eastward. If $F_1 > F_2$, which of the following is most likely to be the velocity (v) vs. time (t) graph?

（中文）一物體在水平面上向東作直線運動，在時間 t＝15 s 之前，物體所受合力大小為 F_1 方向向東；時間 t＝15 s 之後，物體所受合力大小為 F_2，方向也向東。若 $F_1 > F_2$，則下列何者最可能為其速度 (v) 與時間 (t) 的關係圖？



（109 年國中會考 24）

解題 Solution：

0-15 秒間，物體維持等加速度運動，因此預測 v-t 圖會是一條斜直線。15 秒後，物體受力變大但方向不變，根據牛頓第二運動定律，可知物體加速度變大但方向不變，因此 v-t 的關係線應該會是傾斜程度增加，故答案選 C。

Between 0 and 15 seconds, the object maintains a movement with constant acceleration, so the V-T graph is predicted to be an oblique straight line. After 15 seconds, the force of the object becomes larger but the direction does not change. According to Newton's second law of motion, it can be seen that the acceleration of the object becomes larger but the direction does not change, so the relationship line of v-t should be an increase in the degree of inclination, so the answer is (C).

Teacher: Class, do you still remember how to determine the magnitude and direction of acceleration from the V-t graph?
Student: The magnitude of the acceleration can be determined by the degree of inclination.
Teacher: Correct, and what about the direction of acceleration?
Student: Look at the direction of the slash.
Teacher: Correct, if it tilts to the upper right, it is accelerating, and if it is decelerating, it is tilting to the lower right.
Teacher: Therefore, the next step is to determine the acceleration change caused by different external forces. Can anyone tell me how the magnitude and direction of the external force change from the title?
Student: The external force becomes larger but the direction does not change.
Teacher: That’s correct. So we can infer how the acceleration of an object changes?
Student: The acceleration becomes larger but the direction doesn’t change.
Teacher: That's right. So what trend will the V-T relationship line show if the acceleration becomes larger but the direction does not change?
Student: The degree of tilt increases but the direction of inclination is fixed.
Teacher: That's correct. The figure that best matches the title of these four options is C.

老師： 同學們，還記得要如何從 v-t 圖中，判斷加速度的大小和方向嗎？
學生： 加速度的大小可以看傾斜程度。
老師： 正確，那麼加速度方向呢？
學生： 看斜線的方向。
老師： 正確，若是向右上方傾斜，就是加速，若是減速，就是向右下方傾斜。

老師： 因此接下來要判斷不同的外力，會如何影響加速度?有沒有人可以告訴我從題目中外力的大小和方向如何改變？

學生： 外力變大，但是方向不變。

老師： 沒錯，因此我們可以推斷物體的加速度會如何改變？

學生： 加速度變大，但是方向不變。

老師： 沒錯，當加速度變大但方向不變時，v-t 圖關係線會呈現什麼現象？

學生： 傾斜程度增加，但是傾斜的方向固定。

老師： 沒錯，因此在這四個選項中，最符合題意的圖為 C。

2-3 作用力與反作用力定律
Law of Action Force and Reaction Force

■ 前言 Introduction

本節介紹牛頓第三運動定律，利用實例，使學生理解“力”是來自兩物體之間的交互作用，稱之為作用力與反作用力，且兩者大小相等，方向相反。並透過實例，分析作用力與反作用力。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
action force	作用力	law of action and reaction	作用力與反作用力定律
reaction force	反作用力	Newton’s Third Law of Motion	牛頓第三運動定律
interaction	交互作用		

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

❶ Object A applies an action force on object B. Object B must produce an _____ and _____ on object A.

例句：**Object A applies an action force on object B. Object B must produce an** equal magnitude **and** opposite force **on object A.**

A 物對 B 物施加一個作用力，B 物會產生一個相等大小且方向相反的反作用力，作用在 A 物上。

❷ The _____ the force applied, the _____ the reaction force generated.

例句：**The** greater **the force applied**, **the** greater **the reaction force generated.**

施加的作用力愈大，產生的反作用力愈大。

■ 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、理解作用力與反作用力的大小、方向的關係。

To understand the magnitude and direction between the action force and the reaction force.

二、正確辨別出某作用力的反作用力。

To identify the reaction force of a given action-force.

例題講解

例題一

說明：正確認識牛頓第三運動定律。

To understand the concept of Newton's third law of motion.

（英文）阿問 applied a force of magnitude F with his hand, pushing the stake horizontally to the east, the stake still standing. His hand was pushed back by the stake for a reaction force. Which of the following is true about the action of its reaction force?

(A) The stake simultaneously pushes 阿問's hand horizontally westward with a reaction force of magnitude F.

(B) The stake simultaneously pushes 阿問's hand horizontally westward with a reaction force greater than F.

(C) The stake simultaneously pushes 阿問's hand horizontally eastward with a reaction force of magnitude F.

(D) The stake simultaneously pushes 阿問's hand horizontally eastward with a reaction force greater than F.

（中文）阿問以手施一大小為 F 的作用力，水平向東推木樁，木樁仍然立著不動，手受到木樁回推一個反作用力。關於其反作用力的作用情形，下列何者正確？

(A)木樁同時以大小為 F 的反作用力，水平向西回推阿問的手。

(B)木樁同時以大小大於 F 的反作用力，水平向西回推阿問的手。

(C)木樁同時以大小為 F 的反作用力，水平向東回推阿問的手。

(D)木樁同時以大小大於 F 的反作用力，水平向東回推阿問的手。

（104 年國中會考 8）

解題 Solution：

根據牛頓第三運動定律，反作用力與作用力之大小相等，方向相反，且作用在不同的物體上。因此答案選 A。

According to Newton's Third Laws of motion, the reaction force is equal to the magnitude of the action force in opposite directions, and acts on different objects.

Teacher: What is the relationship between action and reaction forces?
Student: Equal in magnitude and opposite in direction.
Teacher: Correct. If 阿問 applies an action force on the stake, then who exerts the reaction force on whom?
Student: The stake exerts a reaction force on 阿問.
Teacher: Correct. So the answer to this question is A.

老師： 作用力和反作用力之間，有什麼的關係？
學生： 大小相等，方向相反。
老師： 正確，而且如果阿問施一個作用力在木樁上，那麼反作用力是誰施加在誰身上？
學生： 木樁施一個反作用力在阿問身上。
老師： 正確，因此這題的答案是 A。

例題二

說明：認識作用力與反作用力的關係。
To know the relationship between action force and reaction force.

（英文）阿耀 applies the same magnitude of force F to different objects in three ways: 甲, 乙, and 丙, as shown in the table. In 甲, 乙, 丙, how many magnitudes of "F" and "F's reaction force" are different?

甲	Push a wooden block placed on a smooth horizontal table with a horizontal force F to the right.
乙	Lift a ball with a straight upward force F.
丙	Press down on a button with a lead straight down force F.

(A) 0
(B) 1
(C) 2
(D) 3

（中文）阿耀分別以甲、乙、丙三種方式施相同大小的力 F 作用於不同物體上，如表所示。則於甲、乙、丙中，「F」與「F 的反作用力」兩者大小不同的有幾個？

甲	以一水平力 F 向右推一個置於光滑水平桌面的木塊
乙	以一鉛直向上的力 F 舉起一顆圓球
丙	以一鉛直向下的力 F 壓下一顆按鈕

(A) 0
(B) 1
(C) 2
(D) 3

（102 年國中基測 48）

解題 Solution：

根據牛頓第三運動定律，作用力與反作用力的大小恆相等，故答案選 A。

According to Newton’s third law of motion, the magnitude of the action force and the reaction force are equal. Therefore, the answer is A

Teacher: This question is about a concept in Newton’s third law of motion, can anyone talk about it?
Student: The magnitude of the action and reaction forces is equal.
Teacher: Very smart. So the answer to this question is A.

老師： 這題是考牛頓第三運動定律中的一個概念，有沒有同學能說說？
學生： 作用力和反作用力的大小相等。
老師： 聰明，所以這題答案是 A。

2-4 圓周運動與萬有引力
Circular Motion and Universal Gravity

■ 前言 Introduction

牛頓第二運動定律也可應用於圓周運動，或是涉及萬有引力的行星運動。本節針對圓周運動與萬有引力的探討，使學生了解，力所造成的加速度，不僅可改變速度大小之一維運動現象，也可能改變速度方向之二維運動現象，如星體運行或任何曲線軌跡之運動。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
uniform circular motion	等速率圓周運動	radius	半徑
centripetal force	向心力	universal gravity/ gravitational force	萬有引力
centripetal acceleration	向心加速度	constant of gravitation	萬有引力常數
tangential velocity	切線速度	weight	重量

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

❶ **When an object makes a circular motion at an equal rate, the _____ the radius, the _____ the centripetal force required.**

例句：**When an object makes a circular motion at an equal rate,** the smaller **the radius, the** greater **the centripetal force required.**

物體做等速率圓周運動時，半徑愈小，需要的向心力愈大。

❷ **When two objects are _____ together, the _____ the universal gravity _____.**

例句：**When two objects are** closer **together, the** greater **the universal gravity** resulted.

當兩個物體的距離愈近，萬有引力愈大。

❸ **The _____ the masses of two objects, the _____ the universal gravity _____.**

例句：**The** greater **the masses of two objects, the** greater of **the universal gravity** between the two objects.

當兩個物體的質量愈大，彼此作用的萬有引力就愈大。

■ 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、了解物體圓周運動需要向心力，來造成向心加速度。

To understand that circular motion of an object requires centripetal force to produce centripetal acceleration.

二、了解加速度可能改變物體的運動方向。

To understand acceleration may change the direction of an object's motion.

三、認識萬有引力定律

To know the Law of Universal Gravity.

∞ 例題講解 ∞

例題一

說明：熟知萬有引力定律之內涵。

To understand the Law of Universal Gravity.

（英文）俊傑 and 美玲 each shares the following views on the law of universal gravitation:

俊傑: For example, the eraser on my desk attracts every object in the universe with the same amount of force, which is gravity.

美玲: For example, the Earth under my feet is very massive, so its gravitational pull on me will be much greater than my gravitational force on it.

Regarding whether the two people's views match the law of gravity, which of the following is true?

(A) Both of their views match.

(B) Neither of their views match.

(C) Only 俊傑's view matches.

(D) Only 美玲's view matches.

（中文）俊傑與美玲對於萬有引力定律分別提出以下看法：

俊傑：舉例來說，我桌上的橡皮擦，它以相同大小的力吸引著宇宙中的每一個物體，這種力就是萬有引力。

美玲：舉例來說，我腳底下的地球，它的質量非常大，所以它作用於我的萬有引力會遠大於我作用於它的萬有引力。

關於兩人的看法是否符合萬有引力定律，下列何者正確？

(A)兩人的看法均符合 **(B)兩人的看法均不符合**

(C)只有俊傑的看法符合 (D)只有美玲的看法符合

（109 年國中會考 45）

解題 Solution：

根據萬有引力定律，可知引力大小取決於兩物質量乘積和兩物之間的距離，不同質量物體的力大小不等。此外，兩物之間的萬有引力為一對作用力與反作用力，根據牛頓第三運動定律，大小恆相等，故兩人的敘述都有誤，答案選 B。

According to the law of universal gravity, it can be seen that the magnitude of gravity depends on the mass product of two objects and the distance between them, and the force of objects of different masses is not the same. In addition, the gravitational force between two things is a pair of action and reaction forces, and the magnitude is the same due to Newton's Third Law of Motion. So the answer is B.

Teacher: Let's first see what 俊傑 said. The eraser on the table will attract every object in the universe with the same size gravity. Is this correct?

Student: This is incorrect.

Teacher: So what's wrong? Can you take an example of the gravitational force between the eraser and other objects to show that the magnitudes of gravity would be always fixed?

Student: The gravitational force between the eraser and the pencil is not as large as the gravitational force between the eraser and the desk.

Teacher: Correct, it's a very good example. Therefore, 俊傑's statement is wrong. Next, let's see if 美玲's statement is correct. We know that the gravitational force between two things is a pair of action and reaction, so what is the relationship between this pair of gravitational forces between the earth and 美玲?

Student: Equal in size and opposite in direction.

Teacher: That's right, according to Newton's Third Law od Motion, 美玲's narrative does not fulfill the law of gravity. The answer is B.

老師： 我們先來看看俊傑怎麼說，桌上的橡皮擦會以相同大小的萬有引力，吸引著宇宙中的每個不同物體，對不對？

學生： 錯。

老師： 那麼錯在哪，可不可以舉個橡皮擦與其他物體間的萬有引力，來說明萬有引力的大小，永遠固定？

學生： 橡皮擦和鉛筆之間的萬有引力，與橡皮擦和書桌之間的萬有引力相比，是不一樣大的。

老師： 正確，非常好的舉例。因此俊傑的說法是錯的。接下來我們看看美玲的說法是否正確。我們知道兩物之間的萬有引力，是一對作用力與反作用力，因此地球和美玲之間，這一對萬有引力有什麼樣的關係？

學生：　大小相等，方向相反。

老師：　沒錯，根據牛頓第三運動定律，美玲的敘述也不符合萬有引力定律，這題答案應該要選 B。

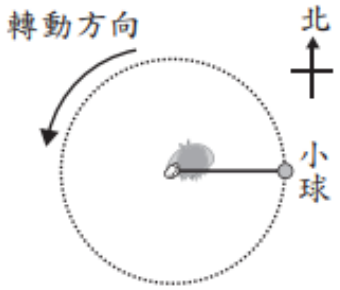
例題二

說明：能夠從圓周運動的軌跡，判斷每個瞬間的位置，及其切線方向，並推出其速度方向。

To understand the direction of an object's velocity is tangential when it is moving with uniform circular motion.

（英文）Fix the ball at one end of the string. 阿峰 holds the other end of the string, and he uses the end as an application of force point to make the ball do a uniform circular motion on the horizontal plane, and the position of the hand remains motionless. It is known that the ball rotates 2 times per second, and when the time t=0 s, the ball is located due east of the hand, and its top view is shown in Figure (21), at the time t=3 s, the velocity direction of the ball is which of the following?

(A) Due east
(B) Due west
(C) Due south
(D) Due north



圖(二十一)

（中文）將小球固定在細繩的一端，阿峰手持細繩的另一端，施力使小球在水平面上作等速率圓周運動，手的位置保持不動。已知小球每秒旋轉 2 圈，且當時間 t＝0 s 時小球位於手的正東方，其俯視圖如圖(二十一)所示，在時間 t＝3 s 時，小球的速度方向為下列何者？

(A)正東方 (B)正西方
(C)正南方 (D)正北方

（110 年國中會考 39）

解題 Solution：

已知小球每秒轉兩圈，因此第三秒時小球恰回到阿峰的東方，此時，小球的切線速度向北方。

The ball is known to rotate twice per second, so at the third second the ball returns due east of 阿峰, at which point the tangent velocity of the ball is due north.

Teacher: The velocity of each position on the uniform circular motion follows the tangent direction. This question should determine which point on the circumference of the ball in the third second, so we can further judge the tangent direction. Can anyone tell me where the ball is in the third second?

Student: Right side.

Teacher: The right side is the east of the question, and the ball is counter blocked. Therefore, in this position, the tangent velocity of the ball is northward. The answer is D.

老師： 等速率圓周運動過程，每個位置的速度均沿切線方向，因此本題要判斷，在第 3 秒時小球在圓周上的哪一個點，就可以進一步判斷切線方向。有沒有同學可以告訴我小球第三秒的位置在哪邊？

學生： 右邊。

老師： 右邊即是題目指的東方，且小球是逆時鐘轉，因此在這個位置，小球的切線速度是向北方，答案選 D。

2-5 力矩與槓桿原理
Torque and Lever Principle

■ 前言 Introduction

物體的運動除了移動還有轉動，本章旨在探討影響物體轉動效果的因素，進而介紹力矩，並且介紹力矩在生活中的應用——槓桿原理。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
torque	力矩	rotation	轉動
moment arm	力臂	counterclockwise	逆時針
force	作用力	clockwise	順時針
extending line of acted force	力的延伸線	net torque/resultant torque	合力矩

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

❶ The _____ the moment arm is, the _____ it is to cause rotation.

例句：**The** longer **the moment arm is**, **the** easier **it is to cause rotation**.

力臂愈長，愈容易造成轉動。

❷ Under the same moment arm, the _____the force is, the _____ the torque is.

例句：**Under the same moment arm, the** greater **the force is, the** greater **the torque is.**

力臂相同的條件下，作用力愈大，造成的力矩愈大。

■ 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、認識力矩會造成物體由靜止開始轉動。

To know that a torque causes an object to rotate from rest.

二、了解轉動平衡的條件。

To understand the conditions for achieving rotational equilibrium.

例題講解

例題一

說明：了解力矩平衡。

To understand torque equilibrium.

（英文）A father took his son and daughter to the park to play seesaw. The position where the three sat was shown in Figure (3), and the weight of the father, son and daughter was 75 kgw, 20 kgw, and 25 kgw respectively. At this time, "the weight of the father makes the torque generated by the seesaw" is greater than "the weight of the son and daughter makes the torque generated by the seesaw", and the seesaw will fall to the father's end. If they want to reduce the gap between the torque on both sides, with the following ways to adjust the position, which one may achieve their purpose?

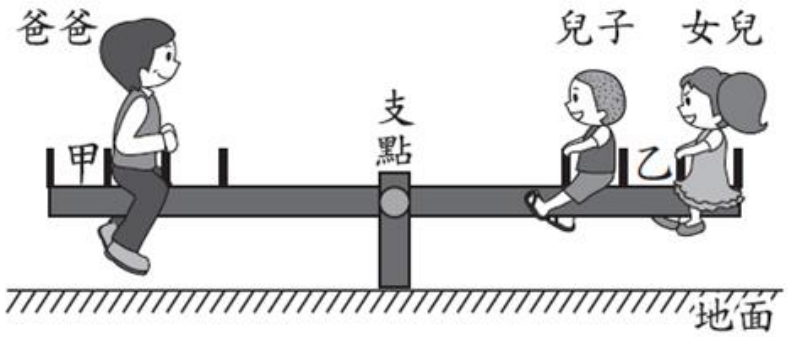
(A) Dad switched to position A.

(B) The son switched to position B.

(C) The daughter shifts to position B.

(D) The son and daughter change positions.

（中文）爸爸帶著兒子與女兒到公園玩蹺蹺板，三人所坐的位置如圖(三)所示，爸爸、兒子、女兒的體重分別為 75 kgw、20 kgw、25 kgw。此時「爸爸的體重使蹺蹺板產生的力矩大小」大於「兒子與女兒的體重使蹺蹺板產生的力矩大小和」，蹺蹺板將倒向爸爸那一端，若他們希望減少兩邊力矩的差距，則下列調整位置的方式，哪一個可能達到他們的目的？



圖(三)

(A)爸爸換到位置甲。

(B)兒子換到位置乙。

(C)女兒換到位置乙。

(D)兒子、女兒的位置互換。

（106 年國中會考 5）

解題 Solution：

從題目可知，蹺蹺板倒向爸爸那邊，指的是爸爸造成的力矩，大於兒子加女兒造成的力矩。因此爸爸向靠近支點移動，或是兒子女兒其中一人遠離支點，均能減少力矩的差距，故答案選 B。

From the title, we can know that the seesaw falling to the father's side means that the moment caused by the father is greater than the moment caused by the son and daughter. Therefore, the father moves close to the fulcrum or one of the son and daughter moves away from the fulcrum can achieve a reduction in the torque gap. The answer is B.

Teacher: It is known from the title that which is the greater torque caused by Dad or caused by the son and daughter?

Student: The torque caused by Dad.

Teacher: That's right, so there are two ways to reduce the gap in torque. One way is to reduce Dad's torque and the other way is to increase the torque of the son and daughter, what to do?

Student: Dad sits forward or the son sits back.

Teacher: That's right, both methods are fine, so why can't daughter and son exchange seats?

Student: The heavier you are, the better you sit back, but the daughter is heavier than the son, so the son has to sit back to have an effect.

Teacher: That's correct. Therefore the answer is B.

老師： 從題目已知，爸爸造成的力矩，和兒子加女兒造成的力矩哪一個大？

學生： 爸爸的。

老師： 沒錯，因此要減少力矩差距有兩個方法，減少爸爸的力矩或是增加兒子加女兒的力矩，這要怎麼辦到？

學生： 爸爸往前坐，或是兒子往後坐。

老師： 沒錯，這兩個方法都可以，那為什麼女兒和兒子不能交換坐？

學生： 要愈重的愈往後坐愈好，但女兒比兒子重，所以兒子往後坐才有效果。

老師： 正確，所以這題答案選 B。

例題二

說明：熟悉力矩的計算。

To become familiar with calculating torque.

（英文）As shown in Figure (10), bacon and roast duck are hung with string on both sides of a lever, and after hanging the lever is still maintained horizontally balanced. At this time, the bacon causes the lever to produce a counter-clock torque of 0.2 kgw · m. If we neglect the amount and friction at the fulcrum of the lever and string, which of the following statements is correct?

(A) The mass of bacon is 2 kg.

(B) The mass of the roast duck is 4 kg.

(C) The clockwise moment produced by the roast duck is 0.2 kgw · m.

(D) The clockwise moment produced by roast duck is 0.4 kgw · m.

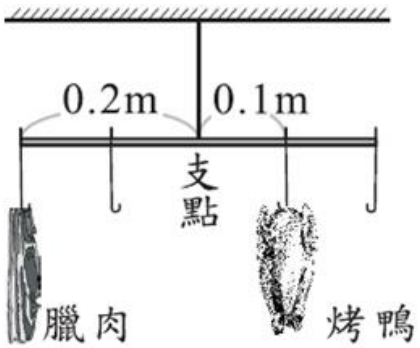
（中文）如圖(十)所示，在一個槓桿兩側分別以細繩吊掛臘肉與烤鴨，吊掛後槓桿仍保持水平平衡。此時臘肉使槓桿產生 0.2 kgw · m 的逆時鐘力矩，若槓桿、細繩的質量與支點處的摩擦力皆忽略不計，則下列敘述何者正確？

(A)臘肉的質量為 2 kg。

(B)烤鴨的質量為 4 kg。

(C)烤鴨產生的順時鐘力矩為 0.2 kgw · m。

(D)烤鴨產生的順時鐘力矩為 0.4 kgw · m。



圖(十)

（104 年國中會考 17）

解題 Solution：

由題目已知，此情形已達轉動之平衡，故臘肉造成的逆時針力矩，等於烤鴨造成的順時針力矩。根據力矩的定義，烤鴨的重量為 0.2kgw-m/0.1m=2kgw，臘肉重量為 0.2kgw-m/0.2m=1kgw，故答案選 C。

It is known from the topic that this situation reaches a rotational equilibrium, so the counterclockwise moment caused by bacon is equal to the clockwise moment caused by roast duck. According to the torque definition, it can be known that the weight of roast duck is 0.2kgw-m/0.1m=2kgw, and the weight of the bacon is 0.2kgw-m/0.2m=1kgw, so the answer is C.

Teacher: From the title, it is known that this situation has reached a rotational equilibrium, and the counterclockwise moment caused by bacon is equal to the clockwise moment caused by roast duck, so what is the torque value of roast duck?

Student: 0.2kgw · m.

Teacher: What about the direction of the torque of the roast duck?

Student: clockwise.

Teacher: Very good, then we can further calculate the quality of the roast duck. Does anyone know how to calculate it?

Student: 0.2 divided by 0.1.

Teacher: Correct, so the weight of the roast duck should be 2 kgw. Similarly, the weight of the bacon is 0.2kgw-m/0.2m=1kgw. So, the answer is C.

老師： 從題目知，此情形已達轉動平衡，臘肉造成的逆時針力矩等於烤鴨造成的順時針力矩，所以烤鴨的力矩值是多少？

學生： 0.2kgw · m。

老師： 烤鴨力矩的方向呢？

學生： 順時針。

老師： 很好，那麼我們可以進一步計算出烤鴨的重量，有沒有人知道怎麼算？

學生： 0.2 除以 0.1。

老師： 正確，所以烤鴨重量應該是 2kgw。同理，臘肉重量為 0.2kgw-m/0.2m=1kgw，答案選 C。

★主題三 功與能★
Work and Energy

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■ 前言 Introduction

本章節中，介紹力與能量的關係，並應用於各種簡單機械中。整章將會從力如何作功，接續到能量有哪些種類、作功會改變物體的什麼能量、能量在什麼條件下會守恆，到最後將這些知識用於槓桿、滑輪、輪軸等簡單機械之力與能量的探討。

3-1 功與功率
Work and Power

■ 前言 Introduction

本節介紹力透過位移可以作功的概念，當物體受力，且物體能沿著施力方向產生位移，則此力對物體作功。力量作功可能可以改變物體的動能。另外，也定義功率為每單位時間對物體所作的功。

使用英語時，教師可以多引入生活範例，逐漸帶出力作功與速率變化，之間的關係。並提醒學生速度與速率的差別，以及其英文用語的差異，另外也讓學生熟悉描述方向的英文單字（如：向左、向右、向上、向下、垂直、水平），最後再延伸到較抽象的功與能量。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
work	功	velocity	速度
energy	能量	friction force	摩擦力
power	功率	watt	瓦特
joule	焦耳	perpendicular	垂直
external force	外力	positive work	正功
displacement	位移	negative work	負功

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

❶ The greater _____, the faster _____.

例句：**The greater** displacement the force pushes an object, **the faster** the velocity will be generated.

力使物體移動的距離愈長，產生的速度就愈大。

❷ Although _____, _____.

例句：**Although** the external force acts both 10 joules on two objects, the time duration of the exerting the two work may be different.

雖然施力對兩物作功皆為 10 焦耳，但兩力作功的時間長短可能不同。

❸ What is the relationship between _____ and _____?

例句：**What is the relationship between** the velocity **and** the velocity variation of an object?

物體的速度與速度變化，有何關聯呢？

❹ _____ from _____ to _____.

例句：Push an object **from** the origin **to** the position of 20 meters.

將物體從原點推至 20 公尺處。

❺ _____ is either _____ or _____.

例句：The exerted external force and the object's velocity could **be either** perpendicular **or** parallel to each other.

外力與物體速度，可能互相垂直或平行的。

■ 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、了解力與功的關係，並懂得施力方向與物體位移方向的夾角不同，會影響作功大小。

Understand the relationship between force and work, and knowing that the angle between the exerted force and the object's displacement would affect the magnitude of work.

二、了解功與功率的關係，並計算不同情況的功率。

Understand the relationship between work and power, and can calculate the power in different situations.

❧ 例題講解 ☙

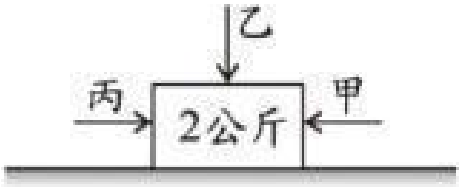
例題一

說明：知道力與位移內積，就是作功的大小。

Know that the resultant force dot product the displacement of the object is called work.

（英文）There are three forces called 甲, 乙, and 丙 acting on a two kilogram object upon a smooth and horizontal surface. According to the diagram, force 甲 is a 10N force pointing to the left, force 乙 is a 3N downward force, and the force 丙 is a force to the right. The object moves 3 meters to the left when the three forces are applied, and the net force to this object works 24 joules. How many Newton is force 丙?

(A)2　(B)4　(C)6　(D)8



（中文）一個質量為 2 公斤的物體在光滑水平面上同時受到甲、乙、丙三力作用，如圖所示，甲力水平向左 10 牛頓，乙力鉛直向下 3 牛頓，丙力水平向右。三力作用期間，物體水平向左移動 3 公尺，合力對此物體共作功 24 焦耳，則丙力的大小為多少牛頓？

(A)2　(B)4　(C)6　(D)8　（99 年第一次基測 54）

解題 Solution：

所作的功為$W = \vec{F} \cdot \vec{S}$ 其中，力與位移平行的分量，才有效。因為位移方向向左，所以只需考慮向左/右的力，向上/下的力不需考慮。

因此作功＝ [甲力－丙力]$\cdot 3 = (10 - F) \times 3 = 24$，$10 - F = 8$，$F = 2$(N)。故選(A)。

The total work can be calculated by $W=\vec{F}\cdot\vec{S}$. Besides, the force which is parallel to the displacement is the effective one. As a result, we only need to consider the left and right force, but not the upward and downward force while the direction of the displacement is left.

The work equals to force 甲 minus force 丙, and then times three $= (10 - F) \times 3 = 24$, $10 - F = 8$, $F = 2$(N). So, the answer is (A).

Teacher: What is the definition of work?

Student: Work is force times the displacement.

Teacher: Both force and displacement are vectors, so the multiplication of the two can be either an inner product or an outer product. Which one should it be?

Student: It might be the inner product of force and displacement.

Teacher: Great! As a result, only the force which is parallel to the displacement can act effectively. According to the diagram, which force do you think is acting on the object?

Student 1: I think both force 甲 and 乙 are acting on the object, because both of them are pushing it.

Student 2: Are you sure? Force 乙 is vertical to the object, I'm wondering if it is acting on the object.

Teacher: You found the main point! When the force is vertical to the displacement of the object, the work will be zero.

Student: Then, there only left force 甲 and 乙. Should we calculate the net force times the displacement first?

Teacher: Right! When force and displacement are in the same direction, it will be positive work. On the other hand, the work done becomes zero when force and displacement are perpendicular to each other. Let's set force 丙 as F and we can know the net force equals $(10 - F)$. The net force times the displacement is 24 joules as mentioned in the question. Then, we can get the formula, $(10 - F) \times 3 = 24$, and get the answer of F.

老師： 作功的定義是什麼？

學生： 力乘以位移。

老師： 力與位移都是向量，所以兩者相乘，可以是內積或是外積，應該是哪一種呢？

學生： 應該是力與位移的內積。

老師： 很好，所以，只有與位移相平行的力，才能有效地作功。從圖來看，你們覺得哪些力有對物體作功呢？

學生 1： 應該甲、乙和丙都有作功吧，因為他們都有對物體出力。

學生 2： 是嗎？可是乙出的力是跟物體位移垂直，這樣有作功嗎？

老師： 你發現重點了！施力的方向跟位移垂直時，這種力不會作功。

學生： 那剩下甲跟乙兩個力，是不是要先算合力再乘上位移呢？

老師： 是的，因為施力跟位移方向同向時，作功為正，施力跟位移方向相反時，作功為負，所以先假設丙力為 F，寫出合力為 $(10-F)$，合力再乘上位移 3 公尺，就是題目寫的 24 焦耳，$(10-F)\times 3=24$，即可得到 F 的大小。

例題二

說明：從力的單位，推導出功率的單位。

Students can speculate the unit of power.

（英文）The unit of force is N (Newton). The unit of length is m (meter), and the unit of time is s (second). We can know the physical meaning of the physical quantity through different combinations of units. Work is defined as the magnitude of the force multiplied by the distance moved in the direction of the force, and power is defined as the rate of work done per unit time. According to the description, which of the following answers is the unit of power?

(A) N × s (B) N × m × s **(C) N × m/s** (D) N × s/m

（中文）力的單位為 N(牛頓)，長度的單位為 m(公尺)，時間的單位為 s(秒)，由單位的組合即可推知該物理量的物理意義。功的定義為作用力乘以物體沿作用力方向的位移，功率的定義為單位時間內所作的功，由此可知下列何者為功率的單位？

(A) N × s (B) N × m × s **(C) N × m/s** (D) N × s/m

（103 年國中會考 15）

解題 Solution：

功率=功/時間，作功=力×位移，因此：功率=力 × 位移/時間，單位為(C) N × m/s。

Power is defined as work divided by time, where work is defined as force multiply displacement Thus, power is equal to force multiplied by the distance then divided by time. Thus, the unit of power is (C) N × m/s.

Teacher: Power is the efficiency of doing work. For example, if there are two machines which do the same work, but one spends less time than the other, then the one that spends less time has better efficiency. Thus, power not only depended on the amount of work, but also depended on the time duration. So, how can we compare the efficiency of the work?

Student: We can let the work be divided by time so that we can compare the work done per unit time.

Teacher: That's right! If we put the time as the denominator and the work as the numerator, the denominator unit of power will be second in SI units. In addition, the numerator unit will be the unit of work. Do you still remember how to calculate the magnitude of work?

Student: Yes! Work equals to force multiplied by the distance.

Teacher: Correct. The unit of force is Newton (N), and the unit of distance is meter (m), so the numerator unit is N times m. After understanding this, we can know the unit of power is N times m divided by s. According to the unit, we can also know its physical meaning of power is work done per unit time. That's why the question mentioned that we can speculate the physical meaning through the combination of units.

老師： 功率就是作功的效率，假設有兩台機器作功相同，但是一台機器花的時間比較少，其效率就會比較好。因此功率除了跟作功有關，也跟作功時間有關，我們該如何比較作功的效率呢？

學生： 可以把功除上時間，這樣比較的就是單位時間所做的功了！

老師： 沒錯，若將時間放在分母，功放在分子，那麼功率分母的單位就會是 SI 制中的秒。而分子的單位就是功的單位，還記的如何計算作功的大小嗎？

學生： 作功是力乘上位移。

老師： 對，力的單位是牛頓，位移單位是公尺，所以分子(作功)的單位是 N × m = Joule，因此功率的單位就是 N × m/s = Joule/s，從功率的單位也可看出，其物理意義就是單位時間內所作的功，因此題目才說單位的組合即可推知該物理量的物理意義喔！

3-2 功與動能
Work and Kinetic Energy

■ 前言 Introduction

本節從被速度較快的球打中會較痛當作引導，先介紹動能，再將動能與前一節的功做連繫，最後找出功與能的關係，討論到外力與物體運動方向相同或相反的情況，以及外力作正功或負功時，動能將會如何變化。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
acceleration	加速度	velocity	速度
kinetic energy	動能	friction	摩擦力
speed	速率	potential energy	位能

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

❶ make_____ + 原形動詞.

例句：When an external force has done positive work on an object, it may **make** the object **gain** kinetic energy.

外力對物體作正功，可以使其獲得動能。

❷ On the other hand, _____.

例句：**On the other hand,** an object in motion is capable of doing work on other objects.
另一方面，運動中的物體也具有對其它物體作功的能力。

■ 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、知道能量有動能、位能、光能與電能等，不同的形式，且可以互相轉換。
Know that there are different forms of energy which can be converted to each other, including kinetic energy, potential energy, light energy, and electric energy.

二、了解力可以透過作功並改變物體的能量。
Understand that force may change an object's energy by means of doing work of it.

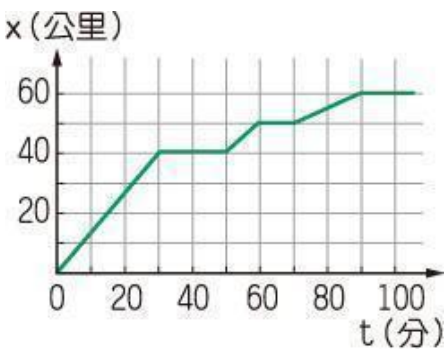
三、能透過距離、速度與時間等，來描述物體的運動。
Be able to describe objects' motion in terms of distance, speed and time.

❧ 例題講解 ☙

例題一

說明：能從 x-t 圖分析出速度大小，並藉此推估動能變化。
Be able to analyze the velocity through the position versus time graph, and further determine the change of kinetic energy.

（英文）The relation between position (x) and time (t) are given in the figure for a truck moving along a straight line. The truck starts to move when time t = 0. If the mass of products on the truck is constant, which of the following moments does the products have the greatest kinetic energy?



(A) t = 20 minutes　(B) t = 40 minutes
(C) t = 55 minutes　(D) t = 75 minutes

（中文）圖為某貨車作直線運動的位置（x）與時間（t）的關係圖，貨車在 t＝0 時開始移動，若貨車內貨物質量固定不變，則貨物在下列哪一時刻的動能最大？

(A)t＝20 分 (B)t＝40 分 (C)t＝55 分 (D)t＝75 分

（101 年國中基測 32）

解題 Solution：

當質量不變時，速率愈快，動能愈大；在位置和時間關係圖中，關係線的傾斜度愈大，代表速率愈大。由圖形可知 t 在 0～30 分之間關係線最陡，所以速率最大。又因動能與速率平方成正比，此區域的動能最大，故選(A)。

When the mass is constant, the faster the speed is, the greater the kinetic energy will be. In the position-time graph, the steeper the slope of the line is, the greater the speed will be. According to the figure, we can know that the largest v exists when t is between 0 to 30 which means the speed is the fastest in that period. Furthermore, the kinetic energy is proportional to the square of the speed. So, the answer is (A).

Teacher: Do you know the relationship between the position and the speed?

Student: I know! Speed is the distance traveled by a moving object per unit time.

Teacher: Yes! The speed can also be acquired by manipulating. Thus, the slope of the line in the position-time graph is the speed at each moment.

Student: Does it mean that the steeper the slope is, the greater the speed will be?

Teacher: Exactly! Then, which part in this figure shows the steeper slope?

Student: The steepest slope exists from the time 0 to 30 minutes. If the mass of the object is constant, it means that the kinetic energy is the greatest during that period.

老師： 你們知道位置與速率的關係嗎？

學生： 我知道，單位時間移動的路程就是速率。

老師： 是的，速率也可以透過而求得，所以速率等於在 x-t 圖中，關係線的斜率。

學生： 所以，若斜率越大，就代表速率越快嗎？

老師： 沒錯！關係線越陡，則斜率越大，速率就越快。
在這個圖中哪個部分斜率最大呢？

學生： 在時間為 0～30 分鐘之間，斜率最大，若物體質量不變，那就代表那一區間的動能最大。

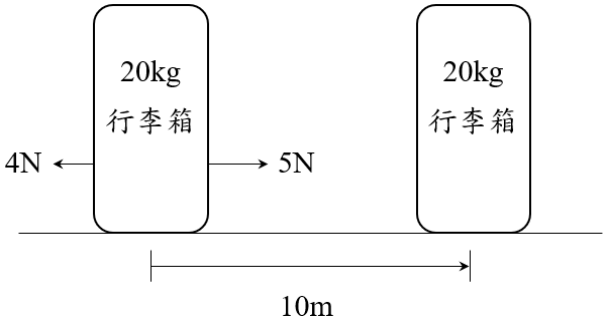
例題二

說明：學生能分析不同外力做功與動能變化的關係。

Students can analyze the relationship between the work done by different external forces and the change of kinetic energy.

（英文）小雄 use a horizontal force of 5N to push a suitcase which is 20kg, and the suitcase moves horizontally for 10m with kinetic energy. Assuming that the suitcase is originally stationary, and the friction force between it and the horizontal ground is 4 N when moving. How much does the kinetic energy of the suitcase increase after 小雄 pushes the suitcase for 10 m?

(A)10J　(B)20J　(C)30J　(D)40J



（中文）小雄以 5 N 的水平力推質量為 20 kg 的行李箱，行李箱水平移動了 10 m，並具有動能。假設行李箱原來靜止，且在移動時它與水平地面間的摩擦力為 4 N，則在小雄推動行李箱 10 m 之後，行李箱的動能增加了多少？

(A)10J　(B)20J　(C)30J　(D)40J

（95 年第二次國中基測 36）

解題 Solution：

所有的外力=拉力−摩擦力= 5 − 4 = 1 N。外力和對行李箱所作的功＝箱子增加的動能=箱子末動能−箱子初動能= $\vec{F}\cdot\vec{S}$ =1 N × 10 m = 10 N · m = 10 J。故答案為(A)。

The resultant external force equals the pull minus the friction force. (5 − 4 = 1 N) The work done by the external force on the suitcase equals the increasing kinetic energy of the suitcase, which is also equal to the final kinetic energy of the suitcase minus the initial kinetic energy of the suitcase.

The formula of increasing kinetic energy is $\vec{F}\cdot\vec{S}$ (force times distance) = 1N × 10m = 10 N·m which is 10 J. The correct answer is (A).

Teacher: What does the work-energy theorem mean?

Student: It means that the work of the external force equals the change of the energy.

Teacher: That's right. To be more specific, it means the work of resultant force equals the change of kinetic energy.

Teacher: Then, in this question, how much is the total of the external force on the object? If we assume the right side to be positive.

Student: If the direction to the right is positive, the friction force to the left will be -4N, so the total external force will be 5 N – 4 N = 1 N (5 N minus 4 N equals 1 N).

Teacher: Good job! Then what kind of energy changes in objects will be caused by the work of external forces?

Student: The external force acting on the object will cause the change of kinetic energy, so the total force times the distance equals the change of the kinetic energy of the suitcase.

Teacher: That's right. So, 1N times 10 m equals 10 J. The kinetic energy of the suitcase increases 10 J after the work of 小雄.

老師： 功能定理，指的是什麼？

學生： 外力作功＝能量變化。

老師： 是的，但更精確的說法，應該是「合力作功=動能變化」。

老師： 此題，物體所受的外力總和是多少呢？如果令向右為正的話？

學生： 如果令向右為正的話，那麼向左的摩擦力就是–4 N，所以總共是 5N – 4N = 1N。

老師： 很好！那外力作功，會造成物體什麼能量變化呢？

學生： 外力作功會造成動能變化，所以力與位移內積，就等於行李箱的動能變化！

老師： 沒錯！所以 1 N×10 m = 10 J，行李箱動能就是增加 10 J。

3-3 位能、能量守恆定律與能源
Potential Energy, Conservation of Energy Principle and Energy

■ 前言 Introduction

前一節介紹動能，本節將探討位能。物體因受到重力，從不同高度掉落至地面時，速度會不同，因此定義不同高度的物體儲存不同的「重力位能」。相似的情況，彈簧系統因為彈力，也可因不同的伸長/壓縮量，而儲存彈力位能。再定義力學能，及探討其守恆之條件。進而延伸到能量守恆定律的條件，也將能量與生活情境結合，探討再生能源以及非再生能源的區別。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
conservation of energy	能量守恆	spring	彈簧
energy	能源	elastic potential energy	彈力位能
gravitational potential energy	重力位能	conservation of mechanical energy	力學能守恆
compression	壓縮	renewable energy	再生能源
extension	伸長	non-renewable energy	非再生能源

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

❶ The higher _____ is, the greater _____ will be.

例句：**The higher** the position **is, the greater** the gravitational potential energy **will be**.
位置越高，物體的重力位能越大。

■ 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、了解外力作功＝0 總能量會守恆。

Understand that the total energy is conserved when the work of external force is zero.

二、理解動能與位能之和稱為力學能，且動能與位能可以互換。

Understand that the sum of kinetic energy and potential energy is called mechanical energy, and the two types of energy can be converted to each other.

三、認識各種發電方式，與新興能源科技的特性。

Know the characteristics of various electric power generation methods and emerging energy technologies.

❧ 例題講解 ☙

例題一

說明：能將重力位能的概念，應用於生活經驗中。
Students can use gravitational potential energy to analyze their life situation.

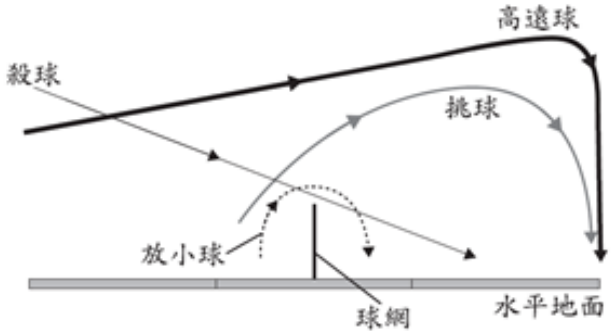
（英文）The figure shows the basic strokes of badminton, and the lines represent the trajectory of shuttlecock while the arrows indicate the direction of movement. Based on the conditions, which trajectory of shuttlecock will let the gravitational potential energy of shuttlecock keep decreasing?

(A) smash　(B) lofted shot　(C) clear　(D) lift

（中文）圖為羽毛球運動常見基本球路，圖中線段代表羽毛球的運動軌跡，箭頭代表移動方向，由此判斷，哪一種球路的運動過程，羽毛球相對於地面的重力位能只會一直減少？

(A)殺球　(B)挑球

(C)高遠球　(D)放小球



（109 年國中會考 9）

解題 Solution：

重力位能一直減少，代表物體位置愈來愈接近地面，由圖形中可知只有(A)滿足這條件，(B)(C)(D)均是先增加後減少。故選(A)。

If the gravitational potential energy keeps decreasing, it means that the position of the object is getting closer and closer to the ground. According to the figure, only option (A) smash satisfies the condition while (B)(C)(D) increases at the beginning then decreases. So the answer is (A).

Teacher: If the gravitational potential energy keeps decreasing, how will the position of the object change?

Student: The higher the position is, the greater the gravitational potential energy will be. Therefore, the object only falls down if the gravitational potential energy keeps decreasing. Am I right?

Teacher: That's right! According to the figure, which trajectory of shuttlecock will let the gravitational potential energy of shuttlecock keep decreasing?

Student: The shuttlecock only falls down to the ground during the smash.

Teacher: Yes. For the other three basic strokes, the gravitational potential energy of the shuttlecock increases firstly, then decreases.

老師：若相對於地面的重力位能只會一直減少，代表物體的位置會如何改變呢？

學生：物體位置越高，相對於地面的重力位能就越大，所以若相對於地面的重力位能只會一直減少，代表物體只向下落嗎？

老師：沒錯，所以圖中哪種擊球方法會使相對於地面的重力位能只會一直減少？

學生：圖中只向下落的只有殺球。

老師：是的，其他三種都是相對於地面的重力位能先增加再減少。

例題二

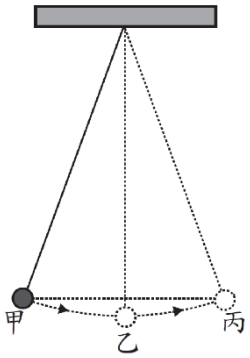
說明：能應用力學能守恆，於分析單擺之擺錘在不同位置的能量。

Can implement conservation of mechanical energy into analyzing the energy when the bob of the pendulum moves at different positions.

（英文）There is a simple pendulum as shown in the figure. The bob of a pendulum is released from point 甲 at rest freely, passing through point 乙 which is the lowest point, and reach point 丙 which is the same height as point 甲. It is known that the gravitational potential energy of the pendulum at points 甲, 乙, and 丙 are respectively $U_{甲}$, $U_{乙}$ and $U_{丙}$, and the kinetic energy of the pendulum at points 甲, 乙, and 丙 are $E_{甲}$、$E_{乙}$及 $E_{丙}$. If there is no friction, which of the following formula is correct?

(A) $U_{甲}-U_{乙}=2E_{丙}$　(B) $U_{乙}-U_{丙}=2E_{甲}$

(C) $U_{甲}-U_{乙}=E_{甲}-E_{乙}$　**(D) $U_{丙}-U_{甲}=E_{甲}-E_{丙}$**



（中文）有一單擺如圖所示。將擺錘自甲點從靜止自由釋放，經過最低點乙點，到達與甲點等高的丙點。已知擺錘在甲點、乙點及丙點的重力位能分別為 $U_{甲}$、$U_{乙}$及 $U_{丙}$，擺錘在甲點、乙點及丙點的動能分別為 $E_{甲}$、$E_{乙}$及 $E_{丙}$，若不計任何摩擦力，則下列何者正確？

(A) $U_{甲}-U_{乙}=2E_{丙}$　(B) $U_{乙}-U_{丙}=2E_{甲}$

(C) $U_{甲}-U_{乙}=E_{甲}-E_{乙}$　**(D) $U_{丙}-U_{甲}=E_{甲}-E_{丙}$**

（110 年國中會考 27）

解題 Solution：

根據力學能守恆定律，$U_{甲}+E_{甲}=U_{乙}+E_{乙}=U_{丙}+E_{丙}$，故 $U_{丙}-U_{甲}=E_{甲}-E_{丙}$。故選(D)。

According to conservation of mechanical energy principles, $U_{甲}+E_{甲}=U_{乙}+E_{乙}=U_{丙}+E_{丙}$. Therefore, $U_{丙}-U_{甲}=E_{甲}-E_{丙}$. The correct answer is (D).

Teacher: In this picture, what's the relationship between kinetic energy and potential energy?

Student: If there is no friction, the sum of kinetic energy and potential energy is constant during the whole moving process. Am I right?

Teacher: Exactly! This is due to the principle of mechanical energy conservation, so we can know that $U_{甲}+E_{甲}=U_{乙}+E_{乙}=U_{丙}+E_{丙}$.

Student: I see! Thus, we can get the result of $U_{丙}-U_{甲}=E_{甲}-E_{丙}$.

老師：在這張圖中，動能與位能兩者有什麼關聯嗎？

學生：若不計摩擦力，那是不是整個過程的動能加位能都是定值？

老師：是的，這是根據力學能守恆定理，因此 $U_{甲}+E_{甲}=U_{乙}+E_{乙}=U_{丙}+E_{丙}$。

學生：所以 $U_{丙}-U_{甲}=E_{甲}-E_{丙}$，原來如此！

3-4 簡單機械
Simple Mechanics

■ 前言 Introduction

先前探討了作功與能量，本節將功與能的轉換，應用於不同的簡單機械中，包含斜面、槓桿、滑輪與輪軸所組成的基本工具，探討斜面上作功、施力臂與抗力臂、定滑輪與動滑輪、省力與費力的輪軸工具等等。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
simple machine; simple device	簡單機械	wheel and axle	輪軸
inclined plane	斜面	fixed pulley	定滑輪
lever	槓桿	movable pulley	動滑輪
pulley	滑輪	radius	半徑

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

❶ _____can only_____, but will not _____.

例句：These machines **can only** deliver or transform the work and energy through the applying process**, but will not** increase or decrease the work to the object.

這些機械在作用過程中，只能傳遞或轉換功與能，不會增加或是減少對物體的作功。

❷ There are different _____, but _____.

例句：**There are different** input forces**, but** may do the same work.

不同施力大小，作功卻可能相同。

❸ As long as _____.

例句：**As long as** the effort arm is longer than the load arm, the effect of force-saving can be achieved.

只要槓桿的施力臂比抗力臂長，就能達到省力效果。

❹ neither _____ nor _____

例句：Using a fixed pulley is **neither** force-saving **nor** time-saving.

使用定滑輪既無法省力也無法省時。

■ 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、認識簡單機械的工作原理。

Be able to know the working principles of simple machines.

二、能應用功能定理於簡單機械。

Be able to apply the work-energy theorem in simple machines.

例題講解

例題一

說明：能分析定滑輪的功能，並掌握其功能互換。

Can analyze the function of fixed pulleys and comprehend the work-energy transformation mechanism.

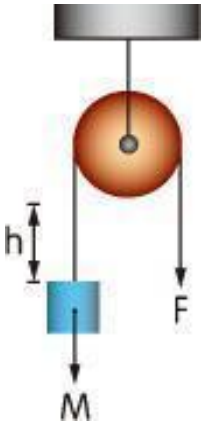
（英文）According to the figure, 小禹 use a rope and a fixed pulley by applying a force F to lift an object of weight M a height h at a constant velocity. Assume there is no resistance and friction, and the weight of the rope and fixed pulley can be ignored. Which of the following descriptions is correct?

(A) The fixed pulley is a force-saving machine.

(B) Using a fixed pulley can change the direction of force.

(C) If using a fixed pulley with a larger radius, it will be more force-saving.

(D) The work applied by the force is less than the increments of the gravitational potential energy.



（中文）如圖所示，小禹使用細繩及定滑輪，施一力 F 將一重量 M 的物體以等速度提升 h 的高度。假設沒有阻力與摩擦力，且細繩、定滑輪的質量均可忽略，則下列敘述何者正確？

(A)定滑輪是省力的機械。

(B)使用定滑輪可改變施力的方向。

(C)改用半徑愈大的定滑輪，則會愈省力。

(D)施力所作的功小於物體重力位能的增加量。

（95 年第二次國中基測 33）

解題 Solution：

使用定滑輪吊起物體時，施力臂＝抗力臂＝定滑輪半徑（故半徑大小不影響施力的大小），根據力平衡：因為物體維持等速上升，滑輪兩側之力矩應互相抗衡，故施力＝物重，定滑輪不能省力。又因滑輪兩側半徑相同，物體吊升的長度等於繩子拉下的長度。因此，重量 M 的物體，上升高度 h 時，施力位移也是 h，所以施力作功＝F×S＝Mgh 等於增加的重力位能。故答案為(B)。

When using the fixed pulley to lift an object, the effort arm equals the load arm equals the radius of the fixed pulley (so the radius doesn't affect the applying force). According to the force balance: Because the object is lifting up at the same speed, the torque on both sides of the pulley should compete with each other. Thus, the input force is equal to the weight of the object which means that the fixed pulley cannot save effort. Furthermore, the radius on both sides of the pulley is the same, so the height of the lifting object equals the length of the rope pulled down. For an object of weight M, lifting up by a height h, the input force equals F times S equals Mgh which is the increment of the gravitational potential energy. Thus, the answer to this question is (B).

Teacher: According to the question, the object is lifted by force F and keeps lifting up at the same speed. Then, which physical quantity reaches the balance on the left and right side of the pulley?

Student: The torque.

Teacher: Excellent! According to "force balance," the torque on both sides of the pulley should be balanced. In the formula: torque equals effort times arm. The arm is the radius on the left and right side of the pulley while the effort arm is on the right side and the load arm is on the left side.

Teacher: In the diagram, which is longer, the effort arm or the load arm?

Student: I think the effort arm is as long as the load arm because both of them equals the radius of the fixed pulley. The effort arm is equal to the load arm no matter how long the radius is. Is that right?

Teacher: Yes, you're right! So, the torque and effort arms are equal. What is the relationship between effort force and resisting force?

Student: Effort force is equal resisting force.

Teacher: Good job! F is equal Mg. Do you think we can apply less work by using a fixed pulley?

Student: The distance the object goes up should be the same as the distance the rope is pulled down.

Teacher: Yes, the fixed pulley is neither effort-saving nor hard sledding, the distance is also equal, so it is no longer time-saving or time-consuming.

Teacher: The function of the fixed pulley is only to change the direction of the resistance force. In this case, we can raise the weight upwards by exerting downward force.

Student: I get it! It means that the work of the force is equal to the increment of the gravitational potential energy of the object under this situation.

老師： 根據題意，物體受到 F 拉動而維持等速度上升。則滑輪左右兩側，應該有哪個物理量達到抗衡？

學生： 力矩。

老師： 非常好，依據「力平衡」，左右兩側的力矩應該抗衡。而 [力矩=力量×力臂]，力臂就是滑輪左右兩側的半徑，右邊是施力臂，左側是抗力臂。

老師： 在這張圖中，施力臂與抗力臂的誰比較大？

學生： 應該是一樣大，因為兩者距離都正好是定滑輪半徑。這樣是不是不管半徑大或小，施力臂大小都跟抗力臂相同呢？

老師： 沒錯，所以力矩相等，力臂又相等。施力與抗力的大小，應該如何？

學生： 施力=抗力。

老師： 很好，所以，F=Mg，那你們覺得用定滑輪可以做比較小的功嗎？

學生： 因為滑輪左右兩側半徑相同，所以物體上升，跟我手向下拉的距離應該相同。

老師： 是的，所以定滑輪不會省力或費力，距離也相等，所以已不會省時或是費時。

老師： 定滑輪的功用，只是改變抗力的方向，如此題，我們可以透過向下出力，而使重物向上升高。

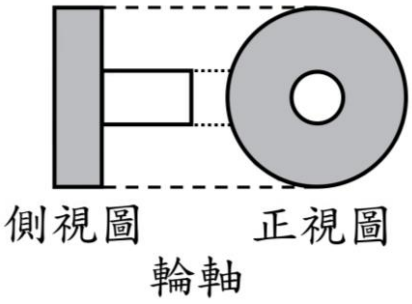
學生： 原來如此！所以這種情況下施力所作的功，會等於物體重力位能的增加量。

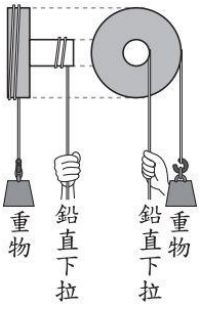
例題二

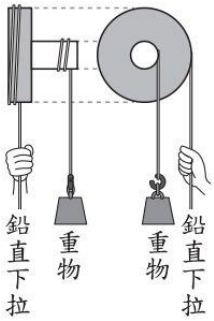
說明：能分析不同組裝的輪軸，所產生的效果。
Be able to analyze the effects of different assemblies of wheel and axle.

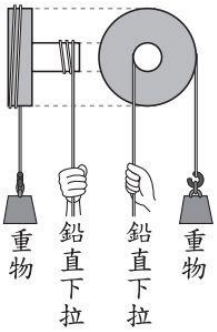
（英文）The front view and side view of the wheel and axle device are shown in the figure. If you want to use this device to force-savingly lift a heavy object upward at a constant speed, which of the following options is the most appropriate way to use it?

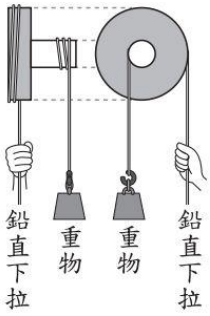
（中文）圖為輪軸裝置的正視圖及側視圖，若要使用此裝置「省力地」將重物等速向上抬起，下列何種使用方式最適當？



(A)


(B)


(C)


(D)


（109 年國中會考 12）

解題 Solution：

因物體被等速地抬起，符合「力平衡」現象，因此，輪軸兩側的力矩需互相抗衡。[施力 × 施力] = [抗力×抗力臂]，因為要省力，施力 < 抗力，所以①施力臂 > 抗力臂，只有(B)(D)可行。另外②施力與抗力，應分別在輪軸的兩側，只剩(D)；且③施力向下拉時，物體應向上升：(D)也符合。故選(D)。

Solution: When the object is lifting up at the same speed, it conforms to the “force equilibrium” phenomenon. Thus, the torque on both sides of the pulley needs to be balanced. (effort times effort arm equals load times load arms) In order to save effort, the effort should be less than the load, so the effort arm needs to be longer than the load arm, and only (B)(D) is right. Additionally, the effort and the load should be on the two sides of the pulley, then only option (D) left. Moreover, option (D) also shows that when the force is straightly downwards, the object will be pulled up. Therefore, the correct answer is (D).

Teacher: When using the device of wheel and axle, how will the heavy object move when the force is applied while the force is on the same side as the object?

Student: If the force is on the same side as the object as shown in the figure of (A) and (B), the object might fall down if I pull down the rope.

Teacher: That's right! The question is asking to lift up the object, so we cannot choose option (A) and (B). Think about this. If I want to lift the heavy object with less force, what should be the relationship between the effort arm and the load arm?

Student: I think the effort arm should be longer than the load arm so that we can save force.

Teacher: Exactly! Just like the screwdriver and faucet, these are all force-saving tools.

老師： 在輪軸的情況中，若施力與重物的方向在同一邊，那施力的時候，重物會如何移動呢？

學生： 如果像(A)(B)兩圖一樣同一邊的話，那我向下拉，物體應該會一起下降才對。

老師： 沒錯，因為題目是重物要向上抬升，所以不能選(A)(B)兩圖。如果我想要省力地將重物抬起，那施力臂與抗力臂的關係應該如何？

學生： 我覺得施力臂應該大於抗力臂，才會省力。

老師： 正確！就像生活中的螺絲起子或水龍頭一樣，這些都是省力的工具喔。

★主題四 電流、電壓與歐姆定律★
Electric Current, Voltage, and Ohms' Law

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■ 前言 Introduction

本章從電荷與靜電現象出發介紹電流、電壓、電阻之關係，與歐姆定律。此外，也使用三用電表、伏特計或安培計測量電流、電壓與電阻，並觀察其性質。

4-1 電荷與靜電現象
Charges and Electrostatic Phenomenon

■ 前言 Introduction

在此小節，透過實驗介紹產生靜電現象的方法，例如：摩擦起電、接觸起電、感應起電，並介紹帶電球間的靜電力。產生靜電現象的步驟中，有許多因果關係，因此加入英語講述時，需注意句型架構的先後順序。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
charging by friction/ triboelectric charging	摩擦起電	Coulomb	庫侖
negative charge	帶負電	electrostatic induction	靜電感應
charged object	帶電體	electrostatic phenomenon	靜電現象
positive charge	帶正電	contact electrification	接觸起電
electron	電子	insulator	絕緣體
conductor	導體	elementary charge	基本電荷
charging by induction	感應起電	proton	質子
Coulomb's force/ electrostatic force	庫倫力/靜電力	Coulomb's force/ electrostatic force	庫倫力/靜電力

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

❶ _____ is called _____. = _____ refers to _____.

例句(1)：The method of rubbing against each other to electrify objects **is called** triboelectric charging.
這種互相摩擦使物體帶電的方法稱為摩擦起電。

例句(2)：The process that electrons get transferred between the two different materials that are rubbed together **refers to** triboelectric charging.
電子在兩個不同材料間，因摩擦而移轉的過程，稱為摩擦起電。

❷ _____ be opposite to _____.

例句：Charging by induction makes the charge of the conductor **be opposite to** that of the charged stick
感應起電使導體帶電的電性，與帶電棒的電性相反。

❸ _____ after rubbing _____?

例句：Why do the two materials attract each other **after rubbing** against each other?
為何兩種材料摩擦後就會互相吸引呢？

❹ _____ attract each other. /_____ repel each other.

例句：Opposite charges **attract each other**. /Like charges **repel each other**.
電荷相反的會互相吸引。／電荷相同的會互相排斥。

❺ _____ more _____ than _____.

例句：If an object has **more** protons **than** electrons, the net charge of the object is positive.
若物體的正電荷多於負電荷，則該物體帶正電。

❻ In addition to _____, _____.

例句：**In addition to** charging by induction, a conductor can also be charged by touching it with a charged object.

除了感應起電外，以帶電的物體接觸另一不帶電的導體，也可使其帶電。

❼ _____ directly proportional to _____.
_____ inversely proportional to _____.

例句：The attractive or repulsive force between two electrically charged spheres is **directly proportional to** the product of the magnitudes of charges and **inversely proportional to** the square of the distance between them.

兩帶電球間的吸引力或排斥力，會與兩帶電球所帶電荷量的乘積成正比，而與彼此間距離的平方成反比。

❽ Since _____.

例句：**Since** the charge carried by objects is an integer multiple of the charge of the electron, the charge of an electron is called the basic charge.

由於物體所帶電荷，都是電子所帶電量的整數倍，因此將一個電子的電量 稱為基本電荷。

❾ After _____, if _____, _____ will _____.

例句：**After** the process of electrostatic induction, **if** you use another hand or conductor to let electrons move in or out the object, the object **will** be charged, and the process is called charging by induction.

此時若再以另一不帶電的手或導體，將電子移出或移入，便能使導體帶靜電，此方法稱為感應起電。

■ 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、能從相關實驗，理解摩擦起電、接觸起電及感應起電等產生靜電的方法。

Students can understand the methods of triboelectric charging, contact electrification, and charging by induction through related experiments.

二、根據物質的導電性，可分為導體與絕緣體，並知道其特性。

Can classify objects into conductors and insulators based on materials' conductivity and know their features.

三、了解帶電物體之間有靜電力。同性號電荷會相斥，異性電荷則會相吸。

Understand there is electrostatic force between charged objects. Opposite charges attract each other while like charges repel each other.

❧ 例題講解 ☙

例題一

說明：了解靜電感應的機制與概念。

Understand the mechanism and concept of electrostatic induction.

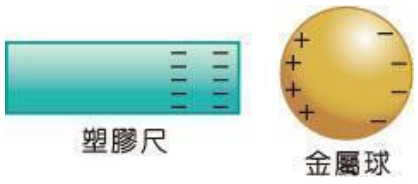
（英文）There is a negatively charged plastic ruler getting closer to an uncharged metal ball, and the distribution of their charges is as shown in the picture on the right side. Which of the following explanations is correct?

(A)There are more protons than electrons in the metal ball.

(B)There are less protons than electrons in the metal ball.

(C)The separation of protons and electrons in the metal ball is called the magnetic effect of the electric current.

(D)The separation of protons and electrons in the metal ball is because of the movement of electrons.



（中文）帶負電的塑膠尺靠近原來不帶電的金屬圓球，它們電荷的分布，如右圖所示，則下列敘述何者正確？

(A)金屬球上的正電荷量比負電荷量多。

(B)金屬球上的正電荷量比負電荷量少。

(C)金屬球上的正、負電荷分開的現象稱為電流的磁效應。

(D)金屬球上的正、負電荷分開的現象是電子移動的結果。

（95 年第一次國中基測 24）

解題 Solution：

帶負電的塑膠尺靠近金屬球，因靜電感應而使金屬球中電子移動，造成電荷分離。左端帶正電、右端帶負電，且仍維持電中性。

When the negatively charged plastic ruler gets closer to the metal ball, the electrons in the metal ball will move because of electrostatic induction, and thus cause charge separation. The left side of the metal ball is positive charge and negative on the right, but the whole object is still neutral.

Teacher: Let's see the picture first. We know that the metal ball is a conductor. So, what will happen if the negatively charged plastic ruler is brought near the metal ball?

Student: The protons in the atomic nucleus of the metal ball will move to the left side because of Coulomb force.

Student: Are you sure that protons will move by attraction?

Teacher: Excellent! Someone noticed the detail! The uneven charge distribution in the conductor is because of the movement of electrons.

Student: Oh, I understand! You mean that the free electrons in the mental ball will be repealed to the right side because of Coulomb force.

Teacher: That's right! The left side of the metal ball will be positive charge due to free electrons shifting to the right. But you should notice that the numbers of protons and electrons are still the same, i.e., the metal ball is still electrically neutral. Thus, when the metal ball will return back to uniformly electric distributed if you take away the plastic stick.

老師： 我們來看圖，金屬球是導體，所以將帶負電塑膠尺靠近它時，會有什麼現象呢？

學生： 金屬球原子核內的質子，會因庫倫靜電力之異性相吸而移到左邊。

學生： 你確定質子會被吸引而移動嗎？

老師： 很好唷！有人注意到細節了！造成導體內電荷分布不均，是因為自由電子移動的結果。

學生：　哦，我懂了！所以意思是金屬球內自由電子，會因靜電力被排斥到右端。

老師：　沒錯！金屬球左端因自由電子移向右側而呈現正電性，但要注意到金屬球內正、負電荷量仍相等，所以金屬球仍然是電中性。若將塑膠棒移開，金屬球又會恢復正負電的均勻分佈。

例題二

說明：了解接觸起電的機制與原理。

Understand the mechanism and principle of contact electrification.

（英文）Carry out the experimental steps with two uncharged metal blocks called block 甲 and block 乙 as shown in the picture. Then, which of the following descriptions about the electrical properties of the two metal blocks is correct?

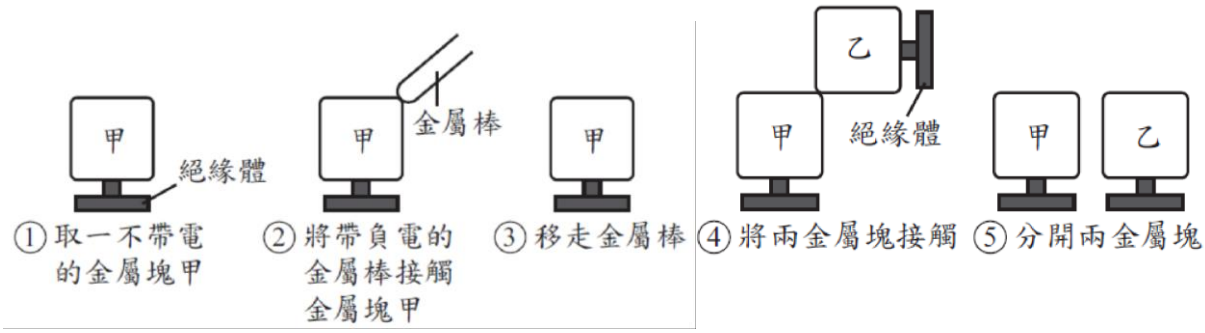
(A) 甲:positive charged, 乙: positive charged

(B) 甲: positive charged, 乙: negative charged

(C) 甲: negative charged, 乙: positive charged

(D) 甲: negative charged, 乙: negative charged

（中文）將甲、乙兩不帶電金屬塊進行圖中的實驗步驟，關於步驟中兩金屬塊的電性，應為下列何者？



(A)甲：帶正電，乙：帶正電

(B)甲：帶正電，乙：帶負電

(C)甲：帶負電，乙：帶正電

(D)甲：帶負電，乙：帶負電

（110 年國中會考 29）

解題 Solution：

金屬棒，會帶負電（接觸起電）。步驟 4 中甲金屬塊會把所帶的負電，一部分傳給乙。故甲、乙兩金屬塊均帶負電。

There are free electrons because both 甲 and 乙 are metal. According to the second and third steps of the diagram, block 甲 will be negatively charged because it contacts the negatively charged metal stick (contact electrification). In the fourth step, block 甲 will transfer electrons to block 乙. Thus, two blocks are all negatively charged.

Teacher: According to the problem, 甲, 乙 are both metal blocks containing free electrons, which can move freely due to electric force.
Let's see the first and second steps in the picture. In the first step, it is mentioned that block 甲 is neutral. Then, what will happen if we use a negative charged object to touch the metal block as shown in step 2?

Student 1: The negative charge on the charged object will repel the electrons of the metal block.

Student 2: So, it is negatively charged on the right side of the metal block, and positively charged on the left.

Teacher: That's right. Besides, the free electrons on the charged metal rod will be attracted to the metal block through electrostatic force because the charged body is in contact with the conductor.

Teacher: Thus, the uncharged metal ball will be negatively charged after removing the charged object away. This phenomenon is called contact electrification.

Student: The fourth step is familiar to me! It is similar to step 2 to let the charged object touch the conductor.

Teacher: You observed very detail! Just as we have already mentioned, regarding block 甲 as a charged object to touch block 乙. In other words, block 甲 and 乙 will both be negatively charged after contact electrification.

老師： 根據題意，甲乙皆是金屬，金屬含有自由電子，可以在受到電力時，自由移動。
我們來看圖的步驟一和二。步驟一說明此金屬塊導體為電中性，接著將一個帶負電的帶電體觸碰金屬塊會發生什麼事呢？

學生 1： 帶電體上的負電，會排斥金屬塊的電子。

學生 2： 所以金屬塊左端帶負電、右端帶正電。

老師： 是的，而且現在因為帶電體有接觸到導體，所以金屬棒上自由電子，會因為靜電力異性相吸，被吸引到金屬塊上。

老師： 因此步驟三，把帶電體移開後，原本不帶電的金屬球上，就會變成帶負電。此稱為接觸起電，可以看出導體所帶的電性與帶電體相同。

學生： 那步驟四好像似曾相識欸！很像步驟二，將負電的帶電體接觸導體。

老師： 觀察入微！所以同理，現在將金屬塊甲視為帶電體接觸金屬塊乙，接觸起電後，金屬塊甲和乙會帶同性電，也就是分開後兩者皆帶負電。

4-2 電流
Electric Current

■ 前言 Introduction

本章節介紹電流、電路中元件串聯、並聯的意義，與其對應的電路圖。使用英語時可搭配實際元件示範。此外，本章節亦使用安培計測量電流，因此實驗過程，加入英語講述步驟時，應明確且精簡，不宜過於冗長。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electric current	電流	closed circuit	通路
electric circuit/ electrical network	電路	open circuit	斷路
power supply	電源	short circuit	短路
circuit components	電路元件	ammeter	安培計
wire	電線	in series	串聯
circuit diagram	電路圖	in parallel	並聯

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

❶ When _____.

例句：**When** an electric circuit forms a closed loop, the bulb of the circuit can be lit up.
當電路是一個封閉迴路時，電路中的燈泡會發光。

❷ _____ can be defined by _____.

例句：The magnitude of electric current **can be defined by** the quantity of charge passing through a cross section of a wire per second.
藉由每秒通過導線某一截面的電量，來定義電流的大小。

❸ Connect _____ to _____.

例句：**Connect** the positive terminal **to** the under-test circuit closed to the positive terminal of the battery.
使用時，將正極端子與待測電路靠近電池正極的一端相接。

❹ start with _____, and then _____, _____ avoid +Ving.

例句：When measuring the current, we should **start with** a larger scale, **and then** decide whether to select a smaller range based on the measurement situation, so that we can **avoid burning** out the ammeter.
測量電流時，先從較大的刻度開始，再依測量情形決定是否需選取較小的刻度，以免安培計燒毀。

❺ connect head-to-end in a line/connect across each other's leads

例句：If there are more than two batteries **connected head-to-end**, it is called series connection.
將兩個以上的電池，頭尾按順序串接在一起，稱為串聯。

■ 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、能分辨靜電與流動電荷的差異。

Can differentiate between static charges and moving charges.

二、能將真實電路轉換為電路圖。

Be able to transform the assemble of electric elements into electric circuit diagrams.

三、理解通路、斷路、短路的定義。

Understand the definitions of closed circuit, open circuit, and short circuit.

四、知道電流與電子流動的方向相反。

Know that the direction of electric currents is opposite to the direction of electrons move.

五、了解電流的定義，並能使用安培計測量電流。

Understand the definition of electric current, and be able to use an ammeter to measure current.

六、能辨識串聯與並聯之不同，並能推導電路中各處電流。

Can distinguish the difference of in series and in parallel, and be able to determine the electric current of elements in electric circuits.

❧ 例題講解 ☙

例題一

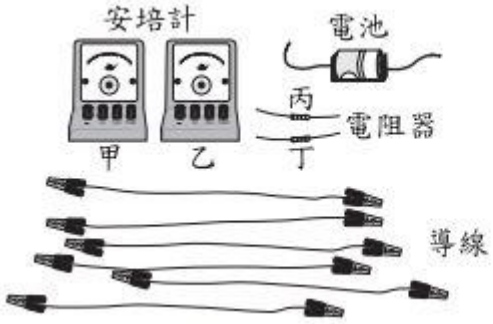
說明：能透過線路圖，判斷實際的接線圖。

Be able to determine the assembly of electric elements by means of an electric circuit diagram.

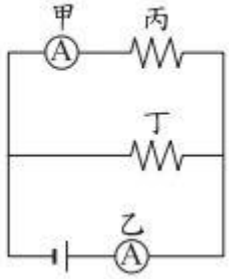
（英文）According to Figure 1, there are two ammeters, two resistors, a battery, and several wires. Besides, the resistors are conductors that comply with Ohm's law. Figure 2 is a circuit diagram. The teacher asks 小玉 to assemble the materials in Figure 1 based on the circuit diagram of Figure 2, then record the measured data of electric current through two ammeters in the experiment report.

Which of the following pictures is compiled with the circuit diagram in Figure 2?

（中文）圖(一)為兩個安培計、兩個電阻器、一個電池與數條導線，其中的電阻器為符合歐姆定律的導體，圖(二)為一電路圖。老師要求小玉將圖(一)中的器材依據圖(二)組裝，並將兩個安培計測得的電流值紀錄於實驗報告中。



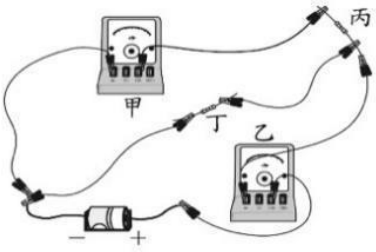
圖(一)



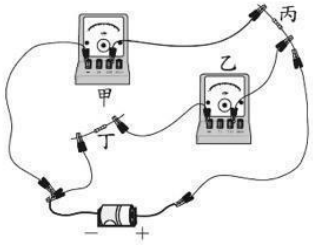
圖(二)

下列哪一個組裝方式符合圖(二)中的電路圖？

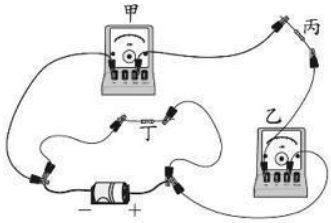
(A)



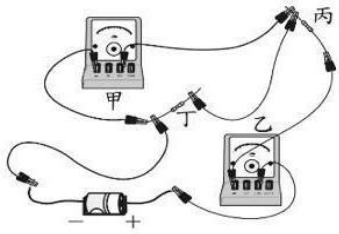
(B)



(C)



(D)



（111 年國中會考 47）

解題 Solution：

將甲與丙串連後，同時也將電池及乙串聯，將前面兩者並聯後，最後再與丁並聯。

First, connect the ammeter 甲 and resistor 丙 in series, and connect battery and ammeter 乙 in series at the same time. Connect the previous two sets in parallel. Then, make a parallel connection with resistor 丁 at last.

Teacher: It is important to learn to transform from the electric circuit diagram to the actual element assemble diagram.

Teacher: Do you still remember the two connection ways to assemble electric elements?

Student: Yes, in series and in parallel connection.

Teacher: That's right! We should identify the connections in series and in parallel first.

Teacher: According to the circuit diagram, ammeter 甲 and resistor 丙 are connected in series, and so do the battery and ammeter 乙. As a result, these two sets are in series. After connecting these two sets in parallel, then connect them with resistor 丁 in parallel.

Student: According to the actual electric circuit, (B) not only connect ammeter 乙, but also connect resistor 丙 in series. Thus, we can exclude this option first.

S: I found out that option (C) connect ammeter 乙 and resistor 丁 in series which doesn't meet the circuit diagram, too.

Teacher: Exactly, you observe in detail. How about the last option?

Student: For option (D), ammeter 甲, ammeter 乙, and resistor 丙 are connected in series, so the correct answer is option (A).

Teacher: That's correct!

老師： 這個單元很重要的，就是電路圖與實際接線圖互相的對應。

老師： 大家還記得元件之間的連接方式，可以是哪兩種呢？

學生： 串聯與並聯！

老師： 沒錯唷！那我們要先分辨哪些是串聯，哪些又屬於並聯。

老師： 由電路圖看出甲與丙頭尾相接，電池與乙也頭尾相接，所以這兩個都是屬於串聯。接著，前兩串互相並聯，並聯完這兩組後，再與電阻丁並聯。

實際電路中可以看出(B)選項，電池除了與乙串聯，也與丙串聯，所以可以刪除。

學生： 我發現(C)選項，乙與丁串聯，也不符合線路圖。

老師： 觀察入微，那最後一個選項呢？

學生： (D)選項，甲、丙與乙三者串聯，也不符線路圖，所以最終答案選擇(A)。

老師： 正確無誤！

例題二

說明：能推導串、並聯電路中，各處的電流。

Can derive the electric currents in circuits containing both in series and in parallel connections.

（英文）The table is the electric circuit data recorded by 小玉 in her report. If we want to judge whether $I_{甲} > I_{乙}$ is reasonable based on Figure 2, which of the following judgments and descriptions is the most appropriate one?

(A) $I_{甲} > I_{乙}$ is reasonable because the negative terminal side is where electrons come out, and ammeter 甲 is close to the negative terminal of the battery.

(B) $I_{甲} > I_{乙}$ is reasonable because the data of electric current collected by ammeter 甲 is the combination of that go through 丙 and 丁.

(C) $I_{甲} > I_{乙}$ is unreasonable. The positive terminal side is where electric current come out, and ammeter 乙 is close to the negative terminal of the battery, so $I_{乙} > I_{甲}$ is correct.

(D) $I_{甲} > I_{乙}$ is unreasonable. The data of electric current collected by ammeter 乙 is the combination of that go through 丙 and 丁, so $I_{乙} > I_{甲}$ is correct.

（中文）表為小玉報告中所記錄的電流值，若根據上題的圖(二)來判斷表中 $I_{甲} > I_{乙}$是否合理，下列的判斷與論述何者最適當？

安培計	代號	電流
甲	$I_{甲}$	200mA
乙	$I_{乙}$	100mA

(A)合理，因為負極為電子流流出端，而甲較靠近電池負極，所以 $I_{甲} > I_{乙}$合理。

(B)合理，因為甲測得的電流值應為流過丙與丁的電流值相加，所以 $I_{甲} > I_{乙}$合理。

(C)不合理，因為正極為電流流出端，而乙較靠近電池正極，所以 $I_{乙} > I_{甲}$才合理。

(D)不合理，因為乙測得的電流值應為流過丙與丁的電流值相加，所以 $I_{乙} > I_{甲}$才合理。

（111 年國中會考 48）

解題 Solution：

根據電源（乾電池）的位置，乙安培計量到總電流，而甲安培處，則為總電流的其中一個分支電流（通過丙的電流），而乙安培計則測得通過丙和丁的電流總合。因此 $I_{乙} > I_{甲}$，小玉的紀錄不合理。

According to the position of the battery, ammeter 乙 can measure the total electric current while ammeter 甲 can only measure one of the branch currents which go through 丙. For ammeter 乙, it measures the total electric current that go through 丙 and 丁. Thus, $I_{乙} > I_{甲}$ is the correct formula which indicates that 小玉's record is unreasonable.

Teacher: Do you still remember why and how to use an ammeter?

Student: We use an ammeter to measure the data of electric current.

Student: I remember that the ammeter should be connected with the measured object in series.

Teacher: Both of you are correct! Thanks for your additional information!

Student: So, the data we selected from ammeter 乙 is the total amount of electric current provided by the battery.

Teacher: Exactly! According to the position of the battery, we can get the data of the total electric current from ammeter 乙 while it is connected with the battery in series. And the total electric current would be divided into two for 甲 and 丙.

Student: Oh, I see! So the data of electric current go through 丙 which is collected by ammeter 甲 should be less than that collected by ammeter 乙. In other words, 小玉 recorded the wrong data in her report, so the answer in option (D).

老師： 同學們有印象安培計用途與如何使用嗎？

學生： 應該是測量電流值吧？

學生： 好像說要與待測物串聯。

老師： 對極了，謝謝你們的補充。

學生： 所以乙安培計測得的是電池提供的總電流！

老師： 對，根據電源(乾電池)的位置，乙安培計因為與電池串聯，可測得總電流，而總電流會再分給甲和丙。

學生： 原來如此，所以甲安培計測得通過丙的電流值應小於乙安培計所測得的電流值，表示說小玉紀錄錯誤，答案選(D)。

4-3 電壓
Voltage

■ 前言 Introduction

本章節介紹電壓的定義，與測量電壓的工具伏特計。接著探討燈泡串聯、並聯時的電壓關係。此外，講解電壓時，可使用水流與水位的比喻。加入英語講述時，可使用大量圖片或影片輔助。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
voltage	電壓	turbine	渦輪
voltmeter	伏特計	water pump	抽水機
bulb	燈泡	open circuit	斷路
battery	電池	closed circuit	通路
water pipe	水管	short circuit	短路

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

❶ Why can _____ cause _____?

例句(1)：**Why can** a battery **cause** charge movement in electric circuits?
為何電池可造成電路中電荷的流動呢？

例句(2)：**Why can** a water pump **cause** water flow in the waterway?
為何抽水機可造成水路中的水流流動？

❷ _____, similar to _____, is _____.

例句(1)：Electric current, **similar to** water flow, is the movement of the charge.
電流有如水流，是電荷流動。

例句(2)：A battery in an electric circuit, **similar to** water pump, **is** giving electric power to trigger charges to move.
電路中電池有如抽水機，能驅動電荷流動。

❸ _____ works on _____ increase _____ the potential energy.

例句：Water pump **does works on** water which **increases** its gravitational **potential energy**; the chemistry energy **of** batteries does work on electric charges, which increases its electric potential energy.
抽水機對水作功，可增加水的重力位能；電池的化學能則對電荷作功，增加電荷的電位能。

❹ _____ need to be connected in parallel with _____.

例句：When measuring the voltage of batteries, the voltmeter **needs to be connected in parallel with** the battery.
測量電池電壓時，伏特計需與電池並聯。

❺ Connect _____ in series.

例句：**Connect** two identical bulbs **in series** so that we can observe the lightness of the bulbs.
將兩個相同燈泡串聯，觀察燈泡亮度。

❻ When the bulbs are connected in _____, the total voltage of the battery would equal _____.

例句：**When bulbs are connected in** series, **the total voltage of the battery would equal** the sum of the two bulbs' voltage.
燈泡串聯時，電池的總電壓，等於兩燈泡的電壓總和。

❼ Turn on/turn off _____, what is the reading of the voltmeter?

例句(1)：When we **turn off** the switch and the bulb does not light up, w**hat is the reading of the voltmeter?**
當切斷開關，燈泡不亮，伏特計的讀數為多少？

例句(2)：When we **turn on** the switch and the bulb lights up, **what is the reading of the voltmeter**?
當按下開關，燈泡發亮，伏特計的讀數為多少？

❽ What is/are the voltage/es of _____?

例句：**What are the voltages of** bulb 1 and bulb 2 on their two sides?
燈泡 1 與燈泡 2 兩端的電壓分別是多少？

■ 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、了解電壓的定義。
Understand the definition of voltage.

二、能比較燈泡串聯與並聯時的電壓關係。

Be able to compare the voltage when the bulbs are connected in series and in parallel.

三、能應用伏特計測量元件的電壓。

Be able to use voltmeter to measure voltage of elements.

∞ 例題講解 ∞

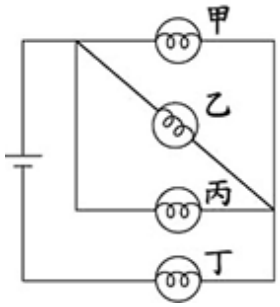
例題一

說明：了解通路、斷路的意義，及燈泡串聯或並聯時的電壓。

Understand the meanings of closed circuit and open circuit, and be able to determine the voltage of bulbs connected in series or in parallel.

（英文）There is an electric circuit device as shown in the figure while the four bulbs (甲乙丙) are in the same specification. If the battery and bulbs are all available, which of the bulb broken would cause the four bulbs to light off?

(A)甲　　(B)乙　　(C)丙　　**(D)丁**



（中文）一電路裝置如圖所示，燈泡甲、乙、丙、丁的規格均相同。若電池與燈泡均可正常使用，則哪一顆燈泡絲燒斷後，會導致四顆燈泡均不會亮？

(A)甲　　(B)乙　　(C)丙　　**(D)丁**

（100 年第一次國中基測 38）

解題 Solution：

根據線路圖，四顆燈泡之間的連接為:甲、乙、丙三燈泡並聯後，與燈泡丁串聯。當燈泡丁燒斷就形成斷路，所有分支迴路上都無電流流通，導致所有燈泡均不會亮。

According to the circuit diagram, the connection among the four bulbs is as following: After bulbs 甲, 乙, and 丙 are connected in parallel, they are then connected with bulb 丁 in series. When bulb 丁 is broken, the loop of bulb 甲, 乙, and 丙 will become open circuit which make all the bulbs to light off.

Teacher: Recalling about the experiments we have done before. Will the bulb light up if the electric circuit is not closed?

Student: I remember that the bulb will not light up.

Teacher: Then, do you know the scientific explanation about this phenomenon?

Student: I only know that the bulb will light up when the electric circuit is closed.

Teacher: That's right! It is important to build a complete loop around the battery. After the circuit gets closed, the voltage on the both sides of the bulb will cause electric current so that the bulb can be lit up.

Keep this information in your mind, and then we can start to identify the connection relationship among bulb 甲, 乙, 丙, and 丁.

Student: Let me see! The electric circuit shows that bulb 甲, 乙, and 丙 are connected in parallel first, then they are connected with bulb 丁 in series.

Teacher: Exactly, you observe very detail! According to your observation, bulb 丁 appears in all the other bulb's loop. Think about this: If bulb 丁 is broken, just like making the circuit become open circuit, will the other bulbs still light up?

Student: No! It is mentioned previously that the bulb will not light up if the electric circuit of battery is not closed, so all the four bulbs will not light up when bulb 丁 is broken.

老師： 回想一下我們做過的實驗，若電路未接通，那我們觀察到燈泡會不會發光？

學生： 我印象中是不會。

老師： 知道背後的科學解釋嗎？

學生： 我只知道需要接通電路，燈泡才會發光。

老師： 沒錯！從電源處有完整的迴路很重要。因為接通電路後，燈泡兩端有電壓而造成電流，燈泡才能發光。

我們有這個知識後，來判斷甲、乙、丙、丁四個燈泡的串、並聯關係。

學生： 我看看，這個電路圖是甲、乙、丙三個燈泡並聯後，再與燈泡丁串聯。

老師： 沒錯，觀察入微！言下之意就是燈泡丁，皆出現在其他燈泡的迴路中。所以如果燈泡丁燒毀，如同斷路，其他燈泡會不會亮呢？

學生： 不會！因為前面有回顧到，如果電源處沒有通路，所有燈泡就不會亮，所以這題是四個燈泡皆不亮！

例題二

說明：了解通路、斷路的意義，及燈泡串聯或並聯時的電壓。

Understand the meanings of closed circuit and open circuit, and be able to determine the voltages of bulbs connected in series or in parallel.

（英文）There is an electric circuit device as shown in the figure while bulb 甲 and 乙 are in the same specification, and both of them can light up. Which of the following statements is true if the wire resistance and the internal resistance of the battery are ignored?

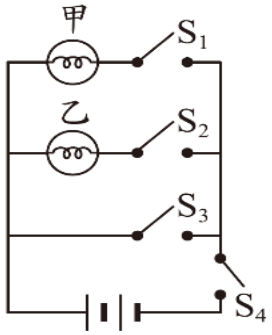
(A) Both of the bulbs light up after turning on the switch of S1, S2, and S3.

(B) Both of the bulbs do not light up after turning on the switch of S2, S3, and S4.

(C) Bulb 甲 light up and bulb 乙 does not light up after turning on the switch of S1, S3, and S4.

(D) Bulb 甲 does not light up and bulb 乙 light up after turning on the switch of S1, S2, and S4.

（中文）有一電路裝置如圖所示，其中燈泡甲、乙的規格相同，且可正常發亮，若忽略導線電阻及電池內電阻，下列敘述何者正確？



(A)接通開關 S1、S2 及 S3 後，兩燈泡均發亮。

(B)接通開關 S2、S3 及 S4 後，兩燈泡均不亮。

(C)接通開關 S1、S3 及 S4 後，燈泡甲發亮，燈泡乙不亮。

(D)接通開關 S1、S2 及 S4 後，燈泡甲不亮，燈泡乙發亮。

（109 年國中會考 40）

解題 Solution：

根據電路圖的電池位置，(A)S4 切斷，則電源形成斷路，兩燈泡均不亮。(B)接通 S2、S3、S4 後，甲燈泡斷路，乙燈泡短路，兩燈泡均不亮。(C)接通 S1、S3、S4，甲燈泡短路，乙燈泡斷路，兩燈泡均不亮。(D)接通 S1、S2、S4，甲乙丙燈泡皆是通路，均會發亮。故選(B)。

According to the battery position of the circuit diagram, option (A), when S4 is disconnected the battery forms a closed circuit, both of the bulbs do not light up. (B) When S2, S3, and S4 are disconnected, bulb 甲 is in open circuit and bulb 乙 is in short circuit, so both bulbs do not light up. (C) When S1, S3, and S4 are disconnected, bulb 甲 is in short circuit and bulb 乙 is in open circuit, so both bulbs do not light up. (D) When S1, S2, and S4 are disconnected, both bulb 甲 and 乙 are in closed circuit, so both of them light up. So, the correct answer is (B).

Teacher: Let's discuss all the options together. For option (A), According to the position of the battery from the electric circuit diagram,
When disconnect S4, the electric power forms an open circuit. Then, do you think bulb 甲 and 乙 will light up or not?
We can imagine when the battery, wire, and the bulb create a closed circuit, then the electric current will come out from the positive terminal of the battery. On the other hand, if the complete loop is accidentally broken somewhere, then there is no voltage and electric current so that the bulb will not light up.

Student1: It seems that bulb 甲 and 乙 need to build up their own loop. However, the electric current must pass through S4 to go back to the negative terminal of the battery. As a result, both of the bulbs will not light up if S4 is disconnected.

Student2: I know! If S2, S3, and S4 are closed, bulb 甲 will be in the open circuit. For bulb 乙, it is in the short circuit though it has a complete loop. Thus, both of the bulbs do not light up. The correct answer to this question is (B).

Teacher: That's right! For option (C), it is similar to option (B) while bulb 甲 changes to be in short circuit and bulb 乙 changes to be in open circuit, so both of them do not light up either.

Student: Oh! If we want to avoid bulb 甲 and 乙 being in short circuit, we cannot close S3! For option (D), S1, S2, and S4 are disconnected, which can make both bulbs to light up! So, the description of option (D) is incorrect.

老師： 我們每一個選項都來討論看看。根據電路圖的電池位置，（A）S4 切斷，則電源形成斷路，那甲、乙會不會亮呢？
我們可以想像電池、電線與燈泡形成通路的話，電流會從電池正極出發。若此迴路不小心在某處斷掉了，則無法形成電壓或電流，所以燈泡就不會亮。

學生 1： 看起來甲、乙各自要形成迴路，電流要回到負極的話必定會通過 S4，所以如果那裡斷路了，燈泡甲和乙皆不會亮。

學生 2： 我知道如果接通 S2、S3、S4 後，甲燈泡斷路，雖然乙燈泡有個完整迴路，但短路了，所以兩燈泡均不亮。這提要選(B)。

老師： 沒錯，那 C 選項類似於 B 選項，只是變成甲燈泡短路，乙燈泡斷路，所以兩個燈泡均不亮。

學生： 喔！所以如果想要燈泡甲與乙不短路，S3 就不能連接！那選項(D)，若將甲迴路中 S1、乙迴路 S2 與通過兩燈泡的 S4 皆接通，兩燈泡皆會發亮！所以（D）選項不對。

4-4 歐姆定律與電阻
Ohm’s Law and Resistance

■ 前言 Introduction

本章節介紹電阻的定義。測量通過不同物體的電壓與電流值，繪製 I-V 圖，解釋其中意義與影響因素。另外也介紹歐姆定律。物理量或變因可能出現正比、正相關或反比的關係，加入英語講述時，可以提供學生書面中英句型之輔助。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
semiconductor	半導體	cross-sectional area	截面積
conductor	導體	length	長度
resistor	電阻	material	材料
insulator	絕緣體	variable	因素

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

❶ Connect _____with the electric current.

例句：**Connect** a pencil lead/LED **with the electric current**, and record the voltage and the current.

將鉛筆芯/LED 連上電路，記錄電壓和電流值。

❷ With _____ as the vertical axis and _____ as the horizontal axis.

例句：**With** the electric current (I) **as the vertical axis** and the voltage (V) **as the horizontal axis**, the experimental results are drawn in different colors on the same graph paper.
以電流（I）為縱軸，電壓（V）為橫軸，將實驗結果以不同顏色描繪於同一方格紙上。

❸ Is _____ the same under the same _____?

例句：**Is** the amount of the electric current passing through the pencil lead and LED **the same under the same** voltage?
相同電壓下，通過鉛筆芯及 LED 的電流大小，是否相同？

❹ What does _____ look like? What is the meaning of_____?

例句：**What does** the graph show the relationship between the voltage and electric current of the pencil lead/LED? **What is the meaning of** the curve?
鉛筆芯/LED 的電壓與電流關係圖，是怎樣的圖形？代表何種意義？

❺ _____ the ratio of the voltage to the electric current is/is not a constant value.

例句：This is an oblique line passing through the origin, which means that **the ratio of the voltage to the electric current is a constant value**, thus the passing voltage is proportional to the current.
為一通過原點之斜直線，代表通過的電壓與電流的比值為定值，電壓與電流大小成正比。
(This is a curve passing through the origin, which means that the passing voltage and current are only positively correlated, but not proportional, and **the ratio of the voltage to the electric current is not a constant.)**
（為一通過原點之曲線，代表通過的電壓與電流，只呈現正相關，但不成正比，電壓與電流的比值也不為定值。）

❻ _____ is inversely proportional to _____.

例句：The resistance **is inversely proportional to** the cross-sectional area of a metal wire.
電阻大小，與金屬導線的截面積成反比。

❼ _____ obey _____ is/are called _____, such as _____.

例句(1)：Electric elements which **obey** Ohm's law **are called** Ohmic conductors.
滿足歐姆定律的電路元件，稱為歐姆式導體。

例句(2)：If the relationship between the voltage and the electric current does not **obey** Ohm's law, it **is called** a Non-Ohmic conductor, **such as** diodes.)
若物體兩端的電壓與通過的電流關係，並不符合歐姆定律，則稱為非歐姆式導體，如二極體

❽ the smaller _____ is, the larger _____ will be.

例句(1)：Under the same voltage, **the smaller** the resistance **is**, **the larger** the passing current **will be**.
相同電壓下，電阻值愈小者，可通過的電流愈大。

例句(2)：Under the same length, **the larger** the cross-sectional area is, **the smaller** the resistance of the wire **will be**.
相同長度下，截面積愈大的導線電阻愈小。

❾ _____ has smaller _____ while _____ has larger one.

例句：A conductor **has smaller** resistivity **while** an insulator **has larger one**.
導體的電阻率較小，絕緣體的電阻率較大。

■ 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、能探討電路元件的電壓與電流的關係，並了解電阻的定義。

Students are able to grasp the relationship between electric voltage and current of electric elements, and understand the definition of resistance.

二、認識歐姆定律。

Be familiar with Ohm's Law.

三、能分辨歐姆式導體與非歐姆式導體的差異。

Be able to identify the difference between Ohmic conductors and Non-Ohmic conductors.

四、了解影響電阻大小的因素。

Understand the factors affecting resistance.

❧ 例題講解 ☙

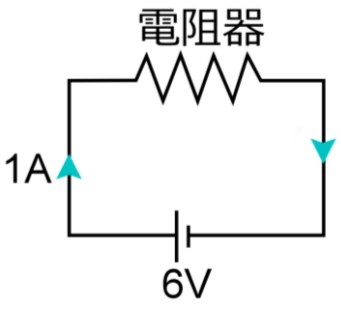
例題一

說明：了解歐姆定律的概念。

Understand the meaning of Ohm's law.

（英文）There is an electric circuit device as shown in the figure while the electric current is 1A. If we connect the original battery with another same battery in series, the total voltage of the power supply becomes 12V. If the resistor obeys Ohm's law while the resistance of the wires in the circuit is negligible and the circuit is undamaged, and the battery has no internal resistance, then how much is the current through the resistor?

(A)1/2A　(B)1A　**(C)2A**　(D)4A



（中文）電路裝置如圖所示，電路的電流為 1A。若將原來的電池再串聯上一顆相同的電池，電源的總電壓變為 12V，若電阻器符合歐姆定律，電路中導線的電阻忽略不計，電路並未受損，且電池沒有內電阻，則通過電阻器的電流變為多少？

(A)1/2A (B)1A **(C)2A** (D)4A

（99 年第二次國中基測 33）

解題 Solution：

根據歐姆定律，在溫度一定時，金屬導體的兩端電壓與通過電流的比值是固定的，即電阻為定值。因電流與電壓成正比，故當電池串聯時，電壓將變成 2 倍而成為 12V，電流也變成 2 倍而為 2A。故選(C)。

According to Ohm's Law, the ratio of the voltage across the metal conductor to the passing current is fixed when the current is constant which means that the resistance is a constant value, too. Because the current is proportional to the voltage, the voltage will be doubled to 12V when the batteries are connected in series, and the current will also be doubled to 2A. Thus, the correct answer is (C).

Teacher: Hello, everyone. The main point of this example is that the resistor obeys Ohm's law.

Student: It is mentioned previously that the resistance of Ohmic conductors is a constant value.

Teacher: That's right! In other words, the voltage across a conductor is proportional to the current passing through it.

Teacher: According to the question, what is changed after the batteries are connected in series?

Student: I know! The series connection will let the voltage of the resistor become doubled.

Teacher: Exactly! Because of the doubled voltage, the electric current will become doubled, too. This is the concept of proportionality in Math.

Student: Now I get it! So the electric current will change from 1A to 2A which is two times larger.

Teacher: Excellent! So, the answer to this question is (C).

Teacher: I would like to emphasize that the temperatures of electric elements need to be fixed in order to fulfill Ohm's Law.

老師： 同學們，這題的重點在於題目說，電阻器符合歐姆定律。

學生： 剛剛上課有提到歐姆式導體的電阻會是定值。

老師： 的確！也就是導體兩端電壓，與通過其的電流會成正比。

老師： 題目說電池串聯是改變了什麼？

學生： 我知道！會讓電阻器兩端電壓變兩倍。

老師： 沒錯！所以電流也會跟著變兩倍，這就是成正比在數學上的概念。

學生： 原來如此！我知道電流會從 1A 變 2A，也就是兩倍大。

老師： 非常好，所以答案選(C)。

老師： 在此需強調，元件需要保持溫度固定，否則無法成為歐姆電阻。

例題二

說明：了解導線形狀影響電阻大小的因素。

Understand the factors that the shape of conducting wires affecting the resistance.

（英文）The conductor 甲, 乙, and 丙 are relatively built up to three different circuit devices as shown in the figure. The three conductors are all made of the same material. For conductor 甲, the length is L cm, and the cross-sectional area is A cm^2. For conductor 乙, the length is 2L cm, and the cross-sectional area is A cm^2. For conductor 丙, the length is L cm, and the cross-sectional area is 2A cm^2. In the three circuit devices, the value of the electric current passing through conductor 甲, 乙, and 丙 are $I_{甲}$, $I_{乙}$, and $I_{丙}$. If ignoring the resistance of the wire and ammeter, and the resistance in the battery, what is the relationship among $I_{甲}$, $I_{乙}$, and $I_{丙}$?

(A)$I_{甲} > I_{乙} > I_{丙}$

(B)$I_{乙} > I_{甲} > I_{丙}$

(C)$I_{丙} > I_{甲} > I_{乙}$

(D)$I_{丙} > I_{乙} > I_{甲}$

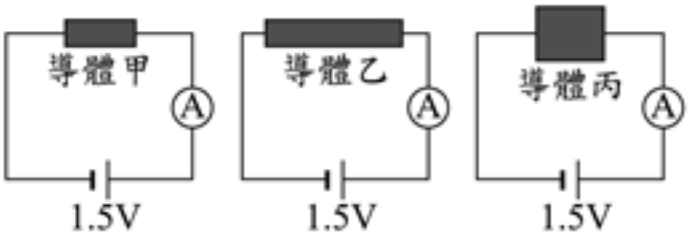
（中文）導體甲、乙、丙分別連接成三個電路裝置，如圖所示。三個導體均由相同的材質組成，導體甲的長度為 L cm，截面積為 A cm^2；導體乙的長度為 2L cm，截面積為 A cm^2；導體丙的長度為 L cm，截面積為 2A cm^2。若電路中導線及安培計的電阻、電池內電阻忽略不計，導體甲、乙、丙所連接的電路裝置中，流經三導體的電流值分別為 $I_{甲}$、$I_{乙}$、$I_{丙}$，其大小關係為下列何者？

(A)$I_{甲}>I_{乙}>I_{丙}$

(B)$I_{乙}>I_{甲}>I_{丙}$

(C)$I_{丙}>I_{甲}>I_{乙}$

(D)$I_{丙}>I_{乙}>I_{甲}$



（108 年國中會考 31）

解題 Solution：

電阻大小 R 正比於 L/A，所以 $R_{甲}$正比於 L/A，$R_{乙}$正比於 2L/A，$R_{丙}$正比於 L/2A，可得 $R_{乙}>R_{甲}>R_{丙}$。又電壓相同，電阻越大，電流越小，所以 $I_{甲}$、$I_{乙}$、$I_{丙}$的關係會跟 $R_{甲}$、$R_{乙}$、$R_{丙}$完全相反。由此可知，$I_{丙}>I_{甲}>I_{乙}$，故選(C)。

The resistance is proportional to L/A, so $R_{甲}$ is proportional to L/A; $R_{乙}$ is proportional to 2L/A; $R_{丙}$ is proportional to L/2A. As a result, we can know that $R_{乙}>R>R_{丙}$. Additionally, the resistance will be larger and the electric current will be smaller under the same voltage which means that the relationship among $I_{甲}$, $I_{乙}$, and $I_{丙}$ will be opposite to $R_{甲}$, $R_{乙}$, and $R_{丙}$. Thus, we can know that $I_{丙}>I_{甲}>I_{乙}$, the correct answer is (C).

Teacher: Do you still remember those factors that can affect the resistance of the conductor?

Student1: I remember that the longer the wire is, the larger the resistance will be. The length is proportional to the resistance.

Student2: It is also related to the cross-sectional area. The larger the cross-sectional area is, the smaller the resistance of the wire will be. The cross-sectional area is inversely proportional to the resistance.

Teacher: Exactly! Based on your previous explanation, $R_{甲}$ is proportional to L/A; $R_{乙}$ is proportional to 2L/A; $R_{丙}$ is proportional to L/2A, so $R_{乙}>R_{甲}>R_{丙}$.

Teacher: Additionally, when the resistance is larger and the electric current would be smaller under the same voltage. Therefore, the greatest of the resistance has the smallest current. The answer is $I_{丙}>I_{甲}>I_{乙}$, which is option(C).

老師：同學們記得哪些因素，會影響導體的電阻值嗎？

學生 1：我記得長度越長，電阻越大。長度與電阻大小成正比。

學生 2：也和截面積有關。截面積愈大的導線電阻愈小，截面積與電阻大小成反比。

老師：沒錯，所以合併上述，電阻大小(R)正比於 L/A。$R_{甲}$正比於 L/A，$R_{乙}$正比於 2L/A，$R_{丙}$正比於 L/2A，可得 $R_{乙}>R_{甲}>R_{丙}$。

老師：當電壓相同，電阻越大時，則電流越小。所以把電阻最大時，電流會最小。可得 $I_{丙}>I_{甲}>I_{乙}$，故選(C)。

★主題五 電與生活★
Electricity and Life

國立彰化師範大學物理系　曾于恩、林妍君

■ 前言 Introduction

本章節從電流的熱效應出發，介紹電功率的意義，也討論生活用電，並認識電池的結構和運作原理。最後探討電解反應及電鍍的技術。

5-1 電流的熱效應
Heating Effect of Current

■ 前言 Introduction

此單元討論電流的熱效應，以及電流所傳送的電能（E），並且定義電功率（P）來表示電器在單位時間內消耗的電能。同時也介紹電壓、電流和電阻的關係，以及「歐姆定律」。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electrical appliance	電器	consume	消耗
(electric) current	電流	resistance	電阻值
conductor	導體	resistor	電阻器
heating effect of current	電流熱效應	voltage	電壓
electrical energy	電能	series connection	串聯
Joule (J)	焦耳	in parallel	並聯
electric circuit	電路	electric power	電功率
battery	電池	Watt (W)	瓦特

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

❶ _____ is the phenomenon that_____ when_____.

例句：Heating effect of current **is the phenomenon that** occurs **when** current flowing through a conductor will heat it up gradually.

電流熱效應，是電流通過導體，使其溫度會逐漸增高。

❷ When _____ is the same, the amount of _____ consumed is proportional to _____.

例句：**When** the current through a conductor **is the same, the amount of** electrical power **consumed is proportional to** the resistance of the conductor.

當通過導體的電流相同時，所消耗電功率大小，與導體的電阻成正比。

■ 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：

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

一、知道電流會產生熱效應。

To understand electric current can cause heating effects.

二、能夠應用 V=IR 公式，來計算電功率。

Be able to apply V=IR to calculate electric power.

例題講解

例題一

說明：了解電流會產生熱效應，及電流熱效應的應用。

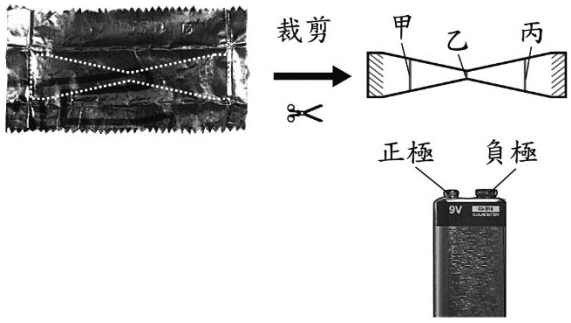
Understand that electric current will generate heat in a conductor and the applications of this heating effect.

（英文）Xiao-qing trims and shapes a piece of aluminum foil for chewing gums like the one showed in the diagram on the right. As indicated, the cross-sectional area marked in A is equal to that marked in C, but the values of the cross-sectional area of either Area A or Area C are greater than the middle area marked in B. She then takes out a 9v battery and bends the foil into an arched shape. The shaded ends of the foil are next wrapped around both the positive and negative sides of the battery. After the wrapping is secured, the aluminum foil begins to increase in temperature, and flames are then detected at Area B. Which of the following effects can best explain the flames?

(A) Electrostatic induction　　(B) Electromagnetic induction

(C) Magnetic effect of current　　**(D) heating effect of current**

（中文）小青將包裝口香糖的鋁箔紙剪成如圖中所示的形狀，圖中甲、丙兩處截面面積相等，中央乙處截面面積較甲、丙處小。接著她取一個電壓為 9 V 的電池，並使裁剪過的鋁箔紙呈拱形彎曲，讓兩端斜線處分別接觸電池的正極、負極，接觸後鋁箔紙溫度上升，隨即在乙處起火燃燒。請問本實驗中的鋁箔紙起火燃燒，最適合以下列何種科學現象來解釋？



(A)靜電感應　(B)電磁感應　(C)電流的磁效應　**(D)電流的熱效應**。

（105 年國中會考 49）

解題 Solution：

鋁箔紙溫度上升且起火燃燒，這是電能透過電流，變成熱能的現象，為電流的熱效應，故選(D)。

The temperature of aluminum foil increases and eventually burns. This is an example of the heating effect of electric current to demonstrate how electrical energy is transformed into thermal energy through current flow. As a result, Option D is correct.

Teacher: When we are in the wild, we can start a fire using this experiment demonstrated. What is the physics behind it?
Student: The heating effect of electric current!
Teacher: Good job! Why do you think there is electric current?
Student: Because a piece of aluminum foil is connected to both terminals of a battery, a circuit is formed and electric current is generated as a result.
Teacher: That is correct. In addition, this circuit offers little resistance to the flow of current, so the foil becomes hot really fast. This is called a short circuit and we should stay vigilant whenever we conduct an experiment like this one.

老師： 在野外可以運用題目中小青的方法來生火，其中的原理是什麼呢？
學生： 電流熱效應！
老師： 太棒了，那為什麼會產生電流呢？
學生： 連接電池正負極，形成迴路產生電流。
老師： 沒錯！而且因為迴路中電阻很小，所以電流很大，稱為短路，會快速發熱，須特別小心使用。

例題二

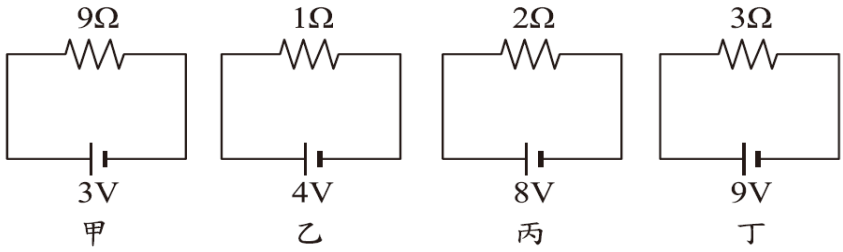
說明：透過 V=IR 來計算電功率。

Apply the equation of V = IR to determine electric power.

（英文）Figure 2.5 shows four circuits labeled as A, B, C, and D. Each circuit has a resistor and a cell of varied electric potential differences. Assuming the resistance of all connecting wires and the internal resistance of all cells are negligible, find the resistor that consumes the most power.

(A) A　　(B) B　　**(C) C**　　(D) D

（中文）有甲、乙、丙、丁四組電路裝置，其電池的電壓值及電阻器的電阻值如圖所示若不計導線電阻及電池內電阻，則哪一組電路裝置中電阻器的耗電功率最高？



圖(二十五)

(A)甲　　(B)乙　　**(C)丙**　　(D)丁。

（109 年國中會考 37）

解題 Solution：

電功率 $P = IV = I^2R = \frac{V^2}{R}$，$P_{甲}=\frac{3^2}{9} = 1$ W，$P_{乙}=\frac{4^2}{1} = 16$ W，$P_{丙}= \frac{8^2}{2} = 32$ W，$P_{丁}=\frac{9^2}{3} = 27$ W，丙的耗電功率最大。故選(C)。

Since $P = IV = I^2R = \frac{V^2}{R}$, $P_A=\frac{3^2}{9} = 1$ W, $P_B = \frac{4^2}{1} = 16$ W, $P_C = \frac{8^2}{2} = 32$ W, and $P_D = \frac{9^2}{3} = 27$ W

The resistor in Circuit C consumes the most power. As a result, Option (C) is correct.

Teacher: We are given the resistance of each circuit and its cell voltage in this problem. How do we solve for the electric power of each circuit?

Student: I only know the equation for electric power is P = IV, but this problem does not provide the magnitude of electric current for each circuit. What should I do?

Teacher: Do you still remember the equation that we learned last semester to determine power voltage?

Student: Yes, I do. The equation is V =IR.

Teacher: Good job. Although the electric current (I) for each circuit is unknown, we can apply V=IR to solve for I. First, we divide both sides by resistance. It gives us I=$\frac{V}{R}$.

Next, we substitute I=$\frac{V}{R}$for the I in the equation of P = IV and what we end up with is P = $\frac{V^2}{R}$.

Student: I can see it now! Because we are already given the voltages and resistances, all we need to do here is to use the last formula to determine electric power for each circuit.

Teacher: That is correct. What is your result? Which of the circuits delivers the most electric power?

Student: Circuit C delivers the most electric power. It is 32 W.

Teacher: Excellent!

老師： 我們已知四個迴路中的電阻及電源供給的電壓，要如何求各自的電功率呢？

學生： 我只知道電功率 P = IV，題目沒有給我電流，怎麼辦？

老師： 還記得我們在上學期學過的電阻定義嗎？

學生： 記得！是 V = IR。

老師： 很好，題目沒有給我們電流 I，我們可以透過 V=IR，將電流 I 用電壓 V 和電阻 R 取代。從 V = IR 可以得到 I=$\frac{V}{R}$ ，再把 P = IV 中的 I 換掉，最後得到 P =$\frac{V^2}{R}$。

學生： 原來如此！接著只要分別代入每個選項的條件，就可以得到各自的電功率了。

老師： 沒錯，那你們算出來電功率，最大的是哪個選項呢？電功率又是多少呢？

學生： 丙的電功率最大，是 32 W。

老師： 太棒啦！

5-2 生活用電
Domestic Electricity

■ 前言 Introduction

本單元先介紹電力輸送的過程，以及如何減少電能在長途輸送上的耗損。並將生活用電分為直流電（電池），與家用電路所使用的交流電（插座）。亦會討論電器標示和電費計算的方法，最後提醒同學，注意用電安全避免短路造成危險。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
power station/ power plant	發電廠	kilowatt (kW)	千瓦
transmit	輸送	kilowatt-hour (kWh)	度
high voltage	高電壓	short circuit	短路
socket	插座	wire	電線
direct current	直流電	insulation	絕緣
alternating current	交流電	load	負荷
(voltage) transformer	變壓器	fuse	保險絲
watt-hour meter	瓦時計(電表)	open circuit	斷路

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

❶ The reason that _____ is to _____.

例句：**The reason that** electricity is transmitted at high voltage and low current **is to** minimize the amount of power loss over long distances.
為了減少電能在長途輸送上的耗損，電力輸送會採用高電壓、低電流。

❷ _____change periodically with_____.

例句：The direction and magnitude of alternating current would **change periodically with** time.
交流電的電流方向及大小，會隨時間作週期性改變。

❸ When the _____ is short-circuited, _____ will increase and generate _____ to _____, even cause _____.

例句：**When the** wire **is short-circuited**, the current **will increase and generate** a large amount of heat to melt the wire, **even cause** fire.
電線短路時，電流會遽增，可能產生大量熱能熔化電線，甚至造成火災。

■ 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、認識 1 度電的電能定義。
To know the definition of one kilowatt-hour of electric energy.
二、能辨別造成電線走火的原因，主要與電流熱效應有關。
Be able to distinguish the reason causes electrical faulty wiring is related to the heating effect of electric current.

例題講解

例題一

說明：熟悉 1 度電的計算。

Know how to calculate electrical energy in 1kWh.

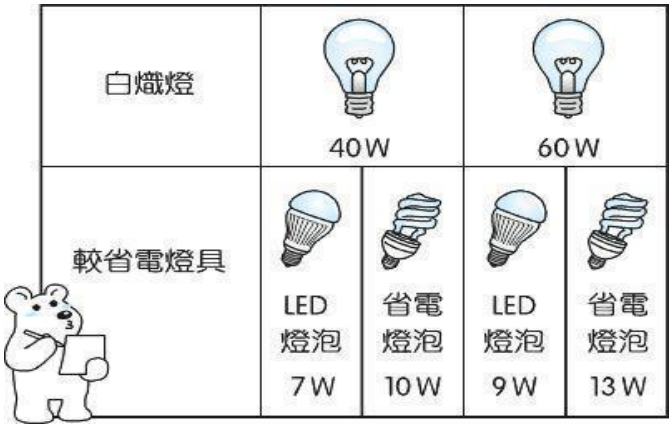
（英文）Having seen an advertisement about how to save energy and reduce carbon emissions for a building, A-Sheng decides to replace all the incandescent light bulbs in his factory with energy-efficient ones. The diagram on the right shows one section of the ad, an illustration of recommended choices of different energy-efficient light bulbs for traditional ones. According to the information provided, A-Sheng figures out a replacement of 300 incandescent light bulbs in his factory can save 2,700 kWh of electricity in a month and reduce 1,447 kgs of CO2. If these 300 incandescent light bulbs are used for an average of 10 hours each day, 30 days a month, and his math is also accurate, ___ incandescent light bulbs in his factory will be replaced with ____ LED bulbs.

(A)40w, 7w

(B)40w, 10w

(C)60w, 9w

(D)60w, 13w



（中文）阿勝看到一篇有關節能減碳的文宣，決定將工廠裡的白熾燈全部改為某種較省電的燈具，右圖為該文宣的部分內容，文宣中的白熾燈可以用下方同一欄中的較省電燈具來取代。阿勝利用此文宣，計算出他更換 300 盞相同的白熾燈，一個月可節省電能 2700 度，同時可減少相當於 1447 公斤的 CO_2 排放量。已知阿勝的計算方式為燈具共 300 盞，每天皆使用 10 小時，一個月使用 30 天來計算，且他的計算結果無誤，則根據他計算的結果來推論，工廠裡的燈具將由何種白熾燈更換為哪一種較省電燈具？

(A)將 40 W 的白熾燈改為 7 W 的 LED 燈泡。

(B)將 40 W 的白熾燈改為 10 W 的省電燈泡。

(C)將 60 W 的白熾燈改為 9 W 的 LED 燈泡。

(D)將 60 W 的白熾燈改為 13 W 的省電燈泡。

（107 年國中會考 51）

解題 Solution：

1 度電=1 千瓦•小時=1000(J/hr)·1hr。每個選項所能節省的電能計算如下:

(A)[(40-7)/1000]千瓦 ×(300 × 10 × 30)小時 = 2970 度

(B)[(40-10)/1000]千瓦 ×(300 × 10 × 30)小時 = 2700 度

(C)[(60-9)/1000]千瓦 × (300 × 10 × 30)小時 = 4590 度

(D)[(60-13)/1000]千瓦 × (300 × 10 × 30)小時 = 4230 度。故選(B)。

kWh = 1000 watts per hour and 1 hour = 1000 (J/hr) x 1hr. The math of how much kWh each option can save up is showed below

(A) [(40-7)/1000] kW × (300 × 10 × 30) hours = 2970 kWh

(B) [(40-10)/1000] kW × (300 × 10 × 30) hours = 2700 kWh

(C) [(60-9)/1000] kW × (300 × 10 × 30) hours = 4590 kWh

(D) [(60-13)/1000] kW × (300 × 10 × 30) hours = 4230 kWh

Option B matches A-Sheng's math, so it is correct.

Teacher: Do you still have it that how many watts is equal to 1kWh?

Student: It is 1000 watts per hour.

Teacher: That is correct. We also know that changing his incandescent light bulbs can save A-sheng 2700 kWh of electricity a month. Now, all we need to do to solve this problem is to figure out how much electricity each option can save and the answer would come up right here.

Student: But how?

Teacher: Let's see Option A first. How many watts are reduced if a 40w bulb is replaced with a 7w LED bulb?

Student: 40-7=33. The change of power is 33 watts.

Teacher: Good job. We also know that A-Sheng replaces 300 incandescent light bulbs in the factory and these light bulbs are on for 10 hours a day, 30 days a month. Now, tell me how much electricity he can save if he goes with Option A?

Student: Okay! In this option, the difference in power is 33w, so the math = $\frac{33}{1000}$ kilo watts × 300 × 10 hours × 30 = 2970 kWh. A-Sheng can save 2970 kWh if he goes with Option A.

Teacher: Excellent! Now repeat the math with the other options.

老師：大家還記得 1 度電的定義嗎？

學生：1 度電是 1 仟瓦・小時。

老師：很好。阿勝更換燈具後，一個月可節省 2700 度的電能，我們可以把四個選項分別可節省多少電能都算出來，只要選項符合節省 2700 度就是正確答案。

學生：那要怎麼算呢？

老師：大家看看選項(A)。更換燈具後，電功率減少了多少？

學生：40−7=33，電功率減少 33 W。

老師：沒錯！阿勝總共有 300 盞燈具，每天使用 10 小時，一個月有 30 天。我們可以計算出節省了多少電能。

學生：哦！選項(A)電功率減少 33 W，$\frac{33}{1000}$ 仟瓦 $\times 300 \times 10$ 小時 $\times 30 = 2970$ 度，總共節省了 2970 度。

老師：太棒了，其他選項也可以用同樣的方式計算出來。

例題二

說明：認識家用電器的電路連接方式，並了解電線走火的原因及相關原理。

Know how home appliances are connected in a house circuit, as well as the causes and general principles of electrical fires.

（英文）In a fire protection guide for electrical installation, one item says, “No plug too many electrical appliances into one socket for overheating. An overloaded outlet can lead to a house fire.” This is in accordance with which of the following principles.

(A) Electromagnetic induction

(B) Inductive electrification

(C) Magnetic effect of current

(D) Heating effect of current

（中文）在某電器的用電安全說明中，其中一項為：「同一插座勿連接過多的電器，以避免導致電線走火，引起火災。」導致電線走火的主要原因，應是下列哪一項科學原理？

(A)電磁感應

(B)感應起電

(C)電流的磁效應

(D)電流的熱效應

（98-1 年國中基測 6）

解題 Solution：

家用電器均採並聯，同一插座連接過多電器時，電路的總電流變大，根據 $P=I^2R$，電源處之內電阻固定，總電流增大，則電功率會增大，因此電流的熱效應增強，升溫過快，導致電線(在電源處)走火。故答案為(D)。

Because home appliances are connected in parallel, an increase in the number of appliances plugged into an electrical source can draw a lot of power. According to $P=I^2R$, the internal resistance of the electrical supply remains unchanged, the higher the current flow, the more the electric power created. An electrical fire can happen at the wiring near the power source, as too much current flow causes heat to build up too quickly. C is the answer to this problem.

Teacher: How do you think our home appliances are connected – in parallel or in series?

Student: They are connected in parallel.

Teacher: Good job. We've learned this concept before. The total current in a parallel circuit can be written mathematically like this $I=I_1+I_2+I_3+....$ This equation means the sum of individual branch currents. How does the total current change in a parallel circuit when more parallel resistances to the paths are added?

Student: Adding more parallel resistances can increase the number of the branches to the circuit, which increase the total current flow.

Teacher: That is correct! According to $P = I^2R$, an increase in electrical current needs more power while the internal resistance of the power supply remains constant. As a result, the wire temperature spikes. What effect causes that?

Student: Heating effect of electric current!

Teacher: That is right! At the same time, the most possible place to see an electrical fire is somewhere near the power source or a socket. Therefore, the main power supply of a household is usually installed with a fuse box to prevent accidental overheating.

老師： 家中電器的電路連接，是並聯還是串聯呢？

學生： 並聯。

老師： 很棒。之前我們學過，在並聯電路當中，總電流可以表示為 $I=I_1+I_2+I_3+...$，也就是各個分支電路的電流總和。那當並聯的電阻越來越多時，電路的總電流會如何變化？

學生： 當並聯的電阻越來越多時，表示電路的分支也越來越多，總電流就會增加，

老師： 答對了！而當通過導線的電流越來越大時，根據 $P=I^2R$，電源處之內電阻固定，總電流增大，則電功率會增大，導線升溫會增快，這是什麼效應造成的呢？

學生： 電流熱效應！

老師： 很好！此時，可能出現電線走火的地方，是在電源處，也就是插座，因此總電源處通常會安裝保險絲，以防過熱火燃燒。

5-3 電池
Battery

■ 前言 Introduction

本節從伏打發現將兩種金屬和浸有鹽水的布排列在一起，會產生電流出發，介紹鋅銅電池，認識電池的結構和運作原理。接著將生活中常見的電池分成一次電池及二次電池，並說明廢電池回收的重要性。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
zinc-copper battery	鋅銅電池	electron	電子
voltaic cell	伏打電池	electrically neutral	電中性
galvanometer	檢流計	primary cell	一次電池
electrode	電極	secondary cell	二次電池
positive electrode	正極	rechargeable	可充電的
negative electrode	負極	dry cell	乾電池
ion	離子	alkaline battery	鹼性電池
cation / positive ion	陽離子	lead storage battery	鉛蓄電池
anion / negative ion	陰離子	lithium-ion battery	鋰離子電池
salt bridge	鹽橋	nickel-hydrogen battery	鎳氫電池

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

❶ **By _____, we can know that the current flows from _____ to _____. Therefore, _____ is the positive electrode, and _____is the negative electrode.**

例句：**By** checking the deflection direction of the galvanometer pointer, **we can know that the current flows from** the copper rod **to** the zinc rod. **Therefore,** the copper rod **is the positive electrode, and** the zinc rod **is the negative electrode**.

根據檢流計指針偏轉的方向，可知電流由銅棒流向鋅棒，因此銅棒為正極，鋅棒為負極。

❷ **Inside a battery, _____ in the salt bridge flow to _____ electrode and _____ flow to _____ electrode, which make both of the solutions be _____.**

例句：**Inside a battery,** the cations (K^+) **in the salt bridge flow to** the positive **electrode and** the anions (NO_3^-) **flow to** the negative **electrode**, **which make both of the solutions be neutrality.**

在電池內部，鹽橋中的陽離子(K^+)流向正極，陰離子(NO_3^-)流向負極，使兩杯水溶液呈電中性。

■ 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、了解鋅銅電池兩極分別的運作機制。

To understand how the two poles of a zinc-copper battery work.

二、能使用檢流計，也了解電池正負極及電流的關係。

Be able to use a galvanometer and understand the relationship between the positive/negative electrodes of the battery and the current.

例題講解

例題一

說明：了解鋅銅電池的運作原理。

Students can understand how zine copper batteries work.

（英文）Two different experiment setups are showed on the diagram below. In Experiment A, it is found that some copper forms on the surface of the zinc rod and the solution temperature increases. In Experiment B, the voltmeter registers some electrical energy. Which of the following statements is true?

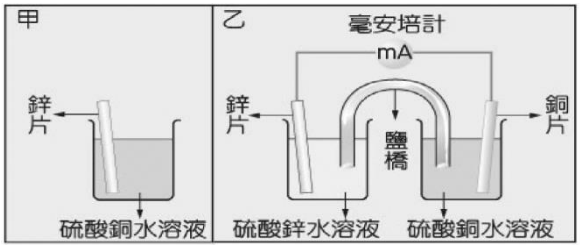
(A) The chemical reaction in Experiment A converts electrical energy into heat energy.

(B) The chemical reaction in Experiment B converts heat energy into electrical energy.

(C) The chemical reaction in Experiment A can be written as $Cu^2+Zn \rightarrow Cu+Zn^{2+}$.

(D) The chemical reaction in Experiment B can be written as $Cu+Zn^{2+} \rightarrow Cu^{2+}+Zn$.

（中文）甲、乙兩實驗裝置如下圖，在實驗中發現甲實驗的鋅片上有銅析出，且溶液的溫度升高，而乙實驗的毫安培計顯示有電流產生。下列有關此兩實驗的敘述何者正確？



(A)甲實驗的反應是將電能轉變為熱能。

(B)乙實驗的反應是將熱能轉變為電能。

(C)甲實驗的反應式為：$Cu^2+Zn \rightarrow Cu+Zn^{2+}$。

(D)乙實驗的反應式為：$Cu+Zn^{2+} \rightarrow Cu^{2+}+Zn$。

（97-2 年國中基測 45）

解題 Solution：

(A)甲實驗：化學能→熱能；(B)乙實驗：化學能→電能；(C)甲實驗是鋅片放在硫酸銅水溶液中，由於鋅的活性大於銅，因此會產生氧化還原反應：$Zn+CuSO_4 \rightarrow ZnSO_4+Cu$；(D)乙實驗是鋅片及銅片分別放在有鋅離子及銅離子的水溶液中，藉由外電路連接鋅片及銅片，產生氧化還原反應，將鋅氧化並還原硫酸銅水溶液中的銅離子，其反應式為：$Zn+Cu^{2+} \rightarrow Zn^{2+}+Cu$。故答案為(C)。

(A) Experiment A: from chemical energy to heat energy; B) Experiment B: from chemical energy to electrical energy; C) In Experiment A, a piece of solid zinc is submerged in a beaker of $CuSO_4$ solution. Because zinc is a metal more reactive than copper, the solid zinc will undergo oxidation. This redox reaction can be written as $Zn+CuSO_4 \rightarrow ZnSO_4+Cu$; D) Experiment B involves a piece of solid zinc being submerged in a solution of zinc ions and a piece of solid copper in a solution of copper ions. These two solid metals are connected via an external circuit. As a result, the solid zinc has become oxidized at the anode over time. The electrons produced during the oxidation reaction leave the solid zinc and travel into the cathode via the external circuit, and so the copper ions in the solution are reduced to copper atoms. This reaction can be written as $Zn+Cu^{2+} \rightarrow Zn^{2+}+Cu$. Therefore, Option C is correct.

Teacher: In Experiment A, inside the $CuSO_4$ solution submerged in it we have a zine rod. What reaction will we see?

Student: We will see a redox reaction because zinc is more reactive than copper. It can be written as $Cu^{2}+Zn \rightarrow Cu+Zn^{2+}$.

Teacher: That is right! Therefore, Option C is the answer to this problem. In addition, we know that the redox reaction generates chemical energy, which tells us that Option A is wrong. Do you know the reason?

Student: It should be the chemical energy that is being converted into heat energy.

Teacher: That is correct. Can you see what kind of battery Experiment B aims to reproduce here?

Student: It is a copper-zinc battery!

Teacher: That is correct. A cooper-zinc battery is a device which can convert chemical energy into electrical energy. In Experiment B, we use one zinc sheet and a copper one. The zinc sheet is submerged in a solution of zinc ions, and the copper sheet in a solution of copper ions. What is happening here is that the zinc sheet gets oxidized at the anode and so the zinc atoms become zinc ions. The copper ions at the cathode precipitate on the copper rod adding more copper to it. How can we write the entire reaction in an equation?

Student: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$.

Teacher: Excellent!

老師： 甲實驗中，鋅片放在硫酸銅水溶液裡面，會發生什麼反應呢？

學生： 鋅的活性比銅大，所以會發生氧化反應：$Cu^{2} + Zn \rightarrow Cu + Zn^{2+}$。

老師： 沒錯！我們可以選擇(C)選項。而且氧化反應的能量是化學能，請問選項(A)錯在哪？

學生： 應該是反應的化學能轉變成為熱能。

老師： 很好，大家看得出來乙實驗是什麼嗎？

學生： 是一組鋅銅電池！

老師： 對，鋅銅電池是能將化學能轉換成電能的裝置。乙實驗是鋅片及銅片分別放在有鋅離子及銅離子的水溶液中，鋅片氧化變成鋅離子，而銅離子還原成銅，在銅片上析出，那整體的反應應該如何表示呢？

學生： $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$。

老師： 太棒啦！

例題二

說明：從檢流計的指針，得知電流的流動方向，並根據電池正負極方向，判斷電流方向。

Know how to read a galvanometer to determine the direction of current flow. The current direction can also be identified based on which orientation of a cell terminals.

（英文）Figure 1 shows a copper-zinc battery. In the figure, the needle on a galvanometer moves to the left. The same galvanometer is used in another battery experiment but with two different metals, X and Y. As indicated in Figure 2, the needle deflects to the right side. This indicates that ____ is at the cathode and the electrons produced are flowing out of the _____ terminal.

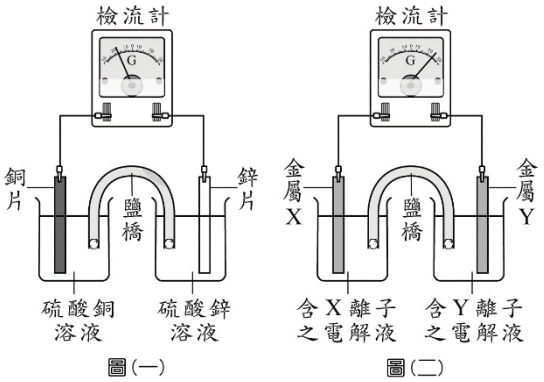
(A) Metal X, negative.

(B) Metal X, positive.

(C) Metal Y, negative.

(D) Metal Y, positive.

（中文）某鋅銅電池的裝置如圖（一）所示，其檢流計指針由中央向左偏轉。若以相同的檢流計檢測金屬 X、金屬 Y 所組成的電池，指針由中央向右偏轉，如圖（二）所示。關於圖（二）電池的負極與電子流向的敘述，下列何者正確？



(A)金屬 X 為負極，電子由電池負極流出。

(B)金屬 X 為負極，電子由電池正極流出。

(C)金屬 Y 為負極，電子由電池負極流出。

(D)金屬 Y 為負極，電子由電池正極流出。

（105 年國中會考 30）

解題 Solution：

鋅銅電池中，鋅為負極，銅為正極，所以電子由鋅片流出，並流入銅片。而檢流計偏向為電子流的方向。由圖(二)之檢流計偏轉方向(向右)，可知電子由金屬 X 流向金屬 Y，故金屬 X 為負極，故選(A)。

The zinc electrode of a copper-zinc battery is always the negative terminal and the copper electrode the positive terminal. As a result, the electrons produced from the solid zinc are following into solid copper. A galvanometer is an ammeter that records the direction of electron flows. According to the reading of the galvanometer showed in Figure 2 (to the right), the electrons produced from Metal X are flowing into Metal Y, which proves to us that Metal X is the negative terminal. Option A is correct.

Teacher: The galvanometer showed in Figure 2 deflates to the right. What does it tell us - from which side the flow of electrons is moving into the galvanometer – right or left?

Student: The needle deflates to the right. That means the flow of electrons is moving into the galvanometer from the left.

Teacher: That is right! We have learned this before – from which terminal the flow of electrons flows?

Student: The flow of electrons flows from the negative terminal of a battery.

Teacher: That is correct. As a result, we can make out the terminal for Metal X and Metal Y based on the direction of the needle movement. What are the terminals for these two solid metals?

Student: The electrons from Metal X flow out, so it is the negative terminal, while the ones from Metal X flow in, so it is the positive terminal.

Teacher: Great job!

老師： 圖(二)裝置中的檢流計指針是向右偏轉，這表示電子流是從左端，或是右端流入檢流計呢？

學生： 檢流計指針向右偏轉，代表電子流是由左端流入檢流計。

老師： 很棒！之前我們學過，電子流是從電池正負極的哪個電極流出呢？

學生： 電子流會從電池的負極流出。

老師： 沒錯。因此我們可以由電子流的流出流入方向，發現金屬 X 和金屬 Y 分別代表的電極是什麼呢？

學生： 金屬 X 流出電子流，是負極；金屬 Y 流入電子流，是正極。

老師： 太棒啦！

5-4 電流的化學效應
Chemical Effect of Current

■ 前言 Introduction

從實驗中探討水和硫酸銅水溶液的電解反應，並將電極換成碳棒或銅片，討論其變化。最後介紹電鍍的技術。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electrolysis / electrolyze	電解 (n./v.)	adhere	附著
electrolyte	電解質	copper sheet	銅片
carbon rod	碳棒	electroplating / electroplate	電鍍 (n./v.)
copper sulfate solution	硫酸銅水溶液	plating solution	電鍍液
atom	原子		

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

❶ In the process of_____.

例句：**In the process of** electroplating, the object to electroplate is connected to the negative terminal of an external power source and the metal to electroplate with is connected to the positive terminal.

在電鍍時，被鍍的物體，接上電源負極，擬鍍金屬接於正極。

❷ Through the electrolysis of _____ solution with _____electrodes, the _____ ions _____ electrons to form _____, which adhere to the _____, making _____.

例句：**Through the electrolysis of** copper sulfate **solution with** carbon **electrodes, the** copper **ions** gain **electrons to form** copper atoms, **which adhere to the** carbon rod**, making** some parts of the black carbon rod look reddish-brown.

透過以碳棒為電極，電解硫酸銅水溶液時，銅離子獲得電子形成銅原子，並附著碳棒上，使黑色碳棒部分呈紅棕色。

■ 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、了解電解水在正負兩極的反應，以及電鍍金屬的方法。

To understand the reactions occur at positive and negative electrodes and the method of metal electroplating.

二、能分辨被鍍物及擬鍍金屬，應分別連接到哪個電極，並了解不同材料電極對應的化學反應。

To be able to distinguish the part to be electroplated and the metal to be electroplated should be connected to which electrodes, and understand the corresponding chemical reactions of the electrodes with different materials.

例題講解

例題一

說明：能從電解水兩極所產生的氣體體積，判斷正負極，並了解電鍍金屬的運作機制。Students can observe two different rates of bubbling on both electrodes to determine which terminal either one is. They can also understand how electroplating works.

（英文）Xin-ru conducts an experiment of electrolysis of water and the experiment setup is showed on the diagram below. During the experiment, Xin-ru collects two types of gas, X and Y, from the two test tubes. If the tubes are to be replaced with two sheets of copper and nickel for nickel electroplating, Terminal i of the DC power supply should be connected to _____, the Terminal ii should be connected to _____, and ____ solution should be used for the electrolyte.

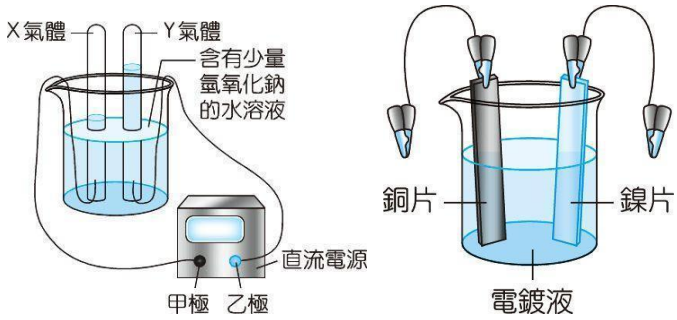
(A) copper, nickel, $NiSO_4$

(B) copper, nickel, $CuSO_4$

(C) nickel, copper, $NiSO_4$

(D) nickel, copper, $CuSO_4$

（中文）欣如進行電解水的實驗，其裝置及收集到 X、Y 二種氣體的體積，如圖所示。若將此直流電源改接到圖的電鍍裝置進行銅片鍍鎳，應如何正確連接和選用電鍍液？



(A)甲極接銅片，乙極接鎳片，電鍍液選用硫酸鎳溶液。

(B)甲極接銅片，乙極接鎳片，電鍍液選用硫酸銅溶液。

(C)甲極接鎳片，乙極接銅片，電鍍液選用硫酸鎳溶液。

(D)甲極接鎳片，乙極接銅片，電鍍液選用硫酸銅溶液。

（107 年國中會考 36）

解題 Solution：

電解水反應式為 $2H_2O \rightarrow 2H_2 + O_2$，可知 X 氣體為 H_2，甲為負極，Y 氣體為 O_2，乙為正極。銅片鍍鎳，被鍍物為銅片接負極（甲），擬鍍金屬鎳片接正極（乙），電鍍液需含有鎳離子，應選用硫酸鎳溶液。故選(A)。

The electrolysis reaction can be written as $2H_2O \rightarrow 2H_2 + O_2$. It is known that Gas X is hydrogen gas so Terminal i is the negative side of the power supply. Gas Y is pure oxygen gas so Terminal ii is the positive side of the power supply. The metal to nickel electroplate is a sheet of copper and so should be connected to the negative side (Terminal i). The solid Nickel to electroplate with should be connected to the positive side (Terminal ii). The electrolyte should be a nickel-based solution that includes nickel ions and so $NiSO_4$ from the given answers is the best solution for nickel electroplating. As a result, Option A is correct.

Teacher: We can observe two different bubbling in an experiment of electrolysis of water. What are they?

Student: Hydrogen and oxygen.

Teacher: That is right! Can anyone come up here to write down the chemical equation for this reaction? Remember to balance the equation.

Student: $2H_2O \rightarrow 2H_2 + O_2$..

Teacher: Good job! This balanced equation also tells us that the 2:1 ratio of hydrogen to oxygen is equal to their mass ratio. Now, look at the diagram and tell me what Gas X and Gas Y are.

Student: Gas X is H_2 and Gas Y is O_2.

Teacher: That is correct! As a result, Terminal i is the negative side and Terminal ii is the positive side of the external power source. The problem asks for nickel electroplating the solid copper. How should we charge the electrodes?

Student: The copper we want to plate should be connected to Terminal i and the nickel we want to plate with is connected to Terminal ii.

Teacher: That is right! How about the electrolyte?

Student: We should use the NiSO4 solution that already contains a bath of positive ions of Nickel.

Teacher: Excellent!

老師：　在電解水的實驗中會產生兩種氣體，分別是什麼呢？

學生：　氫氣跟氧氣。

老師：　沒錯！那有同學可以上來寫出電解水的反應式嗎？記得將反應式平衡喔！

學生：　$2H_2O \rightarrow 2H_2 + O_2$。

老師：　很好，從平衡方程式可知 H_2 跟 O_2 係數比是 2：1，體積比也是 2：1。根據圖片，X、Y 分別是什麼氣體？

學生：　X 氣體為 H_2，Y 氣體為 O_2。

老師：　答對了！由此可知甲為負極，乙為正極。題目要將銅片鍍上鎳，銅片和鎳片要怎麼放呢？

學生：　銅片是被鍍物，應接甲，鎳片是擬鍍金屬接乙。

老師：　很好，那電鍍液要使用什麼呢？

學生：　含有鎳離子的硫酸鎳溶液。

老師：　太棒了！

例題二

說明：能由電鍍銅金屬的裝置圖，辨認導線與電池正負極的連接，及了解不同材料的電極，對應到的化學反應與生成物。

Can identify which wires should be connected to the positive or negative terminal of a power source by looking at an installation diagram. Students can also understand how electrodes of different materials are subject to different chemical reactions yielding varied products.

（英文）The diagram below shows three installation diagram. Starting from the left diagram correctly demonstrates how to copper electroplate a key. The experiment in the middle diagram follows the same setup as the first experiment but the key and the solid copper are replaced with two carbon rods. Carbon Rod A is connected to the red wire and Carbon Rod B to the black wire. The right diagram illustrates another electrolysis experiment but with the same power source as the previous two experiments. In this third experiment, Copper Rod C and Copper Rod D are clipped to the red wire and black one respectively.

In the last two experiments of electrolysis of copper (II) sulfate solution, which of the electrodes generates oxygen?

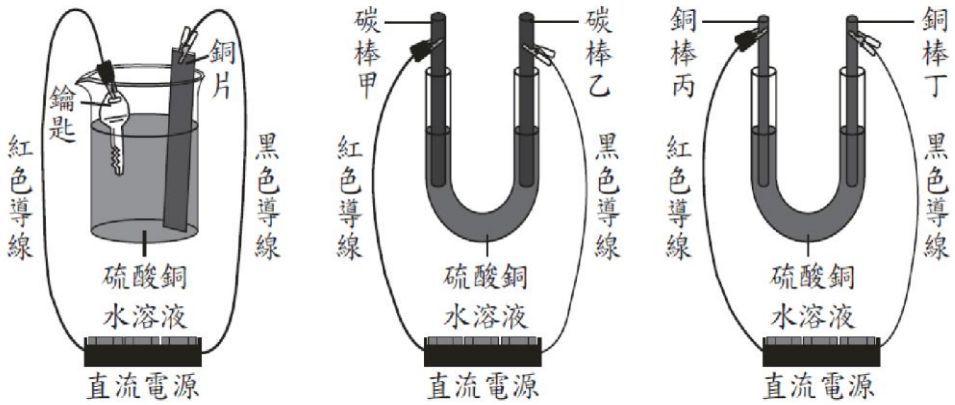
(A) Carbon Rod A

(B) Carbon Rod B

(C) Copper Rod C

(D) Copper Rod D

（中文）圖(一)為在鑰匙上鍍銅實驗的正確裝置圖，圖(二)是以相同的電源裝置，將紅色導線改接碳棒甲，黑色導線改接碳棒乙所組成的電解裝置。接著再以相同的電源裝置，將紅色導線改接銅棒丙，黑色導線改接銅棒丁組成另一個電解裝置如圖(三)。



在圖(二)和圖(三)兩組電解硫酸銅實驗過程中，哪一支電極附近產生的主要產物為氧氣？

(A)碳棒甲

(B)碳棒乙

(C)銅棒丙

(D)銅棒丁

（110 年國中會考 33）

解題 Solution：

由圖(一)中可知紅色導線接電池負極，黑色導線接電池正極，再根據圖(二)及(三)可知電極上半反應式如下：

碳棒甲：$Cu^{2+}+2e^{-}\rightarrow Cu$

碳棒乙：$2H_2O\rightarrow O_2+4H^{+}+4e^{-}$

銅棒丙：$Cu^{2+}+2e^{-}\rightarrow Cu$

銅棒丁：$Cu\rightarrow Cu^{2+}+2e^{-}$。故選(B)。

In the left diagram, the red wire is connected to the negative terminal of an external power source and the black wire to its positive terminal. Based on the middle and the right diagrams, the half-reaction equations of redox reactions for each electrode given are showed below

Carbon Rod A: $Cu^{2+} + 2e^- \rightarrow Cu$

Carbon Rod B: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Copper Rod C: $Cu^{2+} + 2e^- \rightarrow Cu$

Copper Rod D: $Cu \rightarrow Cu^{2+} + 2e^-$. As a result, Option B is correct.

Teacher: We can see from the left diagram that the key to electroplate is clipped to the red wire and the solid copper to electroplate with is to the black wire. Can you tell me to which terminal the red and black wires are connected?

Student: The red is connected to the negative terminal of a power source and the black to its positive terminal.

Teacher: That is correct! Now, tell me the half-reaction equations for the four different electrodes, anyone?

Student: Carbon Rod A: $Cu^{2+} + 2e^- \rightarrow Cu$.

Student: Carbon Rod B: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$.

Student: Copper Rod C: $Cu^{2+} + 2e^- \rightarrow Cu$.

Student: Copper Rod D: $Cu \rightarrow Cu^{2+} + 2e^-$.

Teacher: Great job! The answer to this problem is Carbon Rod B.

老師： 從圖一我們可以出：紅色導線接著被鍍物鑰匙，黑色導線接著擬鍍金屬銅。請問紅色導線及黑色導線分別連接電池的哪一極呢？

學生： 紅色導線接電池負極，黑色導線接電池正極。

老師： 沒錯！那有同學可以說出甲、乙、丙、丁，4 個電極分別的反應嗎？

學生： 甲：$Cu^{2+} + 2e^- \rightarrow Cu$。

學生： 乙：$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$。

學生： 丙：$Cu^{2+} + 2e^- \rightarrow Cu$。

學生： 丁：$Cu \rightarrow Cu^{2+} + 2e^-$。

老師： 太棒了！答案就是碳棒乙。

★主題六 電與磁★
Electricity and Magnetism

國立彰化師範大學物理系　宋德致、王瑞德

■ 前言 Introduction

電和磁原理的應用，在我們的生活中可說是處處可見，兩者之間也存在著密切的關係。本章透過一些歷史故事，配合生活中常見的事物或現象，來介紹電與磁相關原理的概念及發現，以讓學生們認識並理解基本的物理原理。

6-1 磁鐵與磁場
Magnets and Magnetic Fields

■ 前言 Introduction

本節介紹磁鐵具有「同極相斥，異極相吸」的性質，進而延伸出磁力線與磁場的概念。此外，也介紹磁化現象，及暫時磁鐵和永久磁鐵之間的區別。透過種種實例，展現原理的意義及用法，幫助學生理解相關原理，也促進原理內容與生活經驗的連結。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
magnet	磁鐵	repel	排斥
magnetic field	磁場	magnetic field line	磁力線
magnetic force	磁力	temporary	暫時的
N pole	N 極	permanent	永久的
S pole	S 極	magnetization	磁化
attract	吸引	paper clip	迴紋針

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

❶ A magnet attracts ferrous objects such as _____.

例句：**A magnet attracts ferrous objects such as** paper clips.

磁鐵可吸引如迴紋針等含鐵的物品質。

❷ We call the area around the _____ where _____ force _____.

例句：**We call the area around the** magnet a magnetic field **where** magnetic **force** might be acting on.

我們將磁鐵周圍可能造成磁力作用的空間，稱為磁場。

❸ The ____ all start from ____ and go to ____.

例句：**The** magnetic field lines outside magnets **all start from** the N pole **and go to** the S pole.

在磁鐵外部的磁力線，皆是由 N 極出發，走向 S 極。

■ 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、能判斷磁鐵的磁力線方向。

Being able to determine the directions of the magnetic field lines via magnets.

二、理解磁針指向，與磁力線之間的關係。

Understand the relationship between magnetic needle pointing and magnetic field lines.

例題講解

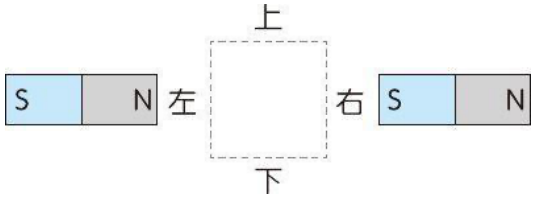
例題一

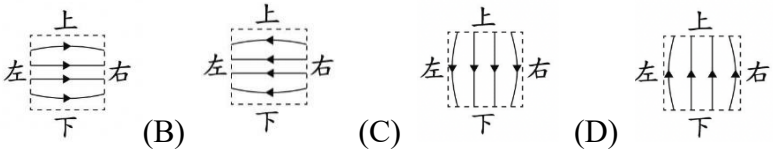
說明：根據磁極判斷磁力線方向。

Students can determine the direction of the magnetic field lines based on the N pole and S pole of a magnet.

（英文）Two bar magnets of the same size and the same strength are rested on a table as showed on the diagram. Which of the following drawings correctly represents the direction of the magnetic field circled in a dotted line?

（中文）若將兩根相同的條形磁鐵靜止擺放如圖所示，則圖中虛線區域中磁力線分布及磁場方向，下列何者最合理？





(A) (B) (C) (D)

（107 年國中會考 17）

解題 Solution：

磁力線在磁鐵外部方向為 N 極到 S 極。故選(A)。

Magnetic field lines start from the north pole and end into the south pole outside bar magnets. As a result, Option A is correct.

Teacher: Do you still have it that from which pole the magnetic field lines run outside a magnet – the north or the south?

Student: The north pole.

Teacher: That is right! And to which pole?

Student: The south pole.

Teacher: Great job. This tell us that magnetic field lines run north to south, closing the entire loop. They are always closed loops. Now, let's plot the magnetic field lines in question on this diagram together.

Student: Okay.

老師： 大家知道磁力線在磁鐵的外面，是從 N 極還是從 S 極，出來的嗎？

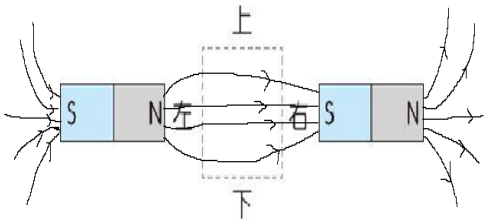
學生： N 極。

老師： 沒錯！那麼從哪裡進入呢？

學生： S 極。

老師： 說的好，所以磁力線是從 N 極出去，S 極進入的封閉曲線，讓我們一起畫出這張圖的磁力線吧。

(磁力線分布示意圖)



學生： 好的。

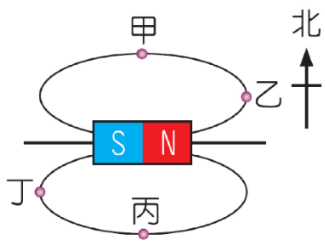
例題二

說明：從磁極的方位，判斷磁力線及磁針的指向。

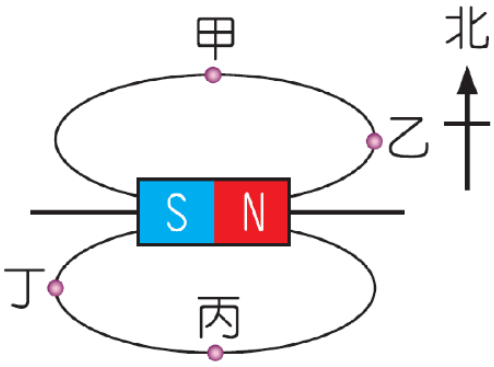
Can determine the direction of magnetic field lines and the orientation of a compass needle from the N pole and S pole of a given magnet.

（英文）A bar magnet is placed on a horizontal table and the lines of its magnetic field are plotted on the diagram. As showed in the diagram, a magnetic compass is placed at four different points, A, B, C, and D. Assuming Earth' s magnetic field can be negligent, in which of the following directions the compass points is FALSE?

(A)A: West　(B)B: North　(C)C: West　**(D)D: South**



（中文）將一根長條形磁鐵放置在水平桌面上，在磁鐵周圍分布的磁力線示意圖如圖所示。今在水平桌面上甲、乙、丙、丁四點各放置一個磁針，若地球磁場的影響忽略不計，則關於磁針 N 極的指向，下列何者錯誤？



(A)甲：向西　(B)乙：向北　(C)丙：向西　**(D)丁：向南**

（102 年國中基測 39）

解題 Solution：

N 極所指的方向為磁力線的切線方向，而磁力線皆從磁棒的 N 極出發，S 極收回。由圖中可看出磁真 N 極的方向，在甲位置應向西、乙向北、丙向西、丁向北。故答案為(D)。

The tangent at any point of magnetic field lines shows the direction of the field. In this problem, the direction is in line with the arrow that points to the north pole as illustrated on the diagram. Similarly, the lines of the magnetic field of a magnet always go from the north pole and move into the south pole and a magnetic compass should indicate the direction of magnetic fields. As a result, at Point A, the compass needle will point in the west direction, at Point B the compass needle in the north direction, at Point C the compass needle in the west direction, and at Point D the compass needle in the north direction. Option D is the answer to this problem.

Teacher: Do you know how to determine the direction of the magnetic field line outside a magnet?

Student: From the N pole to the S pole.

Teacher: That is correct. What would happen when we place a magnetic compass at a point on a magnetic field line?

Student: At that point, the compass will align itself along a tangent drawn to that field. The direction of the magnetic field lines is the same as the direction at which the north end of a compass needle moves.

Teacher: That is right. Now, all we need to do is to mark the direction of the magnetic field lines.

Student: I see it now! Thank you.

老師： 同學們知道磁力線，在磁鐵外部的方向嗎？

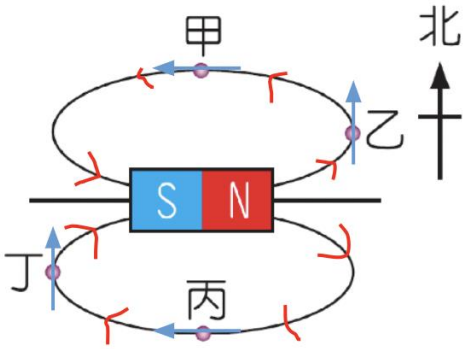
學生： 從 N 極出來，S 極進入。

老師： 正確，那如果在磁力線的路徑上方，放上磁針呢？會發生什麼事？

學生： 磁針的 N 極，會指向該點磁力線的切線方向，且與磁力線箭頭同向。

老師： 沒錯，所以我們只要在圖上標示出磁力線的方向，就可以得到答案了喔。

學生： 知道了，謝謝老師！



(磁力線方向與各點之切線方向)

6-2 電流的磁效應
Magnetic effect of Current

■ 前言 Introduction

磁場並非僅能由磁鐵產生，電流也能夠產生磁場，此現象稱為電流磁效應，而電流所造成之磁場方向，可利用「安培右手定則」判斷。此外，我們還可以透過電流磁效應，來設計出許多實用的產品，例如：搬運大型鐵製物體的電磁起重機，因此，電流磁效應與我們的生活息息相關。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
current	電流	Ampere's right hand rule	安培右手定則
magnetic needle	磁針	number of turns	匝數
deflection	偏轉	solenoid	螺線管
wire	導線	electromagnet	電磁鐵
iron powder	鐵粉		

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

❶ A _____ creates a _____ around it.

例句：**A** current-carrying wire **creates a** magnetic field **around it**.
載流導線會在周圍產生磁場。

❷ When a magnetic needle is _____ to the current-carrying wire, the deflection angle of the magnetic needle _____, indicating that the magnetic field is _____.

例句：When a magnetic **needle** is brought close **to the current-carrying wire**, **the deflection angle of the magnetic needle** increases, **indicating that the magnetic field is** stronger.
若將磁針靠近載流導線,磁針偏轉角度增加,表示磁場較強。

❸ The relationship between the _____ and the _____ can be ____ by ____.

例句：**The relationship between the** current of a solenoid **and the** direction of the magnetic field **can be** determined **by** Ampere's Right-Hand Rule.
螺線形線圈的電流與磁場方向的關係，可用安培右手定則來判斷。

■ 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、了解電流方向和磁針位置，如何影響磁針的偏轉。
Learn how current direction and magnetic needle position affect the needle's deflection.
二、學習如何應用安培右手定則在螺線管上。
Learn how to apply Ampere's Right Hand Rule to current-carrying solenoids.

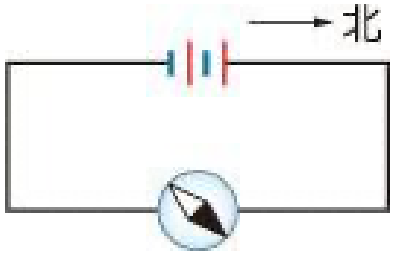
例題講解

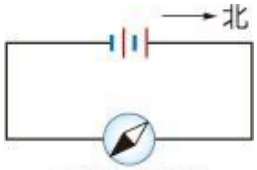
例題一

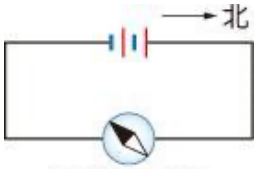
說明：了解導線之電流方向，與其所造成之磁場方向之關係，並以磁針指向表達。
Understand the relationship between the direction of the current flowing in a wire and the magnetic field it creates around the wire. Also, know how to read a magnetic compass to express such a relationship.

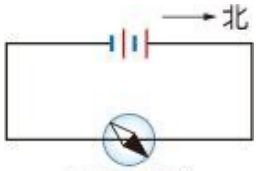
（英文）The diagram below shows an experiment setup Xiao-hua has drawn aiming to prove the electromagnetic effect. As indicated, a compass is situated on a wire carrying electric current. The north end of the compass needle is painted black and points in the direction of the magnetic field of the wire. However, his teacher finds something wrong in this sketch. Which of the following changes to his experiment is MOST logical?

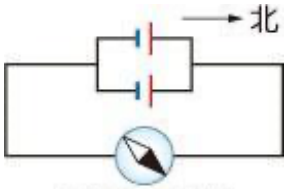
（中文）小華畫了一張電流的磁效應實驗示意圖，如圖所示，圖中磁針放置於導線的上方，磁針黑色部分為 N 極，所指方向為磁場方向。老師發現此示意圖並不合理，則下列哪一個修改方式的示意圖最為合理？



(A) 

(B) 

(C) 

(D) 

（108 年國中會考 43）

解題 Solution：

根據安培右手定則，磁針如置於導線上方，N 極應該往西偏，磁針 N 極因地磁向北，加上導線磁場，故會指向西北方，若改置於導線下方，才會偏向東，磁針 N 極指向東北方。故選(C)。

According to Ampere's right hand rule, the north end of a magnetic compass should deflect to the west when the compass is placed directly above the wire that carries an electric current. If Earth's magnetic field is taken into account, the compass needle should go upwards a bit and end up pointing to the northwest, or to the northeast when the compass is relocated directly below the current-carrying wire. As a result, Option C is correct.

Teacher: Now, how should we determine the direction of the magnetic field induced by a wire that carries an electric current?

Student: We use Ampere's right hand rule to find the direction!

Teacher: That is right. Let's look at the diagram given. The compass is situated directly above the current-carrying wire. According to Ampere's right hand rule, tell me the direction of the magnetic field around that wire at this point.

Student: West!

Teacher: That is right. The compass needle should point upwards a bit to northwest due to Earth's magnetic field.

Teacher: Yet, we could not see any of the given options that have words like northwest, so we can try to move around the compass a little bit.

Teacher: Let's look at the diagram again. Where should we put the compass to make the needle deflect to the northeast as illustrated?

Student: We should put the compass directly below the wire.

Teacher: Why is that?

Student: The direction of the magnetic field below the current-carrying wire should go east. Given the factor of Earth's magnetic field, the direction of the compass needle should be settled in the northeast direction.

Teacher: That is right. At this point, the compass needle will point in the northeast direction, so Option C is correct.

老師：　同學們，這題我們要如何判斷電流所造成的磁場方向呢？

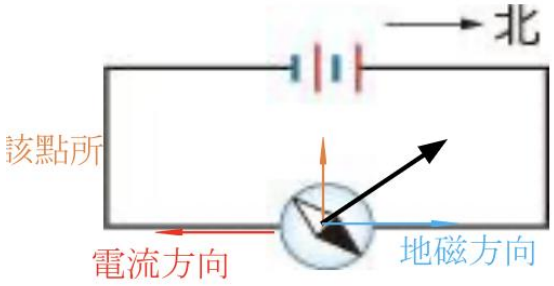
學生：　使用右手安培定則。

老師：　沒錯，讓我們看一下題目的示意圖，磁針是放在導線上方的，而根據安培右手定則導線上方所造成的磁場方向應該往哪呢？

學生：　往西！

老師：　沒錯，所以指針應受到地磁向北，加上導線磁場，故會指向西北方才對。

老師：　但選項中並沒有把指針方向改為西北方的選項，所以我們試著改改看磁針的位子吧！



(示意圖)

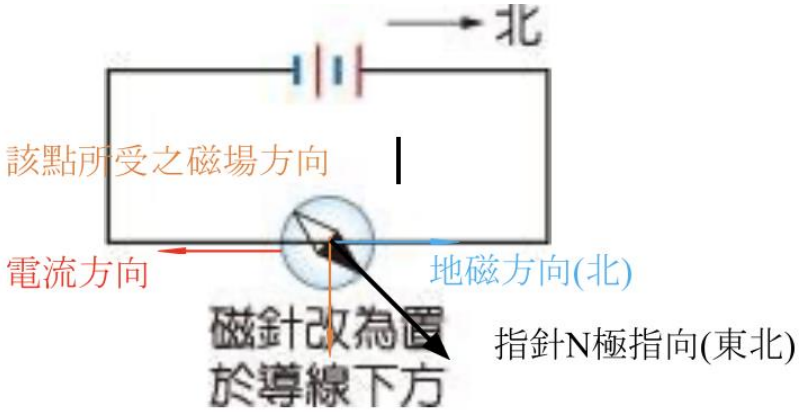
老師：　根據上圖，磁針放哪裡，才能讓指針指向圖中所示的東北方呢？

學生：　將磁針放在導線的下方。

老師：　為什麼呢？

學生：　因為導線下方所造成的磁場方向是向東，結合地磁方向，就可以知道磁針會指向東北方。

老師：　沒錯，磁針 N 極會指向東北方，所以正確答案就是(C)。



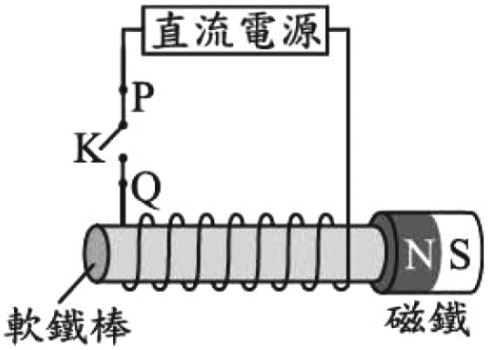
(示意圖)

例題二

說明：透過「安培右手定則」，判斷螺線管電流，與其所產生的磁場方向分佈之間的關係。
Students can use Ampere's right hand rule to determine the direction of the current that flows in a solenoid and its relationship with the magnetic field it induces.

（英文）A soft iron bar, a coil of wire, a DC power supply, and a switch marked K, are built together as showed on the diagram. At the right end of the iron bar, a magnet is attached to it through magnetic force. However, soon after the switch is turned on, the magnet drops off the iron bar as these two objects repel each other. The electric current flows from _____ to _____ via the switch, and the right side of the iron bar behaves like the ____ magnetic pole.

(A) Point P, Point Q, South
(B) Point P, Point Q, North
(C) Point Q, Point P, South
(D) Point Q, Point P, North.



（中文）將軟鐵棒、導線、直流電源、開關 K 連接如圖，軟鐵棒的右端有一個磁鐵因磁力作用而吸附在軟鐵棒上。按下開關 K 接通電路後，發現磁鐵因為與軟鐵棒相互排斥而掉落，下列有關磁鐵掉落的敘述，何者最合理？

(A) 電流由 P 點經開關 K 流向 Q 點，使軟鐵棒右端為 S 極。
(B) 電流由 P 點經開關 K 流向 Q 點，使軟鐵棒右端為 N 極。
(C) 電流由 Q 點經開關 K 流向 P 點，使軟鐵棒右端為 S 極。
(D) 電流由 Q 點經開關 K 流向 P 點，便軟鐵棒右端為 N 極。

（103 年國中會考 41）

解題 Solution：

按下開關後，磁鐵會掉落，是因軟鐵棒的右端因線圈通入電流後，感應成 N 極而排斥磁鐵，使其掉落。根據安培右手定則，拇指代表螺線管的磁場(由 S 極到 N 極)，所以拇指向右，則其他四指可推出螺線管的電流方向。因此判斷電流應由 Q 點經開關 K 到 P 點。故答案為(D)。

As soon as the switch opens, the magnet drops off the iron bar. This is caused by the iron bar temporarily magnetized by the electric current, which flowing from its right side. The action like a North pole as the current generates its own magnetic field. As a result, the North pole generated repels the magnet. Similarly, Ampere's right hand rule defines that the thumb points in the direction of the magnetic field around a solenoid (moving from the South pole into the North pole), which is to the right as this direction is where the thumb is pointing. The right hand rule also shows that the direction of the current flow around the solenoid can be referred to the four encircling fingers. Therefore, the flow of the electric current should go from Point Q to Point P through the switch. Option D is the answer to this problem.

Teacher: When we turn the switch on, some electric current passes through the soft iron bar and the magnet that has been originally attached to it drops off because the current creates its own temporary magnetic field, exerting a repulsive force on the right side of the charged iron bar. Do you know what is the pole of the right side of this iron bar?

Student: North pole.

Teacher: That is right. According to Ampere's right hand rule for solenoids, the encircling fingers represent the direction of current flow and the thumb shows the direction of a magnetic field. Let's draw an arrow on the diagram to represent the direction of the magnetic field around that current-carrying wire.

Teacher: Now, the directions for the current and magnetic field are marked. What can you see?

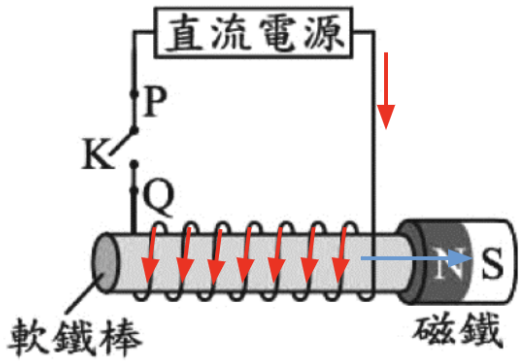
Student: The current flows from Point Q to Point P through Switch K.

Teacher: Great job! As a result, Option D is the answer to this problem.

老師： 按下開關 K 接通電路後，發現磁鐵因為與軟鐵棒相互排斥而掉落，那軟鐵棒的右端是什麼極呢？

學生： N 極。

老師： 沒錯，那根據螺線管的右手安培定則，四指方向是電流方向，大拇指方向是磁場方向，我們來把它們畫出來吧！



1. 根據題目判斷通電後，軟鐵棒的右端為N極而左端為S極。

2.根據安培右手定則，求出螺線管內的電流方向。

紅箭頭:電流方向
藍箭頭:磁場方向

老師： 現在我們把電流和磁場的方向都標示出來了，你們有看到什麼嗎？

學生： 電流方向是由 Q 點經由開關 K 流向 P 點的。

老師： 說得好，那麼我們就可以知道答案是(D)了。

6-3 電流與磁場的交互作用
Interaction of Electric Current and Magnetic Field

■ 前言 Introduction

當電流導線放置在有外加磁場之空間時，導線會受到磁場的作用而受力，我們稱此力為磁力。也就是說，有速度的帶電粒子在磁場中，會受到磁力，馬達就是透過此原理的應用。電流導線所受磁力方向，可由「右手開掌定則」來判斷，「右手開掌定則」包含：電流、外加磁場、及磁力，大拇指方向為電流，四指方向為外加磁場，最後手心方向為磁力方向。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electric current	電流	parallel	平行
magnetic field	磁場	motor	馬達
wire	導線	right-hand rule	右手開掌定則
perpendicular	垂直	velocity	速度
magnetic force	磁力	magnetic field line	磁力線

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

❶ A current-carrying wire _____ when being placed in _____.

例句：**A current-carrying wire** will experience a force **when being placed i**n a magnetic field.
在磁場中，電流流通的導線會受磁力。

❷ Outside of _____, its _____.

例句：**Outside of** a magnet, **its** magnetic field lines go from the North pole and into the South pole.
磁鐵外部之磁力線，是從 N 極射出，指向 S 極。

❸ It has been found _____ that _____ can be_____.

例句：**It has been found** in experiments **that** the magnetic force direction of a wire in magnetic field **can be** determined by the right-hand rule.
經實驗發現，電線在磁場中所受磁力方向，可由右手開掌定則來判斷。

❹ _____ due to the interaction of the electric current of coils and _____.

例句：Electric motors rotate **due to the interaction of the electric current of coils and the** magnetic field provided by magnets.
電動馬達的轉動，是由於線圈的電流與外加磁鐵的磁場，兩者間的作用而造成。

■ 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、磁力可透過運動的帶電粒子，與外加磁場間的作用而產生磁力。

Understanding magnetic force can be caused by the interaction of moving charged particles and external magnetic fields.

二、右手開掌定則。

Right-Hand Rule.

❧ 例題講解 ☙

例題一

說明：根據「右手開掌定則」，了解磁場會對移動的帶電粒子作用，產生磁力。

Understand that magnetic force can be felt by moving charged particles in a magnetic field according to the Right Hand Rule.

（英文）Electrically charged particles ejected from the Sun can hurt all animals on Earth, but this situation does not happen. Instead, people live peacefully and enjoy the amazing auroras in the southern hemisphere and the northern equivalent. Auroras are caused by those solar particles which collide with Earth's atmosphere and move further to Earth's poles. What makes this interaction happen?

(A) Earth's Magnetic Force

(B) The force exerted by the rotation of Earth

(C) Gravity of Earth

(D) Wind force

（中文）太陽輻射線中，含有會傷害生物的帶電粒子，但我們卻能安然生活在地球上，並可在南、北兩極區內欣賞到美麗的極光。下列何種力量把帶電粒子引到兩極區，並和大氣碰撞產生極光？

(A)地球磁場的力量

(B)地球自轉的力量

(C)地球引力

(D)風力

（94-1 年國中基測 11）

解題 Solution：

地球磁場會對移動的帶電粒子，造成磁力，使其偏移，答案為(A)。

Charged particles moving in Earth's magnetic field will feel the force which deflects those moving charges. As a result, Option A is the answer to this problem.

Teacher: We know that moving charges in a wire feels the magnetic force in a magnetic field.

Student: So, charged particles when moving can feel the presence of a magnetic field.

Teacher: That is correct. That also tells us that charged solar particles moving in Earth's magnetic field will feel the force which deflects those moving charges.

Student: As a result, Option A is the answer to the problem.

老師： 在磁場中，電流流通的導線會受力。

學生： 也就是說，有速度的帶電粒子在磁場中會受力。

老師： 沒錯，因此地球的磁場，會對運動中的帶電粒子，造成磁力，使其偏移。

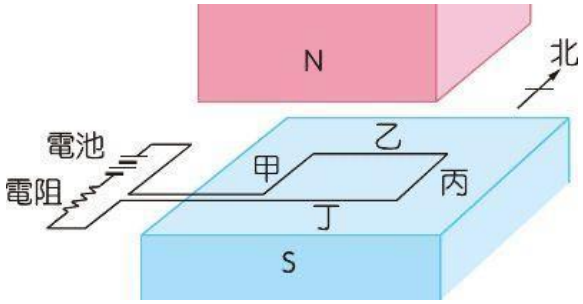
學生： 所以答案為 A。

例題二

說明：根據「右手開掌定則」，判斷:電流、外加磁場、及磁力，三個向量之間的關係。
Using the Right Hand Rule to determine the relationship directions among between the vectors of electric current, external magnetic fields, and magnetic force.

（英文）In a given circuit, four copper wires, A, B, C, D, are respectively perpendicular to the wire next to it. Each wire is also perpendicular to the directions of the magnetic fields. When the wires are connected to the power supply, magnetic force is felt in the magnetic fields. Which of the following wires with the direction of magnetic force felt is true?

(A) Copper Wire A: North
(B) Copper Wire B: South
(C) Copper Wire C: East
(D) Copper Wire D: West



（中文）根據「右手開掌定則」，判斷：電流、外加磁場、及磁力，三個向量之間的關係。

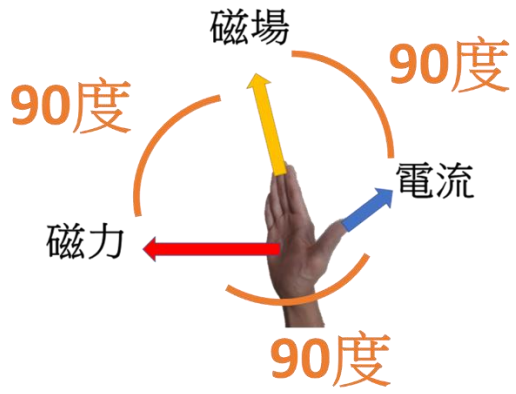
(A) 銅線甲：向北
(B) 銅線乙：向南
(C) 銅線丙：向東
(D) 銅線丁：向北

（106 年國中會考 32）

解題 Solution：

根據電池的正負極方向，電流方向為:甲→乙→丙→丁。根據右手開掌定則(如右圖)，拇指代表電流方向，其餘四指代表磁場方向，掌心代表磁力方向。調整右手掌的方向，讓電流與外加磁場與右手之拇指、其餘四指吻合，則可推出銅線四邊之電流，分別所受到的磁力方向。銅線受力方向為(A)銅線甲：向西(B)銅線乙：向北 (C)銅線丙：向東(D)銅線丁：向南。答案(C)。

Based on the given arrangement given, the direction of current flow should be: Copper Wire A -> B -> C -> D. As showed on the diagram of the right hand rule (the right), the thumb represents the direction of current flow and the four fingers gives the direction of magnetic fields. The right palm should always align with the current flow at each wire in determining in which direction current flows and how each wire is felt the magnetic force. As a result, the direction of force experience by i) Copper Wire A: West, ii) Copper Wire B: North, iii) Copper Wire C: East, iv) Copper Wire D: South. As a result, C is correct.



Teacher: First, we should identify where are the positive and negative terminals of the cell so as to determine the direction of current flow. Tell me how electric current flows in a circuit.

Student: Electric current flows from the positive terminal to the negative terminal of a cell. The long bar represents the positive and the short bar the negative, so the direction of electric current flows should: Copper Wire A →B →C →D.

Teacher: That is correct. How about the direction of the external magnetic fields?

Student: It should be from the N pole to the S pole. That means the entire loop is surrounded by the external magnetic fields created by the two magnets above and under. The directions of the external magnetic fields should go downwards.

Teacher: That is right. Now, by using the right hand rule to find the direction of magnetic force results in each wire. Open our right hands and adjust the palm position according to the current flow and external magnetic field. This way we can determine the current direction of the magnetic force for each side. Tell me your results.

Student: Copper Wire A: North, Copper Wire B: South, Copper Wire C: East, and Copper Wire D: West

老師： 我們先觀察電池的正負極方向，來判斷電流流通方向。請問電流從哪方向流通？

學生： 正極流向負極，長線為正、短線為負，所以電流方向應是:甲→乙→丙→丁。

老師： 不錯，那外加磁場的方向呢？

學生： 由 N 向 S，所以整個線圈，受到上下磁鐵所產生的外加磁場，是向下。

老師： 是的，接下來用右手開掌定則，來判斷導線每一邊，所受磁力的方向。將右手掌打開，根據電流及外加磁場，來調整手掌的方向，就能判斷每一邊電流的磁力方向，分別是如何呢？

學生： 銅線甲：向西、銅線乙：向北、銅線丙：向東、銅線丁：向南。

6-4 電磁感應
Electromagnetic Induction

■ 前言 Introduction

當環形導線內的磁場發生變化時，導線會產生感應電流，稱為「電磁感應」，發電機就是運用此一原理。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
magnetic flux	磁通量	electromagnetic induction	電磁感應
electromotive force	電動勢	induced current	感應電流
Lenz's law	冷次定律	direct current (DC)	直流電
galvanometer	檢流計	alternating current (AC)	交流電
magnetic bar	磁棒	number of turns	匝數
index pin	指針	generator	發電機

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

❶ When _____, _____, and _____.

例句：**When** moving a magnetic bar of a coil**,** the magnitude of magnetic field inside the coil will change**, and** electric current will be induced.
當移動磁棒時，線圈內的磁場大小會產生變化，進而產生感應電流。

❷ A change either _____ or _____.

例句：**A change either** in the rate of change of a magnetic field **or** in the number of coil turns will affect the magnitude of the induced current that flows in the coil.
改變磁場變化速率，或調整線圈匝數，都會影響線圈上的感應電流大小。

❸ After _____ discovered that _____, _____ began to _____.

例句：**After** Ørsted **discovered that** current-carrying wires can generate magnetic fields, many scientists **began to** ask "can magnetism also generate electricity"?
自從厄斯特發現有電流的導線會產生磁場後，許多科學家開始提問—磁是否也能生電？

❹ _____ is an application of _____.

例句：Generators **are** one of **the applications of** electromagnetic induction.
發電機就是電磁感應的應用。

■ 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、產生電磁感應的條件。

Understand the conditions of electromagnetic induction.

二、電磁感應應用於搖動手電筒。

One of the applications of electromagnetic induction is shake flashlights.

例題講解

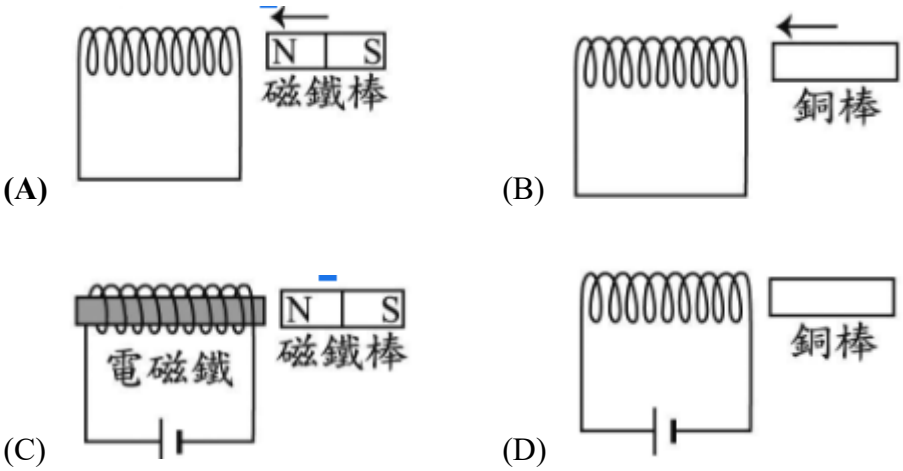
例題一

說明：了解造成電磁感應的條件。

Students can understand the conditions necessary for electromagnetic induction.

（英文）The diagram below shows four different arrangements of solenoids. Which can cause an induced current in the solenoid?

（中文）下列四種裝置及其處理方式中，哪一種裝置的線圈會發生電磁感應現象？



（105 年國中會考 31）

解題 Solution：

電磁感應必須在線圈內的磁場產生變化時，才會發生，答案(A)。(B)及(D)，使用的是銅棒，無法提供磁場；而(C)的右側磁鐵，則因為沒有移動，不會在線圈產生磁場變化，也無法造成磁生電的現象。

Only when the magnetic field through a coil changes, electromagnetic induction occurs. As a result, Option A is correct, while both Option B and Option D are not as both options give a copper bar which is not magnetic. The bar magnet with Option C is stationary and does not interact with the magnetic field around the coil. A steady magnetic field does not produce electricity.

Teacher: The answer to this problem is Option A. Because the bar magnetic is moving to the coil, the force experience by the coil is also growing. As a result, electromagnetic induction occurs and a current is induced in that coil.

Teacher: Now, tell me why the arrangement with Option C fails to induce a current?

Student: It is because the bar magnet in Option C does not move, the magnetic field around the magnet has no change in it. There is no electromagnetic induction.

Teacher: Great job! Do you also know why there is no electromagnetic induction with either Option B or Option C?

Student: That is because a copper bar cannot produce a magnetic field.

Teacher: That is right. Although copper is a metal, it is not magnetic. There is no magnetic field around copper.

老師： 答案是(A)，由磁鐵棒靠近線圈，使得線圈感應到的磁場變大，發生電磁感應現象，產生感應電流。

老師： 那麼，(C)為何沒有電磁感應現象呢？

學生： 但(C)磁鐵棒沒有動，所以沒有磁場變化，因此無發生電磁感應現象。

老師： 很棒喔！那為什麼(B)、(D)為何也沒有電磁感應呢？

學生： 因為銅棒不會產生磁場。

老師： 答對了，銅雖然是金屬，但不屬於鐵性材料，所以沒有磁場。

例題二

說明：電磁感應應用在搖動手電筒。

Shake flashlights, one of the applications of electromagnetic induction.

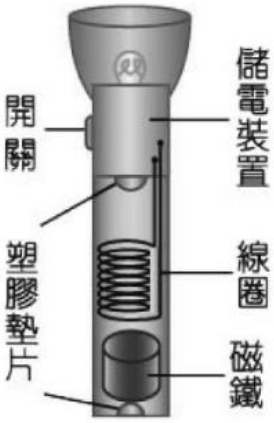
（英文）The diagram on the right is a see-through of a shake flashlight. A shake flashlight is a device that can light an LED by shaking the flashlight left and right. As showed on the diagram, this mechanical movement causes the magnet between the two plastic bumpers to go through its overhead solenoid to generate power. The capacitor at the top can store the induced electricity and power the light bulb. Which of the following statements is the MOST reasonable?

(A) The shaking of a shake flashlight converts the kinetic energy to light energy.

(B) The physics behind a shake flashlight is that the sliding magnet that goes through the solenoid induces current.

(C) The solenoid inside a shake flashlight generates direct current by shaking it back and forth.

(D) The purpose of shaking a shake flashlight is to generate electric current to create a magnetic field.



（中文）有一種手電筒，只需在使用前搖一搖，使磁鐵穿過線圈，在兩個塑膠墊片之間來回運動，就能發電並先將電能儲存，再供電給燈泡，它的構造如右圖所示。有關該手電筒的敘述，下列何者最為適當？

(A)搖晃手電筒的發電過程，是將磁鐵的動能直接轉換成光能。

(B)搖晃手電筒時，磁鐵來回經過線圈會使線圈產生感應電流。

(C)在來回搖晃手電筒的發電過程中，線圈會產生直流電。

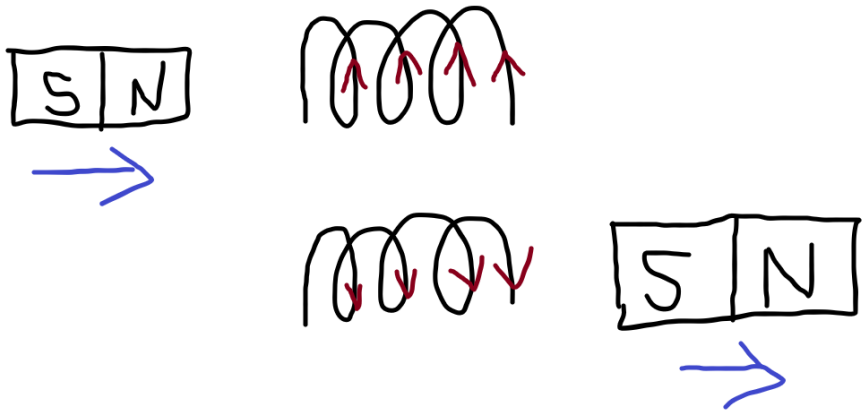
(D)搖晃手電筒的發電過程，是運用電流產生磁場。

（95-2 年國中基測 17）

解題 Solution：

(A)手搖使磁場產生改變，形成感應電流，電能再轉換成光能；(C)當磁鐵接近線圈時，若假定感應電流流動方向為順時針；當磁鐵離開線圈時，其感應電流方向為逆時針，因此為交流電；(D)磁場改變產生電流。故答案為(B)。

(A) The mechanical energy by hand changes the magnetic field around the solenoid to create induced current. The electricity induced is converted to light energy. (C) when the magnet moves closer to the solenoid, assuming the current induced in the solenoid flows in the clockwise direction, which makes the direction of the induced current anti-clockwise when the magnet leaves the solenoid. In this case, the current induced should be alternating one. (D) it should be a changing magnetic field that induces current. As a result, Option (B) is the answer to this problem.



Teacher: The physics behind a shake flashlight is that the mechanical movement which causes the magnet slide back and forth changes the magnetic field in the solenoid. A changing magnetic field induces current in the solenoid to power the light bulb. At this time, the electricity is converted to light energy.

Teacher: As a result, Option B is the answer to this problem. Do you know why Option A is wrong?

Student: Because the kinetic energy should be converted to electricity first. This step of conversion is missing.

Teacher: Good job.

Student: But I don't understand why Option C is also wrong? Does it not create direct current?

Teacher: Let's assume the current induced in the solenoid flow in the clockwise direction when the magnet moves closer to the solenoid. This assumption will also tell us that the direction of the induced current should be anti-clockwise when the magnet leaves the solenoid. In this case, the current induced should be alternating one.

Student: I see it now!

老師： 搖晃手電筒，其原理為手搖使磁鐵來回移動，造成線圈內的磁場改變，在線圈上形成感應電流，線圈上電流，在點亮線圈上的小燈，因此電能再轉換成光能。

老師： 所以答案是(B)，哪(A)錯在哪裡？

學生： 動能轉換成光能的過程，還需先轉成電能。

老師： 很好。

學生： 那為甚麼不是(C)：產生直流電？

老師： 當磁鐵接近線圈時，若假定感應電流流動方向為順時針；當磁鐵離開線圈時，其感應電流方向為逆時針，因此為交流電。

學生： 了解。

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/	
泛科學	
介紹自然科學相關的知識。 https://pansci.asia/	
ISLE Physics	
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

[九年級]

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

[9th grade]

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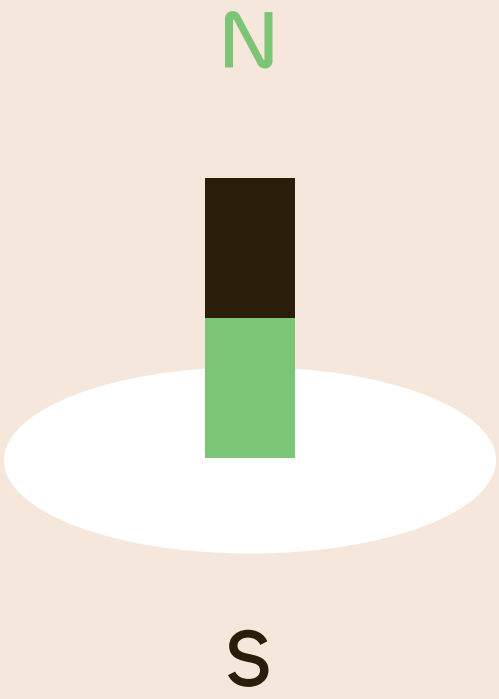

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