

PBL: Magnetism

活動單元：磁性

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0. Introduction 簡介

在這個單元，你要用虛擬實驗，來瞭解三個生活中的磁性物理現象。

在開始回答問題之前，請大家先玩線上的模擬實驗。熟悉每一個特性和按鈕，也確定瞭解怎麼用每一個每個工具。玩模擬實驗的時候，可以使用中文和英文兩種界面，大家就可以同時學到中英文關鍵字的對應囉！

In this activity unit, you will perform virtual experiments with three different public domain physics simulations dealing with magnetism and magnetic field \vec{B} .

Before you start answering the questions, play with each simulation. Get familiar with each of the different effects and buttons of the animations. Where there are tabs, utilize them. Run the simulations in both Chinese and English so you can be bilingual!

1. Magnets and Compass 磁鐵和指南針

A 下載模擬器「磁鐵和電磁鐵」，選「磁棒」分頁。Download, Run and Play with the PhET Simulation: "Magnets and Electromagnets" Use the Tab "Bar Magnet".

B 觀察並描述看到的現象：磁鐵和地球之間的關係 Observe & Interpret: Magnets and our Planet

1. 重置模擬器。在磁鐵附近移動指南針。觀察白色和紅色的指針會指向哪個方向？Reset the simulation. Move the compass (a small magnet) around the magnet. In which directions does the red (N) compass needle point?

2. 顯示地球。在地球旁邊移動指南針。觀察白色和紅色的指針會指向哪個方向？Show the earth. Move the compass around the earth. In what direction does the red end of the compass needle point?

3. 做完上面兩個實驗後，地球的北極和磁鐵的北極有什麼關係？Consider the above two experimental results. What is the relationship between the earth's "North Pole" and the magnet's "North Pole"?

C 觀察磁場 Investigate the Magnetic Field (\vec{B})

1. 點選顯示磁鐵內部特性、電場和磁場強度計。磁場強度在哪裡最強？Check "Show the Inside of the magnet" and "Show Magnetic Field Meter" Where is the magnetic field largest?

2. 在磁鐵外面，磁場是什麼方向？What is the direction of the magnetic field outside of the magnet?

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3. 在磁鐵裡面，磁場是什麼方向？What is the direction of the magnetic field inside of the magnet?

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4. 就你所知電偶（或電池）的電場方向和強度，跟磁場方向和強度有什麼差異？Based on your knowledge of the electric field direction and strength in and around a dipole, how does the magnetic field direction/magnitude differ from the electric field?

2. 電磁鐵 Electromagnets

A 換到電磁鐵分頁。電源選用直流電（電池）。Switch to the Electromagnetic Tab. Set the Current Source to DC (Battery)

B 觀察磁場的磁場方向 Observing the Direction of Magnetic Field (\vec{B})

1. 把電池的電壓設定為 0V。試著在電池旁邊移動指南針，指南針的指針有什麼反應？Set the voltage on the battery to 0V. How does the compass needle react as you move the compass around?

2. 把電池電壓設定為 10V。試著在電池旁邊移動指南針，指南針的指針有什麼反應？在左邊的空白處畫下不同地方指針的反應，然後在右邊說明你看到的現象。Change the voltage on the battery to 10V. How does the compass needle react as you move the compass around? Draw a picture of the compass at representative points (left). Summarize in words what you see (right)

Picture	Description in words

3. 把電池電壓設定為-10 伏特。試著在電池旁邊移動指南針，指南針的指針有什麼反應？在左邊的空白處畫下不同地方指針的反應，然後在右邊說明你看到的現象。Change the voltage on the battery to -10V. How does the compass needle react as you move the compass around? Draw a picture of the compass at representative points (left). Summarize in words what you see (right)

Picture	Description in words

4. 指南針能夠在磁場中指出磁場方向。參考前面的實驗，線圈裡的電流（或電子流）會在線圈兩端產生什麼磁場方向？（提示：可以用手的方向說明）The compass gives the direction the magnetic field. Look at the results of the previous experiments. How does the direction of current (or electron flow) relate to the direction of the magnetic field inside the coiled wire?

C 觀察磁場強度-實驗二 Observing the Strength of a Magnetic Field – 2 Experiments.

1. 設計一個實驗能夠量出電壓 ΔV_{bat} [V] 變化對磁場強度 $|\vec{B}|$ 有什麼影響？你需要用什麼實驗器材？請寫下你的實驗步驟。 Design an experiment to find the relationship between the voltage supplied by the battery ΔV_{bat} [V] and the strength of the magnetic field $|\vec{B}|$. What equipment do you need to use? Write down your algorithm (the steps of the experiment) below:

2. 繼續前面的實驗。在左邊的表格中，記錄電壓 ΔV_{bat} [V] 和磁場強度 $|\vec{B}|$ 的變化。依照你得到的結果，在右邊的空白寫下電壓 ΔV_{bat} [V] 和磁場強度 $|\vec{B}|$ 變化的關係式。 a. Conduct the experiment and record your data on the left side of the table. b. Graph the relationship. c. Write an equation relating the voltage supplied by the battery ΔV_{bat} [V] with the strength of the magnetic field $|\vec{B}|$. It may help to use a spreadsheet program like Microsoft Excel to graph and curve fit.

a. Data		b. Graph $ \vec{B} = f(\Delta V_{\text{bat}})$	c. Write Equation
ΔV_{bat} [V]	$ \vec{B} $ [G]		

3. 設計一個實驗找出線圈數和磁場強度 $|\vec{B}|$ 的關係。你需要什麼實驗器材？請寫下你的實驗步驟。 Design an experiment to find the relationship between the number of loops of wire (N) and the strength of the magnetic field $|\vec{B}|$. What equipment do you need to use? Write down your algorithm (the steps of the experiment) below:

4. 繼續前面的實驗。在左邊的表格中，記錄線圈數 N 和磁場強度 $|B|$ 的變化。依照你得到的結果，在右邊的空白寫下線圈數 N 和磁場強度 $|B|$ 變化的關係式。 a. Conduct the experiment and record your data on the left side of the table. b. Graph the relationship. c. Write an equation relating the number loops (N) with the strength of the magnetic field $|\vec{B}|$, i.e. $|\vec{B}| = f(N)$

a. Data		b. Graph $ \vec{B} = f(N)$	c. Write Equation $ \vec{B} = f(N)$
N loops	$ \vec{B} $ [G]		

5. 結合你得到的磁場 B 、電壓 ΔV 和線圈數 N 的兩個關係式，寫下這三個參數彼此的關係式。另外，寫下如何用手來預測通電線圈磁場的方向？ Combine the equations you have found for the dependence of magnetic field \vec{B} on ΔV and N into one equation. State how to tell the direction of the \vec{B} in the coil.

D 把電源從直流電 (DC) 改為交流電 (AC) Set the Current Source to AC

1. 改變交流電的電流，磁場有什麼變化？ How does the magnetic field vary with the AC current supply?

E 反應 Reflect

1. 觀察磁場變化，怎麼區分磁場來源是永久磁鐵或電磁鐵？ By observing the magnetic field (\vec{B}), how can one tell if the source of the field is a regular permanent magnet or an electromagnet?

3. 法拉第電磁感應定律 Faraday's Experiment

在前面的實驗裡，我們使用通電的電磁鐵，觀察到一些現象：

- 移動電荷會產生磁場
- 穩定電流（例如：靜電場）情況下，磁場也保持固定不變。
- 非穩定電流（例如：電場改變）的情況，磁場也跟著改變。

法拉第想如果從相反的方式來做，會有什麼事情發生？磁場能夠產生電場嗎？

In the experiments we conducted with the electromagnet in the previous section we have observed:

- moving electric charges (current, I) create a magnetic field \vec{B}
- If the electric current (I) is not changing, i.e. \vec{E} is constant, then \vec{B} is constant
- If the electric current changes, i.e. \vec{E} is not constant, then \vec{B} changes

Faraday wondered whether the reverse could happen: Can \vec{B} cause electric charges to move (current, I)? Before this no one had been able to observe magnets causing a current to flow through a wire.

A 下載、執行「法拉第定律」模擬實驗。打開「Field Lines」Download, Run and Play with the PhET Simulation: Faraday's Law. Turn on the Field Lines

B 觀察 Observe

1. 如果磁鐵不動（固定磁場），有可能產生電流嗎？If the magnet is not moving (constant magnetic field), is it possible to have an electric current?

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2. 解釋怎麼產生最大電壓讓燈泡最亮？有兩個關鍵因素。Explain how to maximize the voltage on the meter and brightness of the light bulb?

1.	
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2.	
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3. 用盡模擬實驗所有的功能，找出不需要移動磁鐵而能夠讓燈泡變亮的方法，然後解釋原因。Look carefully at the simulation. Find a way to make the light bulb light up without moving the magnet. Explain.

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4. 線圈數跟燈泡亮度有什麼關係？怎麼調整線圈數來得到最高電壓？How do the number of coils affect the brightness of the light bulb and the maximum voltage generated?

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5. 重要的結論：一個變化的磁場可以在線圈中產生電流。發電機用這個原理來產生電。如果磁場不變，則不會有電流產生。The key conclusion: A **changing** magnetic field results in **current** flowing through a wire. This method is the way in which generators work and how electric power is created. If the magnetic field does not change, no current flows.

4. 發電機 Generators

A 下載、執行「法拉第電磁實驗」，請選用「發電機」分頁。Download, Run and Play with the PhET Simulation: Faraday's Electromagnetic Lab and click on the Tab "Generator"

B 觀察 Observe

1. 列出實驗中的重要元件 List the key parts in the experiment

1. 能量的來源（水從高處落到地面上） Source of energy (Water falling to the ground)
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2. 打開水龍頭。列出實驗中發生的所有現象，並說明發生的原因。 Turn on the water tap. Explain what happens in a step-by-step fashion with its cause.

1. 水流穩定轉動有磁鐵的輪子。 Water starts to flow → wheel with the magnet turns at a constant rate

3. 打開電壓計。增加水龍頭的水量後，有什麼事情發生？ Switch to the Voltage meter. Increase the rate of flow of water from the tap. What happens?

4. 在磁鐵指向什麼方向的時候，電壓會最大？ What direction does the magnet point when the voltage is maximum?

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5. 輪子轉動速度影響電流變化頻率。在歐洲，電流頻率是 $f=50\text{Hz}$ （輪子 1 秒轉動 50 次）。在美國是 $f=60\text{Hz}$ 。請問在臺灣的電流頻率是多少？如果不知道，請上網找出答案。 The speed at which the wheel turns is what determines the frequency of the electric current. In Europe the frequency (number of rotations of the wheel per second) is $f=50\text{ Hz}$. In America it is $f=60\text{ Hz}$. What is the frequency in Taiwan? If you don't know, search on the internet.

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5. 總結你在這些實驗學習到的重點，請逐一敘述。 Summarize. What you have learned about generators in these experiments?

6. Transformers

Transformers are a key component of electrical circuits and are used to change the voltage level up or down. In these experiments we will look at the fundamentals of transformers. A transformer is basically physically unconnected loops of wire.

A Click on the Tab “Transformers” in Faraday’s Electromagnetic Lab

B Observe:

1. Change the light bulb to a voltage meter in the pick-up coil. With the battery supplying $\mathcal{E}=10\text{V}$, how much voltage is generated in the pick-up coil? How much current flows in the pick-up coil?

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2. Change current source from a battery to an AC source. a. Does current flow in the pick-up coil? b. How about voltage? c. Does the voltage meter move?

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3. Change the voltage meter back to a light bulb (you may also use voltage meter for further insight). Play with the frequency and magnitude of the AC current supply and position of the pick-up coil
 a. Where should I place the pick-up coil to maximize the brightness of the light bulb? Why?

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- b. What current should I use in the current source to maximize the brightness of the light bulb?

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- c. What frequency should I use in the current source to maximize the brightness of the light bulb?

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4. Does changing the loop area of the pick-up coil increase the maximum voltage?

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5. Does changing the number of loops of the pick-up coil change the maximum voltage?

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C Summarize: How does one maximize the transfer of energy between the two sides of a transformer?

1	
2	
3	

7. Your Experiment

1. Design an experiment to do using Faraday's Electromagnetic Lab:

2. a. Conduct the experiment and record your data on the left side of the table. b. Graph the relationship. c. Write an equation relating variables

a. Data		b. Graph	c. Write Equation
independent	dependant		

3. Ask a question about the experimental results and answer it.

Question:
Answer:

8. 您的意見 Student Comments

A Did you enjoy the activity? 你喜歡這個活動嗎？ Choose one”

LOVED 喜愛 75% 普通 25% HATED 討厭

Why? 為什麼？

B 提出1個或2個推薦的問題加到本題目卷，如果你的問題被採用，加1分！（最多加5分） Suggest one or two additional questions that could be asked concerning any of the simulations you played with. (If we add your question, you will get 1% bonus marks for the course!)

Activity	Suggested Question	Answer to suggested question

C 有沒有別的建議？ Any other suggestions to improve this activity?

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