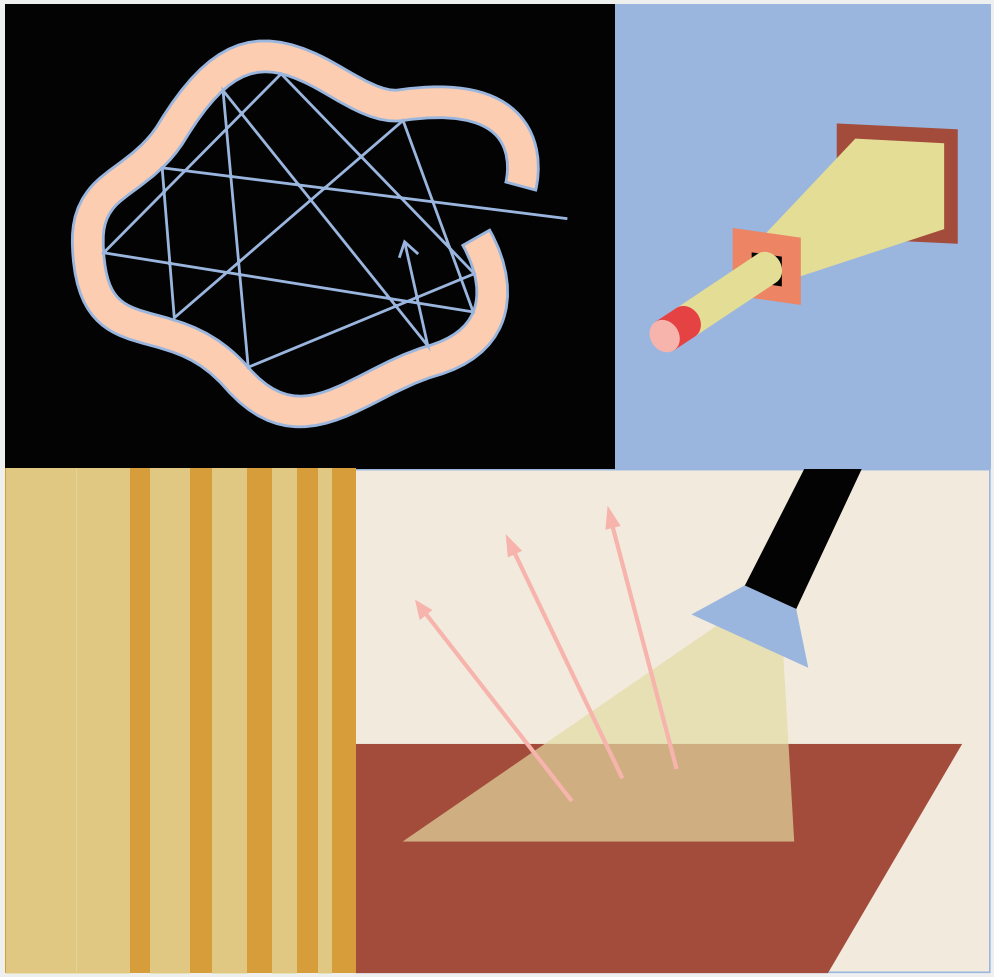
高中自然領域

雙語教學資源手冊

物理科 英語授課用語

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

〔高中選修(V)〕



國立彰化師範大學雙語教學研究中心 發行

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Electric Current and Circuits

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■ 前言 Introduction

現代人每天幾乎都離不開「電」的應用，各種電器用品為生活帶來許多便利。本章旨在了解電路中的物理量定義，例如：電阻、電流、電壓，再學會判斷與簡化基本電路的計算，亦藉由前面所學靜電的基礎，理解電動勢的原理及學會安培計、伏特計的設計，利用這兩種裝置檢測電阻值並計算電功率，也熟悉生活中各種電器的耗電量與是否過載。

英語在本章中，會常以 elements 和 components 概括電路中的零件，老師可在章節前讓學生認識一些電路零件的術語，有助於之後學生之後對於電路的描述和理解。

1-1 電動勢與電流
Electromotive Force and Electric Current

■ 前言 Introduction

本節將學習「電動勢」與電流的關係，並辨別電動勢與電池的端電壓的差異。

使用英語時，老師要注意在教導字彙時可先帶入形容詞 electric(電子的)去修飾各個專有名詞，學生也較容易理解且不易與單字的其他意思搞混，待學生足夠熟悉後可將 electric 去除。例如：電位 electric potential。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
battery	電池	positive terminal	正極
electric charge	電荷	negative terminal	負極
resistance	電阻	electric potential difference/ voltage	電位差（電壓）
connecting wire	導線	joule	焦耳
sequent	連續的	coulomb	庫侖
polar	兩端	electric current	電流
like	同性的（電荷）	conductor	導體
unlike	異性的（電荷）	electric field	電場
voltaic pile	伏打堆	metal	金屬

steady	穩定的	drift velocity	漂移速度
electricity	電學	collide(v.)/ collision(n.)	碰撞
magnetism	磁學	atom	原子
electromotive force	電動勢	neutron	中子
electric potential	電位	proton	質子
		electron	電子

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

❶ _____ is driven to _____.

例句：The positive charge in the low electric potential could **be driven to** the high electric potential inside the battery.

在電池內，正電荷可由低電位驅動到高電位。

❷ _____, whereas _____.

例句：Like charges repel**, whereas** unlike charges attract.

對電荷而言，同性相斥，異性相吸。

❸ _____ be positively / negatively/ neutrally charged.

例句：When an ion carries more electrons than those of the protons, it **is negatively charged.**

當離子所帶的電子多於質子，離子即具負電性。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、學生能了解電動勢的定義。

Students can understand the definition of electromotive force.

二、學生能了解電動勢與電流的關係。

Students can understand the relation between electromotive force and current.

三、學生能了解電位差或電壓的定義。

Students can understand the definition of voltage or electric potential difference.

❧ 例題講解 ☙

例題一

說明：學生能應用與分析電流的定義。

Students can apply and analyze the definition of electric current.

There is a circular coil with a radius a on the xy-plane, which is uniformly distributed by static charge q. If the circular coil rotates counterclockwise around the z-axis at an angular velocity of ω, as shown in Figure 4, then for a static observer, there is a current flowing in the coil, what is the average current?

(A) $\frac{q\omega}{4\pi}$ **(B)** $\frac{q\omega}{2\pi}$ (C)$\frac{q\omega}{\pi}$ (D) $\frac{2q\omega}{\pi}$ (E) $\frac{4q\omega}{\pi}$

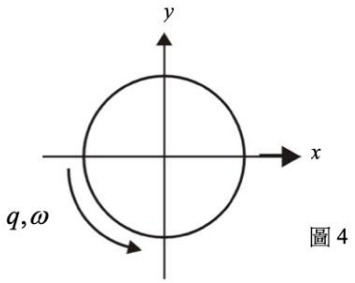


圖 4

xy 平面上有一半徑為 a 的圓形線圈，共有均勻分布的靜止電荷 q，如果圓形線圈以 ω 的角速度繞 z 軸逆時針快速旋轉，如圖 4 所示，則對靜止觀察者而言，線圈上有一個電流在流動，試問平均電流的大小為何？

(A) $\frac{q\omega}{4\pi}$ **(B)** $\frac{q\omega}{2\pi}$ (C)$\frac{q\omega}{\pi}$ (D) $\frac{2q\omega}{\pi}$ (E) $\frac{4q\omega}{\pi}$

（93 年指考 10）

解題 Solution：

From the formula of electric current, $I = \frac{\Delta Q}{\Delta t} = \frac{Q}{T}$ and the period $T = \frac{2\pi}{\omega}$, we can acquire the formula, $I = \frac{Q}{T} = \frac{q}{\frac{2\pi}{\omega}} = \frac{q\omega}{2\pi}$. So, choose (B)

由電流公式 $I = \frac{\Delta Q}{\Delta t} = \frac{Q}{T}$ ，又週期 $T = \frac{2\pi}{\omega}$ 可得 $I = \frac{Q}{T} = \frac{q}{\frac{2\pi}{\omega}} = \frac{q\omega}{2\pi}$

故選(B)。

Teacher: What is the main focus of the question?
Student: Electric current.
Teacher: Good, What is the electric current?
Student: The amount of the charge transferred per unit time.
Teacher: Great. I will leave you some time to figure out the question, and then we will have students go on the stage and share the solution.
Student: $I = \frac{Q}{T} = \frac{q}{\frac{2\pi}{\omega}} = \frac{q\omega}{2\pi}$
Teacher: Yes, so what option should we choose?
Student: (B)

老師： 請問這一題主要想問什麼？
學生： 電流。
老師： 很好，那什麼是電流呢？
學生： 單位時間內通過的電量。
老師： 很好。那給大家一些時間，嘗試看看把這題算出來，我們等一下請同學上臺分享。
學生： $I = \frac{Q}{T} = \frac{q}{\frac{2\pi}{\omega}} = \frac{q\omega}{2\pi}$
老師： 所以我們要選什麼答案呢？
學生： (B)

例題二

說明：學生能應用與分析導線的電流。

Students can apply and analyze the definition of electric current.

As shown in Figure 9, there is a circular coil with a radius a on the *xy*-plane, and the density of the charges, λ, on the coil, and the amount of charge per unit length, are the same. When the coil rotates around the axis passing through the center of the circle and perpendicular to the *xy* plane at a constant angular velocity of ω, which of the following options is the current I generated on the coil?

(A) $\frac{a\lambda}{\omega}$ **(B)** $\boldsymbol{a\lambda\omega}$ (C) $\frac{2\pi a\lambda}{\omega}$ (D) $\frac{\lambda\omega}{a}$ (E) $\frac{a\lambda\omega}{2\pi}$

如圖 9 所示，*xy* 平面上有一半徑為 *a* 的圓形細線圈，其上的電荷線密度 λ (即每單位長度的電量)均相同。當線圈以 ω 的等角速度繞通過圓心且垂直 *xy* 平面的轉軸轉動時，則線圈上所產生的電流 I 為下列何者？

(A) $\frac{a\lambda}{\omega}$

(B) $\boldsymbol{a\lambda\omega}$

(C) $\frac{2\pi a\lambda}{\omega}$

(D) $\frac{\lambda\omega}{a}$

(E) $\frac{a\lambda\omega}{2\pi}$

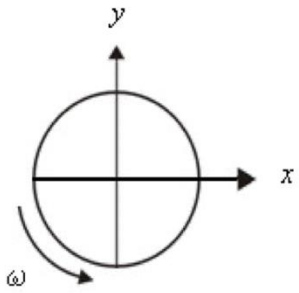


圖 9

（100 年指考 20）

解題 Solution：

From the formula of the electric current $I = \frac{\Delta Q}{\Delta t} = \frac{Q}{T}$, we can know Q stands for the electric charges on the coil and T stands for the period.

$$\Longrightarrow Q = \lambda \times 2\pi a, T = \frac{2\pi}{w}$$

$$\Longrightarrow I = \frac{Q}{T} = \frac{\lambda \times 2\pi a}{\frac{2\pi}{\omega}} = a\lambda\omega$$

So we should choose (B)

由電流公式 $I=\frac{\Delta Q}{\Delta t}=\frac{Q}{T}$，其中 Q 為圓周上電荷，T 為週期

$\Longrightarrow Q=\lambda\times 2\pi a, T=\frac{2\pi}{w}$

$\Longrightarrow I=\frac{Q}{T}=\frac{\lambda\times 2\pi a}{\frac{2\pi}{\omega}}=a\lambda\omega$，故選(B)

Teacher: What is the question asking for?
Student: Electric current.
Teacher: Good. What is the electric current?
Student: The amount of the charge transferred per unit time.
Teacher: Great. How can we figure out the amount of the charges? Does the question provide us with any clues?
Student: We know the density of the charging coil λ.
Teacher: Great! Now, can anyone tell me what linear charge density is?
Student: It's the amount of charge per unit length.
Teacher: Good. The electric current is passing through the circular coil with a radius a. Does anyone know what is the amount of electric charges on the circular coil?
Student: $Q=\lambda\times 2\pi a$, and the $2\pi a$ is the circumference of the circular coil.
Teacher: Excellent. Then, I will leave you some time to figure out the questions, later we will have students go on the stage and share.
Student: $I=\frac{Q}{T}=\frac{\lambda\times 2\pi a}{\frac{2\pi}{\omega}}=a\lambda\omega$
Teacher: So which option should we choose?
Student: (B)

老師： 請問這一題主要想問什麼？
學生： 電流。
老師： 很好，那什麼是電流呢？
學生： 單位時間內通過的電量。
老師： 很好。那我們該怎麼算出電量呢？題目有給我們什麼線索嗎？
學生： 有給我們電荷線密度是 λ。
老師： 很棒，那什麼是電荷線密度呢？
學生： 是每單位長度的電量。

老師： 很好，電流是流經半徑為a的圓形線圈，有沒有同學知道這個流經圓形線圈上的電量(Q)為何呢？

學生： $Q = \lambda \times 2\pi a$，其中$2\pi a$是圓形線圈的周長。

老師： 很棒，那現在給大家一些時間，嘗試看看把這題算出來，我們等一下請同學上臺分享。

學生： $I = \frac{Q}{T} = \frac{\lambda \times 2\pi a}{\frac{2\pi}{\omega}} = a\lambda\omega$

老師： 所以我們要選什麼答案呢？

學生： (B)

1-2 歐姆定律與電阻
Ohm's Law and the Resistance

■ 前言 Introduction

本節從歐姆定律出發，說明當初歐姆如何發現電流與電壓的正比關係，並延伸出不同元件下歐姆定律的適用性，最後再引入電阻的定義。

在英文方面，學生將會認識表達正比與反比的用法，老師可針對單字 inversely(逆轉地)意義講解。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
torsion balance	扭秤	graphite	石墨
magnetic needle	磁針	semiconductor device	半導體元件
deflect	偏轉	diode	二極體
electric current	電流	transistor	電晶體
material	材料	resistance	電阻
Ohmic material	歐姆材料	resistivity	電阻率
symbol	符號	ohm	歐姆

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

❶ When _____ is constant, _____ is proportional to _____.

例句：**When** the temperature **is constant**, for any conductors, the electric current passing through the conductors **is proportional to** the electromotive force being provided.
當溫度固定時，對任意導體而言，通過導體的電流與所提供的電動勢成正比。

❷ When _____ is constant, ___ is inversely proportional to _____.

例句：**When** the temperature **is constant**, the conductor resistance **is inversely proportional to** the cross-sectional area.
當溫度一定時，導體電阻會與導體的截面積成反比。

❸ If S_1+V_1, S_2+V_2

例句：If **the resistance is** not the ohm resistance, **the ratio of** $\frac{V}{I}$ **is** not constant.

(S_1　V_1　S_2　V_2)

若為非歐姆電阻：$\frac{V}{I}$ = 非定值。

❹ _____ be one of _____.

例句：Resistivity **is one of** the characteristics of a substance.
電阻率是物質的一種特性。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、學生了解電阻的定義與單位。

Students can understand the definition and the unit of electric resistance.

二、學生能了解電阻率的定義。

Students can understand the definition of resistivity.

三、理解電阻與溫度的關係。

Students can understand the relation between resistance and temperature.

❧ 例題講解 ☙

例題一

說明：學生能夠理解並應用與分析電阻與溫度的關係。

Students can understand and apply the relations between resistance and temperature.

There are two solid cylinders, which are the same in shape and size, and they are made respectively from the silicon and material A. The Figure below shows the temperature, resistance and the relation of the voltage exerted on the two ends. It is known that the resistivity of silicon at 20°C is about 5000 times than that of germanium, so which of the following is the most likely material A at room temperature? Add the substance to water and see if it dissolves.

Material	Temperature	The Voltage on Two Sides	Resistance
Silicon	20°C	10V	1000KΩ
Material A	20°C	10V	5Ω
Material A	100°C	10V	3Ω

(A) Superconductor

(B) Insulator

(C) metal conductor

(D) Pure germanium

(E) P-type or T-type semiconductor

有兩個形狀與大小完全相同的實心圓柱體，分別由純矽與甲材質做成，下表為兩圓柱體的溫度、電阻及施加於其兩端的電壓關係。已知在 20℃時純矽的電阻率約為純鍺的 5000 倍，則甲材質在常温下最可能是下列何者？將物質加入水中觀察是否溶解。

圓柱材質	溫度	圓柱兩端電壓	圓柱電阻
純矽	20℃	10V	1000KΩ
甲材質	20℃	10V	5Ω
甲材質	100℃	10V	3Ω

(A) 超導體　(B) 絕緣體　(C) 金屬導體
(D) 純鍺半導體　**(E) P 型或 N 型半導體**

(100 年指考 14)

解題 Solution：

The laws of resistance,

$$R = \rho\frac{L}{A}$$

According to data, the resistance of the solid cylinder of material A would decrease with the increase of temperature, thus the material A could be the semiconductor. However, from the question, when the temperature of solid cylinder of material A is at 20℃, the resistivity $\rho_{silicon} = 5000\rho_{germanium}$

So $R_{germanium} = \frac{1}{5000} \times 1000 = 200\Omega$ does not match the resistance of A material at 20°C

Thus we choose (E)。

電阻定律 $R = \rho\frac{L}{A}$

由數據表可知：甲材質隨溫度升高而電阻降低，則甲可能為半導體。但由題意中，在 20 $°C$ 時，電阻率$\rho_{\text{甲}} = 5000\rho_{\text{鍺}}$，所以$R_{\text{鍺}} = \frac{1}{5000} \times 1000 = 200$ Ω 與甲材質在 $20°C$ 時之電阻不符，故選 (E)。

Teacher: According to the data, what can we know about the solid cylinder of material A?

Student: The resistance decreases while the temperature increases.

Teacher: Correct. What could be the material A?

Student: It could be a semiconductor.

Teacher: Good, but what can we know from the end of the second line?

Student: When it is at 20 ℃, the resistivity $\rho_{silicon} = 5000\rho_{germanium}$

Teacher: How can we know the resistance from the resistivity?

Student: From the law of resistance $R = \rho\frac{L}{A}$, we can know that the resistance

$$R_{germanium} = \frac{1}{5000} \times 1000 = 200$$

Teacher: Good. Does it match resistance of material A at 20 ℃ ?

Student: No.

Teacher: So, what could it be?

Student: P-type or N-type semiconductor.

Teacher: Great. Which option should we choose?

Student: (E)

老師： 從甲的數據表當中我們可以看到什麼呢？

學生： 溫度升高時，電阻會降低。

老師： 沒錯，所以大家覺得他有可能會是什麼材質呢？

學生： 可能是半導體？

老師： 很好，但是題目的第二行後半段說了什麼了？

學生： 在 20 ℃ 時，電阻率$\rho_{矽} = 5000\rho_{鍺}$

老師： 我們知道電阻率以後要如何知道電阻呢？

學生： 利用電阻定律 $R = \rho\frac{L}{A}$ 可知 $R_{鍺} = \frac{1}{5000} \times 1000 = 200$

老師： 很好，但這個和甲材質在 20 ℃ 時的電阻一樣嗎？

學生： 不一樣。

老師： 所以，大家覺得這會是什麼材質呢？

學生： 可能是 P 型或 N 型半導體。

老師： 很棒，所以我們要選什麼答案呢？

學生： (E)

例題二

說明：學生能應用與分析電阻定律。

Students can apply and analyze the laws of resistance.

As shown in the Figure, the battery with an electromotive force of 0.10 volts connects to an ammeter A. Both of the internal resistances can be ignored. One end of the battery is connected to the right end of a wire with a length of 1.0 meters, the other end of the ammeter is connected to a certain point of the wire, x refers to the distance between the contact point and the left end of the wire, and the wire is made of a tungsten wire (resistivity 5.6×10^{-8} ohm·meter) and a piece of copper wire (resistivity 2.8×10^{-8} ohm·meter) connected in series, the cross-sectional area is the same. According to the current I measured by the ammeter, the relation between the total circuit resistance R and x is shown in Figure 9. Which of the following options are correct?

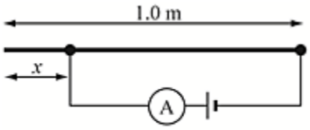


圖 8

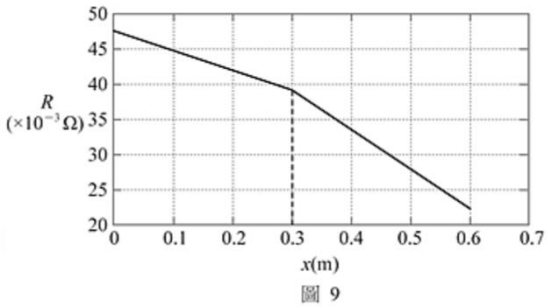


圖 9

(A) The tungsten wire is on the left end, and the length is 0.3 m.

(B) The copper wire is on the left end, and the length is 0.3 m.

(C) The cross-sectional area of the wire is 1.0×10^{-8} m^2 .

(D) When x=0.3 m, the total resistance of the circuit is 38 Ω .

(E) When x=0.5m, the power the battery consumes is 0.36 watts.

如圖 8，電動勢為 0.10 伏特的電池，連接一安培計 A，兩者的內電阻均可忽略。電池的一端連接一長度為 1.0 公尺導線的右端，安培計的另一端接上導線的某一點，x 為接點與導線左端的距離，導線由一段鎢線（電阻率為 5.6×10－8 歐姆·公尺）和一段銅線（電阻率為 2.8×10－8 歐姆·公尺）串接而成，其截面積相同。由安培計測得的電流 I，所推得的電路總電阻 R 和 x 的關係如圖 9。下列選項哪些正確？

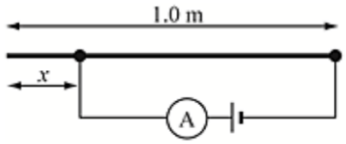


圖 8

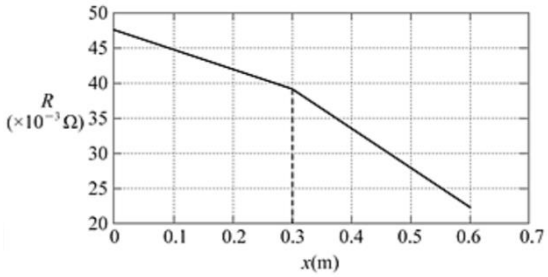


圖 9

(A) 鎢線在左，長度為 0.3 公尺。

(B) 銅線在左，長度為 0.3 公尺。

(C) 導線的截面積約為 1.0×10^{-8} 平方公尺。

(D) 當 $x=0.3$ 公尺時，電路的總電阻約為 38 歐姆。

(E) 當 $x=0.5$ 公尺時，電池消耗的功率約為 0.36 瓦特。

(103 年指考 24)

解題 Solution:

(A)(B) could be examined by the laws of resistance

$$R=\rho\frac{L}{A}\ \Rightarrow R\propto\rho,L,\frac{1}{A}\Rightarrow\frac{R}{L}=\frac{\rho}{A}\propto\rho$$

when x=0.3m, the value of $\frac{R}{L}$ is greater so we can infer that the remaining 0.7m wire on the right side of the wire is a tungsten wire and the copper wire is on the left, with the length 0.3m

(C) when x=0.3m, the tungsten wire on the right side, which the value of the resistance is measured to be $39\times10^{-3}\Omega$ at that time and the $\frac{R}{L}$ could be calculated as

$$\frac{R}{L}=\frac{39\times10^{-3}}{0.7}=\frac{5.6\times10^{-8}}{A}\Rightarrow A\cong10^{-6}\ \text{m}^2$$

(D) when x=0.3m, the total resistance R is about $39\times10^{-3}\ \Omega$.

(E) when x=0.5m, the consumed power of the battery is $P=\frac{V^2}{R}=\frac{0.1^2}{28\times10^{-3}}=0.36W$

so we choose (B)(E).

(A)(B)根據電阻定律

$$R = \rho\frac{L}{A} \Rightarrow R \propto \rho, L, \frac{1}{A} \Rightarrow \frac{R}{L} = \frac{\rho}{A} \propto \rho$$

當 x=0.3m 時，可以看出 $\frac{R}{L}$ 值較大，所以推測導線右邊剩餘 0.7m 的導線為鎢線；銅線在左，長度為 0.3m。

(C) 當 x=0.3m 時，導線右邊 0.7m 的鎢線，當時測得知電阻值 R 約為$39 \times 10^{-3}\Omega$，計算其 $\frac{R}{L} = \frac{39\times10^{-3}}{0.7} = \frac{5.6\times10^{-8}}{A} \Rightarrow A \cong 10^{-6}$ m^2

(D) 當 x=0.3m 時，電路的總電阻 R 約等於$39 \times 10^{-3}\ \Omega$。

(E) 當 x=0.5m 時，電池消耗的電功率$P = \frac{V^2}{R} = \frac{0.1^2}{28\times10^{-3}} = 0.36W$。

故選(B)(E)。

Teacher:	Everyone, please read the question first. Let's take a look at the options of (A) and (B). According to the figure showing the relation between the resistance and the length, does anyone know what the resistance laws are?
Student:	$R = \rho\frac{L}{A}$.
Teacher:	Correct! What's the relation between R and L(shown as *x* in the figure)?
Student:	$\frac{R}{L} = \frac{\rho}{A}$ The resistance of the wire (R) is proportional to its length (L).
Teacher:	Great. Because the cross-sectional area is the same, what can we know from this?
Student:	$\frac{R}{L} = \frac{\rho}{A} \propto \rho$ The slope of the resistance vs. length is the material's resistivity.
Teacher:	Good, From the graph, what can we know at x= 0.3m?
Student:	The slope of the graph which is $\frac{R}{L}$ becomes greater.
Teacher:	What kind of material could be on the right side of the remaining wire?
Student:	The right side of the wire is Tungsten since its resistivity is higher than that of copper.
Teacher:	Good. Look at option (C), when x=0.3m what is the resistance value of the remaining wire on the right side in Figure 9?
Student:	It's about $39 \times 10^{-3}\Omega$

Teacher: Very good, and then we can figure out the cross-sectional area by the laws of the resistance. Now please try to calculate the value of the cross-sectional area, later we will have students share.

Student: The cross-sectional area is about 10^{-6} m^2

Teacher: Excellent, then we can look at the option (E). The main point here asks for electric power. Does the question provide any clue?

Student: The electromotive force and the resistance.

Teacher: How can we know the electric power by these two clues?

Student: By using $P = \frac{V^2}{R}$

Teacher: Great. Now I will leave you some time to calculate the electric power it consumes, later we will have students share the result.

Student: $P = \frac{V^2}{R} = \frac{0.1^2}{28 \times 10^{-3}} = 0.36\ W$

Teacher: Bravo, what should we choose?

Student: (B)(E)

老師： 請大家閱讀一下題目。 我們先來看(A)(B)選項。由圖中我們可以看到電阻與長度的關係，有沒有同學還記得電阻定律的公式是什麼呢？

學生： $R = \rho\frac{L}{A}$

老師： 是的，所以 R 與 L（圖中以 x 為符號）的關係為何？

學生： $\frac{R}{L} = \frac{\rho}{A}$ 導線的電阻 (R) 與其長度 (L) 成正比。

老師： 很好，但是因為導線截面積相等，所以我們可以知道什麼呢？

學生： $\frac{R}{L} = \frac{\rho}{A} \propto \rho$ 電阻與長度的斜率是材料的電阻率。

老師： 很棒，從圖中可以看出，那如果 0.3m 時，可以看出來什麼呢？

學生： 圖形的斜率（$\frac{R}{L}$）值較大。

老師： 所以右側 0.7m 應該是什麼材料呢？

學生： 導線的右側是鎢絲，因為它的電阻率比銅線高。

老師： 很棒，那我們再來看（C）選項，當 x=0.3m 時，導線右邊 0.7m 的鎢線，電阻值 R 在圖 9 中是多少呢？

學生： 約為$39 \times 10^{-3}\Omega$

老師： 非常好，如此我們便能藉由電阻定律知道截面積是多少。現在請大家嘗試看看計算出截面積是多少，我們等一下請同學分享。

學生： 截面積大約10^{-6}平方公尺。

老師： 很好，那我們最後來看（E）選項，題目所求是電功率，那題目有給什麼線索嗎？

學生： 電動勢、電阻。

老師： 那我們該如何利用這兩個線索得到電功率呢？

學生： 可以用 $P = \frac{V^2}{R}$

老師： 很棒，現在給大家一點時間算一下這題所消耗的電功率為何，我們等一下請同學分享。

學生： $P = \frac{V^2}{R} = \frac{0.1^2}{28 \times 10^{-3}} = 0.36 \ \ W$

老師： 非常好，所以我們要選什麼答案呢？

學生： (B)(E)。

1-3 電阻的串連與並聯
The Series and Parallel Connection of Resistors

■ 前言 Introduction

本節將介紹電阻的串並聯，由單一迴路延伸，透過電阻之串並聯，分析更複雜的電路。

在英文方面，會以直觀的方式描述不同電路連接，老師講解時可多以圖片輔助英文講解。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
series connection	串聯	parallel connection	並聯
generator	發電機	equivalent resistance	等效電阻
electron current	電子流	open circuit	斷路

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

❶ _____ be the sum of _____.

例句：The equivalent resistance of a series circuit **is the sum of** each of the resistance of the in series resistors.

串聯電路的等效電阻，為每個串聯電阻的總和。

❷ _____ be connected end to end, head to head

例句：When the resistances **are connected end-to-end, head-to-head**, it is known as parallel series.

當兩個電阻以頭接頭、尾接尾的方式連結，稱為並聯。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、學生能分析電阻的串並聯，算出等效電阻值。

Students can manipulate the equivalent resistance by analyzing the resistor connections of series and parallel circuits.

❧ 例題講解 ☙

例題一

說明：學生能分析電阻的串並聯，進而算出等效電阻。

Students can calculate the equivalent resistance by analyzing the series and parallel connection of the circuit resistors.

As shown in the figure, the schematic diagram of the circuit is composed of four resistors connected. What is the equivalent resistance between cd as follows?

(A) 1.5Ω　**(B) 2 Ω**　(C) 2.5 Ω　(D) 4 Ω

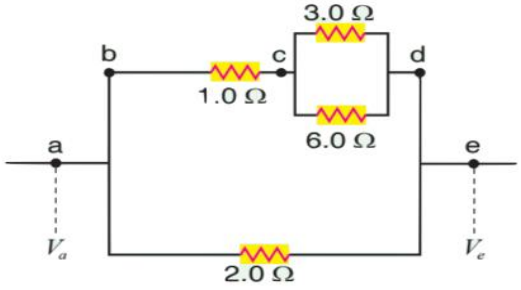
如下圖所示，由四個電阻連接而成的電路示意圖，請問 cd 之間的等效電阻為何？

(A) 1.5Ω

(B) 2 Ω

(C) 2.5 Ω

(D) 4 Ω



(改編自翰林版選修物理 V 第一章 第 20 頁 範例 1-5)

解題 Solution:

From the figure, there are two resistors in parallel connection, and from the formula of the parallel connection, we know that

$$\frac{1}{R_{cd}}=\frac{1}{R_{上}}+\frac{1}{R_{下}}=\frac{1}{3}+\frac{1}{6}=0.5 \Rightarrow R_{cd}=\frac{1}{0.5}=2$$

So choose (B).

由圖可知，cd 之間的兩電阻並聯，可由並聯公式知 $\frac{1}{R_{cd}}=\frac{1}{R_{上}}+\frac{1}{R_{下}}=\frac{1}{3}+\frac{1}{6}=0.5$ $\Rightarrow R_{cd}=\frac{1}{0.5}=2$ ，故選(B)。

Teacher: Are the resistors between cd series or parallel connections?

Student: Parallel connection.

Teacher: Good. Now please try to figure out the equivalent resistance of these two parallel-connected resistors, then we will have students go on stage and share the result.

Student: $\frac{1}{R_{cd}}=\frac{1}{R_{上}}+\frac{1}{R_{下}}=\frac{1}{3}+\frac{1}{6}=0.5$

$\Rightarrow R_{cd}=\frac{1}{0.5}=2$

Teacher: Great. what should we choose for the answer?

Student: (B).

老師： 請問 cd 之間的電阻是串聯還是並聯呢？

學生： 並聯。

老師： 很棒，那現在我們請大家練習，計算出兩電阻並聯的等效電阻，等一下請同學上台分享。

學生： $\frac{1}{R_{cd}}=\frac{1}{R_{上}}+\frac{1}{R_{下}}=\frac{1}{3}+\frac{1}{6}=0.5$

$\Rightarrow R_{cd}=\frac{1}{0.5}=2$

老師： 很棒，所以我們要選什麼答案呢？

學生： (B)。

例題二

說明：學生能分析與計算電阻的串並聯。

Students can analyze and calculate the series and parallel connection of the resistance.

As shown in the figure, the circuit diagram of the circuit is composed of five resistors connected. What is the equivalent resistance between a and b as follows?

(A) 7Ω　**(B) 9Ω**　(C)11 Ω　(D)13 Ω

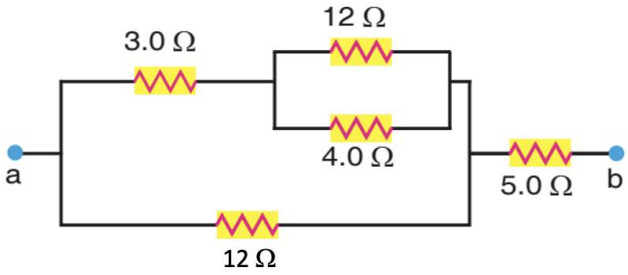
如下圖所示，由五個電阻連接而成的電路示意圖，請問 ab 之間的等效電阻為何？

(A) 7Ω

(B) 9Ω

(C)11 Ω

(D)13 Ω

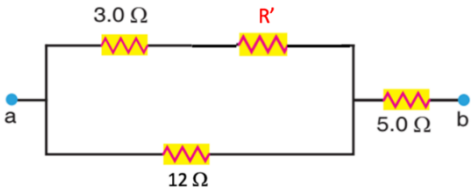


(改編自翰林版選修物理 V 第一章 第 32 頁 習題 1-3 第 4(1)題)

解題 Solution:

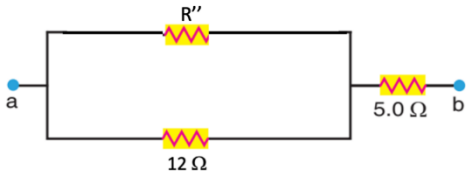
From the figure, the resistor of 12Ω and 4Ω is a parallel connection, so we have to figure out the value of the resistance R' first.

$$R' = \frac{1}{\frac{1}{12}+\frac{1}{4}} = 3\Omega$$



then, the resistor of 3Ω and R' is a series connection, so we have to figure out the equivalent resistance R''.

$$R'' = 3 + 3 = 6\Omega$$



Because the resistors of R'' and 12Ω are parallel connections, we can calculate the R'''

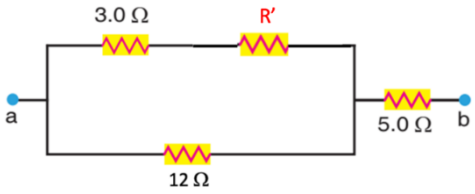
$$R''' = \frac{1}{\frac{1}{6}+\frac{1}{12}} = 4\Omega$$

Because the resistors of R''' and 5Ω are series connection, we can calculate the R_{ab}

$R_{ab} = 4 + 5 = 9\Omega$. So choose (B).

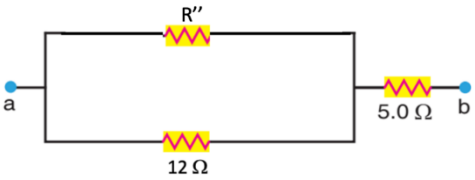
由圖可知 12 Ω 與 4 Ω 為並聯，先將 R'計算出來

$$R' = \frac{1}{\frac{1}{12}+\frac{1}{4}} = 3\Omega$$



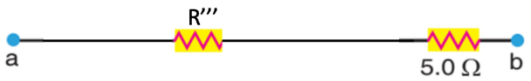
接著 3Ω 與R'為串聯，將其等效電阻R''計算出來

$$R'' = 3 + 3 = 6\Omega$$



因為R''與 12 Ω 為並聯，將R'''計算出來

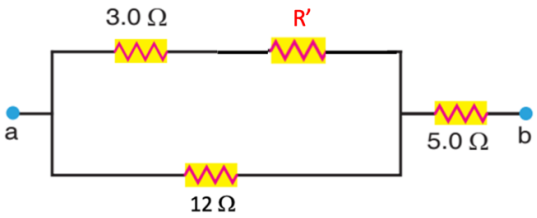
$$R''' = \frac{1}{\frac{1}{6}+\frac{1}{12}} = 4\Omega$$



因為 R''' 與 5Ω為串聯，將 R_{ab} 計算出來。

$R_{ab} = 4 + 5 = 9\Omega$，故選(B)。

Teacher: I will divide this circuit diagram into three parts, and we will calculate the equivalent resistance together step by step. Please take a look at this diagram. I will give you some time to figure out the value of the resistor R' corresponding to the original diagram.

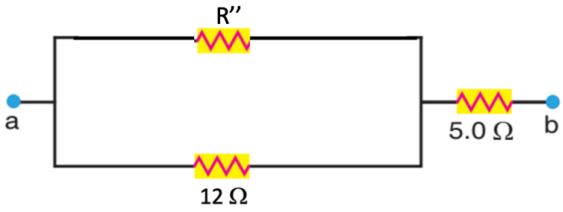


Student: R' is the equivalent resistance of the in-parallel connection of the 12 Ω and 4 Ω resistors. Thus, $R' = \frac{1}{\frac{1}{12}+\frac{1}{4}} = 3\Omega$

Teacher: Good. Then let's deal with the upper part. Are the resistors of 3 Ω and R' series or parallel connection?

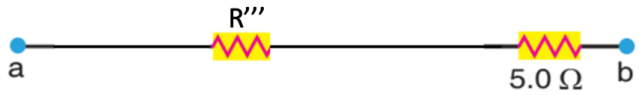
Student: They are series connections.

Teacher: Good. Let's take a look at this diagram, What's the value of the resistor R''?



Student: $R'' = 3 + 3 = 6\Omega$

Teacher: Great. How about this? I will leave you some time to figure out the resistance of R'''



Student: $R''' = \frac{1}{\frac{1}{6}+\frac{1}{12}} = 4\Omega$

Teacher: Great. So are the resistors of R''' and 5 Ω series or parallel connection?

Student: They are series connections.

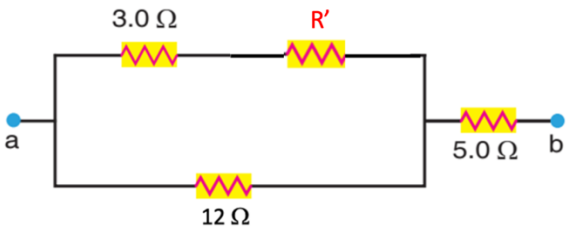
Teacher: Good. I will leave you some time to figure out the equivalent resistance between a and b

Student: $R_{ab} = 4 + 5 = 9\Omega$

Teacher: Excellent, Which option should we choose?

Student: (B).

老師： 老師先將電路圖分為三個部分，我們一步一步慢慢把等效電阻計算出來，請先看到這張圖，給同學一些時間，請同學對照原本的圖計算看看 R'為何。



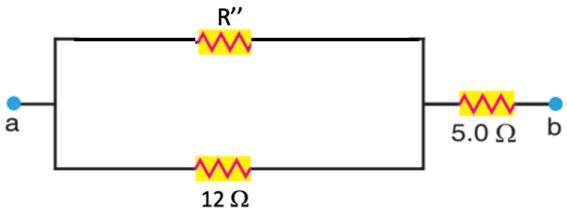
學生： R' 是 12 Ω 及 4 Ω 並聯，所得到的等效電阻，因此

$$R' = \frac{1}{\frac{1}{12}+\frac{1}{4}} = 3\Omega$$

老師： 很好，接著我們來處理上半部的部分，請問 3 Ω 和 R' 是串聯還是並聯呢？

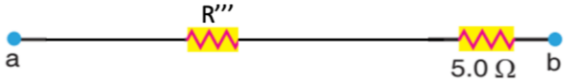
學生： 是串聯。

老師： 很棒，接著看到下圖，請問R''為何呢？



學生： $R'' = 3 + 3 = 6\Omega$ 。

老師： 很好，再來看到這張圖，給同學一些時間，嘗試看看將R'''計算出來。



學生： $R''' = \frac{1}{\frac{1}{6}+\frac{1}{12}} = 4\Omega$

老師： 非常棒，所以R''' 與 5 Ω 為串聯還是聯呢？

學生： 是串聯。

老師： 非常好，那最後再給大家一些時間，請大家嘗試計算看看 ab 之間的等效電阻為何。

學生： $R_{ab} = 4 + 5 = 9\Omega$

老師： 非常棒，所以我們要選什麼答案呢？

學生： (B)。

1-4 電路中之電荷守恆與能量守恆
Law of Charge Conservation and Energy Conservation in Circuit

■ 前言 Introduction

在前一節學習了電阻串並聯的計算，來分析多個電阻的電路。然而，大部分電阻的組合，不一定可以簡化成串並聯的等效電阻來分析。面對更加複雜的電路時，可利用「克希荷夫定律」中的兩項定則，包含「電荷守恆」及「能量守恆」來解題。

在英文方面，學生能學習利用英文介係詞 from, to, through 來描述電流的流向。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Kirchhoff's law	克希荷夫定律	meet (v.)	交會
node (n.)	節點	through (prep.)	通過
loop (n.)	迴路	remain (v.)	保持
disappear (v.)	消失		

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

❶ _____ meet

例句：A point in a circuit where two or more circuit elements **meet** is known as electrical node.
在電路上有兩條或兩條以上導線交會而成的點，稱為節點。

❷ ____ from _____ to ____ (through ___).

例句：The current returns **from** the positive terminal of a battery **to** that of the negative terminal **through** a wire, and then returns to the positive terminal through the battery's interior, forming a closed path.
電流自電池的正極經由導線回到電池負極，再經由電池內部回到電池正極，構成一條封閉路徑。

❸ _____ remain + adj.

例句：For a steady electric current, the sum of the electric charges passing through each part of the circuit **remains constant.**
在穩定電流下，通過電路每一處的電量，總和維持不變。

❹ _____ is equivalent to _____.

例句：The voltage law **is equivalent to** the circuit's energy conservation law.
電壓定律相當於電路的能量守恆定律。

■ 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：
At the end of learning the chapter, students are able to acquire the following concept:
一、學生能了解電路中的能量守恆，以及電量守恆。
Students can understand the concepts of conservation of energy and conservation of charge.

例題講解

例題一

說明：學生能運用克希荷夫定律推算線路中的電流或電壓。

Students can utilize Kirchhoff's law to determine the currents or voltages of circuits.

There are two batteries, whose internal resistances are zero, connected to three resistors, which are $R_1 = 3\Omega$、$R_2 = 1\Omega$. What is the voltage of V_1 ?

(A) 6　(B) 8　(C) 10　**(D) 12**

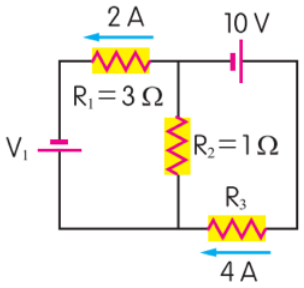
下圖中有兩理想電池與三電阻連結，其中 $R_1 = 3\Omega$、$R_2 = 1\Omega$，請問電池 V_1 的電壓為多少 V？

(A) 6

(B) 8

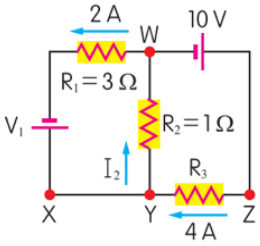
(C) 10

(D) 12



(改編自翰林版選修物理 V 第一章 第 1-34 頁 演練 2)

解題 Solution:



From Kirchhoff's law's principle of the conservation of charge, we take node Y (Σ I=0 at nodes).

$I_2 = 2 + 4 = 6 \ \ (A)$ (the direction is from Y to W)

Due to the principle of conservation of energy of Kirchhoff's law, we take the loop from W-X-Y-W (Σ V=0 along any closed loop)

$-2 \times 3 + V_1 - I_2 \times 1 = 0 \Longrightarrow V_1 = 12 \ \ (V)$. So the answer is (D)

先由克希荷夫的節點定則（電荷守恆，Σ I=0），取節點 Y：

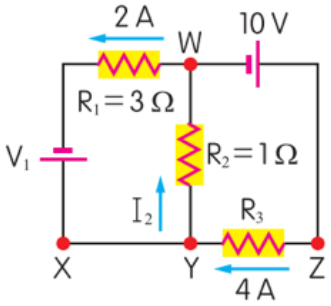
$I_2 = 2 + 4 = 6 \ \ (A)$ 方向由 Y 到 W

再由克希荷夫的迴路定則（能量守恆，Σ V=0），取 W 到 X 到 Y 到 W 迴路：

$-2 \times 3 + V_1 - I_2 \times 1 = 0 \Longrightarrow V_1 = 12 \ \ (V)$，故答案選(D)。

Teacher: Please try to use Kirchhoff's law and loop rule to take the reference node by yourselves and calculate the loop, and later we will have students go on stage and share.

Student:



First, from Kirchhoff's law, we take node Y (Σ I=0 at nodes).

$I_2 = 2 + 4 = 6 \ \ (A)$ (the direction is from Y to W)

Then, from Kirchhoff's law, we take the loop from W-X-Y-W. The potential for resistors decreases along the direction of electric current. (Σ V=0 along any closed loop)

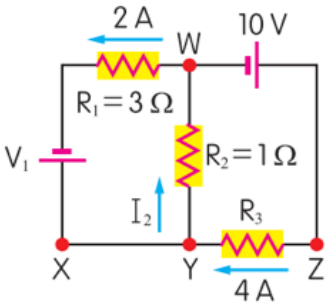
$-2 \times 3 + V_1 - I_2 \times 1 = 0 \Longrightarrow V_1 = 12 \ \ (V)$

Teacher: Great. so which option would be the answer?

Student: (D)

老師：請大家嘗試看看，利用克希荷夫節點定則與迴路定則，自行取節點與迴路來計算這題，我們等一下請同學上台分享。

學生：



先由克希荷夫節點定則，取節點 Y，I=0：

$I_2 = 2 + 4 = 6 \ \ (A)$ 方向由 Y 到 W

再由克希荷夫迴路定則，取 W 到 X 到 Y 到 W 迴路，在電阻上，順著電流，電位會下降(Σ V=0)：

$-2 \times 3 + V_1 - I_2 \times 1 = 0 \Longrightarrow V_1 = 12 \ \ (V)$

老師：很好，所以我們要選哪個答案呢？

學生：(D)。

例題二

說明：學生能應用克希荷夫定律，推出電流。

Students can determine the electric current by applying Kirchhoff's law.

In the diagram below, the two batteries have no internal resistance, and we can also see the magnitudes of each resistance. what is the current in amps flowing through the resistors 2?

(A) $\frac{4}{7}$ (B) $\frac{3}{7}$ (C) $\frac{2}{7}$ **(D)** $\frac{\mathbf{1}}{\mathbf{7}}$

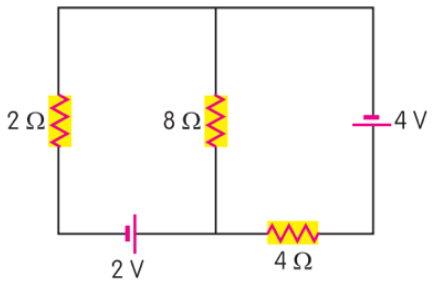
下圖中兩電池均無內電阻，且每個電阻的電阻值如圖所示，則流過 2 Ω 電阻的電流為多少 A?

(A) $\frac{4}{7}$

(B) $\frac{3}{7}$

(C) $\frac{2}{7}$

(D) $\frac{\mathbf{1}}{\mathbf{7}}$

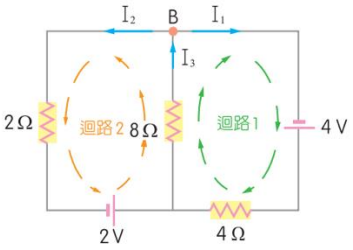


(改編自翰林版選修物理 V 第一章 第 1-34 頁 演練 3)

解題 Solution:

Assumed that the directions of the current are as follows,

First, according to the loop theorem, we can list the following two equations.



loop 1: $4-4I_1-8I_3=0$ $4-4I_1-8I_3=0$

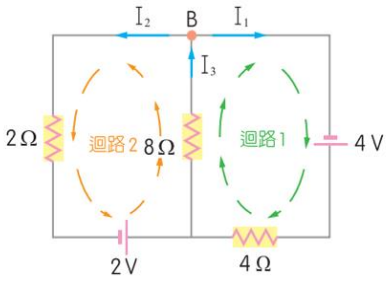
loop 2: $2-8I_3-2I_2=0$ $2-8I_3-2I_2=0$

Then, due to the node theorem, at node B: $I_1+I_2=I_3$

from these three equations, we find that $I_1=\frac{3}{7}(A)$, $I_2=-\frac{1}{7}(A)$

So the answer is (D).

設 I_1、I_2、I_3 三電流的方向如下圖所示，根據迴路定則(Σ V=0):



迴路 1：$4-4I_1-8I_3=0$

迴路 2：$2-8I_3-2I_2=0$

再根據節點定則 (Σ I=0):

節點 B：$I_1+I_2=I_3$

由上述三式可得 $I_1=\frac{3}{7}(A)$、$I_2=-\frac{1}{7}(A)$

故答案為(D)。

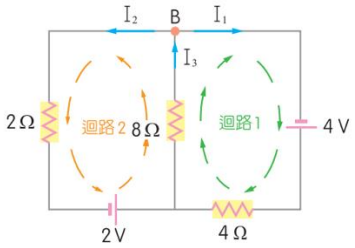
Teacher: Can you determine if the resistances are connected in series or parallel?

Student: No.

Teacher: Correct! Because there are multiple sets of electric power, the resistances are not simply connected in series or parallel. Therefore, we need to apply Kirchhoff's Law to manipulate the electric current.

Student: Please try to use Kirchhoff's law of the node theorem and the loop theorem to solve the problem. Later, we will have students come up to the stage and share their answers.

Teacher: We can assume that the direction of the current is in the picture below.



Loop 1: $4-4I_1-8I_3=0$

Loop2: $2-8I_3-2I_2=0$

Node B: $I_1+I_2=I_3$

From these three equations, we can know that $I_1=\frac{3}{7}(A)$、$I_2=-\frac{1}{7}(A)$

Student: Good, so what should we choose for the answers?

Teacher: (D).

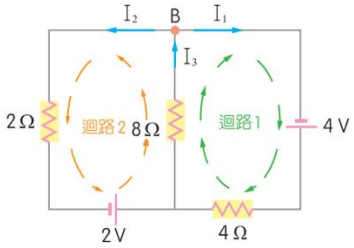
老師：　請問這個線路，能否透過電阻的串並聯，來推出電流？

學生：　不行。

老師：　沒錯，因為有多重電源，所以無法用探討電阻的串並聯。因此必須用克希荷夫定律來探討。

學生：　請大家嘗試利用克希荷夫的節點定則，以及迴路定則，來解這題，我們等一下請同學上台分享。

老師：　設I_1、I_2、I_3三電流的方向如下圖所示



Loop 1: $4-4I_1-8I_3=0$

Loop 2: $2-8I_3-2I_2=0$

Node B: $I_1+I_2=I_3$

由上述三式可得 $I_1=\frac{3}{7}(A)$、$I_2=-\frac{1}{7}(A)$

學生：　很好，所以我們要選哪個答案呢？

老師：　(D)。

1-5 電功率與電流的熱效應
Electric Power and Heating Effect of Current

■ 前言 Introduction

當電子在一個電路裡流通時，因為導線中的自由電子與導體內的原子碰撞，而使這些原子振動劇烈，致使導體的溫度上升，也就是電能轉成熱能，稱為「電流的熱效應」。本節將介紹其與電功率的關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
(instantaneous) electric power	(瞬時) 電功率	atom	原子
Watt	瓦特	ion	離子
heating effect of electric current	電流的熱效應	collision(n.)/ collide (v.)	碰撞
vibration(n.) / vibrate (v.)	震動	consume	消耗

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

❶ convert _____ into _____.

例句：When electric current pass through a resistance, it would **convert** the electrical energy **into** thermal energy, and this is known as heating effect of electric current.
電流通過電阻時，將電能轉換成熱能，稱為電流的熱效應。

❷ _____ be defined as _____.

例句：According to Joule's law, the power dissipated in a conductor can **be defined as** the product of the resistance and the square of the current.
根據焦耳定律，導體發熱的功率可以被表示為電阻與電流平方的乘積。

❸ the 比較級 + S_1 + V_1, the 比較級 + S_2 + V_2

例句：**The more** intensively the atoms or ion in conductor vibrates, **the higher** the temperature of the conductor would be.
因為導體內的原子或離子震動變得更劇烈，因而導體的溫度上升。

■ 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：
At the end of learning the chapter, students are able to acquire the following concept:
一、學生能了解電流的熱效應及電功率的定義。
Students can understand the heating effect of electric current and the definition of electric power.

例題講解

例題一

說明：學生能應用與分析電功率。

Students can apply and analyze the electric power.

There are two light bulbs which are light bulb A and B, the light bulb A is labeled as 110V, 40.0W and the light bulb B is labelled as 110V, 60.0W. If these two light bulbs are in series connected with a power supply of 220V and no light bulbs are burnt out, what is the electric power at the time?

(A) 32　(B) 50　**(C) 96**　(D) 504

A、B 兩個燈泡，A 燈泡上面標示為 110V、40.0W，B 燈泡上面標示為 110V、60.0W，若將此兩燈泡串聯後接在 220V 的電源上，假設燈泡沒有燒壞，則此時兩燈泡電功率之總和為多少？

(A) 32　(B) 50　**(C) 96**　(D) 504

(改編自翰林版選修物理 V 第一章 第 34 頁 習題 1-5 第 14 題)

解題 Solution:

From $P = IV = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$, we can know that $R_A = \frac{110^2}{40} 302.5\ \Omega$, $R_B = \frac{110^2}{60} 201.7\ \Omega$

We can also know the equivalent resistance from the series connection of two light bulbs.

$R = R_A + R_B = 302.5 + 201.7 = 504.2\ \Omega \fallingdotseq 504\Omega$

from $I = \frac{V}{R}$ we can know that $I = \frac{220}{504} = 0.437\ A$

$P = P_A + P_B = 0.437^2 \times 504 = 96\ w$

so choose (C) for the answer.

由 $P = IV = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$ 可得 $R_A = \frac{110^2}{40} 302.5\ \Omega$、$R_B = \frac{110^2}{60} 201.7\ \Omega$

由兩燈泡串聯，可知等效電阻 $R = R_A + R_B = 302.5 + 201.7 = 504.2\ \Omega \fallingdotseq 504\Omega$

由 $I = \frac{V}{R}$ 可得 $I = \frac{220}{504} = 0.437\ A$, $P = P_A + P_B = 0.437^2 \times 504 = 96\ w$

故答案選(C)。

Teacher: What is the question asking for?

Student: To calculate the electric power.

Teacher: Good. What formulas we can use to calculate the eclectic power of the light bulbs.

Student: $P = IV = I^2R = \frac{V^2}{R}$

So, we need to determine the equivalent resistance of the circuit first. Then calculate the electric current in order to find the electric power.

Teacher: Great. we have already figured out the electric power and the voltage and then we can use it to calculate the resistance of each light bulbs. Now I will leave you some time, later we will have students come up stage and share the result.

Student: From $P = IV = \frac{V^2}{R} \Longrightarrow R = \frac{V^2}{P}$, we can know that

$$R_A = \frac{110^2}{40} 302.5 \ \Omega, \ R_B = \frac{110^2}{60} 201.7 \ \Omega$$

Teacher: Good, it is stated that the two light bulbs are in a series connection, and I will also give you some time to calculate the equivalent resistance of the two light bulbs in series connection, later we will have students come up to the stage and share the result.

Student: $R = R_A + R_B = 302.5 + 201.7 = 504.2 \ \Omega \fallingdotseq 504\Omega$

Teacher: Very good. Now we have the equivalent resistance of the two light bulbs in series connection, so can we try to calculate the current? I will leave you some time and later we will have some students to share the answers.

Student: From $I = \frac{V}{R}$, we can know that $I = \frac{220}{504} = 0.437 \ A$

Teacher: Excellent, and finally we have to figure out the electric power. I will give you some time, and later we will have some students to share the answer.

Student: Since $P = I^2R$, $P = 0.437^2 \times 504 = 96 \ w$

Teacher: Great. so what should we choose?

Student: (C)

老師：這題主要想問什麼呢？

學生：想問兩個燈泡的電功率。

老師：很好，那燈泡的電功率，可由什麼公式算出來呢？

學生：$P = IV = I^2R = \frac{V^2}{R}$ 所以需要先算出等效電阻，再求出電流，才能算出電功率。

老師：很棒，我們現在已經有了燈泡的功率和電壓，那我們先來把兩個燈泡各自的電阻計算出來，給大家一些時間嘗試計算看看，我們等一下請同學上台分享。

學生：由$P = IV = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$ 可得

$R_A = \frac{110^2}{40} 302.5\ \Omega$, $R_B = \frac{110^2}{60} 201.7\ \Omega$

老師：很好，題目說他把兩個燈泡串聯，一樣給大家一些時間，計算串聯後的等效電阻 R，我們等一下請同學上台分享。

學生：$R = R_A + R_B = 302.5 + 201.7 = 504.2\ \Omega \fallingdotseq 504\Omega$

老師：非常棒，那有了串聯後的等效電阻，能不能將電流計算出來呢？我們一樣給大家一些時間計算看看，我們等一下請同學上台分享。

學生：由 $I = \frac{V}{R}$ 可得 $I = \frac{220}{504} = 0.437\ A$

老師：非常好，最後就要算出電功率總和了，一樣給大家一些時間，我們等一下請同學上台分享。

學生：根據 $P = I^2R$, $P = 0.437^2 \times 504 = 96\ w$

老師：很棒，所以我們要選什麼答案呢？

學生：(C)。

例題二

說明：學生能夠從電流與電壓推算出電功率。

Students can derive electric power from given electric current and electric potential.

If the electric heater with a maximum rate of 1200W has a rated voltage of 120V, what is the current when it is used at the rated voltage?

(A) 4 A　(B) 6 A　(C) 8A　**(D) 10A**

若依最大通率為 1200W 的電熱器，額定電壓為 120V，請問一額定電壓使用時，電流為多少？

(A) 4 A

(B) 6 A

(C) 8A

(D) 10A

(改編自翰林版選修物理 V 第一章　第 29 頁　範例 1-7)

解題 solution:

From $P = IV = \frac{V^2}{R} = I^2R$, we can know that, $I = \frac{P}{V} = \frac{1200}{120} = 10A$

So (D) is the answer.

由 $P = IV = \frac{V^2}{R} = I^2R$ 可得 $I = \frac{P}{V} = \frac{1200}{120} = 10A$，故選(D)。

Teacher:	What is this question asking for?
Student:	The maximum electric current.
Teacher:	Good. Does the question provide any clue?
Student:	The maximum electric power and the given voltage.
Teacher:	Good. Is there any equation showing the three physical quantities?
Student:	$P = IV$
Teacher:	Great, then I will leave you some time and you can figure out the current by using the formula. Later we will have students come up stage and share the result.
Student:	$I = \frac{P}{V} = \frac{1200}{120} = 10A$
Teacher:	Great, which option should we choose?
Student:	(D).

老師： 請問這題題目想求什麼呢？

學生： 最大電流。

老師： 很好，請問題目有提供什麼線索嗎？

學生： 最大電功率與已知的電壓。

老師： 很好，那有什麼關係式，可以呈現這三個物理量嗎？

學生： $P = IV$

老師： 很棒，現在給大家一些時間嘗試利用公式將電流求出，我們等一下請同學上台分享。

學生： $I = \frac{P}{V} = \frac{1200}{120} = 10A$。

老師： 非常好，所以我們要選哪個答案呢？

學生： (D)。

★ 主題二 近代物理的重大發現 ★
Major Discoveries in Modern Physics

國立彰化師範大學物理學系 黃詒
國立彰化師範大學英語學系 巫冠誼

■ 前言 Introduction

本章節開始為近代物理學的範疇，將帶領學生進入與古典物理學不同的領域。古典物理從牛頓力學開始，到十九世紀末建立了看似完整的理論體系，但古典物理的理論卻無法合理解釋部分現象，如:熱輻射、光電效應或氫原子光譜線。因此激發了人們研究物理的熱潮，開啟了物理學的新領域，稱為近代物理。教師可從科學史開始，接著導入研究歷程所提出的新觀念，突破同學在古典物理所建立的既有思維。

英語在本章，主要希望學生能靈活運用被動態表達，並著重連接詞和副詞的用法，另外也能以 that 帶出的名詞子句，為敘述補充說明。

2-1 電子的發現
The Discovery of the Electron

■ 前言 Introduction

本節主要介紹科學家湯姆森，利用陰極射線管研究氣體放電的現象，偶然發現電子的歷程。此粒子比道爾頓所提出的原子模型還小得多，為組成原子的成份之一，並探討電子的荷質比。

使用英語時，老師要注意避免使用過多艱澀的專有名詞，試著用相似而較通俗的字眼取代，也要讓學生透過實驗體驗物理概念。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electron	電子	positively-charged	帶正電的
cathode ray tube	陰極射線管	negatively-charged	帶負電的
particle	粒子	electric plate	電板
metal plate	金屬板	central line	中央線
evacuated	真空的	corpuscle	微粒
discharge tube	放電管	cathode ray	陰極射線
charge-to-mass ratio	荷質比	deflected	偏轉
corpuscle	微粒	J. J. Thomson	湯姆森

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

❶ _____ remain + adj

例句：When the separation distance between two plates is reduced to half, while the voltage of the battery **remains unchanged**, then the electric field becomes double the original value.
當板距間隔減為原來的一半，而電壓維持不變，則電場變為原來的兩倍。

❷ ____ be composed of _____

例句：The cathode ray **is composed of** negatively charged particles.
陰極射線由帶負電粒子所組成。

❸ _____ so that _____

例句：Electrons experience an upward electrostatic force between parallel metal plates **so that** it results in an upward acceleration.
電子在平行金屬板間受到向上的靜電力，所以會產生向上的加速度。

❹ _____ be/get deflected _____

例句：When cathode rays pass through a magnetic field applied transversely, the rays **get deflected** perpendicular to the plan of its velocity and the applied magnetic field.
當陰極射線垂直穿過外加磁場，射線會偏轉，而偏轉方向會垂直於射線速度和外加磁場所構成的平面。

❺ _____ move perpendicularly to _____

例句：When cathode rays **move perpendicularly to** a magnetic field applied, the rays get deflected and form a circular path.
當陰極射線垂直射入外加磁場時，射線會被偏轉，且形成圓周軌跡。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解放電管之實驗。

Students can understand the experiments using discharge tube.

二、了解湯姆森的電子荷質比實驗。

Students can understand Thomson's electron charge-to-mass ratio experiment.

❧ 例題講解 ☙

例題一

說明：學生能應用湯姆森電子荷質比實驗。

Students can apply Thomson's electron charge-to-mass ratio experiment.

As shown in Figure 10, there is a set of parallel metal plates in a vacuum, with a length of L and a separation distance of d. Initially, switch S is closed, creating a uniform electric field (electric field strength denoted as E) between the two plates. The right end of the parallel metal plates is at a distance D from the screen. Now, an electron is horizontally launched from the left end of the parallel plates with an initial velocity v. The electron produces a vertical displacement y on the screen, disregarding the influence of gravity. Assuming that during the process described in the following options, the electron can definitely reach the screen, which of the following statements are correct?

(A) If the initial velocity v is reduced to half, ty becomes 4 times the original value.

(B) If increase the separation distance d to 2 times, while the voltage of the battery remains unchanged, E becomes 2 times the original value.

(C) If reduce the separation distance d to half, while the voltage of the battery remains unchanged, E becomes 2 times the original value.

(D) If increase the separation distance d to 2 times its original value, while the voltage of the battery remains unchanged, y becomes 2 times the original value.

(E) **If reduce the separation distance d to half, while the voltage of the battery remains unchanged, y becomes 2 times the original value.**

如圖 10 所示，真空中有一組平行金屬板，長度為 L，板距為 d，開始時開關 S 是接通的，兩板之間為均勻電場(電場量值為 E)，且平行金屬板右端與螢幕的距離為 D。今將電子以初速度 v 自平行板左端水平射入，電子在螢幕上所產生 光點的垂直偏移量為 y，忽略重力的影響。假設在下列選項所述過程中，電子一定可以抵達螢幕，則下列敘述哪些是正確的？

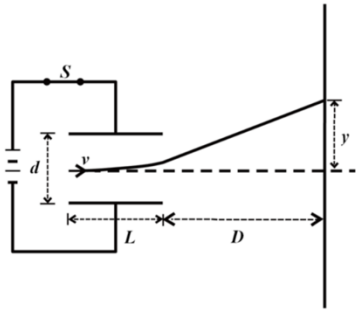


圖10

(A) 若僅將初速度 v 減為原來的一半，則 y 變為原來的 4 倍。

(B) 若僅將板距 d 增為原來的 2 倍，但電池的電壓不變，則 E 變為原來的 2 倍。

(C) 若僅將板距 d 減為原來的一半，但電池的電壓不變，則 E 變為原來的 2 倍。

(D) 若僅將板距 d 增為原來的 2 倍，但電池的電壓不變，則 y 變為原來的 2 倍。

(E) 若僅將板距 d 減為原來的一半，但電池的電壓不變，則 y 變為原來的 2 倍。

（105 指考 24）

Teacher: Let's take a look at (B) and (C) first. Is there anyone willing to share the relationship between the electric field intensity E, the potential difference V, and the separation distance d in a parallel electric field?

Student: $E = \frac{V}{d}$. (E equals V times d) .

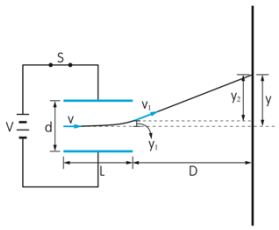
Teacher: Very good. So, when the voltage remains constant, what is the relationship between E and d?

Student: $E \propto \frac{1}{d}$ (E is inversely proportional to d).

Teacher: Excellent. This is hold when the potential difference is fixed. So, if we want E becomes twice the original value, how will d change?

Student: The separation distance d much reduce to half of the original value.

Teacher: Very good, so (B) and (C) are incorrect. Now, let's derive the displacement "y" of the electron on the parallel plates together. We will start by deriving the upward displacement "y_1" of the electron between the parallel metal plates. Now, I'll give everyone some time to think, and we'll invite a student to come up and share their thoughts shortly.



Student: The electron experiences an upward electrostatic force between the parallel metal plates, resulting in upward acceleration.

$$a = \frac{F}{m} = \frac{eE}{m} = \frac{eV}{md}$$

To find the time the electron moves between the parallel metal plates, considering horizontal motion:

$$t_1 = \frac{L}{v}$$

Based on the formulas regarding constant acceleration motion, the upward displacement "y_1" of the electron between the parallel metal plates can be calculated as:

$$y_1 = \frac{1}{2}at_1^2 = \frac{1}{2}\frac{eV}{md}\cdot\left(\frac{L}{v}\right)^2 = \frac{eVL^2}{2mdv^2}$$

Teacher: Excellent! Now, let's practice calculating the displacement "y_2" when the electron leaves the parallel metal plates. We'll continue to give everyone some time to think, and then we'll invite a student to come up and share.

Student: The upward velocity of the electron when it leaves the parallel metal plates is:

$$v_y = at_1 = \frac{eV}{md}\cdot\frac{L}{v}$$

To find the time it takes for the electron to travel horizontally outside the parallel plates, we can use:

$$t_2 = \frac{D}{v}$$

The upward displacement "y_2" of the electron outside the parallel plates can be calculated as:

$$y_2 = v_y t_2 = \frac{eVL}{mdv}\cdot\frac{D}{v} = \frac{eVLD}{mdv^2}$$

Teacher: Well done! So, what is the total displacement "y"?

Student: $y = y_1 + y_2 = \frac{eVL}{2mdv^2}(L + 2D)$

Teacher: Great! From the total displacement "y," we can conclude that $y \propto 1/dv^2$. Finally, let's determine which of the options (A), (D), and (E) are correct. We'll again give everyone some time to decide, and then we'll invite a student to share.

Student: (A) and (E) are correct, while (D) should be corrected to “y becomes 1/2 times the original value.”

Teacher: Excellent! So, which options should we choose?

Student: (A), (C), (E).

Teacher: Good job!

老師： 我們先來看(B)與(C)，有沒有同學願意分享平行板的電場 E、端電壓 V 與板距 d 有什麼關係式呢？

學生： $E = \frac{V}{d}$

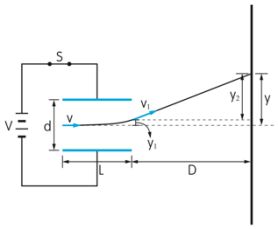
老師： 很好，那當電壓不變的情況，E 與 d 的關係為何呢？

學生： $E \propto \frac{1}{d}$（電場與板之間距成反比）。

老師： 很棒，這是在外加電壓不變的條件下成立的。所以如果 E 變成原來的 2 倍，則 d 應該如何調整呢？

學生： d 應該調整成原來的 1/2 倍。

老師： 非常好，所以(B)錯誤、(C)正確。再來我們來一起推導電子在平行板上的位移 y。我們先從電子在平行金屬板間向上的位移y_1開始推導，現在給大家一些時間，我們等一下請同學上台分享。



學生：電子在平行金屬板間受到向上的靜電力，產生向上的加速度

$$a = \frac{F}{m} = \frac{eE}{m} = \frac{eV}{md}$$

由水平方向運動，求電子在平行金屬板間的飛行時間

$$t_1 = \frac{L}{v}$$

電子在平行金屬版間向上的位移，根據等加速度公式可得:

$$y_1 = \frac{1}{2}at_1{}^2 = \frac{1}{2}\frac{eV}{md}\cdot(\frac{L}{v})^2 = \frac{eVL^2}{2mdv^2}$$

老師：非常好，接著我們來一起練習計算看看，電子離開平行金屬板的位移 y_2，給大家一些時間，等一下請同學上台分享。

學生：電子離開平行金屬板向上的速度

$$v_y = at_1 = \frac{eV}{md}\cdot\frac{L}{v}$$

由水平方向運動求電子在平行金屬板外飛行時間

$$t_2 = \frac{D}{v}$$

電子在平行金屬板外向上的位移y_2

$$y_2 = v_y t_2 = \frac{eVL}{mdv}\cdot\frac{D}{v} = \frac{eVLD}{mdv^2}$$

老師：非常棒，所以總位移 y 為何？

學生：$y = y_1 + y_2 = \frac{eVL}{2mdv^2}(L + 2D)$

老師：非常好，由總位移 y 可知 $y \propto \frac{1}{dv^2}$，最後我們來一起判斷(A)、(D)、(E)，我們一樣給大家一些時間判斷，等一下請同學分享。

學生：(A)與(E)正確，(D)需更正為 y 變成原來的 $\frac{1}{2}$ 倍。

老師：非常棒，所以我們該選哪些選項呢？

學生：(A)(C)(E)。

老師：非常好。

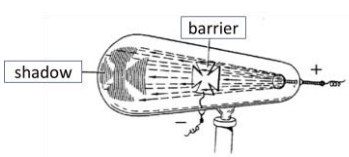
例題二

說明：了解湯姆森從陰極射線實驗的發現。

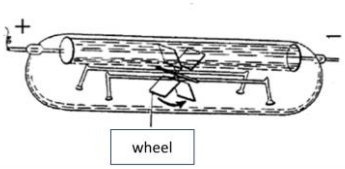
Students can apply the findings of Thomson's cathode ray tube experiment.

Understand that J.J. Thomson discovered electrons from the cathode ray tube experiment.

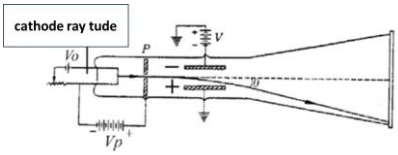
(A)



(B)

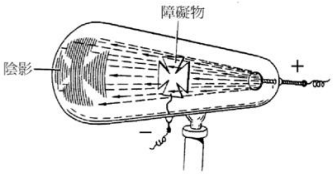


(C)

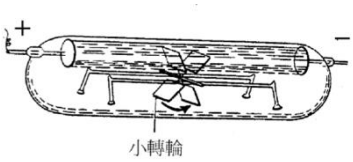


湯姆森從真空放電的實驗中發現了電子。下列有關湯姆森實驗裝置的圖形何者為不正確？

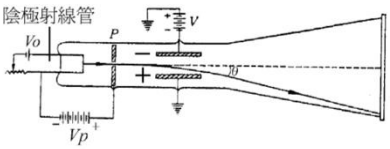
(A)



(B)



(C)



（88 年學測 29）

Teacher: According to J.J. Thomson's cathode ray experiment, does anyone know which diagram is incorrect?

Student: (A).

Teacher: Why is that? What's wrong with it?

Student: Cathode rays originate from the negative electrode and move toward the positive electrode, but in (A), the polarity is reversed.

Teacher: Very good. Since the particles of the cathode ray are electrons with negative charges, which would be attracted and deflected by the anode. So, which option should we choose?

Student: (A).

Teacher: Excellent.

老師： 根據湯姆森陰極射線實驗，有沒有同學知道哪一張圖是不正確的呢？
學生： (A)。
老師： 為什麼呢？它錯在哪裡呢？
學生： 陰極射線是由負極出發，射向正極，(A)的正負極顛倒了。
老師： 很好，因為陰極射線是帶負電的電子，所以會受到正極吸引而偏移。我們應該選哪個選項呢？
學生： (A)。
老師： 很棒。

2-2 密立坎油滴實驗
Millikan's Oil Drop Experiment

■ 前言 Introduction

接續前一節，湯姆森雖然從實驗中測得電子的質量與電量比值，卻仍無法確定其中任何一個量的數值。本節將介紹密立坎如何透過油滴實驗，計算出電量的最小數值，推論出電子的帶電量。

英語在本節中需注意 compare to 在此處為副詞片語，所以後面只能接名詞，不能接完整的句子，教師宜提醒學生副詞及連接詞的用法。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
elementary charge	基本電量	hydrogen atoms	氫原子
oil drop experiment	油滴實驗	constant	常數
neutral/uncharged	不帶電的	electron volt	電子伏特
electromagnetic waves	電磁波	penetrate	穿透(v.)
electric field	電場	penetration	穿透(n.)
electrostatic filed	靜電場	radiation	輻射
irradiate	照射(v.)	Millikan	密立坎

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

❶ Compared to _____, _____.

例句：**Compared to** protons or neutrons, electrons are two thousand times lighter than them.
與質子或中子相比，電子輕了近兩千倍。

❷ _____ be multiple of _____

例句：The charges carried by oil droplets **are a multiple of** the elementary charge.
油滴所帶的電量，是基本電量的整數倍。

❸ see ____ as _____

例句：Scientists used to **see** cathode rays **as** a type of electromagnetic waves.
科學家曾將極陰射線視為是電磁波的一種。

❹ _____ possess the property of _____

例句：Electromagnetic waves **possess the property of** traveling along straight lines despite the existence of external magnetic fields.
電磁波在外加磁場中，仍具有維持直線傳播的特性。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、透過密立坎油滴實驗，以了解基本電荷的意義。

Know the meaning of elementary charge through Millikan's oil drop experiment.

例題講解

例題一

說明：整合湯姆森陰極射線實驗與密立坎油滴實驗，推出電子質量。

Determine the mass of the electron by integrating the findings of the cathode ray tube experiment by J.J. Thompson and the oil drop experiment by Millikan.

Among the four experiments A, B, C, and D, which combination of experiment results can determine the mass of electrons?

A: Rutherford's particle scattering experiment

B: Thomson's cathode ray experiment

C: Roentgen's X-ray experiment

D: Millikan's oil drop experiment

(A) A、B、C、D　　(B) A、B、C

(C) B、D　　(D) D、C

甲、乙、丙、丁四種實驗，哪種實驗的結果組合可以決定電子質量？

甲：拉塞福的粒子散射實驗　　乙：湯姆森的陰極射線實驗

丙：侖琴的 X 射線實驗　　丁：密立坎的油滴實驗

(A)甲、乙、丙、丁　　(B)甲、乙、丙

(C)乙、丁　　(D)丁、丙

（84 年學測 43）

Teacher: Which of the experiments mentioned above are related to electrons?

Student: B and D.

Teacher: What did the two experiments acquire respectively?

Student: Experiment B determined the charge-to-mass ratio of electrons.

Teacher: Good, and what about experiment D?

Student: Experiment D predicted the charge of electrons.

Teacher: Great, how can we use the results of these two experiments to determine the mass of electrons?

Student: By using the known charge-to-mass ratio (charge/ mass) and the charge of electrons, we can calculate the mass of electrons.

Teacher: Very well, so mass of electrons = charge/charge-to-mass ratio. Which option should we choose?

Student: (C).

老師： 請問上述實驗中，與電子有關的有哪些呢？

學生： 乙和丁。

老師： 這兩項實驗，各得到什麼結論呢？

學生： 乙算出了電子的荷質比。

老師： 很好，那丁呢？

學生： 實驗丁則推測出電子的電量。

老師： 很棒，那我們可以如何應用這兩個實驗的結果，來推算電子質量呢？

學生： 利用已知荷質值比(電量/質量)，與電量大小，可以求出電子質量。

老師： 非常好，電子質量=電量/荷質比，所以我們應該選哪個選項呢？

學生： (C)。

例題二

說明：學生能了解密立坎油滴實驗的發現。

Students can understand the findings of Millikan's oil drop experiment.

In Millikan's oil drop experiment, with a separation distance of d between two parallel plates and the switch S closed as shown in Figure 12, if a small oil droplet with mass m and charge q remains at rest between the parallel plates when the switch S is connected, assuming the gravitational acceleration is g and neglecting air buoyancy, which of the following statements are correct?

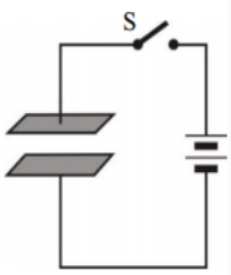


圖 12

(A) The small oil droplet is positively charged.

(B) The electromotive force provided by the DC power supply is $\frac{mgd}{q}$.

(C) Increasing the separation distance between the parallel plates will still keep the small oil droplet at rest.

(D) Millikan's oil drop experiment can be used to measure the mass of photons.

(E) Millikan's oil drop experiment can be used to measure themagnitude of the elementary charge.

密立坎油滴實驗裝置中，兩平行板之間距為 d，接上電源後 如圖 12 所示，S 為電路開關。若開關 S 壓下接通後，發現平行板間有一質量為 m，帶電量為 q 之小油滴在平行板間靜止不動，設 g 為重力加速度。若忽略空氣浮力，則下列敘述哪些正確？

(A) 小油滴帶正電。

(B) 直流電源提供之電動勢為 $\frac{mgd}{q}$。

(C) 將平行板間距加大時，該小油滴仍將停留不動。

(D) 運用密立坎油滴實驗可測量光子的質量。

(E) 運用密立坎油滴實驗可測量基本電荷的電量。

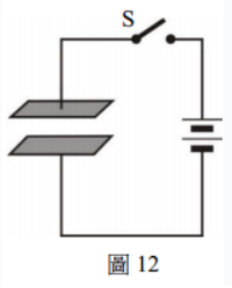


圖 12

（102 指考 24）

Teacher: Let's go through each option together. First, let's look at option A. What forces act on the small oil droplet?

Student: Gravity and electrostatic force.

Teacher: Very good. When the small oil droplet is at rest, what can we say about the net force?

Student: The consultant force is zero.

Teacher: Excellent. The upper plate is positively charged, and the lower plate is negatively charged. So, what kind of charge should the small oil droplet have to experience an upward electrostatic force, in order to balance the downward gravity?

Student: It should have a negative charge.

Teacher: Very good. So, option (A) should be changed to a negative charge. Now, let's move on to (B). Given that the small oil droplet is only subjected to electrostatic force and gravity, and the consultant force is zero, can anyone share how we can calculate the electromotive force?

Student: $mg = qE = q\frac{\varepsilon}{d} \Rightarrow \varepsilon = \frac{mgd}{q}$

Teacher: Very good, so (B) is correct. Next, let's consider (C). If the plate separation distance (d) increases, how does the electrostatic force change?

Student: The electrostatic force decreases.

Teacher: Excellent. In that case, the gravitational force on the small oil droplet will be greater than the electrostatic force, so what will happen to the small oil droplet?

Student: The small oil droplet will fall acceleratedly.

Teacher: Very good, so (C) should be changed to "the small oil droplet will fall acceleratedly." Finally, let's look at (D) and (E). Using Millikan's oil drop experiment, which physical quantities can we determine?

Student: The charge of the elementary charge or the charge of the electron.

Teacher: Perfect, so (E) is correct, and (D) should be changed to "the charge of the elementary charge or the charge of the electron." Now, which options should we choose?

Student: (B) and (E).

Teacher: Excellent.

老師： 我們來一起從每一個選項看，首先是 A 選項，請問小油滴受到那些力的作用呢？

學生： 重力與靜電力。

老師： 很好，請問小油滴靜止表示合力如何呢？

學生： 合力為零。

老師： 很棒，上電板帶正電，下電板帶負電，那麼小油滴為了能平衡向下的重力，所以需要受到向上的靜電力。那麼，由滴應帶什麼電呢？

學生： 負電。

老師： 非常好，所以(A)應改為負電。接著來看到(B)，已知小油滴僅受靜電力與重力，且合力為零，請問有沒有同學願意分享我們該如何計算出電動勢呢？

學生： $mg = qE = q\frac{\varepsilon}{d} \Rightarrow \varepsilon = \frac{mgd}{q}$ 。

老師： 非常好，所以(B)正確。再來我們來看(C)，如果板距 d 加大，靜電力會如何變化呢？

學生： 靜電力會變小。

老師： 很好，那麼小油滴的重力就會大於靜電力，所以小油滴會如何呢？

學生： 小油滴會加速落下。

老師： 很棒，所以(C)應該改為小油滴會加速落下。最後我們來看(D)與(E)，使用密立坎的油滴實驗，我們主要能推導出什麼物理量呢？

學生： 基本電荷的電量或電子的電量。

老師： 很好，所以(E) 正確，而(D)應該改為基本電荷的電量或電子的電量。
那我們應該選哪些選項呢？

學生： (B)與(E)。

老師： 非常棒。

2-3 X 射線
X-ray

■ 前言 Introduction

本節將介紹侖琴在研究氣體放電管實驗時，偶然發現的 X 射線與其性質。教師在說明本節時，宜與前兩節的實驗做連結。說明三者實驗及其科學發現，其實是同時期的。

英語在本節中會學習特定句型，闡述兩種不同特性，老師可以用 the other/another 強調定冠詞的用法，或以 other+N / others 說明其不同。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
flash	閃光	crystal	晶體
uncharged	不帶電的	crystal structure	晶體結構
diffraction	繞射	illuminate	照射
penetration depth	穿透力	wave	波
custom	海關	welding	焊接
interference	干涉	influence	影響
Roentgen	侖琴	X-ray	X 射線

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

❶ _____ be influenced by _____.

例句：The path of X-ray **is** not **influenced by** magnetic or electric fields because it is uncharged.

X 射線的路徑不受磁場或電場的影響，因為 X 射線不帶電。

❷ _____ have/ has nothing to do with _____

例句：The high penetrating power of X-ray **has nothing to do with** the wave interference.

X 射線的高穿透力，跟波的干涉無關。

❸ irradiate A with B

例句：When Laue **irradiates** a crystal **with** X-rays radiation, diffraction occurs, confirming that X-rays are electromagnetic waves.

利用 X 射線照射晶體時產生繞射，證實 X 射線是一種電磁波。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、認識產生 X 射線的方式。

Students can understand the generation of X-rays.

二、了解 X 射線是電磁波的一種。

Students can understand X-rays are a type of electromagnetic waves.

三、認識 X 射線在生活上的應用。

Students know the application X-rays in daily life.

例題講解

例題一

說明：了解對於 X 射線應用及特性。

Understand the application and the characteristics of X-ray.

X-rays are used in medical imaging and crystal structure analysis, with a frequency range of approximately 3×10^{17} Hz to 3×10^{19} Hz. Which of the following statements about X-rays is correct? (Speed of light c = 3.0×10^{8} m/s)

(A) X-rays can display images of bone structures due to wave interference.

(B) X-rays can reveal crystal structures due to their high penetrating characteristics.

(C) The path of X-rays is not influenced by magnetic fields and electric fields.

(D) The interference patterns of X-ray can be observed with a double slit spacing of 0.1 mm.

(E) The Lyman series in the hydrogen atom spectrum corresponds to X-ray frequencies.

X 射線應用於醫學影像及晶體結構分析，其頻率範圍約在 3×10^{17} Hz 至 3×10^{19} Hz。下列有關 X 射線的敘述何者正確？（光速 c = 3.0×10^{8} m/s）

(A) X 射線可顯示骨骼結構影像，是由於波的干涉所產生。

(B) X 射線可顯示晶體結構，是由於其高穿透力特性所產生。

(C) X 射線的路徑不受磁場與電場的影響。

(D) 用狹縫間距為 0.1 mm 的雙狹縫即可觀察到 X 射線的干涉條紋。

(E) 氫原子光譜的來曼系就有 X 射線的頻率。

（改編自 109 年指考 3）

Teacher: Let's take a look at each option and correct it. First of all, for (A) Does anyone want to share the reason why the X-rays can display images of bone structures?

Student: Since the high penetrating power has nothing to do with the wave interference.

Teacher: Good. Let's move on to option (B) what's the reason that the X-ray can display the crystal structure?

Student: Because of the diffraction of the waves.

Teacher: Great. How about option (C)? Can anyone share whether the path of the X-ray is influenced by magnetic or electric field and why?

Student: The path of the X-ray is not influenced by magnetic and electric fields, because it is a kind of electromagnetic wave, which is uncharged. Therefore, no electric force neither magnetic force is reacted.

Teacher: Excellent. Let's take a look at option (D). Based on the condition provided by the question, please figure out the wavelength range. Later, we will have students go on the stage and share the results.

Student: $\lambda = \frac{c}{f}$, wavelength range $\frac{3\times10^8}{3\times10^{17}} > \lambda > \frac{3\times10^8}{3\times10^{19}} \Rightarrow 10^{-9}m > \lambda > 10^{-11}m$

Teacher: Very good. Can we observe the wave interference pattern of X-ray?

Student: No, because $\lambda \ll 0.1mm$ When X-rays are directed through a double slit with a spacing of 0.1 mm, the interference patterns of X-rays cannot be observed due to the very small bright fringe spacing."

Teacher: Very well, let's finally look at option (E). What is the frequency range of the Lyman series in the hydrogen atom spectrum

Student: It is ultraviolet light.

Teacher: Great, which option should we choose?

Student: (C).

Teacher: Good!

老師： 我們一起來看每一個選項並更正。首先是(A)選項，有沒有同學可以分享 X 射線可顯示「骨骼結構影像」是因為什麼原因呢？

學生： 是因為 X 光的「高穿透力特性」，與波的干涉無關。

老師： 很好，再來我們來看(B)選項，那 X 光可以顯示「晶體結構」是因為什麼原因呢？

學生： 是因為波的「繞射」。

老師： 很棒，接著我們來看(C)選項，請問有沒有同學可以分享(C)選項，X 射線的路徑是否受磁場與電場的影響呢？為什麼呢？

學生： X 射線的路徑不受磁場或電場的影響，因為它是一種電磁波，不帶電，所以不受到電力或磁力作用。

老師： 非常好，我們繼續看(D)選項，根據題目的條件，請大家嘗試計算出 X 射線的波長範圍，我們等一下請同學上臺分享。

學生： $\lambda = \frac{c}{f}$，波長範圍 $\frac{3\times10^8}{3\times10^{17}} > \lambda > \frac{3\times10^8}{3\times10^{19}} \Rightarrow 10^{-9}m > \lambda > 10^{-11}m$

老師： 非常棒，所以我們能不能觀察到 X 射線的干涉條紋呢？

學生：　不行，$\lambda \ll 0.1mm$，用 X 射線照射間距為 0.1 mm 的雙狹縫，因亮紋間距太小，無法觀察到 X 射線的干涉條紋。

老師：　很好，我們最後來看(E)選項，請問氫原子光譜的來曼系屬於電磁波的甚麼頻率範圍呢？

學生：　是紫外光。

老師：　非常棒，所以我們這題該選什麼選項呢？

學生：　(C)。

老師：　很棒。

例題二

說明：學生能了解陰極射線與 X 射線相關概念。

Students can understand concepts related to cathode rays and X-rays.

The following statements are about the cathode ray and X-ray. Which one of the following is true?

(A)　Both can generate current while traveling.

(B)　Both of them can be deflected by an electrostatic field.

(C)　They have different natures.

(D)　Their generation methods are similar, both emitted from the same pole.

有關陰極射線與 X 射線的敘述，下列何者正確？

(A)　兩者的行進均可產生電流。

(B)　兩者均可受靜電場的影響而偏向。

(C)　兩者本質不同。

(D)　兩者產生方式類似，均由同一極射出。

（改編自翰林版高中物理 V 教師手冊第二章第 2-23 頁教學補充資料-師生對談問與答第 1 題與第 3 題）

Teacher:　Let's look at each option together. First, the (A) option, does anyone want to share whether (A) is correct? Why or why not?

Student:　X-ray is an electromagnetic wave, so it is electrically neutral and does not generate electric current as they travel. So (A) is incorrect.

Teacher: Very good. How about option (B)? Does anyone want to try this one?

Student: Since X-ray is an electromagnetic wave, so it is electrically neutral, it can not be influenced by the electric field. So it does not deflect when passing through an electric field.

Teacher: Excellent. Next is (C). Does anyone want to give it a try?

Student: The cathode rays are composed of electron beams rather than a type of electromagnetic wave, so cathode rays are different from X-rays.

Teacher: Excellent. Although X-ray and cathode rays appear to be lights to us, they are completely different in components. Finally, (D). Is there anyone else willing to give it a try?

Student: X-ray is an electromagnetic wave produced when high-speed cathode rays strike the anode, so the mechanism of generating the two are different. And they originate at opposite poles.

Teacher: Good, so which option should we choose?

Student: (C).

老師： 我們一起來看每一個選項。首先是(A)選項，有沒有同學願意分享(A)是否正確呢？為什麼呢？

學生： X 射線為電磁波，所以不帶電，行進時不會產生電流，因此(A)不正確。

老師： 很好，那(B)選項呢？有沒有同學願意嘗試看看呢？

學生： 因為 X 射線是電磁波，所以不受靜電場影響，通過電場時不會偏向。

老師： 很棒，接著是(C)有沒有同學願意嘗試呢？

學生： 陰極射線的成分是電子束，不是電磁波，所以和 X 射線不同。

老師： 非常好，雖然陰極射線與 X 射線，看起來都是一道光，但其本質不同。最後是(D) 還有沒有其他同學願意嘗試呢？

學生： X 射線是由高速的陰極射線撞擊陽極所產生的電磁波，所以兩者產生的方式不同，也分別在相反的兩極產生。

老師： 沒錯，那我們應該選哪個呢？

學生： (C)。

2-4 黑體輻射—能量的不連續性
Blackbody Radiation - the Discreteness of Energy

■ 前言 Introduction

本節將簡述近代科學的發展歷程，從科學家為何要研究黑體輻射、研究過程中遭遇的困難，以及何謂黑體輻射，進而引入普朗克的量子論。

英語在本章要注意連接詞和副詞的運用，連接詞是連接同等層次，而副詞則不具有連接的功能，確保學生了解兩者的不同。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
black body radiation	黑體輻射	cavity	空腔
ideal	理想的	pole	小孔
wave length	波長	energy intensity	能量強度
spectra	光譜(複數)	spectrum	光譜(單數)
irradiate	照射	photon theory	量子論
emit	發射	absorb	吸收
radiation	輻射		

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

❶ _____ have something/nothing to do with _____

例句：The radiation spectra emitted by a blackbody **has something to do with** the temperature of the walls of the apparatus but has nothing to do with the material and shape.
黑體所發出的輻射光譜，只與器壁上的溫度有關，與材料和形狀無關。

❷ S+V and thus S+V.

例句：When an object emits electromagnetic waves, the energy decreases **and thus** the temperature drops.
物體放出電磁波，本身的能量降低，因此溫度會下降。

■ 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：
At the end of learning the chapter, students are able to acquire the following concept:
一、了解黑體輻射的意義與性質。
Students can understand the meaning and the characteristics of blackbody radiation.

例題講解

例題一

說明：學生能了解黑體輻射在生活中的應用。

Students can understand the application of Blackbody radiation in daily life.

During the COVID-19 pandemic, forehead thermometers are commonly used to measure body temperature. Which of the following statements is correct?

(A) The physical principle for measuring temperature with a forehead thermometer is similar to detecting the background radiation of the universe.

(B) Forehead thermometers primarily detect radiation in the ultraviolet range.

(C) The stronger the radiation intensity detected in the main frequency range by the forehead thermometer, the lower the temperature is.

(D) The radiation frequency at which the forehead thermometer detects the maximum radiation intensity decreases as the temperature rises.

(E) Forehead thermometers need to reach thermal equilibrium with the skin surface of the forehead to measure temperature accurately.

新型冠狀病毒防疫期間，常使用額溫槍量測人體額溫，下列敘述何者正確？

(A) 額溫槍量測額溫的物理原理與偵測宇宙背景輻射類似。

(B) 額溫槍偵測的主要波段為紫外線範圍。

(C) 額溫槍偵測到主要波段的輻射強度越強，表示額溫越低。

(D) 額溫槍偵測到最大輻射強度的輻射頻率，隨額溫升高而變小。

(E) 額溫槍需與額頭表面皮膚達熱平衡才能準確量測額溫。

(109 指考 1)

Teacher: Let's go through each option. First, (A): Would anyone like to share how forehead thermometers work?

Student: Forehead thermometers use the same principle as detecting the background radiation of the universe, which utilizes the radiation intensity or the wavelength of the most intensive radiation to determine the temperature of the object surface.

Teacher: Great, now let's look at (B): What is the primary wavelength range detected by forehead thermometers?

Student: The primary range is the infrared range.

Teacher: Excellent. The temperature of human can only emit infrared. Moving on to (C): According to the relationship between blackbody radiation intensity and temperature wavelengths, what can we conclude when a forehead thermometer detects stronger radiation intensity?

Student: It indicates a higher forehead temperature.

Teacher: Very good, the relationship between temperature and the radiation intensity is discussed by Stefan-Boltzmann Law. Now, (D): Based on Wien's displacement law, we know that $\lambda_{max} \cdot T$ is constant. So, as the forehead temperature rises, what happens to the most intensive wavelength?

Student: It gets smaller.

Teacher: Great. And what about the radiation frequency?

Student: It increases.

Teacher: Excellent. Since the speed of light is fixed, the greater the wavelength is, the lower of the frequency becomes. Finally, (E): Is (E) correct? If not, what needs to be modified?

Student: (E) is not correct. Forehead thermometers detect the radiation spectra, so do not need to contact the skin's surface on the forehead to measure temperature accurately.

Teacher: Correct, so the forehead thermometer is nothing related to thermal equilibrium, which requires the objects to contact each other. So what should be our answer for this question?

Student: (A).

老師： 我們來一起看每一個選項。首先是(A)選項，有沒有同學願意分享額溫槍是利用什麼原理呢？

學生： 和偵測宇宙背景輻射一樣，都可以利用黑體輻射能量強度，或是能量最強的波長，來判定物體表面的溫度。

老師： 很好，接著來看(B)選項，那麼額溫槍偵測到的主要波段為何呢？

學生： 主要是紅外線波段。

老師： 很棒，因人體體溫屬於紅外線的電磁波。再來看(C)選項，依據黑體輻射能量強度與溫度波長的關係曲線，我們可以知道額溫槍測得的輻射強度愈強，表示量測之額溫越如何呢？

學生： 額溫會越高。

老師： 非常好，探討溫度與熱輻射能量強度的關係，是根據斯特凡-波茲曼定律。再來看(D)選項，根據維因位移定律，我們知道 $\lambda_{max} \cdot T = 定值$，所以當額溫升高時，能量最強的波長會如何變化呢？

學生： 會變小。

老師： 很好，那麼輻射頻率又會如何變化呢？

學生： 會變大。

老師： 很棒。因為光速固定，所以波長減小，頻率會增大。我們最後來看(E)選項，請問(E)選項正確嗎？如果不正確的話，有哪裡需要修改呢？

學生： 不正確。額溫槍是透過熱輻射的光譜來推斷溫度，所以不需與額頭接觸，即可藉由額頭之熱輻射測量額溫。

老師： 非常好，而選項(E) 所述的熱平衡，則需要兩物體接觸，所以額溫槍不需與額頭達到熱平衡。所以，我們這題該選什麼選項呢？

學生： (A)。

例題二

說明：學生能分辨黑體輻射的光譜與激發光譜之不同。

Students can distinguish the difference between the spectra of blackbody radiation and that of the stimulated lights.

Below are five sources of electromagnetic waves:

Hydrogen discharge tube: exhibits a discontinuous spectrum

Tungsten filament lightbulb: its spectrum is temperature-dependent and continuous

Blue laser: emits laser light with wavelengths ranging from approximately 360 nm to 480 nm

FM radio broadcast: operates in the wavelength range of 2.8 m to 3.4 m

X-rays: have wavelengths between 0.01 nm and 1 nm.

Which of the above sources has a spectrum that most closely resembles blackbody radiation?

(A) Hydrogen discharge tube

(B) Tungsten filament light bulb

(C) Blue laser

(D) FM radio broadcast

(E) X-rays

下列為五種電磁波源：
氫氣放電管：為不連續的光譜線。
鎢絲電燈泡：其光譜與溫度有關且為連續光譜。
藍光雷射：波長約介於 360 nm 到 480 nm 之間的雷射光。
FM 調頻廣播：其波長介於 2.8 m 到 3.4 m 之間。
X 射線：其波長介於 0.01 nm 到 1 nm 之間。

以上何者之光譜最接近黑體輻射？
(A) 氫氣放電管
(B) 鎢絲電燈泡
(C) 藍光雷射
(D) FM 調頻廣播
(E) X 射線

（102 指考 18）

Teacher: Does anyone would like to share the characteristics of blackbody radiation spectra?
Student: It is continuous spectrum that has a much wider range of frequency than stimulated lights and depends only on the surface temperature of the blackbody.
Teacher: Great! Based on the spectra of the five electromagnetic waves mentioned above, which one should we choose as being closer to blackbody radiation?
Student: (B)

老師：有沒有同學願意分享，黑體輻射的光譜，具有哪些特性？
學生：黑體輻射是連續光譜、頻率範圍較激發光來得寬廣許多，且僅與黑體表面的溫度有關。
老師：很棒，根據上述五種電磁波的光譜，我們應該選擇哪一個較接近黑體輻射呢？
學生：(B)。

2-5 光電效應—輻射的粒子性
The Photoelectric Effect—Particle Nature of Radiation

■ 前言 Introduction

本節將介紹近代物理史上相當重要的理論—光電效應，包含光電效應現象與違反古典物理的特徵，及愛因斯坦所提出的光子理論，順利解釋光電效應的現象，並與古典的波動光學做比較。與上一節不同之處是，黑體輻射屬於電磁波的量子化，而光電效應則展現光量子化的特性。

英語在本節學生可以練習到以 that 帶出名詞子句當補充用的文法，教師宜提醒學生在 that 之後應該是一個完整的子句。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
light quanta	光量子	metal	金屬
photoelectric effect	光電效應	surface	表面
electromagnetic wave	電磁波	photo electron	光電子
photoelectric current	光電流	cut-off voltage	截止電壓
threshold frequency	底線頻率	linear	線性的
relation	關係	work function	功函數
incident light	入射光	Einstein	愛因斯坦

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

❶ Based on _____.

例句：**Based on** the classical theory of light, as long as the light intensity is sufficient, the light can stimulate electrons from the metal and resulting in electric current.
根據古典光學，只要光的強度夠強，就足以使電子從金屬逸出，產生電流。

❷ ____ that S +V (that 帶出的名詞子句可進行補充說明)

例句：The photoelectric effect is the phenomenon **that** electrons pop out from metals, which are emitted by light beams.
光電效應是指當光束照射到金屬表面時，電子會彈射出來的現象。

❸ ____ be called

例句：When irradiating a metal surface with light, the electrons of the metal require enough photon energy to pop out from the metal. The phenomenon **is called** the photoelectric effect.
用光照射到金屬表面，金屬裡的自由電子若獲得足夠的光子能量，就能從金屬表面逃逸。這個現象稱為光電效應。

■ 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：
At the end of learning the chapter, students are able to acquire the following concept:
一、了解光電效應與光量子論。
Students can understand the photoelectric effect and model of light quantization.

例題講解

例題一

說明：學生能計算光子的能量，並由輻射強度推算出光子個數。

Students can calculate the energy of one photon, and determine the number of photons by the given radiation intensity.

A mask contaminated with the influenza virus can be treated with ultraviolet-C (UV-C) radiation at a wavelength of 253.7 nm. This radiation destroys the viral DNA and RNA structures, effectively eliminating the virus. If the mask's surface is exposed to UV-C radiation with an intensity of 6,600 μW/cm² for 2.0 seconds, approximately how many UV-C photons per square centimeter will be involved within these two seconds?

(Planck's constant $h = 6.63 \times 10^{-34} J \cdot s$, speed of light $c = 3.0 \times 10^{8}\, m/s$)

(A) 2.4×10^{13} (B) 6.4×10^{14} (C) 8.4×10^{15} **(D) $\mathbf{1.7 \times 10^{16}}$** (E) 9.6×10^{17}

表面沾有流感病毒的口罩，可使用波長為 253.7 nm 的紫外線-C 照射，破壞病毒的去氧核糖核酸(DNA)及核糖核酸(RNA)結構，達到消滅病毒的效果。若以強度為 6,600 μW/cm2 的紫外線-C 垂直照射口罩表面 2.0 s，則兩秒鐘內每平方公分的紫外線-C 光子數約為若干？（普朗克常數 $h = 6.63 \times 10^{-34} J \cdot s$，光速 $c = 3.0 \times 10^{8}\, m/s$ ）

(A) 2.4×10^{13}

(B) 6.4×10^{14}

(C) 8.4×10^{15}

(D) $\mathbf{1.7 \times 10^{16}}$

(E) 9.6×10^{17}

(109 指考 2)

Teacher: Does any student would like to share the formula for the energy of a photon?

Student: $E = h\nu = \frac{hc}{\lambda}$

Teacher: Great, let's start by calculating the energy of a single photon. I'll give everyone time to try, and then we'll have a student share their calculation.

Student: $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{253.7 \times 10^{-9}} (J)$

Teacher: Very good. The UV intensity is 6600 μW/cm², which we can convert to 6600×10^{-6} *J/s*·cm². Next, let's calculate the number of photons the UV radiation generates. Could someone try to calculate how many photons are emitted?

Student: Number of photons $= 6600 \times 10^{-6} \times 2 \div \frac{6.63\times10^{-34}\times3\times10^{8}}{253.7\times10^{-3}} \fallingdotseq 1.7 \times 10^{16}$

Teacher: Good, so which option should we choose?

Student: (D)

老師： 有沒有同學願意分享光子的能量公式？

學生： $E = h\nu = \frac{hc}{\lambda}$

老師： 很好，這題我們一樣先從計算一個光子的能量著手，等一下給同學一些時間，請大家嘗試看看計算出一個光子的能量，我們等一下請同學上台分享。

學生： $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{253.7 \times 10^{-9}} (J)$

老師： 很好，紫外線的光強度為 6600 $\mu w/cm^2$ 我們先把它單位換成 6600×10^{-6} *J/s*·cm²，接著一樣給大家一些時間，算出紫外線照射的光子數為何？

學生： 光子數 $= 6600 \times 10^{-6} \times 2 \div \frac{6.63\times10^{-34}\times3\times10^{8}}{253.7\times10^{-3}} \fallingdotseq 1.7 \times 10^{16}$

老師： 很棒，所以我們應該選什麼選項呢？

學生： (C)。

例題二

說明：學生能根據光的波長，選擇需要的已知，計算光子能量。

Students can calculate the energy of a photon based on the given wavelength and select the required variables.

In the laboratory, there is a laser light source that emits light with a wavelength of 200 nm and power of 3.0 W. Given the speed of light ($c = 3.0 \times 10^8\, m/s$) and Planck's constant ($h = 6.63 \times 10^{-34} J \cdot s$), approximately what is the energy (with the unit of J) of each photon emitted by this light source?

(A) 1.0×10^{-14} (B) 1.0×10^{-16} **(C) $\mathbf{1.0 \times 10^{-18}}$** (D) 1.0×10^{-20} (E) 1.0×10^{-22}

在實驗室中有一台可發出波長為 200 nm 的雷射光源，功率為 3.0 W。已知光速為 $3.0 \times 10^8\, m/s$，普朗克常數為 $6.63 \times 10^{-34} J \cdot s$，此光源發出的每個光子之能量約為下列何者(單位為 J)？

(A) 1.0×10^{-14} (B) 1.0×10^{-16} **(C) $\mathbf{1.0 \times 10^{-18}}$**

(D) 1.0×10^{-20} (E) 1.0×10^{-22}

（105 指考 19）

Teacher: Is there any student willing to share the formula for photon energy?

Student: $E = \frac{hc}{\lambda}$

Teacher: Very good, now I'll give students some time to calculate using the clues provided in the question. Let's hear from one of the students.

Student: $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{200 \times 10^{-9}} \fallingdotseq 1.0 \times 10^{-18} J$

Teacher: Excellent, which given variable is not needed to determine the energy of a photon?

Student: The power of the laser light.

Teacher: Excellent, since the energy of a photon depends only on the wavelength or its frequency, not the intensity or power of the light beam. So what should we choose as the answer to this question?

Student: (C).

老師：有沒有同學願意分享光子的能量公式？

學生：$E = \frac{hc}{\lambda}$

老師：很好，現在給同學一些時間，利用這題題目給的線索計算一下，我們等一下請同學上台分享。

學生：$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{200 \times 10^{-9}} \fallingdotseq 1.0 \times 10^{-18} J$

老師：很棒，題目中，有哪一項已知並不需要？

學生：發光的功率。

老師：很好，因為光子的能量，只跟光的波長或頻率有關，與整道光的強度或功率無關。所以，我們這題要選什麼答案呢？

學生：(C)。

★ 主題三 原子結構與原子核 ★
Atomic Structure and Atomic Nucleus

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■ 前言 Introduction

本章從近代物理史的先驅湯姆森原子模型開始，接著是拉塞福的電子軌道，再到波耳的氫原子定態假定，慢慢地建立起我們現在所認知的原子構造，最後再探討原子核的組成和四大交互作用。這些重要的理論開啟了近代物理的新發現和新觀點，揭開了許多自然的奧秘，也引領現代科技的發展。例如:雷射的發明和半導體的研發，促成電子工業的革命。

3-1 拉塞福原子模型與原子光譜
The Rutherford Atomic Model and Atomic Spectra

■ 前言 Introduction

本節主要探尋科學家們提出的原子模型，了解原子內部的構造，也逐步揭開基本粒子的面紗。在英文部分，教師在講述時可視學生程度，以簡單的句型描述原子模型，例如: be analogous to(將...比喻為...)為較艱深且重要的單字但是講述時學生較難理解其字義，教師可以 be similar to(和...相似)作為補述。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
atom	原子	penetrate	穿入
atomic nucleus	原子核	diameter	直徑
plum pudding model	葡萄乾布丁模型	reflect	偏折
collide…..with	碰撞	point mass	質點
empty	空無一物的	hyperbolic	雙曲線
orbit	軌道	structure	結構
planet	行星	break down	崩潰
atomic spectrum	原子光譜	scarce	稀薄的
glass tube	玻璃管	radiate	輻射

triangular prism	三稜鏡	bright	明亮的
spectral line	光譜線	analyze	分析
hydrogen spectral series	氫原子光譜	visible spectrum	可見光譜
distribution	分布	Lyman	來曼
Paschen	帕申	spectrum/spectra	光譜
emission spectrum	發射光譜	continuous spectrum	連續光譜
incandescent bulb	白熾燈	bright line spectrum	明線光譜
discrete spectrum	不連續光譜	atomic emission spectrum	特徵光譜
absorption spectrum	吸收光譜	pattern/regularity	規律

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

❶ _____ surround _____

例句：The electrons of atoms **surround** the nucleus in a circular orbit.
原子內的電子在圓形軌道繞著原子核運轉。

❷ ____ be analogous to _____ (視學生程度，可利用 be similar to____作為講解)

例句：In the Rutherford's nuclear model of the atom, the nucleus **is analogous to** the sun.
在拉塞福的原子模型中，原子核被比喻為太陽。

❸ be supplied by _____

例句：The centripetal force causing the electron to follow a circular path **is supplied by** Coulomb's force between the electrons and the nucleus.
電子繞行圓形軌道所需的向心力，是由電子和原子核間的庫倫吸引力。

❹ be concentrated in _____

例句：The mass of an atom **is** highly **concentrated in** very tiny area, which is the nucleus of the atom.

原子的質量高度集中於非常小的區域，也就是原子核。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解拉塞福的原子模型。

Understand Rutherford's atomic model.

二、了解氫原子光譜。

Understand the spectral series of hydrogen.

❧ 例題講解 ☙

例題一

說明：能分析氫原子光譜。

Analyze the hydrogen spectral series

A system composed of numerous hydrogen atoms in their ground state absorbs a single-frequency light beam, transitioning individually to excited states with a principal quantum number n. When these hydrogen atoms in the excited state return to the ground state, 6 distinct wavelength spectrum lines can be measured. What is the value of n?

(A) 7　(B) 6　(C) 5　**(D) 4**　(E) 3

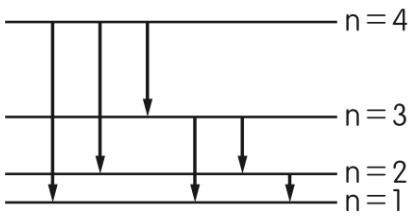
由許多個處於基態的氫原子所組成的系統，吸收一束單一頻率的光後各自躍遷 到主量子數為 n 的激發態，當這些處於激發態的氫原子回到基態時，可以測量到 6 條不同波長的光譜線，試問 n 為何?

(A) 7　(B) 6　(C) 5　**(D) 4**　(E) 3

（110 年指考 16）

Teacher: Let's give the students some time to try drawing this, then I'll ask a student to come up and share

Student:

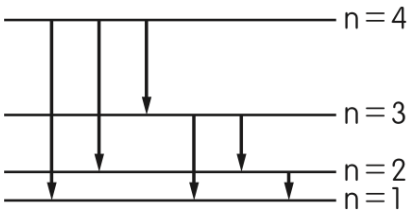


Teacher: Very well, so which option should we choose?

Student: (D)

老師： 我們給同學一些時間嘗試畫看看，等一下請同學上臺分享。

學生：



老師： 非常好，所以我們該選哪一個選項呢？

學生： (D)。

例題二

說明：了解拉塞福的原子模型。

Understand Rutherford's atomic model.

Which of the following statements correctly describes the conclusions drawn from Rutherford's scattering experiment using alpha particles on gold foil?

A: In an atom, positive and negative charges are equal.

B: Almost all of the mass is concentrated in the positive charge.

C: There is an attractive Coulomb force between the electron and the nucleus, inversely proportional to the square of the distance.

D: The mass of the electron is much smaller than that of an alpha particle.

(A) A,B　**(B) B,C**　(C) A,C　(D) B,D

針對拉塞福以粒子對金箔作散射實驗後所提出之結論，下列敘述何者正確？

甲：原子中，正、負電荷相等

乙：正電荷幾乎集中了全部原子的質量

丙：電子與原子核間以距離平方反比的庫侖力相吸

丁：電子的質量遠小於〈粒子

(A)　甲乙

(B)　乙丙

(C)　甲丙

(D)　乙丁

（改編自翰林版教師手冊 3-10 頁演練 2）

Teacher: Let's go through each statement together. First is statement A. Was statement A a conclusion drawn from Rutherford's experiment?

Student: No, it's not. The neutrality of the atom has always been one of the assumptions of atomic models.

Teacher: Very good. Next is statement B. Was statement B a conclusion drawn from Rutherford's experiment?

Student: Yes.

Teacher: Great. Now, statement C. Was statement C a conclusion drawn from Rutherford's experiment?

Student: Yes.

Teacher: Very good. Lastly, statement D. Was statement D a conclusion drawn from Rutherford's experiment?

Student: No, it wasn't. Because alpha particles are heavy enough that they were chosen as projectiles for collision.

Teacher: Excellent. Statement D was already known before Rutherford designed his experiment. So, which option should we choose?

Student: (B).

老師： 我們一起來看看每一個敘述。首先是甲，請問敘述甲是拉塞福實驗得出的結論嗎？

學生： 不是，原子是電中性，一直是原子模型的假設之一。

老師： 很好，再來是敘述乙，請問敘述乙是拉塞福實驗得出的結論嗎？

學生： 是。

老師： 很棒，再來是敘述丙，請問敘述丙是拉塞福實驗得出的結論嗎？

學生： 是。

老師： 非常好，最後是敘述丁，請問敘述丁是拉塞福實驗得出的結論嗎？

學生： 不是，正是因為〈粒子的質量夠重，才會選定它為砲彈去撞擊。

老師： 非常棒，丁選項是拉塞福設計實驗前的已知。所以我們該選哪個選項呢？

學生： (B)。

3-2 波耳的氫原子模型
Bohr Model of the Hydrogen Atom

■ 前言 Introduction

波耳利用半古典的物理概念:駐波，與普朗克的電磁波量子模型，在拉塞福的原子模型基礎下，提出兩項氫原子模型所需遵守的基本假設。本節中，將會從兩個基本假設出發，說明原子光譜的實驗結果與原子能階概念。

教師在講解激發態(excited state)的英文時，可從單字本身的字義和詞性去做推演學生也較容易理解；而當講述到能量階時，雖然中文都是跳躍至，英文也有通用字 transition，但是若帶入 jump to (由低至高)和 step back(由高至低)的概念，學生在學習時也能更加區分概念的差別和訓練語感。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
stationary state	定態	quantization	量子化
transition	躍遷	angular momentum	角動量
orbit	軌道	emit	發射
absorb	吸收	Bohr radius	波爾半徑
principal quantum number	主量子數	ground state	基態
first excited state	第一受激態	ionized state	游離態
energy level	能階	Rydberg constant	芮得柏常數

probability	機率	laser	雷射
semiconductor	半導體		

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

❶ be said to _____

例句：If the electrons of an atom are at the lowest energy level, they **are said to** be in the ground state. If they are at a higher energy level, they **are said to** be in excited states.
如果一個原子的電子處於最低能階，它們被稱為處於基態。如果它們處在較高能階，則被稱為是處於激發狀態。

❷ jump up to ____/ step back to _____/transit

例句：When the atom absorbs electromagnetic radiation, its electrons can **jump up** (from a lower energy level) **to** a higher energy level.
原子若吸收電磁輻射，則電子會由低能階跳到高能階。

❸ _____ absorb/emit _____

例句：When an electron transitions from a higher energy level to a lower one, it **emits** electromagnetic radiation.
電子若由高能階跳回低能階，則會放出電磁輻射。

❹ according to _____ / based on _____

例句：**According to** the appearance, radiation spectrum can be classified as either continuous spectrum or discrete spectrum.
輻射光譜依照其樣式，可分成連續光譜和不連續光譜。

❺ be divided/group/ categorized/ classifies into _____

例句：Based on the formed mechanism of spectrum, it could **be divided into** two forms, emission spectrum and absorption spectrum.

光譜依照其形成的機制，可分為發射光譜和吸收光譜兩大類。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解波耳的氫原子模型。

Understand Bohr model of the hydrogen atom.

❧ 例題講解 ☙

例題一

說明：了解波耳的氫原子模型與物質波。

Understand Bohr model of the hydrogen atom and matter wave.

In Bohr's model of hydrogen atom, the electrons can be seen as moving in a circular path around the proton at a radius r with constant velocity. Considering the matter wave model, when an electron is in a stable state, the circumference of its orbit must meet the condition for standing wave. The orbit's radius also increases with the principal quantum number n. Assuming Planck constant is h, what is the magnitude of momentum p of the electron when it's in a stable orbit with a principal quantum number n?

(A) $p = \frac{nh}{2r}$ (B) $p = \frac{nh}{2\pi}$ **(C)** $\boldsymbol{p = \frac{nh}{2\pi r}}$ (D) $p = \frac{nhr}{2\pi}$ (E) $p = \frac{h}{2\pi r}$

在波耳的氫原子模型中，電子可視為以質子為中心做半徑為 r 的等速圓周運動。考量物質波模型，當電子處於容許的穩定狀態時，軌道的周長必須符合圓周駐波條件。軌道半徑也隨著主量子數 n 而愈來愈大。設普朗克常數為 h，當電 子處於主量子數為 n 的穩定軌道的情形之下，電子的動量 p 量值為何?

(A) $p = \frac{nh}{2r}$　(B) $p = \frac{nh}{2\pi}$　**(C)** $\boldsymbol{p = \frac{nh}{2\pi r}}$　(D) $p = \frac{nhr}{2\pi}$　(E) $p = \frac{h}{2\pi r}$

（102 年指考 19）

Teacher: What are the given variables and what is the unknown of this problem?

Student: This problem needs to determine the electron's momentum from the given radius of the electron's orbit and the quantum number n, as well as the Plank Constant h.

Teacher: Great! Let's give the students some time to try and write out the equations for calculation. Later, I'll ask a student to come up and share.

Student: $2\pi r = n\lambda = n\frac{h}{p} \Longrightarrow p = \frac{nh}{2\pi r}$

Teacher: Great. $2\pi r = n\lambda$ is the condition for the electron to form a standing wave. Then, $\lambda = n\frac{h}{p}$ is the relation between electron's momentum (p) and its wavelength of matter wave (λ). So which option should we choose?

Student: (C).

老師：這一題，已知有哪些？未知是甚麼？

學生：要從已知電子的軌道半徑 r，及量子數 n 還有普朗克長數 h，推出電子的動量 p。

老師：很好，我們給同學一些時間，嘗試列出方程式計算看看，等一下請同學上臺分享。

學生：$2\pi r = n\lambda = n\frac{h}{p} \Longrightarrow p = \frac{nh}{2\pi r}$

老師：很好，$2\pi r = n\lambda$是電子在軌道上形成駐波的條件，$n\lambda = n\frac{h}{p}$則是動量 p 與物質波的波長 λ 之關係。所以我們該選哪一個選項呢？

學生：(C)。

例題二

說明：能應用波耳角動量量子化的假設。

Apply Bohr's hypothesis of angular momentum quantization.

Assuming the description of the quantization of electron angular momentum in Bohr's hydrogen atom model also applies to the motion of a free electron at different velocities within a tiny circular metal loop with a fixed radius. If the minimum kinetic energy of the free electron moving along this circular metal loop is ε, what would be the kinetic energy of the free electron in its first excited state?

(A) 2ε　**(B) 4ε**　(C) 6ε　(D) 9ε　(E) 12ε

假設波耳的氫原子模型中電子角動量量子化的描述，也適用於自由電子以不同速率在一個半徑固定之微小圓形金屬線圈中的運動。若自由電子沿此圓形金屬線圈運動的最低動能為 ε，則自由電子在第一受激態時所具有的動能為下列何者？

(A) 2ε　**(B) 4ε**　(C) 6ε　(D) 9ε　(E) 12ε

（104 年指考 18）

Teacher: What are the knowns and unknowns in this question?

Student: To derive the kinetic energy of the ground state from the known minimum kinetic energy.。

Teacher: Is there anyone willing to share what the assumption of Bohr's angular momentum quantization is?

Student: $L = rmv = n\frac{h}{2\pi}$

Teacher: Great, let's give everyone some time to try and figure out how to formulate an equation related to kinetic energy using this equation. Later, I'll ask a student to come up and share.

Student: $L = rmv = n\frac{h}{2\pi} \Rightarrow v = n\frac{h}{2\pi mr} \propto n$

The kinetic energy of the electron: $K = \frac{1}{2}mv^2 \propto v^2 \propto n^2$

Teacher: Very good, The angular momentum L of an electron in an atom is quantized, which equals an integer multiple of the reduced Planck constant $\hbar$ （$\hbar = \frac{h}{2\pi}$）.

Teacher: We can utilize this to derive the relationship between the velocity *v* and the principal quantum number *n* (energy level). So, if the kinetic energy of the electron in the ground state (n=1) is ε, based on the above equations, what would be the kinetic energy in the first excited state (n=2)?

Student: 4ε.

Teacher: Excellent. So, which option should we choose?

Student: (B).

老師： 這一題，已知有哪些？未知是甚麼？

學生： 要從已知的最低動能，推導出第一受基態的動能。

老師： 有沒有同學願意分享波耳角動量量子化的假設是什麼？

學生： $L = rmv = n\frac{h}{2\pi}$

老師： 很棒，那我們給大家一些時間，嘗試看看利用這個方程式要怎麼列出與動能相關的式子，等一下請同學上臺分享。

學生： $L = rmv = n\frac{h}{2\pi} \Rightarrow v = n\frac{h}{2\pi mr} \propto n$

電子的動能 $K = \frac{1}{2}mv^2 \propto v^2 \propto n^2$

老師： 很好，原子中電子的角動量 L 為約化普朗克常數 $\hbar$（$\hbar = \frac{h}{2\pi}$）的整數倍，我們可以藉此整理出速度 v 與 n（能階）的關聯，因為速度 v 與動能有關聯，也能得知他們之間的關係式。所以如果電子在基態（n=1）時的動能為 ε，由上述的式子我們可以知道第一受基態（n=2）的時候動能為何？

學生： 4ε。

老師： 非常好，所以我們該選哪一個選項呢？

學生： (B)。

3-3 物質波與波粒二象性
The Wave-Particle Duality of Matter Waves

■ 前言 Introduction

本節主要介紹德布羅意所提出的物質波，又稱為德布羅意波。是指物質可能展現波動的特性。其物質波之波長(λ)與其動量(p)成反比:$\lambda = h/p$，其中 h 為普朗克常數。物質具有 “波動-粒子”二象性，即物質可能在不同現象中，有時展現出粒子特性，但有時卻是波動特性，動量越小，波動性越明顯。

教師在此章節要留意，片語中的 to 並非不定詞而是介系詞，請學生特別留意在 to 之後的詞性變化。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
matter wave	物質波	wave	波
particle	粒子	electron	電子
neutron	中子	duality	二象性
monatomic molecule	單原子	characteristic	特性
standing wave	駐波	ideal gas	理想氣體
wave-particle duality	波粒二象性	silicon crystal	矽晶體
complement	互補	wave function	波函數
principle of complementarity	互補原理		

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

❶ _____ as well.

例句：Electromagnetic waves can be seen as waves or particles **as well**.
電磁波可以被視為波，或是粒子。

❷ owing to/ due to _____

例句：**Owing to** the interference and diffraction phenomena, light is seen as a kind of waves.
光由於具有干涉、繞射現象而被視成是一種「波」。

❸ the 比較級 S+V, the 比較級 S+V

例句：**The less** momentum of a particle has, **the longer** the wavelength of this matter wave is.
若粒子動量愈小，物質波波長就愈長。

❹ be correspondent to _____

例句：Each moving particle **is correspondent to** a specific wavelength, similar to the relationship between a photon and its light wave.
運動的粒子都可對應一特定波長，就像光子跟光波一樣。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解波粒二象性。

Understand wave-particle duality.

❧ 例題講解 ☙

例題一

說明：Understand the formulas of wavelength of photons and that of matter waves.

了解光子波長與物質波波長的不同推導公式。

If an alpha particle and a neutron each possess kinetic energy of E, which is equivalent to the energy of a photon. Considering the matter waves of alpha particle and neutron alongside the electromagnetic wave of the photon, with the masses of the alpha particle and neutron being 4m and m respectively, and c representing the speed of light, what is the ratio of their wavelengths:

$\lambda_{\alpha\ particle} : \lambda_{neutron} : \lambda_{photon}$

(A) $\frac{1}{\sqrt{8m}} : \frac{1}{\sqrt{2m}} : \frac{1}{\sqrt{E/c^2}}$　(B) $\frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{2m}} : \frac{1}{\sqrt{E/c^2}}$　(C) $\frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{m}} : \frac{1}{\sqrt{E/c}}$

(D) $\frac{1}{\sqrt{16m}} : \frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{E/c^2}}$　(E) $\frac{1}{\sqrt{16m}} : \frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{E/c}}$

若有一個 α 粒子與某一個中子的動能均為 E，此動能也與某一個光子的能量相等。考慮此 α 粒子與此中子的物質波及此光子的光波，設 α 粒子與中子的質量分別為 4m 與 m，c 為光速，則此三者的波長之比 $\lambda_{\alpha粒子} : \lambda_{中子} : \lambda_{光子}$ 為下列何者？

(A) $\frac{1}{\sqrt{8m}} : \frac{1}{\sqrt{2m}} : \frac{1}{\sqrt{E/c^2}}$　(B) $\frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{2m}} : \frac{1}{\sqrt{E/c^2}}$　(C) $\frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{m}} : \frac{1}{\sqrt{E/c}}$

(D) $\frac{1}{\sqrt{16m}} : \frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{E/c^2}}$　(E) $\frac{1}{\sqrt{16m}} : \frac{1}{\sqrt{4m}} : \frac{1}{\sqrt{E/c}}$

（104 年指考 19）

Teacher: Is there anyone willing to share the formula for the wavelength of particle matter waves and the wavelength of photons?

Student: *The wavelength of a photon* $=\frac{hc}{E}$.

The wavelength of particle matter waves $=\frac{h}{p}=\frac{h}{\sqrt{2mK}}$

Teacher: Great, since a photon has no mass, the formula of the photon's wavelength is different from that of the matter wave. Based on the clues given in the question, let's give everyone some time to calculate. Later, I'll ask a student to come up and share.

Student: $\lambda_{\alpha\ particle}:\lambda_{neutron}:\lambda_{photon}=\frac{h}{\sqrt{2\times4m\times E}}:\frac{h}{\sqrt{2\times m\times E}}:\frac{hc}{E}=\frac{1}{\sqrt{8m}}:\frac{1}{\sqrt{2m}}:\frac{1}{\sqrt{E/c^2}}$

Teacher: Fantastic, so which option should we choose

Student: (A).

老師： 有沒有同學願意分享，物質波的波長與光子波長的公式，各是什麼呢？

學生： 光子的波長$=\frac{hc}{E}$

粒子物質波的波長$=\frac{h}{p}=\frac{h}{\sqrt{2mK}}$

老師： 很好，因為光子沒有質量，所以光子的波長公式與物質波不同。根據題目給的線索，我們給大家一些時間嘗試計算看看，等一下請同學上臺分享。

學生： $\lambda_{\alpha粒子}:\lambda_{中子}:\lambda_{光子}=\frac{h}{\sqrt{2\times4m\times E}}:\frac{h}{\sqrt{2\times m\times E}}:\frac{hc}{E}=\frac{1}{\sqrt{8m}}:\frac{1}{\sqrt{2m}}:\frac{1}{\sqrt{E/c^2}}$

老師： 很棒，所以我們該選哪一個選項呢？

學生： (A)。

例題二

說明：了解與分析波-粒二象性。

Understand and analyze wave-particle duality.

Scientists often use X-ray diffraction to determine crystal structures. If the wavelength λ of X-rays is replaced by an electron beam of the same crystal and produces the same diffraction pattern, what is the energy of the electron? (where h h is the Planck constant and m is the electron mass)

(A) $\frac{h^2}{2m^2\lambda^2}$ (B) $\frac{h}{2m\lambda}$ (C) $\frac{h^2}{m\lambda}$ (D) $\frac{h^2}{m\lambda^2}$ **(E)** $\boldsymbol{\frac{h^2}{2m\lambda^2}}$

科學家常用 X-射線繞射來測知晶體結構，若將波長為 λ 的 X-射線改用電子束取代，並進行相同晶體的繞射實驗，以測得相同的繞射圖樣，則電子的能量為何？（h 為普朗克常數，m 為電子質量）

(A) $\frac{h^2}{2m^2\lambda^2}$ (B) $\frac{h}{2m\lambda}$ (C) $\frac{h^2}{m\lambda}$ (D) $\frac{h^2}{m\lambda^2}$ **(E)** $\boldsymbol{\frac{h^2}{2m\lambda^2}}$

（110 年指考 11）

Teacher: Because the diffraction pattern matches that of electrons, we can infer that the energy of this crystal will be the same as that of electrons. Is there anyone willing to share what the wavelength of an electron's matter wave is?

Student: $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

Teacher: Great, where mv of the formula is the momentum of the electron. That means the wavelength of the matter wave is inversely proportional to its momentum. Therefore, from the above equation, can we find the energy K of the electron?

Student: $K = \frac{h^2}{2m\lambda^2}$

Teacher: Fantastic, so which option should we choose?

Student: (E).

老師：因為題目中的晶體繞射圖樣與電子相同，所以我們可以知道此晶體的能量會與電子相同，有沒有同學願意分享電子的波長是什麼呢？

學生：$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

老師：很好，式子中的 mv 代表電子的動量，也就是物質波的波長與其動量成反比。所以由上述式子，我們可以推導出電子的能量 K 為何呢？

學生：$K = \frac{h^2}{2m\lambda^2}$

老師：很棒，所以我們該選哪一個選項呢？

學生：(E)。

3-4 原子核的組成
The Constitution of Atom Nucleus

■ 前言 Introduction

本節主要介紹原子核的構造與作用力，還有其組成的基本粒子，以及不同元素及同位素的特性。

英文部分，教師可以圖片方式輔佐學生能連結英文單字的意義，加強學生對單字的記憶。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
mass number	質量數	atomic number	原子序
nucleon	核子	proton	質子
neutron	中子	electron	電子
symbol	符號	isotope	同位素
nuclear force	核力	repulsion	斥力

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

❶ _____ be represented with _____

例句：The atomic number **is represented with** letter “Z”.

原子序以字母“Z”來表示。

❷ by _____ times

例句：Because the strong force (nuclear force) is stronger than Coulomb force **by** approximately 100 **times**, it could easily hold the positive charged nucleons tightly.
由於強力（核力）比庫倫力高出約 100 倍，因此能夠輕鬆地將帶正電的核子緊密結合在一起。

❸ _____ be short/long ranged _____

例句：Since nuclear forces **are short ranged**, and the Coulomb force **is long ranged**, an excess of neutrons keeps the protons a little farther apart, reducing its Coulomb repulsion.
由於核力的作用範圍較短，而庫倫力的作用範圍較長，多出的中子使質子之間的距離稍微增加，減少了庫倫斥力。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解原子核的組成與結構。

Understand the constitution and structure of atomic nucleus.

❧ 例題講解 ☙

例題一

說明：了解原子核的組成及結構。

Understand the constitution and structure of the nucleus.

What are the correct statements regarding the atomic structure?

A: The mass of an atom is uniformly distributed throughout the entire atom.

B: The majority of an atom's mass is concentrated in the atomic nucleus.

C: The numbers of electrons and protons are always equal.

D: The numbers of protons and neutrons are always equal.

(A) A, C　(B) A, D　**(C) B, C**　(D) B, D

下列有關原子構造的敘述，何者正確？
甲：原子的質量均勻分布於整個原子之中。
乙：原子的質量絕大部分集中在原子核。
丙：電子和質子的數目一定相等。
丁：質子和中子的數目一定相等。
(A)甲丙　(B)甲丁　**(C)乙丙**　(D)乙丁

（84 年學測自然 58）

Teacher: Let's go through each statement. First, statements A and B. Which one is correct?
Student: The majority of an atom's mass is concentrated in the atomic nucleus, rather than being uniformly distributed throughout the entire atom. So, statement B is correct, and A is incorrect.
Teacher: Very good. Since the mass of the electrons is much lighter than those of the protons and neutrons. Next is statement C. Is statement C correct?
Student: It's correct because it's an atom, so it's electrically neutral; the numbers of protons and electrons must be equal.
Teacher: Great. Lastly, statement D. Is statement D correct?
Student: It's incorrect; the numbers of protons and neutrons may not be equal.
Teacher: Excellent. So, which option should we choose?
Student: (C).
Teacher: Exactly! Let me explain further: if two materials have the same number of protons but different neutron numbers, they are called isotopes.

老師：我們一起來看看每一個敘述。首先是甲和乙，請問哪一個敘述正確，原子的質量如何分佈呢？
學生：原子的質量絕大部分集中在原子核，而非均勻分布於整個原子之中，所以乙正確，甲不正確。
老師：很好，因為外圍的電子質量，遠小於原子核內的質子與中子。接著是丙敘述，請問丙敘述正確嗎？
學生：正確，因為是原子，所以為電中性，質子和電子的數目一定相等。
老師：很棒，最後是丁敘述，請問丁敘述正確嗎？
學生：不正確，質子與中子數不一定相等。
老師：非常好，所以我們該選哪一個選項呢？

學生： (C)。
老師： 正確，再補充一下，如果兩物質具有相同質子數，但中子數不同，我們稱為這兩者為同位素。

例題二

說明：了解同位素概念。

Understand the concept of isotope.

The following are the numbers of protons (p) and neutrons (n) in the nuclei of atomic elements A, B, C, D, and E. Which pair represents isotopes?

A：6p，6n

B：7p，7n

C：8p，8n

D：6p，7n

E：9p，10n

(A) A, D　(B) B, D　(C) B, C　(D) C, E

下列為元素甲、乙、丙、丁、戊的原子核中所含的質子數(p)與中子數(n)，試問那兩者是同位素？

甲：6p，6n

乙：7p，7n

丙：8p，8n

丁：6p，7n

戊：9p，10n

(A) 甲丁　(B) 乙丁　(C) 乙丙　(D) 丙戊

（修改自 87 年學測自然 64）

Teacher: Is there anyone willing to share the characteristics of isotopes?
Student: They have the same number of protons but different numbers of neutrons.
Teacher: Great. Now, can anyone determine which two of these five atoms are isotopes?
Student: A and D.
Teacher: Excellent. So, which option should we choose?

Student: (A).

Teacher: The chemistry characteristics between two isotopes are the same, but different in their nucleus features.

老師： 有沒有同學願意分享，同位素的特色是什麼呢？

學生： 質子數相等，中子數不相等。

老師： 很好，現在請大家判斷一下，這五個原子中，哪兩個原子為同位素呢？

學生： 甲丁。

老師： 很棒，所以我們該選哪個選項呢？

學生： (A)

老師： 同位素彼此之間，具有相同的化學性質，但原子核特性不同。

3-5 原子核衰變
Nuclear Decay

■ 前言 Introduction

當原子核內的質子越多時，彼此的庫倫排斥力也會越大，造成原子核較不穩定，這些不穩定原子藉由釋放 α 粒子、β 粒子、γ 粒子轉變為原子核，本節主要介紹核衰變、質量數守恆與原子序守恆概念。

教師在引導學生說出英文句型.... until, 若時間有餘裕則可再多補充 until 的相關用法，例如: It's not…until./ Not until…(倒裝)

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
nuclear decay	核衰變	radioactivity	放射性
parent nucleus	母核	daughter nucleus	子核
alpha decay	α 衰變	interaction	交互作用
deflect	偏折	beta decay	β 衰變
antineutrino	反微中子	gamma decay	γ 衰變
nuclear fission	核分裂	nuclear fusion	核融合

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

❶ _____ proposed that S+V

例句：After discovering the existence of atomic nucleus, Rutherford **proposed that** decay is caused by nucleus.

拉塞福在發現原子核後，提出了衰變的成因來自於原子核的概念。

❷ with _____

例句：Atoms **with** high energy and unstable nuclei would form radioactive elements.

具高能量、且呈現不穩定的原子核，會形成放射性元素。

❸ _____ until _____

例句：An unstable atomic nucleus would undergo a series of decay **until** it become stable

不穩定的原子核將經歷一系列的衰變，直到變得穩定。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解原子核的衰變及放射性。

Understanding nuclear decay and radioactivity.

∞ 例題講解 ∞

例題一

說明：了解核分裂反應的種類與性質。

Understanding the category and characteristics of nuclear fission reactions.

The Fukushima nuclear power plant disaster, triggered by a severe earthquake and tsunami, highlighted the crucial role of nuclear power generation and its safety in modern life. The $92^{235}U$ nucleus undergoes nuclear fission upon absorbing thermal neutrons, converting the lost mass after fission into energy that can be used for generating electricity. Which of the following statements about basic nuclear energy knowledge is correct?

(A) The order of penetrating depth through substances for γ-rays, α, and β particles produced by nuclear decay is γ > β > α.

(B) After absorbing thermal neutrons, the $92^{235}U$ nucleus releases only one neutron per nuclear fission.

(C) Fragments resulting from the fission of $92^{235}U$ nuclei no longer exhibit radioactivity.

(D) The energy of solar radiation primarily comes from nuclear fission reactions.

(E) $92^{235}U$ accounts for approximately 99% of natural uranium elements.

日本福島核電廠因大地震及海嘯而產生核災變，突顯核能發電與其安全使用在現代生活上的重要性 $92^{235}U$ 原子核吸收熱中子後產生核分裂，分裂後減損的質量轉換成能量而可用來發電。下列有關核能基本知識的相關敘述，何者正確？

(A) 核衰變產生的 γ 射線、與 β 粒子，穿透物質能力的順序為 γ > β > α。

(B) $92^{235}U$ 原子核吸收熱中子後，每次核分裂後僅可釋出 1 個中子。

(C) $92^{235}U$ 原子核分裂後的碎片不再具有放射性。

(D) 太陽輻射的能量主要來自核分裂反應。

(E) $92^{235}U$ 約占天然鈾元素中的 99%。

（100 年指考 16）

Teacher: Let's go through each option. First, option (A), is there anything that needs to be modified?

Student: No, option (A) is correct.

Teacher: Great, let's move on to option (B). Is there anything that needs to be modified?

Student: 92235U fission can release 2 to 3 neutrons.
Teacher: Excellent. Now, regarding option (C), is there anything that needs to be modified?
Student: The fragments resulting from the fission of 92235U nuclei still exhibit radioactivity.
Teacher: Very good. Now, onto option (D). Is there anything that needs to be modified?
Student: The energy of solar radiation primarily comes from "nuclear fusion" reactions.
Teacher: Excellent. Lastly, for option (E), is there anything that needs to be modified?
Student: 92235U accounts for approximately 0.7% of natural uranium elements.
Teacher: Great, so which option should we choose?
Student: (A).

老師： 我們一起來看每一個選項。首先是(A)選項，請問有什麼地方需要修改嗎？
學生： 沒有，(A)選項正確。
老師： 很好，再來看(B) 選項，請問有什麼地方需要修改嗎？
學生： 92235U 分裂可釋出 2~3 個中子。
老師： 很棒，再來看(C) 選項，請問有什麼地方需要修改嗎？
學生： 92235U 原子核分裂後的碎片仍具有放射性。
老師： 非常好，再來看(D) 選項，請問有什麼地方需要修改嗎？
學生： 太陽輻射的能量主要來自「核融合」反應。
老師： 非常棒，最後來看(E) 選項，請問有什麼地方需要修改嗎？
學生： 92235U 約占天然鈾元素中的 0.7%。
老師： 很好，所以我們應該選哪一個選項呢？
學生： (A)。

例題二

說明：能應用原子序守恆與質量數守恆。

Apply conservation of atomic number and conservation of mass number.

The transformation of $^{238}_{92}U$ into $^{206}_{82}Pb$ is one of the natural radioactive decay series. In this series, how many α decays and how many β decays occur in total? ($\alpha = {}^{4}_{2}He; \beta^-$ refers to an electron)

(A) 8 α，6 β^-　(B) 8 α，8 β^-　(C) 10 α，8 β^-　(D) 10 α，10 β^-

從 $^{238}_{92}U$ 衰變為 $^{206}_{82}Pb$ 是天然放射性衰變系列之一，此系列總共經過幾個 α 衰變，幾個 β 衰變？($\alpha = {}^{4}_{2}He; \beta^-$ 即電子)

(A) 8 α，6 β^-　(B) 8 α，8 β^-　(C) 10 α，8 β^-　(D) 10 α，10 β^-

（87 年學測 12）

Teacher: From the given information, we can write the decay reaction equation as:

$^{238}_{92}U \longrightarrow {}^{206}_{82}Pb + x\ {}^{4}_{2}\alpha + y\ {}^{0}_{-1}\beta$

Let's give everyone some time to try and solve for x and y. Later, I'll ask a student to come up and share.

Student: From the reaction equation, we can set up the following simultaneous equations:

$238 = 206 + 4x$

$92 = 82 + 2x - y$

Solving these equations, we find:

$x = 8\ ,\ y = 6$

Teacher: Great! The two equations we listed were based on the conservation of atomic number as well as that of mass number. So, which option should we choose?

Student: (A)

老師： 由題意我們可以寫出衰變反應方程式為：$^{238}_{92}U \longrightarrow {}^{206}_{82}Pb + x\ {}^{4}_{2}\alpha + y\ {}^{0}_{-1}\beta$

我們給大家一些時間嘗試看看將 x 和 y 解出，等一下請同學上臺分享。

學生： 由反應方程式可列出聯立方程式

$238 = 206 + 4x$

$92 = 82 + 2x - y$

解得

$x = 8\ ,\ y = 6$

老師： 很好，我們所列的兩個方程式，是分別根據原子序及質量數守恆而得的。

所以我們該選哪一個選項呢？

學生： (A)。

3-6 交互作用與守恆律
Interactions and the Laws of Conservation

■ 前言 Introduction

物理科學的本源是尋求背後的基本原理，在尋源的同時，常會利用一些數學式來解決問題，有些數學式會依據某種物理量的守恆而得。本節主要介紹動量守恆、角動量守恆、電荷守恆、質能守恆等四大守恆定律及其適用的條件。

在英文裡，需要教師多補充 neither…nor 的用法，學生容易將其視為雙主詞，但是在判斷動詞是否為單數型時是依據靠近動詞的主詞作為依據，而不是直接視為複數的主詞。另外，與之相似的句型包含: either…or… / both… and …, 教師可視情況做補充。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Conservation Laws	守恆律	Conservation of Momentum	動量守恆律
Conservation of Angular Momentum	角動量守恆	Conservation of Charge	電荷守恆
Conservation of Mass-Energy	質能守恆	mass-energy	質量能量
neutrino	微中子		

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

❶ ____ be subjected to _____

例句：When a system **is** not **subjected to** external forces, the total momentum of the system remains constant.

當系統不受外力作用時，則系統的總動量保持不變。

❷ ____ be proportional to _____

例句：The angular momentum of a planet **is proportional to** the change rate of the area swept by the planet to the sun.

行星繞行的角動量，正比於行星對太陽所掃出面積的時變率。

❸ ____ remain+ adj.

例句：In an isolated system, the total electric charge **remains unchanged**.

在孤立系統裡，總電荷量不會改變。

❹ neither ___ nor ___

例句：In an isolated system, energy can **neither** be created **nor** extinct, but only converted from one form to another.

在孤立系統裡，能量既不能被創造也不能被消滅，只能從一種形式轉換為另一種形式。

❺ be converted _____ to _____

例句：After the combustion and explosion of gunpowder, chemical energy can **be converted into** the kinetic energy, potential energy, thermal energy, light energy, sound energy, and so on, of the fragments.

火藥燃燒爆炸後，化學能可轉換為碎片的動能、位能、熱能、光能、聲能等。

■ 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：

At the end of learning the chapter, students are able to acquire the following concept:

一、了解交互作用與四種守恆律的關係。

Understand the relationship between interactions and the four conservation laws.

❧ 例題講解 ☙

例題一

說明：能應用質能守恆定律。

Apply the law of mass-energy conservation.

In a nuclear reactor, continuous nuclear reactions result in a reduction of 1 gram of mass from the nuclear fuel. Assuming all the reduced mass converts into electrical energy, how many kilowatt-hours (kWh) of electrical energy can be generated? (Given the speed of light c=3×10^8 m/s, 1 kWh = 1 kilowatt-hour)

(A) 8.3×10^4 **(B) $\mathbf{2.5 \times 10^7}$** (C) 2.5×10^{10}

(D) 9×10^{13} (E) 9×10^{16}

核能電廠的核反應器內由於不斷的進行核反應，結果核燃料減少了 1 公克的質量。假設減少的質量全部轉換成電能，則可產生多少度的電能？(已知光速 c=3×10^8 公尺/秒，1 度電能=1 瓩-小時)

(A) 8.3×10^4 **(B) $\mathbf{2.5 \times 10^7}$** (C) 2.5×10^{10}

(D) 9×10^{13} (E) 9×10^{16}

（89 年學測自然 48）

Teacher: In this problem, which quantity is transformed to which in the nuclear reaction? .

Student: From the reduction of mass to determine the gain of electric energy.

Teacher: Great! Then, what is the formula to link mass and energy?

Student: $E=mc^2$

Teacher: Very good! It is the famous formula proposed by Einstein regarding mass-energy conservation. Let's give everyone some time to calculate and then share their answers

Student: $E = mc^2 = 0.001 \times (3 \times 10^8)^2 = 9 \times 10^{13}(\ J\ )$

As 1 *kWh* equals $3.6 \times 10^6\ (\ J\ )$

So, $\frac{9\times10^{13}}{3.6\times10^6} = 2.5 \times 10^7$ *kWh* of electricity can be generated.

Teacher: Very well. So, which option should we choose?

Student: (B).

老師： 這一題，是要討論核反應過程，由甚麼物理量轉換為甚麼呢？

學生： 由質量的減少，推算出增加的電能。

老師： 很好，那麼質量與能量間的轉換，有哪個公式呢？

學生： $E=mc^2$

老師： 沒錯，就是愛因斯坦所提出的質能守恆公式。我們給大家一些時間嘗試計算看看，等一下請同學上臺分享。

學生： $E = mc^2 = 0.001 \times (3 \times 10^8)^2 = 9 \times 10^{13}(\ J\ )$

因為 1 度電能為 $3.6 \times 10^6\ (\ J\ )$

所以可產生 $\frac{9\times10^{13}}{3.6\times10^6} = 2.5 \times 10^7$ 度電。

老師： 非常好，所以我們該選哪一個選項呢？

學生： (B)。

例題二

說明：應用動量守恆與原子的衰變。

Apply conservation of momentum and atomic decay.

If a stationary atomic nucleus $212\ Bi$ undergoes an α decay, which of the following statements regarding this decay are correct?

(A) The total momentum of the system is conserved before and after the decay.

(B) The total mechanical energy of the system is conserved before and after the decay.

(C) The ratio of the velocities of the emitted α particle to the resultant nucleus after decay is approximately 1.

(D) The ratio of the velocities of the emitted α particle to the resultant nucleus after decay is approximately 52.

(E) The ratio of the velocities of the emitted α particle to the resultant nucleus after decay is approximately 105.

若一靜止的原子核 $212\ Bi$ 發生一次 α 衰變，則下列有關此次衰變的敘述，哪些正確？

(A) 衰變前後，系統總動量守恆。

(B) 衰變前後，系統總力學能守恆

(C) 衰變後所射出之 α 粒子與衰變後原子核的速率比值約為 1。

(D) 衰變後所射出之 α 粒子與衰變後原子核的速率 比值約為 52。

(E) 衰變後所射出之 α 粒子與衰變後原子核的速率比值約為 105。

（104 年指考 24）

Teacher: Let's go through each option. First, for option (A), what condition is required for the law of conservation of momentum to hold?

Student: The system must not be subjected to external forces for momentum to be conserved.

Teacher: Great, this is based on Newton's 2nd Law: $\vec{F} = \frac{\Delta \vec{p}}{\Delta t}$ and Newton's 3rd Law.

Was there any external force acting before or after the decay?

Student: No, there wasn't.

Teacher: So, is the option (A) correct?

Student: Yes, it is.

Teacher: Excellent. Now, looking at option (B), was there a change in kinetic energy before and after the decay?

Student: Yes, there was. After decay, both particles went from being at rest to having velocity, so the system's kinetic energy increased.

Teacher: Very good. Now, did the total mechanical energy change?

Student: Yes, because the system's kinetic energy increased, the total mechanical energy changed.

Teacher: Right! Since the kinetic energy increased and the potential energy remained unchanged, the mechanical energy changed.

Student: So option (B) is incorrect.

Teacher: Now, for options (C), (D), and (E), I'll give everyone some time to use the law of conservation of momentum to calculate the velocity ratio before and after the decay. Let's have a student share their calculation results.

Student: Using the principle of conservation of momentum, assuming the α particle has a mass of 4m: $0 = 4mv_{\alpha}^{\rightarrow} + 208m \times v^{\rightarrow} \Rightarrow \frac{|v^{\rightarrow}|}{v_{\alpha}^{\rightarrow}} = \frac{208m}{4m} = 52$

Teacher: So, which options should we choose?

Student: (A) and (D).

老師： 我們一起來看每一個選項，首先是(A)選項，請問動量守恆定律成立的條件為何？

學生： 系統不受外力作用，則動量守恆。

老師： 很好，這是根據牛頓第二運動定律：$\vec{F} = \frac{\Delta \vec{p}}{\Delta t}$ 以及牛頓第三定律。請問衰變前後有受到外力嗎？

學生： 沒有。

老師： 所以(A)選項正確嗎？

學生： 正確。

老師： 很棒，再來看(B)選項，請問衰變前後，動能有改變嗎？

學生： 有，衰變後的兩個粒子從靜止變成有速度，所以系統動能增加。

老師： 非常好，那麼總力學能有改變嗎？

學生： 有，因為系統動能增加，所以總力學能會改變。

老師： 非常棒，因動能增加，且沒有涉及位能變化，所以總力學能沒有守恆。

學生： 所以(B)選項不正確。

老師：　再來看(C)(D)(E)選項，給大家一些時間，利用動量守恆定律計算看看衰變前後的速率比，我們等一下請同學上臺分享。

學生：　利用動量守恆定理，設〈粒子質量為 4m，則

$$0 = 4m\vec{v_\alpha} + 208m \times \vec{v} \Longrightarrow \frac{|\vec{v}|}{\vec{v_\alpha}} = \frac{208m}{4m} = 52$$

老師：　非常好，所以我們該選哪些選項呢？

學生：　(A)(D)。

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/	

自然領域雙語教學資源手冊：物理科英語授課用語

[高中選修(V)]

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

[Elective Physics (V)]

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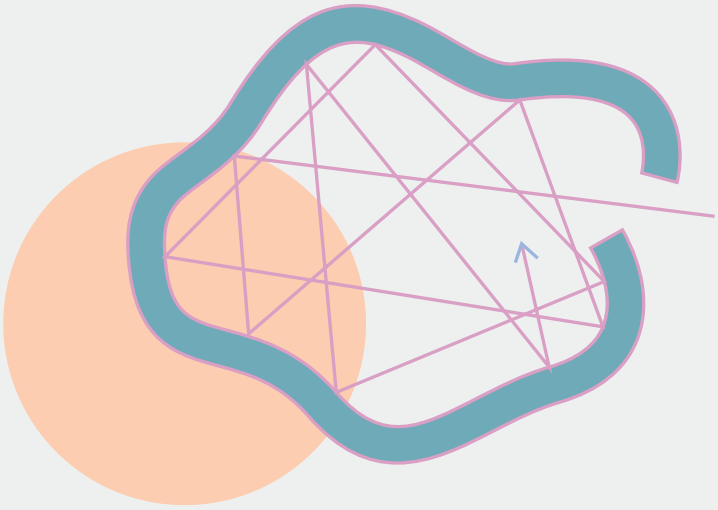

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