高中自然領域

雙語教學資源手冊 地球科學科英語授課用語

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

〔高中一年級〕

國立彰化師範大學雙語教學研究中心 發行

目次 Table of Contents

★主題一 地球的歷史★ 1

1-1 地球的起源 2

1-2 大氣與海洋的演變 6

1-3 探索地球的歷史 12

★主題二 固體地球的結構與組成★ 20

2-1 震波與地球內部分層 21

2-2 地表與地殼的變動 27

2-3 地震災害 34

★主題三 大氣★ 40

3-1 大氣的溫壓垂直結構 42

3-2 大氣的水氣變化 47

3-3 大氣的運動 52

3-4 天氣圖判讀 56

3-5 氣象災害-颱風 60

★主題四 海洋★ 65

4-1 海洋的結構 66

4-2 海洋的運動 70

4-3 大氣與海洋的交互作用 76

★主題五 地球與太空★ 80

5-1 從太空看地球 81

5-2 從地球看太空 87

5-3 宇宙 95

★主題六 氣候變遷★ 103

6-1 多重時間尺度的氣候變遷 104

6-2 氣候變遷造成的環境影響 109

6-3 人類活動與近期氣候變化 114

6-4 因應氣候變遷 117

★主題七 永續發展與資源利用★ 122

7-1 永續發展 123

7-2 節用資源與合理開發 128

★主題一　地球的歷史★
The History of Earth

彰化縣田中高中地球科學科　胡祖寧老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

地球起源、地球環境的發展、地球中生命的演變，當我們回顧整段地球的歷史，究竟何者為源頭，何者為一切的開端？再回溯於更古老的宇宙形成，宇宙從何而來？組成萬物的粒子、元素又從何而來？當真正回顧地球、太陽系更甚宇宙之故事時才會驚覺，原來人類只是這漫漫長河中渺小如沙的塵埃。

1-1 地球的起源
The Origin of Earth

■ 前言 Introduction

宇宙起源之學說以「大霹靂理論」為基礎，當大霹靂產生空間、時間後，元素、塵埃也逐漸開始作用，因重力聚集的雲氣不斷增加其質量，當中心溫度到達一定後便開始產生氫的核融合反應，形成初代恆星。

太陽系則是屬於較晚形成的恆星系統，中心的雲氣到達一定溫度後形成我們抬頭所見之太陽，而圍繞在恆星周遭的吸積盤也因太陽風的作用，依序由內而外形成密度較大的類地形星與密度較小的類木行星。

語言方面，學生可習得事件發生順序先後的說法，將宇宙形成期間重要事件以英語描述並排列。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
molecular cloud	分子雲	(fixed) star	恆星
big bang	大霹靂	hydrogen atom	氫原子
solar wind	太陽風	accretion disk	吸積盤
solar system	太陽系	galaxy	星系
Jovian planet	類木行星	planet	行星
terrestrial planet	類地行星	gravity	重力
nuclear fusion	核融合	universe	宇宙

helium atom	氦原子	element	元素

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

❶ The theory of _____ is currently based on _____.

例句：**The theory of** the formation of the universe **is currently based on** the Big Bang Theory; while the theory of the formation of the solar system is currently based on the solar nebula theory.

宇宙形成的學說目前以大霹靂學說為模型；太陽系形成的學說目前以太陽星雲說為模型。

❷ The first step of _____ is _____, the second step of _____ is _____, and the third step of _____ is _____.

例句：**The first step** in the formation **of** the solar system **is** the accumulation of clouds and gas under the influence of gravity**, the second step is** the nuclear fusion reaction after the central temperature rises**, and the third step is** the gradual formation of terrestrial planets and Jovian planets from the surrounding accretion disk material.

太陽系形成之第一步為雲氣受重力影響聚集、第二步為中心溫度升高後產生核融合反應、第三步為周遭吸積盤物質逐漸形成類地與類木行星。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

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

一、理解宇宙演化的先後順序與恆星形成所需之條件。

Understand the sequence of evolution of the universe and the conditions required for star formation.

例題講解

例題一

說明：學生能夠理解宇宙演化的過程並依序排列。

Students are able to understand the process and sequence of the evolution of the universe.

（英文）Situation A, B, and C belong to different stages in the evolution of the universe:

A. Most particles in the universe are electrons and protons, which have not yet been combined into atoms.

B. Helium atoms began to appear in the universe.

C. Stellars begin to form.

Which of the following is correct in chronological order?

(A) ABC　(B) BAC　(C) CBA　(D) CAB　(E) ACB

（中文）下列甲、乙、丙描述的狀況，屬於宇宙演化過程中的不同階段：

甲、宇宙中大部分粒子為電子與質子，尚未結合成原子

乙、宇宙中開始出現氦原子

丙、恆星開始形成

依時間先後順序排列，下列何者正確？

(A)甲乙丙　(B)乙甲丙　(C)丙乙甲　(D)丙甲乙　(E)甲丙乙

（110 年學測第 12 題）

Teacher: So the first two kinds of atoms the universe formed were...?

Student: Hydrogen and helium atoms!

Teacher: That's right! After that, the elements in the periodic table of elements are gradually produced by the interaction of hydrogen atoms and helium atoms!

Teacher: Thinking further, should the solar system be a relatively old star system or a young star system?

Student: Hmm…How do we tell?

Teacher: If we are talking about an old star system, it should only contain hydrogen and helium, right? In other words, if it is a younger star system, there should be other elements produced by the interaction of hydrogen and helium!

Student: I see! Because the solar system contains many other elements, the solar system should be a relatively young star system.

Teacher: That's right!

老師： 所以宇宙最一開始形成的兩種原子分別是...？

學生： 氫原子和氦原子！

老師： 沒錯！之後週期元素表中的元素都是由氫原子與氦原子作用後逐漸產生的！

老師： 更進一步思考，太陽系應該是相對年老的恆星系統還是年輕的恆星系統？

學生： 恩...要怎麼判斷呢？

老師： 如果今天是年老的恆星系統，當中應該只會包含氫與氦元素對吧！換句話說，如果今天是較年輕的恆星系統，才有可能包含氫氦作用後產生的其他元素！

學生： 我知道了！因為太陽系當中包含著許多其他元素，所以太系應為相對年輕的恆星系統。

老師： 沒錯！

1-2 大氣與海洋的演變
Evolution of the Atmosphere and Oceans

■ 前言 Introduction

46 億年前地球剛形成時，其主要氣體為太陽星雲殘存之氣體：氫氣與氦氣，但因氫氣與氦氣較輕，引力無法留住而使其逸散。

而當地球逐漸冷卻，地表火山開始產生釋氣作用，火山噴發之氣體最主要為水氣、二氧化碳與氮氣，水氣因地表逐漸降溫而冷卻降水，形成海洋，二氧化碳則是和海洋中的離子作用形成碳酸鹽類礦物，原本占比第三的氮氣因水氣、二氧化碳皆消失而形成目前大氣最主要之氣體。

約於 35 億年前，海洋出現地球的最初生命-藍綠菌，藍綠菌進行光合作用形成氧氣，氧氣與海洋中的鐵離子作用形成帶狀鐵礦床，當海洋中之鐵離子被氧氣耗盡後，氧氣才正式進入大氣層，形成目前大氣組成的第二多氣體，並使生物離開海洋，登入陸地。

語言方面，學生可習得如何以英文表達地質排列與海洋形成事件的順序，學生能將不同密度之材質進行比較，並以英文分析事件發生之前因後果。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
core	地核	helium gas	氦氣
banded iron formation (BIF)	帶狀鐵礦床	fossil	化石
crust	地殼	volcanic action	火山作用
mantle	地函	hydrogen gas	氫氣

stromatolite	疊層石	ozone	臭氧
carbonate minerals	碳酸鹽類礦物	aqueous vapor	水氣
iron ion	鐵離子	ultraviolet ray	紫外線
cyanobacteria	藍菌	carbon dioxide	二氧化碳
photosynthesis	光合作用	oxygen	氧氣

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

❶ The main gases in _____ are _____.

例句：**The main gases in** the most primitive atmospheric composition of the earth **are** hydrogen and helium; the main gases in the current atmospheric composition of the earth are nitrogen and oxygen.

地球最原始的大氣組成，主要氣體為氫氣與氦氣；地球目前的大氣組成，主要氣體為氮氣與氧氣。

❷ _____ interacts with _____ to form _____.

例句：Oxygen **in**teracts with iron ions in the ocean **to form** the banded iron formation.

氧氣與海洋中的鐵離子作用後形成帶狀鐵礦床。

❸ _____ is/are _____ according to _____.

例句：The internal structure of the earth **is** the core, the mantle, and the crust **according to** the density from the inside to the outside.

地球內部結構由內而外依據密度大小分為地核、地函、地殼。

■ 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：

一、理解地球內部的分層結構與密度大小。

Understand the layered structure and density of the earth's interior.

二、了解地球歷史中大氣組成成分的變化。

Understand changes in the composition of the atmosphere over Earth's history.

❧ 例題講解 ☙

例題一

（英文）In the early stage of the formation of the earth, the substances consisted were redistributed by density because of the high temperature of melting, and finally, the earth had a layered structure. In these different layers, there are unique rocks, such as granite, basalt, peridotite, etc. In addition, iron meteorites are often found on the surface, and their main component is iron-nickel alloy. Which of the followings are correct when comparing the densities of these three rocks with that of an iron meteorite? (Choose two answers.)

(A) granite>iron meteorite>peridotite

(B) basalt>granite>peridotite

(C) peridotite>basalt>granite

(D) basalt>granite>iron meteorite

(E) iron meteorite>peridotite>granite

（中文）地球在形成初期，組成物質曾因經歷高溫熔融過程而依密度重新分布，最終使地球具有分層結構。在這些不同分層結構中有其特有的岩石，例如花岡岩、玄武岩、橄欖岩……等。此外在地表上也常發現鐵隕石，其主要成份為鐵鎳合金。下列有關這三種岩石與鐵隕石的密度比較，哪些正確？（應選 2 項）

(A)花岡岩＞鐵隕石＞橄欖岩

(B)玄武岩＞花岡岩＞橄欖岩

(C)橄欖岩＞玄武岩＞花岡岩

(D)玄武岩＞橄欖岩＞鐵隕石

(E)鐵隕石＞橄欖岩＞花岡岩　（107 年學測第 67 題）

Teacher: In the early days of the earth's formation, the earth's interior was re-layered due to the effect of gravity. What is the structure of the earth's interior from outside to inside?
Student: Crust, mantle, and core!
Teacher: Is the outer crust denser or the inner core denser?
Student: The inner core.
Teacher: What is the main component of the earth's core?
Student: Liquid or solid metal.
Teacher: What is the main component of the mantle?
Student: Peridotite.
Teacher: What is the main component of the earth's crust?
Student: The lower oceanic crust is mainly basalt; the upper continental crust is mainly granitee.

老師： 在地球形成初期，因受到重力作用使地球內部重新分層，地球內部由外而內依序是？
學生： 地殼、地函、地核！
老師： 是外層的地殼密度大還是內層的地核密度大呢？
學生： 內層的地核。
老師： 那地核主要的組成成分是？
學生： 液態或是固態的金屬。
老師： 地函的主要組成成分呢？
學生： 橄欖岩。
老師： 地殼的主要組成成分呢？
學生： 較下層的海洋地殼是以玄武岩質為主；較上層的大陸地殼是以花岡岩質為主。

例題二

（英文）During the formation of the earth, there was a period of time when it was in a molten state, and then it gradually cooled down and evolved into the initial earth. Which of the following events as described in the options resulted from the gradual cooling of the Earth from the initial molten state as it was about 4 billion years ago? (Choose 3 items)

(A) Formation of oceans.

(B) Emergence of trilobites.

(C) Formation of the atmosphere.

(D) Formation of large amounts of oxygen in the atmosphere.

(E) Layering of the earth's interior core, mantle, and crust.

（中文）地球形成的過程中曾經有一段時期處於熔融的狀態，之後逐漸冷卻下來演變成初始地球。下列哪些選項的事件是在約四十億年前，地球由形成初始時期的熔融狀態逐漸冷卻而產生的結果？（應選 3 項）

(A)海洋的形成。

(B)三葉蟲的出現。

(C)大氣層的形成。

(D)大氣層中大量氧氣的形成。

(E)地球內部地核、地函及地殼的分層。

（101 年學測第 32 題）

Teacher: The answers to this question are A, C, and E. However, the timelines shown in option B and option D are miscinceotions that people often have! Did option B and option D appear at the same time?

Student: It should be... around the same time, right?

Teacher: It is usually reasoned that because trilobites can produce oxygen through photosynthesis, oxygen should begin to accumulate in the atmosphere, right?

Student: Right.

Teacher: But, did trilobites live on land or in the sea?

Student: In the sea....so the oxygen they produced would first interact with the iron ions in the ocean!

Teacher: That's right. After the iron ions in the ocean had finished interacting with oxygen, the oxygen would slowly escape into the atmosphere from the ocean, and the oxygen would gradually accumulate in the atmosphere!

Student: So, it should be after the appearance of trilobites that oxygen began to accumulate in the atmosphere after a period of time!

老師： 雖然這題的答案為 A、C、E，但 B 與 D 兩個選項的時間線也是大家時常產生的迷思概念喔！請問同學 B、D 是同時出現的嗎？

學生： 應該...在差不多的時候吧？

老師： 大家試著思考，三葉蟲會行光合作用製造氧氣，所以大氣應該也要開始累積氧氣，對嗎？

學生： 對。

老師： 但是，三葉蟲的生長環境是在陸地還是海洋呢？

學生： 海洋....所以他們製造出的氧氣會先跟海洋中的鐵離子作用！

老師： 沒錯，等海洋中的鐵離子與氧氣作用完後，氧氣才會慢慢從海洋進到大氣中，大氣層才會逐漸累積氧氣喔！

學生： 所以應該是三葉蟲出現後，隔了一段時間大氣才開始累積氧氣的！

1-3 探索地球的歷史
Exploring the History of Earth

■ 前言 Introduction

地質學之父赫登曾說：「現在是通往未來的鑰匙」，透過觀察現今岩層，可以推知過去岩層曾經發生的事件或是形成的先後順序，相對定年法與絕對定年法即為探索地球歷史時常使用的兩種方式。

相對定年法主要是使用於未經翻轉的岩層，可以透過原始水平定律、疊置定律、截切定律等方式了解岩層形成的先後順序。絕對定年法則是更準確的利用放射性元素衰變的時間，嘗試求出岩層形成的確切時間。

而現今地質年代表則是使用生物大量出現或是滅絕所區分，時間尺度由大至小分別為元、代、紀、世，不同的地質年代擁有不同的指標化石，例如古生代是以三葉蟲為標準化石，中生代是以菊石、恐龍為標準化石。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Relative dating	相對定年	isotope	同位素
the principle of inclusions	包裹體定律	law of faunal succession	化石層序定律
half life	半衰期	the principle of crosscutting relationship	裁切定律
xenolith	捕獲岩	absolute dating	絕對定年
radiometric dating	放射性定年法	facies fossil	指相化石

Geochron	地質年代	index fossil	指準化石(標準化石)
principle of superposition	疊置定律	principle of original horizontality	原始水平定律

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

❶ The formation of _____ can be known through _____.

例句：**The** sequence of **formation of** the rock strata **can be known through** the relative dating method; **the** exact time of **formation of** the rock strata **can be known through** the absolute dating method.

透過相對定年法可以知道岩層形成的先後順序；透過絕對定年法可以知道岩層形成的確切時間。

❷ After _____, _____ will decay into _____.

例句：**After** one half-life, half of the number of original elements **will decay into** daughter elements; after two half-lives, another half of the number of the rest parent elements will decay into child elements.

經過一個半衰期，母元素數量的一半會衰變為子元素；經過兩個半衰期，剩下的母元素數量的一半又會衰變為子元素。

❸ The index fossils of the _____ are _____.

例句：In the geological time scale, **the index fossils of** the Paleozoic Era **are** trilobites, the indexindex fossils of the Mesozoic Era are dinosaurs, and the indexindex fossils of the Cenozoic Era are mammoths.

地質年代表中的古生代其指準化石為三葉蟲、中生代其指準化石為恐龍、新生代其指準化石為長毛象。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

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

一、可以使用相對定年法判斷岩層形成的先後順序。

The relative dating method can be used to determine the sequence of formation of rock strata.

二、對於絕對定年法與其使用方式有一定的理解並了解其限制。

Have an understanding of the absolute dating method, how to use it as well as its limitations.

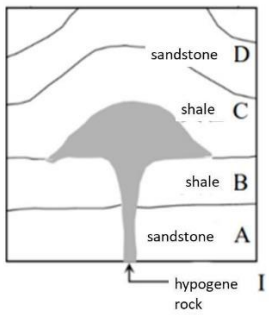
三、可以統整相對定年法之不同定年方式。

Different relative dating methods can be integrated.

❧ 例題講解 ☙

例題一

（英文）Scientists have drawn a stratigraphic profile of a certain area after various geological explorations. Assuming that this outcrop has not experienced stratigraphic reversal, which of the following statements are correct? (Choose two answers.)



Picture 18

(A) The formation sequence of the rock layers may be A–B–I–C–D.

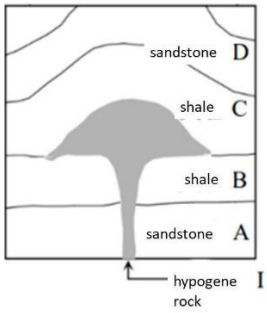
(B) The formation sequence of the rock layers may be A–B–C–D–I.

(C) The igneous rock is shaped like a volcano, A and B formed first, and volcanoes I and C formed at the same time.

(D) According to the principle of crosscutting relationship, I formed earlier than A, B, and C.

(E) There is no fossil and dating data, and the exact age of the rock formation cannot be determined.

（中文）科學家透過各種地質探勘後，繪製出某地區的地層示意圖，假設此露頭不曾經過地層倒轉，則下列敘述哪些正確？（應選 2 項）



Picture 18

(A) 岩層的生成順序可能是 A–B–I–C–D。

(B) 岩層的生成順序可能為 A–B–C–D–I。

(C) 該火成岩形似火山，A、B 先生成，火山 I 和 C 同時形成。

(D) 根據截切定律，I 比 A、B 和 C 早生成。

(E) 缺乏化石和定年資料，無法判斷岩層的確切年代。

（109 年學測第 66 題）

Teacher: The question asks whether we should use the relative dating method or the absolute dating method to judge the formation sequence of rock strata?

Student: Relative dating method!

Teacher: That's right! Therefore, the description specifically emphasizes that “this outcrop has not undergone stratigraphic reversal”. When using the relative dating method, the first thing is to determine whether the stratum has been reversed.

Teacher: How to determine the formation sequence of A, B, C, D and plutonic rock I?

Student: Using the principle of superposition, we can tell that A is formed first, followed by B.

Teacher: Therefore, most of you are wondering whether I is formed first, and then superimposed by C and , or whether C and D are formed first before I is formed.

Student: Right!

Teacher: Considering if I was formed prior to C, how would the C layer be deposited?
Student: Hmm…Was the C stratum deposited in a horizontal manner?
Teacher: Great! The C rock layer must be deposited in a horizontal manner to comply with the principle of original horizontality!

老師： 題目是希望大家使用相對定年法還是絕對定年法判斷岩層形成先後順序？
學生： 相對定年法！
老師： 沒錯！所以題目敘述有特別強調「此露頭不曾經過地層倒轉」，使用相對定年法時，首要條件便是確定地層是否經過翻轉。
老師： 那題目中如何判斷 A、B、C、D 與深成岩 I 的形成先後順序呢？
學生： 利用疊置定律可以判斷 A 先形成後，B 才形成。
老師： 所以大部分同學產生疑惑的地方應該是 I 先形成，C、D 才疊加上去，還是 C、D 先形成，I 才形成。
學生： 對！
老師： 大家可以思考一下，如果是 I 先形成才形成 C 岩層，C 岩層會以什麼方式沉積呢？
學生： 恩...C 岩層應該會以水平方式沉積上去嗎？
老師： 很好！C 岩層要以水平方式沉積才符合原始水平定律喔！

例題二

（英文）Which are correct about the carbon-14 dating in the following statements? (Choose two answers.)

(A) Carbon-14 dating is an absolute dating method.

(B) Carbon-14 is radioactive.

(C) The half-life of carbon-14 is about 5730 years. This dating method is suitable for exploring geological events on a time scale of more than 100,000 years.

(D) The amount proportion of the parent element decreases linearly with time in carbon-14 dating.

(E) Carbon-14 and carbon-12 are isotopes, and the nucleus of carbon-14 consists of 8 protons and 6 neutrons.

（中文）有關碳-14 定年的敘述，下列哪些正確？（應選 2 項）

(A) 碳-14 定年法為絕對地質年代定年法。

(B) 碳-14 具放射性。

(C) 碳-14 之半衰期約為 5730 年，此定年方式適用於時間尺度十萬年以上事件之探討。

(D) 碳-14 定年中，母元素含量的比例隨時間呈線性衰減。

(E) 碳-14 和碳-12 是同位素，碳-14 的原子核由 8 個質子和 6 個中子組成。

（111 年學測第 44 題）

Teacher: Carbon-14 dating is a method of absolute dating. Can the absolute dating determine the sequence of formation of rock layers or the exact age of rock layers?

Student: The exact age of rock layers.

Teacher: Yes, but the absolute dating method also has its limitations. Do you still remember the limitations of the absolute dating method?

Student: It can be used only in rock strata with radioactive material!

Teacher: Good! Anything else?

Student: No more than ten half-lives can be set!

Teacher: Right! Because after ten half-lives, the decayed amount the parent element would be too small, and it would be difficult for the instrument to perform accurate dating. Therefore, usually we do not perform dating if it has undergoneten half-lives!

Teacher: Therefore, we will also use different radioactive elements for dating the rock strata in different geological time periods. Taking carbon-14 as an example, we will not use it to date strata that are more than 57,300 years old.

老師： 碳-14 定年法是一種絕對定年的方式，絕對定年代表可以判斷岩層形成先後順序還是岩層的確切年齡？

學生： 岩層的確切年齡！

老師： 對，但絕對定年法也有其限制存在，大家還記得絕對定年法的限制嗎？

學生： 只能用在當中有放射性物質的岩層中！

老師： 非常好！還有嗎？

學生： 不能定超過十個半衰期！

老師： 對！因為超過十個半衰期後，母元素的衰變量太小，儀器難以進行準確的定年，所以通常我們不會進行超過十個半衰期的定年！

老師：　所以其實面對不同時間長度的岩層，我們也會使用不同的放射型元素進行定年，以碳-14 為例，我們就不會用來定年超過 57300 年以上的地層。

例題三

（英文）This is a zoomed-in image of Figure 12, in which (a) small craters, (b) corrugated sand dunes, and (c) deltas can be seen. What is the formation order of this landform from old to new?

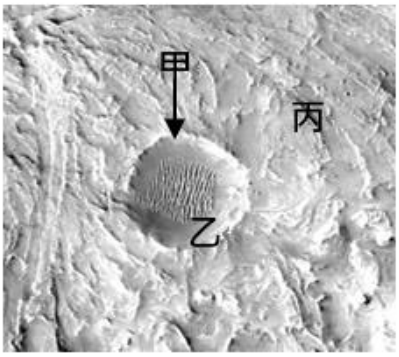


圖 13

(A) abc　(B) bca　(C) cba　**(D) cab**　(E) bac

（中文）下圖為某地局部放大影像，當中可見（甲）小隕石坑、（乙）波紋狀的風成沙 丘、（丙）三角洲。此地貌由老到新的形成順序為何？

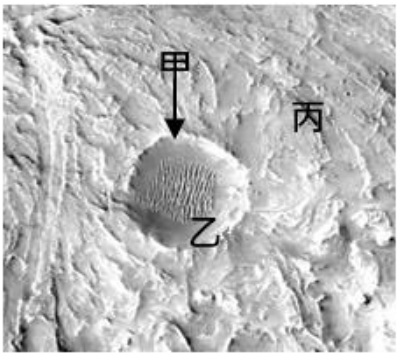


圖 13

(A)甲-乙-丙　(B)乙-丙-甲　(C)丙-乙-甲　**(D)丙-甲-乙**　(E)乙-甲-丙

（111 年學測第 29 題）

Teacher: What law of relative dating do you use to determine the sequence of formation of A, B, and C?

Student: The principle of crosscutting relationship!

Student: Right! The principle of crosscutting relationship means that the geological phenomenon that occurs later will affect the geological phenomenon that occurred earlier, so it can be seen from the figure that the aeolian dunes appear on the small crater, and the small crater appears on the delta. Therefore, we can tell the three in order!

Teacher: Do you think this is similar to the theory mentioned at the beginning of the chapter about geological age?

Student: Is it Hutton's Uniformitarianism?

Teacher: That's right. The main idea of Uniformitarianism is that by observing the current rock strata, we can know the geological events that happened in the past formations.

Student: So by observing the geological phenomena of this place, we can also speculate whether this place was once hit by a small meteorite, can't we?

Teacher: Very good! Everyone has gradually understood the concept of Uniformitarianism!

老師： 大家是利用相對定年法的什麼定律判斷甲、乙、丙的先後形成順序？

學生： 截切定律！

老師： 對！截切定律指的是後發生的地質現象會影響先發生的地質現象，所以從圖中可以看出風成沙丘出現在小隕石坑上面，小隕石坑又出現在三角洲上面，以此判斷三者的先後順序！

老師： 有沒有覺得這跟我們進入地質年代這一個章節開頭所提到的理論很像呢？

學生： 赫登的均變說嗎？

老師： 沒錯，均變說的核心思想指的就是觀察現今的岩層可以知曉過去地層曾經發生的地質事件。

學生： 所以透過觀察這個地方的地質現象，我們也可以推測此地曾經被小隕石撞擊嗎？

老師： 很好！大家逐漸了解均變說的概念了！

★主題二 固體地球的結構與組成★
Structure and Composition of Solid Earth

彰化縣田中高中地球科學科　胡祖寧老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

當 50-46 億年前間地球慢慢冷卻，地球內部逐漸產生分層並趨於穩定，看似堅硬的固體地球，其實仍不斷的變化與運動。在此章節中主要介紹我們如何利用直接探測外的方式了解地球內部、板塊運動的發展演變以及板塊邊界的種類，再者，當我們回頭思索所居住的臺灣，為何臺灣地震頻頻、地震對臺灣造成那些災害，又為何不能在地震前更早發出預警減少災害呢？

2-1 震波與地球內部分層
Seismic Waves and Stratification of Earth's Interior

■ 前言 Introduction

過去人們想知道地球內部結構時，最直接的方式便是鑽井，但受高溫高壓影響，並無法輕易地鑽過地球表面，目前對於地球內部分層的依據，其實是來源於地震波的波速快慢，透過地震波經過地球內部的層圈，將地球內部由外至內分層為地殼、地函與地核。

語言方面，學生能以英文理解地殼相關事實敘述，嘗試敘述地震等板塊移動現象之影響因素。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
primary wave	P 波	elastic rebound theory	彈性回跳理論
secondary wave	S 波	body wave	體波
plate	板塊	Lehmann discontinuity	雷嫚不連續面
surface wave	表面波	Rayleigh wave	雷利波
surface of discontinuity	不連續面	love wave	洛夫波
wave speed	波速	olivinefels	橄欖岩
Moho discontinuity	莫荷面/莫氏不連續面	Gutenberg discontinuity	古氏不連續面
continental crust	大陸地殼	oceanic crust	海洋地殼

crust	地殼	granite	花崗岩
core	地核	medium	介質
mantle	地函	basalt	玄武岩
earthquake	地震	asthenosphere	軟流圈
earthquake wave	地震波	lithosphere	岩石圈

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

❶ The _____ is the ____ between _____ and _____.

例句：**The** Moho discontinuity **is the** interface **between** the crust **and** the mantle; while Gutenberg discontinuity **is the** discontinuity **between** the mantle **and** the core.
莫氏不連續面為地殼與地函的交界面；古氏不連續面為地函與地核的不連續面。

❷ _____ can be transmitted in _____ states.

例句：P waves **can be transmitted in** solid and liquid **states** in the interior of the earth; S waves **can** only **be transmitted in** solid **states** in the interior of the earth.
P 波在地球內部可傳遞於固態與液態；S 波在地球內部僅可傳遞於固態。

❸ The main component of _____ is _____.

例句：**The main components of** the crust **are** granite and basalt; **the main component of** the mantle **is** peridotite.
地殼主要組成岩石為花岡岩與玄武岩；地函主要組成岩石為橄欖岩。

❹ The _____ contains part of the upper/lower _____.

例句：**The** lithosphere **contains** the crust and **part of the upper** mantle.
岩石圈包含著地殼與一部分的上部地函。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

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

一、了解震度與距離之關係並且分析題目意涵。

Understand the relationship between earthquake intensity and distance. Also, students should be able to analyze the content of questions.

❧ 例題講解 ☙

例題一

（英文）One day, A, B, C, and D chatted together on a social network at their respective homes, and it was known that the homes of the four were scattered (not in order) in Taipei, Taichung, Kaohsiung, and Los Angeles, USA. A suddenly felt a strong earthquake (intensity 6), 10 seconds later B also felt a weak earthquake (intensity 3), and 7 seconds later C felt a moderate earthquake (intensity 4), and D felt a moderate earthquake 18 seconds later A felt the strong earthquake (intensity 4). It is known that the speed of seismic waves is about 4 to 6 kilometers per second, and the earthquakes felt by the above four people belong to two different earthquakes. Which of the following inferences about where the four people live is most likely to be correct? (Choose two answers.)

(The intensity scale in this question has been replaced by Taiwan's earthquake intensity scale for the convenience of comparison)

(A) A lives in Kaohsiung.

(B) B lives in Los Angeles.

(C) C lives in Los Angeles.

(D) D lives in Taichung.

(E) A lives in Taichung.

（中文）某日，甲、乙、丙、丁四人在各自家中上社群網站一起聊天，且知四人的家分散在（未按順序）臺北、臺中、高雄、與美國洛杉磯。甲突然感覺到有烈震（震度 6 級），10 秒後乙也感覺到弱震（震度 3 級），又過了 7 秒丙感覺到中震（震度 4 級），丁則在甲感到烈震之後 18 秒才覺得有中震（震度 4 級）。今已知地震波傳播的速率約為每秒鐘 4 至 6 公里，而且上述四人所感覺到的地震分屬兩個不同的地震，則下列四人住處的推論哪些最為可能？（應選 2 項）（此題中的震度級距，為方便比較均已換為臺灣震度表示形式）

(A)甲住高雄。

(B)乙住洛杉磯。

(C)丙住洛杉磯。

(D)丁住臺中。

(E)甲住臺中。

（107 年學測第 68 題）

Teacher: Why do the four people in the question feel different earthquake intensity?

Student: Because they are not at the same distance from the epicenter!

Teacher: That's right! Therefore, the earthquake intensity will vary due to the distance. When the same earthquake occurs, people in different places would feel earthquake intensity differently.

Student: Then would the smaller the intensity be when the farther the distance is?

Teacher: Good question! In fact, there are many factors that affect the earthquake intensity, such as distance, rock formation composition, and whether the stratum is compact, etc. that will all affect the level of earthquake intensity!

Student: I get it! Then, is the seismic wave mentioned in the question a body wave or a surface wave?

Teacher: Because the question mentions that the speed of seismic waves is 4-6 kilometers per second, it should refer to physical waves, that is, P waves and S waves!

老師： 為什麼在題目中的四人感受到的震度都不一樣呢？

學生： 因為他們距離震央的遠近都不一樣！

老師： 沒錯！所以地震的震度會因為距離的遠近產生差異，同一個地震發生時可能在不同地方會感受到不一樣的震度。

學生： 那距離越遠，震度一定越小嗎？

老師： 好問題！其實影響震度的原因有很多：距離、岩層組成、地層是否緊密等都會影響著震度的大小喔！

學生：我了解了！
老師，那題目中所說的地震波應該是實體波還是表面波呢？
老師：因為題目提到地震波的傳播速率是每秒鐘 4-6 公里，所以應該指的是實體波，也就是 P 波和 S 波！

例題二

（英文）In the solid structure of the earth, the outermost crust can be divided into continental crust and oceanic crust. Which of the following statements about the continental crust and oceanic crust are correct? (Choose 2 answers)

(A) In general, continental crust is thicker than oceanic crust.

(B) The continental crust is less dense than the oceanic crust.

(C) The continental crust is mainly composed of silicon-magnesian rocks, while the oceanic crust is mainly composed of silicon-aluminous rocks.

(D) The oldest oceanic crust found so far is 4 billion years old.

(E) The oceanic crust consists mainly of sedimentary rock layers.

（中文）地球的固體結構中，最外部的地殼可區分為大陸地殼與海洋地殼。下列有關大陸地殼與海洋地殼的敘述，哪些正確？（應選 2 項）

(A)一般而言，大陸地殼的厚度較海洋地殼為厚。

(B)大陸地殼的密度較海洋地殼小。

(C)大陸地殼主要為矽鎂質岩石，而海洋地殼則以矽鋁質為主。

(D)目前發現最老的海洋地殼為 40 億年。

(E)海洋地殼主要為沉積岩層。

（106 年學測第 34 題）

Teacher: Can anyone tell me the components of continental crust and oceanic crust?
Student: Continental crust is mainly composed of granitic rock, and oceanic crust is mainly composed of basalt!
Teacher: Then let's think deeper. Does the crust represent the plate?
Student: No, it doesn't… .
Teacher: Right! The plate refers to the broken lithosphere, and the lithosphere actually includes the crust and part of the upper mantle!

Student: I get it! So is the asthenosphere that has been mentioned in class located under the lithosphere?

Teacher: That's right! And you should keep the depths of the lithosphere, plates, and crust well in mind!

老師： 大家知道大陸地殼與海洋地殼分別的組成物質嗎？

學生： 大陸地殼主要由花岡岩質組成，海洋地殼主要由玄武岩質組成！

老師： 那再更進階的問，地殼等於板塊嗎？

學生： 應該...不等於吧

老師： 對！板塊指的是破裂的岩石圈，而岩石圈其實包含地殼和一部分的上部地函喔！

學生： 我了解了！所以岩石圈底下就是老師說過的軟流圈嗎？

老師： 沒錯！岩石圈、板塊、地殼所代表的範圍要記清楚喔！

2-2 地表與地殼的變動
Movements in the Earth's Surface and Crust

■ 前言 Introduction

在地球歷史中，我們腳踩的板塊也不停的分合，從大陸漂移學說所提出的盤古大陸，至海底擴張學說發現中洋脊為海底擴張的中心，在到近年所提出的板塊構造學說，板塊構造學說利用地震波的特性發現造成板塊分合的動力來源：軟流圈與地函熱對流。而我們身處的臺灣，因受到菲律賓海板塊與歐亞板塊擠壓聚合，更是造就島上豐富的地質景觀！語言方面，學生能藉由判讀圖表，解讀火山相關位置，以英文表示其相對地理關係。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Benioff zone	班尼奧夫帶	trench	海溝
theory of plate tectonics	板塊構造學說	Curie temperature	居禮溫度
fractures zone	破裂帶	convergent plate boundary	聚合型板塊邊界
Pangaea	盤古大陸	divergent plate boundary	張裂型板塊邊界
Philippine Sea Plate	菲律賓海板塊	transform fault	轉型斷層
suture zone	縫合帶	mid-ocean ridge	中洋脊
continental drift	大陸飄移	scratch	擦痕

island arc	島弧	transform plate boundary	錯動型板塊邊界
seafloor spreading theory	海底擴張說	Eurasian Plate	歐亞板塊

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

❶ **_____ is a hypothesis, so a lot of evidence is needed to prove its authenticity. For example, _____.**

例句：Continental drift is a hypothesis, so a lot of evidence is **needed to prove its authenticity. For example,** the coastlines of South America and Africa match with each other.

大陸漂移說是一個學說，所以需要有許多佐證佐證其真實性，例如南美洲與非洲的海岸線接近吻合。

❷ **Centering outward from _____, the further away from the _____ the crust is, the ____ it is**

例句：**Centering outward from** the mid-ocean ridge, **the further away from the** mid-ocean ridge **the crust is**, **the** older **it is**. **Centering outward from** the mid-ocean ridge, **the further away from** the mid-ocean ridge **the crust is**, **the** more sediments **it is** on top of the crust.

以中洋脊為中心向外，越遠離中洋脊之地殼年齡越老；以中洋脊為中心向外，越遠離中洋脊之地殼上方沉積物越多。

❸ **The _____ boundary is formed when the plates are under _____, and the common fault type is _____ fault.**

例句：**The** convergent plate **boundary is formed when plates are under** pressure, **and the common fault type is** the reverse **fault**; **the** divergent plate **boundary is formed when the plates are under** tension, **and the common fault type is** a normal **fault**.

聚合型板塊邊界為板塊受到壓力作用而造成，會產生斷層，常見之斷層種類為逆斷層；張裂型板塊邊界為板塊受到張力作用而造成，常見之斷層種類為正斷層。

❹ **_____ was formed by the extrusion of _____ plate and _____ plate.**

例句：Taiwan **was formed by the extrusion of** the Philippine Sea pla**te and** the Eurasian **plate.**

臺灣是由菲律賓海板塊與歐亞板塊擠壓型成。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

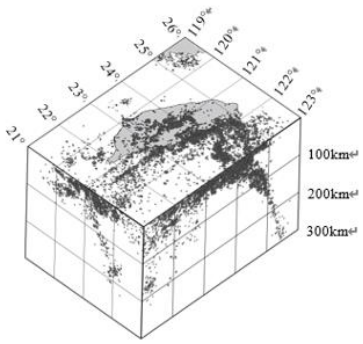
一、了解臺灣之板塊結構與版塊邊界類型。

Understand the plate tectonics in Taiwan and types of plate boundary.

例題講解

例題一

（英文）The picture below shows the distribution of earthquakes with a magnitude greater than 4.0 that occurred around Taiwan from 1991 to 2012. From this picture, we can infer Taiwan's plate tectonics. Which of the following statements about Taiwan's plate tectonics is correct?



(A) The Eurasian plate and the Philippine Sea plate only slide past each other.

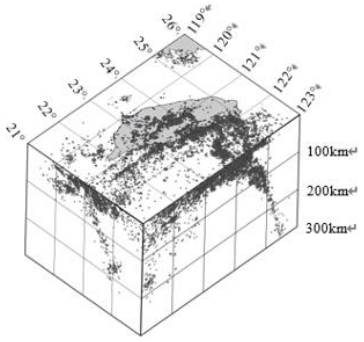
(B) Off the northeast coast of Taiwan, the Philippine Sea plate thrusts northward above the Eurasian plate.

(C) Off the northeast coast of Taiwan, the Eurasian plate subducts southward under the Philippine Sea plate.

(D) In the southern part of Taiwan, the Eurasian plate thrusts eastward over the Philippine Sea plate.

(E) In the southern part of Taiwan, the Eurasian plate subducts eastward under the Philippine Sea plate.

（中文）下圖是 1991 年至 2012 年間發生在臺灣周遭規模大於 4.0 的震源分布圖，從此圖可推測臺灣的板塊構造，下列有關臺灣板塊構造的敘述哪一項正確？



(A)歐亞板塊和菲律賓海板塊僅相互錯動。

(B)在臺灣東北部外海，菲律賓海板塊向北逆衝到歐亞板塊上方 。

(C)在臺灣東北部外海，歐亞板塊向南隱沒到菲律賓海板塊下方。

(D)在臺灣南半部，歐亞板塊向東逆衝到菲律賓海板塊上方。

(E)在臺灣南半部，歐亞板塊向東隱沒到菲律賓海板塊下方。

（109 年學測第 21 題）

Teacher: Have you ever wondered why the Philippine Sea plate submerges under the Eurasian plate and also the Eurasian plate subducts under the Philippine Sea plate at the same time in Taiwan?

Student: Hmm...the oceanic crust is relatively dense, so is it reasonable for the Philippine Sea plate to subduct under the Eurasian plate?

Teacher: That's right! But why is the Eurasian plate on the southern side of Taiwan subducted under the Philippine Sea plate?

Student: I don’t know. Why?

Teacher: Because there is actually another plate at the front end of the Eurasian plate, which is called the South China Sea plate. South China Sea plate is an oceanic crust, which is denser than the Philippine Sea plate. So, the South China Sea plate is pulling the Eurasian Plate from behind and subducting downward together!

Student: I see! That's why there are two Benioff zones near Taiwan!

Teacher: Right! This is the reason why there are earthquakes from shallow to deep in Taiwan!

老師： 大家有沒有想過，為什麼臺灣會同時發生菲律賓海板塊隱沒於歐亞板塊底下和歐亞板塊隱沒於菲律賓海板塊底下的情形呢？

學生： 嗯...海洋地殼密度比較大，所以菲律賓海板塊隱沒到歐亞板塊比較合理嗎？

老師： 沒錯！但為什麼在臺灣的南側歐亞板塊卻會隱沒到菲律賓海板塊之下呢？

學生：　我不知道耶，為什麼？

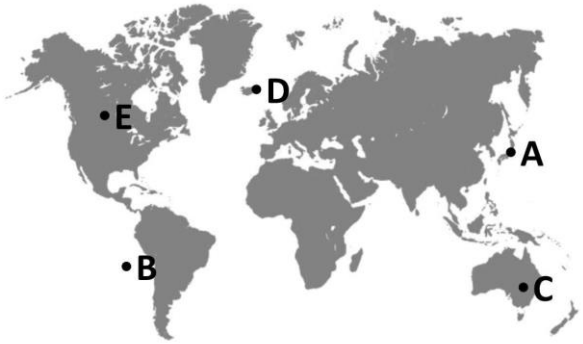
老師：　因為歐亞板塊已經隱沒的前端其實有另一個板塊，叫做南中國海板塊，南中國海板塊的主要組成為海洋地殼，其密度比菲律賓海板塊還要大，所以南中國海板塊就拉著後方的歐亞板塊一起向下隱沒！

學生：　原來如此！所以臺灣附近才會有兩條班尼奧夫帶！

老師：　對！臺灣也是因為有兩條班尼奧夫帶，所以才會淺源到深源地震都有！

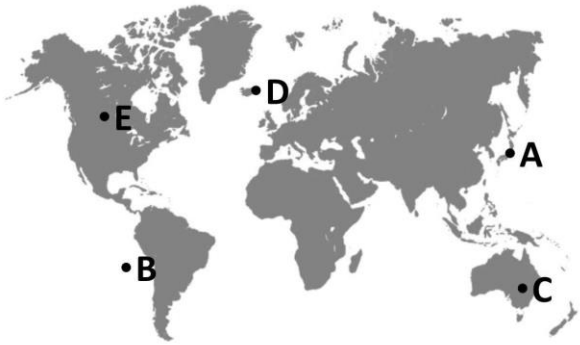
例題二

（英文）Volcanoes are formed by magma from deep underground along with gas and debris eruptung to the surface, mostly related to the movement of plates. In this global map, which locations can we find volcanoes?



(A) ABC　　(B) BCD　　(C) CDE　　**(D) ABD**　　(E) BCE.

（中文）火山由地下深處的岩漿伴隨著氣體、碎屑從地表噴出而形成，多數與板塊的運動有關。圖中何處為現今有火山分布的地區？



(A)甲乙丙　　(B)乙丙丁　　(C)丙丁戊　　**(D)甲乙丁**　　(E)乙丙戊。

（103 年學測第 3 題）

Teacher: The distribution of volcanos is similar to what concept we have learned before?
Student: The volcanic belts almost overlap the tectonic plate boundaries!
Teacher: Yes. Because when the plates converge or are pulled apart, molten magma erupts upward to form volcanoes.
Student: Then are there any volcanoes near Taiwan?
Teacher: The Ryukyu Arc and Luzon Arc near Taiwan are volcanic island arcs!
Student: I know! There are also Ryukyu Trench and Manila Trench near the two arcs!
Teacher: That's right. Trenches and island arcs are formed when continental and oceanic crusts converge resulting in subduction of ocean crust!

老師： 火山分布的地區跟我們之前學的什麼觀念很類似呢？
學生： 火山帶與板塊邊界幾乎重疊！
老師： 對，因為當板塊聚合或張裂時時，融熔的岩漿向上噴發便形成火山。
學生： 那臺灣附近也有火山分布嗎？
老師： 在臺灣附近的琉球島弧和呂宋島弧就屬於火山島弧喔！
學生： 我知道！在兩個島弧的附近也有琉球海溝和馬尼拉海溝！
老師： 沒錯，當大陸地殼和海洋地殼聚合造成海洋地殼隱沒時便會形成海溝和島弧！

2-3 地震災害
Earthquake Disaster

■ 前言 Introduction

臺灣位於環太平洋地震帶（火環帶）上造成地震發生頻頻，且目前地震仍無法預測，我們僅能在地震發生後以 P 波與 S 波的時間差盡速進行地震預警，減少地震災害之影響。土壤液化、海嘯、火災等皆為常見的地震災害，如何在最短的時間進行救災與如何於平日預防減災都為臺灣需思索與精進之議題。

語言方面，學生能以英文理解地震造成之相關災害，並以英文表示斷層彼此之間相對位置。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
earthquake	地震	earthquake magnitude	規模
earthquake early warning	地震預警	tsunami	海嘯
soil liquefaction	土壤液化	earthquake intensity	震度
water table	地下水位		

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

❶ The _____ is mainly based on _____.

例句：**The** earthquake early warning system **is mainly based on** the time lag between the P wave and the S wave.

地震預警系統主要是透過 P 波與 S 波之時間差進行預警。

❷ Earthquake magnitude scale is _____; while the earthquake intensity scale is _____.

例句：**Earthquake magnitude scale is** the energy released by the earthquake; **while the earthquake intensity scale is** how much shaking people feel after the earthquake.

規模為地震所釋放的能量；震度為地震後人們感受到的搖晃程度。

❸ _____, _____, _____, etc. are all possible disasters after an earthquake.

例句：Soil liquefaction, tsunamis, fires**, etc. are all possible disasters after an earthquake.**

土壤液化、海嘯、火災等皆為地震發生後可能產生的災害。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解地震相關之基本概念。

Understand basic concepts related to earthquakes.

二、理解斷層上下盤之觀念與正逆斷層如何分辨與推測。

Understand the concept of normal and reverse faults and how to distinguish them.

三、進行地震預警之原理與計算方式。

The principle of earthquake early warning and how to calculate.

例題講解

例題一

（英文）Earthquakes are mostly caused by fault dislocation. Its energy is transmitted outwards in the form of seismic waves. Seismic waves fault disclocation are all likely to cause disasters. Which of the following statements about earthquakes is correct?

(A) The size of the earthquake is irrelevant to the energy released by fault dislocation.

(B) With the velocities of P-wave and S-wave of the earthquake and difference in the arrival time of the P-wave and S-wave measured by a single station, the hypo-center of the earthquake can be calculated.

(C) The earthquake intensity decreases with farther away from the hypocenter and has nothing to do with the geology of each place.

(D) Earthquakes can induce soil liquefaction, causing buildings to sink and collapse.

(E) The higher the velocity of seismic waves, the bigger the surface shaking.

（中文）地震大多為斷層錯動所造成，其能量以地震波的形式向外傳遞，地震波及斷層錯動都可能造成災害。下列有關地震的敘述，何者正確？

(A)地震規模大小與斷層錯動所釋放的能量無關。

(B)從地震的 P 波和 S 波速率及單一測站測得的 P 波和 S 波到達時間差，即可算出該地震震源的位置。

(C)地震震度隨著距離震源越遠，震度越小，和各地地質無關。

(D)地震可引起土壤液化，造成建築物下陷、倒塌。

(E)地震波的波速越快，造成的地表搖晃越大。

（109 年學測第 23 題）

Teacher: The question mentions that earthquakes may cause soil liquefaction, but will soil liquefaction occur in every earthquake?

Student: No, it won't…?

Teacher: There are three conditions for soil liquefaction to occur: an earthquake with a scale large enough, a high water table, and a soft bedrock!

Student: If the shaking degree of the earthquake is large, the pore space in the soft bedrock will become smaller. Will the water table rise relatively?

Teacher: Right! Soil liquefaction will not occur if the water table in a place is not high enough!

Student: So if the bedrock in a place are very compact, the pore space of the rock material is initially small. It's less likely to cause soil liquefaction, isn't it?

Teacher: Right! It's good to know how to draw inferences from one example!

老師： 題目有提到地震可能會引發土壤液化，但是每一次地震都會發生土壤液化嗎？

學生： 應該不會...？

老師： 土壤液化要產生需要滿足三個條件：夠大的地震、較高的地下水位以及鬆軟的土層！

學生： 如果地震搖晃程度很大，鬆軟岩層的孔隙就會變小，地下水位就會相對上升嗎？

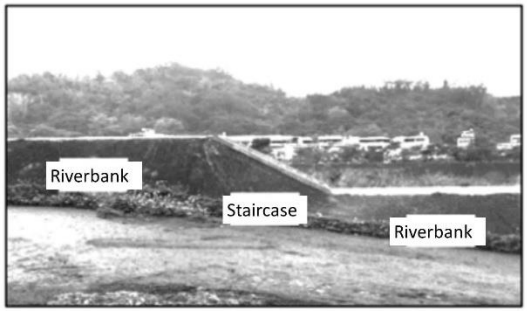
老師： 對！如果一個地方地下水位不夠高也不會發生土壤液化！

學生： 所以如果一個地方岩層十分緊密，原本岩石材質的孔隙就小，也較不容易產生土壤液化嗎？

老師： 對！懂得舉一反三很好！

例題二

（英文）The picture below is the view of the riverbank seen from the viewing window of the "921 Earthquake Education Park" in Wufeng, Taichung. The originally continuous and flat riverbank has been displaced due to the dislocation of the Chelungpu fault. The riverbank at the fault has been repaired, and staircases have been built for walking. According to the geological phenomena resulted from the effect ofplate movements on Taiwan Island, which of the following statements are correct? (Choose 2 answers.)



(A) The Chelungpu fault is a normal fault.

(B) The Chelungpu fault is a reverse fault.

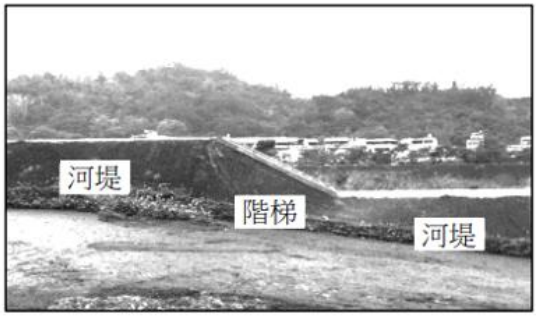
(C) The Chelungpu fault is a normal fault.

(D) The hanging wall is on the right in the photo.

(E) The hanging wall is on the left in the photo.

(F) The hanging wall and footwall cannot be determined in the photo.

（中文）下圖是從臺中霧峰「921 地震教育園區」觀景窗中看出去的河堤景象。原本連續平坦的河堤因車籠埔斷層錯動而產生位移，目前斷裂處的河堤已經修復，而且建造了階梯以供步行。根據臺灣本島受板塊運動作用而成的地質現象，下列敘述哪些正確？（應選 2 項）



(A)車籠埔斷層為正斷層。

(B)車籠埔斷層為逆斷層。

(C)車籠埔斷層為平移斷層。

(D)相片中上盤位置在右側。

(E)相片中上盤位置在左側。

(F)相片中上下盤無法判斷。

（107 年學測第 32 題）

Teacher: Is Taiwan located on a divergent plate boundary or a convergent plate boundary?

Student: It is located on a convergent plate boundary.

Teacher: So is the fault type in Taiwan mainly normal fault or reverse fault?

Student: Reverse fault.

Teacher: The hanging wall of a reverse fault will move relatively upward, and the footwall will move relatively downward, so the riverbank moving upward on the left in the picture should be the hanging wall, and the riverbank moving downward on the right should be the footwall!

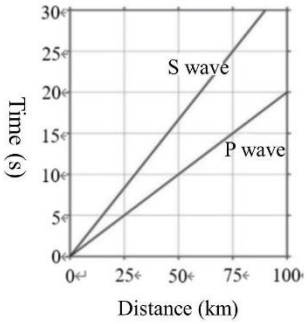
Student: Oh! We were misled by the direction of the stairs!

Teacher: Right! The staircase is man-made and does not represent a fault plane!

老師： 台灣本身位處於張裂型板塊邊界還是聚合型板塊邊界？
學生： 聚合型板塊邊界。
老師： 所以臺灣的斷層類型主要是正斷層還是逆斷層呢？
學生： 逆斷層！
老師： 逆斷層的上盤會相對向上移動，下盤會相對向下移動，所以圖中左邊向上移動的河堤應該是上盤，右邊向下移動的河堤應該是下盤！
學生： 喔! 我們被階梯的方向誤導了！
老師： 對！ 階梯是人為建造的，並不代表斷層面喔！

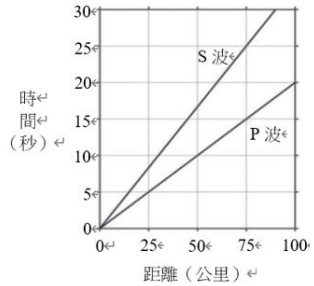
例題三

（英文）Below is the time required for the P wave and S wave to travel from the source to different distances, also known as the seismic wave travel time curve. An earthquake occurred today, and the time difference between the arrival of the P wave and the S wave measured at a certain station is 8 seconds, how many kilometers is the distance between the certain station and the hypocenter?



(A) 40. (B) 50. **(C) 60.** (D) 70. (E) 80.

（中文）下為 P 波與 S 波從震源傳遞到不同距離所需要的時間，又稱地震波走時曲線圖。今有一地震發生，在某測站測得 P 波和 S 波到達的時間差為 8 秒，則某測站距震源約多少公里？



(A) 40。(B) 50。 **(C) 60。** (D) 70。 (E) 80。

（110 年學測第 16 題）

Teacher: According to the chart, which wave travels faster, the P wave or the S wave?

Student: P wave is faster!

Teacher: Therefore, the mechanism of earthquake early warning is to know the occurrence of an earthquake through the P wave that arrives first, and quickly issue a warning to notify people before the arrival of the S wave.

Student: But the time is so short, the warning doesn't seem to help?

Teacher: When human beings face an emergency, there will be a psychological freezing period of about 10 seconds when they cannot make a quick judgment. For the time being, if there is an early warning system to notify us a few seconds earlier, it is actually very helpful!

Student: I see how important an early warning system is!

Teacher: You can also think about what to do if a serious earthquake does occur, which can limit the time for you to shelter yourself.

老師： 透過圖表可以知道 P 波和 S 波誰的波速比較快？

學生： P 波！

老師： 所以地震預警的機制就是透過先抵達的 P 波知道地震發生，趕在 S 波抵達前迅速發布警訊通知大家。

學生： 可是時間這麼短，預警好像沒有什麼幫助？

老師： 人類在面對緊急狀況發生時會有大約心理上 10 秒的凍結時期，無法迅速判斷，這時如果有預警系統為我們爭取到幾秒的時間其實很有幫助喔！

學生： 原來如此！那預警系統真的很重要！

老師： 平日也可以先想好如果大地震真的發生要怎麼辦，這樣也可以加速避難的速度喔。

★主題三 大氣★
Atmosphere

桃園市平鎮高中地球科學科　郭信嘉老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

人類生存於地球，每天呼吸所需的空氣，感受晴天、雨天和陰天等各種天氣現象，對於人類是生存所需，大氣在自然界伴隨著不同的現象與特徵，圍繞在我們的周遭，在此章節中將會初步介紹大氣層的垂直分層及氣壓，大氣中的水氣變化如何影響天氣現象，大氣的運動主要受到那些作用力的影響，新聞中的天氣圖該如何判讀，以及對於臺灣的最大的氣象災害，也就是颱風。

3-1 大氣的溫壓垂直結構
Temperature and Pressure Vertical Profile of the Atmosphere

■ 前言 Introduction

我們要理解大氣的狀況和變化，第一步就是觀察大氣中的物理量，首先大氣的種種物理量中，我們在這個小節首要觀察的是大氣溫度以及大氣壓力，於大氣層中的垂直分布情形，及大氣分層的原理。

語言方面，學生能習得如何以英文表示大氣中各分層之事實描述。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
stratosphere	平流層	mesosphere	中氣層
troposphere	對流層	ozonosphere	臭氧層
air pressure	氣壓	thermosphere	增溫層

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

❶ In the _____, the temperature gradually _____ with _____ altitude.

例句：**In the** troposphere, **the temperature gradually** decreases **with** increasing **altitude**; **in the** stratosphere**, the temperature gradually** increases **with** increasing **altitude**.

在對流層內，隨著高度逐漸增加，溫度會逐漸降低；在平流層內，隨著高度逐漸增加，溫度會逐漸增加。

❷ **The heat source in the _____ comes from _____.**

例句：**The heat source in the** troposphere **comes from** infrared rays radiated from the surface, so the farther away from the surface, the temperature will gradually decrease.
在對流層的熱源，來自地表輻射的紅外線，所以越遠離地表，溫度就會逐漸降低。

❸ **There is _____ in the _____, and weather phenomena such as _____ will occur.**

例句：**There is** obvious atmospheric convection **in the** troposphere**, and weather phenomena such as** clouds, rain, and thunder **will occur.**
對流層有明顯的大氣對流，會發生雲、雨、雷等天氣現象。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解大氣的垂直氣壓變化。

Understanding vertical profile changes in the atmosphere.

二、理解各大氣分層的熱源以及現象。

Understand the heat sources and phenomena of each atmospheric layer.

例題講解

例題一

說明：讓學生分辨各大氣分層的熱源

（英文）According to the vertical profile of atmosphere temperature, in the troposphere, the temperature decreases with increasing altitude, about 6.5°C per kilometer. However, the temperature in the tropopause does not decrease anymore, and it roughly maintains a constant temperature. The temperature of the uppermost layer of the atmosphere increases with altitude. What are the main reasons for the formation of this structure? (Choose two answers.)

(A) Because radio waves in the solar radiation heat the uppermost atmosphere.

(B) Because ultraviolet rays and X-rays in the solar radiation heat the uppermost atmosphere.

(C) The temperature of the tropopause is roughly maintained the same because ozone absorbs ultraviolet rays in solar radiation which increases the temperature.

(D) Because human activities increase carbon dioxide and cause the greenhouse effect, the temperature of the uppermost layer of the atmosphere increases.

(E) Because of the atmospheric convection, the energy near the ground is brought to the tropopause, which makes the temperature of the tropopause increase to maintain the same.

（中文）依據大氣平均溫度垂直變化，溫度隨高度上升而降低，每公里約降 6.5℃。但是在對流層頂的溫度，並不再降低，大致維持一定的溫度。最上層的大氣溫度則隨高度增加而增加。形成這種結構的主要原因為何？(應選二項)

(A) 因為太陽輻射中的無線電波加熱了最上層的大氣。

(B) 因為太陽輻射中的紫外線、X 射線加熱了最上層的大氣。

(C) 因為臭氧吸收太陽輻射中的紫外線，增加了溫度，使對流層頂的溫度大致維持一定。

(D) 因為人類的活動使二氧化碳增加，造成溫室效應，使最上層的大氣溫度增加。

(E) 因為大氣的對流活動，將地面附近的能量帶至對流層頂，使對流層頂的溫度大致維持一定。

（97 年學測第 48 題）

Teacher: Next, I would ask three questions, then I would then ask you to think about the answers.

Teacher: What happens to the atmpspheric temperature in the troposphere as the altitude increases?

Student: The temperature decreases.

Teacher: Where does the heat source come from in the troposphere?

Student: From the sun.

Teacher: Which is closer to the sun, the sky, or the ground?

Student: The sky.

Teacher: To sum up what you have just answered, the first question is that the temperature in the troposphere decreases with the increase of altitude. The second question also referred that the heat source of the troposphere comes from the sun. Therefore, logically it should be that because the “high altitude” zone is closer to the sun, the temperature would be higher. Then why is the ground warmer?

Student: Is the heat source coming from the ground?

Teacher: That’s right! The troposphere is mainly heated by long-wave radiation from the ground.

Teacher: Then which layer is the outermost layer of the atmosphere?

Student: The thermosphere.

Teacher: How does the atmospheric temperature in the thermosphere change with altitude?

Student: It increases.

Teacher: Isn’t it very different from the troposphere?

Student: Yes.

Teacher: The heat source of the thermosphere comes from solar radiation.

Teacher: Regarding the heat sources of the stratosphere and the mesosphere, please go home and review again.

Student: Thank you, teacher.

老師： 接下來老師會進行三個提問，再請各位同學思考答案。
老師： 對流層內的大氣溫度隨著高度增加，溫度會有什麼變化？
學生： 溫度下降。
老師： 對流層內的大氣，熱源是從哪裡來的呢？
學生： 太陽。
老師： 請問高空和地面哪裡比較接近太陽呢？
學生： 高空。
老師： 老師總結一下，剛才同學回答我的答案，第一題對流層內溫度隨高度增加而降溫，第二題又回答說對流層的熱源是來自於太陽，所以照理來說應該是接近太陽的「高空」，溫度較高，那麼為什麼反而地面較高溫呢？
學生： ㄟ，真的欸，難道熱源是來自地面嗎？
老師： 沒錯！對流層的熱源主要是來自於地面的長波輻射。
老師： 那麼最外層的大氣分層是哪一層呢？
學生： 增溫層。
老師： 增溫層的大氣溫度隨高度會有什麼變化呢？
學生： 增加。
老師： 這裡是不是跟對流層很不一樣呢？
學生： 沒錯。
老師： 增溫層的熱源，就是來自於太陽輻射。
老師： 關於平流層和中氣層的熱源，麻煩各位同學回家再次複習。
學生： 謝謝老師。

3-2 大氣的水氣變化
Changing of Vapor in the Atmosphere

■ 前言 Introduction

生活中很常會聽到以下的對話,「今天濕氣好重,感覺東西都濕濕的」、「今天天氣好乾燥,我要多喝水」等,諸如此類的對話,這些與大氣中的水氣變化有關連性,小至生活中感受到大氣濕濕的以及天氣乾燥等,大至午後對流雨以及山上的霧,這些都是與水氣變化有關連性,接著這個小節會介紹原理及現象。

語言方面,學生能藉由判讀氣溫相關圖表,闡述氣溫相關變化之現象。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
ambient temperature	環境溫度	saturation	飽和
saturation vapor pressure	飽和水氣壓	fog	霧
vapor pressure	水氣壓	cloud	雲
relative humidity	相對溼度	latent heat	潛熱
dew-point temperature	露點溫度	adiabatic expansion cooling	絕對膨脹降溫

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

❶ _____ is defined as _____.

例句：Relative humidity **is defined as** the actual water pressure divided by the saturated water pressure.

相對溼度的定義為實際水氣壓除以飽和水氣壓。

❷ _____ is _____ under the condition of _____.

例句：The definition of dew point temperature **is** the temperature when water vapor in the air reaches saturation and condenses into liquid water **under the condition of** fixed air pressure and water vapor volume.

露點溫度的定義為在固定氣壓和水氣量的情況下，空氣中的水氣達到飽和而凝結成液態水所需要降至的溫度。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

一、理解露點溫度和實際水氣壓的關係。

Understand the relationship between dew point temperature and actual water pressure.

二、理解環境溫度和飽和水氣壓的關係。

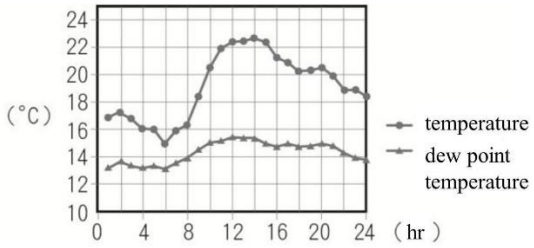
Understand the relationship between ambient temperature and saturated water pressure.

例題講解

例題一

說明：理解環境溫度和露點溫度之間的關係。

（英文）The picture shows the chart of hourly temperature and dew point temperature change of a station on a certain day. Regarding the description of the weather conditions at the station on that day, which of the following is correct? (Choose two answers.)



(A) The actual water vapor content is the highest at 6:00 of the day.

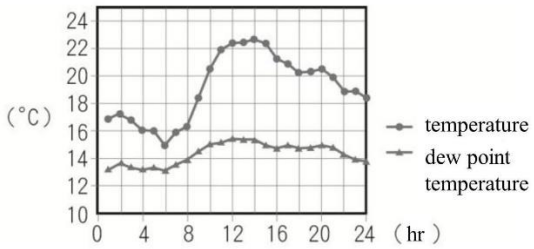
(B) The relative humidity is the highest at 6:00 on the same day.

(C) The relative humidity was the lowest at 12:00 on the day.

(D) The saturated water vapor content in the air was the highest at 14:00 that day.

(E) Dense fog occurred in the early morning of that day.

（中文）圖為某測站某日逐時氣溫與露點溫度變化圖，關於該測站當日的天氣狀況描述下列哪些正確？（應選 2 項）



(A)當日 6 時實際水氣含量最高。

(B)當日 6 時相對溼度最高。

(C)當日 12 時相對溼度最低。

(D)當日 14 時空氣中飽和水氣含量最高。

(E)當日清晨有濃霧發生。

（107 年學測第 35 題）

Teacher: Which temperature in the picture is related to the actual water pressure?

Student: (Silence.)

Teacher: The actual vapor pressure is related to the dew point temperature. The higher the dew point temperature is, the higher the actual vapor pressure is.

Student: What is the dew point temperature?

Teacher: I'll gradually explain it. How is the morning dew formed?

Student: Is it because of the dropping temperature?

Teacher: That's right. Because the temperature keeps dropping down in the morning, the unsaturated air would reach saturation and condense into liquid water.

Teacher: The term of "dew point temperature" comes from the forming of dew. When the temperature of "unsaturated air" cools down and the air becomes saturated, it is called the dew point temperature.

Teacher: Please refer to the saturation curve in the textbook. When the actual vapor pressure is higher, would the dew point temperature get higher or lower?

Student: It gets higher.

Teacher: That's right! Great, so when the dew point is higher, the actual vapor pressure is also higher. According to the picture, what time of the day is the actual vapor pressure the highest?

Student: At 14:00.

Teacher: Correct! Now so far so good?

Student: So far so good.

老師： 請問實際水氣壓跟圖片中的哪個溫度有關連呢？

學生： (一片靜默)

老師： 實際水氣壓跟露點溫度有關連，當露點溫度越高，實際水氣壓就越高。

學生： 什麼是露點溫度？

老師： 那老師先一步一步的引導，清晨的露水怎麼產生的？

學生： 溫度降低嗎？

老師： 沒錯，未飽和的空氣，因為清晨持續降溫，最後達到飽和狀態，就凝結出液態水。

老師： 露點溫度的名詞由來就是來自於露水形成，當「未飽和空氣」降溫使空氣變飽和時的溫度，就稱為露點溫度。

老師： 各位同學可以利用課本中的飽和曲線圖，對比一下，當實際水氣壓越高，那麼露點溫度會變高還是變低呢？

學生： 變高。

老師： 沒錯！很棒，所以當露點溫度越高時，實際水氣壓也會愈高。根據圖片回答我，當天幾點鐘的實際水氣壓最高？

學生： 14 時。

老師： 沒錯！這樣學會了嗎？

學生： 學會了，謝謝老師。

3-3 大氣的運動
Atmospheric Circulation

■ 前言 Introduction

這個小節將會介紹大氣在地球上的運動方式，也就是風的流動。從高氣壓往低氣壓的方向開始流動，因氣壓差而產生的作用力，稱之為「氣壓梯度力」。風開始流動之後，受到地球自轉的影響，而產生偏轉，造成此偏轉的作用力，稱之「科氏力」。最後在靠近地球表面，空氣的運動還會受到摩擦力的影響，降低風速間接影響到科氏力，進而改變風向，而背後較細的影響機制，就讓我們在這個小節仔細學習和品嘗吧！

語言方面，學生能習得不同風向種類的英文說法，與氣壓流動之相關成因。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
pressure gradient force	氣壓梯度力	wind velocity	風速
Coriolis Force	科氏力	wind direction	風向
friction force	摩擦力	high-pressure	高氣壓
earth rotation	地球自轉	low-pressure	低氣壓
Geostrophic wind	地轉風		

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

❶ There are _____ affecting _____: _____, _____, and _____.

例句：**There are** three main forces **affecting** wind**:** pressure gradient force**,** Coriolis force**, and** friction force.

主要影響風的作用力有三種：氣壓梯度力、科氏力、摩擦力。

❷ The more _____ is, the more _____ is.

例句：**The faster** the speed of the object **is, the greater** the Coriolis force **is**; **the higher** the latitude of the object **is, the greater** the Coriolis force would **be**.

物體速度變快，科氏力就越大；物體所在的緯度越高，科氏力就越大。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解影響科氏力的因素。

Understand the factors that affect the Coriolis force.

二、理解作用力影響大氣運動的詳細過程。

Understand the detailed processes by which forces affect atmospheric circulation.

例題講解

例題一

說明：理解地轉風與近地面風的差異性。

（英文）The geostrophic wind is formed when the pressure gradient force and the Coriolis force are in balance. The geostrophic wind at high altitude in some location in the northern hemisphere is the north wind. Assuming that the distribution pattern of isobars from the ground to the high altitude remains unchanged, what direction of the surface wind is most likely to blow from?

(A) North wind.

(B) East wind.

(C) West-Southwest wind.

(D) East-Northeast wind.

(E) North-Northwest wind.

（中文）氣壓梯度力和科氏力平衡時所吹的風稱為地轉風。北半球某地高空的地轉風是吹北風，假設從地面到高空的等壓線分布型態不變，則地面風最有可能吹什麼風？

(A)北風。

(B)東風。

(C)西南西風。

(D)東北東風。

(E)北北西風。

（100 年學測第 53 題）

Teacher: What is the relationship between the wind direction of the geostrophic wind and the isobars?

Student: (Silence.)

Teacher: Let's say that is the geostrophic wind parallel to the isobar, or does it intersect with the isobar?

Student: It is parallel to the isobar!

Teacher: That's correct, the answer is very good. So you can first draw the distribution of isobars in the high altitude. (The teacher is drawing on the blackboard, assuming that the north is facing upwards, drawing the north wind (the geostrophic wind) and the isobar next to it.)

Teacher: Is the relative high pressure in the east or west of the wind direction?

Teacher: Remember that the wind blows from high pressure to low pressure and is deflected by the Coriolis force. The higher the wind speed, the stronger the Coriolis force.

Teacher: Is the wind in the northern hemisphere tilted to the right or to the left?

Student: It is tilted to the right.

Teacher: Good. Then which direction do you think is the relative high pressure?

Student: At the west.

Teacher: That's right, the answer is the west. According to the question description, assuming that the distribution of isobars at high altitude and ground is the same, the wind blowing from high pressure to low pressure is affected by the Coriolis force and titled to the right. However, since the surface friction decreases the wind speed, it reduces the effect of Coriolis force. As a result the surface wind direction is not parallel to the isobar but has an included angle with the isobar.

Student: Then we understand.

老師： 請問地轉風的風向和等壓線有呈現什麼關聯性呢？

學生： （一片靜默）

老師： 那麼老師再給個提示，地轉風平行等壓線，還是與等壓線有交角呢？

學生： 平行等壓線！

老師： 沒錯，回答得很好，所以你們可以先把高空中等壓線分布的狀況畫出來。

（老師在黑板，假設朝上方為北方，畫出北風 (地轉風)，以及旁邊的等壓線。）

老師： 請問相對高壓是在風向的東邊還是西邊呢？

老師： 老師給大家提示，風由高壓吹向低壓，並且受科氏力的影響進而偏轉。風速越高，科氏力越大。

老師： 北半球偏向右邊還是左邊呢？

學生： 右邊。

老師： 非常好，所以請各位同學思考，相對高壓是在哪個方位呢？

學生： 西方！

老師： 沒錯答案是就是西方，根據題目的敘述，假設高空以及地面等壓線分布狀況相同，風由高壓吹向低壓，並且受到科氏力影響偏右，然而摩擦力讓地面風風速降低而減低了科氏力的影響，以至於地面風風向不會平行等壓線，而是與等壓線有一個夾角。

學生： 謝謝老師，這樣子我懂了。

3-4 天氣圖判讀
Weather Map Interpretation

■ 前言 Introduction

藉由地面觀測資料以及高空觀測資料，分析觀測資料將大氣狀況描繪出來，製成不同用途的天氣圖，進而可以判斷目前大氣的狀況。在日常生活中，觀看氣象預報時，氣象主播報導今日天氣或未來一週的天氣，背後常見的天氣圖，就是藉由觀測資料製成的。在此小節，將會教導學生如何初步的判讀天氣圖上的資訊。

語言方面，學生能以英文闡述天氣圖上相關現象，並延伸表示後續天氣變化。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
wind direction	風向	meteorological forecast	氣象預報
wind speed	風速	air pressure	氣壓
surface observation	地面觀測	air temperature	氣溫
ground temperature	地溫	humidity	濕度
weather phenomenon	天氣現象	insolation	日照
visibility	能見度	satellite cloud image	衛星雲圖
radar echo	雷達回波	cloudage	雲量
upper-air observation	高空觀測	cloud height	雲高
amount of precipitation	降水量	cloud form	雲狀

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

❶ There is currently _____, and there will be _____.

例句：**There is currently** a cold front over Taiwan**, and there will be** rain after the cold front.
臺灣目前上空有冷鋒，在冷鋒鋒後會有降雨。

❷ There is/are _____ observation(s) a day.

例句：**There are** two observations at the upper-air **observation a day**, at 0:00 and 12:00 UTC.
高空觀測一天之中觀測兩次，分別時間為國際標準時間，0 時以及 12 時。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解鋒面在衛星雲圖上的特徵。

Understand the characteristics of fronts on satellite cloud images.

二、理解颱風在衛星雲圖上的特徵。

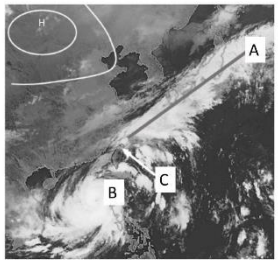
Understand the characteristics of typhoons on satellite cloud images.

例題講解

例題一

說明：由地面衛星雲圖顯示的雲分布的狀況，判斷不同的天氣系統。

（英文）On the satellite cloud image of East Asia on a certain day in the fall of a certain year, H means high pressure, the white line is the local isobar, the gray line is the long ribbon cloud of weather system A, B is another weather system, and the arrow C points to Taiwan. According to the image, which of the following is correct? (Choose 3 answers.)



(A) The long ribbon-shaped clouds of weather system A are formed by the warm sea temperature of the Kuroshio Current.

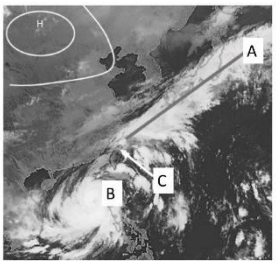
(B) The clouds of B weather system is the clouds of typhoon or tropical depression system.

(C) The location indicated by arrow C is affected by weather systems A and B at the same time.

(D) B weather system is formed by the interaction of cold and warm air masses

(E) Beware of heavy rain in northeastern Taiwan.

（中文）某年秋天某日東亞地區的衛星雲圖，H 表示高壓，白線為局部等壓線，灰線為甲天氣系統長帶狀的雲，乙為另一天氣系統，丙箭頭所指處為臺灣的位置。依圖，下列哪些較為正確？（應選 3 項）



(A)甲天氣系統長帶狀的雲為黑潮暖海溫所形成。

(B)乙天氣系統的雲為颱風或熱帶低壓的雲系。

(C)丙箭頭所指位置同時受到甲、乙兩天氣系統影響。

(D)乙天氣系統是冷、暖氣團交會形成。

(E)臺灣東北部要提防豪雨。

（111 年學測第 34 題）

Teacher: What are the characteristics of two different weather systems, A and B?
Student: System A covers an extended long area.
Teacher: That's right. We can call it a banded distribution. So what about system B?
Student: System B seems to be spinning around.
Teacher: What does it mean spinning around? Please elaborate more.
Student: The clouds of B system seems to be spiraling counterclockwise.
Teacher: Very good. What kind of weather system does the characteristic belong to?
Student: I know! It's typhoon!
Teacher: That's right. System B may be a typhoon, or it could be a cloud system of tropical depression.
Teacher: Then about system A, answer me, please. Which latitude is it probably located at?
Student: About somewhere in the midlatitudes.
Teacher: Correct. In fact, this is a very common weather system in midlatitudes, a cloud band is produced at the junction of cold and warm air masses.
Teacher: Then choose the corresponding answer based on the discussion just now.
Student: Thank you, sir/miss.

老師： 甲和乙兩個不同的天氣系統，各有什麼特徵呢？
學生： 甲的天氣系統，感覺範圍很大很長。
老師： 沒錯，我們可以稱為帶狀分布，那麼乙的天氣系統呢？
學生： 乙的天氣系統感覺像是在旋轉一樣。
老師： 什麼叫做在旋轉呢？請再描述得更詳細。
學生： 乙的雲像是逆時針螺旋狀。
老師： 很好，請問他是哪種天氣系統的特徵呢？
學生： 我想想，我知道了！是颱風！
老師： 沒錯，乙的天氣系統有可能是颱風，或者是熱帶低壓的雲系。
老師： 那麼甲的天氣系統，請同學回答老師，請問大概是位於在哪個緯度呢？
學生： 大約是位在中緯度的地方。
老師： 沒錯，其實這個就是中緯度很常見的天氣系統，由冷暖氣團交界處所產生的雲帶。
老師： 再請各位同學根據剛才的討論，進而挑選出相對應的答案。
學生： 謝謝老師。

3-5 氣象災害-颱風
Weather Disaster-Typhoon

■ 前言 Introduction

在臺灣的種種氣象災害中，「颱風」對於我們生活有著很大的影響，所造成的災害往往是其他氣象災害無法比擬的，除了颱風造成的災害之外，也會帶來豐沛的降水量，為臺灣重要水資源來源之一。在這個章節，學生將會學習有利颱風生成的條件、颱風的結構、颱風的路徑以及颱風對於臺灣的影響。

語言方面，學生能解讀與颱風相關之英語訊息，以英文表達颱風影響所致之天系現象。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
subtropical high	副熱帶高壓	mild typhoon	輕度颱風
typhoon	颱風	southwest flow	西南氣流
typhoon eye	颱風眼	moderate typhoon	中度颱風
spiral rain belt	螺旋狀雨帶	steering flow	駛流
accompanied effect	共伴效應	tropical depression (TD)	熱帶性低氣壓
severe typhoon	強烈颱風	eye wall	眼牆

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

❶ In the _____ structure, the _____ has _____.

例句：**In the** typhoon **structure, the** eye wall **has** the strongest wind and rain.

在颱風結構中，眼牆的風雨最強。

❷ _____ affects the raining area.

例句：The path of a typhoon **affects the raining area**.

颱風的路徑會影響降雨的區域。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、了解有利颱風生成的條件。

Understand the conditions favorable for typhoons to form.

二、了解影響颱風路徑的因素。

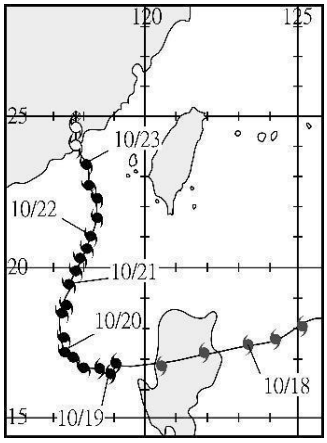
Understand the factors that affect a typhoon's track.

例題講解

例題一

說明：了解颱風路徑不同所造成的降雨區域分布狀況。

（英文）The terrain of Taiwan is complicated. Although the rainfall is abundant, the distribution is quite uneven. The rainfall brought by typhoons is an important water resource in Taiwan, but typhoons often bring floods. When Typhoon Meiji invaded Taiwan on October 21, 2010, the northeast monsoon was prevailing. On that day, heavy rainfall occurred in various parts of Yilan. Due to the low-lying terrain, the cumulated rainfall in 24 hours reached 432 mm, which had reached the standard of super heavy rain. As a result, the road was flooded and people and vehicles were blocked. Please refer to the track of Typhoon Meiji to choose the correct descriptions. (Choose two answers.)



(A) Due to the accompanied effect of typhoon circulation and northeast monsoon, heavy rain fell in Yilan area.

(B) Due to the strong southwest airflow induced by the typhoon, torrential rain fell in the Yilan area.

(C) Because Yilan area is located on the windward side, the rainfall is heavy.

(D) Because Yilan is located in the lower circulation of the typhoon's periphery, the rainfall increased sharply.

(E) This report is wrong, and the accumulated rainfall in Yilan cannot exceed 400mm in one day.

（中文）臺灣全島地形複雜，雖然雨量豐沛但是分布相當不均勻。颱風帶來的降雨是臺灣重要的水資源，但是颱風也常帶來洪水災害。2010 年 10 月 21 日梅姬颱風侵臺之際，正值東北季風盛行，當天宜蘭各地出現強降雨現象，部分地區更因地勢低窪，且 24 小時內累積雨量達 432 毫米，已達超大豪雨標準，致使水淹路面，人車受阻。試參考梅姬颱風路徑，選出正確敘述。（應選 2 項）

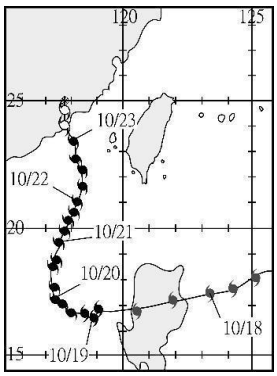
(A)因為颱風環流與東北季風共伴效應，致使宜蘭地區降下超大豪雨。

(B)因為颱風引發強烈西南氣流，致使宜蘭地區降下超大豪雨。

(C)因為宜蘭地區位於迎風面，降雨量大。

(D)因為宜蘭位於颱風外圍環流下降處，降雨量暴增。

(E)此報導有誤，宜蘭一天的累積雨量不可能超過 400 毫米。



（102 年學測第 35 題）

Teacher: From the typhoon's path map, we know that the path and timing of the typhoon's movement. In addition to the description of the question, we can know that there is heavy rainfall in Yilan area. Where will the cloud band formed by the northeast monsoon of this typhoon be located in Taiwan?

Student: Northeast?

Teacher: Why is it northeast?

Student: Because the northeast monsoon blows from the northeast, and the intersection point of the wind direction of the typhoon and the northeast monsoon will be at northeast of Taiwan on the sea area.

Teacher: That's right! Good job! This is the accompanied effect, which refers to the rainfall caused by the interaction of the typhoon and the northeast monsoon. So, when and how will the typhoon move forward to induce the southwest airflow?

Student: When it is summer!

Teacher: Why is it in summer?

Student: Because in summer, the southwest monsoon is strong.

Teacher: So how should the typhoon go to induce southwest airflow?

Student: From the southeast to the northwest of Taiwan.

Teacher: That's right. Then when does it usually happen, before the typhoon comes, lands or leaves Taiwan?

Student: When it leaves Taiwan.

Teacher: Correct. So in the southwest, it is often after this typhoon has left when it rains for several days in a row. I am impressed by the typhoon Morakot that occurred in 2009. At that time, I lived in Tainan, and my house also got flooded.

Teacher: You will find that the rainfall conditions that affect typhoons are not only affected by different paths, but also affected by other weather systems.

Student: Got it!

老師： 藉由颱風的路徑圖，可以知道颱風前進的路徑以及時間點，又加上題目的敘述可以知道，宜蘭各地有強降雨，請問各位同學，此颱風雨東北季風的共伴效應，形成的雲帶會分布在台灣的哪個方位呢？

學生： 東北方嗎？

老師： 為什麼是東方北呢？

學生： 因為東北季風從東北方吹來，而颱風的風向與東北季風的交會點會在臺灣的東北方的海域上。

老師： 沒錯！這位同學回答的很棒，這個就是共伴效應，所指的就是颱風和東北季風的交會處造成的降雨狀況，那麼颱風什麼時候以及該如何前進才會引起西南氣流呢？

學生： 在夏季的時候！

老師： 為什麼是在夏季的時候呢？

學生： 因為夏季的時候，西南季風旺盛。

老師： 那麼颱風的路徑該如何前進才有可能會引起西南氣流呢？

學生： 從臺灣的東南方往西北方前進。

老師： 沒錯，那麼通常是颱風來臨前、登陸或者離開臺灣，哪一個時段呢？

學生： 離開臺灣的時候。

老師： 沒錯，所以在西南部，常常是這種颱風走了之後，才開始連續下了好幾天的雨，老師最有印象的就是，2009 年發生的莫拉克颱風，當時老師住在臺南，我家也淹水了。

老師： 所以各位同學你們會發現，影響颱風的降雨狀況，除了路徑不同之外，也會受到其他天氣系統的影響。

學生： 明白了，謝謝老師！

★主題四 海洋★
Ocean

桃園市平鎮高中地球科學科　郭信嘉老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

臺灣為四面環海的國家，海水對於我們的生活息息相關，小至我們的休閒娛樂會選擇去海邊進行玩耍，大至整個洋流系統影響地球環境，此章節將從海洋結構，海洋的物理性質（溫度及鹽度），從表面分布以及垂直分布情形，探討其影響的變因。陸續談論到海水的運動，像是洋流、波浪以及潮汐，最後將大氣和海洋的章節進行連結，談論兩者的交互作用。

4-1 海洋的結構
Structure of the Ocean

■ 前言 Introduction

海水性質與結構，從海水鹽度與溫度兩個物理特徵進行分析，並且細究表面海水以及垂直海水分層性質，進而了解海洋受到哪些外在因子的影響。

語言方面，學生能以英文理解海洋現象發生的因果，並能比較不同地區之海水鹽度及降雨量。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
average salinity	平均鹽度	thermocline	斜溫層
mixed layer	混合層	evaporation	蒸發量
precipitation	降水量	deep ocean	深水層
$^{0}/_{00}$: parts per thousand (ppt)	千分比	salinity	鹽度

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

❶ **_____ is mainly affected by _____.**

例句：The salinity of surface seawater **is mainly affected by** evaporation and precipitation.
表層海水的鹽度主要受到蒸發量以及降水量的影響。

❷ **_____ is stirred by external forces such as _____.**

例句：The seawater in the mixed layer **is stirred by external forces such as** waves and currents, and the temperature and salinity properties of seawater are relatively similar.
混合層的海水受到海浪、海流等外力攪和，海水溫鹽性質較為類似。

❸ **What is the difference between _____ and _____? Why is there such a difference?**

例句：**What is the difference between** subtropical surface salinity **and** equatorial surface salinity**?**
Why is there such a difference?
副熱帶表面海水鹽度以及赤道表面海水鹽度有何差異？為什麼會造成這樣的差異？

❹ **_____ will generally decrease as the _____ increases.**

例句：The temperature of the surface seawater **will generally decrease as the** latitude **increases**.
What are the factors behind it?
表層海水的溫度，隨著緯度增加，大致上溫度會降低，請問背後的因素是什麼？

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：
After studying this section, students should be able to:
一、了解海水的垂直分層。
Understand the vertical stratification of oceans.
二、理解鹽度的表示方式及其單位。
Understand how salinity is expressed and its units.
三、理解影響海水溫度及鹽度的因素。
Understand the factors that affect seawater temperature and salinity.

例題講解

例題一

說明：讓學生理解影響表面海水鹽度的因素。

Enable students to understand the factors that affect the salinity of surface seawater.

（英文）The surface salinity of the Pacific Ocean reaches the highest in the subtropical sea region. Which of the following is the main reason for this distribution?

(A) There is a confluence of ocean currents in this area.

(B) There is more evaporation than precipitation in this area.

(C) There is a large input of fresh water at the edge of this ocean.

(D) Saline material on land is transported to the area by wind.

(E) Significant vertical mixing occurs in this region.

（中文）太平洋的表面鹽度在副熱帶海域有極大值。造成這種分布的主要原因為下列何者？

(A)此區域有洋流的匯合。

(B)此區域的蒸發量大於降雨量。

(C)大洋邊緣有大量淡水輸入。

(D)陸地上的含鹽物質由風傳輸至此區域。

(E)此區域發生大量的垂直混合。

（106 年學測第 18 題）

Teacher: Please take out your textbooks and turn to the page of the average seawater salinity map.

Teacher: First of all, determined by latitude, where has the higher salinity?

Student: Places at low latitude.

Teacher: Why?

Student: Because it is hotter there.

Teacher: According to your answer, the higher the temperature is, the higher the salinity of the seawater would be.

Teacher: Where has the higher temperature? The equator or the subtropical regions?

Student: The equator.

Teacher: Very good, so where has the higher salinity?

Student: Subtropical. (There is a voice of doubt in the class.)

Teacher: Do you feel something wrong? Does anyone know the reason behind it?

Teacher: What is the exact factor that affects the salinity of seawater?
Student: (Silence.)
Teacher: Let me give you a hint. You have learned in geography class before that the climates in the subtropical region and the equatorial region are very different. What are the characteristics of the climate in the equatorial region?
Student: There are rainforests! Therefore, there are lots of precipitation!
Teacher: How about the subtropics?
Student: Is there less rainfall?
Teacher: Yes, that's right. Why is there less rainfall?
Student: Because there is a subtropical high-pressure zone over there?
Teacher: Exactly, there will be less rain, so one of the things that affects surface salinity is the amount of precipitation.
Teacher: The second factor is evaporation, so when precipitation exceeds evaporation, will salinity increase or decrease?
Student: Will it decrease?
Teacher: Great, precipitation will lower the salinity. So on the contrary, when the precipitation is less than the evaporation, what will the salinity be?
Student: It will increase!
Teacher: That's right, it will increase! So the answer to this question would be (B) There is more evaporation than precipitation in this area.

老師： 請各位同學將課本拿出來，翻開到表面海水鹽度分布圖。
老師： 首先，先以緯度來判斷，哪裡的鹽度比較高呢？
學生： 低緯度。
老師： 什麼原因？
學生： 因為比較熱。
老師： 根據你的回答，所以溫度越高，海水鹽度就會越高。
老師： 請問一下，赤道和副熱帶地區，哪裡溫度比較高呢？
學生： 赤道。
老師： 很好，那麼請問哪裡鹽度比較高呢？
學生： 副熱帶。（全場發出疑惑的聲音。）
老師： 是不是有感覺哪裡怪怪的呢？那有同學知道背後的原因是什麼嗎？
老師： 影響海水鹽度的因素到底是什麼呢？
學生： （一遍寂靜。）

老師： 老師給大家一點提示，之前地理課有學過，副熱帶地區和赤道地區的氣候是很不一樣的，赤道地區的氣候有什麼特徵呢？

學生： 熱帶雨林！降水量很多！

老師： 那麼副熱帶地區呢？

學生： 雨量比較少嗎？

老師： 對，沒錯。為什麼雨量會比較少呢？

學生： 因為那裡有副熱帶高壓籠罩嗎？

老師： 沒錯，降雨會較少，所以影響表面鹽度因素其中一個是降水量。

老師： 第二個要素就是蒸發量，所以當降水量大於蒸發量，鹽度會增加還是降低呢？

學生： 降低嗎？

老師： 很棒，就是降低鹽度。那麼相反的，當降水量小於蒸發量，鹽度會？

學生： 增加！

老師： 沒錯就是增加！所以這題才會選擇(B)此區域的蒸發量大於降雨量。

4-2 海洋的運動
Oceanic Currents

■ 前言 Introduction

海水在地球上並非靜止不動，在這個小節將會介紹海水最主要的運動，包含洋流、波浪以及潮汐。學生在這個單元通常在潮汐單元，會有比較多的疑問，包含潮汐週期的概念，大潮小潮的差異性等等。

語言方面，學生能闡述潮汐造成之相關現象，以英文理解地球潮汐與月球運行之間的關聯。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
semi-diurnal tide	半日潮	diurnal tide	全日潮
wave	波浪	neap tide	小潮
high tide	滿潮	Planetary wind system	行星風系
density current	密度流	flood tide	漲潮
wind wave	風浪	tidal current	潮流
Sneaker Wave	瘋狗浪	tide	潮汐
spring tide	大潮	tidal range	潮差
ebb tide	退潮	breaker	碎浪
tidal force	引潮力	longshore current	沿岸流

low tide	乾潮	rip current	離岸流
marine deposition topography	海積地形	ocean current	洋流
Tsunami	海嘯	gravitation	萬有引力
marine deposition topography	海蝕地形	thermohaline circulation	溫鹽環流
Kuroshio	黑潮	swells	湧浪
mixed tide	混合潮	upwelling current	湧升流

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

❶ **_____ currents are mostly caused by _____, such as _____.**

例句：Surface **currents are mostly caused by** wind**, such as** the Kuroshio.

表面洋流的成因最主要受到風的作用，例如：黑潮。

❷ **_____are delayed by _____ each day, mainly due to _____.**

例句：The tides **are delayed by** about 50 minutes **each day, mainly due to** the revolution of the moon.

潮汐每天會大約延後 50 分鐘，主要是因為月球公轉。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解影響潮汐的作用力主要為月球萬有引力作用下的產生的引潮力。

Understand that tides are mainly generated by tidal force caused by moon's gravitational effect.

二、了解湧升流成因，以及對於天氣和生物的影響。

Understand the causes of upwelling and its effects on weather and living creatures.

❧ 例題講解 ☙

例題一

說明：學生能夠以原本的先備知識（潮汐的成因），進行應用分析。

Students are able to carry out applied analysis based on the original prior knowledge (causes of tides).

（英文）A scenario in a science fiction novel mentioned that the moon orbits the earth in an direction opposite to it does now, but the speed remains the same. If this scenario is true, and other factors affecting tidal changes do not change, which of the following statements are true? (Choose 2 answers.)

(A) The moon will change to rise in the west and set in the east.

(B) The moon appears about fifty minutes earlier each day.

(C) The moon will still rise in the east, and it will not affect the ebb and flow of tides.

(D) For areas with semi-diurnal tides, the time of high tide is about fifty minutes earlier each day.

(E) Tidal changes only affect the semi-diurnal tide area but do not affect at all the diurnal tide area.

（中文）某科幻小說中的情境曾提及月球公轉方向與現在相反，但公轉速率不變。如果此情境為真，其他影響潮汐變化的因素亦不改變，則下列敘述哪些正確？（應選 2 項。）

(A)月亮會變成自西方升起，東方落下。

(B)月亮每天會提早約五十分鐘出現。

(C)月亮依然會由東方升起，且不影響潮汐的漲退時間。

(D)對於半日潮的地區，每天滿潮的時間大約會提早五十分鐘。

(E)潮汐變動只影響半日潮地區，全日潮地區完全不受影響。

（108 年學測第 18 題）

Teacher: What is the key point in this question?

Student: The revolution direction of the moon is opposite to it is now.

Teacher: Good. Now the question says that the moon orbits the earth in an opposite direction. Then let's explain the options one by one. Option A describes the rising position of the moon. What is the main reason for that the moon rises in the east and sets in the west in reality?

Student: It is because of the earth rotation!

Teacher: Great answer! Because the direction of the earth's rotation has not changed, the moon will still rise in the east and set in the west.
About option B, regarding the daily change of the tidal cycle, what will happen to the original tidal cycle after one day?

Student: It will be delayed by 50 minutes.

Teacher: Why?

Student: Because the moon revolves.

Teacher: Great, so now the moon is orbiting in the opposite direction, 50 minutes delayed will become 50 minutes earlier. An additional question for you: how often would the semi-diurnal tide become in a single tidal cycle?

Student: (Silence.)

Teacher: Let me give you a hint. The original cycle is 12 hours and 25 minutes but now the moon's orbiting direction has become opposite. So what would the answer be?

Student: I see, it's 11 hours and 35 minutes!

Teacher: That's right, your answer is great!

老師： 請問各位同學，現在題目的關鍵是什麼呢？

學生： 月球公轉方向與現在相反。

老師： 沒錯，同學回答得很好，現在題目主要描述公轉方向與現在相反。那我們就從選項一個個的講解。選項 A，在描述關於月球升起的方位，我詢問各位同學，請問月球會東升西落最主要是因為什麼原因呢？

學生： 地球自轉！

老師： 回答的很棒！因為地球自轉方向沒有改變，因此月球一樣會東升西落。選項 B，關於潮汐週期每天的變化，請問原本潮汐週期經過一天會有什麼變化呢？

學生： 延後 50 分鐘。

老師： 是因為什麼原因？

學生： 月球公轉。

老師： 很好，所以現在月球公轉的方向相反，延後 50 分鐘會變成提早 50 分鐘。那老師這裡要額外提問問題，請問半日潮單一次潮汐週期變為多少時間？

學生： （一片寂靜）

老師： 老師先給一個提示，原本的週期為 12 小時又 25 分鐘，但現在的公轉方向是相反的，那答案會是？

學生： 啊！我知道了，是 11 小時 35 分鐘！

老師： 沒錯，同學回答的很棒！！

4-3 大氣與海洋的交互作用
Atmosphere-Ocean Interaction

■ 前言 Introduction

前面的章節，學習關於大氣以及海洋的相關知識，接著這個小節將會討論大氣和海洋之間的交互作用，因此在這個小節將會著重在大氣是如何影響海洋，以及海洋是如何影響大氣，這兩者是密不可分的關係。

語言方面，學生能以英文理解聖嬰現象之相關事實，闡述氣溫、降雨量等數值變化。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Peru	祕魯	Southern Oscillation	南方震盪
Darwin	達爾文港	Southern Oscillation Index (SOI)	南方震盪指數
Tahiti	大溪地	equatorial easterlies	赤道東風
El Niño	聖嬰現象	ENSO	聖嬰-南方震盪現象
La Niña	反聖嬰現象		

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

❶ During El Niño, the sea temperature in the _____ will be higher than usual.

例句：**During El Niño, the sea temperature in the** eastern Pacific Ocean **will be higher than usual.**

聖嬰現象時，東太平洋的海水溫度會比平常還要高溫。

❷ The occurrence cycle of El Niño is about ____ to ____ years.

例句：**The occurrence cycle of El Niño is about** 2 **to** 7 **years.**

聖嬰現象的發生週期大約為 2 至 7 年。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解聖嬰現象對於東西太平洋的影響。

Understand the impact of El Niño on the East and West Pacific Oceans.

二、分辨東西太平洋氣壓以及海水溫度的變化，判斷聖嬰現象是否發生。

Distinguish the changes in air pressure and sea temperature in the eastern and western Pacific Oceans, and determine whether El Niño has occurred.

∞ 例題講解 ∞

例題一

說明：了解聖嬰現象發生時，海洋與大氣之間的交互作用。

Understand the interaction between the ocean and the atmosphere during the El Niño.

（英文）The El Niño is a natural phenomenon caused by the interaction of the atmosphere and the ocean, which will lead to short-term climate anomalies in some areas on the earth. Which of the following statements is incorrect about the atmospheric and oceanic changes or effects accompanying El Niño?

(A) Equatorial easter lies weakens.

(B) Sea temperature rises in the equatorial eastern Pacific.

(C) Upwelling intensifies on the west coast of South America.

(D) The sea level decreases in the equatorial western Pacific.

(E) Precipitation decreases in the equatorial western Pacific.

（中文）聖嬰現象是大氣與海洋交互作用下的大自然變化，會導致地球上部分地區短期氣候異常。有關聖嬰現象發生時所伴隨的大氣與海洋變化或影響，下列敘述何者錯誤？

(A)赤道東風減弱。

(B)赤道東太平洋地區海溫上升。

(C)南美洲西岸湧升流增強。

(D)赤道西太平洋地區海水高度降低。

(E)赤道西太平洋地區降雨量減少。

（108 年學測第 2 題）

Teacher: This question describes the impact on the ocean and the atmosphere during El Niño. What will happen to the equatorial easterlies when the El Niño occurs?

Student: The equatorial easterlies weakens.

Teacher: That's right, the speed of the equatorial easterly wind will weaken. When the equatorial easterlies weakens, what will happen to the ocean currents below?

Student: The speed of the ocean current below will also weaken.

Teacher: Great answer. Let’s keep going. When the underlying current weakens, what will happen to the upwelling in the eastern Pacific Ocean?

Student: The speed of the upwelling will also weaken.

Teacher: The answer is great, and the upwelling will also weaken. Accordingly, what would happen in the surface seawater temperature in the eastern Pacific Ocean?

Student: Will it decrease?

Teacher: No, you need to think about it carefully.
Let me give you a hint. In normal years, the upwelling will bring up the colder seawater from the deep ocean, so now that the upwelling has weakened, what will happen to the temperature of the seawater?

Student: So if the upwelling weakened, the amount of seawater coming up from the deep ocean will also decrease, so...
Ah I see! The surface sea temperature in the eastern Pacific Ocean will increase!!

Teacher: That's right! The seawater temperature in the eastern Pacific Ocean will increase, so this is an example of the interaction between ocean and the atmosphere. Changes in the atmosphere will affect the ocean, and changes in the ocean will also affect the atmosphere.

Student: Thank you, teacher, we got it!

老師： 此題目最主要是在描述聖嬰現象時，對於海洋以及大氣的影響。老師現在進行提問和引導，請問聖嬰現象發生時，赤道東風會有什麼改變呢？

學生： 赤道東風會減弱！

老師： 沒錯，赤道東風風速會減弱，當赤道東風減弱後，底下的洋流會有什麼變化呢？

學生： 下方的洋流流速也會跟著減弱。

老師： 很好，回答的很棒。老師繼續提問，當底下的洋流減弱，會導致東太平洋的湧升流有什麼變化呢？

學生： 也會跟著減弱！

老師： 回答的很棒，湧升流也會跟著減弱，進而導致東太平洋的表面海水溫度有什麼變化呢？

學生： 降低嗎？

老師： 不是，可以仔細思考一下。
老師給提示讓各位同學思考，當正常年的時候，湧升流會將深水層較低溫的海水帶上來，所以現在湧升流減弱了，就會導致海水溫度有什麼變化呢？

學生： 所以假如湧升流減弱了，深水層的海水上來的量也會減少，所以…
啊我知道了！東太平洋表面海水溫度會增加！！

老師： 沒錯！東太平洋的海水水溫會增加，所以各位同學，這個就是海水和大氣之間有交互作用的例子，大氣發生改變，會影響到海洋，海洋發生改變了也會影響到大氣的變化。

學生： 謝謝老師，這下子我懂了！

★主題五 地球與太空★
Earth and Space

彰化縣田中高中地球科學科　胡祖寧老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

自古閃爍點點的星空就是人們嚮往且追尋的，究竟我們所身處的地球在無垠宇宙中的何處？星體日日的東升西落又從何而起？偶一劃過天邊的流星又帶來什麼樣的訊息？正是因為渺小的我們難以理解宇宙的全貌，才僅能利用雙眼所觀察到的天文現象推測宇宙中的種種奧秘。

5-1 從太空看地球
Earth Seen from Space

■ 前言 Introduction

太陽系的組成除卻不斷提供地球能量的恆星「太陽」外，圍繞在太陽周遭的八大行星、多數位於海王星外區域的矮行星、以及週期性經過太陽的彗星皆為太陽系中的成員，雖各自有其不同的特點存在，但日復一日的相同處即是，我們都圍繞著太陽進行公轉。

而太陽與地球也因其中太陽風的吹拂、地球磁層的保護、掉入地球大氣中的宇宙碎屑等產生許多炫麗且特別的天文景象，讓人們置身其中感嘆天文的奧妙。

語言方面，學生能以英文形容宇宙中發生之太空現象，了解其形成之前因後果。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
small solar system body	太陽系小天體	ecliptic plane	黃道面
astronomical unit	天文單位	aurora	極光
ion tail	離子尾	asteroid belt	小行星帶
meteor shower	流星雨	planet	行星
orbit	軌道	circumstellar habitable zone (CHZ)	適居帶
light year	光年	magnetosphere	磁層
Kuiper belt	柯伊伯帶	dwarf planet	矮行星
comet	彗星	Oort cloud	歐特雲

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

❶ Members of the solar system include _____, _____, and _____.

例句：**Members of the solar system include** the sun, eight planets, dwarf planets**, and** small solar system bodies.

太陽系的成員包含太陽、八大行星、矮行星與太陽系小天體。

❷ ____, _____, and _____ are all common distance units in the universe.

例句：Light year, astronomical unit**, and** parsec **are all common distance unit in the universe**.

光年、天文單位與秒差距皆為宇宙中常見的距離單位。

❸ The two main causes of the aurora are _____ and _____.

例句：**The two main causes of the aurora are** the earth's magnetosphere **and** the solar wind emitted by the sun.

形成極光的兩大主因為地球具有磁層以及太陽所放出的太陽風。

❹ The solar system, from the center to the outermost region, consists of ____, _____, and ___.

例句：**The solar system, from the center to the outermost region, consists of** the Sun, terrestrial planets, asteroid belt, the Jovian planets, the Kuiper belt, **and** the Oort cloud.

太陽系從中心至外圍依序為太陽、類地行星、小行星帶、類木行星、柯伊伯帶與歐特雲。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解宇宙中的階層分類。

Understand the classification of the universe.

二、對於太陽上所發生之天文景象形成原因有初步理解。

Understand the causes of the astronomical scenes on the sun.

❧ 例題講解 ☙

例題一

（英文）Arranged in order of distance from Earth, from near to far, Moon, Jupiter, Vega, X, Andromeda. X is most likely which of the following?

(A) Virgo Cluster. (B) Halley's Comet. (C) Uranus. **(D) Galactic Center.** (E) Pluto.

（中文）依照距離地球由近而遠排列：月球、木星、織女星、X、仙女座星系。X 最可能是下列何者？

(A)室女座星系團。 (B)哈雷彗星。 (C)天王星。 **(D)銀河系中心。** (E)冥王星。

（109 年學測第 62 題）

Teacher: According to the question, how do you determine the distance of these stars or planets from Earth?

Student: Should we refer to the structure of the universe?

Teacher: Right! We can first determine if the celestial bodies are outside or inside the solar system to consider it is near the earth or not.

Student: In the question, only the moon and Jupiter are in the solar system, so is Vega outside the solar system?

Teacher: That's right! Because Vega is a bright star, and the only star in the solar system is our sun, it can be speculated that X should be a celestial body outside the solar system!

Student: Comet Halley is recognized as a small solar system body, Uranus is one of the eight major planets, and Pluto is a dwarf planet. All of which are located in the solar system, so neither of them is the correct answer.

Teacher: The galaxy cluster is at a higher level than the galaxy. There are many galaxies in the galaxy cluster, so option A should not be selected.

老師：依照題目所述，要如何判斷選項中距離地球的遠近呢？

學生：利用宇宙的階層圖嗎？

老師：對！我們可以透過天體在太陽系外或內先判斷距離地球的遠近。

學生：題目中只有月球和木星在太陽系內，織女星就已經在太陽系外了嗎？

老師：沒錯！因為織女星是一顆發亮恆星，而太陽系中唯一一顆的恆星就是我們的太陽，所以可以由此推測 X 應該會太陽系外的天體！

學生：哈雷彗星屬於太陽系小天體，天王星屬於八大行星，冥王星屬於矮行星，都位在太陽系內，所以都不是正確答案。

老師：而星系團則是比星系更高的階層，星系團中會有許多的星系，所以 A 選項也不能選擇。

例題二

（英文）The solar wind is a stream of high-energy charged particles released from the surface of the sun. When these substances reach the earth, the speed often exceeds one million kilometers per hour. Which of the following phenomena is the solar wind most directly related to?

(A) Tides. **(B) Aurora.** (C) Total solar eclipse. (D) Meteor showers. (E) Sandstorm.

（中文）太陽風是太陽表面所噴發出來的高能帶電粒子束。當這些物質到達地球時，時速常超過百萬公里。太陽風與下列哪一現象最有直接關係？

(A)潮汐。 **(B)極光。** (C)日全食。 (D)流星雨。 (E)沙塵暴。

（108 年學測第 1 題）

Teacher: The question says that the solar wind is a stream of high-energy charged particles, so is the solar wind an electromagnetic wave?

Student: No! The high-energy charged particles and electromagnetic waves are two different things!

Teacher: That's right! Therefore, when high-energy charged particles enter the earth's atmosphere, they will disturb earth's magnetosphere. As a result, it is easy to form auroras the north and south poles where the magnetic fields are the strongest.

Student: Sir then, what is the reason for the formation of meteor showers?

Teacher: The reason for the formation of meteor showers is due to the burning of debris left by the comet falling into the earth's atmosphere when the earth passes the orbit of a comet.

Student: I see! So can we infer the time of meteor showers based on the time when the earth passes comet's orbit?

Teacher: Yes! We can know the time of the meteor showers in advance!

老師： 題目中說到太陽風為高能帶電粒子，所以太陽風是電磁波段嗎？

學生： 不是！高能帶電粒子與電磁波段是兩件不同的事情！

老師： 沒錯！所以當高能帶電粒子束進入大氣層，會擾亂地磁場，就容易在磁場最強的南北兩極形成極光。

學生： 老師，那流星雨的形成原因是什麼呢？

老師： 流星雨的形成原因是地球經過彗星之軌道時，彗星遺留下來的碎屑墜入地球大氣層燃燒後所形成的現象！

學生： 原來如此！所以流星雨出現的時間可以利用地球與彗星軌道交會的時間來推斷嗎？

老師： 對！所以流星雨的時間是可以提前知道的喔！

5-2 從地球看太空
Space Seen from Earth

■ 前言 Introduction

太陽、月亮、星星每天的東升西落似乎是一個正常不過的現象，但天體日日在天空中劃出一道道軌跡的原因其實並非天體自身的移動，最主要的原因其實是因為我們所身處的地球不斷的在自轉！

再者，每個季節抬頭所觀賞到的星空都有不同的美，為何星座似乎會隨著季節產生變化，又為何有些星座中的星星似乎散發著不同顏色的亮光，星座中的所有星星都是彼此相互關聯、密不可分的嗎？種種我們觀測到的現象其實背後都有規律的科學依據可以參考！

語言方面，學生能以英文理解星體移動的現象，並以英文表示觀測天體時的相對位置。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
polar star (polaris)	北極星	blackbody radiation	黑體輻射
parallax arcsecond (pc)	秒差距	ecliptic	黃道
celestial sphere	天球	absolute magnitude	絕對星等
north celestial pole	天球北極	stellar magnitude	星等
celestial equator	天球赤道	annual motion	周年運動
luminosity	亮度	diurnal motion	週日運動

brightness	光度	apparent magnitude	視星等
revolution	公轉	rotation	自轉

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

❶ The extension of ____ to the celestial sphere is called ____.

例句：**The extension of** the north pole **to the celestial sphere is called** the north celestial pole; **the extension of** the equator **to the celestial sphere is called** the celestial equator.
地球北極延伸至天球上稱為天球北極；地球赤道延伸至天球上稱為天球赤道。

❷ The reason for ____ is due to _____.

例句：**The reason for** the diurnal motion **is due to** the rotation of the earth; the reason for the annual motion is due to the revolution of the earth.
周日運動的原因是因為地球自轉；周年運動的原因是因為地球公轉。

❸ The electromagnetic wave released by stars with _____ temperature is more inclined to _____ wave radiation.

例句：**The electromagnetic wave released by stars with** higher **temperatures is more inclined to** short**wave radiation**; **the electromagnetic wave released by stars with** lower **temperatures is more inclined to** long**wave radiation**.
溫度越高的恆星所放出的電磁波段越偏向短波輻射；溫度越低的恆星所放出的電磁波段越偏向長波輻射。

❹ The farness of the star from the earth can be determined by using the difference between ___ and _____.

例句：**The farness of the star from the earth can be determined by refering to the difference between** the absolute magnitude **and** the apparent magnitude of the celestial body.
利用天體絕對星等與視星等的差值可以判斷星體距離地球的遠近。

■ 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：

一、了解天球的基本觀念與天球赤道與黃道間的關係。

Students understand the basic concepts of the celestial sphere and the relationship between the celestial equator and the ecliptic.

二、理解周日運動的概念並能分辨不同緯度所觀察到的星體軌跡。

Students understand the concept of diurnal motion and distinguish the star trails observed at different latitudes.

三、理解恆星顏色所代表的意義與區分恆星與行星的差異。

Students understand the meaning of star colors and distinguish the difference between stars and planets.

❧ 例題講解 ☙

例題一

（英文）The ancients thought of the starry sky as the projection of stars on an infinite celestial sphere with the earth at the center and having the same rotation axis as the earth. The apparent track of the sun for one year makes the circle of the ecliptic, which inclines 23.5º with respect to the celestial equator. The illustrative diagram of the celestial sphere is shown in the figure below. If the earth's revolution around the sun is used to infer the movement of the sun in the celestial sphere, which of the following is the order of the sun's movement from the vernal equinox to the winter solstice for the northern hemisphere?

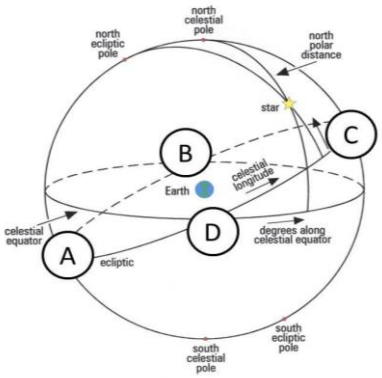
(A) A→B→C→D.

(B) B→C→D→A.

(C) A→D→C→B.

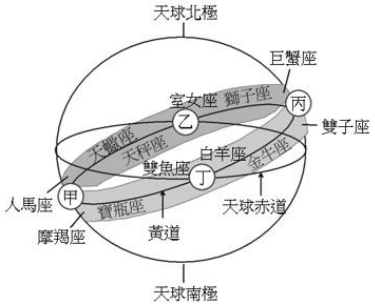
(D) D→C→B→A.

(E) C→D→A→B.



（中文）古人將所見星空，想成是繁星投影在一個無限大，以地球為中心且具有相同旋轉軸的天球。太陽一年的視軌跡為黃道，與天球赤道夾 23.5⁰。天球概念之示意圖如下圖，若以地球繞太陽公轉來推論太陽在天球中的移動軌跡，圖中對北半球而言，太陽自春分到冬至的移動順序為下列何者？

(A) 甲→乙→丙→丁。
(B) 乙→丙→丁→甲。
(C) 甲→丁→丙→乙。
(D) 丁→丙→乙→甲。
(E) 丙→丁→甲→乙。



（111 年學測第 33 題）

Teacher: There are two time points in the picture where the sun is directly shining on the equator. What are the two time points among A, B, C, and D?

Student: They are B and D!

Teacher: That's right! So we need to focus on how to determine whether B and D are vernal equinox or autumnal equinox respectively!

Student: How do we determine the vernal equinox and autumnal equinox?

Teacher: Do you still remember the zodiac constellation we mentioned? The zodiac constellation refers to the constellation where the sun is located on the day of your birth, that is, the constellation blocked by the sun on your birthday is your zodiac constellation.

Student: So if you're born in March...Shall the sun block Pisces or Aries?

Teacher: Very good! Therefore, it can be determined from the picture that B is just blocking Pisces, so the position of B should be the vernal equinox, and the position of D is the autumnal equinox!

Student: I got it! Since C is located in the northernmost position where the sun directly shines on the north hemisphere, the position of C is the summer solstice; because D is located in the southernmost position where the sun directly shines on the south hemisphere, the position of D is the winter solstice.

老師：圖中有兩個時間點太陽都直射赤道，是甲乙丙丁哪兩個時間點呢？
學生：乙和丁！
老師：沒錯！所以這題的重點在於如何去判斷乙和丁分別為春分或秋分！
學生：要怎麼判斷春分與秋分呢？
老師：還記得我們提過的黃道星座嗎？黃道星座指的是出生當天太陽所座落在的星座，也就是出生當天太陽擋住的星座即是你的黃道星座。
學生：所以如果是三月出生的人...太陽應該就會擋住雙魚座或牡羊座嗎？
老師：非常好！所以透過圖中可以判斷乙太陽剛好擋住雙魚座，所以乙的位置應該是春分，而丁的位置才是秋分！
學生：我懂了！而丙因為位於太陽直射北半球位置的最北方，所以丙的位置是夏至；丁因為位於太陽直射南半球位置的最南方，所以丁的位置是冬至。

例題二

（英文）The pictures of star trails taken by Xiaohui and Xiaojie at places A and B respectively are as follows. Both of them are facing east, under long exposure. Which of the following is true? (choose 2 answers)


甲地　乙地

(A) Place A is located in the northern hemisphere, and its latitude is higher than 45 degrees.
(B) Place B is located in the southern hemisphere, and its latitude is lower than 45 degrees.
(C) Place A is quite close to the equator.
(D) The latitude of A is higher than that of B.
(E) Place B is located in the northern hemisphere, and its latitude is approximately 45 degrees.

（中文）小蕙與小傑分別於甲、乙兩地點所拍得的星跡照片如下圖。兩人皆面向東方，長時間曝光拍攝，下列哪些正確？（應選 2 項）

甲地

乙地

(A)甲地位於北半球，且緯度高於 45 度。

(B)乙地位於南半球，且緯度低於 45 度。

(C)甲地相當接近赤道。

(D)甲地的緯度，較乙地高。

(E)乙地位於北半球，且緯度約等於 45 度。

（111 年學測第 30 題）

Teacher: The question says that the pictures taken by the two people who were facing the east, so are the stars supposed to be rising or setting?

Student: Rising! Because the stars rise in the east and set in the west!

Teacher: So when we face the picture, is it south or north on our right-hand side?

Student: Is it south…?

Teacher: That's right. According to the description, the photographers were facing east when taking the pictures, so our right-hand side is south, and the left-hand side is north. According to the diurnal motion, the star's trail will be perpendicular to the axis of rotation, so...?

Student: The angle between the rotation axis and the ground plane will be consistent with the latitude of the observer!

Teacher: According to the two key points you just mentioned, you can infer the latitudes and locations of A and B!

老師：題目告訴大家說，甲地與乙地的拍攝方向都是東方，所以星星應該在升起還是落下呢？

學生：升起！因為星體東升西落！

老師：所以這樣可以判斷，當面對圖片是，我們的右手邊都是南邊還是北邊？

學生：南邊嗎...？

老師：沒錯，根據題目敘述，此圖片拍攝時，攝影者是面向東方，所以我們的右手邊

都是南方，而左手邊是北方。配合周日運動我們所提到的重點，星體視軌跡會與自轉軸垂直，所以…？

學生：自轉軸與地平面的夾角又會與觀測者所在緯度一致！

老師：透過大家剛剛提到的兩個重點，就可以知道甲地與乙地位在緯度位置了！

例題三

（英文）The colors of celestial bodies provide rich information. For example: Vega emits blue-white light, Antares is reddish in appearance, Uranus is blue-green in appearance, and Mars is dark red in appearance. Based on the above description, which of the following is correct?

(A) Vega has a warmer surface than Antares.

(B) Uranus has a hotter surface than Mars.

(C) Uranus has a hotter surface than Antares.

(D) Vega is more luminous than Antares.

(E) Mars is more luminous than Antares.

（中文）天體的顏色提供豐富訊息。例如：織女星發出藍白光芒，心宿二顏色偏紅，天王星外觀為藍綠色，火星呈暗紅色。依據以上描述，下列何者正確？

(A)織女星的表面溫度比心宿二高。

(B)天王星的表面溫度比火星高。

(C)天王星的表面溫度比心宿二高。

(D)織女星的發光能力比心宿二強。

(E)火星的發光能力比心宿二強。

（111 年學測第 31 題）

Teacher: We have mentioned before that stars with higher temperatures should look more blue-white, and stars with lower temperatures should look redder, do you still remember?

Student: Yes, sir. But why is the surface temperature of Uranus not higher than that of Antares?

Teacher: Thinking about what we just said, when the “star” temperature is higher. Is Uranus a star?

Student: No! Uranus is a planet.

Teacher: Since Uranus is a planet, the planet itself does not emit light, but reflects the light of the star. The planet itself will not perform nuclear fusion reactions, and its temperature will thus be lower than that of stars.

Student: Ah! We are too careless!

Teacher: So next time remember to see clearly whether the celestial body described in the question is a star or a planet, and then determine whether you can directly use color to distinguish whether the temperature is higher or lower!

老師： 我們上課的時候提過，溫度越高的恆星看起來應該越偏向藍白色，而溫度越低的恆星看起來應該越偏向紅色，大家還記得嗎？

學生： 記得，那老師為什麼天王星的表面溫度沒有比心宿二高？

老師： 再想一次我們剛剛說的，我們說，溫度越高的「恆星」，天王星是恆星嗎？

學生： 不是！天王星是行星。

老師： 既然天王星是行星，行星本身不會發光，而是反射恆星的光，所以行星本身也不會行核融合反應，溫度自然會比恆星還要低。

學生： 啊！我們太大意了！

老師： 所以下次看題目時記得看清楚題目所描述的天體是恆星還是行星，再來判斷是否可以直接使用顏色來分辨溫度高低喔！

5-3 宇宙 Universe

■ 前言 Introduction

我們之所以可以看到世間萬物，是因為人類的肉眼可以接收可見光，但其實除卻可見光外，還有許多不同波長的電磁波段存在於宇宙中，透過天體發出能量大小不一的電磁波段推測天體各自的特性，波長不一的電磁波段就像是不同濾鏡的照相機，拍出各式天體的差異與特色。

科學家利用觀測各式波段的電磁波，希望可以看到接近大霹靂產生的時間點，了解宇宙的起源與過程。雖然目我們無法利用觀測 138 億年前發生的事情證實大霹靂，但哈伯定律與宇宙微波背景輻射兩個觀測事實卻也佐證了大霹靂理論的真實性，我們的宇宙正在不斷膨脹中！

語言方面，學生能以英文表示宇宙中相關數據之差異。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
electromagnetic wave	電磁波	galaxy	星系
X ray	X 射線	galaxy cluster	星系團
visible light	可見光	nebula	星雲
Hubble law	哈伯定律	super-cluster	超星系團
red shift	紅移現象	ultraviolet ray	紫外線
infrared rays	紅外線	galaxy	銀河系

isotropy	均向性	radio wave	無線電波
star cluster	星團	cosmic microwave background	宇宙微波背景輻射

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

❶ The wavelengths of the electromagnetic wave band from short to long should be ____, ____, and ____.

例句：The wavelengths of the electromagnetic wave band from sho**rt to long should be** X-rays, ultraviolet rays, visible light, infrared rays **and** radio waves.

電磁波段之波長由短到長應為 X 射線、紫外線、可見光、紅外線與無線電波。

❷ Two observations that support the ____ theory are ____ and ____.

例句：**Two observations that support the** Big Bang **theory are** expansion of the universe **and** the cosmic microwave background radiation.

支持大霹靂理論的兩個觀察事實為宇宙膨脹與宇宙微波背景輻射。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、學生能夠將紅移現象應用於觀測現象中。

Apply the redshift phenomenon to observational phenomena.

二、對於恆星皆會放出不同能量的電磁波段有初步理解。

Understand preliminarily that stars release different energies of the electromagnetic wave.

三、了解宇宙微波背景輻射所觀測到之現象與其內容。

Understand the phenomenon and content of the cosmic microwave background radiation.

❧ 例題講解 ☙

例題一

（英文）An astronomer focuses on the observation data of two celestial bodies, A and B, for analysis, and then determines that one of them is a galaxy and the other is a galaxy cluster. If the mass of A is about 1000 times that of B, and if the wavelength of the corresponding spectral lines emitted by some elements in body A is greater than that of the same elements in body B. Which of the following statements is correct?

(A) A is a galaxy cluster, and recessional velocity is smaller than that of B.

(B) A is a galaxy and is farther away from earth than B.

(C) B is a galaxy cluster, and the recessional velocity is smaller than that of A.

(D) A is a galaxy, and is closer to earth than B.

(E) A is a galaxy cluster, and the recessional velocity is greater than that of B.

（中文）某天文學家鎖定甲、乙兩個天體的觀測資料進行分析，之後確定其中一個是星系而另一個是星系團。若甲的質量約為乙的 1000 倍，且甲、乙兩天體相同元素所發出的對應光譜線，甲的波長皆大於乙，則下列敘述何者正確？

(A)甲為星系團，遠離速率較乙小。

(B)甲為星系，距離較乙遠。

(C)乙為星系團，遠離速率較甲小。

(D)甲為星系，距離較乙近。

(E)甲為星系團，遠離速率較乙大。

（109 年學測第 6 題）

Teacher: In the question, it is said that “the wavelength of A is greater than that of B”. Therefore, is A more likely to be infrared or ultraviolet?

Student: Infrared! Infrared has a longer wavelength.

Teacher: Just like Hubble’s law we mentioned before, the phenomenon observed by Hubble is that the galaxies in the universe are all ...?

Student: Moving away from the Milky Way galaxy!

Teacher: So does the phenomenon of moving away from the Milky Way produce redshift or blueshift?

Student: It produces the redshift phenomenon; the wavelength gradually shifts toward red light.

Teacher: That’s right! The farther a galaxy is from us, the faster it moves away!
Then let me ask everyone again, will Polaris gradually move away from the Earth?

Student: No, it won’t! Because the unit of Hubble’s Law is “galaxy”. The Polaris and the Earth are both celestial bodies in the Milky Way. Therefore, they will not be affected by Hubble’s Law!

老師： 題目中說道「甲的波長皆大於乙」，代表甲較偏向紅外線還是紫外線呢？

學生： 紅外線！紅外線波長較長。

老師： 就像我們之前提到的哈伯定律，哈伯所觀察到的現象是宇宙中的星系皆在...？

學生： 遠離銀河系！

老師： 所以遠離銀河系所產生的是紅移現象還是藍移現象？

學生： 紅移現象，波長逐漸往紅光偏移。

老師：沒錯！離我們越遠的星系其遠離速度越快！
那想再詢問大家，北極星也會逐漸遠離地球而去嗎？
學生：不會！因為哈伯定律的單位是「星系」，北極星與地球都屬於銀河系中的天體，所以並不會受到哈伯定律的影響！

例題二

（英文）Through a sheet of red glass, we would view all scenes in various shades of red. When using the sheet of red glass to photograph the starry sky, all the stars are bright and red in different shades. Now let us take a picture of the starry sky with a camera through a telescope. For the same sky area, we take an photo with a sheet of red and blue glass respectively. What information about stars can be obtained from the photos?

(A) Comparing the two photos, the age of the star can be determined.

(B) Comparing the two photos, the distance to the star can be determined.

(C) Comparing the two photos, hot blue stars can be identified.

(D) From the photo taken via a blue glass, it is possible to distinguish which are cool stars.

(E) From the photo taken via a red glass, red stars are very bright.

（中文）透過紅色玻璃片，觀看所有景象呈現深淺不一的紅色色調。用來拍攝星空，則所有恆星都呈明亮不同的紅色。現透過望遠鏡用相機拍攝星空，針對同一天區，分別以紅色及藍色玻璃片各拍一幅影像。依此可獲得恆星的何種訊息？

(A)比對兩幅影像，能判斷出恆星的年齡。

(B)比對兩幅影像，能判斷出恆星的距離。

(C)比對兩幅影像，能辨別出藍色高溫恆星。

(D)從藍色玻璃片影像中，能辨別哪些是低溫恆星。

(E)在紅色玻璃片影像中，紅色恆星非常明亮。

（110 年學測第 66 題）

Teacher: When using different filters to observe stars, what characteristics do we know from the stars?

Student: The length of the electromagnetic wave radiated by stars?

Teacher: Right! Therefore, the photos of stars taken with sheets of red and blue glass can only tell the lengths of electromagnetic waves radiated by celestial bodies!

Student: So.... can we not determine the distance between the stars and the earth from the photo?

Teacher: That's right. If you want to determine the distance of a star, you need to do it through the magnitude value!

Student: Got it! Then if a star emits more lights with electromagnetic wavelength toward blue lights than red lights, the temperature of this star should be relatively high!

Teacher: Very good! So observations through different filters can actually provide us with a lot of information about stars.

老師： 使用不同濾鏡觀測恆星時，最主要可以知道恆星的什麼特性呢？

學生： 恆星輻射出的電磁波段長短？

老師： 對！所以當中提到利用紅藍玻璃片所拍出的恆星照片僅能判斷出天體輻射出的電磁波波長長短！

學生： 所以....照片中無法判斷恆星與地球間的距離嗎？

老師： 沒錯，如果要判斷恆星的距離，則需要透過星等值判斷！

學生： 了解！那如果一顆恆星放出的電磁波段藍光大於紅光，這一顆恆星的溫度應該相對是較高的！

老師： 非常好！所以透過不同濾鏡的觀測，其實可以提供給我們關於恆星的許多資訊。

例題三

（英文）Which of the following statements about the cosmic microwave background radiation and stars observed in the 20th century are correct? (choose 2 answers)

(A) The cosmic microwave background radiation has existed in the universe longer than the age of stars.

(B) The temperature of cosmic microwave background radiation must be higher than the average surface temperature of stars.

(C) Regarding the spectrums of cosmic microwave background radiation and stars, both haves discontinuous spectrum lines.

(D) The average wavelength of the cosmic microwave background radiation must be longer than the visible light wavelength of the stellar spectrum.

(E) The distribution of the cosmic microwave background radiation in each direction of the power passing through per unit area vertically in space is more uneven than that of stars.

（中文）下列關於二十世紀觀測到的宇宙微波背景輻射和恆星的敘述，哪些正確？（應選 2 項）

(A) 宇宙微波背景輻射在宇宙中存在的時間大於恆星的年齡。

(B) 宇宙微波背景輻射的溫度，一定比恆星的表面平均溫度高。

(C) 宇宙微波背景輻射和恆星星光的光譜，都具有不連續的譜線。

(D) 宇宙微波背景輻射的平均波長，一定比恆星光譜的可見光波長還長。

(E) 宇宙微波背景輻射於空間中垂直通過每單位面積之功率在各方向的分布，比恆星星光更為不均勻。

（106 年學測第 31 題）

Teacher: The cosmic microwave background radiation refers to the radiation released by early stars formed after Big Bang. Due to the expansion of the universe, the wavelengths of electromagnetic waves emitted by early stars are stretched causing the decline in energy. The stretched wavelength as it can be observed today is just in the microwave spectrum.

Student: So the microwave found in the universe should fill in the entire universe, that is, are there microwaves found in all directions?

Teacher: Yes, just think about it, should the microwave of the universe be evenly dispersed everywhere or not?

Student: Is it spread evenly everywhere...?

Teacher: If the microwave radiation is a result of the Big Bang when the Big Bang occurs, will the matter be distributed evenly or unevenly in each source ?

Student: It should be distributed unevenly.

Teacher: That's right, so the cosmic microwave background radiation is also distributed in the universe unevenly, but because the energy is rather small, more sophisticated instruments are needed to observe the microwave radiation!

老師： 宇宙微波背景輻射指的是從大霹靂發生後，早期恆星形成時釋放的電磁波波長因宇宙膨脹而變長，輻射能量逐漸下降，而今可見這些被拉長的電磁波波段即是微波波段。

學生： 所以宇宙中的微波波段應該充滿整個宇宙，也就是四面八方都有微波嗎？

老師： 對，大家也可以想一下，宇宙中的電磁波應該是均勻分散在各處還是不均勻呢？

學生： 均勻分散在各處...？

老師： 如果微波波段的產生是因為大霹靂，當大霹靂產生時，物質會均向性的分布還是不均向性的分佈在各出處呢？

學生： 應該是不均向。

老師： 沒錯，所以宇宙微波背景輻射也是不均向的分散在宇宙中喔，只是因為他的能量太小，所以需要更為精密的儀器才能觀察到微波的輻射！

★主題六 氣候變遷★
Climate Change

桃園市平鎮高中地球科學科　郭信嘉老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

科幻電影《明天過後》揭示著氣候變遷帶來的環境變化、紀錄片《洪水來臨前》是由李奧納多・狄卡皮歐主演的紀錄片，勘查了全球因人為活動造造成的環境破壞和衍生出全球暖化的狀況、拜訪各國飽受氣候變遷影響的人。這幾年氣候的異常，已經深深地影響到大自然以及人類生活，讓人們不敢忽視氣候變遷所帶來的變化。這個章節將會結合前面所學的知識內容，並且一同討論「人類活動」對於氣候影響。

6-1 多重時間尺度的氣候變遷
Climate Change on Multiple Time Scales

■ 前言 Introduction

藉由不同的氣候證據可以得知過去地球氣溫，觀察氣溫變化狀況，其持續週期大至億~百萬年，小至數十年。有許多影響氣候的因素，每個因素影響的時間尺度都不一樣，此小節將會教導學生，多重時間尺度下的氣候變遷。

語言方面，學生能以英文判讀氣候相關之圖表，以英文理解氣侯形成之原因。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
climate change	氣候變遷	Little Ice Age	小冰期
plate movement	板塊運動	Younger Dryas	新仙女木事件
glacial period	冰期	Snowball Earth	雪球地球
ice core	冰芯	axial precession	轉軸進動
icehouse climate	冰室氣候	axial tilt (obliquity)	轉軸傾角
eccentricity	偏心率	stalactite	鐘乳石
Last Glacial Maximum	末次冰盛期	sediment	沉積物
Milankovitch cycle	米蘭科維奇循環	coral	珊瑚
albedo	反照率	tree-ring	樹輪
fossil	化石	greenhouse gas	溫室氣體

interglacial period	間冰期	greenhouse climate	溫室氣候
megathermal	全新世暖期	stable isotope	穩定同位素

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

❶ ____ mainly discusses _____, and it causes _____.

例句：The Milankovitch cycle **mainly discusses** the changes in the relationship between the sun and the earth**, and it causes** the replacement of glacial and interglacial periods.
米蘭科維奇循環主要探討日地關係的變化，並造成冰期和間冰期的更替。

❷ _____ caused a drop in temperature that lasted for _____.

例句：The Younger Dryas **caused a drop in temperature that lasted for** about 1,000 years.
新仙女木事件造成氣溫下降，持續約 1 千年。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：
After studying this section, students should be able to:

一、理解米蘭科維奇循環影響日地關係的三個要素。
Understand the three elements of the Milankovitch cycle, which affect the relationship between the sun and the earth.

二、可以分辨「冰室氣候及溫室氣候」與「冰期及間冰期」。
Distinguish “icehouse climate and greenhouse climate” from “glacial and interglacial periods”.

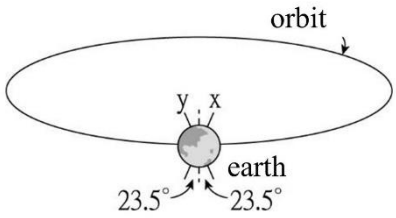
三、理解不同氣候變遷因子影響的時間尺度。
Understand the time scales of the impacts by different climate change factors.

例題講解

例題一

說明：讓學生理解日地位置與氣溫之間的關係

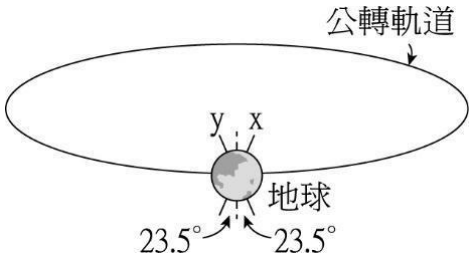
（英文）As the figure, the current rotation axis of the earth is pointing to x in the figure, and it tipped by 23.5 degrees from the revolution axis around the sun. If the earth's rotation axis is tilted to y in the figure, and the angle of tilt is still 23.5 degrees. From the astronomical point of view, how does the summer and winter in the northern hemisphere of the earth compare with the actual (current) situation?



option	summer	winter
(A)	about the same	about the same
(B)	colder than now	hotter than now
(C)	colder than now	colder than now
(D)	hotter than now	hotter than now
(E)	**hotter than now**	**colder than now**

（中文）如圖所示，目前地球自轉軸指向為圖中 x，與繞日公轉軸交角約為 23.5 度。如果地球自轉軸的指向偏轉為圖中 y，但交角仍為 23.5 度。僅就天文的角度來看，則地球北半球的夏天與冬天，與實況（現況）相比為何？

選項	夏天	冬天
(A)	與現況差不多	與現況差不多
(B)	比現況冷	比現況熱
(C)	比現況冷	比現況冷
(D)	比現況熱	比現況熱
(E)	**比現況熱**	**比現況冷**



（103 年學測第 46 題）

Teacher: Is the current summer in the northern hemisphere at perihelion or aphelion?

Student: At perihelion.

Teacher: Why do you think it's at perihelion?

Student: When the earth is closer to the sun, it will be hotter, and summer will be formed.

Teacher: This concept is wrong!

Teacher: That's fine. Does anyone know the key reason for the formation of spring, summer, autumn, and winter?

Student: Is it because of the change in the altitudea of straight sunlight?

Teacher: That's right, the answer is very good. In summer, the angle between direct light and the ground line is relatively large, so the energy received per unit area is larger, too. Thus, the temperature increases.

Teacher: In winter it's vice versa. The sunlight strike obliquely on the ground with smaller angle, so the energy received per unit area is less. Thus, the temperature drops.

Student: I see!

Teacher: Currently the northern hemisphere is located at the aphelion in summer and at the perihelion in winter.

Teacher: So according to the description, if the rotation axis of the earth is tilted to the other direction, what will happen?

Student: Summer and winter in the northern hemisphere will be reversed!

Teacher: That's right! The answer is great, so the summer in the northern hemisphere will begin when the earth is at perihelion that may result in hotter weather than the current situation.

Teacher: In winter, the earth will be at aphelion, and it will become colder than the current situation, so the answer is E.

老師： 請問現在目前北半球的夏天是處於近日點還是遠日點呢？

學生： 近日點。

老師： 為什麼會覺得是近日點呢？

學生： 靠近太陽，會比較熱，才會形成夏天。

老師： 這個概念是錯誤的喔！

老師： 沒關係，有人知道影響春夏秋冬的關鍵是什麼嗎？

學生： 日照角度的變化嗎？

老師： 沒錯，回答得很好，在夏天的時候，直射太陽光與地平線的夾角比較大，因此單位面積接收到的能量較大，溫度進而提高。

老師： 冬天則反之，太陽以較小的角度斜照地面，所以單位面積接收到的能量比較少，溫度進而下降。

學生： 原來如此！

老師： 現在北半球的夏天是位於遠日點，冬天則是近日點。

老師： 所以根據題目的描述，自轉軸指向與現在是相反的話，那會發生什麼事情呢？

學生： 北半球夏天和冬天會顛倒！

老師： 沒錯！回答的很棒，所以北半球夏天時，地球變成在近日點，會比現況還要熱。

老師： 北半球冬天時，地球變成在時，地球變成在遠日點，會比現況還要冷，所以答案選 E。

6-2 氣候變遷造成的環境影響
Environmental Impacts of Climate Change

■ 前言 Introduction

這個小節將會與學生介紹關於過去地球歷史上氣候變遷對於環境的影響，將會以臺灣作為主要探討對象。介紹冰期及間冰期時的環境變化，例如海平面高度。末次冰盛期過後，臺灣環境的變化。

語言方面，學生能以英文理解氣候變遷的相關影響與成因。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
glacial period	冰期	U-shaped valley	U 型谷
Last Glacial Maximum	末次冰盛期	Xue Mountain Glacial Cirques	雪山圈谷
relict species	孑遺生物	fagus	山毛欅
interglacial period	間冰期	Oncorhynchus masou formosanus	櫻花鉤吻鮭

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

❶ Sea level varies in _____ and _____.

例句：**Sea level varies in** glacial **and** interglacial periods.
海平片高度在冰期與間冰期不同

❷ _____ and _____ are relict species of the ice age.

例句：Oncorhynchus masou formosanus **and** fagus **are relict species of the ice age**.
櫻花鉤吻鮭及山毛櫸為冰河時期的孑遺生物。

❸ During the Last Glacial Maximum, the sea level was _____, allowing ____ to migrate to Taiwan.

例句：**During the Last Glacial Maximum, the sea level was** about 120 meters lower than it is now, and the Taiwan Strait was almost above the surface of the water**, allowing** terrestrial organisms **to migrate to Taiwan**.
末次冰盛期的海平面比現在低了約 120 公尺，臺灣海峽幾乎露出水面，陸生生物可遷徙至台灣。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：
After studying this section, students should be able to:
一、理解冰期對海陸分布的影響。
Understand the impact of ice ages on the distribution of land and sea.
二、理解末次冰盛期以來臺灣環境的變化。
Understand changes in Taiwan's environment since the Last Glacial Maximum.
三、理解臺灣在冰期的證據。
Understand the evidence of ice age in Taiwan.

例題講解

例題一

說明：讓學生理解為何地球在冰期及間冰期的有不同的自然景象。
Enable students to understand why the earth shows different natural phenomena in the glacial and interglacial periods.

（英文）In the history of earth, the climate has undergone many changes of warm and cold, and the earth is now in an interglacial period. What phenomena will happen when the earth enters the interglacial period from the ice age, in which the global temperature rises.? (Choose 2 items)

(A) Glaciers retreat, ice sheets shrink, and global average sea level rises.

(B) The ice sheet melts and the previously covered land rises.

(C) After the ice melts, a large amount of fresh water is injected into the ocean, causing the ocean thermohaline circulation to become stronger.

(D) Water evaporation decreases, precipitation rainfall decreases, and deserts expand.

(E) Hotspot volcanos erupts actively, releasing large amounts of greenhouse gases.

（中文）在地球的歷史中，氣候發生過許多次冷暖變化，地球現正處於間冰期。當地球由冰期進入間冰期時，全球氣溫上升，會引發哪些現象？（應選 2 項）

(A)冰川後退、冰原範圍減小，全球平均海平面上升。

(B)冰層融解，原先被覆蓋的陸地上升。

(C)冰融後，因淡水大量注入海洋，造成海洋溫鹽環流增強。

(D)水氣蒸發量降低、降雨少，沙漠擴張。

(E)熱點火山噴發活動旺盛，釋出大量溫室氣體。

（104 年學測第 65 題）

Teacher: The options are the phenomena that happen when the earth enters the interglacial period from the glacial period. Let's discuss the options in order.

Teacher: Option A, global temperature rises, so what would happen to the volume of glaciers?

Student: The glacier will melt, so the volume of the glacier will decrease.

Teacher: That's right, you responded well. So when the glacier melts and the volume decreases, the glacier will retreat. Then, where does the melted ice go?

Student: Does it melt into water and run into the ocean?

Teacher: That's right, a large amount of glaciers melts into water and goes to the ocean, causing sea levels to rise.

Teacher: Next, let's discuss option B. As discussed just now, a large number of glaciers will melt, and because the weight of the glaciers is gone, what will happen to the land?

Student: Will it rise?

Teacher: Yes, so glaciers melt and the land beneath them may rise.

Teacher: Let's go on to option C. After the ice melts, a large amount of fresh water goes into the ocean. How will the density of sea water change?

Student: Will the density increase?

Teacher: Let me remind you, whose density is higher, fresh water or sea water?

Student: Sea water has higher density.

Teacher: Why?

Student: Is it because of his higher salinity?

Teacher: That's right, there are two factors that affect the density of seawater, temperature and salinity. The greater the salinity is, the greater the density is.

Student: I got it. Because a lot of fresh water flows into the sea, the density of sea water decreases!

Teacher: Yeap. As a result, the surface seawater doesn't sink, and thus the thermohaline circulation will not become stronger.

Teacher: Option D is relatively simple. What will happen to the evaporation when the temperature rises?

Student: The evaporation will increase!

Teacher: That's right! And in option E, the eruptions of hotspot volcanoes have nothing to do with glacier melting. So we choose A and B for this question.

老師： 題幹敘述地球從冰期進入間冰期，會引發的現象，我們依序討論選項。

老師： A 選項，全球氣溫上升，那麼冰川體積會發生什麼事情呢？

學生： 冰川會融化，所以冰川體積減少。

老師： 沒錯，同學回答得很好，所以當冰川體積融化減少時，冰川就會後退，那麼請問，這些融化的冰跑去哪裡了呢？

學生： 融化成液態水，跑到海洋裡面嗎？

老師： 沒錯，大量的冰川融化成液態水，進入到了海洋裡，造成海平面上升。

老師： 接著我們來討論 B 選項，剛剛有討論到，大量的冰川會融化，並且因為上面少了冰川的重量，陸地會發生什麼事情呢？

學生： 上升嗎？

老師： 沒錯，所以冰川融化，下方的陸地會上升。

老師： 我們接著來回答討論 C，冰融後淡水大量注入海洋，會造成海水的密度如何變化？

學生： 密度變大嗎？

老師： 老師提示一下，淡水和海水的密度誰比較大呢？

學生： 海水的密度比較大。

老師： 為什麼呢？

學生： 因為他鹽度比較高嗎？

老師： 沒錯，影響海水密度的因素有兩種，溫度以及鹽度。當鹽度越大，密度就會越大。

學生： 那我懂了，因為大量淡水流到海中，造成海水密度降低！

老師： 沒錯，所以表層海水不會下沉，進而溫鹽環流不會增強。

老師： D 選項比較簡單，請問溫度上升，進而蒸發量會發生什麼事情？

學生： 蒸發量增加！

老師： 沒錯！接著 E 選項，熱點火山噴發與冰川融化沒有任何關係。所以我們這題選擇 A 和 B。

6-3 人類活動與近期氣候變化
Human Activities and Recent Climate Change

■ 前言 Introduction

科學家探究氣候變遷的資料，原因包含自然因素以及人為因素等面向，此小節將會教導學生分析近 1000 年來地球氣溫的變化，影響氣候的正回饋及負回饋的效應。

學生能以英文理解溫室效應之相關名詞介紹。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Intergovernmental Panel on Climate Change	聯合國政府間氣候變遷專門委員會	greenhouse gas	溫室氣體
global warming	全球暖化		

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

❶ **After the industrial revolution, _____ have been emitted, which has significantly affected _____.**

例句：**After the industrial revolution**, a large amount of greenhouse gases **have been emitted, which has significantly affected** the earth's temperature.

工業革命之後，大量排放溫室氣體，已明顯影響到地球氣溫。

❷ _____ **and** _____ **increases greenhouse gases in the atmosphere.**

例句：Oil recovery **and** use of fossil fuels **increases greenhouse gases in the atmosphere.**
人類開採以及使用化石燃料，增加大氣中的溫室氣體。

■ 問題講解 Explanation of Problems

☙ 學習目標 ❧

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解人類活動對氣候造成的影響。

Understand the impact of human activities on climate.

二、理解溫室氣體的種類。

Understand the types of greenhouse gases.

三、理解影響氣溫的正回饋及負回饋。

Understand the positive and negative feedbacks that affect temperature.

❧ 例題講解 ☙

例題一

說明：讓學生理解與人類活動有關的溫室氣體的來源。

Enable students to understand the sources of greenhouse gases related to human activities

（英文）Greenhouse gases absorb heat radiated from the earth's surface, causing the heat insulation on the earth's surface. The increase of greenhouse gases by human activities is a major cause of global warming. Which of the following gases are "greenhouse gases increased by human activities"? (Choose 3 items)

(A)CH_4 (B)CO_2 (C)N_2O (D)N_2 (E)H_2O

（中文）溫室氣體會吸收地表輻射熱能，導致地表的保溫效果。人為因素所增加的溫室氣體是全球暖化的一大主因。下列哪些氣體是「因人類活動而增加的溫室氣體」？（應選 3 項）

(A)CH_4 (B)CO_2 (C)N_2O (D)N_2 (E)H_2O

（107 年學測第 46 題）

Teacher: Greenhouse gases can be increased by human activities. Which of the options are greenhouse gases?
Student: Are they option A, B, C, and E?
Teacher: That's right! Considering the increase due to human activities, where does option A Ch_4 mostly come from?
Student: Is it from animal husbandry?
Teacher: That's right, it is mostly from animal husbandry! What about option B CO_2?
Student: Does it come from carbon dioxide emitted by living creatures?
Teacher: No, we are talking about sources related to human activities.
Student: Does it come from the burning of fossil fuels?
Teacher: Great answer, what about N_2O?
Student: It is from the exhaust fumes emitted by automobiles and motorcycles.
Teacher: Good answer, what about H_2O?
Student: It exists in nature and is not caused by human activities.
Teacher: All students responded very well, the answer is A, B, C.

老師： 溫室氣體會因為人類活動而增加，請問選項中哪幾個為溫室氣體呢？
學生： A B C E 嗎？
老師： 沒錯喔！考量人類活動所造成的結果，A 選項 CH_4，大多來自於哪裡？
學生： 是畜牧業嗎？
老師： 沒錯就是，畜牧業！那麼 B 選項 CO_2 呢？
學生： 生物吐出二氧化碳嗎？
老師： 不是喔，我們現在談的是跟人類活動有關的來源。
學生： 燃燒化石燃料嗎？
老師： 回答得很好，那麼 N_2O 呢？
學生： 汽機車排放的廢氣。
老師： 回答的很棒！那麼 H_2O 呢？
學生： 自然界本來就有了，並不是人類活動造成的。
老師： 各位同學都回答的很棒，答案就是 A, B, C。

6-4 因應氣候變遷
Responding to Climate Change

■ 前言 Introduction

前幾個小節介紹關於氣候變遷的議題，包含其影響的因素，氣候變遷是確實在地球上演著。這個小節將會與學生介紹，人類針對氣候變遷議題，所做出的因應對策。

語言方面，學生能以英文理解氣候變遷之相關政策。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
Paris Agreement	巴黎協定	retardation	減緩
The United Nations Framework Convention on Climate Change (UNFCCC)	聯合國氣候變化綱要公約	Kyoto Protocol	京都議定書
Copenhagen Accord	哥本哈根協定	climatic adaptation	氣候調適

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

❶ ____ was adopted at ____ on _____.

例句：The Paris Agreement **was adopted at** the 2015 United Nations Climate Summit **on** December 12, 2015.

《巴黎協定》於 2015 年 12 月 12 日在 2015 年聯合國氣候峰會中通過。

❷ Through _____, it is expected that _____ can be controlled.

例句：**Through** climate adaptation actions**, it is expected that** climate change **can be controlled.**

經由氣候調適行動，期望能夠控制氣候變遷的狀況。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、理解巴黎協定的內容。

Understand the content of the Paris Agreement.

二、理解有哪些行為可以進行氣候調適。

Understand what actions are available for climate adaptation.

三、理解人類行為該如何減緩碳排放量。

Understand how human actions can retard carbon emissions.

例題講解

例題一

說明：讓學生理解碳儲量與「四個地球子系統，包含岩石圈、大氣圈、水圈以及生物圈」的關係。

Enable students to understand how carbon storage is related to “the 4 subsystems in the earth system including lithosphere, atmosphere, hydrosphere, and biosphere”.

（英文）In response to the signing of the Kyoto Protocol, developed countries have begun to consider imposing a “carbon tax” to control carbon dioxide emissions. From the perspective of the carbon cycle, the Kyoto Protocol mainly regulates the in-and-out of carbon storage between which two earth spheres out of the four?

(A) The sphere where carbon moved out: the lithosphere; the sphere where carbon moved in: the biosphere.

(B) The sphere where carbon moves out: the hydrosphere; the sphere where carbon moves in: the lithosphere.

(C) The sphere in which carbon moves out: the aerosphere; the sphere in which carbon moves in: the hydrosphere.

(D) The sphere where carbon moves out: the lithosphere; the sphere where carbon moves in: the atmosphere.

(E) The sphere where carbon moves out: the aerosphere; the sphere where carbon moves in: the lithosphere.

（中文）因應京都議定書的簽署，已開發國家開始考慮徵收「碳稅」，以管制二氧化碳的排放量。就碳循環的角度而言，京都議定書主要是管制碳在地球系統的四個圈中，哪兩個圈的碳儲量移出與移入？

(A) 碳移出的圈：岩石圈；碳移入的圈：生物圈。

(B) 碳移出的圈：水圈；碳移入的圈：岩石圈。

(C) 碳移出的圈：氣圈；碳移入的圈：水圈。

(D) 碳移出的圈：岩石圈；碳移入的圈：氣圈。

(E) 碳移出的圈：氣圈；碳移入的圈：岩石圈。

（104 年學測第 18 題）

Teacher: I would like to you, there are four spheres in the earth system, like the biosphere. Do you know any other spheres?
Student: Lithosphere?
Teacher: Great answer, what else?
Student: Hydrosphere!
Student: Atmosphere.
Teacher: That's right, everyone responds very well. Our earth system is mainly divided into these four spheres, namely the atmosphere, lithosphere, hydrosphere and biosphere.
Teacher: In the Kyoto Protocol, it specifically emphasizes carbon dioxide emissions from human activities.
Teacher: Let me ask you, which sphere in the earth system should we restrain the carbon storage?
Student: To retrain carbon dioxide released by human activities, I think the answer is the biosphere.
Teacher: Your idea is very good, but it is not the biosphere. Can you please think more carefully, what humans activities may produce carbon dioxide?
Student: The burning of fossil fuels?
Teacher: That's right, so should fossil fuels be stored in the biosphere or the lithosphere?
Student: Hmm... lithosphere?
Teacher: That's right, the lithosphere, so we want to restrain the release of carbon from the lithosphere.
Teacher: So which earth subsystem does this released carbon dioxide move into?
Student: Because it will move into the atmosphere, I think it is the atmosphere.
Teacher: Bravo! The earth subsystem in which we want to restrain the moving-in of carbon is the atmosphere. So the answer is D.

老師： 請問各位同學，地球系統中有四個圈，像是生物圈，那麼還有其他同學知道其他圈嗎？
學生： 岩石圈嗎？
老師： 回答的很棒，那還有其他的嗎？
學生： 水圈！
學生： 大氣圈。

老師： 沒錯，大家都回答的很棒，我們地球系統中最主要分成了這四個圈，分別為大氣圈、岩石圈、水圈以及生物圈。

老師： 那麼在京都議定書中，特別強調關於人類活動排放二氧化碳的狀況。

老師： 所以老師詢問各位同學，請問我們要限制地球系統哪一個圈的碳儲量呢？

學生： 限制人類活動釋放二氧化碳，所以我覺得是生物圈。

老師： 你的想法很好，但是不是生物圈，可以請你思考更周詳，人類是進行了什麼活動才產生二氧化碳呢？

學生： 燃燒化石燃料嗎？

老師： 沒錯，所以化石燃料本來應該是在生物圈還是岩石圈呢？

學生： 嗯…岩石圈嗎？

老師： 沒錯，就是岩石圈，所以我們要限制岩石圈的碳移出。

老師： 那麼這些二氧化碳排放到哪一地球系統呢？

學生： 因為它是排放到大氣中，所以我覺得是大氣圈。

老師： 很棒喔！我們要限制碳移入的地球子系統就是大氣圈。所以答案是 D。

★主題七 永續發展與資源利用★
Sustainable Development and Resource Utilization

彰化縣田中高中地球科學科　胡祖寧老師
國立彰化師範大學英語學系　陳郁暄

■ 前言 Introduction

如何與地球共存已成為現階段人類所面臨最重要且最刻不容緩的議題。自工業革命以來，人們製造大量廢棄物與各式種類的汙染，造成地圈、水圈、大氣圈的種種負擔，若人們無法正視著近年地球無聲的抗議，未來地球的反撲更有可能讓我們措手不及。

7-1 永續發展
Sustainable Development

■ 前言 Introduction

聯合國於 2015 年提出「永續發展目標」（SDGs）訂定 17 項永續發展指標，希望協助各國推動永續發展政策與目標。臺灣因應永續發展目標，也逐步踏上永續發展的道路，透過減少環境汙染產生、降低溫室氣體的排放量、減低塑膠製品的使用量等政策，期許我們與未來世代皆能繼續生活在這顆孕育生命的美好星球。

語言方面，學生能以英文理解永續發展相關名詞解釋。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
environment	環境	society	社會
environmental pollution	環境汙染	biodiversity	生物多樣性
economy	經濟	greenhouse gas	溫室氣體
energy saving and carbon reduction	節能減碳	Sustainable Development Goals (SDGs)	永續發展目標

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

❶ The _____ of the United Nations Sustainable Development Goals is _____.

例句：**The** first **of the United Nations Sustainable Development Goals is** to eliminate poverty in the world.

聯合國永續發展目標中的第一項，為希望消除世界中的貧窮。

❷ If we can reduce ____ per person, we can contribute to _____.

例句：**If we can reduce** the daily electricity consumption **per person, we can contribute to** energy saving and carbon reduction.

若能降低每人每天的耗電量，就能為節能減碳盡一份心力。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

After studying this section, students should be able to:

一、了解各項環境議題與其對應之成因。

Understand various environmental issues and their corresponding causes.

例題講解

例題一

（英文）There are several mistakes in the following passage. Which of the following statements underlined in bold are correct? (Choose 3 items)

Human life is deeply dependent on oil; however **(A) petroleum is a type of fossil fuel, a non-renewable resource that will eventually be exhausted**, and the extensive use of petroleum has caused many negative impacts on the earth's environment and its sustainable development. Petroleum is often used as fuel and is the source of energy for the operation of many machines. But **(B) the burning of petroleum will release a large amount of carbon dioxide into the atmosphere, strengthening the greenhouse effect, which has been considered the main cause of global warming today.** And **(C) after carbon dioxide enters the stratosphere, it will react with ozone, leading to the generation of the ozone hole.** In addition, the result of the sudden increase of carbon dioxide in the atmosphere also results in a sudden increase in the dissolved and absorbed carbon dioxide in the ocean. Formation of carbonic acid causes ocean acidification. **(D) Organisms with siliceous shells living in the ocean, such as diatoms, will face the risk of shell dissolution**, and the ecosystem will also be in danger. Petroleum is also a raw material for plastic products, and most plastics are difficult to decompose naturally. Many waste plastic products that have not been properly recycled will end up in the ocean. **(E) In the central sea area of the North Pacific Gyre, where the current flow is slow, large blocks of plastic debris are found there.** Because the amount of these debris are too large in seawater, they have seriously damaged the marine ecological environment.

（中文）以下短文有不少謬誤，下列以粗體底線標示的敘述哪些正確？（應選 3 項）

人類生活對石油的依賴甚深；然而**(A)石油是化石燃料的一種，屬於非再生資源，終有枯竭的一天**，且大量使用石油已對地球環境與其永續發展造成了許多負面的衝擊。石油常作為燃料，是許多機具運作的能量來源，但是**(B)石油的燃燒會釋放出大量的二氧化碳到氣圈中，強化溫室效應，這已被認為是今日全球暖化的主因**，且**(C)二氧化碳進入平流層後，會與臭氧產生反應，導致臭氧洞的產生**；此外，大氣中二氧化碳氣體驟增的結果，亦使得海洋中溶解、吸收的二氧化碳驟然增加，二氧化碳被海水吸收後會形成碳酸，造成了海洋酸化，**(D)海洋中具矽質殼體的生物，例如：矽藻，將首當其衝受到殼體溶解的威脅**，生態系統也將岌岌可危。石油亦是塑膠製品的原料，而塑膠多難以自然分解，眾多未被妥善回收的廢棄塑膠製品會到達海洋。**(E)在北太平洋環流系統包圍的中央海域中，那裡流速緩慢，也發現有塑膠碎屑聚集的大型區塊**，由於這些碎屑在海水中過於富集，已嚴重破壞海洋生態環境。

（109 年學測第 67 題）

Teacher: What do you think the question stem is mainly conveying?

Student: Human impact and harm to the environment?

Teacher: Yes. As you can see from the various options, whether it is the use of petroleum or plastic waste, there is a certain impact on the environment.
But when we see option C, in fact, it is a bait!

Student: Why isn't carbon dioxide the cause of the ozone hole?

Teacher: The formation of the ozone hole is mainly due to the influence of chlorofluorocarbons, it is not directly related to carbon dioxide!

Student: I know! The Montreal Protocol is banning the use of CFCs!

Teacher: That's right. In fact, the ozone hole does not mean that the ozone really broke a hole, but only the local ozone concentration is lower than that of other places, so it is called the ozone hole!

Teacher: When facing the issue of climate change, we often blame all the causes of events on the most commonly heard greenhouse effect, but in fact, different phenomena have different influencing factors!

Student: So is it necessary to understand exactly the phenomena and causes of various climate changes?

Teacher: Right! Like in option D, it is because carbon dioxide causes ocean acidification, and ocean acidification makes calcium carbonate more soluble, so it should be calcium carbonate shell organisms not siliceous shell organisms that are threatened by shell dissolution!

Student: Got it! Thank you teacher!

老師： 大家覺得題目的敘述主要概念是什麼呢？

學生： 人類對環境造成的影響與危害嗎？

老師： 沒錯，從各個選項中可以看到，無論是石油的使用或是塑膠廢棄物，都對環境造成一定的影響。
但當我們看到選項 C，其實 C 是一個誘答項喔！

學生： 對呀，為什麼二氧化碳不是造成臭氧洞的原因？

老師： 臭氧洞之所以會形成，主要其實是因為氟氯碳化物的影響，而跟二氧化碳沒有直接關係！

學生： 我知道！蒙特婁議定書就是在禁止氟氯碳化物的使用！

老師： 沒錯，其實臭氧洞指的也不是臭氧真的破了一個洞，而只是當地的臭氧濃度相對於其他地方的臭氧濃度低，才被稱作臭氧洞！

老師： 在面對氣候變遷議題的時候，我們很常把所有的事件成因都怪罪於最常聽到的溫室效應，但其實不同的現象都有不同的影響因素！

學生： 喔～所以應該要確切理解各種氣候變遷產生的現象與其成因嗎？

老師： 臭氧洞之所以會形成，主要其實是因為氟氯碳化物的影響，而跟二氧化碳沒有直接關係！

學生： 我們了解了！謝謝老師！

7-2 節用資源與合理開發
Saving Resources and Rational Development

■ 前言 Introduction

地球資源可以被區分為兩大類型，再生能源與非再生能源。過去我們所使用的大多為非再生能源，如煤炭、原油、天然氣等，不僅資源有限，在獲取資源時更造成環境傷害以及生態失衡。近年各國開始開發再生能源的使用與規劃，如太陽能、水力、風力等資源，希望能夠透過再生能源的開發與適當使用非再生能源，將環境破壞降到最低值，同時也真正落實永續發展的可能性。

語言方面，學生能以英文判讀永續發展相關敘述與解釋。

■ 詞彙 Vocabulary

單字	中譯	單字	中譯
non-renewable energy	非再生能源	fossil energy	化石能源
geothermal energy	地熱能	renewable energy	再生能源
solar energy	太陽能	finiteness	有限性

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

❶ Renewable energy includes ____, _____, etc.; non-renewable energy includes ____, etc.

例句: :**Renewable energy includes** solar energy, geothermal energy, ocean energy, wind energy, **etc.; non-renewable energy includes** oil, coal, natural gas**, etc.**

再生能源包含太陽能、地熱能、海洋能、風能等；非再生能源包含石油、煤炭、天然氣等。

❷ Whether we are using renewable or non-renewable energy is used, _____ needs to be considered.

例句：**Whether we are using renewable or non-renewable energy is used,** the carrying capacity of the environment **needs to be considered.**

無論是使用再生或是非再生能源，都需要考慮環境的負荷量。

■ 問題講解 Explanation of Problems

學習目標

在學習完本單元後，學生應習得以下觀念：

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

一、瞭解資源使用所需考量到的各方問題。

Understand the various issues that need to be considered in the use of resources.

二、瞭解使用能源與其相對應的環境議題。

Understand the use of energy and its corresponding environmental issues.

例題講解

例題一

（英文）Sustainable development must meet the needs of present and future generations without exceeding the "environmental carrying capacity", and the strategies taken should be socially acceptable, economically beneficial, and technically feasible. Taking water resources as an example, "environmental carrying capacity" refers to the maximum water resources that can be supplied. In response to drought events or future water shortages, modern society often adopts the following strategies:

A. Building reservoirs or weirs
B. Promoting water conservation
C. Promote rainwater storage and waste water recycling
D. Build seawater desalination plants
E. Extraction of groundwater

From the perspective of sustainable development, which of the following statements are correct? (Choose 3 items)

(A) There are environmental protection doubts in A, so it is better to wait until water shortage occurs then we implement A.

(B) We should try to give consideration to the quality of life when implementing B.

(C) The water source of D is inexhaustible, and it should be vigorously promoted unconditionally.

(D) We need to consider issues if land subsidence and water quality in E.

(E) Of all the above strategies, B and C fit most with the spirit of sustainable development

（中文）永續發展必須在不超過「環境承載力」之條件下，可持續滿足現在與未來世代之需求，且所採取之措施可為社會接受、符合經濟效益及工程技術可行。以水資源為例，「環境承載力」是指可以供給的最大水資源。現代社會為因應乾旱事件或未來水資源短缺，往往採行以下措施：

甲、蓋水庫或攔河堰　　乙、推行節約用水

丙、推行雨水儲集與廢汙水回收　　丁、蓋海水淡化廠

戊、抽取地下水

從永續發展的觀點，下列敘述哪些正確？（應選 3 項）

(A)甲有環保疑慮，等缺水發生時再做就好。

(B)乙應盡量兼顧生活品質。

(C)丁的水源取之不盡用之不竭，應無條件大力推行。

(D)戊需考慮地層下陷與水質問題。

(E)上述所有措施中，最符合永續發展精神的是乙與丙。

（107 年學測第 62 題）

Teacher: Why can't we choose option A and C in this question?

Student: It will be too late to do option A after the water shortage occurs, and the vigorous implementation of option C will cause the shortage of water resources!

Teacher: Indeed! When using various resources, regardless of the source or type of resources, we should consider if the implementation would strike the balance!

Student: Does the environmental carrying capacity refer to finding a balance between using resources and maintaining resources?

Teacher: Right! We should not demand unlimited resources just because we have a lot of them or because we think that such a resource is not harmful to the environment.

Student: Learn it! In order to achieve sustainable development, learning how to properly use resources is important!

Teacher: Very good! I believe that everyone can become a powerful promoter of sustainable development!

老師： 題目中的 A 與 C 選項為什麼不能選呢？

學生： A 選項等缺水發生後再做會來不及，C 選項大力推行會造成水資源的匱乏！

老師： 說得很好！在使用各式資源時，不管其資源的來源或是種類，過與不及都是我們應當避免的！

學生： 題目中的環境乘載力指的就是在使用資源與維持資源中找到平衡嗎？！
老師： 對！我們不該因為擁有大量資源或是認為此一資源對環境無害就無限索取資源。
學生： 瞭解！為了要達到永續發展，如何適當的使用資源才是重要的！
老師： 非常好！相信大家一定可以成為永續發展的有力推動者！

例題二

（英文）Which of the following environmental problems may be alleviated by using "bioenergy"? (Choose 2 items)
(A) Eutrophication (B) Landslides **(C) Greenhouse effect** (D) Land subsidence **(E) Acid rain**
（中文）使用「生質能源」，將有可能減緩下列哪些環境問題？（應選 2 項）
(A)水質優養化 (B)土石流 **(C)溫室效應** (D)地層下陷 **(E)酸雨**

（台南市黎明中學 107 學年第二學期第三次段考第 24 題）

Teacher: The use of bioenergy can reduce our dependence on non-renewable energy. When we reduce the use of non-renewable energy, such as petroleum and coal, what environmental issues can be reduced?
Student: Air pollution?
Teacher: That's right! For example, the intensified greenhouse effect is due to a large amount of greenhouse gasses released to the atmosphere, and the cause of acid rain is also resulted from the large amount of carbon dioxide emissions caused by the use of non-renewable energy sources.
Student: It turns out that none of the other options are directly related to the use of bioenergy!
Teacher: Right! The main cause of eutrophication is the water polluted by animal husbandry or household wastewater. Landslides are related to water and soil conservation. What about land subsidence?
Student: Excessive groundwater pumping!
Teacher: Very good! Everyone already has a certain understanding of energy use and environmental issues!

老師： 使用生質能源可以讓我們對非再生能源的依賴度降低，當今天減少非再生能源，如石油、煤炭等使用，可以減少哪些環境議題？

學生： 空氣汙染？

老師： 沒錯！像是溫室效應是因為大量溫室氣體進入大氣層中，酸雨形成的原因也是因為非再生能源的使用造成大量二氧化碳排放。

學生： 原來如此，其他選項都與使用生質能源沒有直接關係！

老師： 對！水質優養化的主因是因為畜牧業或是家庭廢水所造成的水質汙染，土石流則是與水土保持相關，那地層下陷呢？

學生： 超抽地下水！

老師： 很好！大家對能源使用與環境議題都已經有一定的瞭解性了！

國內外參考資源 More to Explore

NASA Earth Science | Science Mission Directorate 美國 NASA，提供最新地球科學相關知識。 https://science.nasa.gov/earth-science	
BGS (British Geological Survey) 地質相關主題。 https://www.bgs.ac.uk/discovering-geology/	
NOAA-Basic Weather Education 提供給教師關於大氣層單元的教學資源網站。 https://www.weather.gov/crp/weather_education	
AMS (American Meteorological Society) education-program 提供給 K-12 教師地球科學相關資源。 https://www.ametsoc.org/index.cfm/ams/education-careers/education-program/	
MIT opencourseware 地震學課程知識。 https://ocw.mit.edu/courses/12-510-introduction-to-seismology-spring-2010/	

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/	
Khan Academy	
可汗學院，有分年級的地球科學教學影片及問題的討論。 https://www.khanacademy.org/	
Interactive Simulations, University of Colorado Boulder	
互動式電腦模擬，除了地球科學，還有其他自然科。 https://phet.colorado.edu/	

雙語教學資源手冊：地球科學科 英語授課用語

[十年級]

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

[10th grade]

- 研編單位：國立彰化師範大學雙語教學研究中心
- 指導單位：教育部師資培育及藝術教育司
- 撰稿：胡祖寧、郭信嘉、陳郁暄
- 綜合規劃：曾松德
- 編輯排版：吳依靜
- 封面封底：JUPE Design

發行單位　國立彰化師範大學雙語教學研究中心
NCUE BILINGUAL EDUCATION RESEARCH CENTER

指導單位　教育部師資培育及藝術教育司
MOE DEPARTMENT OF TEACHER AND ART EDUCATION